APPENDIX 3-B

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University of Nevada Cooperative Extension - **Living on the Land Program** from:
http://www.unce.unr.edu/programs/sites/livingontheland
UNCE/WSARE. Living on the Land, a Western SARE Professional Development Project, 2001/2008
Program Web Site Screenshot
Introductory Sections of Curriculum

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Fact Sheets

- Improving Drainage, Managing Roof Runoff, Sacrifice Areas , Washington State University, Clark County Extension, Clark Conservation District
- Manure Management for Small Acreages, **www.ext.colostate.edu/sam**

Publications

- Horse Keeping: A Guide to Land Management for Clean Water, Prepared by the Council of Bay Area Resource Conservation Districts in partnership with the USDA Natural Resources Conservation Service.
- Horse Owners Guide to Water Quality Protection, Prepared by the Council of Bay Area Resource Conservation Districts in partnership with the USDA Natural Resources Conservation Service.

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A Horsekeepers Guide to Manure Management
Livestock and Land Program Nine (9) Month Follow-Up Survey: Technical Trainings

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- Horse Facility BMP Checklist for TMDL Planning, Marin County Department of Public Works
- Livestock and Land Program Implementation Site Selection Criteria and Application Review
- Example Recommendation Report, Natural Resources Conservation Service
- Example Natural Resources Conservation Service BMP Standards
  - Composting Facility
  - Subsurface Drain
  - Fence
  - Filter Strip
  - Heavy Use Area Protection
- Load Reduction Modeling Tool, Fall Creek Engineering, Ecology Action
  - Livestock and Land Program: Required Load Reduction Information
  - Equestrian Facility Best Management Practices Predictive Analysis User Guide for Manure and Erosion Pollution Prevention Program Ecology Action Santa Cruz, California

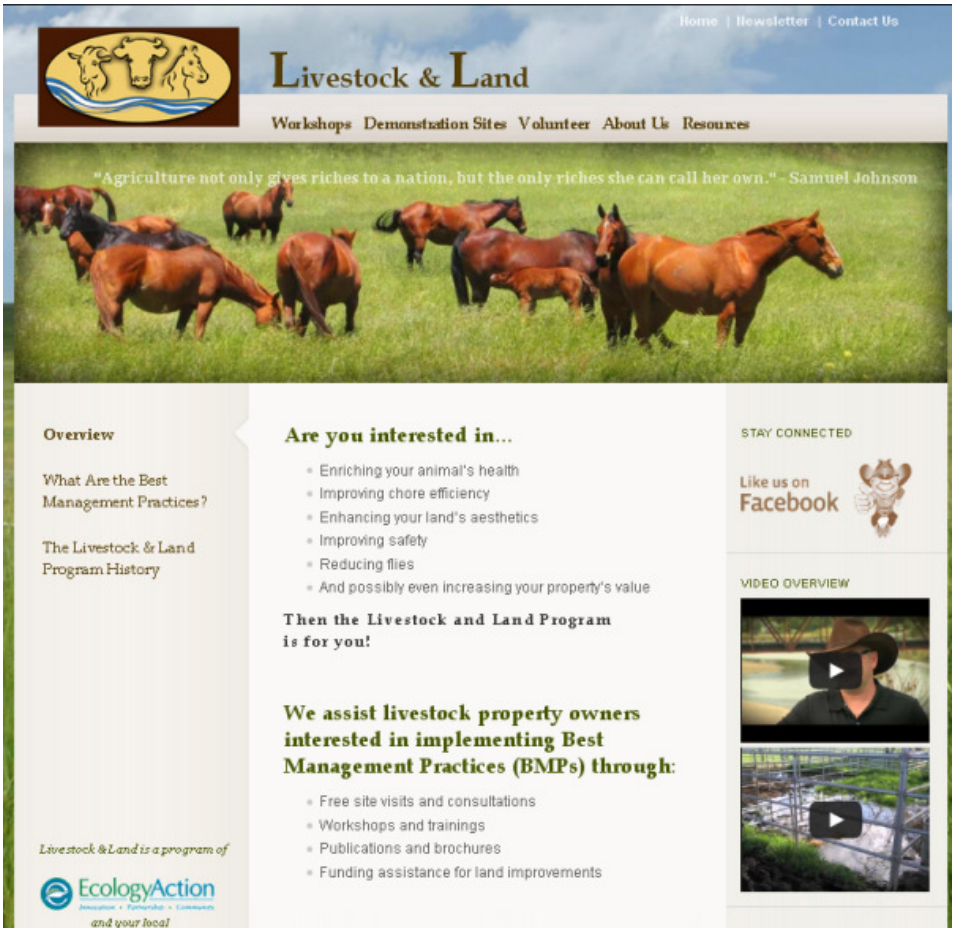
3-B-5 TECHNICAL DOCUMENTATION

Tuolumne County Stream Team, Water Quality Monitoring Report 2007-08
Tuolumne County Final Watershed Assessment, 2007
Tuolumne County Final Water Quality Plan, 2007

APPENDIX 3-B-1

TUOLUMNE COUNTY RESOURCE CONSERVATION DISTRICT

Example Programs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Overview
What Are the Best Management Practices?
The Livestock & Land Program History
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and your local
Are you interested in...
Enriching your animal's health
Improving chore efficiency
Enhancing your land's aesthetics
Improving safety
Reducing flies
And possibly even increasing your property's value
Then the Livestock and Land Program is for you!
We assist livestock property owners interested in implementing Best Management Practices (BMPs) through:
Free site visits and consultations
Workshops and trainings
Publications and brochures
Funding assistance for land improvements
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"Agriculture not only gives riches to a nation, but the only riches she can call her own." - Samuel Johnson
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Best Management Practices
Best Management Practices (BMPs) are practices that you can use on your land to address concerns such as erosion, drainage, mud and manure. By successfully managing these issues you can drastically improve the health of your property and local natural resources. In addition to addressing the challenges listed above, installing BMPs on your property can improve local water, land and air quality, boost neighborhood relationships and encourage community collaboration.
Wild horses might roam up to twenty-five miles a day for food, water and shelter. Their continual movement disperses manure and urine and allows for regrowth of vegetation. With domestic horses, owners provide food and safe shelter. Consequently these practices can unintentionally damage delicate surface and ground water supplies and have detrimental effects on our local water and land resources, recreational activities and the environment.
To see examples of implemented BMPs click here
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Program History
Nutrients, pathogens and sediments from livestock facilities are pollutants of concern in watersheds throughout California. This pollution critically impacts our drinking water, recreation areas, fisheries health and flora and fauna habitat. Better management of manure and drainage on properties that house livestock can lessen these pollutants.
To address these challenges, the State Water Resources Control Board awarded grant funding to create the Livestock and Land Program. The program aims to achieve immediate and lasting water quality and watershed improvements by educating livestock owners on Best Management Practices (BMPs). The educational opportunities are conveyed via workshops, technical trainings and demonstration projects through a non-regulatory and voluntary approach. By raising the awareness in the community we will achieve the cultural changes necessary for healthy livestock and watershed management.
Ecology Action, an Environmental Non-Profit Organization, was invited to participate in the Livestock and Land pilot program by the Resource Conservation District of Santa Cruz County. As a result of the initial success of the pilot program, Ecology Action and local Resource Conservation Districts have partnered to deliver programming throughout California's Central Coast. Efforts are continuing to identify funding sources to maintain existing programming and expand program successes throughout the entire state of California and beyond.
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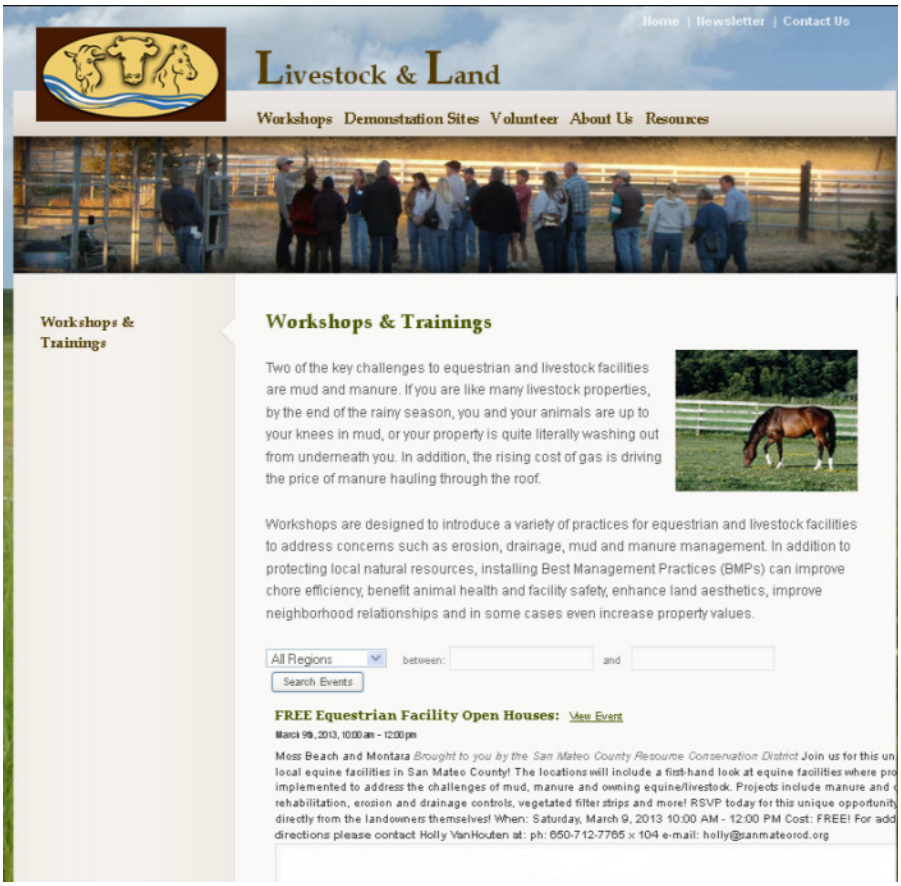
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Workshops & Trainings
Two of the key challenges to equestrian and livestock facilities are mud and manure. If you are like many livestock properties, by the end of the rainy season, you and your animals are up to your knees in mud, or your property is quite literally washing out from underneath you. In addition, the rising cost of gas is driving the price of manure hauling through the roof.
Workshops are designed to introduce a variety of practices for equestrian and livestock facilities to address concerns such as erosion, drainage, mud and manure management. In addition to protecting local natural resources, installing Best Management Practices (BMPs) can improve chore efficiency, benefit animal health and facility safety, enhance land aesthetics, improve neighborhood relationships and in some cases even increase property values.
All Regions
between:
and
Search Events
FREE Equestrian Facility Open Houses: View Event
March 9th, 2013, 10:00 am - 12:00 pm
Moss Beach and Montara Brought to you by the San Mateo County Resource Conservation District Join us for this un
local equine facilities in San Mateo County! The locations will include a first-hand look at equine facilities where pro
implemented to address the challenges of mud, manure and owning equine/livestock. Projects include manure and
rehabilitation, erosion and drainage controls, vegetated filter strips and more! RSVP today for this unique opportunity
directly from the landowners themselves! When: Saturday, March 9, 2013 10:00 AM - 12:00 PM Cost: FREE! For add
directions please contact Holly VanHouten at: ph: 650-712-7765 x 104 e-mail: holly@sanmateorcd.org

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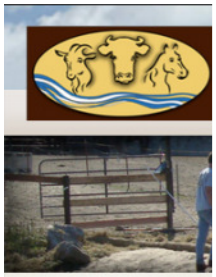
Watershed Steward Demonstration Sites
Best Management Practices (BMPs)
Before & After Examples
Demonstration Site Application
Typical Best Management Practices (BMPs)
Although there are over 74 recommended practices from NRCS alone, the following list addresses a simplified overview of typical BMPs implemented.
Manure Bunkers
Filter Strips
Cross Fencing
Exclusionary Fencing
Gutters and Downspouts
Rainwater Catchment
Pasture Management
Re-stabilize, Vegetate and Exclude
Sacrifice Area
Rock Dissipaters
Landscape Walls
Sediment Basin
French Drain
Horse Trail
Rolling Dip
Wash Rack

Manure Management

Manure bunkers, composting bunkers, windrows systems, manure hauling/management comes in all different shapes and sizes. A variety of materials can be utilized including cinder block, wood, concrete, tarps, recycled poly lumber, pre-cast concrete blocks, etc.
It is recommended to have manure stored on a non-permeable surface, such as concrete, with some sort of cover.



Watershed Steward Demonstration Sites

Best Management Practices (BMPs)

Before & After Examples

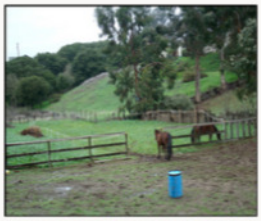
Demonstration Site Application

Filter Strips

A grassed filter strip installed behind the paddocks filters out sediments and nutrients before they reach the drain inlet. This filter strip also serves as a barrier to water coming off the adjacent hillside from flooding the paddocks.

Installing raised grates over drain pipes helps to keep them from clogging.

Cross Fencing & Exclusionary Fencing



Cross fencing can be utilized to divide a pasture area in half to allow for rotational grazing of the area. This will allow pastures to be more evenly grazed with less trampling, allow needed time for plant rest and re-growth and reduce unnecessary soil compaction from hoof action.

Exclusionary Fencing should be constructed along drainage ways to exclude animals from water ways and limit compaction. The direct deposit of manure into water can harm aquatic life. Trampling physically breaks down streambanks and destroys vegetative cover, which can increase sedimentation. Design stream crossings to minimize erosion. Exclusionary fencing and seasonal hand grazing of riparian corridors are possible management choices.

Gutters and Downspouts

Install and/or maintain roof runoff control systems on all existing and planned structures to prevent drainage issues and excessive runoff. Install and/or maintain drainage control

Re-Stabilize, Vegetate and Exclude

Utilize jute netting or an erosion control netting to stabilize erosive soils and re-vegetate problematic areas. Exclude animals from area if possible.

Straw waddles can additionally be used to slow erosive flows of water.

Sacrifice Areas

Giving up a small portion of land where animals are concentrated and no plant growth is expected is considered a Sacrifice Area. Horses typically are confined in stalls/paddocks during wet weather and will remain confined until the ground has dried. A single horse can be housed in a paddock 12' wide by 24' long. Grading a 2% slope from a three-sided shelter to an absorption pit improves drainage.
Use of geotextiles and geogrids can be utilized to increase paddock area performance and longevity.

Sediment Basin

The diverted drainage enters into the basin. Once the sediments settle out, the clean water empties into the vertical black pipe. Maintenance to remove excess buildup of sediments is needed from time to time.

French Drain

French drains can be useful applications to keep water from pooling and allows for water to be diverted and transported away from undesirable areas into filtered areas prior to entering waterways.

Rock Dissipaters

Placing rocks at a pipe outlet slows the water thus minimizing erosion.

Watershed Steward Demonstration Sites

Best Management Practices (BMPs)

Before & After Examples

Demonstration Site Application

Demonstration Site Before & After Photos

BMP Implemented: Grassed Filter Strip

BMP Implemented: Forced Air Manure Bunker

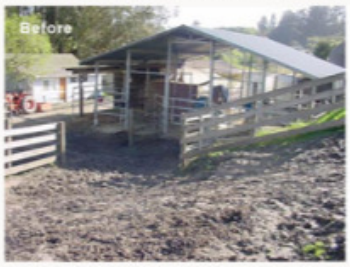
BMPs Implemented: Manure Trailer/transfer, French drain, rainwater catchment, stall and paddock improvements, drainage and erosion control, exclusionary fencing

Before

During

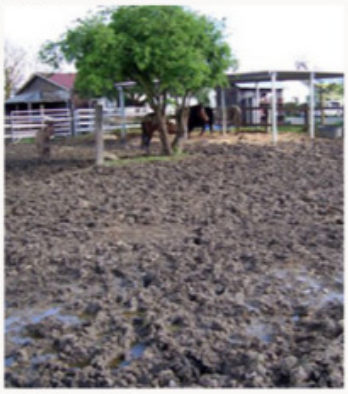
After

BMPs Implemented: Pasture Management, Drainage and Erosion Improvements to Horse Stalls and Paddocks, Manure Bunker



BMPs Implemented: Manage runoff from stall roof, French Drains, Pasture management and improvements, Construct sacrifice paddock area to allow all animals to be confined during winter months, Exclusionary fencing

Before



Mud filled paddocks

After

The paddocks were graded, compacted and new footing was lain.

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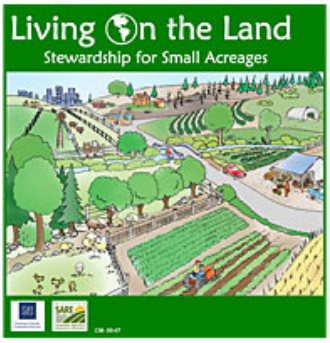
Living on the Land

Welcome to the Living on the Land: Stewardship for Small Acreages instructors' Web site. This site was developed to help you incorporate small-acreage teaching tools and tips from other instructors. You'll find up-to-date copies of the Living on the Land curriculum. We've also provided lists of Web resources included in the lesson plans that we will update every six months. You can also access training materials and presentations provided by other instructors, the Living on the Land team training presentations used in Bozeman and Albuquerque, a photo gallery and links to supplemental Web resources.

To submit materials for posting to the Web site, send them to Sue Donaldson, donaldsons@unce.unr.edu, and include any restrictions on use. We're especially interested in supplementary presentations on materials not currently found in the curriculum, such as local case studies, and before and after photos of small-acreage improvements. Please provide the photographer's name and a caption for each photo you submit.

What's New

Weeds are sprouting fast! The ATTRA publication, Principles of Sustainable Weed Management for Croplands, focuses on helping growers take a sustainable, proactive approach to weed management.



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Featured Program Websites

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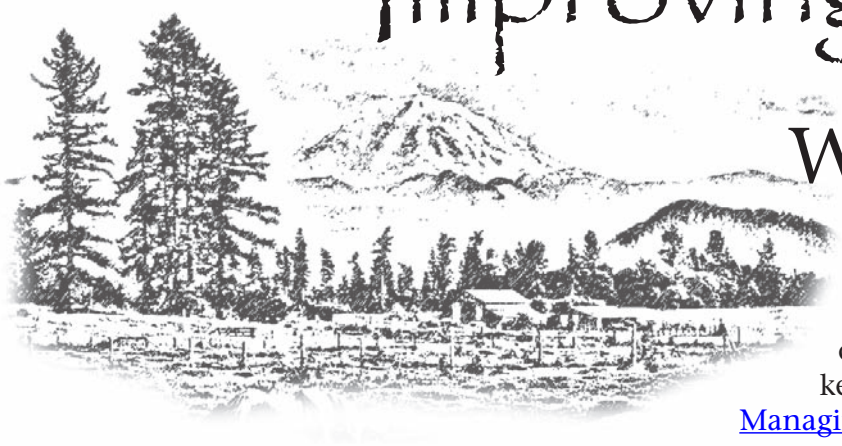
TUOLUMNE COUNTY RESOURCE CONSERVATION DISTRICT

Example Library Materials

Keeping Clean Water Clean and Reducing Mud

Improving Drainage



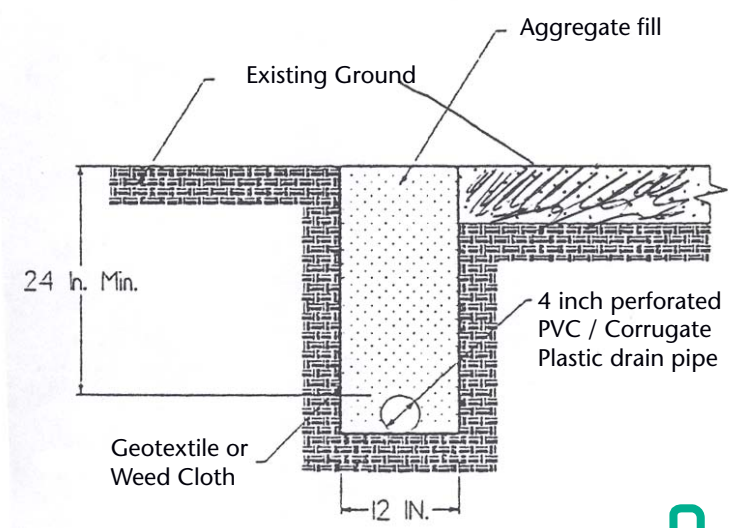
With all of the rain Clark County receives, managing rainwater runoff can be a challenge. Installing and/or properly maintaining gutters on your house and outbuildings provides a simple and effective measure of collecting and diverting rainwater, reducing mud and keeping clean water clean (see the fact sheet Managing Roof Runoff).

What can be done with all of the water collected in those gutters? And how do you manage rain that lands on your pastures and other areas? Water flowing across pastures, turnouts and dry lots, arenas and other areas can pick up particles of sediment and manure. Nutrients attach to sediment particles and can be transported to nearby waterbodies where they can negatively impact stream health and fish and wildlife. Runoff may also cause erosion and create mud, which can affect the health of your animals and your land. Runoff collecting around foundations of barns and other buildings causes significant damage over time. Several methods are available to collect and divert rainwater before it reaches pastures, turnouts and buildings reduces mud and standing water, and limits erosion and property damage including french drains, berms, grassy swales or dry wells.

French Drains

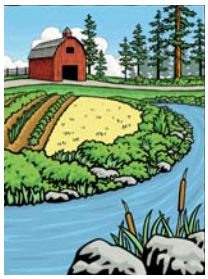
As illustrated in Figure 1, french drains intercept water flowing across a slope. They are shallow trenches lined with weed cloth or geotextile fabric, with a perforated plastic pipe surrounded by gravel. The weed cloth is wrapped over the top of the gravel and then covered with soil. The weed cloth prevents soil from filling in the spaces between gravel, maintaining water flow through the gravel. To facilitate water flow, the trench should be sloped between 0.5% and 1%. For example, for every 100 feet in distance, a one foot drop in elevation would provide a 1% slope.

Figure 1: Cross Section of Typcial French Drain



(Doug Stienbarger, 1995)

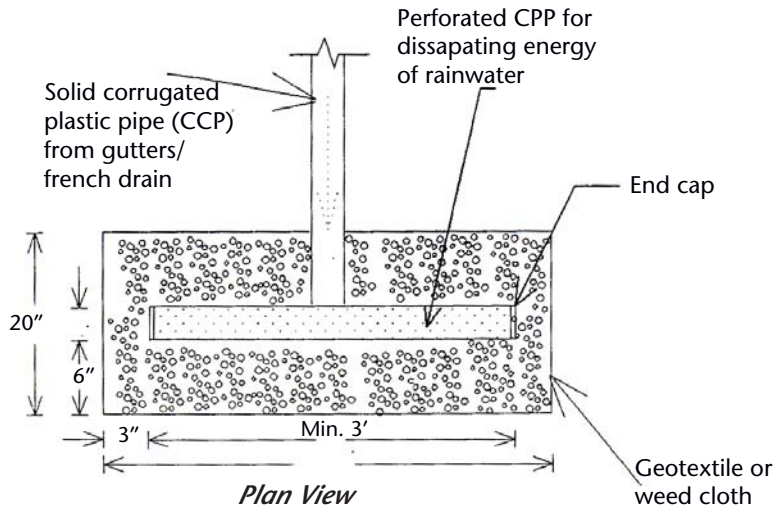
French drains can be used to collect runoff flowing down a slope or from a gutter system and divert the water around a feature such as a building, turnout, driveway or arena. Rainwater from a single roof can be collected in gutters and the buried downspouts connected to a



Small Acreage Program

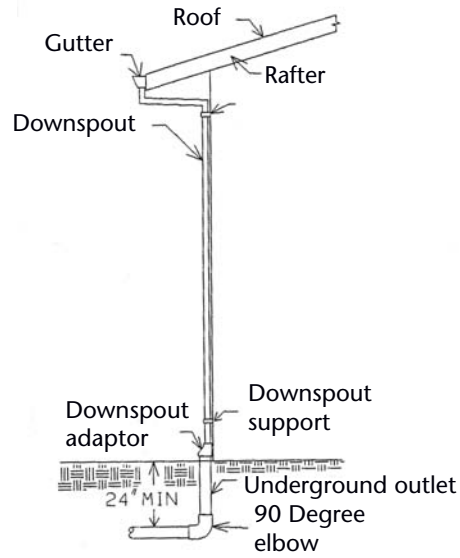
french drain (Figure 2). A T-shaped pipe can be placed at the end of the french drain outlet to slow the speed of the water, and spread it out over a larger area (Figure 3).

Figure 3. T-shaped Buried Outlet

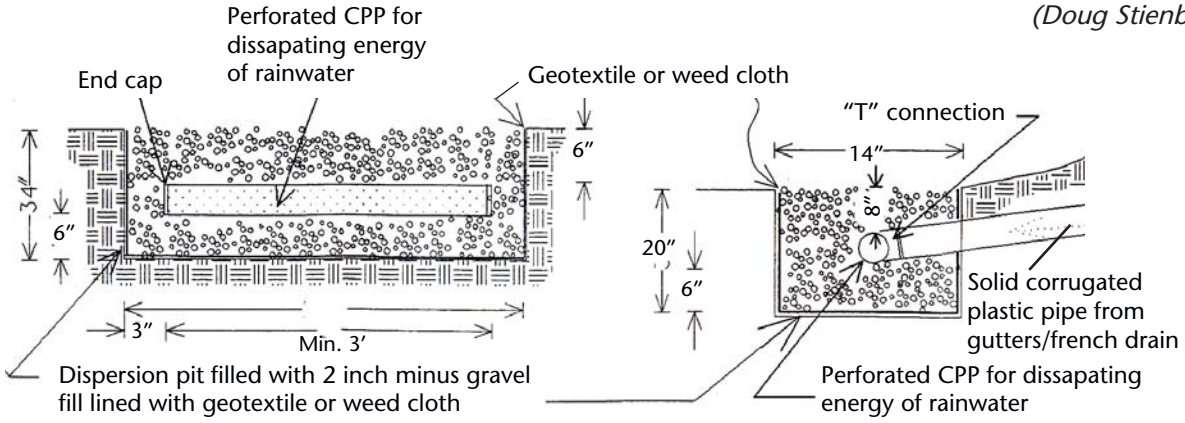


Plan View

Figure 2: Underground Gutter Outlet



(Doug Stienbarger, 1996)

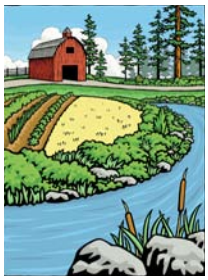


Cross Section (front)

Cross Section (side)

(Doug Stienbarger, 1995)

French drains can also be used to collect water draining from adjacent properties and direct it on your property where it will not do any damage. French drains work best if they are not within the groundwater table. Heavy machinery and livestock should be kept off the french drain. They can compact the soil, crush the drainage pipe and damage the drain, thereby blocking water flow and requiring repairs and possibly replacement.



Berms

Berms are low mounds of vegetated soil two to six inches in height. Berms direct and slow the speed of runoff, allowing it a greater chance to infiltrate and filter out sediments, nutrients and other materials in the water. Berms can also be used to divert water around a building, or at the base of a slope to direct runoff around an area such as a livestock turnout. Diverting this "run-on" water around livestock turnouts can greatly reduce mud in these areas.

Grassy swales

Swales are shallow, gently sloped vegetated ditches that capture runoff and transport it away from heavy use areas. Swales are commonly planted with grass, which slows down runoff and facilitates infiltration and removal of sediment and other particles. Swales can be easily incorporated into the landscape on your property, particularly if there is already a low lying area on your property. Swales are often less expensive to install than some underground drainage systems. Swales should be designed to hold water for no more than 48 to 72 hours to reduce habitat for mosquitoes. If standing water is expected for longer periods of time, wetland plants such as rushes (Juncus spp.), cattails (Typha spp.) or sedges (Carex spp.) can be planted.

Maintenance should occur when the soil is not saturated to prevent compaction, which can limit infiltration of runoff. Cuttings should be removed to prevent smothering of the vegetation. Grazing of these areas may be possible, but should be controlled to maintain healthy vegetation. Do not graze during initial vegetation establishment, when the soil is wet or during reseeding of bare areas. Grass height should be maintained at no less than 3 to 4 inches tall. Shorter grass does not provide adequate erosion protection. Bare or eroded spots should be repaired and reseeded. The swale should not be used as a track or roadway. Frequent traffic may damage the swale and create ruts, which can concentrate water flow and eventually result in erosion and the formation of gulleys.

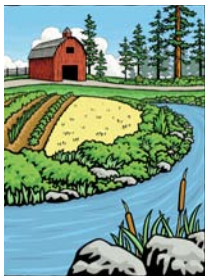
Dry wells

Directing downspouts into drywells can help facilitate infiltration of water into the surrounding soil and prevent it from picking up sediment from the surface. A dry well is a small pit lined with geotextile fabric or weed cloth and filled with 1½" to 3" gravel. Dry wells are best used to collect runoff from a small area with little or no sediment or pollutants, such as stormwater from a roof. Soils surrounding the dry well should be sufficiently permeable to allow adequate infiltration of the runoff. The dry well should be designed to completely drain the water volume into the soil within 48 hours of the rain event. An overflow may be needed to handle large amounts of runoff. Dry wells are relatively small and because they are underground, do not take up much space. They can be installed out of the way, provided the dry well can be easily accessed for maintenance.

Locate dry wells at least 10 feet from building foundations and at least 75 feet from wells, septic systems and surface water bodies.

Permits

Moving soil around on your property to build a french drain, drywell, berm or swale may require a grading permit if more than 50 cubic yards or more of material is moved. More information is available in the fact sheet Frequently Asked Questions: What Can You Do On Your Land? Before beginning any work, contact Clark County Community Development at 360-397-2375 x 4347.



All of these drainage structures can help you manage runoff on your property, reduce mud and erosion, allow runoff water to infiltrate and recharge groundwater and maintain healthy water quality in Clark County surface waters.

Sources:

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For additional information on managing roof runoff and drainage, contact:

Washington State University
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11104 NE 149th Street C 100
Brush Prairie WA 98606
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Brush Prairie WA 98606
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USDA Natural Resource
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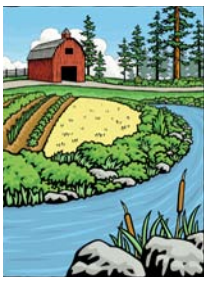
Adapted by Erin Harwood, WSU Clark County Extension (September 2005).

Small Acreage Program



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Keeping Clean Water Clean and Reducing Mud - Improving Drainage

Keeping Clean Water Clean & Reducing Mud

Managing Roof Runoff

What does winter mean to you in Western Washington? You got it, Rain! And with the fall, winter, and spring rains comes the question of how you can best manage all of that water. Why? Well, on small acreages, a little water makes a lot of mud, and we get lots of rainwater. For those who raise livestock, this can bring wet stalls, damp feed, and soggy hay and/or bedding. Of course, wherever you let your livestock out, you can count on muddy turnout areas and pastures as hoofs churn away.

While you cannot completely eliminate mud, you can reduce the amount and the problems it causes. One of the easiest, least expensive, and most effective ways is to divert the clean water from roofs away from livestock (or vehicle use areas). Unless you have lots of gravel and paved driveways, your house and outbuildings probably contribute the most to rainwater runoff on your property. For every 10 foot by 10 foot (100 square feet) of roof surface, one inch of rain produces 62 gallons of water. That means that a 30 foot by 30 foot (900 square feet) barn roof produces 558 gallons of roof runoff for each inch of rain! And you wondered why there was so much mud? (*Wondering how many inches of rainfall you receive? Take a look at the picture on page three.)*

If this roof runoff flows through livestock areas, manure, equipment storage areas, or bare soil, it can transport sediment, oils, chemicals (herbicides and pesticides), pathogens (bacteria), and excess nutrients (nitrogen and phosphorous) to streams and lakes. This can cause health problems for people and wildlife (fish and animals drinking from the stream).

The Best Management Practice (BMP) in this case simply means installing and/or maintaining properly functioning gutters, downspouts, and outlets.

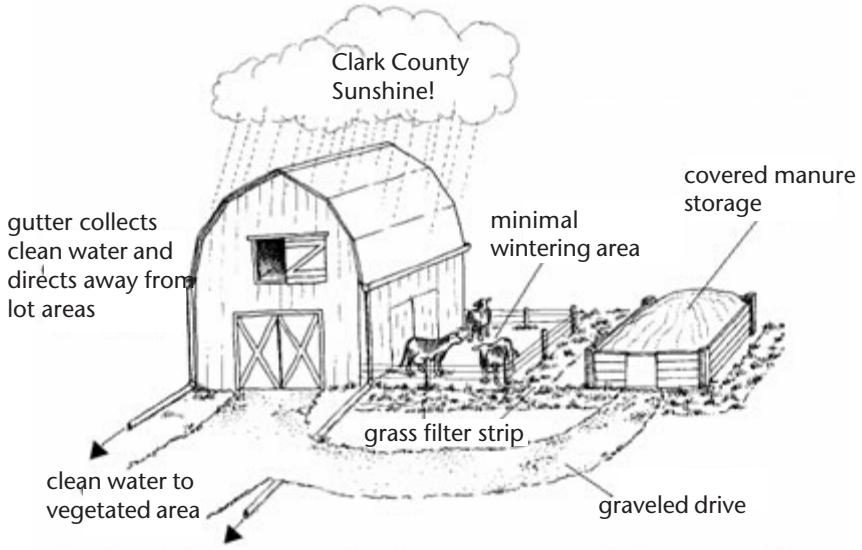
What Are BMPs?

Best Management Practices (BMPs) are practices that protect your resources and may also enhance the value of your property.

What to Do

Installation. If you do not have gutters or the gutters need to be replaced, remove the old gutters and repair or replace damaged rafter ends and facia boards where they attach to gutters. If you contract this work out, the job will cost more, but will save you time.

Gutter slope. As you know, water only runs downhill. The correct downhill slope for gutters is just over 1/8 inch drop for every 10 feet of gutter length. Mark your slope on the facia board using a chalk line, starting about ¾ inch below the roofing material. On some longer buildings, this may mean using several downspouts, both to handle the amount of water and to accommodate the slope on the facia board. A common gutter four inches wide and 2.5 inches deep requires one 2 by 2 inch downspout for each 2000 square feet of roof area. (A five inch wide by 3.5 inches deep gutter requires a 2 x 3 inch downspout every 4000 square feet of roof area.)

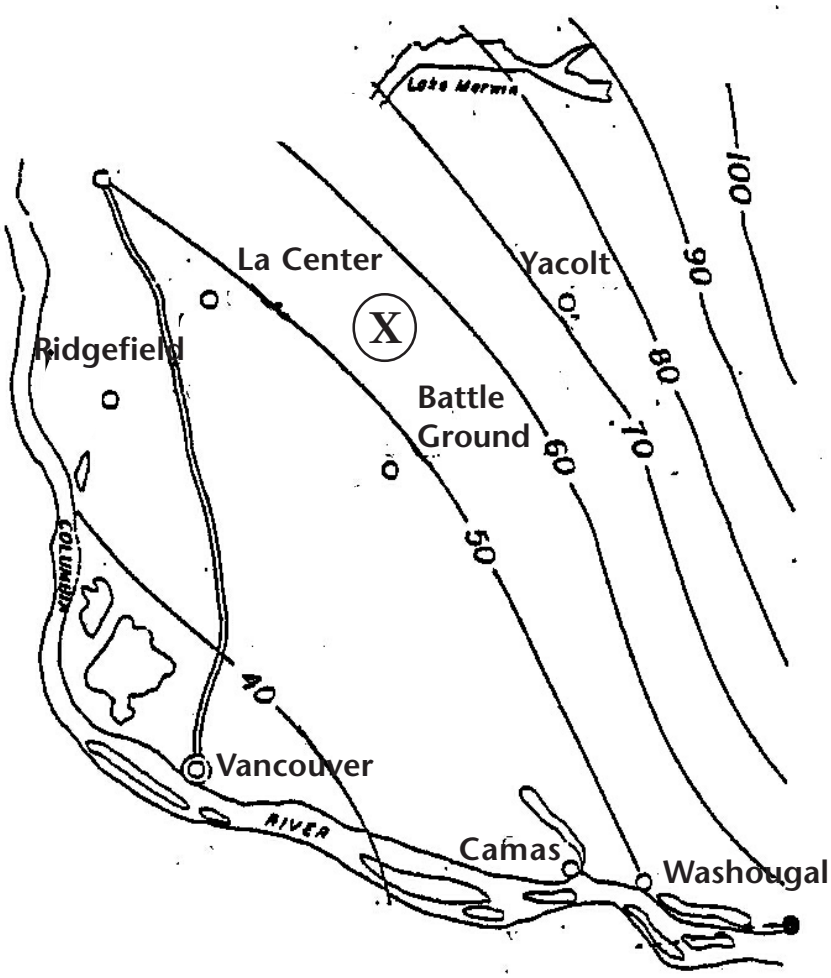


Hanging Gutters. Assemble gutter sections and downspouts using the correct connectors and hangers as specified by the manufacturer. Most home improvement warehouses carry these do-it-yourself gutters. Normally, you place a downspout for every 1000 square feet of roof. In areas with livestock access or frequent vehicle use, protect the lower five feet of downspouts by inserting them through a six inch diameter steel of PVC pipe. A little extra expense now saves you money in the long term.

Outlets. To carry the water from the downspouts, one four inch corrugated plastic pipe can handle the rainwater from a 5400 ft^2 roof area as long as the slope of the outlet pipe is at least .01 feet vertical drop for every foot of horizontal distance (one foot drop for every 100 feet). The outlet pipe should be covered with two feet of backfill to protect it from crushing in areas where vehicles drive over. You should outlet this roof runoff in areas not heavily used by livestock or vehicles. The outlet area should be well vegetated to prevent erosion. It is best if you can locate this where the water can infiltrate back into the ground. You should not outlet this on your property boundary or directly into streams and lakes since this only transfers your problem to someone else.

How Much Rain Do You Receive?

It's simple! Look at the table and estimate rainfall for where you live and figure out how many square foot of roof surface you have. Take these and plug them into the following formula: Area sq. ft. X inches rain X 0.62 = Gallons of runoff per year.



For example, a 60 foot by 35 foot roof equals 2100 sq. ft. (60 x 35). At "X" on the map, you get about 55 inches of rain, so:

2100 x 55 x 0.62 = 71,610 gallons per year from that roof.

Average Rainfall Amounts
Vancouver = 37.32"
La Center = 48.85"
Battle Ground = 47.22"
Yacolt = 75.76"
Washougal = 50"
Ridgefiled = 44"

Adapted by Douglas Stienbarger, WSU Extension Clark County, from Snohomish CD "Easy BMP" series. (2004)

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Reduce Mud & Keep Water Clean

Sacrifice Areas

Maintaining good quality pasture and reducing mud on your property requires limiting livestock grazing during the wet, winter months (November to March). This can be done by utilizing a small enclosure such as a paddock, corral, or pen meant to be your livestock's outdoor living quarters. Called a sacrifice area because it is a small portion of pasture sacrificed for the benefit of the remaining pasture, animals should be confined to the sacrifice area during the winter when soils are saturated and early spring before your pastures become overgrazed (below 3"). A sacrifice area can also be used to care for sick or injured animals or to separate animals. You should wait to create the paddock or sacrifice area until after the ground has dried and firmed. Any materials added to a muddy sacrifice area will only make muddy footing materials!

Why keep livestock off pasture?

Livestock on wet pastures kill grass, compact soils, and create mud. Continuous grazing tramples and weakens grass and churns the soils. Larger animals, such as cows and horses, compact saturated soils due to their size and weight. As grass vigor declines, weeds (some toxic to livestock) take over. Less grass requires purchasing additional feed, while also reducing vegetation that utilizes the nutrients in manure and urine and protects the soil from erosion. Soil particles in rainy season runoff transport nutrients and bacteria which can contaminate nearby household wells and streams.

Location and Size

Locate the sacrifice area on high ground to improve drainage and prevent ponding. Locate the sacrifice area near the barn and manure storage to facilitate maintenance and caring for your livestock. To avoid contaminating nearby water sources, avoid locating the sacrifice area near wetlands, streams, ditches, and wells. Planting a vegetated (grass) buffer strip around the sacrifice area will filter sediment particles, manure, nutrients, and bacteria from runoff leaving the sacrifice area.

How wide should the grass buffer be?

Buffer width depends on soil type, plant density, and slope. A 25 foot grass buffer may be adequate for an area with little or no slope. Generally, the greater the slope, the wider the buffer will need to be. Leave grass at least 3 to 4 inches tall and do not apply fertilizer during the fall. This allows grass to capture nutrients and bacteria on soil particles.

The size of the sacrifice area may vary from a small 20' by 20' area for one animal to a long, narrow paddock (e.g., 20' by 100') where several animals can exercise. Large areas provide active livestock room to move freely and reduce the chances of injury. The amount of land available and the types and number of livestock will determine the size of the sacrifice.

Footing

Footing is the crucial feature in designing and installing a well-drained, all-weather sacrifice area. Footing material builds up the surface and allows stormwater to drain through, thereby decreasing the amount of mud. Considerations when selecting footing material include:

Is it a suitable surface for my animals and property?

Is it a safe surface for my animals to run, stand, and lay down on?

Can I easily pick manure from the footing material?

What is the availability and cost?

Each type of footing has advantages and disadvantages as outlined in Table 1. It pays to spend some time researching and selecting what works best for your situation. Many livestock owners find that combinations of the footings work best, often with gravel and/or sand covered by hogfuel.

TIP: Some horses are allergic to cedar and show skin sensitivity.

Economical: Hogfuel. Typically comprised of bark pieces from evergreen tress such as Douglas fir, pine or cedar, hogfuel packs down and decomposes over time. This requires periodic replacement. Hogfuel locks up some of the nitrogen and urea in manure. As it decomposes, microorganisms breakdown the hogfuel and in the process, convert the nitrogen and other nutrients into a more stable form that releases over a longer period of time than straight manure. Inspect hogfuel before you purchase since there can be a lot of variation in what constitutes hogfuel. Material with mostly small pieces will break down quickly, while larger pieces will make it difficult to remove manure. Installing 12 – 24" of hogfuel with flakes of straw or hay underneath and regularly removing manure will extend the life of the material. Any incidental pieces of wood that are removed with manure can be composted. Hogfuel can be a relatively inexpensive footing for sacrifice areas and other heavy use areas such as feeding and watering areas, gates, and paths.

TIP: Beware of construction materials which may contain metal, nails or other sharp objects. Yard debris sold as hogfuel may contain ornamental plants poisonous to livestock.

Intermediate: Gravel and Sand. When properly installed and maintained, gravel and sand last longer than hogfuel, but are more expensive. Types and sizes of sand and gravel vary. Footing material most often used is an 8-12" layer of 3/8" minus to 5/8" minus crushed gravel. Additional gravel needs to be added over time if it is applied directly to soil. Laying down geotextile fabric will keep the gravel for subsiding, but significantly increases costs. Gravel forms a firm footing for high traffic areas, such as entrances, gateways and walkways, while hogfuel can be used in less trafficked areas.

TIP: Put down twice as much footing as you have mud in the winter. For example, if you have three inches of mud, you would install footing at least six inches deep.

Using coarse sand facilitates better drainage. Since feeding animals on sand may cause digestive tract problems, animals should be fed elsewhere. Careful manure removal from sand and gravel footings is extremely important as manure particles will form a barrier to water percolation over time.

Deluxe: Geotextile Fabric with gravel, sand and/or hogfuel. Geotextile fabric can be used with any of the above footings to improve drainage, separate layers and prevent materials from migrating into the soil. Made of woven plastic and often used in road and other construction projects, the fabric allows water to pass through, but not sand or silt. For best performance, use this fabric on a level surface

Table 1: Footing Materials

Material	Depth	Material Life	Cost	Pros	Cons
Hogfuel	18 – 24"	2 – 3 years	$	Inexpensive Manure removal not required Easier to remove manure	Potential hoof problems Some animals allergic Decomposes and must be removed
Gravel	8 – 12"	indefinite, will need more material over time	$$ -$$$	Packs to make a firm surface Filters water	Expensive Requires thorough manure removal May be too hard a surface Can end up with gravel in manure and compost
Sand	8 – 12"	indefinite, will need more material over time	$$ - $$$	Easy to remove manure Softer footing	Expensive Requires thorough manure removal Ingestion may cause problems
Geotextile Fabric + hogfuel, gravel, or sand	6" + over fabric	indefinite, will need more material over time	$$$$	May require extend life of other footing materials Long lasting	Very expensive

and covered with a minimum of 6 inches of footing, such as gravel. Applying footing material over the fabric at a greater depth will ensure the animals do not dig down to the fabric and tear it up. All edges must overlap at least 6" and outer edges of the fabric should be well covered. One common footing material combination covers the fabric with 6" of gravel, followed by 6" of sand, and topped with a layer of hogfuel. Landscape fabric may substitute for geotextile fabric, but deteriorates faster and may need to be replaced.

Fencing

Livestock can be hard on fences, so it is important to select a sturdy safe fencing for your sacrifice area. Be sure there are no protruding objects that could harm livestock, such as bolt ends or nails. Low building overhangs and roof corners may also pose a danger to livestock. Gates need to be large enough to accommodate farm equipment and deliveries of footing materials, feed, and hay.

TIP: Remember to account for the thickness of your footing when selecting and placing fence posts to ensure correct fencing height.

Runoff

Minimizing water runoff through the sacrifice area is important to prolong the life of footing materials and keep manure out of the runoff. Install gutters on barns or sheds to divert rainwater away from the sacrifice area. To ensure adequate drainage, slightly slope the sacrifice area. To reduce the amount of contamination to runoff from the sacrifice area itself, place a vegetated filter strip or swale along the downhill side to collect and filter runoff. French drains, swales, and berms can be utilized to divert upslope runoff around sacrifice areas.

Your new sacrifice area will be an integral part of any pasture management plan. Use it during the grazing season to allow pasture to recover and prevent overgrazing. During the winter, keep your animals off saturated pasture soils by using this area as your animals' outdoor living area. This will limit compaction and maintain healthy pastures.

If you would like additional information on pasture and weed management, managing mud and roof runoff, or manure composting contact:

Washington State University
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Brush Prairie WA 98606
360-883-1987 extension 3
http://www.wa.nrcs.usda.gov/

Information Sources on the web:

Shady Springs Farm, Equine Winter Turn-Out Project http://www.shadyspringsfarm.com/

WSU King County Extension Agriculture Publications http://www.metrokc.gov/dchs/csd/wsu-ce/agriculture/Publications.htm

Horses for Clean Water http://www.horsesforcleanwater.com/

WSU Small Farms Team http://smallfarms.wsu.edu/publications/index.html

Oregon State University Extension Service, Oregon Small Farms http://smallfarms.orst.edu

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Snohomish Conservation District. n.d. *Sacrifice Areas*. Easy BMP Series. 1 pp.

Stephenson, G., D. Hannaway, A. Blickle, L. Brewer, L.J. Brewer, M. Chaney, and M. Livesay.

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Disposal Options

1. ***Dispose off-site*** to a landfill that accepts manure or hire someone to pickup and dispose of manure for you.
2. ***Compost manure.*** This requires the right ratio of carbon (bedding or leaves) and nitrogen (manure). Try 30 carbon to 1 nitrogen by volume. Water to keep the pile 50% moist and aerate the pile regularly.
3. ***Spread manure***. Spread in spring or summer. Test manure for nutrient content and spread based on soil test recommendations. This will ensure the nutrients are being utilized by the vegetation growing. Unused nutrients can pollute water bodies and ground-water. Remember that raw manure may contain weed seeds which will be spread back on the land.

Estimated Horse Manure Application Rates*

- Dryland range: 1 ton/ac/yr
- Irrigated alfalfa: 5-10 tons/ac/yr

**Test manure for nutrient content and spread based on soil test.*

Use a thermometer to monitor the temperature of your compost.

For more information on manure and composting, visit
www.ext.colostate.edu/sam

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Manure Management for Small Acreages

Colorado State University Extension
USDA NRCS
United States Department of Agriculture
Natural Resources Conservation Service

Sustainable Small Acreages

www.co.nrcs.usda.gov
www.ext.colostate.edu/sam

January 2013

Why Manage Manure?

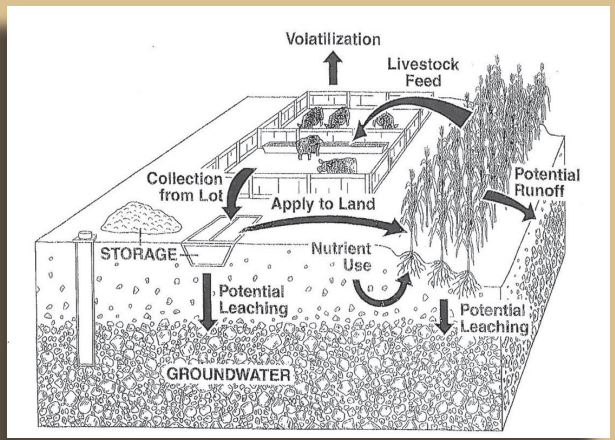
Constituents of Animal Waste

- -Pathogenic organisms
- -Organic matter
- -Heavy metals
- -Salts
- -Micronutrients *(Ca, Mg, S, Mn, Zn, Cu)*
- -Potassium
- -Phosphorus
- -Nitrogen *(nitrate NO3, ammonia NH3, ammonium NH)*

Manure can be a valuable resource but can also be a source of water pollution, odor, flies, parasites, and other nuisances. **If not properly managed, manure can contaminate drinking water, harm wildlife, and reduce property values.**

Mud and manure can cause abscesses, thrush, and other diseases in livestock. Dried manure produces molds that contribute to respiratory problems in horses and cattle. By adopting simple and low cost best management practices (BMPs) for storing, handling, managing and utilizing manure, the environment and health of farm animals will benefit.

Nutrient Management Loss



Lost nutrients can contribute to water pollution. Manure nutrients are lost via:

- **Erosion**
- **Water run-off**
- **Volatilization**
- **Leaching**

Manure Management Goals:

1. Utilize manure nutrients for enhancing soil.
2. Protect the health and safety of the public and livestock.
3. Prevent surface and ground water contamination.

Best Management Practices (*BMPs*)

1. Divert clean water away from manure:

- Construct berms, terraces or waterways, and/or use downspouts to divert clean water away from corrals and manure storage areas.

2. Ensure manure discharge will not enter a water body or leave the property:

- Limit animal access to ponds, streams, ditches, and wetlands.
- Collect manure frequently.
- Stockpile manure at least 100 feet outside a floodplain.
- Do not stockpile manure in a dry creek bed or ditch.

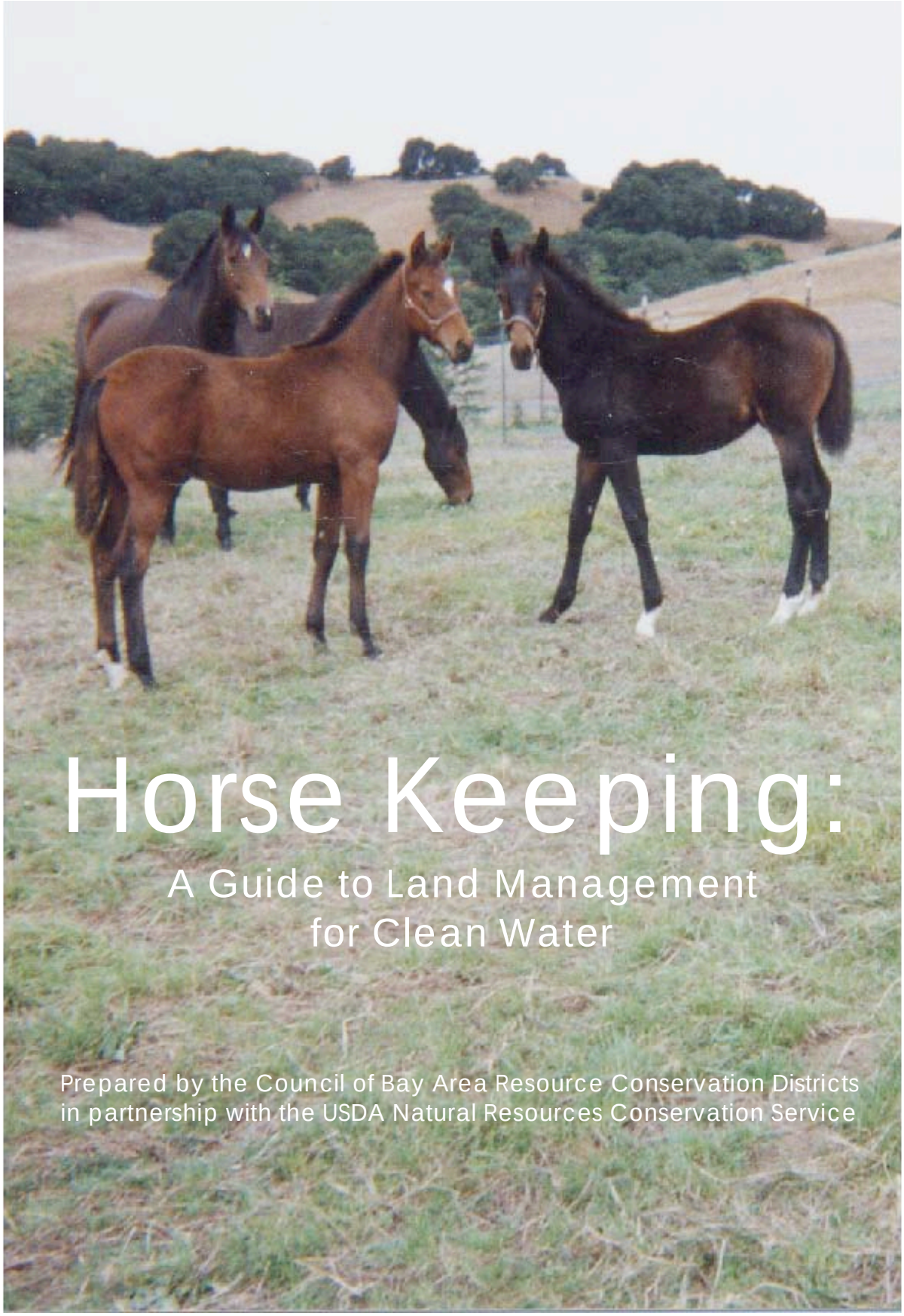
To reduce erosion and maintain water quality, water livestock off-stream and manage stream access with fencing.

3. Protect ground water:

- Locate manure storage piles and livestock corrals at least 150 feet down-gradient from wells.
- Use a 150 foot buffer around wells when land applying manure.

4. Reduce nuisances like flies and odor:

- Stockpile manure downwind from barns and 200 feet away from neighbors.
- Plant trees to reduce wind and odor from stockpiles.
- Keep a lid on manure dumpsters.
- Remove manure from corrals and pens every few days to prevent flies, parasites, and worms.
- Cover fresh manure in stockpiles with at least 5 inches of clean bedding, straw, or hay to prevent flies.
- Prevent flies by using pesticides or fly predatory wasps (non-stinging) which can be purchased to manage flies.



Horse Keeping:

A Guide to Land Management for Clean Water

Prepared by the Council of Bay Area Resource Conservation Districts in partnership with the USDA Natural Resources Conservation Service

For more information about ordering this publication, contact:

San Francisco Bay Resource Conservation & Development Council, (formerly known as the Council of Bay Area Resource Conservation Districts)
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Petaluma CA 94954

The Council of Bay Area Resource Conservation Districts (RCDs): RCDs participating in this project include Alameda County RCD, Contra Costa RCD, Marin County RCD, San Mateo County RCD, and Southern Sonoma County RCD. See Resources Direction, section 5.1 for contact information.

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- *Groundwork: A Handbook for Erosion Control in North Coastal California*. 1987. Marin County Resource Conservation District. Illustrations used.
- *Home*A*Syst: An Environmental Risk Assessment for the Home (NRAES-87)*, published by NRAES, the Natural Resource, Agriculture, and Engineering Service, Cooperative Extension, 152 Riley-Robb Hall, Ithaca NY 14853-5701. (607) 255-7654. <www.nraes.org>
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- Marin Coastal Watershed Enhancement Project. 1995. UC Cooperative Extension, Marin County. Fact Sheets adapted for use in this guide:
  — *Water Quality Variables and Water Testing for Rural Landowners*
  — *Vegetation Monitoring*
- *Fight Nature with Nature: Environmentally Friendly Insect Control for Horse Farms*. 1999. Alayne Blickle, Horses for Clean Water.

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- Alameda County Department of Public Works
- Alameda County Resource Conservation District
- California State Coastal Conservancy, Bay Area Conservancy Program
- Marin County Stormwater Pollution Prevention Program

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Cover Photo: Oldenberg colts at Hawkwood Hill Farms, Sonoma County

Preface

THE HORSE HAS BEEN THE FUEL that stoked the fires of progress in time of peace and war throughout the centuries. When the need was greatest in the building of a new nation, or to carry supplies in time of war, the horse and mule responded to the call.

The horse has served as the early day equivalent of a tractor. They were our first example of rapid transportation and a true dependable friend. When all else failed they would be the food that served the top, or the bottom of the food chain.

The surge in population during the last century, with its need for increased quantities of water, along with the diminished status of the horse, has created a situation where the needs of our horse industry has become secondary and we have ended up with little political power.

So, understanding that the demographics have changed is tantamount to effecting change. Water was once a surplus commodity, is now in great demand and is the subject of lawsuits up to and including the Federal Government. Everyone wants "their share" of a safe, guaranteed-supply commodity.

The water we drink and the fish we eat require clean water, so cleaning up and maintaining available supplies of water is a job for all humanity.

The Council of Bay Area Resource Conservation Districts (RCDs) has prepared this manual as a road-map to help us be a *volunteer part of the solution, rather then a part of the problem*. Many times we see "edicts" handed down where industry has little or no input. In this undertaking the RCD is saying, "Here are graphic examples of typical problems and we would like to work with you to solve yours."

The time to look at your operation is now. The window of opportunity is open For us to manage our properties in a way to minimize or eliminate pollution. If we wait to see what happens, laws *will* be enacted that require us to make changes that may seem unfair and questionable.

Ken Brown
California State Horsemen's Association

Preface

LAND: THEY AIN'T MAKIN' IT ANY MORE, so said Will Rogers. With burgeoning population and suburban encroachment into previously rural areas there is increasing competition for scarce resources. At the same time, there is increasing attention by all levels of government to assure a clean and adequate supply of water and resource protection. Within the next decade the government intends to enforce more stringent regulation to assure clean water for the future.

Horsemen were amongst the original land conservationists is this country. We have a long tradition of respect for the environment, because it is the milieu in which we operate. We must now become proactive, taking the lead in developing Conservation Plans for our horse keeping facilities to be able to answer the challenges that will be coming to us in the future as regulatory enforcement ratchets down to the local level. Not all of our new neighbors will be livestock-friendly. Most certainly, few of them will understand that the equine is unlike most other animals in many ways.

The enlightened horse keeper should begin now to take a number of actions:

- Evaluate your property for possible impacts from sediments or nutrients into water bodies and remove any manure storage away from water bodies
- Immediately write down your manure management plan, so it is ready if challenged
- Begin a Conservation Plan that includes how you intend to modify your property if your current operations are within 50 feet of riparian corridors
- Photograph your current operation and anytime you make a change
- Begin a water monitoring data program for any creeks and seasonal drainage on your property, because you will need it sooner or later.

This manual will help you to do these things yourself. It is a treasure of resources that, when implemented, could save you time and aggravation in the future since the best defense is a good offense.

Happy Trails from Adda Quinn of EnviroHorse

Preface

THROUGHOUT THIS COUNTRY the rural landscape is in significant transition. The face of agriculture is being transformed with the resultant loss of the family farm and subsequent proliferation of impersonal agribusiness. The vast majority of our rapidly increasing population now resides in urban and suburban areas; these non-agricultural citizens are frustrated by the immitigable impact of pollution and sprawl. Caught between these two forces are small agriculturists, including equestrians.

Equestrians are becoming aware of an increasing burden. Our small farms are being consumed by population growth, but jurisdictions fail to zone for new small agricultural parcels so we can continue our lifestyle. As dense population centers with associated noise, pollution, vandalism, and other infringements move towards our fence lines we are told we have become a nuisance. Our farms are being reclassified as "recreational facilities" because we continue the tradition of sharing use of our agricultural properties with neighbors in town. After having struggled to assist with open space preservation and trail development we are told that our impact on these areas will limit our future usage.

Most dramatically, equestrians are now being asked to develop programs to limit our environmental impact. We are threatened with regulation as our urban and suburban neighbors continue to cover their landscape with high water runoff from hard surfaces; spread fertilizers on their vast tracts of artificial landscaping; pollute our waterways with poorly regulated petrochemicals, pet excrement, pesticides, herbicides, detergents, solvents, etc.; and pollute the air with various exhausts, particulate matters, and fumes.

I'm sure fellow equestrians will recognize my words as only a partial description of the problems we face. Many equestrians are concerned that efforts such as this guide are the beginnings of regulatory infringement that will continue to result in limitation of equestrian open space usage; however, this is not the case. Our friends from the Council of Bay Area Resource Conservation Districts, in partnership with the USDA Natural Resources Conservation Service, have prepared this guide to aid equestrians with the endeavor to lead their community toward responsible stewardship of open space resources. This guide has the potential to be used as a tool to demonstrate that equestrian agricultural land usage can continue as an integral component of the working landscape through voluntary programs with minimal regulatory intervention. Use this valuable tool judiciously.

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Introduction

This guide provides practical management information to San Francisco Bay Area horse owners on what they can do to help protect the environment. Whether a horse owner has one animal or operates a boarding facility, all equestrians play an important role in assuring that our watersheds are healthy and our creeks clean. Because of increasing pressures from human activity, all potential sources of environmental pollution are under critical scrutiny. Pollution can come from either point sources (e.g., a specific manufacturing plant) or non-point sources (e.g., livestock throughout a ranch).

All human activities, including livestock keeping, can potentially affect both land and water resources. Water resources include small seasonal drainages, creeks, ponds, and both near-surface and deep ground water. As rainwater flows across the land, it can pick up and transport pollutants such as chemicals, soil and animal wastes which can be deposited into our water resources. Degradation of water resources can affect our drinking water supplies, recreational areas and wildlife habitat, as well as cause flooding, property damage, and harm San Francisco Bay and coastal estuaries. What may appear to be a small action at the top of a watershed, can, in fact, have tremendous consequences for downstream neighbors. As a result, urban and rural communities are now working together to improve water quality through integrated watershed management programs. These programs seek to include a broad base of participants from urban, construction and agricultural sectors. Horse keeping activities, as a potential non-point source of agricultural pollution, will be increasingly scrutinized to assure that horses are not contributing to environmental degradation.

The purpose of this guide is to help horse owners take a look at the big picture and to evaluate how equine facilities might affect local natural resources. It advises evaluating your horse keeping facility to look for opportunities for improvement. It suggests that developing a Conservation Plan for a horse keeping property, which describes both short- and long-term management systems, can be used to prevent and reduce environmental degradation. Finally, it seeks to heighten awareness of the need to implement conservation measures to protect streambanks and water quality for humans and wildlife, prevent accelerated movement of soil from your property, and decrease bare soil where feasible in our increasingly urban setting. Its primary focus is on erosion control, stormwater runoff control methods, and manure management.

As our neighbors move closer to horse keeping facilities it will become more important to reduce flies and dust, and maintain good relationships in increasingly congested areas.

Conservation of our natural resources is a long-term commitment. While there are short-term practices that can be implemented immediately and make a

tremendous positive difference for the environment, many conservation projects are long-term efforts requiring thoughtful planning and careful implementation. It will be important to custom-tailor site-specific management practices to your property. Some practices may work; others may not. Consult with professionals to minimize mistakes. Learn what works from other horse facilities, and share your knowledge with friends. Making informed decisions will save money, time, and energy—leaving more opportunity to enjoy your horses.

How to Use this Guide

Whether you are planning a new facility, upgrading an existing operation, need to solve a specific problem, or want to improve your natural resources, this guide can assist you with identifying problems, and suggest proper management methods for a variety of problems horse keepers might encounter. Some conservation measures will be simple and easy to implement, while others are complex and require professional technical assistance.

This guide is presented in five chapters:

- **Keeping Horses and Protecting Water Quality (Chapter 1)** introduces water quality concerns, objectives of good management, and explains how to develop and implement a Conservation Plan.
- **Evaluate Your Horse Keeping Facility (Chapter 2)** is an overview of horse facility features and activities that are common sources of water quality concerns.
- **List of Conservation Measures (Chapter 3)** used in this manual are listed and noted throughout the guide in ***bold italic.***
- **Conservation Measures to Improve Water Quality (Chapter 4)** covers specific measures to control erosion, manage stormwater runoff, and manage polluted water.
- **Resources Directory (Chapter 5)** includes a compendium of information, including how to obtain technical assistance, seeding recommendations; checklist for “winterizing” horse facilities; what facility operators should know about regulations and permits; what horse keeping managers should know about threatened and endangered species; how to measure progress using photographic monitoring techniques; how to monitor water quality using easy techniques; how to measure vegetative cover by estimating ***residual dry matter*** in pastures; suggestions for alternatives to pesticides; ways to improve songbird habitat; and a list of helpful publications and resources.

A glossary of terms is included in the back of the manual. Websites are included for reference. Website addresses frequently change, so search for keywords in a web browser or try the beginning words in a long website address.

Chapter 1

Keeping Horses and Protecting Water Quality

Healthy creeks and clean ground water reflect good land management and stewardship on the surrounding land. Good horse keeping management practices reduce potential pollution problems. It is important to be aware of the role that good horse keeping can play in the "big picture" of sustaining a healthy watershed.

Section 1.1 describes the water resources that we seek to protect—primarily surface water and ground water.

Section 1.2 presents three key objectives for horse keeping stewardship:

- Control erosion
- Keeping "clean" water clean
- Manage polluted water

Section 1.3 outlines WHY a Conservation Plan should be created and HOW to make one.

1.1 Protecting Surface Water and Ground Water Quality

Safeguarding our surface water (seasonal drainages, creeks, rivers, ponds, etc.) and ground water is an important part of horse keeping. Aquatic life is highly susceptible to pollutants from human activities. Beneficial uses of water, such as swimming, fishing, and drinking water can also be affected. Some environmental consequences of horse keeping activities that may contribute to water pollution are:

- Sediment from eroding areas such as overgrazed pastures, roads and trails, and bare soil in ***paddocks***, ***turnouts***, corrals and arenas
- Polluted water draining from manure piles and ***horse wash areas***
- Excessive nutrients (from horse waste) that wash off pastures during storms
- Removal of, or trampled vegetation at streamside areas that can lead to streambank erosion
- Removal of vegetation which filters and absorbs water and pollutants from runoff

Watersheds

Understanding the connection between land, creeks, ground water and management is a key to preventing problems. A watershed is an area of land that drains into a distinct creek, river, lake, bay or ocean. It includes all major and minor creeks, seasonal drainages, riparian corridors (the vegetated area next to streams), flood plains, and land that water flows over or through on its way to a bay or the ocean. Watersheds are named after the local creeks that drain them. It is important for landowners to know what watershed their property is located in to be aware of where water goes, who they are affected by, and who they might affect.

A healthy watershed will maintain high water quality

A healthy watershed will have clean creeks with cool water and a thriving riparian corridor, clean and abundant ground water supplies for drinking water and other uses, and stable, well-vegetated land. A healthy watershed will maintain high water quality, provide fish and wildlife habitat, control erosion, maintain dry season creek flows, reduce flash flooding, and provide safe drinking water from wells.

Both natural conditions and human activities within a watershed influence the condition of creeks and ground water. Changes in creeks may happen suddenly as the result of a storm event (causing new streambank erosion) or a sudden change in land use (such as clearing land for development). Other problems in the watershed may accumulate and take many decades to develop—such as a creekbed becoming filled with sediment (soil particles that are transported by, suspended in, and deposited by water). Excessive sediment coming from the upper watershed often deposits in flatter reaches of channels in the lower watershed which can cause flooding and can be expensive to dredge.

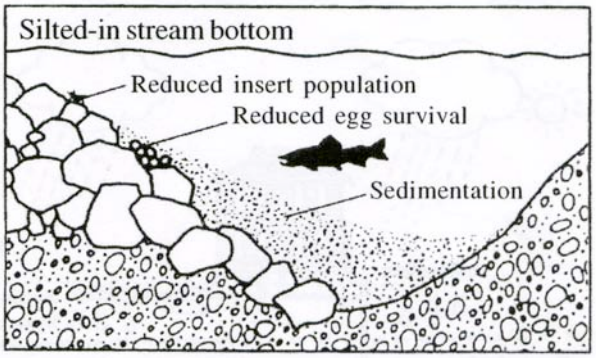
Healthy Creeks[1]

All creeks are important, whether they flow year-round (perennial), part of the year (intermittent), or just during storms (ephemeral). Even small seasonal drainages are important because they can carry water, soil, and pollutants into larger creeks.

In the San Francisco Bay Area, creeks should be managed so they are healthy for people and wildlife. Healthy creeks will have these characteristics:

- **Cool water** is critical for aquatic life. Cool water also helps reduce toxic levels of ammonia, which can come from decomposing horse waste and organic debris. Dense, overhanging vegetation helps keep water cool. Steelhead and salmon require water temperatures between 40º and 60º F.
- **Clean, clear water**. This means plenty of oxygen for fish and other aquatic wildlife to breathe. Suspended sediment, nutrients and salts from animal waste, fertilizers, sewage, and toxics such as metals, pesticides, oil, and grease degrade water quality and reduce the amount of oxygen available.
- **Thriving fish, amphibian, and aquatic insect populations**.
- **A variety of pools and riffles in streambeds** with abundant gravel and cobbles. Pools are depressions in the streambed with calm, deep water. Riffles are stretches of stream with moderate turbulence caused by water flowing over rocks. Pools and riffles are both important habitat areas for aquatic life. Gravel and cobbles are important for spawning and habitat for young fish.
- **A healthy riparian area** characterized by an abundance of native vegetation, minimal erosion, and some undercut banks for aquatic habitat. The riparian zone can provide food, cover, and water for deer, birds, and other wildlife.
- **A high water table.** Healthy creeks receive water percolating through soils in the water table. Acting like a sponge, the soil releases water gradually into creeks and other water bodies.
- **Clean ground water,** free of contaminants, that can be used for drinking water.

Manage horse access to small seasonal drainageways because they carry water and pollutants into larger creeks. Moving the fenceline to the left of this swale will help control erosion, keep creeks and ground water clean, and reduce muddy conditions that create problems for horses.



Too much sediment is a problem for aquatic life. When sediment fills in creek beds, it also fills in pools, eliminates shelter and fish spawning habitat, and diminishes food supplies for fish and aquatic insects. Some chemical compounds can bind to sediment—potentially creating toxic conditions for fish and other aquatic life. Courtesy of Stream Care Guide, County of Santa Cruz.

[1] This section is drawn from *Creek Care: A Guide for Urban Marin Residents*. Marin County Storm Water Pollution Prevention Program. 1998.

- **Water that can be used for contact and non-contact recreational activities.** Swimming, fishing and boating are popular water activities that depend on clean water.
- **Scenic beauty.** Whether in cities, suburban neighborhoods, rural areas, or parks, healthy creeks add to the scenic value of the landscape.

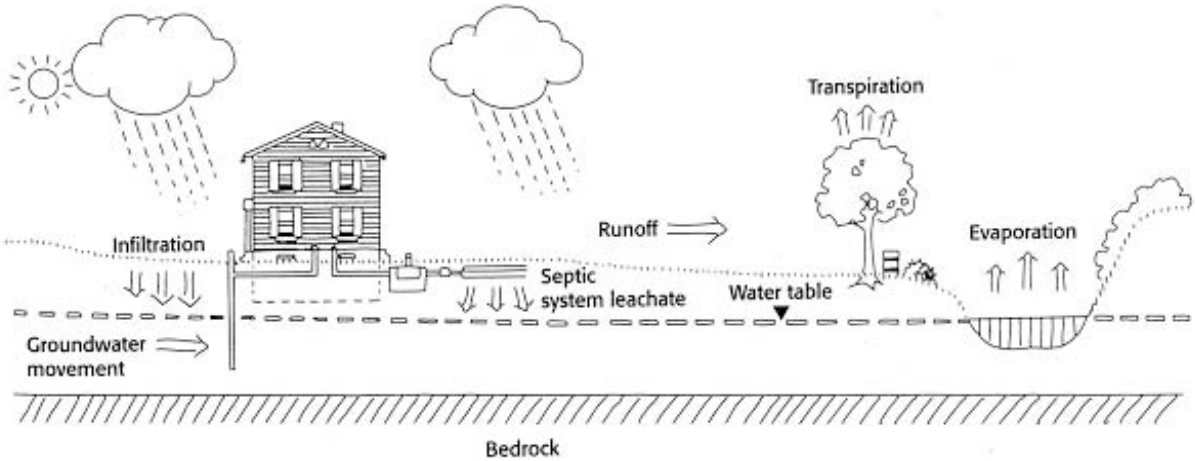
An Underground Link to Clean Ground Water

Ground water and surface water are interconnected. Water not only percolates downward; near-surface ground water also flows horizontally into surface water bodies. While ground water generally follows the same path as surface water, hillside slope is not always a reliable indicator of ground water flow.

Ground water is an important source of drinking water. As water soaks deeper and deeper into the ground, it infiltrates and recharges aquifers, the underground layers of porous rock and gravel that store water. Ground water moves through the earth as part of a dynamic flow system from recharge areas to discharge areas such as springs and wells.

The *water table* marks the boundary in which all pore space within it soil particles are saturated with water. Water tables fluctuate throughout the year and are usually highest in early spring.

Near-surface ground water is the water that collects within the soil zone, usually found at four to six feet below the soil surface and is generally most vulnerable to contamination from pollutants that leach downward through soil layers. This is important because near-surface ground water often feeds directly into creeks. Near-surface ground water should not be tapped for wells.



In the hydrologic cycle, water falls to the earth as rainfall and snow and returns to the atmosphere through transpiration and evaporation. Surface water, ground water, and near-surface ground water are interconnected and provide benefits to humans and wildlife. Your horse keeping activities can help or harm the natural resources on your property and those of your neighbors downstream. Source: *Home*A*Syst: An Environmental Risk Assessment for the Home* (NRAES-87).

The Soil and Water Connection

Different types of soils vary significantly in their capacity to hold water, the ability to percolate water, and the types of vegetation they can support. These characteristics are important because they affect the rate at which excessive nutrients, such as nitrogen from animal waste, are carried by surface flows overland and down through the soil layers. Rainfall that can not soak into the ground starts to flow overland as runoff. Surface runoff increases the erosion hazard and the possibility for sediment and manure to be washed into nearby creeks and seasonal drainages.

> Soil types affect the land's ability to deal with runoff

The porosity, or infiltration rate, of a soil (ability of air or water to pass through minute surface openings) affects the rate at which rainfall can soak into the ground. Soil particle size influences how water moves through the ground. This may be a concern especially if the water table is relatively close to the surface. For example, sandy soils are the most porous soil and can absorb rainfall more quickly than other soil types. However, they may allow water to seep downward too quickly for effective filtration or decomposition of pollutants. Clay soils are the least permeable and absorb rainfall more slowly. However, water can still carry pollutants through the clay soils. In the summer, clay soils often shrink and form deep cracks that allow water to quickly percolate down into the soil many feet. Also, clay hardpans that underlie more porous soil will slow the downward flow of water and cause it to start moving horizontally beneath the surface, and water becomes "perched" upon the hardpan layer. Deep loamy soils support vigorous plant growth and deep roots are best for trapping and storing nutrients and other pollutants that percolate into the soil.

Soil compaction occurs when livestock grazes on wet soils. Grazing by large animals can cause compaction because their hooves have a relatively small area and therefore exert a high pressure. Soil particles are pressed together, reducing the pore space between them. Compaction restricts rooting depth, which reduces the uptake of water and nutrients by plants. Compaction decreases infiltration and thus increases runoff and the hazard of soil erosion.

The type of bedrock or sediment deposits below soil layers also influences how water travels into ground water aquifers. Shale, granites, and other impermeable types of rock impede the downward movement of water and pollutants. Other rock, such as limestone, can be highly permeable, allowing water to move freely into ground water. When bedrock is fractured, water can move through it vertically, laterally or unpredictably, spreading pollutants rapidly over long distances.

1.2 Stewardship Objectives

Practicing good *stewardship* can help keep horse facilities, creeks, and ground water clean. Stewardship means taking care of land and water resources on your property. Neighboring landowners can also work together to promote stewardship within their larger watershed.

Three basic stewardship objectives for horse keepers to remember are:

1. Control erosion – keep soil in place
2. Keep "clean" water clean
3. Manage "polluted" water

Each of these objectives is explained below. The management systems and conservation measures presented in Chapters 2 and 4 of this guide can help landowners meet these objectives. Not only do conservation measures help control erosion, manage stormwater runoff and prevent pollutants from reaching creeks and ground water, they also create healthier conditions for your horses.

Stewardship Objective #1: Control Erosion

Erosion occurs where soil is bare and unprotected from the forces of rainfall, flowing water, wind and gravity. While some sediment is needed to bring nutrients and substrate materials (mineral and/or organic matter that forms the streambed) to aquatic ecosystems, too much sediment causes problems and is considered a pollutant. Some soil erosion is caused by natural process. However, a great deal of erosion is "accelerated erosion" because the natural or "background" rate has been speeded up as a result of human activities. Some erosion problems may be relatively simple to solve, while others are complex.

Vegetation, geology, soil characteristics, steepness and length of slope, rainfall, and human activities (i.e., soil disturbance or alteration of natural drainages) all contribute in varying degrees to the erosion rate at a particular site. For this reason, it is important to know about the site characteristics present at each horse facility (see Section 1.2 on developing Conservation Plans).

Typical erosion areas at horse facilities

Humans can alter natural processes with livestock practices. Accelerated erosion can wash soil from areas of bare ground such as arenas, ***paddocks***, ***turnouts***, and overgrazed pastures. Severe erosion can form gullies, destabilize creek banks, and damage roads.

It is important to determine the cause of soil erosion. Accelerated erosion could be caused by uncontrolled concentrated flows from rain gutters, winter runoff from roads, removal of protective vegetation in pastures due to heavy grazing, livestock access to riparian areas when streambanks are saturated, or other ways.

Why is sediment a pollutant?

Too much sediment reduces the ability of creeks to carry floodwaters by filling in the creek bed. Sediment fills in pools, eliminates shelter and fish spawning habitat, and diminishes food supplies for fish and aquatic insects. It can be very expensive to dredge excess sediment from creekbeds, ponds and lakes.

Accelerated erosion can also pollute drinking water supplies because herbicides, pesticides, chemicals, and organic compounds can all bind to sediment—potentially creating toxic conditions for humans and aquatic life.

Basic Ways to Prevent Accelerated Erosion

To incorporate erosion control measures into your management systems, see Chapter 2. For specific details on conservation measures listed in ***bold italic***, see Chapter 4.

- ***Keep areas well vegetated*** and restore bare areas with vegetation. Plant roots, especially those of grasses, hold soil in place and help water infiltrate into the ground rather than run off. Vegetation also dissipates the force of rainwater hitting the ground, which detaches soil particles.
- ***Avoid concentrating water. Concentrated runoff can be highly erosive.*** Try to disperse runoff by spreading it out in a thin, shallow "sheet." Areas to watch are roads, roofs, compacted soil, and other impermeable surfaces that shed water quickly and increase the amount and velocity of runoff.
- ***Control horse access and human activities in vulnerable areas*** such as wetlands, creek banks, meadows and steep hillsides. Limit access, especially during wet periods.
- ***Manage pastures to prevent heavy grazing***. Avoid soil compaction and excessive removal of vegetation by timing the use of pastures and controlling the numbers of horses. Rotate pastures to allow them to rest from grazing, to allow grasses to regrow and mature so they will reseed.
- ***Use filter strips and riparian buffers*** near creeks. Maintain a strip of ***dense*** grass downslope of bare areas such as ***paddocks*** and ***turnouts*** to help trap sediment. ***Riparian*** buffers provide valuable wildlife habitat and should contain a variety of plants including grasses, forbs, shrubs and trees.
- ***Keep creek banks vegetated*** to hold soil in place, trap sediment, and provide valuable wildlife habitat. Grasses have fibrous roots that hold the soil in place. A good indicator of root mass in grasses is the above ground growth generally equals the below ground root system. Shrubs and trees have deeper roots that are either fibrous or taproots that will anchor the soil in place.
- ***Install kick boards*** or lay railroad ties or telephone poles around arena perimeters. These will help hold footing material in place and keep it from washing away.
- ***Properly construct and maintain roads, trails, and parking lots***. Protect earthen surfaces and drainage ***ditches*** from erosion by using properly designed drainage systems, including ***diversions*** and ***culverts.*** Use appropriate surfacing materials and techniques.
- ***Use proper construction techniques***. Revegetate areas disturbed by construction. During construction install and maintain ***silt fences*** or ***straw bale sediment barriers*** to trap sediment and slow the movement of water. Avoid soil disturbing activities just before and during the rainy season.

Stewardship Objective #2: Keep "Clean" Water Clean

Rainwater flowing across the land, or in channels or pipes, is called stormwater runoff. It is important to keep this "clean" water clean by diverting it away from areas that can be a source of "pollutants" such as a ***manure storage areas***, ***horse wash areas***, and other high-use areas. Keeping "clean" water clean is easier than managing and treating it once it becomes "polluted" with manure, sediment, or chemicals.

Keeping stormwater runoff away from areas with pollutants also promotes horse health. Reducing the amount of manure and mud will help eliminate insect and worm breeding grounds, reduce bacteria and fungi that cause horse disease and hoof problems, and improve footing. It will also reduce the amount of energy that horses spend trying to keep warm while standing in mud. Managing mud and manure can make tending horses more pleasant, as well as improve aesthetics for a facility, neighborhoods, and communities.

Avoid grazing directly in creeks so horse manure and urine as well as sediment from streambank trampling does not enter waterways to create conditions detrimental to drinking water supplies, recreational activities, and the environment.

Basic Ways to Keep "Clean" Water Clean

To incorporate these measures into your management systems, see Chapter 2. For specific details on measures listed in ***bold italic***, see Chapter 4.

- **Divert "clean" water around areas with pollutants.** Use ***berms***, ***grassed waterways***, ***under - ground pipelines***, or other methods. Consider where water will be diverted to, and make sure you do not cause new problems.
- **Locate buildings and confinement areas away from creeks, steep slopes, and floodplains**.
- **Minimize disturbance to wetlands, riparian areas and meadows**.
- **Limit impacts of grading, runoff from roofs and other impermeable surfaces**.
- **Maintain vegetation and replant bare areas.**
- **Control potential runoff from water troughs.**

Stewardship Objective #3: Manage "Polluted" Water

Stormwater becomes polluted if it picks up physical, chemical or biological elements as it flows through manured or bare areas. Polluted water must be managed to prevent it from reaching creeks and/or minimize leaching (moving downward into soil) into ground water. It is easier to minimize the amount of polluted water generated, rather than treat or dispose of it.

Manure and urine can add excessive nitrogen and phosphorus to creeks. These nutrients can enhance algae blooms. The algae's subsequent death and decay can consume much of the water's oxygen that is necessary for fish to breathe. High concentrations of ammonia from animal waste is toxic to fish and other aquatic life. Salts from horse waste can change the variety of insects that a stream can support. During the rainy season, salts and nutrients in manure can leach through soils into ground water. Pathogens in livestock waste may produce fecal coliform contamination levels that may potentially impact drinking water. Manage any polluted water generated by your facility so it does not impact downstream neighbors.

Basic Ways to Manage "Polluted" Water

To incorporate these measures into your management systems, see Chapter 2. For specific details on measures listed in ***bold italic***, see Chapter 4.

- **Keep the size of intensively used areas small** to help reduce the volume of polluted water.
- **Manage Manure**. Remove manure regularly—daily is best. Cover stored manure with a roof, tarp or other cover, and direct runoff away from the ***manure storage area***.
- **Use *filter strips* to trap sediment and manure** that washes off high-use and ***manure storage areas***.
- **Maintain soil moisture during the dry season** by sprinkling with water to enhance bacterial decomposition of nutrients. When soil moisture is maintained in arenas, paddocks, feeding areas and even pastures, the natural breakdown of urea will occur. If areas are maintained as absolutely dry, this discourages the natural process.[2]
- **A waste pond** can be designed to store water for safe distribution at a later time.

[2] Michael Rugg, personal communication. 2001. California Department of Fish & Game, Yountville, CA.

Table 1 lists potential pollutants and related impacts from typical horse keeping activities, the associated problems they can create, and the water quality tests available to determine the levels of the pollutants. More information on ***water quality monitoring*** is in Section 5.7 of the Resources Directory.

Table 1: Potential Pollutants, Impacts, and Water Quality Tests

Potential Pollutants from Horse Keeping Sources	Problems created in creeks, ponds, and wetlands	Easy water quality tests available for landowners
Sediment	Reduces water clarity so fish have a harder time finding food; leads to warmer water, and also settles into creek beds which degrades aquatic habitat; fills in creeks and ponds; kills fish eggs from suffocation due to sediment filling in air spaces around eggs. Also, pollutants adhere to sediment particles, such as metals (e.g., lead, mercury) and organic materials such as pesticides.	Visual observation
Nutrients from manure and other waste • Phosphorus from soaps and manure • Ammonia (decomposition of organic nitrogen such as urea and manure)	• Stimulates the growth of algae and other aquatic plants • Un-ionized ammonia is toxic to aquatic life even in very small concentra-tions	Colorimetric test kit to measure total nitrate and ammonia. Test pH with electronic meter or pH test paper. Also thermometer for temperature.
Salts from horse waste	Affects the kinds of aquatic organisms which can live in a stream	Electrical conductivity probe
Excess organic material (bedding, shavings with manure, runoff from ma-nured areas)	Acts as a source of food for aerobic, decomposing bacteria which may deplete dissolved oxygen which adversely affects aquatic life	Electrical oxygen probe or colorimeter text kit for Dissolved Oxygen (DO)
Removal of streamside trees and shrubs	Creates warmer stream temperatures which reduces the amount of oxygen water can carry; decreases a source of terrestrial insects (fish food); removes deep bind-ing root mass that stabilizes streambanks; and reduces wildlife habitat	Thermometer
Pesticides from fly sprays, etc.	Toxic to aquatic life	Lab analysis needed – no easy tests

1.3 Plan Conservation Improvements on Your Property

Develop and implement a Conservation Plan to help you enhance ranch aesthetics, reduce expenses related to the control of drainage and erosion, protect property and land values, and to keep the facility safe for people and horses. Important stewardship elements of a Conservation Plan for horse facilities are to: 1) control erosion, 2) manage stormwater to keep "clean" water clean, and 3) manage "polluted" water. Planning is important whether you have just one backyard horse or a large, commercial horse boarding facility.

Conservation planning is a natural resource problem-solving process. The process integrates ecological (natural resource), economic, and production (such as pasture) considerations in meeting both the horse owner's objectives and the public's resource protection needs. This approach emphasizes identifying desired future conditions, improving natural resource management, minimizing conflict, and addressing problems and opportunities. This section presents information on conservation plans and outlines steps to create such a plan.

What is a Conservation Plan?

A ***conservation plan*** is a document that is developed by a landowner who wishes to manage land and water resources on the property effectively. Generally help is obtained from a natural resource specialist. The planning process can help horse keepers to identify, assess, and develop ways to avoid potential water quality problems. A plan includes: a written and pictorial description of the features of the horse facility (an inventory of developed and natural features shown on an aerial photograph or scale drawing); an evaluation of problem areas and opportunities; a schedule of operation and activities needed to solve identified problems; and maintenance and monitoring activities. Plans demonstrate awareness and commitment to conservation and good land stewardship.

Who needs a plan?

Horse properties that have creeks or seasonal drainages that lead to creeks, or that have received complaints may need a plan to demonstrate how they will manage areas of concern. If you keep horses near drinking water reservoirs or in areas with endangered species, you may be required to submit a plan to show how the environment will be protected. Owners of horse facilities may need to prepare a comprehensive conservation plan that covers more than the items discussed below in order to meet the requirements of local ordinances or a county use permit.

How do I develop a plan?

Horse owners can gather information and develop a plan by following the five steps below. Assistance may be available from the Natural Resources Conservation Service (NRCS) and Resource Conservation Districts (RCDs). The Alameda County and Southern Sonoma County RCDs have developed a planning workbook that can be completed in conjunction with a planning course or as an

individual project. For further assistance, contact the NRCS, the local RCD, or UC Cooperative Extension, listed in Section 5.1 of the Resources Directory. Private consultants can also assist with developing detailed plans.

What does a plan look like?

A conservation plan can begin simply and need not be an extensive document. A plan can be handwritten and kept in a folder or a binder. It should include maps, site-specific soils and vegetation data, a record of decisions made for conservation improvements, and other reference materials. You'll want to update your plan to keep it current. A photographic record of what is done before and after imple menting a conservation plan would be helpful documentation if future questions arise.

Developing a Conservation Plan for Your Facility

The degree to which a conservation plan needs to be developed will vary according to the property description and intensity of land use. A horse facility with two flat acres, no creeks and two horses kept in small shelters with paddocks may only need to create a simple plan that diverts clean water from horse keeping and ***manure storage areas***, and describes manure management. However, a horse facility with many hilly acres experiencing natural gullying, or with many creeks on the property would be well-advised to develop and maintain a full ranch conservation plan. Thus, the facility manager is able to demonstrate to regulatory agencies concern for proper stewardship of the land and water resources.

The six steps for developing a conservation plan are listed below. Each of these steps is further explained in more detail.

1. Set goals for your operation
2. Inventory and map your resources
3. Identify, assess, and prioritize potential problem areas
4. Develop solutions
5. Properly schedule and install conservation measures
6. Maintain and monitor conservation measures

Step 1. Set goals for your operation

Set goals for an effective conservation plan. Some issues to address are:

- **Goals for your property or horse facility.** What type of operation do you currently have and how would you like it to function in 2 years, 5 years, or 10 years? What type of facilities do you currently have, and which do you plan to add? What type of conditions do you want to provide for your horses? Because the physical health, safety, and mental well-being of your horses are essential, proper housing, sufficient exercise, food and water, and regular veterinary care should be included. Make sure the goals work for you.
- **Conservation goals for land and water.** Would you like to learn more about natural resources on your property or in your area? List conservation concerns

that you have such as reducing erosion, restoring a creek area, improving pasture productivity, or maintaining or improving a healthy ecosystem.

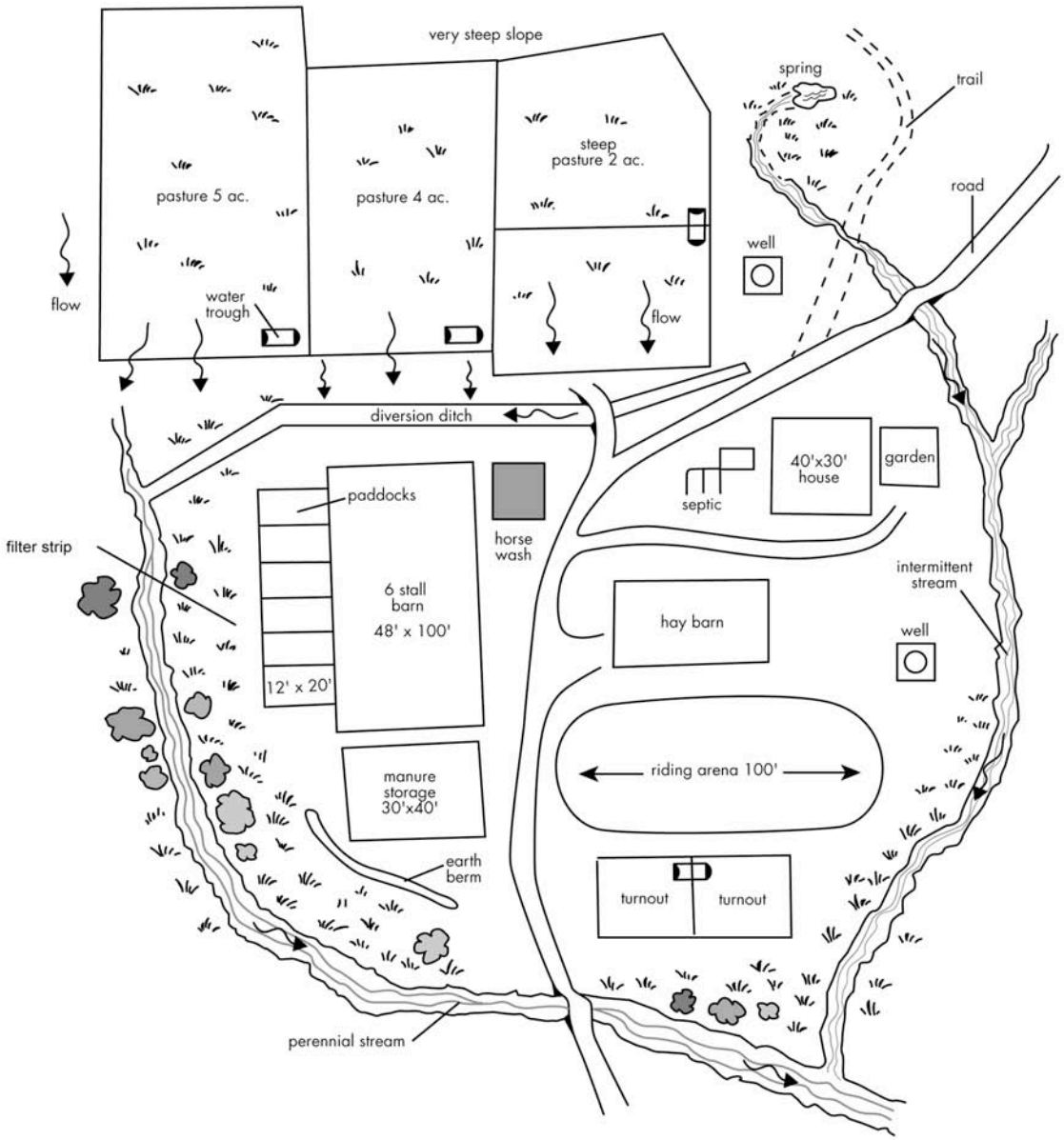
- **Financial feasibility.** Facility maintenance and improvement require time, labor, and money. Consider doing needed work in stages and set priorities. How much of the work can you do yourself? What help is available? Will you have a barn manager or employees for day-to-day operation? It is helpful to have contingency plans and funds for emergencies.

Step 2. Inventory and map your resources

A written resource inventory accompanied by a map is a record of your property and improvements. Use an aerial photograph or draw a site map on graph paper to accurately and easily plot various features. Choose a scale that fits the size of your facility, e.g., 1 inch=100 feet, or 1 inch=50 feet. This map can help you determine the approximate size of structures needed, which helps in developing cost estimates. Gather existing soils, topographic maps and aerial photos for an inventory of your facility. These maps and aerial photos are available from public agencies and private sources at reasonable costs (county planning departments, NRCS, US Geological Survey, etc.). After you have completed your map, you can add areas of conservation concern and possible future conservation measures. *(See Sample Site Plan diagram.)*

Items to include on your site map:

- **Natural water features** such as springs, creeks, seasonal drainages, wetlands, and ponds. Indicate drainage and stormwater runoff patterns, using arrows to indicate the direction of flow. Topographical maps or street maps that show local creeks can help you determine drainage patterns and identify your connection to a larger stream or that enters San Francisco Bay, another regional bay, or the ocean.
- **Water improvement projects** such as developed ***springs***, water ***troughs***, ***wells***, septic system drainfields, pipelines, and ***ditches***, as well as information such as flow rates, well depth, and dates of construction.
- **Property improvements** such as buildings, corrals, paddocks, arenas, ***fences***, pastures, roads and trails, ***bridges***, parking areas, and ***manure storage*** or ***composting*** areas, ***horse wash areas***, and other improvements.
- **Existing conservation measures** that protect soil and water resources.
- **Soil types.** Soil textures and soil depth are important for making management practice decisions. For example, steeper slopes generally have shallow soils that dry out earlier in the season. County *Soil Surveys* describe potential uses for the soil, general characteristics such as texture, erodibility, shrink/swell characteristics, water table, appropriateness for building sites and leach lines, infiltration rate, slope information, and suitability for growing plants, and contain maps (aerial photos) with the soils shown. Check with the USDA Natural Resources Conservation Service (NRCS), your local RCD, or a library to review a copy.
- Topography, terrain, and slopes can be described in your plan in general terms or with more detail if your land has been surveyed. Features to include on your



*SAMPLE SITE PLAN – A site map shows natural features such as springs, creeks, winter swales, wetlands and ponds. Improvements are shown as well—wells***, water troughs, diversion ditches, berms,** *septic system drainfields, pastures,* **fencing, turnouts***, barns, arenas, and* **compost area***. A site plan is an essential part of a conservation plan.*

site map are steep slopes, low lying areas, rocky areas, landslides, and flood-prone areas. Contour lines show slope on topographic maps. Mapping tools, used with topographical maps, allow easy estimation of slopes and acreage. Topographic maps are available from local map stores, or http://topomaps.usgs.gov/, or http://www.topozone.com. Maps of landslide areas may be available for your region from the US Geological Survey, and often from NRCS or your local county planning department.

- **Vegetation and plant communities** differ in their requirements for moisture, shade, soil drainage, and soil fertility. Examples of plant communities in the San Francisco Bay Area include broadleaf evergreen woodland or forest, oak woodland, grassland, riparian (streamside forest), coastal scrub, and chaparral. If you need assistance in describing the wetland communities on your property, consult a US Fish and Wildlife Service "National Wetlands Inventory" map. These are available from the NRCS or your local RCD.
- **Wildlife habitat.** You may wish to note any important wildlife habitat areas or keep track of animal activity. Riparian habitats are especially rich in birds (both migratory and resident) and aquatic species. To find out if you have any threatened, endangered, or special status species on or near your property, contact the California Department of Fish and Game. For information on backyard conservation or wildlife habitat improvement projects, contact your local RCD.
- **Climate.** Average annual rainfall information is available from several sources such as local water districts, *Soil Surveys*, and the US Weather Service. The RCDs and NRCS have National Oceanic and Atmospheric Administration maps that show rainfall intensity. This is important for designing conservation measures (for example, how many inches per hour in a 25-year storm). A rain gauge and knowledge of local weather characteristics will allow you to monitor conservation measures during large storms. Talk to your family and neighbors to find out about any historical weather-related incidents on your property.
- **Ground water conditions** are important to know before installing wells or septic systems. Water districts, the local planning department or public health departments may have information on local ground water resources. Well records give an estimate of the depth to the water table at your property. Be sure to identify any near-surface ground water areas that may be vulnerable to contaminants.
- **Other natural resources information**. For information on geology, wetlands, air quality, or other features of interest, contact government agencies, libraries, and possibly the internet.

Look at your property as a whole to help develop priorities

Step 3. Identify, assess, and prioritize potential problem areas

Look at your property as a whole to help you develop priorities. Refer to Chapter 2: Evaluate Your Horse Keeping Facility to help identify common sources of water quality concern. Steps to consider:

- **Evaluate your water quality to see if you have a problem**. Check areas upstream and downstream of intensively used areas. Many water quality tests are simple to perform, by conducting self-testing from kits. See Section 5.7 of the Resources Directory for water quality monitoring information.
- **Identify potential problem areas** by taking a walk around your facility, preferably during or immediately after a heavy rainfall. Use the site map as a guide and take notes.

For example, draw arrows on the site map to show runoff and drainage patterns, note bare areas such as overgrazed pastures, shade areas of streambank erosion or where sediment deposits, and note areas where pollutants may be present (such as ***manure storage areas***, ***horse wash areas***, or runoff from intensively used or "high-use" horse keeping areas).

- **Assess situations and prioritize areas in need of attention.** During the monitoring or field visit did you discover specific water quality issues you need to address? Are they big problems? Are they related to controlling erosion or managing stormwater runoff?

  Set priorities for the areas you wish to tackle. Give high priority to problem areas that need immediate attention, and then address areas of lesser concern in stages or as part of a long-term strategy. Examples of situations needing immediate attention are where a ***manure storage area*** drains directly to a creek or runs off onto neighboring property, or an actively eroding streambank threatens property or structures.
- **Review your goals** and make sure the planned improvements help you achieve your goals. Revise your goals if necessary.

Step 4. Develop solutions

Select conservation measures that will help solve problems and achieve your goals. Chapter 4 of this guide describes conservation measures that are structural or management practices. Read through this guide, talk to other equestrians, ask questions at your local feed and stable supply stores, and seek technical assistance to determine what options will work best for you. Consult your local RCD or NRCS for assistance. Things to keep in mind include:

- **Conservation measures need to fit the unique conditions at your facility.** For example, if you have highly erosive soils, be sure that sediment is not picked up by runoff. If your streambanks are eroding, do not direct concentrated water flows into those areas. What works for others on their property may not work for you.
- **Conservation measures often work in combination.** Be aware of how they fit together, e.g., applying ***seed*** and ***mulch*** or connecting roof ***gutters*** and ***downspouts*** to a conveyance system that carries the runoff to an erosion resistant outlet at a creek.
- **Start at the source.** Seek solutions for smaller areas near the source of the problem. Sometimes minor changes in management techniques can produce the desired result at little or no cost. For example, empty ***manure storage areas*** before the winter, remove horses from a pasture when grass has been grazed down in order to allow for regrowth, or reseed a ***filter strip*** in the fall.
- **Include a manure management strategy.** Address manure collection, storage, spreading, use and/or disposal. Consider site-specific characteristics of your property and operation to determine what manure management systems will

work best. The strategy should include proximity of manure management locations to creeks, soil type, type of bedding material, number of horses, labor, equipment, and access.

- **Be aware of local, state, and federal regulations that apply to your projects.** Check carefully to be sure you have obtained all necessary permits before developing, expanding, or renovating a horse facility. You are responsible for being informed and for following regulations. See the Resources Directory, Sections 5.4 and 5.5 for more information on permits.
- **This will be a long-term process**. Some measures you may try, may not work. Your plan is a living document meant to change over time and be a record of important things you learn about the stewardship of your property.

Step 5. Schedule and properly install conservation measures

Schedule construction during the dry season, before the winter rains. Allow time to obtain permits. Careful installation will help your projects succeed.

- **Know when to seek professional design assistance.** Medium- to large-scale erosion control and drainage projects will likely require professional design to limit the hazard of washouts, flooding, and impact to neighboring properties. Conservation measures can fail or make problems worse if they are not properly installed. Extensive grading projects are likely to require permits and professional installation.

Careful installation will help your projects succeed

Step 6. Maintain and monitor conservation measures

Regular maintenance is crucial to the effectiveness of conservation practices. Is there room for improvement? What other conservation measures and management systems might help? Regular monitoring and maintenance will help your projects succeed. Remember to:

- **Monitor your project.** Maintenance may necessitate cleaning plant debris from gutters and pipe inlets, removing sediment from water conveyance structures, or mowing grass ***filter strips*** to keep the grass actively utilizing nutrients. The more useful monitoring takes place with a shovel and rain boots, walking the facility during and after a rainstorm to make sure all drainage is functioning properly. Make necessary repairs a part of your "winterization" effort. (See the Winterization Checklist in Section 5.3 of the Resources Directory.) A rain gauge will help you track rainfall amounts by storm, month, and year.
- **Be prepared,** especially after a series of storms when soils are fully saturated. This is when floods and most landslides occur. Have an emergency back-up plan and make sure that your employees and family know the plan. Have emergency repair materials on hand, such as burlap bags and sand, or straw

bales, and know the proper way to install temporary fixes. (See Section 4.1 for information on emergency repairs.)

- **Photographic monitoring** will show the results of your management decisions. (See Section 5.6 of the Resources Directory.)
- **Monitor water quality** of creeks that flow by the facility, with do-it-yourself water quality test kits, and record your efforts. (See Section 5.7 in the Resources Directory.)
- **Document your efforts** to protect natural resources. Record the implementation, maintenance, and monitoring of conservation measures. Record keeping will help you decide how to further improve conditions for your horses and water quality. Your documentation might help you meet local, state, and federal water pollution control requirements.
- **Adjust** your conservation plan based on the results of monitoring.

Chapter 2:

Evaluate Your Horse Keeping Facility

Keeping in mind our three key stewardship objectives, to 1) control erosion, 2) keep "clean" water clean, and 3) manage "polluted" water, we will now evaluate typical features and activities at horse facilities that are common sources of water quality concerns. For example, a ***roof runoff*** system includes the following conservation measures: ***gutters, downspouts***, and ***drainage*** to a ***filter strip*** or ***outlet***. The possible problem areas, as well as ways to manage water are discussed.

Horse owners can implement some management systems themselves. Professional design and installation assistance will be required for other systems. Specific conservation measures, in ***bold italic,*** are further defined in Chapter 4.

Typical places that can be problem areas at horse facilities are:

- **Section 2.1** Roof unoff
- **Section 2.2** High-Use Areas
- **Section 2.3** Manure Management
- **Section 2.4** Composting Horse Manure
- **Section 2.5** Horse Wash Areas
- **Section 2.6** Pasture Management
- **Section 2.7** Water Resources: Creeks, Ponds and Wells. Managing Septic Systems
- **Section 2.8** Design and Maintenance for Roads, Trails, and Stream Crossings
- **Section 2.9** Construction Management

2.1 Roof Runoff

Diverting roof runoff from horse keeping areas in order to minimize creation of mud will result in both healthier animals and cleaner surface water on your property.

Take a look during or after a storm to determine where the "clean" roof runoff drains from: barns, covered arenas, or other buildings. Observe whether or not water is causing erosion, creating mud, or entering areas that contain manure. For more details, see Chapter 4.2: Stormwater Management Measures, Roof Runoff Collection.

Management Strategies for Buildings

- Locate buildings on elevated ground or built-up pads. Slope the land gently away from building foundations. Locate new buildings well away from creeks and flood-prone areas. Avoid disturbing wetlands.
- Use ***gutters*** and ***downspouts*** to direct roof runoff away from erodible land or areas with manure such as ***paddocks*** and ***turnouts*** adjacent to or attached to barns. "Clean" roof runoff should not flow through areas where it can pick up pollutants.

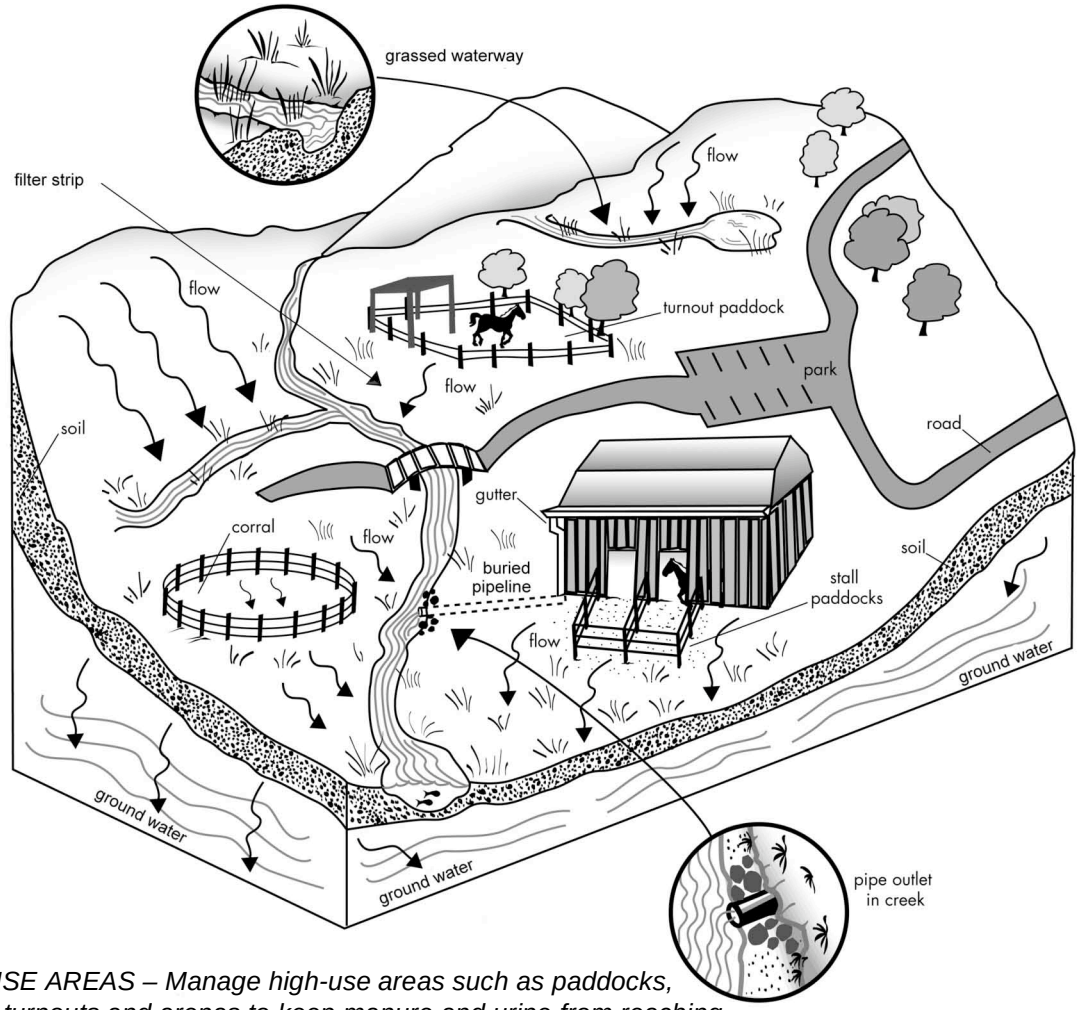
  Using ***gutters*** and ***downspouts*** is especially important for large barns and covered arena roofs that can shed considerable volumes of water during storms. This "clean" water should be directed via pipe or ***ditch*** to an outlet point that will not erode.
- If roofs do not have ***gutters***, slope roofs away from high-use and ***manure storage areas***.
- Install ***subsurface drains*** (perforated pipe) with gravel filled trenches below eves to collect standing water and direct it away from buildings.
- Divert water from surrounding slopes away from buildings. Install ***diversions*** or ***berms*** to direct water away from buildings. Convey water to a ***filter strip*** or ***grassed waterway***. Make sure the ***diversion*** or conveyance method does not cause erosion.
- Place ***energy dissipaters***, such as rock, at pipe outlets to prevent erosion.
- Revegetate areas that have been graded or disturbed to prevent erosion. Maintain ***grassed waterways*** and ***ditches***.
- Follow county regulations regarding creek or other setbacks, such as property line, well, or septic leach field setbacks, and obtain necessary grading permits.

2.2 High-Use Areas

In this guide, the term "high-use areas" refers to specific fenced areas of bare ground where horses are kept, confined, exercised, trained, or ridden. Examples of "high-use areas" are ***paddocks*** attached to stalls, ***turnouts***, circle pens, arenas, and livestock alleyways between paddocks and barnyards.

Because these high-use areas often lack vegetation, they can be subject to erosion. They are also likely to contain manure and urine that must be prevented from being carried by runoff into creeks. It is important to prevent leachate from accumulated manure from being carried into the creeks as runoff, or downward through soil into the ground water.

Mud and accumulation of manure in high-use areas can also pose health problems for horses, and make access difficult for people.



HIGH USE AREAS – Manage high-use areas such as paddocks, corrals, turnouts and arenas to keep manure and urine from reaching creeks, prevent leachate from being carried downward into the soil and ground water, and reduce erosion. Map the flow of drainage at your facility and look for ways to keep "clean water" clean. Consider using conservation measures such as **turnout paddocks** *and grass* **filter strips***.*

Management Strategies for High-Use Areas

Consider location and size

- Locate high-use areas on higher ground with a slight slope for drainage (1-2%). Locate high-use areas away from low spots, drainages, floodplains, or areas that receive a lot of upslope runoff. If there are chronic drainage problems, facilities may need to be relocated.
- Limit the size of high-use areas to what is truly needed. The smaller the area, the less "polluted" runoff will need to be addressed.
- Locate high-use areas in flatter portions of the property. Avoid steep slopes (generally over 30% slope) that are susceptible to erosion.
- Use ***fencing*** to reconfigure the shape of the high-use area to suit the terrain. Follow county regulations that may require setbacks from creeks, wells, septic leach fields and property lines.
- Consider wind direction for dust control.

Maintain grass **filter strips** *adjacent to high-use areas such as arenas to help trap and filter sediment and manure that flow off of these areas.*

Maintain vegetation around high-use areas

- Develop and maintain a ***filter strip*** of dense grass between drainages (even small, seasonal ones) and high-use areas to trap and filter sediment from runoff. See Section 4.3 for more information on ***filter strips***.
- Reseed grass, if necessary. ***Seeding*** recommendations are in Section 5.2 of the Resources Directory.

A grass **filter strip** *will help trap sediment that may run off a horse paddock. Be sure to develop good drainage in high-use areas such as horse paddocks. Create built-up pads, use proper footing materials, and divert clean stormwater around paddocks to help reduce mud.*

Improve drainage in and around high-use areas

- Use base rock and sand to improve drainage in high-use areas and to improve the surface or footing. For horses' health, high-use areas should have well-drained surfaces. "Road base" which consists of a mixture of clay, sand and crushed rock (or gravel) may be needed as a foundation for horse comfort in stalls and small ***paddocks***. Too fine a surface may not allow water to infiltrate and can cause ponding.
- Create built-up pads by "crowning" (building up the center) the pads to promote runoff rather than ponding and infiltration.
- Place filter fabric underneath the drain rock in stalls and small ***paddocks*** to prevent the rock from mixing in with the soil and subsiding. It costs a bit more money up front, but works better in the long run. The alternative is to keep adding rock, which adds stability to the site, however, it could be an ongoing expence.

- Prevent "footing" material from washing off site. Footing that washes off high-use areas could become a form of sediment that should not be allowed to enter creeks and seasonal drainages. Kickboards, made of railroad ties, telephone poles, or boards placed around the perimeter help prevent footing from washing away.
- Use a ***diversion*** to route "clean" stormwater runoff around the high-use area.
- Locate shelters along the edges of ***paddocks*** rather than in the middle so roof drainage can be more easily controlled.

Manage manure regularly

- Regular clean up of manure, soiled bedding, and uneaten feed will minimize the amount of pollutants in high-use areas. Uncollected manure adds to mud problems because it absorbs water. Scrape or otherwise remove manure before winter. Evaluate the manure management element of your ***conservation plan***.

Keep paddocks, corrals, and arenas as dry as possible during the winter rainy season

- Plan horse traffic patterns to avoid wet areas and minimize the formation of areas without vegetation. Select drier areas for the location of gates and other high traffic uses.
- Consider using deep bedding to prevent horses from standing in mud. These bedding materials are usually wood products, up to a foot in depth and can be used in outdoor situations. Various commercial products are available. A filter fabric may be required beneath the deep bedding to keep it from being trampled into the soil. Kickboards placed around the perimeter help retain the bedding on-site. Be aware that wood shavings, once saturated, can produce sufficient amounts of tanolignic materials to create a toxic leachate, which can pollute runoff.
- Use rubber mats over "road base" with bedding materials to keep stalls and other high-use areas dry in the winter.
- "Scratches,"also known as "grease heel," "grease," "cracked heels," or "mud fever," is a dermatitis (inflammation of the skin) of the heel and rear side of the pastern area. It can develop or be aggravated when horses stand in muddy corrals for long periods without relief.[3]
- Use clean fill such as soil for low spots. Don't use manure. As an organic material, manure holds water and actually adds to mud problems.

[3] James, Ruth B., DVM. 1990. *How To Be Your Own Veterinarian (Sometimes): A Do-It-Yourself Guide For The Horseman*. North Carolina: Alpine Press.

- Consider using ground oyster shell or various commercial products to dry urine-soaked or wet areas.
- Plant grasses, shrubs, and trees around high-use areas to utilize excess water, and to help keep the area drier.
- Native trees and shrubs such as California bay laurel, toyon and coffeeberry continue to use water during the winter when deciduous trees are dormant. (Do not plant anything that is toxic to horses. If oleander, oaks, walnut trees, etc., are consumed, they will make horses sick). Trees work well on the north side of a high-use area where they will not block the sun's rays. Protect trees from damage by horses by using heavy fencing, or horses will push down the fence to eat the leaves and bark. Trees in paddocks may have problems because horses also like to scratch on tree trunks and long limbs. Compaction of soil within the trees' drip line can harm roots.

Weed References

For noxious weed information, visit the California Department of Food and Agriculture ENCYCLOWEEDIA:
http://www.cdfa.ca.gov/phpps/ipc/encycloweedia/encycloweedia hp.htm

To learn more about noxious weed eradication in your county, visit the CALWEED Database, California Noxious Weed Control Projects Inventory:
http://endeavor.des.ucdavis.edu/weeds/

Practice dust control measures

- Keep areas as vegetated as possible.
- Plant native trees for windbreaks and dust screens. Keep horses away from plantings by installing conventional horse ***fencing*** or an electric fence.
- Sprinkle water on arenas and ***paddocks*** to keep down dust during the summer. This also helps degrade urine salts that could otherwise accumulate in arid western soils during the long dry summer.[4]

2.3 Manure Management

Proper manure management will help maintain a healthy environment for horses, provide a clean and safe working area for people, and protect water quality in creeks and ground water. Effective manure management can reduce waste volume, removal costs, fly breeding, and neighbor complaints.

Management Strategies for Manure Storage Areas

Develop and implement a manure management element for your *Conservation Plan*

- Be sure to include a description of the facility's plans for manure collection, storage, and use or disposal.
- Consider characteristics of your property and operation to determine what manure management strategies will work best. Take into account: proximity of manured areas and manure handling areas to creeks, runoff from surrounding slopes, soil type, presence of near-surface ground water, type of bedding

[4] Michael Rugg, personal communication. 2001. California Department of Fish & Game, Yountville, CA.

material, volume of material (manure and bedding), number of horses, availability of labor and equipment, and access for clean-out and storage areas.

- Develop storage options. Storage facilities could include covered bins, sheds, concrete pads with low walls, windrows, piles covered with plastic tarps, dumpsters, trucks, or covered garbage cans. One 1000-pound horse may produce 0.75 cubic feet per day of solid waste plus urine.[5] Remember to add the volume of bedding when sizing a storage facility.
- Develop options for manure utilization such as ***composting***, disposal, and land application. Determine the pasture or crops available to utilize nutrients in the manure or compost produced.
- Talk to your neighbors and local RCD. Your solution should be appropriate to your area. It may be possible to develop solutions for a neighborhood or even a region.

Clean up manure

- Clean up manure, soiled bedding, and uneaten feed from stalls and ***paddocks*** regularly. Daily removal is best, especially during the rainy season.
- Use proper tools and a convenient storage site to simplify clean up. Find a manure fork that works. Some carts are too big, while others are hard to push around or awkward to dump.
- Scrape or otherwise remove manure from high-use areas, such as corrals and arenas.
- Pick up or spread manure periodically if horses deposit it in one area.

Proper manure management is essential for horse owners. Manure cleanup, storage, and use are critical components of conservation planning and good stewardship.

Store manure and compost properly

- Store manure and compost away from creeks and wells.
- Make sure that the ***manure storage, compost area***, or disposal container is appropriately located and sized for loading and unloading and can handle the appropriate quantity of manure cleanouts. Loading ramps are useful if manure can be loaded directly into a dump truck or dumpster. If tractors will be used, be sure the facility is large enough and strong enough for the equipment.
- Locate the storage or ***composting area*** on a water-tight surface such as compacted clay,

Composting manure may be an excellent way to handle large quantities of manure and create a useful product. Be sure to calculate the waste volume and allow for equipment access. Proper stormwater management and drainage should be installed near composting areas.

[5] Livestock Waste Facilities Handbook. 1985. Midwest Plan Service – 18. Iowa State University, Ames, Iowa.

concrete, or plastic to reduce the potential for seepage of leachate (liquids high in salts and nutrients draining from manure piles) into ground water.

- Check regulations and required permits before grading for manure storage pads, especially when working around environmentally sensitive areas such as wetlands or streams.
- Install proper stormwater management and drainage measures (see Section 4.2) to route stormwater away from the area. Divert any runoff that leaves the ***manure storage*** or ***composting area*** to a ***filter strip***. Vegetation will utilize the nutrients in manure and help filter manure particles that are carried along in runoff.
- Use a ***cover,*** such as a tarp**,** to protect stockpiled manure from winter rains. Shape piles in long rows, so that the width fits the size of the plastic sheeting used to cover the manure. Tie or weigh down edges and corners as necessary.
- Empty storage areas before the winter rains to reduce the volume of manure that must be contained.
- Take odor into account by considering prevailing winds, and distance to your neighbors.

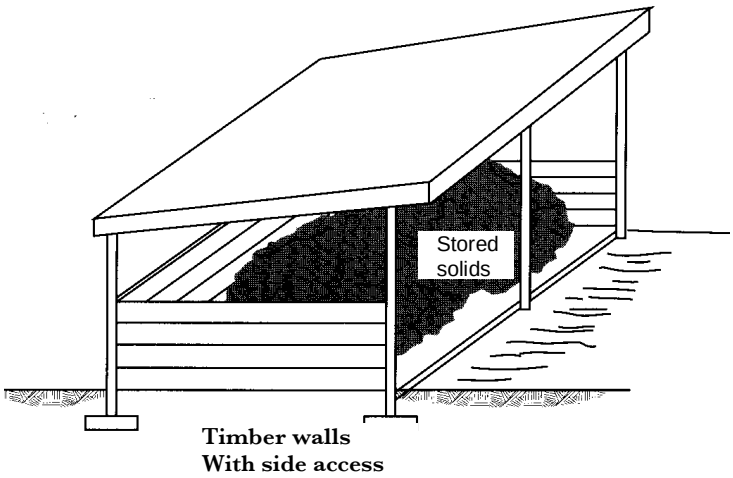
Develop and implement a nutrient management element in your *Conservation Plan*

- Take into account your pasture's needs and determine the amount, placement, and timing of ***manure application or spreading*** to maximize plant growth and minimize the potential for polluting creeks and ground water.
- Have your soil analyzed by a laboratory *before* ***spreading manure*** to determine fertilizer needs, and establish a baseline for future monitoring. This is especially important if manure has been applied to the field for many years. Nutrients such as nitrogen and phosphorous are released over time (many years), so a field that has been used for manure disposal may already be quite high in nutrients and salts.
- Consider having a laboratory analysis of your horse manure to determine the total analysis. This will help ensure that ***manure application*** meets, but does not exceed plant nutrient requirements. For example, some of the nitrogen in manure may not be immediately available for plant use or additional fertilizer may be needed for specific nutrients.

Visual Inspections of Manure Storage Areas

Examine the condition of, and make any repairs to:

- Concrete – Cracks or openings, signs of infiltration, crumbling or rust
- Wood – Splitting, buckling or rotting
- Earthen containment walls – Settling, seepage, slumps, or animal burrows
- Wall alignment (vertical and horizontal) – Curves or bulges
- Foundation – Erosion or piping
- Liners – Tears



Stockpile manure on an impermeable surface. Size the manure storage area according to the amount of manure and bedding produced. The base must be a water tight surface to reduce the potential for seepage of leachate into ground water. The surface must be designed so it can be scraped with a shovel for small facilities, or a front-end loader for larger facilities. Cover the manure storage area so there is no liquid draining from the stack. A tarp or roof must drain away from the manure stack. Roof height should be a minimum of 7 feet, and also be designed to accommodate heavy equipment. Liquid from the manure may accumulate in the storage area and should be absorbed and removed with the bedding material. Empty the storage area before winter to reduce the amount of material to be stored.

Use compost and manure properly as a fertilizer and soil conditioner

- Properly calibrate your manure spreader to avoid over-application. Applying more manure than plants will utilize wastes nutrients. Excessive nitrogen and phosphorus in soils can be lost to ground water by leaching or to surface water through runoff.
- Apply manure and compost to actively growing pasture in the spring so nutrients will be utilized. Wait until after the winter rains when the ground is firm. Additional application in the fall before the winter rains will free up space in the ***manure storage area*** for the winter.
- Do not spread manure near creeks or on steep slopes where it can be carried to creeks by stormwater runoff.
- ***Compost*** bedding materials with manure before application. If undecomposed bedding is applied with the manure, soil organisms will use the available nitrogen to decompose the bedding—reducing the nitrogen accessible for plant growth.
- Use caution when spreading horse manure that has not been composted. Manure may contain weed seeds brought in with hay. Buy hay certified by the Agricultural Commissioner as "weed free," or compost horse

Never store manure near creeks. Rainwater running through this manure pile would run directly into the creek below to the left. Excessive nitrogen from manure feeds algae blooms that ultimately consume much of the oxygen in water. Ammonia from urine and manure can be toxic to aquatic life.

Local nurseries, landscapers, gardeners, agricultural operations, or community gardens may want manure. A hauler may be able to regularly pick up manure from neighboring horse owners. Manure should be composted before using in gardens.

manure to kill weed seeds. Also, spreading manure onto pastures may risk the spreading of internal parasites, if not composted.

- Incorporate manure or compost immediately into the soil by shallow disking or harrowing to increase nutrient availability for plants.
- Spread compost under the canopy cover (drip line) of trees, and be careful not to bury the root crown.
- Keep records of manure and soil tests.
- Keep records of manure and fertilizer applications, and the results of forage production.
- Give away or sell good quality composted manure.

Dispose of manure properly

Do not store manure near creeks or in places where runoff from manure piles can affect creeks or ground water.

- ***Compost*** manure into topsoil and use this valuable by-product to enhance your own property; give it away to local farmers with pasture, orchards, vineyards or annual crops; landscapers; community gardens; or sell it.
- Haul manure away for disposal. While this is usually a costly alternative, it may be the only one available for certain properties. If so, work with neighbors to encourage a local ***manure hauling*** system.
- Exchange, recycle or swap manure with others. The California Materials Exchange (CalMAX) links those looking for organic material or compost with stables providing horse manure. For more information, visit the website at http://www.ciwmb.ca.gov/calmax. Local programs such as the Sonoma Materials Exchange (SonoMax) is a free service helping local business find reuse and recycling opportunities. The goal is to reduce the amount of waste in landfills while giving business an opportunity to save on disposal costs. For a listing, contact: http://www.recyclenow.org/sonomax

2.4 Composting Horse Manure

Caring for your horses can require a considerable amount of time, energy and expense managing manure and soiled bedding. ***Composting*** manure decreases the volume of waste. It is easier to handle composed manure, and turns the waste into a usable product.

Composting Horse Manure: Turn Straw into Gold

For some horse facilities, ***composting*** horse waste may be an effective method to handle manure and stall waste generated by horses. ***Composting*** manure requires controlling conditions to speed up the natural process of decomposition. The benefits of ***composting*** include efficient manure management, reduction in manure volume by more than 50%, lower risk of surface and ground water contamination, and fewer odors. Compost heat kills worm larvae and reduces the parasite transmission between horses, as well as eliminates breeding ground for flies. Compost is a great soil conditioner—organic matter improves soil structure, drainage, and water retention. It also provides nutrients for plants, and the heat kills weed seeds and pathogens.

Compost basics[6]

Horse waste can be composted in numerous ways, although all methods require the same basic ingredients and conditions. Compost is created from a blend of nitrogen rich materials such as manure, carbon rich materials such as bedding, air, and water. Horse manure alone has close to the desired carbon to nitrogen ratio of 30:1. The compost material should be as wet as a wrung out sponge and well aerated to provide a favorable environment for the microbes that decompose horse waste. ***Composting*** requires one to three months depending on your method and management.

Manure is breaking down into **compost***, laid out in windrows for easy turning by tractor. Compost is curing at a different stage in each windrow, and new manure is constantly added to new windrows. Nitrogen-rich materials (such as manure), carbon rich materials (such as bedding), air, and water are used to create compost. Proper moisture and aeration are important. Turning horse manure into compost takes one to three months.*

Different methods of ***composting*** include using bins and turning the compost by hand (for aeration) or long windrows that are either turned with equipment or passively aerated with perforated pipes running through them, that require mechanical blowers and pipes to force air through windrows or piles. It is

Make **compost** *in bins or long windrows that are turned with equipment or aerated with perforated pipe. Piles should be less than 6-8 feet high.*

[6] Information drawn from: *On-farm Composting Handbook* (NRAES-54), Northeast Regional Agricultural Engineering Service Cooperative Extension, 1992. New York.

important to maintain proper height (lower than 6-8 feet) and moisture levels, especially during hot and dry conditions. Piles more than 12 feet high with less than 25-45 percent moisture content could spontaneously catch on fire.

Planning your composting project

The number of horses, labor and equipment available, space available, and management cost and time will determine whether ***composting*** will work for you and the method to use. To learn about ***composting*** options, talk with local certified Master Composters and Master Gardeners (who provide public assistance through the University of California Cooperative Extension) and visit horse facilities that compost. Also see the *Composting Horse Waste* Fact Sheet published by the Council of Bay Area Resource Conservation District's Equine Facilities Assistance Program. Contact your local RCD for a copy. (See Section 5.1 of the Resources Directory for contact information.) Private consultants may be needed to help you develop a large-scale system.

Factors to consider in planning your project:

- **Size**. Plan adequate room to handle the anticipated volume of horse waste plus equipment access. If you have a large operation, check with your local planning department before establishing a ***composting*** operation. Generally, horse waste can be composted and used on-site without a permit from the state although there may be notification, filing and record keeping requirements. Counties and local governments will probably require review of an operation plan.
- **Zoning regulations**. These may require setbacks from creeks or property boundaries. The regulatory aspects of ***composting*** are covered in Title 14, Division 7, Chapters 3.1 and 5.0 of the California Code of Regulations. County permitting departments may have requirements that need to be met.
- **Slope and drainage**. To prevent stormwater runoff from entering ***compost areas***, windrows and bins should be on flat ground or oriented up and down a very gentle slope (not across the slope where more water can drain into the pile). The surface area should be compacted or paved to prevent seepage, particularly in an area with sandy or gravelly soils or with a high water table. Any compost runoff should be directed to a ***waste pond*** or ***filter strip***.
- **Water supply**. A nearby source of water is often needed because ***composting*** may require additional water to maintain moisture content.
- **Wind**. Wind direction is important to consider for dust control and odors. For example, downwind neighbors may be affected when piles are turned.
- **Conservation Measures**. Be sure to include the same conservation measures as you would for ***manure storage areas*** (see Section 2.3, Manure Management).
- **Combustibility**. Under certain conditions, immature compost can undergo self-heating and spontaneous combustion from the heat generated by microbial decomposition. Confined storage, which traps heat, may exacerbate these conditions. Management plans should be developed to prevent this occurrence and contingency plans should be in place to respond appropriately if self-heating occurs.

2.5 Horse Wash Areas

Runoff from horse wash areas may contain soap and limited quantities of manure, chemicals and pesticides from horse health and grooming products that should not be allowed to reach nearby creeks or percolate into ground water.

Management Strategies for Horse Wash Areas

- Prevent wash water from percolating into permeable soils if there is near-surface ground water or a high water table. A storage ***tank*** for wash water may be necessary.
- Elevate the wash area with a built-up layer of crushed rock if the wash area is fairly flat. Wash water should drain away from the area to a ***filter strip*** or other vegetated area.
- Do not allow water from horse wash areas to flow into creeks, ponds or seasonal drainages.
- Keep the wash area free of manure and horse care products.
- Prevent wash water from flowing into storm drains (storm drains typically drain into creeks).
- Create a ***filter strip*** downslope of the wash area, or move the wash area to an area where a ***filter strip*** can be developed. Make sure the ***filter strip*** can accept the amount of wash water generated. Use ***berms***, or other conveyance measures, if necessary to contain and direct water to the ***filter strip***.
- Consider using ***constructed wetlands, grassed waterways*** or ***waste ponds*** as treatment areas for horse wash water.

A curb directs horse wash water away from the creek. Keep horse wash water out of creeks, seasonal drainages, and storm drains. Horse wash areas should be kept clean of manure and grooming products.

Use horse grooming and health care products properly

- Use a shut-off nozzle or low-flow nozzle at the end of the hose.
- Consider sponging off your horse to conserve water.
- Use plain water to rinse horses—avoid using soap as much as possible.
- Follow instructions, read environmental warnings, use only the recommended amounts, and clean up spills. Even biodegradable horse grooming and health care products can have a negative effect on water quality.

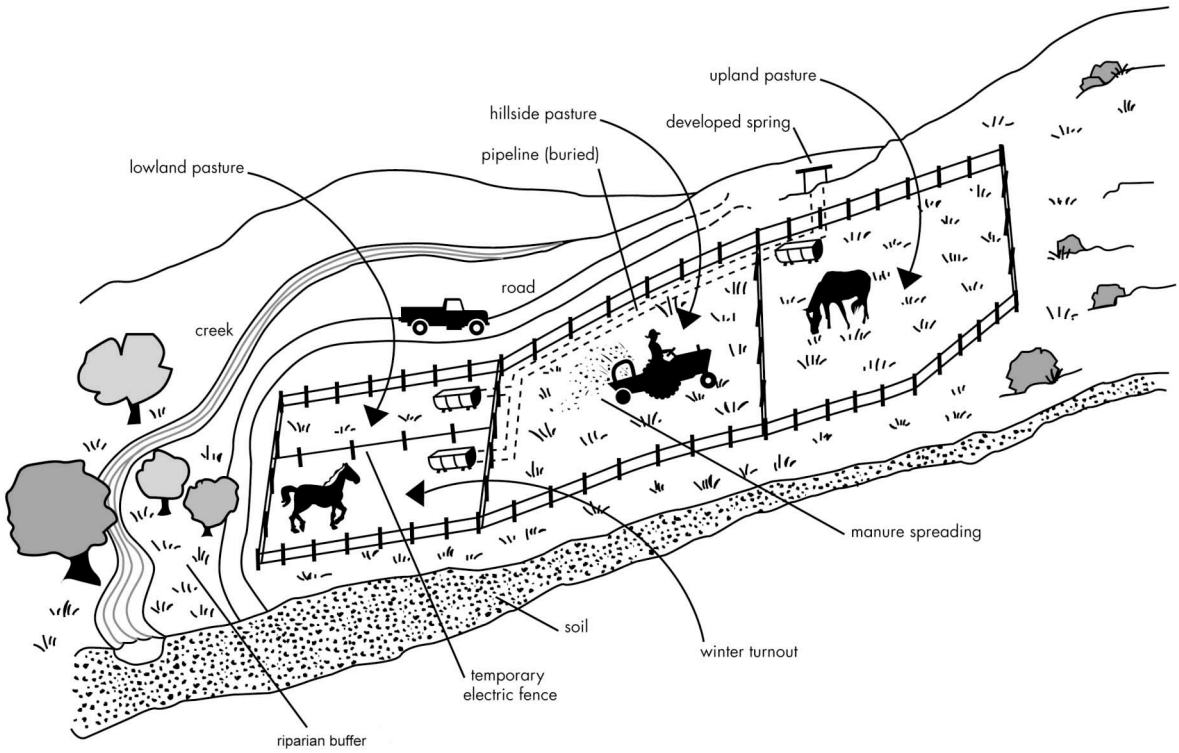
This horse wash area drains into a grass **filter strip** *(along the row of trees). The filter strip traps sediment, horse manure and other contaminants.*

- Use products that do not contain surfactants if wash water might eventually enter creeks. Surfactants, a group of chemicals that make detergents more effective cleaners, are extremely toxic to all aquatic life and can even impair the ability of young salmonids (steelhead and coho salmon) to adapt to ocean waters after they leave freshwater streams.

2.6 Pasture Management

When managing pastures, consider yourself in the business of growing grass. Grass will provide more forage for your horses and protect the soil from erosion. In healthy pastures, grass roots increase the soil's absorption of rainfall, storing moisture to prolong the growing season. In turn, a longer growing season produces more grass. Grass stems slow the rate of overland stormwater runoff. Slowing the rate and reducing the amount of runoff from hillside pastures may reduce drainage problems elsewhere on your property. A grass cover with little bare soil is ideal.

Horses can damage pastures quickly without ***grazing management***. Renovation of pastures is costly. Take care of what you have by controlled ***grazing*** and "resting" pasture so it has time to regrow.



PASTURES – Proper pasture management can include using **cross-fencing** *to promote uniform pasture use, controlling the number of horses and* **grazing distribution** *within pastures, controlling horse access to creeks, developing a* **spring** *as a new water source, and restricting pasture access during the wet season.*

Management Strategies for Pastures[7]

Control horse access to creeks and other water sources

- Control horse access to creeks to prevent manure and urine from being directly deposited in or near creek channels. ***Fencing*** to keep horses out of creeks may be necessary.
- Control horses ***grazing*** along creek banks to reduce trampling and erosion of banks that leads to sedimentation of waterways.
- ***Graze*** riparian areas seasonally when soils are dry enough to withstand the weight of the horses, to keep streambanks from being trampled and broken down.
- Provide horses with alternative sources of water if creek ***fencing*** is installed. Small pasture shelters may be necessary to provide a new source of shade and shelter.
- For crossings or water source, narrow horse access to a point at a creek where the channel can be armored or protected with gravel or other means.

Improve animal distribution to help reduce bare areas and control undesirable weeds.

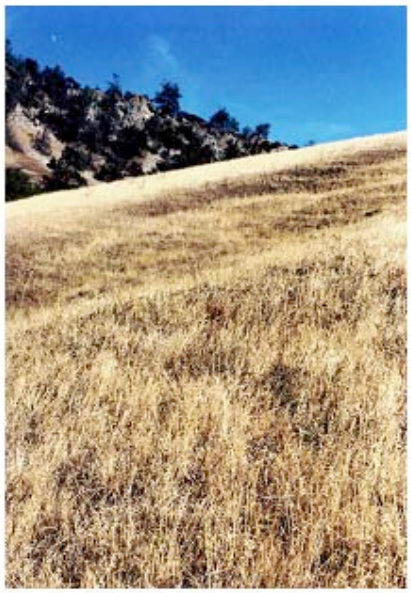
- Manage the number of horses and control ***grazing distribution*** to prevent heavy grazing.
- Develop and adjust a rotation ***grazing*** schedule to provide pastures with periods of ***grazing*** interspersed with periods of rest.
- Locate feed, salt, minerals, and water away from creeks. Regularly move the salt blocks to distribute ***grazing***. Place hay piles far apart with more piles than the number of horses being fed. This will minimize trampling from fighting horses and maximize distribution.
- Use ***cross-fencing*** (dividing up a pasture with fencing into smaller cells) to improve

Overgrazing occurs when plants are so heavily grazed that the root system dies back and plants eventually become less productive or die. A balance of grazing and pasture rest will prevent overgrazing, improve forage production, and keep weeds down.

Be sure to control horse access to vulnerable erosion areas such as a rill in a pasture. Repairing a problem early and installing temporary **fencing** *can help prevent the need for a more costly fix later (such as when a rill turns in to a gully).*

Overgrazed pastures lack plant cover and are susceptible to erosion. Keep horses out of highly erodible areas and **seed** *bare areas. Gully repair is likely to require professional assistance.*

[7] USDA, NRCS - California, Field Office Technical Guide, Prescribed Grazing, July 2000.



Adequate **"Residual Dry Matter"** *(RDM) leaves enough plant residue on the soil surface to protect against soil erosion, and leaves a sufficient seed source for annual pasture regeneration. RDM is measured in the fall, just before the winter rains. The minimum levels of RDM that should remain in a pasture is 800 – 1000 lb/ac in the San Francisco Bay area. This pasture has 900 lb/ac of RDM. Pasture production varies from year to year, with rainfall being a primary influence. Therefore grazing must* be monitored and grazing levels adjusted, each year

Residual Dry Matter *(RDM) is used as a tool to determine adequate erosion control on pastures. RDM is measured by clipping the grass in a ring, and measuring the weight of the dried grass. This site has 900 lb/ac of RDM. For visual estimates of RDM, refer to the "Residual Dry Matter Monitoring Photo-Guide" produced by Wildland Solutions.*

evenness of pasture use. ***Cross-fence*** pastures according to the terrain, soil wetness, and land sensitivity (e.g., steep slopes will erode more easily). Lowland pastures will probably stay green later into the summer and may be too wet to be grazed without damage in the winter. You may need to add alternative water sources for horses.

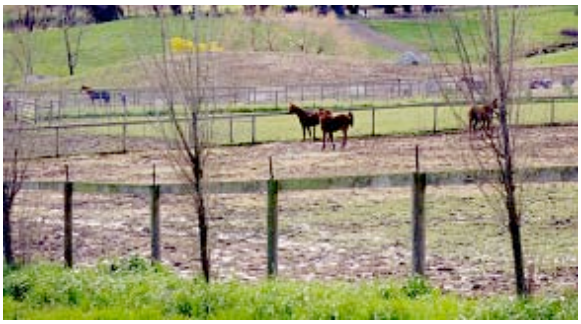
Portable electric fencing is easily installed and affordable, and can be used to define ***grazing*** areas if the horses are allowed to acclimate to the new fencing (temporary flagging helps to demarcate the fencing).

- Provide alternative sources of water by developing ***springs*** or extending an existing water system.
- Small pastures should be used for exercise rather than forage production.
- Maintain sufficient ***residual dry matter (RDM***) for pasture reseeding and erosion control. RDM is the amount of dry grass stems left behind after the grazing season has ended. Be prepared to move horses to another pasture or a ***paddock*** once target RDM levels are reached or exceeded. The rule of thumb is to leave 4 inches of grass stems in the pasture. See Section 5.8 of the Resources Directory for more information on RDM.

Properly manage pasture use

- Turn horses out for only a limited period of ***grazing*** each day to increase the duration of a pasture's use and to reduce soil compaction. ***Grazing*** when the soil is wet causes soil compaction. The soil particles are pressed together by

concentrated pressure from livestock hooves, reducing the pore space between soil particles. A dry soil is more resistant to compaction than a moist or wet soil. Compaction restricts rooting depth, which reduces the uptake of water and nutrients by plants. This affects the activity of soil organisms by decreasing the rate of decomposition of soil organic matter and subsequent release of nutrients. Compaction decreases infiltration and thus increases runoff and the hazard of water erosion.



Control winter access to soggy pastures to help prevent pollutants from leaching into the ground water and to keep horses out of the mud. Fence out springs and seeps.

- Feed horses before turning them out to reduce the ***grazing*** pressure on grasses.
- Remove or spread manure if it has accumulated in a particular area. This will promote plant growth and reduce parasite populations. Horses should not be forced to eat the forage where manure is deposited.
- Restrict use of wet pastures. Some pastures may be too wet to use during the rainy winter months. Confine horses to ***paddocks*** during this time and use pastures seasonally during the dry months.

Develop and use turnout paddocks

- Develop ***turnout paddocks*** in flatter portions of pastures, away from creeks. Turnout areas include exercise lots, pens, corrals, and small ***paddocks***. Follow the guidelines for high-use areas (See Section 2.2).

  Paddock size depends on the number of horses and other considerations. Keep ***paddocks*** to a minimal size to limit the amount of bare ground. General guidelines are a minimum size of 600-800 square feet per horse, with a slope of less than 5% and good drainage. Keep the paddock surface as dry as possible during the rainy season to reduce the possibility of polluted water from running off the area, and also be healthier for horses.

Turnout paddocks *(exercise lots, pens, corrals, and small paddocks) can be used to keep horses off wet pastures. This will help protect pasture soils and grass cover.*

- Preserve pastures by keeping horses in ***turnout areas*** when grass has been grazed down (less than 4-6 inches high).

Follow seasonal pasture management strategies

- Keep horses in ***turnout paddocks*** and off pastures when soils are wet.
- Give exuberant horses time in a ***turnout area*** during the rainy season before putting them on pasture. This will help horses release their energy and protect turf from being churned.
- Keep horses off steeper slopes when pastures are wet.
- ***Seed*** and ***mulch*** bare areas.

- Remove weeds as necessary and make sure that removal occurs at the proper time of year (this will vary by weed species).
- Monitor grass height and weed growth at the end of the growing season (late spring/early summer).

Watch gully formation and accelerated erosion

- Keep areas well vegetated to minimize soil erosion.
- Use ***fencing*** to keep horses out of highly erodible areas.
- Stabilize gullies as recommended by a professional. Options include headcut repair, ***check dams***, grading side slopes and revegetating. See Section 4.1 for more information on these conservation measures.
- ***Seed*** and ***mulch*** bare areas to protect the soil from erosion and maintain desired grass species. (See Section 5.2 of the Resources Directory for seeding recommendations.)

Grass Facts

Plants need energy for growth, maintenance, and reproduction. Green plants get energy from sunlight, *nowhere else!* Green leaves and stems act as solar energy collectors. Roots need the collected energy for growth and replacement. In general, large amounts of leaves and stems can provide energy for a large root system; small amounts of leaves and stems can only support a small root system. As a rule of thumb, the above ground portion of the plant is equal to the underground root system.

Severe grazing creates an imbalance between the energy provided by the plant's solar collector and the needs of the roots. If the solar collector is kept grazed, the root system will die back to match the energy available. Plants with small, shallow root systems will be far less productive or may even die. This is overgrazing. Overgrazing occurs plant by plant. Since horses are selective grazers, their preferred plants may be overgrazed even when the pasture as a whole looks ungrazed.

Adequate rest periods following grazing allow the plant to rebuild its solar collector and restore roots. The length of rest required will change as the growing conditions change. Grazing years should be planned to provide adequate recovery periods and minimize overgrazing of plants. Long periods of rest are sometimes damaging to individual plants and pastures if excessive thatch builds up. Balancing grazing and rest improves forage production and minimizes weed problems.[8]

[8] *How Grass Grows—The" REST" of the Story*. USDA Natural Resources Conservation Service.

2.7 Water Resources: Creeks, Springs and Wells. Managing Septic Systems

Water resources need special attention and protection. Healthy riparian areas along creeks and springs support a variety of plant and animal species, help control erosion, filter pollutants in runoff, and add beauty and diversity to the landscape. Creeks are vulnerable to erosion and other impacts from activities along streambanks. Creeks and smaller seasonal drainages transport pollutants downstream to lakes, larger streams and rivers, bays and eventually to the ocean. Every landowner can help maintain and enhance riparian areas. Springs provide water for wildlife and can be important sources of habitat for amphibians.

Wells tap into ground water for drinking water supplies and irrigation. Ground water resources are vulnerable to pollutants that can leach through the soil. Ground water also keeps dry-season flows (underground flows) in streams in some areas.

Restrict horses from creeks to help keep manure and urine from being deposited in creeks and minimize erosion on streambanks. Use **fencing** *to help manage horse access to riparian areas. Riparian areas can be grazed seasonally when streambanks soils are dry enough to withstand trampling.*

Management Strategies for Surface Waters

Control horse access to springs, creeks, seasonal drainages, and ponds

- ***Fencing*** can be used to keep horses out of riparian areas.
- Graze riparian areas, if necessary, only during the dry season.
- Design ***stream crossings*** to minimize erosion. For more information, see Roads, Trails and Stream Crossings in Section 2.8.
- Develop alternative water sources for horse confinement areas that are located away from creeks and springs. Conservation measures to consider are ***spring development*** with buried ***pipelines,*** and ***troughs,*** extending existing water systems, installing ***storage tanks,*** and utilizing **"**nose pumps**"** where the animal presses a trigger to release water**.**

An alternative water source is critical if horses are restricted from creeks. Be sure to locate water troughs away from creeks, drainages, and springs. Try using a "nose pump" that allows horses to pump their own water.

Manage runoff properly

- Set buildings, covered arenas, high-use areas, ***horse wash areas***, ***manure storage areas***, ***roads and trails*** back away from creeks.
- Prevent polluted runoff from reaching creeks and springs.
- Maintain a ***filter strip*** and/or ***riparian buffer*** between creeks and high-use areas.

- Control erosion to reduce the amount of sediment that fills ponds.

Monitor the creeks

- Landowners who wish to develop baseline data about the quality of water on their properties are encouraged to learn how to monitor their water resources. ***Water quality monitoring*** information is provided in Section 5.7 of the Resources Directory.
- Monitor water quality, especially during the rainy season.

Enhance riparian areas

- Create and maintain a ***riparian buffer*** along the creek to help slow and disperse surface runoff, settle sediment, and filter pollutants. Use native plants to enhance wildlife habitat. (See Section 4.3 Riparian Buffer, for more information.)
- Monitor and stabilize streambank erosion. Seek professional advice for severe erosion and problems on larger streams. These areas may require intensive "bioengineering" or "hard" engineered structures (such as rock riprap) to stabilize the streambank, as well as a ***riparian buffer***. Be sure to obtain required permits. For more information on streambank stabilization, see Section 4.1. For permit information see Sections 5.4 and 5.5 of the Resources Directory.
- Be aware of any habitat needs or areas for threatened or endangered species on your property. See Section 5.5 of the Resources Directory for more information.

Management Strategies for Wells

Keep well water free of harmful contaminants for the health of you and your livestock. Improperly constructed or older wells can create a pathway for fertileizer, bacteria, nutrients, pesticides, or other materials to enter your water supply and the ground water. Once in the ground water, contaminants can flow from your property to a neighbor's well, or from a neighbor's property to your well. After your water becomes polluted, the only options may be to treat water after pumping, drill a new well, or get water from another source. Time and money spent protecting your well water is a bargain compared to the loss of clean water and an associated decrease in property value.

Properly site wells

- Choose a location where surface water drains away from the well. Avoid placing wells in soil depressions.
- Be aware of how ground water flows. If you live in an area with a high water table (or if you have an existing shallow well), ground water often flows in the same direction as surface water. However, surface slope is not always a reliable indicator of ground water flow—meaning ground water may not always move downslope.
- Locate wells upslope of, and well away from, horse confinement areas, fuel tanks, septic fields, or pastures that may receive too much fertilizer.

- Check with your county permitting department for any well setback or well construction requirements and follow local regulations about the proximity of horse confinement areas to well heads.

Regularly test wells

- Establish a water quality baseline to help detect changes.
- Test wells annually for the four most common indicators of trouble: bacteria, nitrates, pH, and total dissolved solids. A more complete water analysis will tell you about its hardness, corrosivity, iron, sodium, and chloride content. In addition, you may choose to obtain a broad scan test of your water for other contaminants such as pesticides. Local conditions may warrant additional testing.
- Talk to your neighbors. If they have had their wells tested, they may be able to provide you with information on water quality in the area. In addition, county or state health departments may have records of water quality tests in your area.
- Have older, shallow wells periodically checked by a qualified well driller or pump installer. Wells older than thirty years are apt to be shallow and more poorly constructed. Older pumps are more likely to leak lubricating oil. Older wells usually have thinner casings that may be cracked or corroded.

  Older wells are more likely to provide a conduit for precipitation and runoff to reach the water table without being filtered through the soil. Wells have steel or plastic pipe “casings” to prevent the collapse of the well hole after drilling. the space between the casing and the sides of the hole are sealed with grout or bentonite clays and the well capped to prevent surface water from entering the well. The depth of the new seal depends on the soil type but should be at least twenty feet. Casing should extend at least 12 inches above the surface or 1 to 2 feet above the highest recorded flood level for the site. Contact county heath or permitting departments for local specifications.

Keep well areas clean and accessible

- Keep contaminants as far away as possible.
- Check nearby fuel tanks or septic systems on a regular basis.

Properly fill and seal unused and abandoned wells for safety, and to prevent waterborne pollutants from reaching ground water

- Contact a licensed, registered well driller or pump installer for this work. A permit is normally required to assure proper well destruction.

Management Strategies for Septic System Drainfields

Properly functioning septic systems depend on good dispersal of wastewater in the drain field and the ability of water to percolate through the soil at a steady rate.

Taking care of drainfields will enhance and preserve the ability of your septic system to break down potential contaminants (such as viruses, bacteria, nutrients, and organic waste) and keep them from contaminating ground water or nearby creeks.

- Keep drain fields covered with grass. Avoid planting trees and shrubs whose deep roots can damage pipes.
- Divert roof and surface runoff away from drainfields. Saturated soil is not effective for treating wastewater.
- Minimize activities that compact drainfield soils. Compaction decreases the ability of water to percolate through the soil, reduces the amount of oxygen available for waste-digesting microbes, and may shorten the life span of the drain field. Activities to watch include ***grazing*** and corrals directly over the leach field, particularly when soils are wet; vehicle use (which can also damage pipes); “high-use” horse activities; as well as paving, constructing buildings, and piling heavy objects.
- Nonstandard septic systems, such as mounds, at-grades, pressure distribution systems, sand filter, etc., can be especially fragile and should be well ***fenced*** for their protection. Local health or permitting departments can offer more specific advice.
- Follow local regulations about the proximity of horse confinement areas to septic leach fields.

2.8 Design and Maintenance for Roads, Trails and Stream Crossings

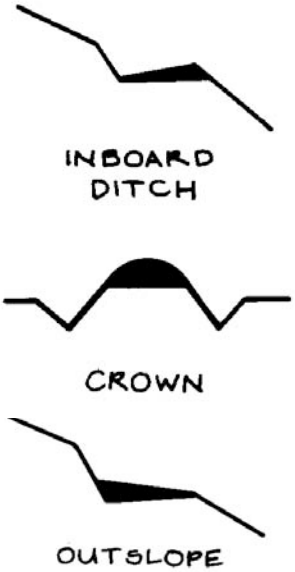
Proper road, trail and ***stream crossing*** design and maintenance will help control erosion. Improperly constructed or maintained roads can cause chronic erosion problems. Unsurfaced roads and horse trails can contribute sediment to creeks and can become dangerous or impassable for horses and vehicles. Even annual regrading of small washouts or eroded areas can contribute significant amounts of sediment to the nearest stream.

Develop longer-term solutions, such as a durable road base, compaction, and gravel surfacing to save time and money while reducing inconvenience, increasing safety, and controlling sediment from reaching creeks.

Management Strategies for Roads and Trails

Properly design and construct roads and trails

- Consider the type and amount of expected traffic, speed, loads, climatic conditions, and environmental resources in need of protection. Keep roads to a minimum, the fewer roads, the less maintenance and erosion. Follow sound engineering measures to insure that the road meets the requirements of its intended use and that maintenance requirements are in line with operating budgets. The *Handbook for Forest and Ranch Roads* is a good resource. To obtain this publication, call the Mendocino County Resource Conservation District at (707) 468-9223.
- Understand how roads are constructed and drained to help determine the appropriate strategy for your property. Roads are constructed to drain in three different ways:
  - **Insloped roads** are graded into the slope and drain to an inboard ***ditch***. ***Ditches*** provide surface drainage for the roadway and should be designed to protect the road surface from upslope runoff.
  - **Crowned roads** are higher in the middle and drain water off to both sides. Crowned roads require more initial grading and regular ***ditch*** maintenance.
  - **Outsloped roads** follow natural drainage patterns and runoff drains across the road in even sheets. Typically, outsloped roads are less expensive to construct and easier and cheaper to maintain. ***Culverts*** and ***ditches*** are not required except where the road crosses small drainages. The addition of large amounts of stormwater runoff from above outsloped roads may cause excessive erosion. Roads may have to be surfaced, regraded, or re-routed.



Roads are constructed to drain in three ways. Insloped roads are graded into the slope and drain to an inboard ditch. Crowned roads are higher in the middle and drain water off to both sides. Outsloped roads follow natural drainage patterns, and runoff drains across the road in even sheets. Outsloped roads are generally less expensive to construct and easier and cheaper to maintain.

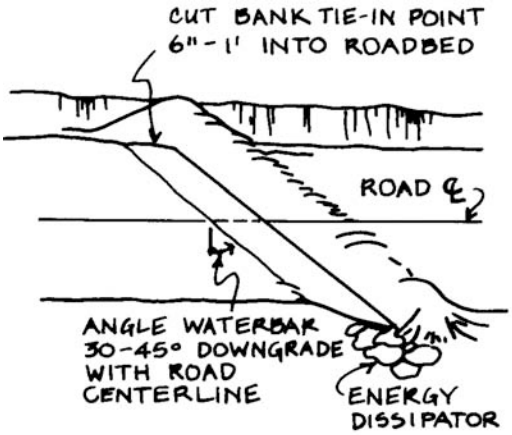
- Develop adequate cross drainage. Long stretches of inboard ***ditch*** accumulate a lot of water that can cause extensive gullying of the ***ditch***, destabilize the roadbed, and undermine the hillside. Some form of cross-drainage is required at regular intervals to channel runoff across the road to non-erodible outfalls, such as ***energy dissipaters***, on the outboard side. Even if a road has some cross-drainage, additional measures may be needed to help prevent washouts. Selecting a method to transport water across a road depends on road location, amount of use and maintenance, the volume of flow, and budget considerations.

A muddy swale is created by improper drainage from a road (uphill of this photo). A properly constructed and maintained road will help control erosion. Culverts and waterbars can provide **cross-drainage**. *Some roads may need surfacing with gravel, while others should be avoided during the wet months.*

Cross-drainage techniques to consider include:

- ***Culverts.*** Culverts are likely to need professional design to handle anticipated flow. Angle ***culverts*** about 30 degrees downgrade to assure proper water movement and prevent plugging and erosion at the inlet. Compact the backfill to prevent water from flowing through the road base. ***Culverts*** should be used in upland areas and avoided for ***stream crossings***, where ***bridges*** are more appropriate.

  Inlet and outlet design is important to prevent erosion. Inlet design must not allow "piping" (water flowing along the outside of the pipe) that could loosen the soil and wash out the pipe. ***Culvert*** outlets should extend at least two feet beyond the edge of the road and empty onto an ***energy dissipater*** (such as rock riprap). For outlets on steep slopes, use a ***lined waterway*** or ***underground pipeline*** to safely convey water to the base of the slope.
- **Rolling Dips** are dips in the grade of the road. Rolling dips are installed in a road bed to drain the road surface and prevent rilling and surface erosion, and are most frequently used on outsloped roads. To effectively direct runoff to the side of the road, the axis of a rolling dip should be angled about 30 degrees to the road alignment.
- **Waterbar.** This is a shallow ditch placed 30 to 45 degrees downslope across the road surface to control surface runoff on low use roads. The excavated material from the ***waterbar*** is piled in a rounded ***berm*** downslope of the waterbar to form an additional water barrier. ***Waterbars*** are a temporary and very effective means of breaking up surface flow on sloped portions of road. Often they must be reconstructed every year as they wear down.



Waterbars *are a temporary form of cross-drainage. To create a waterbar, dig a shallow ditch 30 to 45 degrees downslope across the road. Pile the excavated material in a rounded berm downslope of the waterbar. Waterbars need to be monitored and maintained throughout the winter.*

Waterbars work best on roads that receive little winter traffic. In a pinch, they can be constructed with hand tools. Installing a series of ***waterbars*** reduces the flow volume individual waterbars must handle. ***Waterbars*** can be reinforced with logs, gravel, or a mixture of soil and cement.

- Follow natural contours and slopes to minimize disturbance of drainage patterns. Avoid building roads on unstable slopes or at too steep of a grade. Grades normally should not exceed 10 percent slope except for short lengths. Minimize cuts and fills, and stabilize the side-slopes of all cuts and fills. Areas with geological hazards (such as old landslides) should be avoided.

Set roads and trails back from creeks and maintain a ***riparian buffer.***

Maintain roads, trails, culverts, and ditches

- Go out during a storm, shovel in hand, when you can see drainage patterns and areas that require urgent attention.
- Check for erosion and drainage problems, particularly on road surfaces, ***ditches***, and cross-drainage structures. Often the main cause of soil erosion is from the power of concentrated runoff that roads and trails collect and channel.
- Look for ***ditches*** or ***culverts*** that are washed out, blocked with debris, or are causing downstream erosion at the outlet.
- Keep ***ditches*** vegetated with grass to help maintain stability.
- Keep ***ditches*** cleared of sediment. Vegetated ***ditches*** with a gentle slope of 2 to 6 percent will prevent sediment deposition and allow rapid drainage. For chronic sediment problems, address the erosion source.
- Keep inlets clear. Remove debris before the rainy season and check during and after storms. Look upstream for any material that could wash into the ***culvert***. Consider another method of cross-drainage or address the upstream source of debris if ***culverts*** plug after every major storm.
- Consider using ***trash racks*** to trap debris, if you can maintain them. While trash racks can help keep ***culverts*** open, unmaintained racks can cause more erosion problems than the original debris.
- Control upslope erosion sources to prevent sediment from filling cross-drainage ***culverts***.
- Install and maintain ***energy dissipaters*** at outlets.

A **rock-lined ditch** *is necessary along this steep road. Well-constructed and maintained ditches are key to the long-term stability of an insloped or a crowned road.*

Maintain and improve road and trail surfaces

- Regrade roads to smooth the surface and prevent rills from expanding.
- Provide adequate cross-drainage using ***culverts*** and ***waterbars.***
- Resurface roads and trails that have high traffic, chronic erosion problems, undesirable amounts of dust, or steep grades. For muddy roads, consider using a gravel road base laid over a layer of filter fabric to prevent the gravel from mixing with mud.
- Limit or avoid using certain roads and trails during the winter, particularly those on highly erodible soils.
- Limit side-trails where possible. Shortcuts, especially up steep slopes and across streams, can create highly erodible sections of trail. Encourage riders to stay on established trails.
- Sow grass seed on seldom-used roads and adjoining areas of exposed soil. ***Seeding*** should occur before October 15 to ensure adequate growth.

Roads not used in the winter can be "put to bed" for the season. This road has been seeded and will not be used again until the spring. Roads should be properly graded, seeded and mulched, to help prevent erosion. **Seeding** *should occur before October 15 to ensure adequate growth before the winter rains.*

Put abandoned roads "to rest"

- Grade, ***seed*** and ***mulch***, or use an ***erosion control blanket*** when putting roads to rest for the rainy season. Jute netting with a layer of straw underneath can also be used. Straw wattles (bundles) can also help with erosion control. (For information on ***erosion control blankets*** and straw wattles, see Section 4.1: Erosion Control – Gully Repair.) For roads with chronic erosion problems, laying roads to rest may be an appropriate strategy from an economic, environmental, or safety standpoint.

Stream Crossings

- Select an appropriate crossing (either a ***bridge,*** **rolling dip*****, ford,*** *or* ***culvert***). Select a crossing location that will least impact streambanks and riparian vegetation.

This stream crossing keeps livestock from trampling the streambanks. Stream crossings, such as **bridges***,* **fords** *and* **culverts,** *should be located and designed to minimize impacts to streambanks and riparian plants. Bridges work best on larger streams and have the least impact on aquatic life. Permits are generally required.*

- ***Culverts*** should be properly sized and installed. They should follow the same alignment as the creek and exit at the same level as the channel downstream.
- ***Fords*** may be required for crossing small seasonal drainages or where debris can clog ***culverts***. ***Fords*** should be surfaced with concrete to prevent erosion. ***Fords*** require site-specific engineering design. A correctly designed ***ford*** should require very little maintenance. If horses will use the ***ford***, be sure to roughen the concrete surface, when pouring the concrete, for traction.
- ***Bridges*** are best for larger streams and where there is a lot of floating debris. ***Bridges*** have fewer impacts on aquatic life than other crossings.

- Remember ***ditches*** in the design process. Well-constructed and maintained ***ditches*** are key to the long-term stability of an insloped or a crowned road. Slope the sides of drainage ***ditches*** if possible to control erosion. ***Ditches*** on steeper slopes may need to be lined with rock. Steep-side ***ditches*** will erode more easily than those with 2:1 side slopes. Flat-bottomed ***ditches*** with a 1-2 foot wide bottom are less subject to scouring than V-bottom ditches. ***Ditches*** on steep slopes may require ***check dams*** for grade control (you may want to consult a professional for advice and design).
- Stream crossing references. Check these internet reference sites for additional information on designing stream crossings for fish passage:

National Marine Fisheries Service
http://swr.nmfs.noaa.gov/habitat.htm
Click on Stream Crossing Guidelines

Washington Department of Fish and Wildlife
http://wdfw.wa.gov/recovery.htm
Click on Fish Passage Design at Road Culverts

- Obtain necessary permits. County, state, and federal ordinances regulate many aspects of road construction, reconstruction, and maintenance. Creek crossings will likely require a Streambed Alteration Agreement from the California Department of Fish and Game and can require permits from the US Army Corps of Engineers and the Regional Water Quality Control Board. County public works and building departments may have grading ordinances that describe how roads may be constructed and connected with existing public roads. Other state regulatory agencies with jurisdiction on road construction and related activities include the California Department of Transportation, California Department of Forestry and Fire Protection, and California Coastal Commission (for work in the Coastal Zone). See Sections 5.4 and 5.5 of the Resources Directory for more information on regulations and permits.

- Schedule construction and maintenance activities to minimize soil erosion and allow for revegetation of disturbed areas before winter rainfall. Although some soil moisture is advantageous for roadbed compaction, wait until winter runoff has slackened and soils have begun to dry in the late spring before beginning construction. Heavy equipment should not be used on wet soils. Prevent sediment from entering creeks during and after construction. After construction, revegetate road banks and disturbed areas before the winter rains. ***Seed*** and ***mulch*** for revegetation by October 15.

2.9 Construction Management

Proper construction is important whether building a new horse facility or making improvements at an existing facility. Appropriate installation of erosion control and drainage structures can help protect water quality and reduce future maintenance.

Construction Management Strategies

- Seek technical advice and professional design assistance. Drainage systems must be sized for water volume and velocity.
- Obtain the proper permits for grading and working in streams. See Sections 5.4 and 5.5 of the Resources Directory for more information.
- Avoid grading during the rainy season.
- Minimize disturbance along the edges of creeks.
- Be sure equipment operators fully understand the purpose and extent of grading. Flag-off special areas that you want to protect.
- Implement erosion control measures, such as ***seeding*** and ***mulching*** or installing ***erosion control blankets***, immediately following grading. Utilize emergency measures such as ***straw bale sediment barriers*** until permanent structures can be installed.
- Monitor and maintain all erosion control measures.

Chapter 3

List of Conservation Measures

A conservation measure is a specific treatment, such as a management decision, activity, practice, or structure, that provides a practical, effective, and economical means to prevent or reduce water pollution. Protecting creeks and water quality can create a healthier environment for horses by reducing mud and manure areas.

Table 2 lists conservation measures discussed throughout this guide in ***bold italic*** and identifies the main section(s) in which they are found. Note that conservation measures and suggestions in this guide rely extensively on the standards and specifications of US Department of Agriculture's Natural Resources Conservation Service.[9] Horse owners may need to seek professional assistance with some measures. Conservation measures with an asterisk (*) have an NRCS standard and specification with specific design criteria. Some standards and specifications have different names than used in this guide, which are marked with a footnote, and NRCS practice names are given at the end of the table. Visit the website: http://www.nrcs.usda.gov/technical/efotg/, or contact your local NRCS office for details.

[9] Conservation practices in this section are drawn from USDA Natural Resources Conservation Service *Field Office Technical Guide*. Davis, CA, 1986.

Table 2: Horse Keeping Conservation Measures

Conservation Measures	Section	Page Number
Conservation plan	1.1, 2.3	11, 24
Erosion control Conservation Measures	4.1	52
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Mulch [B]*	4.1, 5.2	52, 80
Erosion control blanket [C]*	4.1	53
Gully repair	4.1	53
Check dam [D]*	4.1	60
Streambank stabilization [E]*	4.1	55
Emergency Erosion Control Measures	4.1	58
Sandbag	4.1	59
Sandbag pipeline drop inlet	4.1	61
Silt fence	4.1	61
Straw bale check dam	4.1	60
Straw bale sediment barrier	4.1	60
Straw bale waterbar	4.1	59
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Bridge	2.8	44
Ford	2.8	44
Culvert	2.8	41
Ditch	2.8	41
Waterbar	2.8	42
Trash rack	2.8	43
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Monitor grass growth	2.6	34
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Weed management	2.6	33

Conservation Measures	Section	Page Number
Stormwater Management Measures		
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Roof runoff management*	2.1, 4.2	20, 62
Gutter	2.1, 4.2	20, 62
Downspout	2.1	20
Splash pad	2.1	20
Subsurface drain*	2.1	20
Runoff Diversion	4.2	63
Diversion*	4.2	63
Berm	4.2	63
Runoff Conveyance	4.2	63
Grassed waterway*	4.2	64
Lined waterway*	4.2	65
Drop inlet	4.2	65
Sediment basin*	4.2	65
Underground pipeline*	4.2	65
Discharge Area	4.2	66
Energy dissipater [I]*	4.2	66
Polluted Water management measures	4.3	66
Filter strip*	4.3	66
Riparian buffer*	4.3	67
Willow sprigging [J]*	4.3	71
Constructed wetland*	4.3	72
Waste pond*	4.3	72
Pond sealing or lining*	4.3	72
Horse wash area	2.5	31
Paddock	2.6	35
Turnout	2.6	35
Water quality monitoring	5.7	90
Manure Management [K]*	2.3	24
Manure storage area [L]*	2.3	24
Manure transfer* or hauling	2.3	28
Manure application [M,N]* or spreading	2.3	27
Composting manure	2.4	29
Compost area [O]*	2.4	30
Water quality monitoring	5.7	90

Natural Resources Conservation Service names for standards and specifications:

[A] Critical area planting
[B] Critical area planting – straw mulch
[C] Critical area planting – erosion control blanket
[D] Grade stabilization structure
[E] Streambank protection
[F] Access road
[G] Prescribed grazing
[H] Trough or tank
[I] Rock riprap
[J] Critical area planting – woody cuttings
[K] Waste management system
[L] Waste storage facility
[M] Nutrient management
[N] Waste utilization
[O] Composting facility

Chapter 4:

Conservation Measures to Improve Water Quality

Conservation measures offer options for making improvements at a horse facility and are designed to assist land users to effectively reduce sources of pollution at horse facilities. You have seen the list of conservation measures (Chapter 3) and references to these conservation measures in Chapter 2. Material in this chapter is designed to assist horse owner knowledge and understanding of how management practices function together within a facility. Now, we will discuss in detail how the items tie together.

This chapter is presented in three sections:

- **Section 4.1:** Erosion Control Conservation Measures
- **Section 4.2:** Stormwater Management Measures: Keep "Clean" Water Clean
- **Section 4.3:** Measures to Manage "Polluted" Water

4.1 Erosion Control Measures

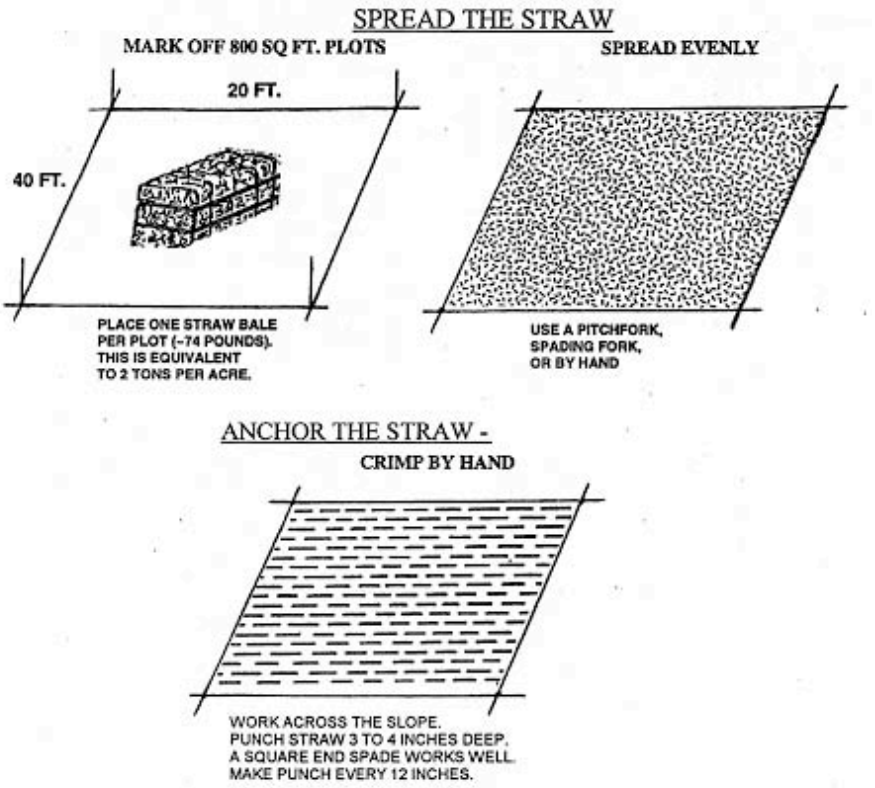
Erosion is easier to control in its early stages when revegetation or simple drainage improvements may be all that are necessary. Once eroded, soils are less productive, and can be more difficult to revegetate. Watch for accelerated erosion in vulnerable areas such as steep slopes and landslides, pastures, gullies, intensively used horse areas such as ***paddocks*** and ***turnouts***, streambanks, unsurfaced roads, road cuts, parking lots, and construction areas.

Seed and Mulch for effective Revegetation

Straw mulch is being applied after tractor work was done to smooth out a gully. ***Seeding*** *and* ***mulching*** *are effective and low-cost erosion control measures. When seeding and mulching bare areas, be sure to prepare the seedbed by removing weeds, and roughening the seedbed. Grass seed should be spread by October 15. Mulch should be weed free.*

Seeding and ***mulching*** provide effective revegetation.. ***Seeding*** is usually needed for ***filter strips***, ***grassed waterways*** and ***pastures***, as part of erosion control, or after construction. A complete seed mix and specifications are in Section 5.2 of the Resources Directory. ***Seeding*** and ***mulching*** tips to keep in mind are:

- Be sure to plant before the rainy season, generally by October 15.
- Properly prepare the seedbed. The area should be weed free. Have a firm seedbed that has been roughened by disking, harrowing, or a similar method. Or use a no-till drill to seed directly into existing grasses, which will minimize erosion.
- Legumes (clovers) must be inoculated with nitrogen fixing bacteria immediately before planting. This will help increase legume production and nitrogen fixation. (See Section 5.2, Legume Inoculation.)
- Maximize the use of native species.
- Do not use fertilizers with native grasses, as weedy annuals will compete for the extra nutrients.
- Use ***mulch***, preferably straw, after seeding. Crimp the straw with a shovel for small areas, or a tractor with tracks for large areas, to anchor it in place. Make sure straw is certified weed free. Rice straw is a good option because the weeds that grow with rice only survive in an aquatic environment.
- Straw wattles can be used to break-up the rainfall over long slopes.
- Keep the soil moist until the rainy season begins.
- Periodically mow or graze, and weed to control noxious weeds and reduce fire danger.
- Restrict human and horse access until grasses are well established.



Apply straw **mulch** *at a rate of two tons per acre (or one 74 pound bale per 800 square feet, at a uniform depth of 2 to 3 inches). Straw can be anchored by hand punching, or in larger areas, by using rollers, crimpers, or a disk.*

Gully Repair

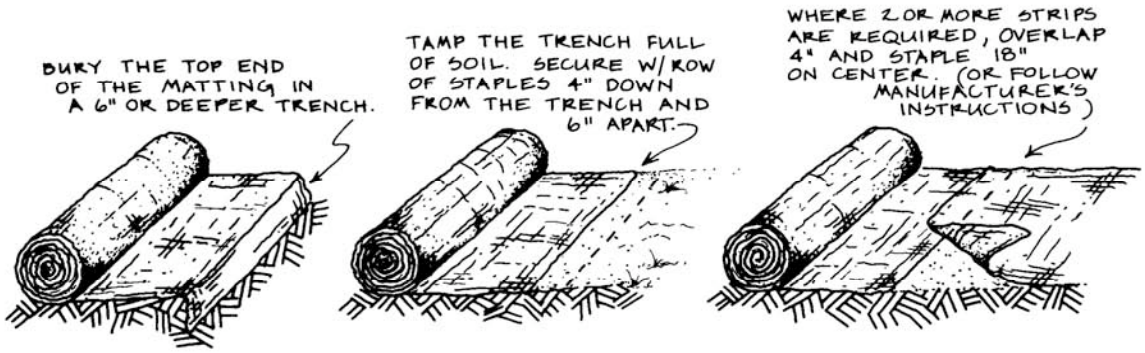
Certain highly erodible soils are particularly susceptible to gully formation. Gullies will deepen and widen if left unchecked. To develop an effective repair, determine what caused the gully to form. Any change in drainage patterns that concentrate water, such as ***ditches*** or road ***culverts***, are likely suspects and may be easy to remedy.

Steps to stabilize a gully include: 1) stopping the gully headcut, so it will not continue to move uphill, and 2) controlling the gully downcut so it will not continue to deepen and widen. Options for ***gully repair*** include one or more of the following: ***fence*** livestock out, install a ***grassed waterway*** or ***lined waterway***, line the headcut with rock to keep it from moving upslope, install rock ***check dams*** to stop downcutting, grade side slopes and ***seed*** and ***mulch*** the area. ***Erosion control blankets***, and straw wattles may also be needed. Avoid using ***erosion control blankets*** with plastic netting as birds and other small animals can become trapped in the mesh.

A gully headcut needs stabilization to keep it from moving upslope. Measures are also needed to control deepening and widening of the gully. Horses should be restricted from gullies as trampling can exacerbate erosion problems or damage repairs.

Erosion Control Blankets are effective tools for the prevention of erosion. Erosion control blankets are made from bio-degradable substances such as straw, coconut, or wood fiber, bonded in place with a variety of netting and stitch patterns. Erosion control blankets are placed onto prepared, seeded, soils to prevent washing away of the seed and erosion of the prepared seed bed. After the vegetation grows the erosion control blanket degrades over time until only the vegetation is left in place. The vegetation, once established, provides permanent erosion control. Erosion control blankets are available in a variety of sizes and grades. For photos and installation recommendations, search "erosion control blanket" on an internet search site for various vendors.

Straw wattles are man-made cylinders of compressed, weed-free straw (wheat or rice), 8 to 12 inches in diameter and 20 to 25 feet long. They are encased in jute, nylon or other photodegradable materials, and have an average weight of 35 pounds. They are installed in a shallow trench forming a continuous barrier along the contour (across the slope) to intercept water running down a slope. Straw wattles are used to increase infiltration, reduce erosion, and help retain eroded soil on the slope. Straw wattles should be effective for a period of one to two years, providing short-term protection on slopes where permanent vegetation will be established to provide long-term erosion control. Search "straw wattles" on an internet search site for various vendors.



Erosion control blankets *must be carefully installed to be effective. Make sure the upper end is securely tucked into a small trench. Blankets range from simple jute netting that works best if straw is laid underneath, to heavy duty coconut fiber. Avoid using blankets with plastic netting as birds and small animals can become trapped in the mesh.*

You will likely need technical assistance before attempting to repair a gully. *Groundwork: A Handbook for Erosion Control in Northern California* contains hands-on, practical advice. Contact the Marin County Resource Conservation District at 415-663-1170 to obtain or review a copy.

It is easier to stabilize a small or beginning gully than to repair a large gully system. Where is the runoff coming from? Can it be diverted? Should it go into an underground pipe? Or perhaps careful placement of rock and proper use of erosion control fabrics will make a successful project. Site specific recommendations are needed for gullies.

Rock **check dams** *are a common gully repair.* **Gully repair** *is site-specific, so obtain technical assistance. Be sure to acquire any permits from the county, California Department of Fish and Game, Regional Water Quality Control Board, and the US Army Corps of Engineers. Continue to monitor and maintain your projects after installation.*

Streambank Stabilization[10]

Evaluate and determine the cause of the problem. Streambank erosion may be caused in three ways or by a combination of the following processes:

Surface flow. Water flowing over the top of the ground usually causes steep, vertical bank erosion. Common sources include ***culverts***, driveways, ***ditches***, or drainage from roofs. Addressing the cause, either by redirecting or slowing the flow and dissipating its energy, will go a long way toward solving the problem.
Ground water. Water flowing a few inches to a few feet below the ground frequently surfaces (or "daylights") on a streambank before reaching the creek channel. This makes streambanks vulnerable to erosion. Although ground water flow can cause or exacerbate erosion, it can also be an asset if you plan to control erosion using vegetative methods. Check to make sure you are not indirectly contributing excess subsurface flow through irrigation.
Stream dynamics. Natural changes—such as big storm events or human activities—can cause the stream channel to adjust. For example, when areas are paved and vegetation is removed to construct buildings and roads, less water soaks into the soil and run-off is increased. This increases storm flows and contributes to flooding problems. Removing vegetation along a creek can reduce streambank stability. This can lead to streambank failure, particularly during major storm events.

Once you have determined the cause of the streambank erosion, you can plan, install, monitor and maintain your repair.

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[10] This information was drawn from the Marin County Stormwater Pollution Prevention Program brochure, *Repairing Streambank Erosion*. 1997.

Determine if the site needs repair

Not all erosion is bad. Streams need to be able to adjust to events in the watershed by changing their shape. Undercut banks and fallen trees provide important habitat for aquatic life. Erosion should be controlled if it threatens a structure, road, utility pole, other property, or prime riparian habitat; is extremely active; or is caused by a human factors (such as a road).

Plant grasses and shrubs (preferably natives) on streambanks to reduce erosion. Streambanks with sparse cover are a common source of erosion. Eroding areas should be repaired if they threaten a structure, road, utility pole, other property, or prime riparian habitat; is extremely active; or is caused by a human-made change, such as a road.

When undertaking a **streambank repair** *project, take photos and make sketches of the site, seek professional assistance for major or complex repairs, incorporate native plants into projects, and be sure to obtain the proper permits. Monitoring and maintenance is critical during the first few years after installation.*

Document the site

If you repair the erosion site yourself, you will need information for calculating materials and getting permits. If an engineer or agency is helping you, this information will save them time and you money. Take photographs (and include a reference object such as a fence line or tree), sketch the site including measurements and any biological information you have, and note any observations you have of the situation.

Determine if this should be a cooperative project

If many of your neighbors have similar streambank erosion, consider working together. Benefits include sharing the permit and planning costs, building repairs that complement and even enhance each other, and, if done in conjunction with a local agency or group, may be eligible for private or government grant programs.

Determine if you need professional help

Consider professional help when the repair is major, and/or an ineffective repair could result in significant damage to a structure, road, or other valuable property; working space is limited; and county regulations and common sense dictate professional design. Civil engineers, biologists, and other restoration specialists can help design repairs. Ask the individual or firm if they have done this type of work before. When, where, and for whom? How do they plan to repair the site? How will they access the site? What type of equipment will be used? How long will the work take? What is the estimated cost of designing and constructing the repair? Can they assist you in obtaining

permits? Visit project sites that they have repaired, and discuss the project with the landowner.

Consider a range of design options

Find out what has worked in your area. Be sure **not** to constrict the channel. Keep fish and wildlife habitat in mind. (For stream crossing information, see Section 2.8 on Roads.) If salmon or steelhead passage is expected, follow ***culvert*** design guidelines by the California Department of Fish & Game and the National Marine Fisheries Service. Also, your local Resource Conservation District, or the Natural Resource Conservation Service are good sources of information. See Section 5.1 of the Resources Directory for contact information.

Incorporate native plants into the repair. The extensive root systems of some native plants can help with streambank stability. Even rock riprap can be interspersed with willows or other trees to enhance habitat. Willow wattle walls, brush mattresses, and other techniques described in *Groundwork: A Handbook for Erosion Control in Northern California* can stabilize streambanks completely with *live* materials, which is preferable.

Obtain necessary permits

Acquire permits before construction. Most stream repair work requires a Streambed Alteration Agreement from the California Department of Fish and Game. Most counties require grading or building permits for work in stream channels. Permits will likely be required from the US Army Corps of Engineers and the Regional Water Quality Control Board. See Sections 5.4 and 5.5 of the Resources Directory for permit information.

Install your project properly

Streams are a demanding and often unforgiving work place. Never underestimate the force of moving water. Pay attention to small details that will make the difference between a successful repair and a headache. Follow all permit requirements. Most work will need to be completed by October 15. See Section 2.8 for Stream Crossing references.

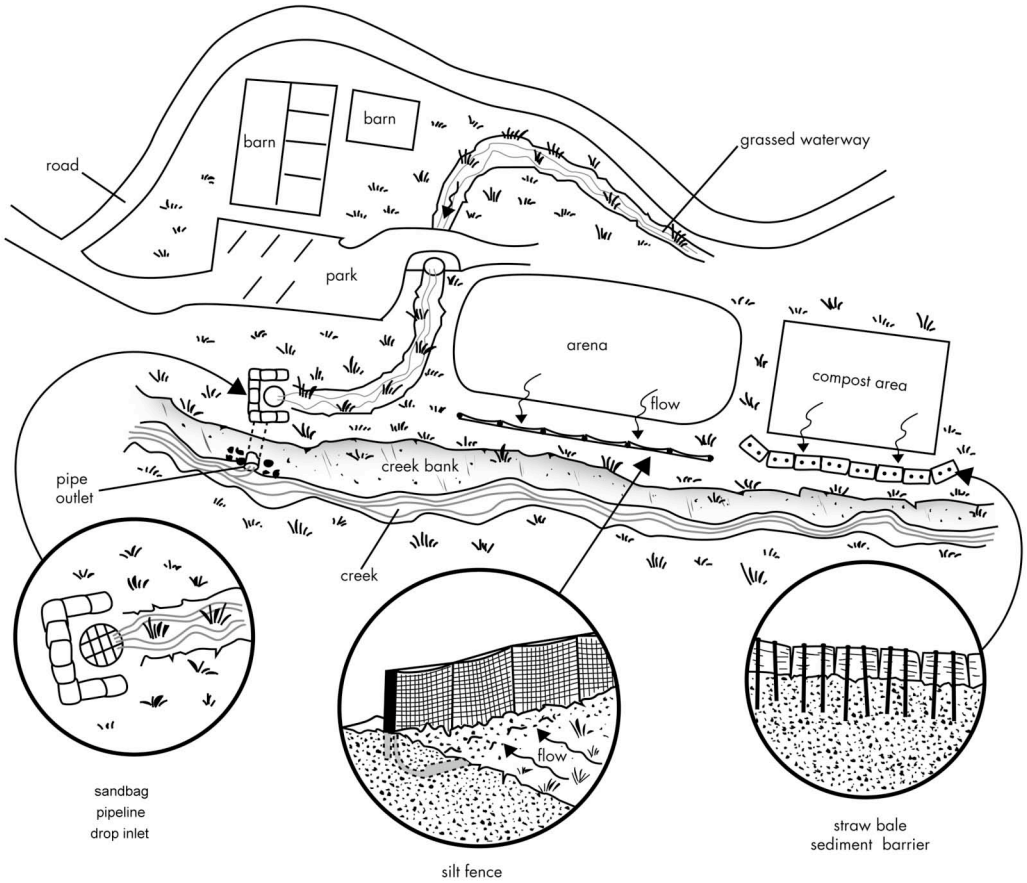
Monitor and care for your repair

Many failures are caused by small problems that could have been avoided if caught early. Check your repair before the winter rainy season, and during and after each storm. Establish a location where you can take “before” and “after” photos.

Emergency Erosion Control Measures

The emergency erosion control measures described in this section are temporary actions that property owners can install themselves. These measures are low-cost, and often do not require special expertise to design or install. However, they require constant maintenance and generally last only one season. They are designed to retain or divert stormwater runoff, reduce flood damage, stabilize overwhelmed drainage structures, or stop erosion. It is best to put in erosion control measures before the rainy season, although these measures can be installed anytime you notice a problem or potential problem.

All of these measures should be considered temporary until access, weather, time, or money allows more permanent solutions to be implemented. For example, straw bales usually rot after one year. Proper companion measures may also be necessary if the temporary fix fails (which often happens), and then creates a bigger problem. It is important to develop long-term solutions for erosion sites.



EMERGENCY MEASURES – Use emergency erosion control measures to divert stormwater runoff, reduce flood damage, stabilize overwhelmed drainage structures, or stop erosion. Temporary measures to consider are **sandbag pipeline drop inlets**, **silt fences**, *and* **straw bale sediment barriers**. *All require proper installation and maintenance, and should be replaced with permanent measures as soon as possible.*

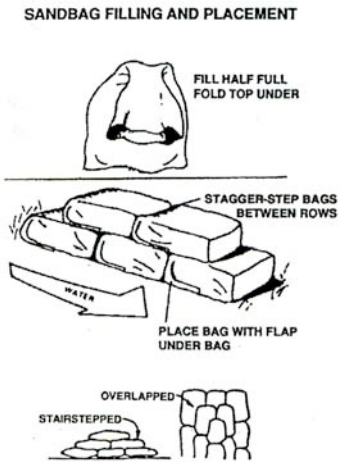
Emergency measures must be properly installed and maintained. This will minimize the chance of failure and avoid causing greater problems on-site or on neighboring land. You may need to seek technical assistance from qualified consultants, Natural Resources Conservation Service, or your local RCD. Remember, each site is unique and some temporary measures may not be appropriate for your property.

During the winter, keep a close eye on drainage conservation measures and known problem areas. Immediate action can prevent problems from becoming larger or causing more damage. Be prepared to act quickly by keeping materials to construct emergency measures on hand. Materials commonly needed for emergency measures include straw bales, straw ***mulch***, ***sandbags*** and fill material, ***erosion control blankets***, plastic tarps, ***silt fence***s, steel t-posts or rebar, fence mending supplies, baling wire, rope, and rock.

These measures should not be put in creek beds, but in upslope areas. The following are emergency erosion control measures to consider.

Sandbags

These are used to direct runoff into ***culverts*** and ***drop inlets*** or other conveyance structure. Abut the ends of ***sandbags*** tightly against one another and overlap joints.



Sandbags can be used to direct runoff into **culverts** *and* **drop inlets**. *Be sure to abut the ends of sandbags tightly against one another and overlap joints.*

Straw bale waterbars

These are also used to divert water off road surfaces. Straw bales used as ***waterbars*** should be installed at a slight angle down the slope of the road. Straw bales should be placed in a trench at least 4 inches deep with the excavated material used to form an earthen ***berm*** against the uphill side of the bales. Drive rebar or t-posts through each bale and at least 1 to 2 feet into the ground. Angle the first stake toward a previously laid bale to force the bales together. Abut the ends of straw bales tightly against one another. Loose straw can be crammed between bales to help seal joints. Overlap joints by at least 15 inches if more than one row or layer of straw bales are used.

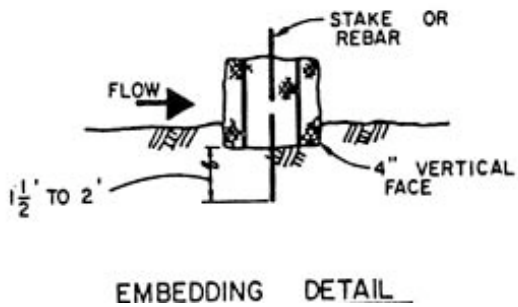
Straw bales are subject to damage by curious and hungry livestock and deer and may need to be protected with chicken wire.

A straw bale ***berm*** can also be used as an emergency ***waterbar***. To divert water, angle the ***berm*** and trench slightly down and across the slope. Place the excavated material in a ***berm*** on the downslope side of the trench. Protect the outlet from erosion with gravel. See Section 2.8 for more information on road and trail maintenance.

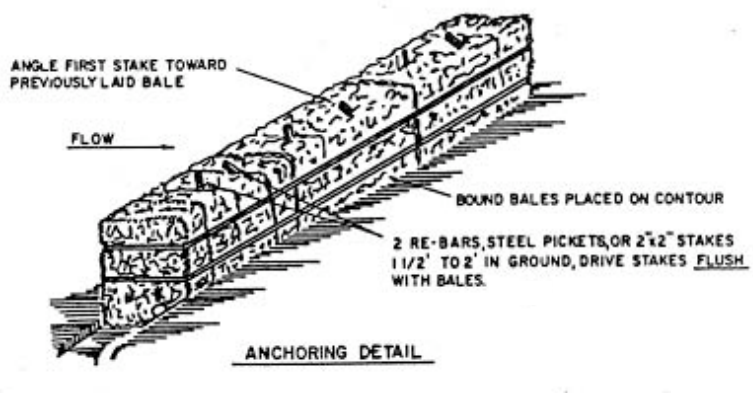
Straw bale sediment barriers

These are used to retain sediment while allowing water to infiltrate through.[11] Install and anchor straw bales as described (in ***straw bale waterbar***). Care should be taken so runoff does not backup behind the barrier and flow around the ends where the concentrated water can cause erosion.

A **straw bale sediment barrier** *retains sediment while allowing water to pass through. Bales need to be anchored with stakes or rebar. Be sure that water cannot flow around the barrier and cause downslope erosion.*



When using straw bales as a **waterbar** *or sediment barrier, place bales in a trench at least 4 inches deep. Drive two metal fence posts or re-bar for stakes through each bale and at least 1 to ound.*



Abut the ends of straw bales tightly against one another. Angle the first stake toward a previously laid bale to force the bales together. Cram loose straw between bales to help seal joints. If using two rows stacked (one atop each other), overlap the joints by at least 15 inches or more.

Straw bale check dam

These can be used to stabilize eroding gullies and ditches. ***Straw bale check dams*** in gullies and ditches are prone to failure and can cause worse erosion problems unless properly installed. Have them installed by an experienced person, or gather further information from NRCS.

Table 3. Straw bale check dam – design limits

Slope	Maximum Drainage Area	Maximum Slope Length Between Check Dams
0 – 15%	1 acre	200 feet
15 – 20%	½ acre	100 feet
>20%	Not Recommended	—

[11] Emergency barrier structures can typically contain the stormwater runoff from one acre and 100 feet of slope length for slopes up to 15 percent; or one-half acre and 50 feet of slope length for slopes greater than 15 percent.

Silt fences

As with ***straw bale sediment barriers***, the purpose of these structures is to settle out sediment in sheet flow, not concentrated flow, while allowing water to pass through. Again, care should be taken so runoff does not pond behind the ***silt fence*** and flow around the ends where the concentrated water can cause erosion. ***Silt fences*** less than 4 feet in height can be supported by sturdy wire fencing, such as woven wire, stapled to 4 x 4 wooden posts set at least 2 feet into the ground and four feet apart. Place the fabric on the upslope side of the fence and staple to the posts. At least 12 inches of the fabric and 4 inches of the wire should be buried in a 3-6 inch deep trench. Backfill and compact the trench.

Other types of fabric less than one-foot in height need to be supported by galvanized cable stretched between one-inch galvanized steel pipes driven at least three feet into the ground. The cable runs through sewn loops in the fabric. At least 12 inches of the bottom of the fabric is buried in a trench at least 6 inches deep and backfilled with compacted soil.

Sandbag pipeline drop inlet

Sandbags can be used to direct runoff into ***culverts*** and ***drop inlets***. Be sure to tightly abut the ends of the ***sandbags*** and overlap any joints.

4.2 Stormwater Management Measures: Keep “Clean” Water Clean

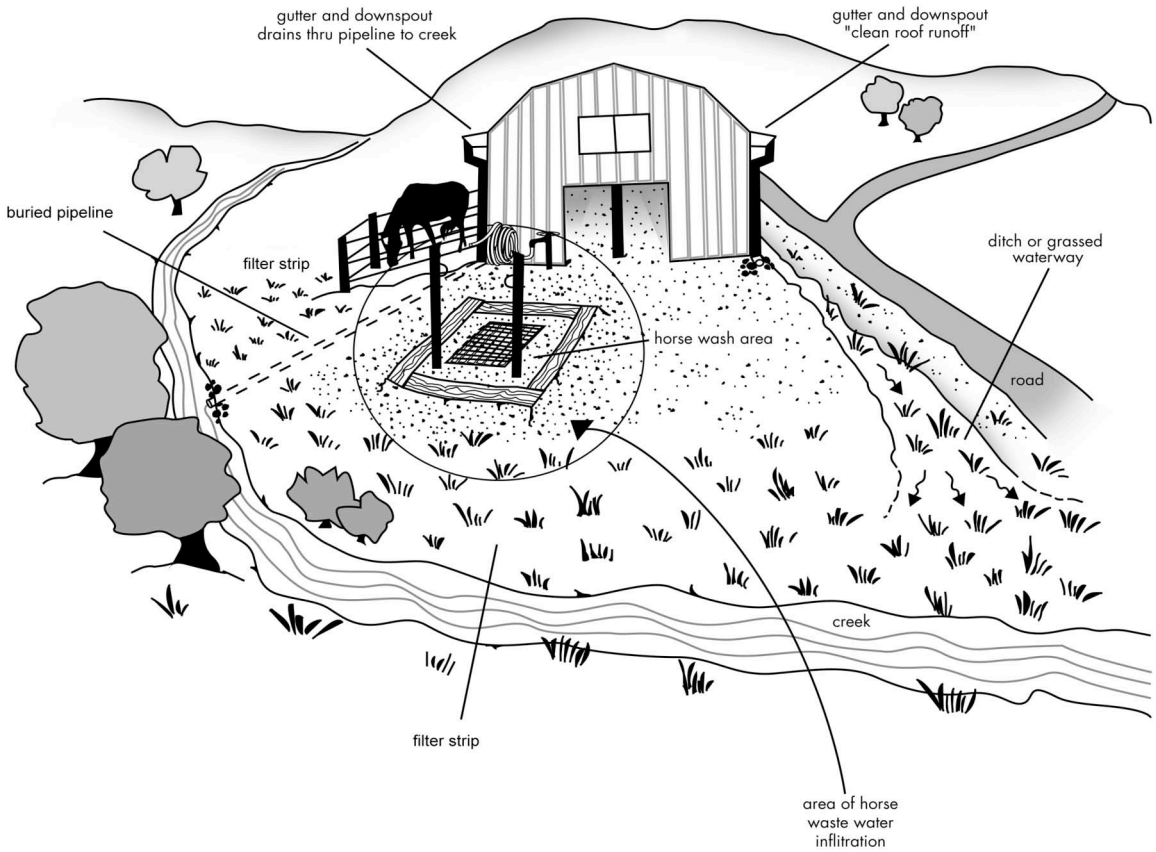
It is much easier to manage “clean” water than to treat water once it becomes polluted. Monitoring your water is a good way to see if you are keeping it clean. It is just as important to limit the impacts of smaller, more frequent storms, as it is to address the typical flooding and drainage problems that occur with larger storms. Runoff must be collected, or diverted, conveyed, and then safely discharged. Remember to incorporate erosion control into your stormwater management.

Conservation measures covered in this section include:

- Runoff Collection
- Runoff Diversion
- Runoff Conveyance
- Discharge Area

Roof Runoff Collection

Collection of runoff is required if rain that falls on roofs drains to areas where it may come in contact with horse waste or cause soil erosion. This is most commonly needed where ***paddocks*** are attached to stalls in a barn. Three conservation measures to consider are ***gutters***, ***downspouts***, and ***splash pads***.



STORMWATER MANAGEMENT – Managing runoff from roofs will help keep "clean" water clean. **Gutters** *and* **downspouts** *can direct clean stormwater away from bare or manured areas.* **Diversions** *or* **berms** *can direct water away from buildings. Buried* **pipelines** *can convey clean water to a creek. Polluted runoff from a* **horse wash area** *should flow into a* **waste pond** *or through a* **filter strip** *before it reaches a creek.*

Gutters

Size ***gutters*** to handle the volume of rainfall calculated for the roof size. ***Gutters*** should have sufficient support to withstand anticipated water. You may need to seek professional help for gutter and downspout sizing. ***Gutters*** may not be required if roof runoff does not drain into ***manure storage*** or animal confinement areas. In such cases, gravel ***splash pads***, vegetation, or ***subsurface drains*** along building foundations may be sufficient to control runoff and prevent erosion.

Downspouts

Fasten ***downspouts*** securely at the top and bottom, with intermediate supports if required. Protect downspouts from damage by animals and equipment.

Splash pads

When downspouts empty onto the ground, surface elbows should direct water away from the building and empty onto ***splash pads*** or other ***energy dissipaters*** to prevent erosion.

Runoff Diversion

Diverting "clean" water around horse keeping areas reduces the creation of "polluted" water that must be managed. ***Diversions***, ***berms***, and curbs can be used to divert "clean" stormwater runoff around buildings, high-use areas, and ***manure storage areas***.

Diversions

A ***diversion*** is a channel or ***ditch***, constructed across the slope, to divert excess water from one area to another. Selecting the proper type and size will depend on site-specific factors such as slope, soil type, and volume of water to be managed. For steeper grades or large flows, the ***diversion*** may need to be lined with rock or similar erosion protection.

A **diversion** *will direct "clean" stormwater runoff around buildings, high-use areas, and manure storage areas. Slope, soil type, and volume of water will determine the specific diversion size, type and design.*

Berms

A ***berm*** is formed by mounding earth materials, similar to building a curb, to redirect water from one location to another. In situations with limited space or where other uses prohibit the use of an open ***diversion ditch***, a compacted earthen ***berm*** can divert runoff into an ***underground pipeline***. Concrete or asphalt curbs, kickboards, and railroad ties can also be used to divert stormwater runoff.

In some cases, a ***grassed*** or ***lined waterway*** can serve as both the ***diversion*** and the means of conveyance used to transport water to the final discharge area such as a ***filter strip*** or ***sediment pond***.

Runoff Conveyance

Once runoff has been collected or diverted, it must often be routed, or conveyed, to the discharge area. To determine the proper type and size of a conveyance system, consider site specific and local factors including slope, soil type, and the volume of water to be managed. For some situations, it may be necessary to link several types of conveyance systems together in a series. For example, ***underground pipelines*** could carry water from a ***downspout*** to a ***grassed waterway*** that then empties into a creek. Be certain that collected and conveyed runoff is "clean" before finally emptying to a creek.

Erosion by the conveyance of water in channels is a prime concern. Large volumes of water with high velocities may require that waterways be lined to prevent erosion.

Conveyance structures include ***grassed waterways, lined waterways, drop inlets,*** and ***underground pipelines***. These are described below.

Grassed waterways *convey concentrated runoff along gradual slopes. They require professional calculations of water volume and velocity. Grass must be established before the waterway is ready to carry winter runoff. Upkeep is needed to maintain capacity, grass cover, and the outlet (or end point).*

Grassed waterway

A grassed water is a wide, shallow, flat-bottomed channel or ditch, with gentle side slopes that conveys concentrated runoff along gradual slopes without causing erosion or flooding. ***Grassed waterway***s generally work well with water velocities of 5 feet per second (fps). For channels with poor grass cover and little maintenance, the velocity should not exceed 3 - 5 fps. Water velocities over 5 cfs need a ***lined waterway***. A professional should calculate the volume and velocity for site-specific conditions. During construction, stockpile topsoil and re-spread where necessary to provide a seedbed for the grass. Excess earth should be spread where it will not interfere with flow into the waterway.

An **erosion control blanket** *can help stabilize the channel until the grass is fully established. It can also be used as an immediate repair for grassed areas that are damaged by horses, machinery, or erosion.*

Sufficient vegetation must be established in the waterway before it carries runoff from heavy winter rains. Seedbed preparation, time of ***seeding***, seeding mixture and rate, and fertilizer requirements are site-specific. Special protection such as a biodegradable ***erosion control blanket*** may be required to help stabilize the channel until vegetation is fully established. (Use heavy duty blankets in situations with flowing water. Avoid using blankets with plastic netting so that birds and small animals do not become trapped.) Supplemental irrigation will help establish grass sooner.

Maintenance is required to ensure waterway capacity, vegetative cover, and the outlet. Vegetation damaged by horses, machinery, or erosion must be repaired promptly. Give special attention to outlets and points where concentrated flow enters the ***grassed waterway***. Maintenance tasks should include checking for sediment accumulation and erosion, removing debris, and making necessary repairs.

Lined waterways

These have erosion-resistant linings of concrete, rock riprap, grouted rock riprap, mortared flagstone, or other permanent material that extend up the side slopes of the channel above the anticipated flow. The bare soil on both sides of the waterway above the permanent lining should be vegetated or otherwise protected. ***Lined waterways*** should be used if concentrated runoff requires a lining to control erosion (flows greater than five cfs); steep grades, prolonged base flow, or seepage may cause erosion; human or animal use of the area precludes using a ***grassed waterway***; high-value property or adjacent facilities warrant the extra cost to contain runoff in a limited space; or if soils are highly erosive.

In areas with flows greater than 5 cubic feet per second, steep grades, prolonged flows, highly erosive soils, or other special conditions, a **lined waterway** *should be used. Concrete, rock riprap, grouted rock riprap, mortared flagstone, or other permanent material will line the channel.*

Drop inlets

Drop inlets can be used to transfer channel flow into an ***underground pipeline***. Elevating the inlet above the channel bottom will cause water to pool up in the trap before entering the inlet. This ponding of water allows heavier suspended particles to settle. Inlets must be regularly checked and kept free of debris during and after storms.

Sediment basin

Sediment basins can be incorporated into the outlet design. Regular clean out of sediment must be performed. Other maintenance includes clearing debris and inspection during and after storms. Screens or ***trash racks*** may be required immediately upstream of the basin to stop debris before it can clog the inlet. Without maintenance, inlets and trash racks cease to function and structures can be undermined by water and cause erosion problems that may be worse than the original situation.

Underground pipelines

These are an effective way to convey water when space is limited and surface channels are not practical. As with all drainage structures, calculation of anticipated flow and proper sizing are crucial.

Be sure **underground pipeline** *is properly installed by compacting soil around the pipe, and installing cutoff collars, if needed, so water does not seep along the pipeline and wash away soil leaving an exposed pipeline susceptible to damage. Also be sure pipes are properly sized to handle flows.*

Rock **energy dissipaters** *reduce the velocity and energy of concentrated storm flows. They are used at the outlets of pipelines, culverts, or other conveyance structures. Calculate the size of rock needed and place rock carefully. Make sure dissipaters are in place before the rainy season.*

Discharge Area

"Clean" water can be discharged into another conveyance structure, a seasonal drainage, creek, ***constructed wetland***, or directed to a ***filter strip*** or pasture. Be sure to use ***energy dissipaters*** to control potential erosion.

Energy dissipaters

These are placed at channel outlets to reduce the velocity and energy of concentrated storm flows, prevent scour, and minimize downstream erosion. They may be needed at the outlets of ***underground pipelines***, ***culverts***, or where ***lined waterways*** discharge to unlined conveyances, e.g., a rock channel discharges into a ***grassed waterway***.

Rock is a common ***energy dissipater***. The type and size of an ***energy dissipater*** depends on local factors. Rock should be carefully and tightly placed over a filter fabric. Loose rock can wash away during high flows. Rock should be angular and large enough to withstand heavy flows.

4.3 Measures to Manage "Polluted" Water

"Polluted" water must be managed so that it does not reach creeks or leach into ground water. Conservation measures that can help utilize nutrients, or store waste water until it can be utilized are:

- Filter Strip
- Riparian Buffer
- Willow sprigging
- Constructed Wetland
- Waste Pond

Filter Strip

A ***filter strip*** is an area of grass designed specifically to trap sediment, horse manure and other pollutants before they enter surface water, such as a creek or a pond. Actively growing grass will use the nutrients in runoff that comes from a manured area. ***Filter strip***s can be developed downslope of high-use areas to trap sediment and manure that washes off of these areas.

Filter strips should be designed and maintained to transport a thin "sheet" of runoff slowly through the vegetation. A gentle slope covered with lush vegetation reduces flow. Thick, sod-forming grass works best to trap sediment. The slow movement of runoff through the vegetation provides an opportunity for sediments to be trapped by vegetation. Nutrients and other pollutants are utilized or degraded through microbial action in the soil.

Use grass **filter strips** *downslope of high-use areas such as turnouts, arenas, and horse wash areas to trap sediment and manure that washes off. Filter strips should be at least 20 feet wide and require annual monitoring and maintenance.*

Obtain professional assistance to determine the size of the strip necessary to treat the water, based on the suitability of the existing soil type, slope, rainfall data, and results of percolation tests. The width of the vegetative ***filter strip*** will be site-specific and depends upon slope, runoff volume, rate of infiltration, pollutants of concern, amount of pollutants, sediment size, and vegetation height and density. A flow-path length of 20 feet is minimal for most sediment removal. An additional 15 to 80 feet is needed to treat nutrients.[12] The key concept is to move water slowly through the vegetation. Too rapid drainage will not allow vegetation to utilize nutrients in the runoff or infiltration to reduce pollutants.

This **filter strip** *is designed and maintained to transport a thin "sheet" of runoff slowly through vegetation. A gentle slope covered with lush vegetation achieves slow flow. Thick, sod-forming grass works best to trap sediment.*

It is important to maintain ***filter strips***. Main tenance activities should include mowing ***filter strip*** grasses to encourage dense, upright vegetative growth; excluding horses and vehicular traffic to keep the land smooth for sheet flow and to avoid soil compaction; inspecting ***filter strips*** after storms, and taking other measures to promote "sheet flow" in the ***filter strip***; and reseed when necessary.

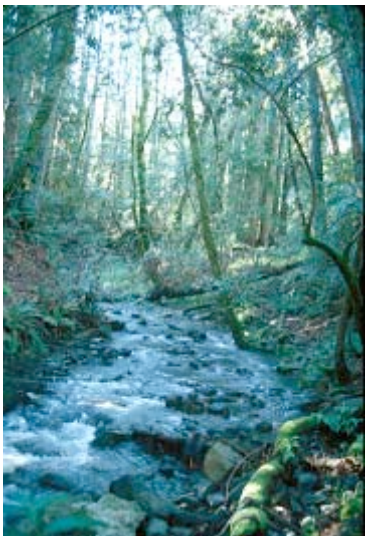
See Section 5.2 of the Resources Directory for ***seeding*** and ***mulch*** specifications.

Riparian Buffer

Riparian areas are located immediately adjacent to creeks. Unlike ***filter strip***s that are primarily grassed areas, ***riparian buffers*** have a dense mix of grasses, trees, and shrubs. These buffers enhance water quality, provide wildlife habitat, and have aesthetic value. Benefits of a buffer include:

- Dense grasses to trap sediment, promote infiltration, and slow runoff flows.

[12] USDA, NRCS - California, Field Office Technical Guide, Filter Strip. July 2000.



A **riparian buffer** *has a mix of trees, shrubs and grasses and is located adjacent to and upslope from creeks. The riparian buffer reduces excess amounts of sediment, organic material, nutrients, pesticides and other pollutants in surface runoff and reduces excess nutrients and other chemicals in shallow ground water flow. The buffer also creates riparian habitat and corridors for wildlife, as well as shade to lower water temperature to improve habitat for fish and other aquatic organisms.*

- Grasses, shrubs, and trees to utilize excess nutrients.
- Trees and shrubs help stabilize streambanks and create a shade canopy to cool water for aquatic life, reduce floodwater velocity and erosive power, and trap debris during floods. A diverse mix of grasses, shrubs, and trees that provide wildlife habitat for a wide range of mammals, reptiles, amphibians, birds, and invertebrates species. Connected stretches of buffers become wildlife corridors.
- A visual screen that also acts as a windbreak and helps capture dust.

Many riparian areas in the San Francisco Bay Area have been cleared of vegetation, or creek channels have been lined with concrete. This section outlines steps to enhance your existing ***riparian buffer*** or to restore a degraded buffer.

1. **Evaluate the existing riparian area to identify any repairs** (such as an eroding streambank or bare areas that need replanting) and management constraints (such as the need for livestock control ***fencing***, ***stream crossing***, and/or an alternative water source).
2. **Determine the minimum buffer width.** The width may vary a great deal depending on site conditions, vegetation, soil type, and landowner objectives. Generally, the wider the buffer, the greater the overall level of benefit. Although a narrow buffer provides more benefits than no buffer at all, wildlife habitat benefits will be reduced. Narrow buffers require careful consideration of slope and selection of vegetation to insure effectiveness. Greater width may be required for shrub and tree vegetation, on steeper slopes, or where sediment loads are particularly high. Some counties require setbacks from creeks.
3. **Consider slope when determining infiltration benefits.** Buffers with a gentle slope and even surface will allow water to flow slowly through the buffer in a thin layer as “sheet flow.” These buffers will have more infiltration than buffers in steeper areas where water flow is concentrated or even flows in tiny channels (rills). Riparian areas should not be graded to change the slope. Grading within riparian areas can require a permit from the California Department of Fish and Game and other agencies.

4. **Select appropriate vegetation.** The mix of grasses, forbs, shrubs, and trees will be dependent upon the benefits you want. Select native plant species to benefit wildlife. If flood control is a prime concern, plant a greater proportion of the buffer width to flood-tolerant trees and shrubs. If supplemental water is not available, choose plants that can survive the first few years without irrigation (such as grasses and willows). The following table lists vegetation types and benefits.

Table 4: Vegetation Type and Riparian Buffer Benefits[13]

Benefit	Grasses	Shrubs	Trees
Filter sediment	High	Low	Low
Utilize nutrients, microbes bound with sediment	High	Low	Low
Utilize nutrients, soluble (in water)	Medium	Low	High
Stabilize bank erosion	Low	High	High
Flood protection	Low	Medium	High
Habitat (range/pasture/wildlife)	High	Medium	Low
Visual diversity	Low	Medium	High

[13] From "How to Design a Riparian Buffer for Agricultural Land," *AgroForestry Notes* 4. 1997. M. Dosskey, D. Schultz, T. Isenhart. Iowa State University Department of Forestry.

Common native riparian trees in the San Francisco Bay Area can include willows, alders, box elder, California bay, Oregon ash, valley oak, coast live oak, black oak, Oregon oak, coast redwood, California buckeye, and big leaf maple. Common riparian shrubs can include California blackberry, elderberry, California hazelnut, coffeeberry, dogwood, ninebark, salmonberry, snowberry, spicebush, thimbleberry, twinberry, toyon, western azalea, and willow. Check with your local Resource Conservation District or native plant nursery for specific species that will thrive in your area.

5. **Develop an installation and maintenance plan.** An installation and maintenance plan is necessary to obtain successful buffer establishment and long-term benefits.

Installation Tips

- Use local knowledge to select the best plant species and spacing for each situation. Emphasize native species yielding quick establishment and good growth on the site. Contact your local RCD, UC Cooperative Extension, local chapter of the California Native Plant Society, or a seed supplier for planting ideas. See Section 5.1 of the Resources Directory for contact information.
- Install livestock control ***fencing*** before planting. Fencing should be set back from the creek to allow the creek to meander naturally.
- Conduct planting and repair work at the appropriate time of year. Grading should occur in the dry season and usually must be completed by October 15. ***Seeding*** and ***mulching*** should occur by mid-October, ***willow sprigging*** should

take place in November or early December when the plants are dormant, and container grown trees and shrubs should be planted between November and February. Planting should occur after the first storms and before soil is saturated during the winter.

- Irrigate and ***mulch*** to enhance tree and shrub survival. A temporary drip irrigation system (for the critical first three years) will help ensure plant success. Thoroughly composted manure makes good mulch.
- Incorporate existing trees and perennial vegetation into the buffer. Be sure not to plant inside the drip line of mature trees.
- Consider removing non-native exotic species that can crowd out existing and new native vegetation. Invasive non-native species to watch include giant reed (*Arundo donax*); periwinkle (*Vinca major*); Scotch, French, and Spanish broom; Himalayan blackberry; tree-of-heaven; bamboo; pampas grass; German and English ivy; acacia; and ice plant.
- Obtain required permits for grading and certain repairs. See Sections 5.4 and 5.5 of the Resources Directory for more information.

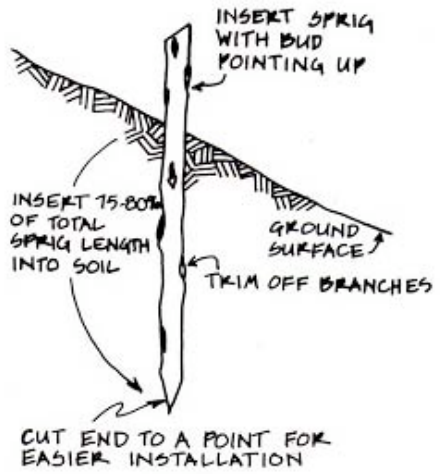
Maintenance Tips

- Control weeds by mowing and ***mulching*** until trees and shrubs are large enough to compete on their own. This is typically required for the first two to three years after planting.
- Protect tree and shrub plantings from wildlife, such as deer, rabbits and mice, with short collars of plastic protective tubing, “gopher baskets,” wire cages, or similar forms of protection.
- Check the irrigation system periodically to make sure it is functioning properly.
- Control livestock ***grazing*** of the buffer area. Once the vegetation is established, you may want to initiate a limited ***grazing*** regime in the buffer. The best time to graze is in the spring when the rains have subsided and the ground is firm.
- Replant areas where plants do not “take.”
- Periodically mow grasses to help maintain vigorous plant growth and promote additional nutrient uptake.
- Do not apply fertilizers or manure, and limit pesticides and herbicides in the buffer zone.

6. **Develop alternative water sources for horses.** If horses are excluded from the creek, they will need another source of drinking water. Horses consume approximately 8-12 gallons of water per day. Alternative water options include ***spring development*** with buried ***pipelines,*** and ***troughs,*** or extending existing water systems. You may also need a ***storage tank***.

Willow Sprigging

Willows are an effective and inexpensive way to armor creek banks and gullies and to provide important wildlife habitat. Prune and shape willows to keep them from invading the creek channel and potentially causing flooding and bank erosion problems. Allow trees to grow tall to help shade out the lower growing vegetation.



Install **willow cuttings** *to armor creek banks and gullies in areas with plenty of sunlight. Cuttings should be 3/4 inch in diameter and planted at least two-thirds into the ground. Plant cuttings low enough on the bank where they will receive adequate moisture in the summer. Angle cuttings downstream so they will "go with the flow" of water. Timing is crucial—make sure cuttings are planted from November through January.*

Revegetating with willows is the easiest way to establish woody vegetation on a denuded creek bank. Adequate year-round water and sun are keys for willow establishment and survival. Even if a creek doesn't have year-round, above-ground flows, the ground water may be near enough to the surface to support willows.

Willows can be planted from dormant cuttings or "sprigs" following these steps:

1. Cut willows in the fall as soon as the leaves have dropped, and the ground is soft and wet. It is critical to plant willows as early as possible (November through January, or earlier with irrigation). This gives them a chance to develop good root systems before they sprout leaves in the spring. Planting too late is the most common cause of failure.
2. Willow cuttings should be at least 3/4-inch in diameter. Bigger is better. Cuttings should be at least 14 inches long.
3. Plant dormant cuttings by pushing the cut end into soft soil, or make a hole with a sharp stick or pick. If you make a hole, be sure to compress soil tightly around the cuttings. They may need to be pounded in with a hammer. To give plenty of area for root growth, bury at least two-thirds of the length of the cutting. Angle sprigs slightly downstream to prevent them from being undermined by storm flows.
4. Plant willows low enough on the bank to ensure adequate soil moisture during the summer. Even if streams or gullies have year-round water, willows that are planted too high are likely to dry out and die. Cuttings should not need water if they are planted in an appropriate area.

More on Willow Planting

How to Plant Willows … for Riparian Rehabilitation, is available at:
http://plant-materials.nrcs.usda.gov/technical/publications/riparian.html
Under Technical Notes, Select: Technical Note 23: How to plant willows and cottonwoods for riparian rehabilitation.

Constructed Wetland

Constructed wetlands "treat" waste from confined animal operations, surface runoff, and manure storage area leachate. Approximately two feet deep, these wetlands have water-loving plants that are capable of removing large amounts of nutrients from the water. Retention time and release rate will depend upon the size of the wetland and period needed to extract the nutrients.

Constructed wetlands must be professionally designed to handle the volume of waste or stormwater runoff, particularly the "first flush" that contains a high concentration of pollutants. Careful construction is required to ensure that the ground is properly prepared and permits may be needed.

Waste Pond

Horse manure is best handled as a solid.[14] If a ***waste pond*** is required by local regulation, then this overview of ***waste ponds*** can help in the planning stages. A waste storage pond collects runoff of polluted water and gives the manager control over the scheduling and timing of waste distribution over the land. Adequate storage gives flexibility to schedule ***manure application*** when spreading operations do not interfere with other necessary tasks, when weather and field conditions are suitable, and when pasture or crops can best use the nutrients in the waste.

Waste ponds *can be used to store polluted runoff. Waste from the pond is typically irrigated or spread on land. Pond maintenance will ensure proper functioning. A professional can assist with pond sizing. Trees and shrubs have been planted around this waste pond to screen it from the road.*

Pond location is important. It should be convenient to the operation with suitable soils that when properly compacted, will be impervious to seepage into the ground water. Various materials are available for ***pond lining***, such as compacted clay or geotextile fabric.

Utilization of the contents in the ***waste pond*** is commonly done by land application. This includes selecting the fields, scheduling ***manure application,*** designing the distribution system, and selecting necessary equipment. It also includes determining application rates and volumes, value of recycled products, and installation and management costs associated with the utilization process.

Pond sizing needs to done by a professional to take into consideration the required storage volume, storage period, and the type, estimated size, location, and installation cost of the pond. Permits are usually required for ***waste pond*** construction; contact local and state officials (see Sections 5.4 and 5.5 of the Resources Directory). Maintenance and protection of the pond are needed to ensure its longevity.

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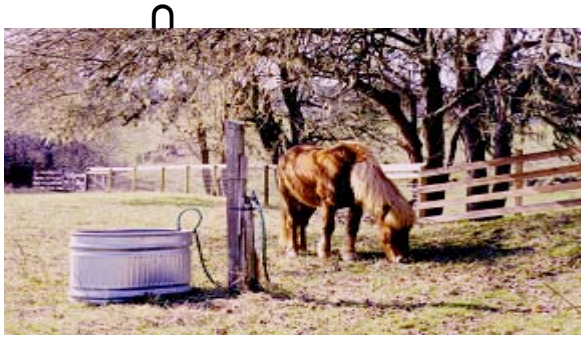
[14] *Feedlots Preliminary Data Summary.* December 31, 1998. EPA. Available at <www.epa.gov/ostwater/guide/feedlots/execsumm.pdf>



Chapter 5

Resources Directory

This Resources Directory provides technical background and contact information. Topics include:

- **Section 5.1:** Technical Assistance
- **Section 5.2:** Seeding Recommendations for Horse Facilities in the San Francisco Bay Area
- **Section 5.3:** Winterization Checklist
- **Section 5.4:** Regulations and Permits
- **Section 5.5:** Threatened and Endangered Species
- **Section 5.6:** Photographic Monitoring
- **Section 5.7:** Water Quality Monitoring
- **Section 5.8:** Guidelines for Managing Residual Dry Matter
- **Section 5.9:** Alternatives to Pesticides
- **Section 5.10:** Improving Songbird Habitat on your Horse Ranch
- **Section 5.11:** Helpful Publications and Resources

5.1 Technical Assistance

Technical assistance is available from the following organizations. Advice is offered as a free service from the RCDs, NRCS, and UC Cooperative Extension.

Resource Conservation Districts

Resource Conservation Districts (RCDs) have been helping landowners to apply conservation measures on Bay Area farms and ranches since the 1930s and can help equine facility landowners in a similar way. RCDs provide information, technical assistance, and implementation of natural resource conservation projects. RCDs work in partnership with the USDA Natural Resources Conservation Service. They are non-regulatory special districts governed by a local volunteer board of directors.

Check with your local RCD to learn about specific services provided in your area. RCDs offer workshops and courses for landowners, as well as one-on-one meetings. In the San Francisco Bay Area, nine RCDs are also part of the Council of Bay Area RCDs and work together on shared natural resource issues. The following RCDs participated in the Equine Facilities Assistance Program. To find other RCDs, visit http://www.carcd.org/

Marin County RCD
P.O. Box 1146
Point Reyes Station, CA 94956
Phone: (415) 663-1170
Fax: (415) 663-0421
http://www.sonomamarinrcds.org/

Southern Sonoma County RCD
1301 Redwood Way, Suite 170
Petaluma, CA 94954
Phone: (707) 794-1242, ext 3
Fax: (707) 794-7902
http://www.sonomamarinrcds.org/

Contra Costa RCD
5552 Clayton Road
Concord, CA 94521
Phone: (925) 672-6522
Fax: (925) 672-8064

Alameda County RCD
1996 Holmes Street
Livermore, CA 94550
Phone: (925) 371-0154
Fax: (925) 371-0155
http://www.baysavers.org/

San Mateo County RCD
625 Miramontes Street, Suite 206
Half Moon Bay, CA 94019
Phone: (650) 726-4660
Fax: (650) 726-0494

USDA Natural Resources Conservation Service

The Natural Resources Conservation Service (NRCS) is an agency of the US Department of Agriculture that provides technical assistance to land users and communities. The NRCS, in cooperation with Resource Conservation Districts, provides free technical information and assistance upon request that address concerns about natural resources such as animal waste management, rangeland, cropland, and watershed management. NRCS also provides free soil survey information, as well as information about local cost-share programs. NRCS offices for the counties participating in the Equine Facilities Assistance Program are listed below. To find offices in other areas, visit http://www.ca.nrcs.usda.gov/

Alameda County
3585 Greenville Road, Suite 2
Livermore, CA 94550-6707
Phone: (925) 371-0154
FAX: (925) 371-0155

Contra Costa County
5552 Clayton Road
Concord, CA 94521
Phone: (925) 672-4577, ext 3
FAX: (925) 672-8064

Marin and Sonoma Counties
1301 Redwood Way, Suite 170
Petaluma, CA 94954
Phone: (707) 794-1242, ext 3
FAX: (707) 794-7902

University of California Cooperative Extension

The University of California Cooperative Extension (UCCE) is part of a state-wide system of specialists and county-based farm advisors who work to bring the University's research-based information to Californians. UCCE's many teaching tools include workshops, demonstrations, field days, meetings, conferences, video programs, newsletters, and manuals. Several publications relate directly to horse keeping and are available from University of California Agriculture and Natural Resources Communication Services, (800) 994-8849. Contact your local office for information about workshops and assistance. Listed below are counties participating in the Equine Facilities Assistance Program. To find a local office in other areas, visit http://vcanr.org/ce.cfm

Marin County Cooperative Extension
1682 Novato Boulevard, Suite 150B
Novato, CA 94947
Phone: (415) 499-4204
Fax: (415) 499-4209
Email: cemarin@ucdavis.edu
http://cemarin.ucdavis.edu

Alameda County Cooperative Extension
1131 Harbor Bay Parkway, Suite 131
Alameda, CA 94502
Phone: (510) 567-6812
Fax: (510) 567-6813
Email: cealameda@ucdavis.edu
http://cealameda.ucdavis.edu

Sonoma County Cooperative Extension
133 Aviation Blvd, Suite 109
Santa Rosa, CA 95403
Phone: (707) 565-2621
Fax: (707) 565-2623
Email: cesonoma@ucdavis.edu
http://cesonoma.ucdavis.edu/

San Mateo County Cooperative Extension
625 Miramontes Street, Suite 200
Half Moon Bay, CA 94019
Phone: (650) 726-9059
Email: cesanmateo@ucdavis.edu
http://cesanmateo.ucdavis.edu/

Contra Costa County Cooperative Extension
75 Santa Barbara Road, 2nd Floor
Pleasant Hill, CA 94523-4488
Phone: (925) 646-6540
Email: cecontracosta@ucdavis.edu
http://cecontracosta.ucdavis.edu/

Private Consultants

Private consultants, such as engineers, construction contractors, and certified erosion control specialists, can provide a variety of services related to water quality management including planning, design, and construction of conservation measures. Lists of local consultants may be available from the local RCD or NRCS office.

Seed Suppliers and Native Plant Information

Some seed supply businesses and nurseries have agronomists and other specialists available to help you select the best seeds to suit your local conditions and needs. For native plant information try the following resources or visit the California Native Plant Society at http://www.cnps.org/

Harmony Farm Supply
3244 Gravenstein Highway North
Sebastopol, CA 95472
Phone: (707) 823-9125
Fax: (707) 823-1734

LeBallister's Seed
1250 Sebastopol Road
Santa Rosa, CA 95407
Phone: (707) 526-6733
Fax: (707) 542-9740

Native Revival Nursery
8022 Soquel Drive
Aptos, CA 95003
Phone: (831) 684-1811

Central Coast Wilds
114 Liberty St.
Santa Cruz, CA 95060
Phone (831) 459-0656
Fax (831) 457-1606

Larner Seeds
235 Grove St./P.O. Box 407
Bolinas, CA 94924
Phone: (415) 868-9407
Fax: (415) 868-2592

Elkhorn Native Plant Nursery
Struve Road (P.O. Box 270)
Moss Landing, CA 95039
Phone: (831) 763-1207
Fax: (831) 763-1659

Clyde Robin Seed Company
P.O. Box 2366
Castro Valley, CA 994546
Phone: (510) 785-0425
Fax: (510) 785-6463

S&S Seeds
P.O. Box 1275
Carpinteria, CA 93014-1275
Phone (805) 684-0436
Fax: (805) 684-2798

Pacific Coast Seed
6144-A Industrial Way
Livermore, CA 94550
Phone: (925) 373-4417
Fax: (925) 373-6855

5.2 Seeding Recommendations for Horse Facilities in the San Francisco Bay Area

Conservation Measures

You have evaluated your horse facility and come to the conclusion that excessive soil erosion is coming from a **pasture** or high-use area (**critical area**), such as paddocks, turn-out areas, roads, or a parking lot. Perhaps you need to convey water around a barn through a **grassed waterway**. Or maybe rainwater flows through a manured area, and you want to use a **filter strip** to reduce pollutants in the polluted water. The vegetation planted for these conservation practices will reduce soil erosion, increase infiltration, percolation, and ground water recharge.

These seeding recommendation mixtures are for general dryland (non-irrigated) purposes. Specific recommendations will vary based on site evaluation that would take into account rainfall, length of growing season, soils, etc. Since the San Francisco Bay Area has many micro-climates, your local USDA Natural Resources Conservation Service, UC Cooperative Extension Farm Advisor, or local seed supplier can help with specific suggestions. Different grass species are suitable for different purposes. Perennial grasses are deeper rooted and certain species are sod-forming (rather than bunchgrasses), which protects the soil from excessive erosion. Annual grasses provide a quick cover and reseed themselves each year.

Filter Strip

A grass filter strip is designed to treat runoff situated between high-use areas and environmentally sensitive areas, such as a creek, seasonal drainage or pond. The filter strip will reduce sediment, sediment adsorbed pollutant loading in runoff, and dissolved contaminant loading in runoff. Also, a filter strip will restore, create or enhance habitat for wildlife and beneficial insects.

A filter strip must be designed so overland flow (runoff) entering it must be primarily sheet flow. Concentrated flow must be dispersed into sheet flow, before entering the filter strip. The minimum width is 20 feet to reduce sediment. Additionally, to reduce dissolved pollutants in runoff, the minimum width is 30 feet. Local site criteria may require filter strip widths of up to 100 feet. *(Reference: USDA NRCS Field Office Technical Guide, Filter Strip.)*

Grassed Waterway

Imagine a gentle flat-bottomed ditch, fully clothed in grass, with gentle side slopes. This simple design is a grassed waterway—a designed channel that is mechanically shaped or graded with a bulldozer, and seeded with grass for the stable conveyance of runoff. The grassed waterway will convey runoff without causing erosion or flooding. As with all engineered conveyances, the grassed waterway must be designed to withstand the velocity of water anticipated. The site must be assessed to see if the waterway needs to be lined for higher water velocities with erosion control matting, rock or concrete. Grassed waterways

Seeding Recommendations

Note: Species in bold are native to California

Seed Mixture	Plant Characteristics	Lbs/Acre	Filter Strip	Grassed Waterway	Critical Area	Pasture
1. Berber orchardgrass[1]	Perennial grass	16	X	X		
2. **Creeping wildrye**[1, 2]	Perennial grass	30[3]	X	X		
3. 'Blando' brome	Annual grass	18	X	X	X	
'Zorro' annual fescue	Annual grass	10				
Rose clover[4]	Annual legume	9				
California poppy[5]	Annual wildflower	1				
Arroyo lupine[5, 6, 7]	Annual wildflower	1				
Crimson clover[4]	Annual legume	1				
4. **California brome**[1]	Perennial grass	25	X		X	
Blue wildrye[1]	Perennial grass	18				
California poppy[5]	Annual wildflower	1				
Arroyo lupine[5, 6, 7]	Annual wildflower	1				
5. Blando brome	Annual grass	25			X	
Annual ryegrass	Annual grass	24				
6. 'Berber' orchardgrass[1]	Perennial grass	4				X
Tetraploid perennial ryegrass[1]	Perennial grass	6				
Subclover[4, 7]	Annual legume	6				
Rose clover[4]	Annual legume	4				
7. 'Blando' brome	Annual grass	6				X
Rose clover[4]	Annual legume	6				
Subclover[4, 8]	Annual legume	6				

[1] Mulch must be used to provide initial erosion control when establishing perennials.
[2] Also known as beardless wildrye.
[3] Or use plugs at 1 foot x 1 foot spacing.
[4] Also see "legume inoculation" section below.
[5] Optional, use for color.
[6] *Lupinus succulentus*, also known as hollowleaf annual lupine.
[7] Lupine may be toxic to horses. Use only where horses do not graze.
[8] Use locally adapted varieties recommended by UC Cooperative Extension.

perform most dependably in areas where dense stands of sod-forming grass will permit anticipated water velocities.

The most critical time in successfully installing a grassed waterway is when vegetation is being established. Special protection such as mulch or an erosion control blanket is warranted at this critical period. Supplemental irrigation is optimal. The vegetation should be well established before large flows are permitted in the channel.

Critical Area

Critical erosion areas such as road cuts and fills, roadbeds, and gullied areas need to be stabilized to reduce damage from runoff. Seeding is used where vegetation is difficult to establish.

Plants should have the ability to provide adequate ground cover, canopy cover and root mass for erosion protection. High seeding rates are needed to insure adequate vegetative cover because these sites have been severely eroded or disturbed, have low fertility, and few resident seeds.

Pasture

It is time to reseed a pasture when horses excessively use one area of pasture, or selectively graze desirable plants and leave the less desired plants. Nearly all pastures have areas where horses concentrate such as around water and feed areas. Under continuous use, these are always overgrazed.

Installation Criteria

Timing: Plant before the rainy season, October 15th of the year.

Seeding rate: Seeding rates are for 100% Pure Live Seed (PLS), and are broadcast (by hand or broadcast seeder) rates. Seed bag "tags" tell the percent purity for PLS and germination rate. If seed bag tag states less than 100% PLS, increase the amount of seed in proportion to the percentage needed (germination x purity). Time since the date of seed test on the tag should not exceed 9 months.

Seedbed preparation: The area to be planted must be weed free and have a firm seedbed which has been previously roughened by disking, harrowing, or otherwise worked to a depth of 2 to 4 inches, except when planting no-till. No implement should be used that would create an excessive amount of downward movement of soil on sloping areas. Weeds and other debris that would interfere with seeding or maintenance should be removed.

Legume Inoculation: All legumes (clovers) should be "inoculated" before planting with a pure culture of nitrogen-fixing bacteria and prepared specifically for that plant species. This is done immediately prior to planting. The seeding rate does not include the weight of inoculant and seed coating.

Why: All legumes, including clover, have the ability (in cooperation with legume bacteria) to draw nitrogen from the air and store it in the small nodules that form on the roots. Studies have shown an increase in forage production and nitrogen fixation when seed is properly inoculated. On poorer soils, the clover seed may be a complete failure if not properly inoculated. The bacteria are helpful to young plants as roots begin to develop, increasing their chance to grow successfully.

How: Put seed on canvas, in tub or other container. Mix the inoculating culture with the seed and stir until the seed is well covered. Mix with grass seed selected. Prevent from drying out by sun or wind. Plant immediately.

Mulch: A straw mulch cover should be uniformly distributed over the seeded area within 48 hours following the seeding. Straw mulch should be applied at a rate of

two tons per acre (or one 74-pound bale per 800 square feet, at a uniform depth of 2 to 3 inches). Straw is the preferred mulch and needs to be anchored in place. Hand punching with a shovel or a square-end spade can work for small areas, whereby straw stands perpendicular to the slope and is embedded at least 4 inches into the slope, and punched about 12 inches apart. For larger areas, anchoring with rollers, crimpers, or disks can be used on slopes up to 3-to-1. Use of rice straw will minimize weed seeds, since the type of weeds that grow in the aquatic environment with rice will not survive on dry land sites. Use of wheat straw will result in less volunteer grain compared to barley straw. When using straw grown in the same county, use clean straw to minimize the spread of noxious weeds. Bales of native grass with seed are also a good option.

Irrigation: A sprinkler system is optimal for establishment and water should be applied during the establishment period. Maintain adequate moisture in the upper six inches of soil during the first four weeks, and then in the upper 12 inches thereafter until the rainy season.

Maintenance: Mowing should be performed for control of noxious weeds or for a firebreak. Periodic mowing can be performed to reduce rank growth and maintain desired species populations. Herbicides should only be used to control noxious weed species.

Limit traffic and do not use as a roadway. Limit livestock use. For filter strips and grassed waterways, eradicate or remove all burrowing rodents and immediately repair any damage caused by their activity.

Written by Lisa Woo Shanks and Dennis Moore
USDA Natural Resources Conservation Service

5.3 Winterization Checklist

Preparing for the rainy season while the weather is still nice can save a lot of time in the long run. Take time to inspect your facility before the rains start. Write and post a "winterization" checklist in your barn to help set priorities, organize work, and take action. It is important to check many of these areas throughout the winter, particularly during and after major storms. A sample list below covers management strategies discussed in this guide.

Buildings

- ❑ Inspect, repair, and remove debris from ***gutters*** and ***downspouts***. Make sure ***gutters***, ***downspouts*** and pipelines are connected.
- ❑ Clear debris from ***diversions***, ***pipe inlets***, grates, ***culvert***s, and ***trash racks***.
- ❑ Make sure ***energy dissipaters*** (such as rock) are placed at outlets.

High-Use Areas

- ❑ Replenish footing in high-use areas.
- ❑ Make sure kickboards are in place to help keep footing material in place.
- ❑ Clear debris from ***diversions*** and other drainage structures.

Manure Management

- ❑ Scrupulously clean out ***paddocks***.
- ❑ Remove all horse waste from ***manure storage areas*** by the fall.
- ❑ Cover ***manure storage areas*** and provide runoff controls. Make sure "clean" water is diverted from manured areas.
- ❑ Apply manure to pastures in early fall, and in spring when grasses are actively growing. Do not spread manure near creeks.

Pasture Management and Filter Strips

- ❑ Re-seed pastures and grass ***filter strips*** by October 15, if needed. Remove weeds regularly.
- ❑ Mow, maintain and/or reseed grass ***filter strips*** downslope of high-use areas.
- ❑ In the fall, check ***Residual Dry Matter*** (RDM) levels in pastures. (See Section 5.8 of the Resources Directory.)

Roads and Trails

- ❑ Clean out ***ditches***, ***culvert*** inlets, and ***trash racks***.
- ❑ Make sure ***waterbars*** and ***energy dissipaters*** are in place and functional.
- ❑ Check roads and trails after storms for any emergency repairs.
- ❑ Close roads and trails not essential for winter traffic. ***Seed*** and ***mulch*** seldom used roads or trails by October 15.

5.4 Regulations and Permits

Regulation Overview

Many federal, state, and local laws pertain to water pollution and its adverse effects on drinking water supplies, recreation, and aquatic life.

The federal Water Pollution Control Act of 1972, commonly called the **Clean Water Act** (CWA), is the nation's principal protection statute. The CWA delegates the process of setting water quality standards to the states, under the supervision of the Environmental Protection Agency. In 1987, Congress amended the Clean Water Act to include establishment of the **Non-Point Source Pollution Management Program,** requiring each state to develop a program to address this problem.

Division 7 of the California Water Code, commonly referred to as the **Porter-Cologne Water Quality Control Act**, covers water quality protection and management in California. Porter-Cologne designates the State Water Resources Control Board (SWRCB) as the state water pollution control agency. Nine Regional Water Quality Control Boards (RWQCB) establish and enforce water quality objectives to protect beneficial uses of water bodies.

Broadly protecting water quality, California's **Fish and Game Code Section 5650** declares it unlawful to deposit in, permit to pass into, or place where it can pass into water any substance or material harmful to fish, plant life, or bird life. This regulation applies as equally to horse owners as to an oil refinery.

Article 1 of the California Health and Safety Code's **California Safe Drinking Water Act** declares that every citizen of California has the right to pure and safe drinking water. In particular, Section 116995 covers pollution of drinking water by domestic animals.

Penalties for violations can include criminal misdemeanor charges, fines, abatement orders, and civil penalties, as well as the cost of legal fees, time and poor community relations. Enforcement agencies often lack the funds and personnel to search for violations, but they are required to respond to complaints. An agency's response to a complaint may include a site visit to assess the magnitude of the problem. A local or county agency may recommend and agree to specific mitigation measures. The California Department of Fish and Game and the RWQCB may recommend temporary emergency measures but refer violators to USDA Natural Resources Conservation Service or private consultants or engineers for permanent conservation measures.

Permit Overview

Federal, state, and local water quality or other environmental laws may apply to your project to develop, expand, or renovate a horse facility, or even to control streambank erosion. If you are working in or near streams, you likely need a permit. Consultants can help you navigate the permit maze. Here is a list of agencies and their regulatory requirements that may be applicable to horse keeping facilities. Also see Section 5.5 for threatened and endangered species.

US Army Corps of Engineers

The Corps of Engineers has regulatory authority under Section 404 of the federal Clean Water Act and Section 10 of the Rivers and Harbors Act. A 404 permit is required for work involving the placement of fill in any "waters of the United States" which includes wetlands as well as perennial, seasonal and ephemeral creeks. A Section 10 permit is required for projects affecting "navigable waters." Corps jurisdiction extends up to the ordinary high water line for non-tidal waters and up the high tide line (for dredge and fill) or mean high water line (for work or structures) in tidal waters. Most landowner projects should fall under the Section 404 Nationwide Permit Program. Pre- or post-project notification may be required. There is no filing fee and permit processing can take up to one year.

- Contact the San Francisco District Regulatory Branch at (415) 977-8462 or http://www.spn.usace.army.mil/regulatory/

California Department of Fish and Game

The California Department of Fish and Game (DFG) requires a Stream Alteration Agreement for projects that occur in or near creeks or streambanks. This permit is necessary for any work that will divert or obstruct the natural flow of water, change the bed, channel, or bank of any stream, or use any material from a streambed. DFG will review the application for compliance with the California Environmental Quality Act (CEQA). The application is $132 and turn-around time can be several months or longer. For permit information or assistance from DFG, contact a regional office or http://www.dfg.ca.gov/1600

- Central Coast Regional office is located in Yountville: (707) 944-5500
- Marine Regional Office is located in Monterey: (831) 649-2870
- A Marine Region field office is located in Menlo Park: (650) 688-6340

Regional Water Quality Control Board

For activities requiring a permit from the US Army Corps of Engineers, the RWQCB must issue a 401 Water Quality certification to ensure that the proposed activity will not violate State water quality standards. A filing fee is required and can be $500 or greater.

- For creeks and tributaries draining into San Francisco Bay, contact:
  San Francisco Bay Regional Water Quality Control Board
  (510) 622-2300 or http://www.swrcb.ca.gov/rwqcb2

- For creeks and tributaries that drain to the ocean in Sonoma County and north, contact:
  North Coast Regional Water Quality Control Board
  (707) 576-2220 or http://www.swrcb.ca.gov/rwqcb1
- For creeks and tributaries draining to the Pacific Ocean south of San Mateo County, contact:
  Central Coast Regional Water Quality Control Board
  (805) 549-3147 or http://www.swrcb.ca.gov/rwqcb3

California Coastal Commission

Development or activity in the coastal zone requires a Coastal Development permit. The coastal zone extends inland from approximately 500 yards in developed urban areas to five miles in undeveloped areas. "Development" includes the construction or alteration of any structure, grading, quarrying of rock, change in density or intensity of land use (including land divisions), and the removal of major vegetation. Contact your local county coastal program to see if you need a permit from them or the California Coastal Commission.

- Contact the Coastal Commission directly at (415) 904-5200 or http://www.coastal.ca.gov/

Bay Conservation and Development Commission (BCDC)

BCDC requires a permit for work within 100 feet of waters of San Francisco Bay or for levee maintenance.

- Contact BCDC at (415) 557-8778 or http://www.bcdc.ca.gov/

Joint Aquatic Resources Permit Application (JARPA)

The purpose of JARPA is **one** permit application form that consolidates federal, state and local permits and simplifies the permit process for applicants proposing construction, fill placement, and other development activities in or near aquatic environments and wetlands. The region covered by JARPA is the San Francisco Bay Area only.

The objectives of JARPA are to develop a single form to be submitted by applicants to the necessary permitting agencies; reduce paperwork and processing time for applicants; reduce violations by improving applicant knowledge of permit requirements; and reduce the number of permit revisions and delays due to permit sequencing.

In addition, an excellent "Guide to Creek and Wetland Project Permitting" from San Mateo County is available. Visit the website at:
http://www.abag.ca.gov/bayarea/sfep/projects/JARPA/JARPA.html

County and City Ordinances

Local cities and counties generally have regulations regarding grading, setbacks, zoning, building, horse density, discharge restrictions, stormwater runoff, odors, pests, and nuisances. Contact your city and county governments for more information.

California Environmental Quality Act (CEQA) Review

Landowners, as well as state and local governments must comply with the California Environmental Quality Act. The main purpose of a CEQA review is to identify and prevent significant potential environmental impacts. CEQA requires the preparation of an initial study and then a Negative Declaration or an Environmental Impact Report.

Some agencies, such as the California Department of Fish and Game, will review permit applications for CEQA compliance. For large projects, cities and counties may require a CEQA review. For more information, contact your city or county planning departments or the California Department of Fish and Game.

Permit Tips

These tips can help you with the often complex permit process.

1. **Find out if your project is regulated or requires a permit.** If you go ahead without the proper permits or without following permit approval conditions, it will very likely cost you time, money, and goodwill.

2. **Carefully select and design your site** to eliminate or reduce environmental impacts.

3. **Consult early with permitting and regulatory agencies** so their concerns can be addressed. Your local planning department may be able to give you a good idea of the permitting process.

4. **Have written descriptions and site plans available.**

5. **Learn the rules.** Study the regulations of those agencies that must approve your project.

6. **Pay attention to details.** Follow all the rules. Respond promptly to requests for information. Be on time for meetings. Do not cut corners.

7. **Be flexible.** While protecting water quality and creeks is a prime responsibility of agencies, they may be willing to consider alternative project designs that still meet your needs.

8. **Get everything in writing** to help prevent misunderstandings.

9. **Plan time for permitting and be patient, as well as persistent.**

5.5 Threatened and Endangered Species

The presence of, or habitat for threatened or endangered species can influence horse keeping management decisions. It is important not to harm any "listed"species such as the California red-legged frog, Alameda whipsnake, or salmon and steelhead. Some conservation measures may provide habitat benefits.

The federal Endangered Species Act of 1973 prohibits any action that could harm, harass, or further endanger a federally designated, endangered or threatened plant or animal species or the associated critical habitat. Similarly, the California Endangered Species Act of 1984 recognizes the importance of endangered and threatened species and their habitats.

The purpose of the federal Endangered Species Act is to preserve species so depleted in numbers that they are threatened with extinction. A species may be classified for protection as "endangered" when it is in danger of extinction within the foreseeable future throughout all or a significant portion of its range. A "threatened" classification is provided for those animals and plants likely to become endangered within the foreseeable future. The Act provides a program for listed species and the ecosystems upon which they depend. The Act also mandates federal agencies to cooperate with state and local agencies to resolve water resource issues relating to endangered species.

Protecting endangered and threatened species and restoring them to a secure status in the wild is the primary objective of the endangered species programs of the US Fish and Wildlife Service and the National Marine Fisheries Service. These federal agencies also cooperate with the California Department of Fish and Game.

To find out if you might have threatened or endangered species or their habitat on your property, contact the California Department of Fish and Game. A continually refined and updated computerized inventory of the locations and condition of the state's rarest plants, animals, and natural communities is available through the Natural Diversity Database at http://www.dfg.ca.gov/whdab/html/cnddb.html

You can order a text report and map of your county, general area or specific property; contact the Information Services staff at (916) 324-3812. It is helpful to know the name of the USGS 7.5' quad map that includes your location. (See Section 1.2, Inventory and map your resources.) Reports vary in cost depending on the number of records involved.

US Fish and Wildlife Service

The US Fish and Wildlife Service (USFWS) has regulatory authority to conserve, protect and restore animals and plants, and their habitat, that are in danger of extinction. If endangered species are affected by activities, the work must be in compliance with USFWS regulations. Information is available on their website: http://endangered.fws.gov/

National Marine Fisheries Service

The National Marine Fisheries Service (NMFS) regulates the recovery of anadromous (ocean-going) species listed under the Endangered Species Act, such as salmon (coho *or silver*, and Chinook *or king*) and steelhead. NMFS is a part of the National Oceanic and Atmospheric Administration (NOAA), and provides expertise in the area of fish passage and fisheries restoration. NMFS identifies issues to protect, conserve and restore habitats vital to self-sustaining populations of salmonids in California. The agency operates under the authority of the Clean Water Act, California water rights, and authorities that influence adequate water for fish, Endangered Species Act, National Environmental Policy Act, and the Fish & Wildlife Coordination Act. For endangered species consultation or assistance to landowners for fisheries restoration efforts, call the National Marine Fisheries Service in Santa Rosa: (707) 575-6050, or visit their website at: http://swr.nmfs.noaa.gov/sro.htm

5.6 Photographic Monitoring

Photographic monitoring is a simple and convenient method for documenting improvements you have made to your horse facility. Photographs can be kept with your ***Conservation Plan***.

Take photographs of specific areas that are addressed in your Conservation Plan to document:

- Before and after conditions to show the short- and long-term effectiveness of conservation measures.
- Changes over time in the condition of natural resources and human-made features.
- Impacts of major events, fires, floods, landslides, etc.
- Sources of pollutants (e.g., manure or chemicals) and how they are transported by stormwater runoff or contained.
- Special management areas (such as creek habitat or oak woodlands).

Take photographs from the same permanent photo points such as a fence post or tree (or create a marker with a wood or steel post). You can return to these exact points at the same time of the year to document changes over time. You may want to take photographs annually or several times per year. For example, you may take photos to correspond with the winter rains (to show runoff patterns) and also during the summer to give a contrasting view. Be sure to record the date of the photograph.

Landscape photographs can show an overview of an area, and close-up photographs can be used to show specific characteristics of an area such as soil surface or plant cover. When taking landscape photographs, always include a permanent identifiable feature in the background such as a building, tree, fence, or rock outcrop. Anticipate possible view obstructions such as tree growth, additions of barns, etc.

For specific details on photographic monitoring, review the *Photographic Monitoring for Equestrian Facilities* fact sheet produced by the Council of Bay Area RCDs. Call your local RCD or the Council of Bay Area RCDs at (707) 794-1242, ext. 121 for a copy.

5.7 Water Quality Monitoring

Testing your surface water will help maintain a healthy environment for horses, fish and aquatic life, and human use. With inexpensive equipment and a little training, horse owners can monitor the quality of water on their property. This section presents an overview of monitoring.[15] For complete information on setting up your own monitoring program and obtaining test kits, contact your local RCD or the Council of Bay Area RCDs for a horse owners monitoring information packet.[16]

Water Quality Variables

The following is a description of the water quality variables and their measurements that are commonly tested by agricultural landowners and regulatory agencies.

Ammonia. Ammonia results from decomposition of manure and other organic debris by microbes, and is toxic to fish and aquatic invertebrates. Total ammonia is composed of two forms: ionized ammonia (NH_4^+), and un-ionized ammonia (NH_3). Of these two forms, the un-ionized NH_3 is far more toxic. The percent of total ammonia in the harmful un-ionized form increases with higher water temperatures and pH values. Un-ionized ammonia can be lethal at concentrations of 0.025 parts per million (ppm.) Higher levels of ammonia are toxic to fish and other organisms. Ammonia is naturally produced by fish and is excreted primarily through their gills. Ammonia excretion is reduced if there are high ammonia levels in surrounding waters, causing high blood ammonia levels in fish. Fish respond to this increase in blood ammonia by reduced feeding that slows metabolic ammonia production. High blood ammonia levels increase a fish's need for oxygen, while at the same time reducing the ability of the fish's blood to transport oxygen. High ammonia levels can damage gills and ultimately kill fish.

Total ammonia can be measured with an electronic ammonia probe or colorimetric kit. Colorimetric kits are inexpensive and relatively accurate. They rely on chemical reactions in which chemicals bind, and then react with ammonia to form a colored product. The intensity of the color then gives a relative indication of the amount of ammonia present.

Conductivity. Conductivity is simply a measure of the capacity of water to transmit an electrical current. Conductivity is useful in detecting pollution from livestock urine due to the high concentration of salts in urine, and the fact that the salts persist much longer than ammonia. High salt concentrations in sur-

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[15] This information was drawn from the *Water Quality Variables and Water Testing for Rural Landowners* fact sheets prepared by the Marin Coastal Watershed Enhancement Project. 1995.

[16] *Simply the Facts on Animal Waste and Water Monitoring*. Fact sheet series. USDA Natural Resources Conservation Service and AmeriCorps. 1995.

rounding waters disrupt the balance of salts in a fish's blood. This causes stress, and for prolonged periods can kill fish. Conductivity is measured in micromhos per centimeter or µmhos/cm.

pH. pH is a measure of the hydrogen ion concentration and ranges in value for 0 to 14. A value of 7 is referred to as neutral, while values below 7 are called acidic, and above 7 are said to be basic or alkaline. The pH of water is influenced by water source, underlying soil, effluent discharges from agricultural, industrial, and urban sources, algae, and microbial activity. The pH of water is important because it influences the amount of total ammonia that is in the most toxic un-ionized (NH_3) form, as well as affecting a variety of chemical reactions and biological functions. High pH values increase ammonia toxicity because a greater percentage of the total ammonia is in the un-ionized form. Electronic meters, small battery operated pH pens, or a litmus paper which changes color according to different pH values can be used to measure pH.

Temperature. Temperature is important because it directly affects animals and also influences the physical characteristics of water and pollutants such as ammonia. Extreme temperatures have harmful effects on animal metabolism, feeding, growth, disease resistance, and reproduction. Cool water contains higher levels of dissolved oxygen than warmer water and has lower levels of toxic un-ionized ammonia. Temperature is measured with electronic and mercury thermometers. The optimum water temperature for steelhead is approximately 55-60° F, well below the summer temperature of many local streams.

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

Water flow rate. It is important to note water flow rate when monitoring because it influences the concentration of pollutants. Knowing whether water quality problems were detected following a rainstorm when flows are high, versus a drier period, can help to identify the source and magnitude of the problem. If pollutants are found during high flows when they are apt to be diluted, it is possible that pollutants will be more concentrated when flows are lower. Problems that are detected at low flows, when runoff from surrounding areas is also low, probably come from a source near to the stream. Water flow can be estimated as low, medium, or high. A more accurate determination can be made by calculating the volume of a given stream area and then measuring the flow rate through this pre-measured area.

Sediment. Excessive sediment from erosion can fill in gravel beds used by salmon and steelhead for spawning. This can make the beds unsuitable for spawning or smother developing eggs in the gravel. Sediment can also fill in deep pools that remain cool in the summer and provide habitat for young fish. Sediment can be measured by allowing a water sample to stand and measuring the amount of sediment that settles. Imhoff sediment cones or tall glass jars can be used for this purpose.

Where and When to Test

Testing at your upstream and downstream property boundaries (where water enters and leaves your property) will tell you how clean the water flowing into your property is, and whether or not conditions on your property are contributing to water quality problems. If water is more polluted at the downstream boundary, test water upstream on your property to find pollution sources. Check for problems near areas of high-use, manure storage, field applications of manure, and ***horse wash areas***. Also check tributary drainages to see if problems are coming from upslope areas. By actively monitoring the water quality conditions on the property, the monitoring results could be a helpful tool in your defense if a dispute arises.

Tests should be done at least monthly throughout the year (in areas with year round water) and more often in the rainy season. Because runoff from early rains can have high concentrations of animal waste that has accumulated over the summer, it is important to test after the first storm that causes runoff. Test immediately after significant storm events (1 inch or more of rain in 24 hours) as these storms pose big threats to water quality. It may be helpful to have a rain gauge at the facility to track the amount of rain in each major storm as well as the total annual rainfall.

Keep records to provide a comparison of water quality over the years. You should be able to detect changes that show the effectiveness of your conservation measures.

5.8 Guidelines for Managing Residual Dry Matter (RDM)

Understanding the life cycle of pasture plants will help you to keep them productive. Annual grasses and forbs (broad-leaf plants) dominate dryland (unirrigated) pastures in the San Francisco Bay Area. Annual plants grow from seed each year. Because their seeds germinate with the onset of fall and winter rains, weather has a great impact on the early growth of annual plants. The growth period continues through the winter and early spring.

In the late spring and summer, annual plants mature and die. The residue or dry plant material that is left on the ground not only provides a seed source for the following year's plants, it also protects the soil from erosion and decreases the potential for manure to be transported downstream. Managing dryland pastures dominated by annual plants is really about managing this residue or "***residual dry matter***" (RDM).

Managing RDM in pastures dominated by annual plants is the most effective way to improve the condition of the soil surface, increase its water holding capacity, increase plant productivity, and minimize the invasion of weedy plants. Mapping of pastures to show areas with varying amounts of ***residual dry matter*** will help determine where pasture distribution can be improved.

The amount of RDM left in horse pastures before the start of the winter rains to protect the soil will vary according to soil type, slope, and climate. For example, areas with erosive soils or steep hills require more RDM than flat, stable soil. The following guidelines represent a range of minimum levels for annual grassland sites in the San Francisco Bay Area.

RDM monitoring can involve actual measurement of plant residues or visually estimating plant residues based on appearance.[17] Clipping and weighing involves measuring patches or "quadrats" of plant residue and can be a time consuming method. Your measurements will be more accurate if you take more quadrat samples.

Minimum Recommended Residual Dry Matter (RDM)[18] to Protect Soil and Water Resources in the San Francisco Bay Area		
	Flat to Gentle Slopes (less than 30% slope) RDM	Steep Slopes (over 30% slope) RDM
San Francisco Bay Area	800 lb/ac	1000 lb/ac

[17] This information is drawn from the fact sheet *Vegetation Monitoring* produced by the Marin Coastal Watershed Enhancement Project.
[18] Wildlands Solutions Field Guide Series. 1998. *Residual Dry Matter (RDM) Monitoring Photo-Guide*.

Visual estimation can be done using the following descriptions:

- High RDM – Little or no patchy appearance. Unused plant matter averages three or more inches in height and small objects are hidden. Light grazing results in high RDM.
- Medium RDM – Patchy appearance with an average of 2 inches of unused plant matter and little bare soil. Small objects will not show at a distance of 20 feet of more.
- Low RDM – Less than two inches of unused plant matter. Small objects and areas or bare soil are visible at 20 feet or more. Heavy grazing results in low RDM.

For more information on conducting RDM monitoring, contact your local RCD or NRCS office.

Common Grazing Terms

Carrying capacity. The maximum number of horses a pasture will provide feed for, while leaving adequate vegetation for pasture regeneration and protection from soil erosion. Carrying capacity depends on the soil's fertility and potential for erosion, slope, climate, the length of the growing season, and management. Carrying capacity can vary from year to year due to weather and previous use.

Grazing distribution. Ideal grazing distribution results in pastures with a uniform cover of ***residual dry matter*** (RDM) remaining at the start of the winter rains to protect the soil surface from erosion and reduce the establishment of unwanted weeds. However, horses are selective grazers and will selectively graze immature forage, which results in spot grazing. Areas with short, new growth are repeatedly grazed while other areas mature past the point of being desirable forage. As desirable plants are grazed out, weedy species tend to increase. Good grazing distribution prevents horses from too heavily "overgrazing" their favorite grass. Even with the proper stocking rate, grazing distribution can be a problem in larger pastures.

Residual Dry Matter (RDM). This is the amount of plant residue left in the field after grazing, expressed in pounds per acre.

Rotation grazing. Moving horses to a fresh pasture after the old pasture has been grazed to the desired level.

Season of Use. Optimal pasture productivity depends on controlling "when" and "how long" horses have access to pasture. Year-round access to pastures may not be an option. When to have horses on pasture depends on soil moisture and amount of forage available. Horses can compact wet soil, making it harder for grasses to grow and can readily trample wet turf.

5.9 Alternatives to Pesticides[19]

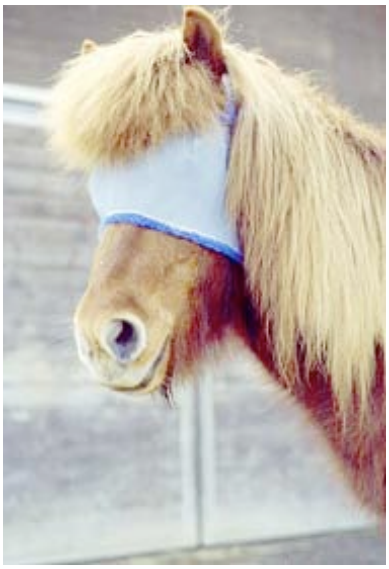
For most horse owners, insect control is a prime concern. Flies can carry diseases and cause problems such as conjunctivitis and wound infections. Biting flies, mosquitoes, and insects such as “no-see-ums” aggravate your horse and cause complications related to itching. Chemical fly sprays, as well as herbicides, fungicides, and other pesticides can severely impair water quality if direct application, airborne transport, or runoff carries the products to creeks.

Environmentally sensitive methods to reduce and manage the fly and insect population at your horse facility include reducing insect habitat, using beneficial insects, putting the local wildlife to work, and setting traps. Using these controls will help you reduce the use of insecticides. Plus, having fewer flies and chemicals will make your place healthier for you and your horses, and more pleasing for your neighbors.

What is Integrated Pest Management?

Integrated pest management is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, and modification of management measures. Pesticides are used only after monitoring indicates they are needed according to established guidelines, and treatments are made with the goal of removing only the target organism. Pest control materials are selected and applied in a manner that minimizes risks to human health, beneficial and non-target organisms, and the environment.

Check with University of California Cooperative Extension or your county agriculture commissioner for more information on alternatives to control undesirable plants or insects.



Use a fly mask to reduce the need for chemical fly control. Also, help control flies by eliminating breeding areas such as mud, manure, or soiled bedding. Managing manure and improving drainage can help create a better environment for horses.

Ways to reduce pesticide use

Address the source of the fly problem first

The crux of effective fly control is to identify and eliminate breeding areas. Virtually any situation that combines moisture and organic material (e.g., mud, manure, or soiled bedding) can support fly maggot development. Mosquito eggs only hatch in water. Contact your local mosquito abatement or vector control district if you have mosquito problems. Practicing sound manure management and having

[19] Adapted from *Fight Nature with Nature: Environmentally Friendly Insect Control for Horse Farms* by Alayne Blickle, Horses for Clean Water. 1999.

proper drainage will greatly reduce the amount of mud and water insects in which flies can breed.

Encourage beneficial insects, birds, and bats

- **Good bugs.** "Fly parasites" are gnat-sized, nocturnal wasps, which lay their eggs in the developing pupae of flies, thereby reducing or nearly eliminating the fly population. They do not harm humans or animals in any way—in fact, you won't even notice their presence. To find the parasites, try local garden stores, check the ads in horse publications, and look in farm supply catalogs. Discuss with the supplier the number of fly parasites and the frequency of release your conditions require to optimize effectiveness.
- **Helpful birds.** Encourage insect-eating birds to move into your barn area as an excellent means to reduce the flying insect population. Swallows are voracious insect eaters consuming up to 6,000 insects per day! Cliff swallows build mud nests when they arrive in spring. Help them along by providing puddles of water where they can gather mud. Screen off areas (using 1/2 inch or smaller wire mesh) where you don't want them. Nest boxes for bluebirds, tree swallows and violet-green swallows can be built or purchased. Nest box plans are available from the Natural Resources Conservation Service. Consult your local Audubon Society, birding organization, or wild bird store for more information. Also see *Steps to Improving Songbird Habitat at your Horse Ranch* in Section 5.10 of the Resources Directory.
- **Bat friends**. Bats eat nocturnal flying insects such as mosquitoes. One bat can eat up to 600 mosquitoes per hour, more than 5,000 per night. They also eat other agricultural pests. Bat houses can be placed on a barn, pole, tree, or the side of a house. The best habitat for bats is within a half mile of a stream, pond, or wetland. Bat houses need to be placed by early April, and it can take up to two years for a bat colony to find the house. Bat houses can be built or ordered through garden catalogs. Bat Conservation International is a good source for more information.

  Be sure to consult your veterinarian for recommendations on vaccinating your horses against rabies. Bat rabies accounts for approximately one human death per year in the United States.

Trap insects

Several types of simple insect traps can be useful for reducing the flying insect population. Flypaper is one of the easiest and cheapest. Pheromone traps are simple jars with one-way lids. A small amount of pheromone solution, a natural substance that attracts flies, is placed in the jar. The flies (and yellow jackets!) buzz into the jar, can't get out, and die. Traps are sold by different companies under various names. Check farm and horse supply outlets.

You can make your own bait jars to trap flies very cheaply and easily. Take an old mayonnaise or similarly sized jar and punch several holes through the lid. Put in

a few pieces of raw hamburger or fish and about an inch of water. Flies make their way into the jar and drown. This method can be smelly and attract other unwanted pests, as well as your dog!

Be cautious when using pesticides

No matter how much fly control you use, there are still likely to be some flies around, especially on hot, sunny days. Regular application of pesticides may still be necessary to control insects that bother horses, especially for those horses hypersensitive to insect bites. If you use chemicals:

- Consult your veterinarian for the type of fly spray recommended and the frequency of application.
- Read and follow instructions carefully to be sure you protect yourself, your horses, and the environment.
- Cover feed ***troughs***, mangers, and water devices to prevent contamination of feed and water. Do not spray inside feed storage rooms.
- Do not apply pesticides near creeks, rivers, lakes, ponds, or other aquatic areas.
- Watch weather conditions to avoid drift of chemical sprays onto other properties.

5.10 Improving Songbird Habitat on Your Horse Ranch

Fact sheet prepared by Point Reyes Bird Observatory
California Partners in Flight and the Riparian Habitat Joint Venture

Equestrians are people who love horses and enjoy being with them outdoors. Many stables or breeding facilities are located on large sections of land, often including creeks or sections of wooded habitat that could sustain a healthy population of native birds. These guidelines are beneficial for both birds and the horse owner, whether you have one horse or an entire stable.

The songbird-breeding season lasts from late March through August in California. During this period, songbirds are constantly busy building nests and raising their young. It is during this period that they are most vulnerable to predators, changes in vegetation and food supply. There are many steps that can be taken to make this time a productive one for birds on your land. We'd like to encourage horse and wildlife lovers to turn their stables into a productive place for bird populations. By providing habitat – especially natural nest sites and foraging areas – you can play an important role in ensuring healthy bird populations for the future. In turn, riding around your property will be more enjoyable with healthy habitat and birds to look at.

Preserve and restore existing "on ranch" native habitat

The best way to begin helping birds is by leaving and enhancing the native vegetation on and around your horse ranch. Native vegetation provides the best nest cover and feeding sites for breeding birds. The following are steps you can take to enhance the existing native habitat on your horse ranch:

- **Fence horses and livestock out of creeks, wetlands, lakes and ponds**—this will increase the native vegetation around creeks and streams which is crucial for breeding songbirds as well as to help reduce muddy areas around water sources that can cause horse ailments such as thrush, mud fever and scratches. Cost effective watering sources are available to supply your horses with water on dry ground.
- **Build water crossings** across creeks to enable horses to move between pastures without damaging the creek or other drainages.
- **Line pastures and driveways** with native trees, shrubs, and grasses to create habitat for birds. This will also eliminate wind, help control weeds toxic to horses such as star thistle, and provide shade for horses. Make sure these areas are ***fenced*** to prevent horses from entering these areas. When possible, connect these rows to existing habitat on creeks or other natural areas on your ranch.
- **Avoid non-native** trees and shrubs such as eucalyptus, tamarisk and broom, when designing your jumping, cross-country, and trail courses. Contact your native plant society for suggestions on native plants and shrubs appropriate to your area. For a list of native plant societies see PRBO's website at http://www.prbo.org/
- **Leave dead trees or dead limbs** for cavity nesting species such as woodpeckers, bluebirds, nuthatches, and titmice.
- **Provide nest material** such as grass clippings, leaf litter, and horsehair.

Manage Your Waste!

Runoff from manure piles, wash racks, and grooming areas can pollute the creeks and seasonal drainages on your ranch. This affects the birds and other wildlife that breed in streamside areas. The following are ways to safely manage your waste:

- **Keep manure** piles far away from creeks, ponds, lakes, and wetlands.
- **Reduce manure** piles by either ***composting manure*** or arranging for removal by local farmers, mushroom growers or other interested parties.
- **Make sure** wash rack drains are not emptying into creeks or other drainages.
- **Use non-toxic** and biodegradable products when grooming and bathing your horse.

Control Predators and Pests!

Eliminate stable pests such as mice, rats, and non-native birds such as house sparrows and starlings.

- **Use traps,** not cats, to control rodents in hay barns and tack rooms. Cats kill an estimated 4.4 million birds a day in North America. For more information see the Cats Indoors Program! at http://www.audubon.org/bird/cat/index.html
- **Keep grain** in sealed containers in designated feed rooms, and clean up spilled grain immediately to keep from attracting rodents.
- **Feed horses in feeders** and remove uneaten hay daily. This not only prevents grain and hay from attracting rodents and flocks of non-native birds to stalls and paddocks, it prevents mud accumulation in winter and can help prevent your horse from ingesting mud or dirt which can lead to sand colic.

Control introduced (non-native) predators:

- **Keep cats indoors**, especially during the songbird breeding season when vulnerable young birds are just out of the nest. Bells on the collar are not enough. Control mice and rodent populations by the methods suggested above, eliminating the need for stable cats.
- **Reduce feral cat** populations, don't feed strays, and spay and neuter all house cats.
- **Eliminate sources** of food such as open garbage, compost, and outdoor pet dishes that attract raccoons, opossums, jays, and stray cats.

Swallows

Barn and Cliff Swallows are insectivorous birds that like to nest under the eaves of roofs on barns and houses. Colonies of swallows provide the invaluable service of free, natural insect control. The large number of flies associated with stables is one of the reasons swallows choose to breed on so many barns. However, if you prefer not to have swallows, there are a few things that you can do to safely discourage them from nesting on your property.

- Discourage swallows from nesting on your house or barn **before** they get their nest started by eliminating space under eaves. You can place boards or a fine wire mesh (1/2 inch or smaller) at an angle to close up the space under roof overhangs.
- Designate one section of your barn or house to allow swallows to nest.
- Don't use Tanglefoot or other sticky substances to discourage the birds as it harms their feet and feathers.

5.11 Helpful Publications and References

Equine Facilities Assistance Program Fact Sheets

The following fact sheets were developed as part of the Equine Facilities Assistance Program. To obtain copies, contact the Council of Bay Area Resource Conservation Districts at (707) 794-1242, ext. 121, or your local Resource Conservation District.

Number 1: *Program Background*
Number 2: *Composting Horse Manure*
Number 3: *Conservation Measures to Reduce Non-point Source Pollution at Horse Facilities*
Number 4: *Photographic Monitoring for Equestrian Facilities*
Number 5: *Horse Paddocks: Designed and Managed to Protect Water Quality*
Number 6: *Controlling Yellow Starthistle*
Number 7: *Dryland Pasture for Horses*
Number 8: *Portable Backyard Garden*
Number 9: *Horse Manure Management*
Number 10: *Stormwater Runoff Management at High-use Areas*

Horse Owners Guide to Water Quality Protection brochure is also available.

Erosion and sediment control

Erosion and Sediment Control Field Manual. 1999. San Francisco Bay Regional Water Quality Control Board. 1999. Contact: Friends of the San Francisco Estuary at (510) 622-2419.

Groundwork: A Handbook for Erosion Control in North Coastal California. 1987. Liza Prunuske. Marin County Resource Conservation District. Contact Marin County RCD at (415) 663-1170 or: marinrcd@svn.net

Principles & Practices of Erosion Control. Santa Cruz County Resource Conservation District. Contact: Santa Cruz RCD at (831) 464-2950.

Repairing Streambank Erosion. 1997. Brochure prepared by Prunuske Chatham, Inc. for Marin County Stormwater Pollution Prevention Program.

Start at the Source: Design Guidance Manual for Stormwater Quality Protection. 1997. Tom Richmond and Associates. Bay Area Stormwater Management Agencies Association (BASMAA). New York: Forbes Custom Publishing.

Water resources/watersheds/riparian environments

Creek Care: A Guide for Urban Marin Residents. Martha Neuman. Marin County Stormwater Pollution Prevention Program. Contact MCSTOPP at (415) 485-3363.

Guide to Stream Project Permitting for the State of California. California Association of Resource Conservation Districts. Call (916) 447-7237 or contact http://www.carcd.org/

Riparian Buffers for Agricultural Land. 1997. Mike Dosskey, et al. Iowa State University. Department of Forestry. Agroforestry Notes AF Note-3.

Stewards of our Streams; Riparian Buffer Systems. 1997. Richard C. Schultz, et al. Iowa State University. University Extension Pm-1626a.

Water quality

California Rangelands website at UC Davis. Fact sheets on water quality and more. Search the web using keywords: California Rangeland Watershed Program Fact Sheets.

Simply the Facts on Animal Waste and Water Monitoring (for Landowners, Farmers, & General Public). A series of fact sheets from USDA Natural Resources Conservation Service and AmeriCorps. Contact the Council of Bay Area RCDs at (707) 794-1242, ext. 121.

Manure and waste management

California Materials Exchange (CalMAX): http://www.ciwmb.ca.gov/calmax

Good Horse Keeping—Managing Manure to Protect the Environment (video). 1999. King's Mark Resource Conservation & Development Area, Connecticut. Horse Environmental Awareness Program. Cost is $10. Call (203) 284-3663.

Horse Wastes and Composting. Adda Quinn. EnviroHorse. Contact: http://www.californiastatehorsemen.com/envirohorse.htm or email at envirohorse@yahoo.com

How to Compost and Use Horse Manure. Alayne Blickle. Horses for Clean Water Tipsheet. Contact http://members.aol.com/arblickle/

Livestock Waste Facilities Handbook. 1993. Midwest Plan Service. MWPS-18. Iowa State University.

Manure and Waste Management for the Horseowner. 1983. Division of Agricultural Sciences, University of California. Leaflet 21397. Call (800) 994-8849.

On-Farm Composting Handbook. 1992. New York: Northeast Regional Agricultural Engineering Service, Cooperative Extension. NRAES-54. (152 Riley-Robb Hall Ithaca, NY 14853-5701. Call (607) 255-7654 or email nraes@cornell.edu

Recommended Best Management Practices for Dairies and Other Animal Facility Operations in Region 1. 2000. California Regional Water Quality Control Board. North Coast Region.

The Rodale Book of Composting. 1992. Deborah Martin and Grace Gershuny, editors. New York: Rodale Press.

Equine facilities management and site planning

*Home*A*Syst, An Environmental Risk-Assessment Guide for the Home*. 1997. New York: Northeast Regional Agricultural Engineering Service. NRAES-87. Call (607) 255-7654 or email: nraes@cornell.edu

Horse Handbook, Housing and Equipment. 1971. Midwest Plan Service. Iowa State University. MWPS-15.

Horse Industry Handbook, A Guide to Equine Care and Management. 1993. Kentucky: American Youth Horse Council. Call (606) 226-6011.

Horse Management Program (video). 1998. Resource Conservation District of the Santa Monica Mountains. 122 North Topanga Canyon Blvd, Topanga CA 90290. Call: (310) 455-1030. Cost is $5.

Horsekeeping on a Small Acreage, Facilities Design and Management. 1990. Cherry Hill. Vermont: Storey Books.

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San Diego County Association of Resource Conservation Districts. 1990. Backyard Ranches, A Horse Management Program for San Diego County.

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Glossary

Aquatic life. Plants or animals that require water and associated riparian habitat to live.

Clean water. Rainfall that has not come into contact with a pollutant such as horse manure, or picked up pollutants such as sediment.

Concentrated water. Water flow that has increased in volume and velocity due to either natural drainage or human-made diversion of drainage.

Conservation measure. Any management practice, activity, or structure to prevent or reduce water pollution and/or enhance natural resourcess.

Conservation plan. A set of decisions for a long-term management strategy to protect and enhance natural resources for a property. These decisions are recorded in a conservation plan, which documents decisions made and describes the schedule of operations and activities needed to solve identified problems. Maintenance and monitoring are also included.

Polluted water. Water that has become adversely affected physically, chemically, or biologically by chemicals or other additives, such as manure or sediment.

Contaminant. The impairment of water quality by waste to a degree that creates a hazard to public health through the spread of disease.

Creek. A watercourse smaller than a river. Used in this guide to cover all sizes and types of fresh water bodies such as rivers and streams. May or may not have year-round surface flow.

Diversion. A channel or structure to divert water at a non-erosive velocity to sites where it can be used or discharged at an erosion resistant outlet.

Downslope. Downhill.

Drainage. Movement of water downward through the soil or across land.

Erosion. The wearing away of land surface by wind or water. Occurs naturally from weather or runoff, but can be intensified or accelerated by human activity.

Ground water. Water stored underground that fills the spaces between soil particles or rock fractures. (Also see near-surface ground water.)

Horse facility. In this guide, the areas used in caring for horses (i.e., barns, paddocks, turnouts, arenas, etc.) whether for a single backyard horse or a larger boarding operation.

Horse waste. Manure, urine, used bedding, and spoiled hay.

Impervious/ impermeable surface. Any surface that cannot be easily penetrated by water, such as roofs, compacted soils, and paved areas.

Leachate. Liquid which has come into contact with or percolated through manure being stockpiled or stored; contains dissolved or suspended particles and nutrients.

Manure. In this guide, manure includes both the feces and urine from horses.

Near-surface ground water. Ground water just below the soil surface and above the normal water table due to water-saturated soils. As well as slowly moving downward, near-surface ground water generally flows in the same direction as the surface runoff above until it reemerges to the surface at a creek.

Nonpoint source pollution. The diffuse discharge of pollutants that can occur

over an extensive area, such as a pasture, as opposed to point source pollution that can be pinpointed to a specific location, such as an outlet at a sewage treatment plant. Nonpoint source pollution occurs as water from rainfall or snowmelt moves over and through the ground, it picks up and transports natural and human-created pollutants, eventually depositing them into surface and ground water.

Nutrient. The portion of any element or compound that can be readily absorbed and assimilated to nourish plants; examples include nitrogen and phosphorus. Even in small amounts these same nutrients can have a harmful effect on water quality. Horse manure can degrade water quality because it is rich in nutrients.

Organic material. Substance derived from living organisms (plants or animals).

Outlet. The area where water is discharged from a downspout, culvert, pipe, channel, or ditch.

Overgrazing. Severe grazing that causes a decrease in plant cover and correspondingly causes plant roots to die back.

Pollutant. The presence of a substance in such quantities that when it reaches a body of water, soil, or air, it is degrading in effect that it impairs their useful ness or renders them offensive.

Pool. A depression in the streambed used by aquatic life.

Residual Dry Matter (RDM). The amount of plant residue, expressed in pounds per acre, left in the field after being grazed.

Riffle. Sections of a stream with moderate turbulence caused by water flowing over rocks.

Rill erosion. Small, well-defined channels several inches deep that form when loose particles of soil and rock are transported downhill by water.

Riparian area. The area immediately adjacent to the banks of a creek, lake, or other waterbody. The riparian area is distinctly different from surrounding lands because of unique soil and vegetation characteristics that are strongly influenced by free or unbound water in the soil.

Riprap. Heavy rock used to protect soil from the erosive action of fast-moving water. Minimum size is typically 12 inches x 12 inches x 6 inches with a bulk specific gravity of 2.5 or greater.

Rolling dip. A shallow, rounded dip in the road to provide effective drainage where surface runoff is directed in the dip to the side of the road.

Runoff. Water from rain or other sources (for example, from a hose or a ***horse wash area***) that does not infiltrate into the ground but runs over the land surface and into creeks.

Seasonal drainages. Small, natural or human created swales, depressions, or drainages that carry water only after a rainfall.

Sediment. The soil material, both mineral and organic, that is suspended, is being transported, or has been moved from its site of origin by erosion and has come to rest on the land surface or at the bottom of creeks, ditches, reservoirs, or bays.

Sheet flow. A shallow flow of water that is spread uniformly over the land surface. Sheet flow will concentrate into rills and gullies.

Soil type. Soil is unconsolidated mineral and organic surface material with

specific physical, chemical, and biological properties to support plant growth. Soil is grouped into three basic types based on particle size: clay has small particles; silt/loam has medium size particles; and sand/gravel has large particles.

Stormwater runoff. Clean rain water that flows over the land surface without entering the soil.

Turnout. A high-use area where horses are "turned out" for exercise after being confined in stalls. Turnouts can be exercise lots, small paddocks, pens, or corrals. These areas are typically bare and not managed as pastures.

Upslope. Uphill.

Water quality. Describes the chemical, biological, and physical characteristics of water. The quality of water can limit its specific use or ability to support various beneficial uses such as water supplies for municipalities, industry, agriculture, recreation, and fish and wildlife habitat.

Watershed. Total land area that drains into a particular creek, river system, or bay. It includes major and minor creeks, seasonal drainages, hillsides, and floodplains. Watershed boundaries are defined by the ridges that separate drainage between watersheds.

Water table. The underground boundary below which all spaces between soil particles are saturated with water. Water tables fluctuate throughout the year but are usually highest in early spring.

Wetlands. Areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions.

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Horse Keeping:

A Guide to Land Management for Clean Water

This is a manual for everyone who enjoys horses and is concerned with managing them in a way that protects our land and water resources. It is interesting, informative, and written so that even the layman with no prior knowledge of land management issues will be able to operate his facility in an environmentally friendly manner.

Joel Bartlett
Horseman and meteorologist

It was a pleasure reviewing this guide, *Horse Keeping: A Guide to Land Management for Clean Water*. When someone says to me, "There's no problem with backyard horse keeping," I disagree. The Sonoma County Horse Council found in the 1999 Horse Census and Economic Survey that the majority of horses in the county are in back yards. When you have over 14,000 horses in the County, the cumulative effect could be drastic to local water bodies. The information used in the manual comes from years of dealing with the same issues concerning the dairy industry.

I work as the equestrian representative on the Animal Resource Committee, a committee that deals with manure and pollution with agriculture producers. I contact the local horse owners who receive complaints from neighbors or agencies. This allows the producer to correct any problems before any fines are levied. During the rainy season one or two situations arise each month. This manual will allow the horse owners easy access to information for improving their horse keeping practices. It is essential to have a Ranch Conservation Plan.

I teach classes at Santa Rosa Junior College titled "Water Quality and Equine Facilities Planning" and "Animal Stewardship and Water Quality." I use the Ranch Plan Workbook from the Marin Coastal Watershed Enhancement Project, and the Water Quality Planning Course for Equine Facilities, created by Alameda County Resource Conservation District. I hope to use this *Horse Keeping* manual in my classes. It is ideal to have the information located in one convenient text.

The equestrian community should be thankful that individuals involved in horse keeping were asked to review this guide and to contribute to its content.

Michael Murphy
Sonoma County Horse Council

Horse Keeping: A Guide to Land Management for Clean Water

This is the label for the spine of a binder.

- Obtain a 1” binder with clear windows in the front, back, and spine.
- Cut out this label, and insert it in the spine of the binder.

Place the front cover in the front of the binder, and the back cover sheet in the back of the binder.

Horse Owners Guide to

Water Quality Protection

COUNCIL OF BAY AREA

RESOURCE CONSERVATION DISTRICTS

in partnership with the USDA Natural Resources Conservation Service

1301 REDWOOD WAY, SUITE 215

PETALUMA, CA 94954

(707) 794-1242 x121

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Horse owners can reduce the need for further regulation by taking responsibility to manage horse waste, limit erosion, control stormwater runoff, and protect creeks and waterways.

Introduction

Conservation practices that protect water quality at horse facilities add to a horse property's value, promote horse health, build good relations between neighbors, and discourage further regulation.

While horses contribute only a small fraction of the total pollutants entering local waterways, horse owners and facility managers bear the responsibility to minimize water pollution through:

- Facility design and siting
- Horse waste management
- Stormwater runoff management
- Pasture and paddock care
- Protection of waterbodies

Implementation of conservation practices does not need to be costly. Often a slight change in operations will achieve the desired result. How can horse waste and erosion affect water quality? How well are you as a horse owner protecting water quality? What more can you do?

With an expanding urban environment, horse owners must diligently protect water quality and present a good image to their neighbors.

With an expanding urban environment, horse owners must diligently protect water quality and present a good image to their neighbors.

What can horse owners do to minimize adverse water quality impacts?

Be informed and proactive. Analyze possible water quality impacts of your operations before and during rains. Learn how to perform simple water quality monitoring tests. Implement conservation practices if necessary. Carefully consider potential water quality problems before expanding your facility. Schedule a workday at your stable to install roof gutters, improve drainage channels, set up a new manure storage system, or revegetate a creek. Volunteer to maintain public trails. Encourage your friends and horse clubs to do the same.

Remember, any complaint about horses reflects on all horse owners. Realize that not everyone loves horses. Consider yourself an ambassador for horses by good stewardship of land and water resources. Care of natural resources in your local area will initiate an expanding ripple.

How can horse waste impair water quality?

Although horse wastes (manure, urine and soiled bedding) are organic, biodegradable materials, many of their biological and chemical properties can be detrimental to fish, insects, and other aquatic life if those wastes get into local waterbodies.

All aquatic life depends on the small amount of ***dissolved oxygen*** that naturally exists in water. The atmosphere contains 20% oxygen, but water saturated with oxygen contains only 11 parts per million (ppm) at 50˚F, and even less, 9 ppm, at 70˚F. The addition of any decomposable organic material to water stimulates the growth of aerobic bacteria that break down, or consume the organic matter. The respiratory demand of the resultant bacterial population can become large enough to overwhelm the water's oxygen dynamics, leaving little or no dissolved oxygen for other aquatic life.

Horses in the wild may roam up to twenty-five miles a day for food, water and shelter. Their continual movement disperses manure and urine and allows for regrowth of vegetation. However, domestic horses can be kept in a small area. If not carefully managed, horse waste and sediment from horse facilities could enter waterways or infiltrate ground water to create conditions detrimental to drinking water supplies, recreational activities and the environment.

Many of the ***nutrients*** ingested by animals, not just horses, return to the environment in feces and urine. On land, moisture and atmospheric oxygen support the bacterial conversion of these wastes to nutrients available for plants. However, when carried by stormwater runoff to streams and lakes, excessive amounts of these same nutrients can stimulate unwanted ***algae blooms***. Algae produce oxygen by photosynthesis, but only during sunny times of the day do they produce more oxygen than they consume. Thus, algal respiration, like the bacterial decomposition of organic material, uses up dissolved oxygen in water.

Ammonia is an intermediate byproduct of bacterial conversion of urea, a principal constituent of urine and other nitrogenous materials excreted by animals. A very small amount of ammonia dissolved in water can kill fish. State, Federal, and international criteria recognize that waters which support a balanced population of fish and aquatic life have an almost undetectable un-ionized ammonia concentration of 0.025 parts per million or less.

Salts contained in all animal waste do not breakdown, and can be carried by rain runoff into local surface and ground waters. The presence of salts in soils of animal confinement areas can increase the salt load to local streams, limiting the species of fish, amphibians, and invertebrate life.

Bacteria and viruses in horse manure rarely cause health problems for people. The potential for spread of disease to other horses, or susceptible wildlife species may be of concern.

How does erosion affect water quality?

Activities, such as heavy grazing or trampling, that remove the soil's vegetative cover and thus expose the soil surface to the energy of raindrops, water runoff, and wind, accelerate the natural process of erosion. Once mobilized into a stream, excessive sediment

A gully needs stabilization to control deepening and widening. Horses should be restricted from gullies as trampling can exacerbate erosion problems. Soil erosion is easier to control in its early stages when revegetation or simple drainage improvements may be all that are necessary.

can fill pools, smother fish spawning beds, cover or obscure food supplies, reduce the amount of sunlight reaching aquatic plants, increase water temperature, and clog fish gills. In addition, heavy metals and other toxic contaminants can temporarily bind to sediments and be carried along into water.

What is voluntary compliance?

Both State and Federal laws set standards for handling of animal waste to provide protection of surface and underground water resources. Currently, regulatory and enforcement agencies encourage owners and managers of animal feeding or confinement operations, as well as individual horse owners, to follow a program of "voluntary compliance" to achieve these "clean water" standards without more formal regulatory action.

Voluntary compliance means ***voluntarily undertaking the necessary and appropriate management practices to minimize the release of pollutants into local waters***. Horse owners and facility managers should evaluate the effectiveness of their existing erosion control, stormwater management, and waste management practices to minimize transport of pollutants. Voluntary compliance allows the horse community the opportunity to demonstrate responsible stewardship of natural resources while avoiding stricter enforcement of regulations. Voluntary compliance does not mean that water quality concerns can be ignored.

Turn out horses for a limited period of grazing each day to increase the duration of the pasture's use and to reduce soil compaction.

Proper manure management is essential. Manure cleanup, storage, and use are critical components of good stewardship.

Conservation Practices for Horse Owners

A conservation practice ***is any activity that improves, protects or restores a natural resource***. To implement conservation practices that protect water quality:

- Identify the source of pollution
- Determine how pollutants reach the water
- Select a conservation practice, or a combination of practices, to cost effectively reduce the adverse impact to water quality
- Monitor and evaluate its effectiveness in achieving the desired result
- Make any necessary changes based on the evaluation

Horse owners should consider the following points to protect water quality:

1 Horse Waste Management

Clean up manure and soiled bedding on a regular basis, especially during wet weather, to limit seepage of salts and nutrients into ground water or runoff of manure into waterbodies.

After clean up, during the arid summer, use a bucket, hose or sprinkler to water areas where horses frequently deposit manure. Watering maintains the moist environment bacteria need to decompose residual waste.

Store horse waste on an impervious surface (a concrete pad or plastic tarp) and under cover (a roof or tarp) during rains to prevent leaching or runoff of pollutants. Locate storage areas away from waterways so that floods or runoff will not wash away waste. Do not dump horse waste on the edge or directly into stream channels.

Disposal fees are expensive. Manure composts into an excellent soil

Composting manure may be an excellent way to handle large quantities of manure and create a useful product.

Control winter access to soggy pastures to help prevent pollutants from leaching into the ground water and to keep horses out of the mud.

Convey runoff from barn roofs through gutters, downspouts and splash pads. Divert this clean water to areas so it will not come in contact with horse waste or cause soil erosion.

amendment. Perhaps neighbors or local gardeners will want your organic material. Keep compost piles moist and well aerated to aid in conversion of urea and ammonia compounds to more useable, and less toxic nitrates. Be innovative and establish a disposal solution rather than create a disposal problem.

2 Facility Siting

Keeping horses close to streams, in flood-prone areas, or on steep hillsides increases the potential for the runoff of manure and sediment. One does not always have an ideal site, given the constraints of topography, soil, rainfall patterns or existing structures; but conscientious management can often offset site shortcomings. New facilities should be sited and designed to address water quality concerns. Work to upgrade existing facilities.

3 Stormwater Runoff Management

• Keep "clean water clean." Use grassed ditches, berms, or subsurface drains to divert "clean" runoff around barns, manure storage areas, and paddocks.

• Install and maintain a system of properly sized roof gutters, downspouts, and drains to prevent "clean" roof water from becoming "polluted" by mixing with barnyard manure and sediment.

• Divert "polluted" runoff from manured areas away from waterways and to low-gradient vegetated buffer areas.

• Separate barnyards, paddocks, and manure storage areas from any waterway with buffer strips of vegetation to filter sediments and absorb nutrients in runoff.

• Construct or repair trails, arenas, roads, parking areas, their associated ditches, and culverts to drain water in a non-erosive manner.

• With a little training, horse owners can use simple water quality test kits to monitor their operations.

Vegetation protects water quality by slowing the rate of stormwater runoff, which increases absorption into soil, increases bacterial conversion of toxic or consumptive constituents, and lessens the risk that soil and manure solids will be carried into streams.

• Additional benefits of runoff management include a drier barnyard, a healthier horse environment, and better working conditions.

4 Pasture and Paddock Care

Vegetation protects water quality by slowing the rate of stormwater runoff, which increases absorption into soil, increases bacterial conversion of toxic or consumptive constituents, and lessens the risk that soil and manure solids will be carried into streams.

Grazing Management

Maintain pasture productivity by controlling the number of horses and the amount of time they spend on a pasture. In most cases, pastures provide an exercise area and not the primary food source. For this reason, pasture management should focus on protecting the pasture's soil and vegetative cover. Prevent bare areas from forming. Allow grass time for regrowth. Cross fence to divide pastures into smaller areas, which can be grazed in rotation. Inexpensive and moveable, electric fencing works well to define grazing areas. During the growing season, graze grass to a height of 3-4 inches and allow regrowth to 6-8 inches before returning horses to the pasture. Manage grazing so that a cover of dry residual vegetation protects soil from the first rains.

Soil Compaction

A porous soil improves plant vigor by allowing the infiltration of water, air, and nutrients. Hoof impact and machinery operation on water saturated land compact soil particles and cause loss of porosity.

Paddocks as a Sacrifice Area

Use turnout paddocks as "sacrifice areas" to preserve pastures. This strategy reduces churning and compaction of wet soils, and overgrazing when pastures require rest. If possible, locate paddocks back from waterways; and avoid swales where overland flows can wash away bare soil or manure. Maintain a vegetated border around paddocks to help filter pollutants. Be sure paddocks provide horses with adequate exercise room.

Restrict horses from creeks to help keep manure and urine from being deposited in creeks and minimize erosion on streambanks. Use fencing to help manage horse access to riparian areas.

5 Protection of Waterbodies

Riparian Buffer Strips

Protect or restore a vegetated riparian (streamside) corridor with grass, trees, shrubs and/or groundcover to filter sediments and horse waste, stabilize streambanks, reduce solar heating of the water, and enhance aquatic habitat.

Limit Horses Access to Waterways

Provide other sources of water and shade. The direct deposit of manure into water can harm aquatic life. Trampling physically breaks down streambanks and destroys vegetative cover, which can increase sedimentation. The loss of streamside vegetation may also result in excessive solar heating of the water, which can harm cold water fish, such as steelhead and salmon. Design stream crossings to minimize erosion. Exclusionary fencing and seasonal grazing of riparian corridors are possible management choices.

Protect Small Tributaries

Ditches and drainage swales carry a large amount of rain runoff. These tributaries also require vegetation to filter sediment and reduce the erosive energy of water. Fencing may be necessary to exclude horses from these smaller waterways.

Wetlands naturally filter pollutants from water and provide excellent wildlife habitat. Protect wetlands from grazing and trampling during the rainy season.

Chemicals in horse grooming and health products, detergents, disinfectants, herbicides, and pesticides can harm aquatic life. Follow instructions for correct application. Minimize use whenever possible. Be careful to avoid direct application or airborne transport of sprays to waterbodies. Do not let horse wash water drain directly into waterways.

Horses benefit from good land management and stewardship by having a healthy and clean environment.

For more information contact:

Local Resource Conservation Districts (RCD):

Alameda County RCD (925) 371-0154

Contra Costa RCD (925) 672-6522

Guadalupe-Coyote RCD (408) 288-5888

Loma Prieta RCD (408) 847-4171

Marin County RCD (415) 663-1170

Napa County RCD (707) 252-4189

San Mateo County RCD (650) 726-4660

Southern Sonoma County RCD (707) 794-1242 x5

Local USDA Natural Resources Conservation Service Office (707) 794-1242 x121

Local U.C. Cooperative Extension office

CA Dept. of Fish and Game (707) 944-5500

S.F. Regional Water Quality Control Board (510) 622-2300

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Resource Conservation Districts (RCD) are non-regulatory, special districts governed by a volunteer board of directors. In addition to educational programs, RCDs provide landowners and the public with technical assistance in natural resource management.

COUNCIL OF BAY AREA RESOURCE CONSERVATION DISTRICTS

in partnership with the USDA Natural Resources Conservation Service

1301 REDWOOD WAY, SUITE 215

PETALUMA, CA 94954

(707) 794-1242 x121

APPENDIX 3-B-3

TUOLUMNE COUNTY RESOURCE CONSERVATION DISTRICT

Example Workshop Materials

PRESS RELEASE

Santa Cruz County
Resource Conservation District
Contact: Angela Stuart
Phone: 831-419-8710

FOR IMMEDIATE RELEASE
9 A.M., September 6, 2005

Workshops help keep landowners from getting stuck in the mud!

EDUCATIONAL AND FUNDING OPORTUNITES FOR COUNTY LIVESTOCK OWNERS

CAPITOLA, CA, AUGUST 16, 2005: The Santa Cruz County Resource Conservation District in partnership with Ecology Action, the Santa Cruz County Horsemen's Association and the Pajaro Valley Water Management Agency presents the second 'Livestock and Land' workshop series. Building off the success of the first series, which drew over 75 interested livestock owners from Los Gatos to Watsonville, this program will focus on land stewardship skills including pasture and paddock management, manure composting, mud issues, livestock health, and well and septic system maintenance. In addition to presentations by area experts, attendees will also receive information about free local resources and how to apply for property improvement funding.

The three week series begins Thursday evening September 8 at Valencia Hall in Aptos and runs from 6:00PM to 9:00PM. The cost for the entire series is $25 per family and includes workshop materials and a light meal.

<u>#1 – Healthy Watersheds & Healthy Hoofs</u>

TOPICS: Watersheds, Wells & Septic Systems plus Livestock Health
WHEN: Thursday, September 8 from 6:00PM to 9:00 PM
WHERE: Valencia Hall, Aptos, CA

<u>#2 – Pastures, Pens, and Paddocks</u>

TOPICS: Site Planning and Pasture, Pen, and Paddock Management
WHEN: Thursday, September 15 from 6:00PM to 9:00 PM
WHERE: Private Ranch, Valencia Rd, Aptos, CA

<u>#3 - Manure Madness</u>

TOPICS: Manure Management and Composting
WHEN: Thursday, September 22 from 6:00PM to 9:00 PM
WHERE: Willow Pond Ranch, Soquel, CA

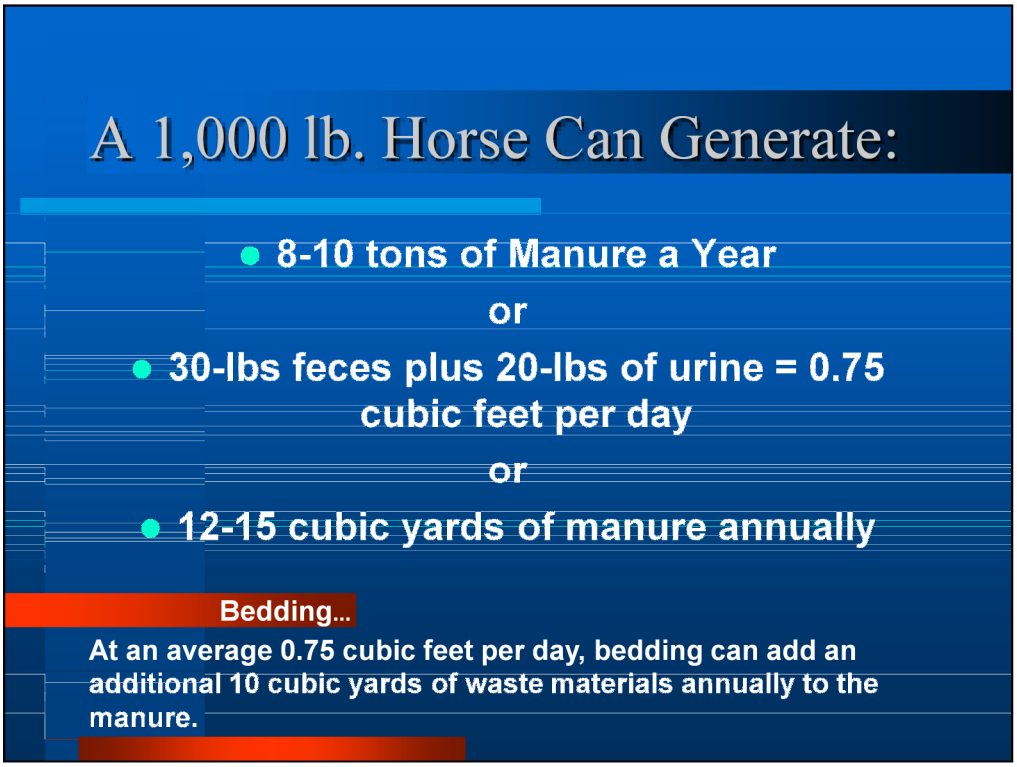
The workshops, funded by the State Water Resources Control Board, offer livestock owners an opportunity to understand Best Management Practices (BMPs) that can be applied on their own properties or looked for at boarding facilities. While all the practices focus on decreasing water contaminants associated with livestock facilities, the benefits are farther reaching.

By applying practices that decrease erosion, reduce sediment, and lessen manure runoff to local water supplies, property owners will enjoy enhanced land esthetics, decreased maintenance costs, a safer environment for workers, land owners, visitors and animals, increased profitability and property value, and better community relationships.

For more information please contact Angie Stuart, Livestock Program Coordinator for the Resource Conservation District at 831-464-2950 or astuart@sccrcd.org or visit the Ecology Action web site at www.ecoact.org and look for the Manure Management Program

A Horse Keeper's Guide to Manure Management

1. Proper Manure Management is an important concern for every horse keeper.
2. Appropriate storage, handling, and recycling or proper disposal of manure helps protect water quality and keeps both horses and people healthy and happy.
3. Good manure management is essential for horses to be accepted as friendly residential neighbors in increasingly crowded suburban settings.
4. The overall result is water quality protection.



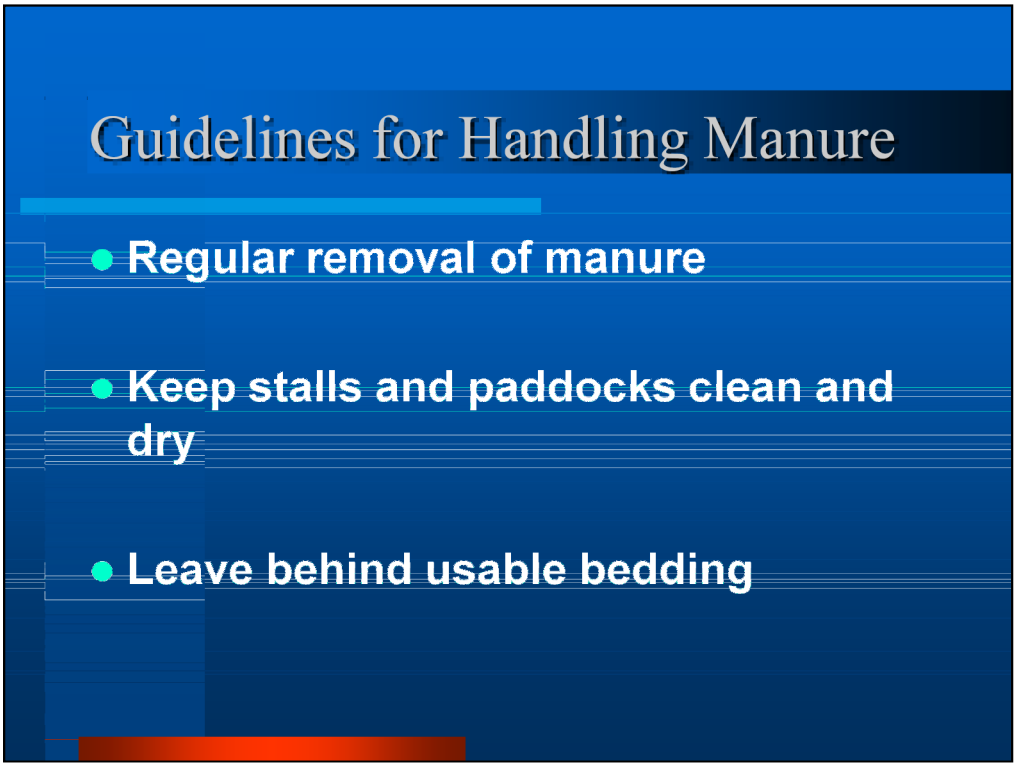
Due to the volume of manure-waste generated from horses there is a pollution potential.

Here is a happy horse. Notice the clean paddock.

Average nitrogen, phosphorus, and potassium content (NPK) of horse manure and manure with bedding (dry weight basis)

Nutrient	Manure		W/ Bedding
	%	lbs./ton of material	
Nitrogen (N)	0.95	19.0	11.0
Phosphorus (P)	0.30	6.0	2.20
Potassium (K)	1.50	30	1.30

1. This table shows the average nutrient content of horse manure alone and with bedding.
2. Equestrians implementing good land and manure management practices can eliminate water quality concerns.
3. In fact, manure that is properly handled can be recycled into a valuable soil amendment for farms and gardens.
4. A horse then might be said to have an environmental value!



1. Regular removal of manure

   - is a good practice in confined areas

   - decomposition of manure starts as soon as it's voided and nitrogen may be easily lost

2. Keep stalls and paddocks clean and dry

   - decomposition of manure depends upon handling and storage

   - nutrients in urine are readily absorbed in bedding

3. Leave behind usable bedding

   - separation of manure and shavings reduces volume of waste generated

   - alternative bedding, like pellets can reduce waste volume and speed recycling time if manure is composted

This paddock is in need of cleaning…….

This paddock is not……(in need of cleaning).

Average amount of storage required for manure *

No. of Horses	Manure		Manure w/Bedding	
	250 days	Year	250 days	Year
	cubic yards			
1	7	10	12-14	17-20
5	35	50	60-70	85-100
15	105	150	180-210	255-300
25	175	250	300-350	425-500
40	280	400	480-560	680-800

*Assumes 0.75 cu. ft. manure/day and 0.50 to 0.75 cu. ft. bedding/day.
A cubic yard is 27 cu. ft. and occupies a cube 3ft x 3ft x 3ft.

1. Storage of manure removed from stalls and paddocks should have an adequate area for the amount of manure generated.

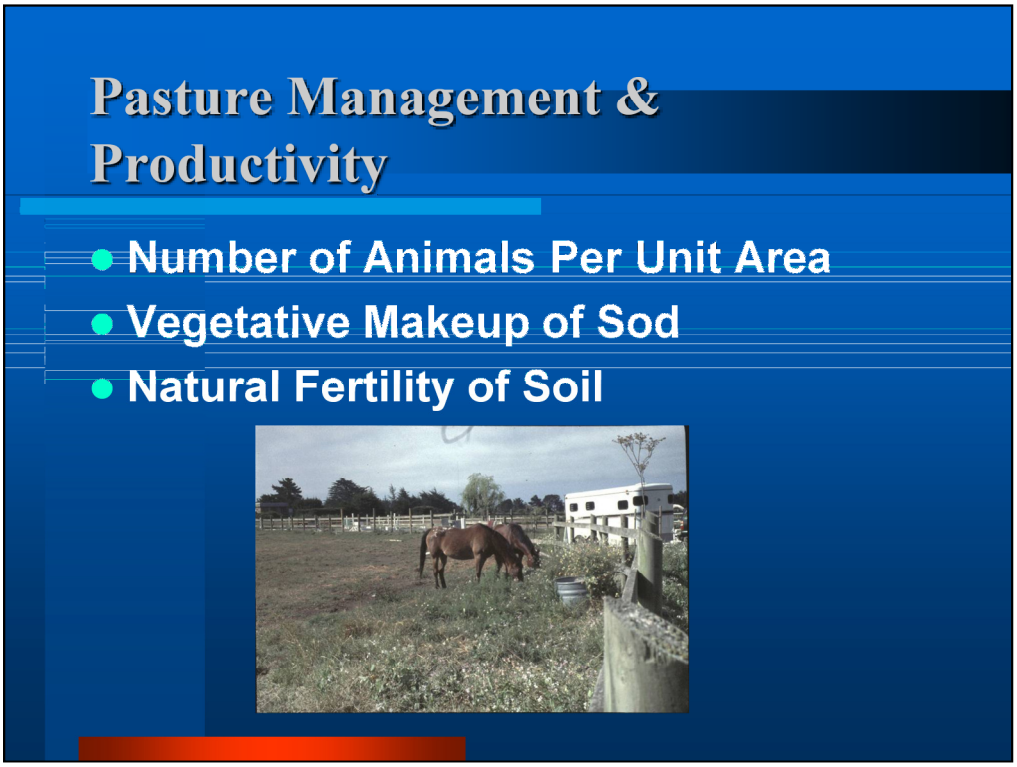
2. This table gives the average amount of manure storage space, in cubic yards, required, based on the number of horses and a range of bedding additions.

3. For example, a 144 square foot confined storage space (12X12 feet at the base) will hold manure from one horse for a year, depending on type and amount of bedding. Accumulation might be 3 to 5 feet in depth (high).

1. Large storage areas should be well constructed and accessible for use of power equipment. They should be large enough to house manure and bedding without any overflow outside of the containment area.
2. The storage area walls should be high enough to prevent manure from spilling over the top. The bottom should be gently sloped backwards.
3. Loading and unloading should be convenient.

   - the entrance should be constructed to catch and divert any runoff to a diversion ditch or grassed swale.

   -the surrounding area should be graded to keep surface water from running over or through the manure.
4. If the manure cannot be removed frequently, then screen or cover the pile with a plastic tarp.
5. Keep roof and yard water from draining into your manure storage area so that **clean water stays clean**.



1. Pasture Management differs from paddock and stall management. Pasture can supply a source of feed for horses, but vary in productivity.
2. Pasture productivity is related to:

   -the number of animals per unit area

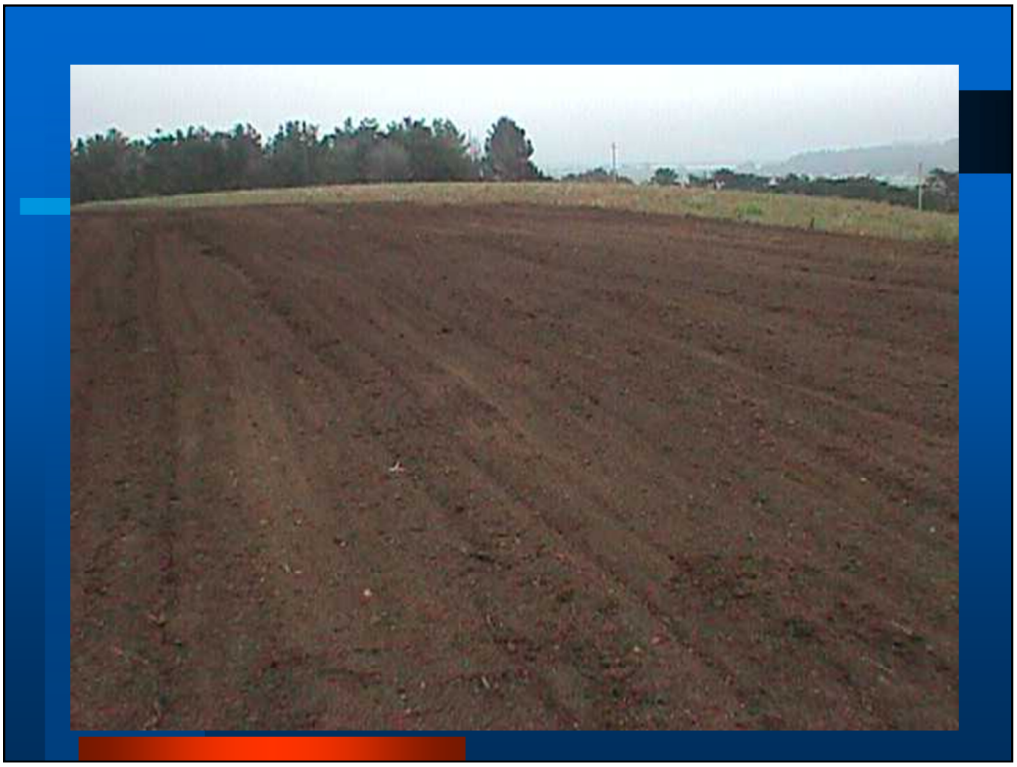
   -vegetative makeup of the sod, and

   -the natural fertility of the soil
3. One to two acres of well-managed pasture can support one mature horse during the grazing season with rotation. When the animal is rotated as frequently as every two-weeks, the acreage needed could be closer to one acre. Four to five acres of unimproved native grass pasture will support only one mature horse for the entire grazing season.

1. Horses can do a fairly good job of distributing manure, but concentrated droppings from horses can suffocate or stunt plants underneath them.
2. To maximize pasture production, drag or harrow the pasture to break up the droppings and more evenly spread the manure.
3. To avoid concentration of manure in one or more isolated areas, the horse keeper should encourage even grazing.
4. If horses in the pasture receive supplemental feed, try moving the feeding location around.
5. Keep horses out of streams, ponds and wetlands. Use troughs or a automatic system to water horses.

1. Land Application is one method of recycling manure as a soil conditioner to grow useful pasture grasses or other crops.
2. Proper application methods require knowledge of soils and application rates suitable to particular crops.

   -your local Farm Advisor or RCD can assist in determining your soils and rate of application.
3. Incorporation of manure into soil immediately following spreading will reduce losses of valuable nutrients, especially nitrogen.
4. Manure spread or piled and left exposed on sloping surfaces is subject to erosion, possibly contributing to nearby water contamination.



Example of land application. This picture shows about 2 inches of composted manure incorporated into soil.

1. Fresh manure is best used for crops with long growing seasons, and better suited to clay and loam soils, while aged or composted manure can be used on sandy soils.
2. Crops grown and harvested annually on one acre of land can easily utilize the nutrients available in the yearly accumulation of manure from a single horse.

Land Application Guidelines

Average manure application and land base area requirements for pasture crops.*

Forage Crop	Annual Manure Application tons/acre	Land Area Required acres/horse/yr
Red Clover	10	0.8
Ryegrass	11	0.8
Tall Fescue	13	0.6
Wheat Grass	2	3.8

*Adapted form Davis and Swinker, 1996 (assumes 8 tons manure/yr).

1. If stored manure is to be spread onto a field that grows crops, then manure nutrient content should match nutrient needs of the specific crop.
   - this increases potential for effective nutrient absorption by plants, which reduces potential for leaching or runoff risk.
   - manure can be sampled, packaged, and sent to a testing laboratory for nutrient analysis.
2. Manure application rates for selected forage crops are shown. Not all of the nutrients in manure are available for plant use
3. For example, the percentage of the total nitrogen available is a function of the method of manure application and management as well as the age and chemical composition of the manure. Nitrogen content ranges from 35% of the total nitrogen if the manure is spread and left on the soil surface, to 60% if the manure is spread and worked into the soil within a day. Phosphorus is 60% and potassium 90% of totals.

1. This slide shows a manure pile that is mostly bedding material.
2. Large amounts of bedding in manure will have a high carbon and low nitrogen content. This can tie up usable nitrogen.
3. A supplemental source of nitrogen may be needed to offset any nutrient imbalance.
4. Avoid applying manure during the wet season.

1. Your manure and bedding is a potentially valuable resource.
2. Don't allow your valuable resource to end up in a landfill!
3. Disposing manure in a landfill is quite costly due to trucking, tipping and landfill-use fees.
4. Gardeners, landscapers, and small farms in your area may be seeking organic amendments.
5. An alternative is to work with other horse keepers and organizations to develop a community or regional composting facility.

1. Composting is an excellent way of disposing and recycling manure.
2. It is the natural microbial breakdown of organic materials into smaller particles forming new organic molecules.
3. Composting manure may do the following:
    a. Decrease waste volume up to 50%
    b. Make handling waste easier
    c. Create demand for a product that could otherwise be a liability.

4. Composting is a managed process. Merely piling manure for some undetermined time is not composting!

Good Composting can Reduce the Risk of Manure To Water Quality by:

- *Reduction and elimination* of microbial pathogens
- *Reduction* of ammonia N-levels
- *Reduction* in water-soluble phosphorus
- *Reduction* of water-soluble organic matter (BOD)
- *Reduction* in total soluble salts

Livestock & Land Program

www.livestockandland.org

Nine (9) Month Follow-Up Survey: Technical Trainings

Livestock and Land

Name: _____

Date: _____

If you HAVE implemented practices from the workshop:

1 Which workshop(s) did you attend?

- ☐ **October 30, 2010** Livestock, Land & Water Quality
  Plemmons Ranch, **Salinas**
- ☐ **November 6, 2010** Healthy Pastures & Paddocks
  River View Ranch, **Salinas**
- ☐ **November 13, 2010** Manure Management & Site Planning
  River View Ranch, **Salinas**
- ☐ **February 12, 2011** Livestock BMPs & Site Planning
  Stillman Ranch, **Morgan Hill**
- ☐ **January 15, 2011** Manure Management
  Quicksilver Farms, **Hollister**
- ☐ **January 22, 2011** Mud & Erosion
  101 Livestock, **Aromas**
- ☐ **January 29, 2011** Pastures & Paddocks
  Slonaker Ranch, **Hollister**
- ☐ **February 26, 2011**
  Combat mud, Combat manure, Go Green
  Aptos Academy, **Aptos**

2 What Best Management Practices (BMPs) have you implemented since the workshop?

- ☐ Manure Management:
  - ☐ Manure Bunker
  - ☐ Increased frequency of pick-up
  - ☐ Other: _____

  Type of animals: _____

  Qty of animals: _____
- ☐ Paddock improvements
- ☐ Erosion and runoff improvements
- ☐ Gutters and Downspouts
  - ☐ Added
  - ☐ Replaced
  - ☐ Repaired
- ☐ Re-seeded pasture
- ☐ Rotational grazing
- ☐ Cross fencing
- ☐ Grassed waterway
- ☐ Sacrifice area
- ☐ Rainwater catchment
- ☐ Filter / buffer strip
- ☐ Diversions / underground outlets
  (ie French drains, rolling dips)
- ☐ Other: (list below)

Descriptive detail of BMPs: _____

_____

_____

3 Shared Learning's: How is the Best Management Practice (BMP) functioning?

BMP 1: _____

- ☐ As expected
- ☐ Better than expected
- ☐ Needs improvements
- ☐ Worse than expected
- ☐ Other: *(describe below)*

BMP 2: _____

- ☐ As expected
- ☐ Better than expected
- ☐ Needs improvements
- ☐ Worse than expected
- ☐ Other: *(describe below)*

BMP 3: _____

- ☐ As expected
- ☐ Better than expected
- ☐ Needs improvements
- ☐ Worse than expected
- ☐ Other: *(describe below)*

BMP 4: _____

- ☐ As expected
- ☐ Better than expected
- ☐ Needs improvements
- ☐ Worse than expected
- ☐ Other: *(describe below)*

Additional Information: _____

_____

_____

_____

4 Has it improved conditions?

- ☐ Yes
- ☐ No
- ☐ Undecided

5 What were your goals for implementing the Best Management Practice(s)?

- ☐ Improving animal health
- ☐ Improving chore efficiency
- ☐ Improving safety
- ☐ Reducing flies
- ☐ Reducing mud buildup
- ☐ Reducing erosion
- ☐ Improving water quality
- ☐ Enhancing land aesthetics
- ☐ Increasing property value
- ☐ Other:_____

6 Have your goals been met?

- ☐ Yes
- ☐ No
- ☐ Not yet / uncertain

7 Did you contact any of the demonstration sites prior or during implementation?

- ☐ Yes
  - **a.** Which site was contacted? _____
  - **b**. How was it helpful?
    - ☐ Yes
    - ☐ No
- ☐ No
- ☐ Unaware of this option

Additional Information: _____

_____

_____

_____

8 Did you have a site visit from National Resource Conservation Services?

- ☐ Yes
- ☐ No
- ☐ During a previous grant cycle
- ☐ Unaware of this option

Additional Information: _____

_____

_____

_____

9 Have you shared any information about the program with other livestock owners?

- ☐ Yes
  How many? _____
- ☐ No

Additional Information: _____

_____

_____

_____

10 **Would you be interested in attending any future workshops?**

- ☐ Yes
  - ☐ 1/2 day trainings
  - ☐ Additional technical workshops
    - *Suggested topics?* _____
  - ☐ HOOFS events
- ☐ No
- ☐ Undecided

11 **What changes would you like to see in our workshops?**

- ☐ Different workshop topics (explain below)
- ☐ Different speakers
- ☐ Different locations
- ☐ Other (explain below)

Additional Information: _____

12 **Are you interested in this type of programming continuing? Why or why not?**

Additional Information: _____

13 **Why should funding exist for this type of programming?**

Additional Information: _____

14

Would you be willing to confidentially share available information so that we can estimate load reduction using the L&L Load Reduction Model on the Best Management Practices you have implemented?
Information will be shared anonymously with the funder to highlight the positive impacts of a voluntary, non-regulatory program.

Additional Information: _____

15 **Are you interested in developing a site plan and/or doing a self assessment of your property?**

☐ Yes

☐ No

Additional Information: _____

_____

_____

_____

16 **Do you need any additional assistance?**

Additional Information: _____

_____

_____

_____

17 **Would you like to include any additional information about your challenges or successes regarding your implementation efforts?**

Additional Information: _____

_____

_____

_____

18 **Would you be willing to provide photos of your implementation site?**

We can travel out to take photos, or you can send photos in

☐ Yes

☐ No

Additional Information: _____

_____

_____

_____

APPENDIX 3-B-4

TUOLUMNE COUNTY RESOURCE CONSERVATION DISTRICT

Demonstration/Pilot Project Materials

MARIN COUNTY DEPARTMENT OF PUBLIC WORKS
FLOOD CONTROL & WATER CONSERVATION DISTRICT

HORSE FACILITY BMP
CHECKLIST FOR TMDL PLANNING

Date of Visit: Time: Weather: Evaluated By:

Watershed: _____

Facility Information

Facility Name: _____ Operator/Contact: _____

Address: _____ Owner (if different): _____

_____ Telephone: _____

Nearest Creek: _____ Fax: _____

Facility/storage distance from creek: _____ ft.

Quantity of Horses: _____ Size of Facility: _____ (acres) Horses per Acre: _____

FACILITY OBSERVATIONS

Buildings

Rain Gutters ❑ Yes ❑ No
Condition (if installed)
- ❑ Good/Functional
- ❑ Bad/Needs repair

Maintenance (if installed)
- ❑ Clean/Unobstructed
- ❑ Obstructed/Needs cleaning

Downspouts ❑ Yes ❑ No
Condition (if installed)
- ❑ Good/Functional
- ❑ Bad/Needs repair

Maintenance (if installed)
- ❑ Clean/Unobstructed
- ❑ Obstructed/Needs cleaning

Gutter Water Diversion
- ❑ Away from paddocks
- ❑ Away from manure piles
- ❑ Away from ponds
- ❑ Gutter water not diverted

Comments: _____

Water Conveyance

Type
- ❑ Open ditch
- ❑ Culvert
- ❑ Grassy swale
- ❑ Other _____

Flows to
- ❑ Sheet flow into grass
- ❑ Sheet flow into dirt
- ❑ Flows directly into creek

Condition
- ❑ Good/Functional
- ❑ Bad/Needs repair

Maintenance
- ❑ Clean/Unobstructed
- ❑ Obstructed/Needs Cleaning

Typical Water Velocity (if known)
- ❑ Low to normal, no erosion
- ❑ Normal to high some erosion
- ❑ High with erosion present

Pollution Status/Potential
- ❑ **No** pollution discharge present/potential
- ❑ Pollution discharge present/potential

Non-point Pollution Source (if present)
- ❑ Erosion/Sedimentation
- ❑ Manure storage
- ❑ Horse stalls/paddock
- ❑ Horse pasture
- ❑ Compost pile/bins
- ❑ Other _____

Runoff through corrals/manure
- ❑ Completely diverted
- ❑ Partially diverted
- ❑ Not diverted
- ❑ Most percolates in ground

BMPs Employed (describe below)
- ❑ Berms
- ❑ Open ditches
- ❑ Grassy Swales
- ❑ Other: _____

❑ Check if no BMPs used/installed

Reasons for not using BMPs
- ❑ No time
- ❑ No money
- ❑ No expertise
- ❑ No interest

Comments: _____

Manure Management

Onsite Collection

Paddock	Pasture
❑ Collected daily	❑ Collected daily
❑ 2 to 3 times/week	❑ 2 to 3 times/week
❑ Weekly	❑ Weekly
❑ Biweekly	❑ Biweekly
❑ Monthly	❑ Monthly
❑ Not collected	❑ Not collected

Onsite Storage ❑ Manure not stored onsite/hauled away

Manure Volume	Containment
❑ <5 CY	❑ Well contained
❑ 5 to 10 CY	❑ Not well contained
❑ 10 to 25 CY	❑ Not contained
❑ 25 to 50 CY	❑ Pervious bottom
❑ 50 to 100 CY	❑ Impervious bottom
❑ >100 CY	❑ Covered

Composting Operations ❑ No onsite composting (if checked, describe reasons below*)

Irrigation	Irrigation Run-Off Containment	Irrigation Run-Off Destination	*Reasons for not Composting
❑ Regularly	❑ Well contained	❑ Completely contained	❑ Not interested
❑ Irregularly	❑ Not well contained	❑ Open dirt area	❑ No room
❑ Sparsely	❑ Not contained	❑ Grassy area/swale	❑ No expertise
❑ Not irrigated	❑ Pervious bottom	❑ Channeled to a creek	❑ No resources/equipment
❑ Water unavailable	❑ Impervious bottom	❑ Culverted to creek	❑ Interested in trying

Comments: _____

Nearby Creek/Watershed Information

❑ There is no creek or water body nearby

Creek Classification	Animal Access	Riparian Zone Condition
❑ Perennial	❑ Animals fenced out of creek	❑ Shaded with trees & shrubs: ____ %
❑ Intermittent	❑ Feed locations away from water	❑ Low-lying vegetation: ____ %
❑ Ephemeral	❑ Animals have access to creek	❑ Minimal to no vegetation: ____ %
❑ Natural Swale	❑ Animals are within the creek area	❑ **Native** vegetation: ____ %
	❑ Creek impaired by animals	❑ **Non-native** vegetation: ____ %

Manure Storage Proximity	Manure Affect on Water Quality	BMP Effectiveness
❑ Storage >100-ft away	❑ No impairment/potential present	❑ Effective in pollution prevention
❑ Storage >50-ft away	❑ Potential impairment	❑ Partially effective
❑ Storage within 50-ft	❑ Creek is impaired	❑ Marginally effective
❑ Storage next to/within watercourse	❑ Pollution discharge present	❑ Not effective

BMPs Employed: _____

Comments: _____

Paddock Mud Management

❑ No muddy conditions occur around paddocks/pastures

- ❑ Horses are not kept in muddy paddocks or pastures
- ❑ BMPs are employed to prevent or eliminate mud
- ❑ Potential muddy conditions in winter/rain months
- ❑ Owner requests follow-up onsite winter inspection

BMPs Employed: _____

Comments: _____

Implementation Site Selection Criteria and Application Review

Livestock and Land

Reviewed by: _____ Date of visit: _____

Primary Property Owner / Lessee: _____ Cooperator No: _____

Secondary Property Owner / Lessee: _____ Telephone: _____

Site Location: _____

Private Ranch ☐ Boarding Facility ☐ Public Access Property ☐

Property is: Owned ☐ Leased ☐ *If leased, permission will be required from property owner.*

Circle only one per each category with the most applicable rating next to each item.

#	Objectives	Rank	Criteria
1	Has the applicant completed a L&L workshop series? *(During past grant cycles and/or in other program regions are acceptable)*	10	Yes
		0	No
			Other *(list suggested points and provide expanation below)*
	Notes: *Consideration of points may be given for Peer Leader participation, attendance at similar workshops to the L&L program (i.e. rangeland workshops), etc.*		
2	Identified area(s) of impact distance from waterway. _____ ft.	10	Waterway runs through impact area
		9	Within 10'
		8	10 - 20'
		7	20 - 30'
		6	40 - 50'
			Other *(list suggested points and provide expanation below)*
	Notes:		
3	Is the project located in a local priority or 303(d) listed or TAC identified local priority watershed addressing Nutrients, Pathogens and/or Sediments? *(see attached list)*		*Local priority watershed:*
		10	With adopted TMDL
		9	With known pending TMDL
		8	303(d) listed
		4	Priority area identified only by TAC
		0	Not listed *(list in notes section name of watershed and proximity of project to watershed)*
	Notes:		

#	Objectives	Rank	Criteria
4	Estimated percent reduction in NUTRIENTS transported off-site utilizing the Load Modeling Tool.	8	91-100%
		7	86-90%
		6	84-85%
	%: _____	5	80%
	Total volume reduced: _____ pounds	2	50-79% *(In notes section, list any reason why site should be potentially funded)*
		0	0-49%
	Skip question if not applicable. *(points will not be counted against overall project)*		
		2	**Bonus Points:** Located within priority watershed for this constituent.
	Notes:		
5	Estimated percent reduction in PATHOGENS (Fecal Coliform) transported off-site utilizing the Load Modeling Tool.	8	91-100%
		7	86-90%
		6	84-85%
	%: _____	5	80%
	Total volume reduced: _____ colonies	2	50-79% *(In notes section, list any reason why site should be potentially funded)*
		0	0-49%
	Skip question if not applicable. *(points will not be counted against overall project)*		
		2	**Bonus Points:** Located within priority watershed for this constituent.
	Notes:		
6	Estimated percent reduction in SEDIMENTS transported off-site utilizing the Load Modeling Tool.	8	91-100%
		7	86-90%
		6	84-85%
	%: _____	5	80%
	Total volume reduced: _____ tons	2	50-79% *(In notes section, list any reason why site should be potentially funded)*
		0	0-49%
	Skip question if not applicable. *(points will not be counted against overall project)*		
		2	**Bonus Points:** Located within priority watershed for this constituent.
	Notes:		
7	Estimated reduction in POTENTIAL POLLUTANT LOADS (Manure) utilizing the Load Modeling Tool.	8	90-100%
		7	80-89%
		6	70-79%
	%: _____	5	60-69%
	Total volume reduced: _____ tons	4	50-59%
		3	40-49%
		2	30-39%
	Skip question if not applicable (points will not be counted against overall project)	0	0-29%
		2	**Bonus Points:** Located within priority watershed for this constituent.
	Notes:		

#	Objectives	Rank	Criteria
8	Does project represent BMPs that have not currently been implemented within County/Region?	10	Opportunity for new BMPs + mulitiple BMPs to showcase. Fits TAC goals/objectives for region.
		8	Opportunity for new BMPs + no other BMPs to showcase. Fits TAC goals/objectives for region.
		5	BMPs have been implemented during past funding cycles, however, have a high potential to meet/exceed program goals.
		3	BMPs have been implemented during past funding cycles.
	Notes:		
9	Does the site have good visibility and location for program implementation?	5	Site has high visibility and is compatible with program accessibilty.
		3	Site has LOW visibility and is compatible with program accessibility.
		0	Site is not ideal for visibility or location *(please list reason in notes section)* .
	Notes:		
10	Is the site suitable for workshops and site tours?	5	Can accommodate 30 people or more.
		3	Can accommodate 15-29 people.
		0	Can accommodate less than 15 people.
	Notes:		
11	Considering permitting, owner funding, contractors and size of project, when can owner/project be ready for implementation if application is selected?	10	Less than 30 days
		5	More than 30 days
		1	Over 60 days
	Question is intended to reflect project rediness within construction season. Timelines may need to be adjusted accordingly.	0	Unknown
	Notes:		
12	Anticipated cost of needed improvements *(total cost includes match)* :	5	$0 - $10,000
		3	$10,001 - $20,000
		1	Greater than $20,000
	Notes:		
13	Cost/Benefit Analysis: (see appendix A)	15	90th percentile of total applicants
		13	80th percentile of total applicants
		12	70th percentile of total applicants
		10	60th percentile of total applicants
			Other *(list suggested points and provide expanation below)*
	Notes:		

#	Objectives	Rank	Criteria
14	Has a Water Quality Site Plan been completed?	10	Yes
		0	No
	Notes:		
15	Has NRCS, RCD or other technical resource completed a site visit?	5	Yes
		0	No
	Notes:		
16	Other		*list suggested points and provide expanation below*
		0	No
	Notes:		

For office use only:

Total available points: _____

Total points accumulated: _____

Scoring percentage: _____

Overall ranking: _____ of _____

Additonal Notes:

Appendix A
Implementation Site Selection: Cost/Benefit Analysis
Livestock and Land

Reviewed by: _____ Date of visit: _____

Cooperator No: _____

1 **MANURE:**

0 tons PRESENT annual load	-	0 tons PROPOSED annual load	=	0 tons Annual Quantity Diverted	
$0.00 Total cost of BMP(s)	÷	0 tons Annual Quantity Diverted	=	#DIV/0! per ton *(1 year diversion)* Cost per quantity diverted	
				#DIV/0! per pound *(1 year diversion)* Cost per quantitiy diverted	

Notes:

2 **NUTRIENTS:**

0 pounds PRESENT annual load	-	0 pounds PROPOSED annual load	=	0 pounds Annual Quantity Diverted	
$0.00 Total cost of BMP(s)	÷	0 pounds Annual Quantity Diverted	=	#DIV/0! per ton *(1 year diversion)* Cost per quantity diverted	
				#DIV/0! per pound *(1 year diversion)* Cost per quantitiy diverted	

Notes:

3 **PATHOGENS:**

0 billion colonies PRESENT annual load	-	0 billion colonies PROPOSED annual load	=	0 billion colonies Annual Quantity Diverted	
$0.00 Total cost of BMP(s)	÷	0 billion colonies Annual Quantity Diverted	=	#DIV/0! per billion colonies *(1 year diversion)* Cost per quantity diverted	

Notes:

4	**SEDIMENTS:**				
	0 tons PRESENT annual load	-	0 tons PROPOSED annual load	=	0 tons Annual Quantity Diverted
	$0.00 Total cost of BMP(s)	÷	0 tons Annual Quantity Diverted	=	#DIV/0! per ton *(1 year diversion)* Cost per quantity diverted
					#DIV/0! per pound *(1 year diversion)* Cost per quantitiy diverted
	Notes:				

For office use only:

Overall ranking: _____ of _____

Additonal Notes:

Natural Resources Conservation Service
744 A La Guardia
Salinas, California 93905
Ph: (831) 424-1036; Fax: (831) 424-7289

"Helping People Help the Land"

xxxxxxxx, 20xx

Mr. xxxxxxxx & Mrs. xxxxxxxx xxxxxxxxx
xxxxxxxxxxx Rd
xxxxxxxxxx, xx xxxxx

SUBJECT: Equestrian Facility

Dear xxxx & xxxxx:

As a follow-up to our meeting on xxxxxxxxx, 20xxx at your property, we are happy to provide you with the following report.

AGENCIES & REPRESENTATIVES AT SITE VISIT

Resource Conservation District of xxxxxxxxx County (RCDxxx) – xxxxxxxxxx (Livestock Project Coordinator, Livestock & Land Program);
USDA Natural Resources Conservation Service (NRCS) – Susan Hoey Lees (Civil Engineering Technician and Livestock & Land Consultant, Salinas Service Center);
Ecology Action – Nick Sudano

NATURE OF REQUEST

The landowner made a request via the Resource Conservation District xxxxxxxxxxx County (RCDxxxx) for USDA Natural Resources Conservation Service (NRCS) technical assistance in evaluating drainage/mud, and manure management system options on an existing equestrian facility with multiple barn/shelter locations for equines.

BACKGROUND DATA

The overall property boundary encompasses approx xxxxx acres in size. The existing barns/shelters, adjacent and proposed paddock facilities will occupy approximately xxxx acres and will usually house xxx horses.

The existing ranch facility has a barn and paddocks (dry lots, no vegetation in paddocks) with shed type roof systems on additional shelters. The current fencing type is a combination of wood, wire and electric with metal or electric gate elements.

The existing potable water source for the residence and equine facilities is an onsite well system on the property, upslope from the residence.

The primary native soils within the equestrian areas on the property are the Arnold loamy sand, 9 to 15 percent slopes (covering 83% of the xxx acres), and the Arnold loamy sand, 15 to 50 percent slopes (covering 17% of the xxxx acres) soils. There is typically a restrictive bedrock layer approximately 48" below the surface. A brief soils report on these soil types are enclosed, along with the soil map which illustrates the estimated perimeter of the area of focus of this facility.

The main limiting factors of the soil (the Arnold loamy sands) are the low water holding capacities and the tendency for these soils to be somewhat excessively drained. Another characteristic of these soil types is the low to very low runoff classifications. These characteristics are of significant importance in a region that receives rainfall ranging from 14-16" annually (averaged).

The area immediately upslope of this parcel and the focus area also share these same soils, limitations and drainage characteristics for both surface and subsurface drainage concerns.

The soils in your region tend to drain downward quickly and tend to reach their water holding capacity quickly during continued rain events, the water then moves laterally along the restrictive layer until it reaches an area of less resistance and weeps to the surface. Collecting this lateral movement of water from the upper slopes draining toward your facilities and paddock areas with drainage infrastructure and increasing vegetation on all bare surfaces will be key elements in reducing the amount of mud generation and erosion issues on your facility areas.

LANDOWNER GOALS & OPPORTUNITIES

The landowner desires recommendation/assistance with; selecting a site for a manure management/bunker system, options for reduction of mud and erosion on to facility as well as fencing and rotational grazing solutions.

Additional goals and opportunities discussed with the landowner were: equipment storage locations, well water protection zones, exclusionary fencing, toxicity of Black Walnut tree elements, and implementation of increased manure management protocols.

RECOMMENDATIONS

1. A Filter Strip planting of dense grasses along the south and southeast property lines is needed to trap sediments and uptake nutrients and pollutants before they leave the property. These areas must be in permanent vegetation and should not be grazed any shorter than 4" in height – this may require a temporary electric fencing to limit horse grazing of these areas in particular or taken offline completely.

2. Roof runoff water should be collected and diverted away from structures, with down spouts with first flush devices then either connected to a solid tightline drainpipe system (separate from the French Drain lines) and daylighting at the south filter strip near the property lines low point, or connected to a Rain catchment system (at minimum this should include rain gutters, down spouts with first flush devices, piping to tanks, valves to isolate tanks and overflow pipe systems to daylight at property low point).

3. Landowner may choose to have the rain catchment system designed to accept additional tanks if desired at a later date to take advantage of full potential annual rainwater capture capabilities. Rough estimate of annual volume of rainfall that can be used for facility use (such as pasture irrigation) is as follows:

    a. Approximate Annual Rainfall: 14"-16" (16" (1.33') of rainfall will be used in these calculations)
    b. Approximate Barn roof area: 1,300 square feet
    c. Shelter/Shed roof area: 288 square feet
    d. Yearly volume of roof runoff in cubic feet:
        i. (1588 Sq. Ft)x(1.33 Ft)=2,112 cubic feet of water
    e. Yearly volume for annual rainfall in gallons:
        i. Convert cubic feet to Gallons: (2,112 cu. Ft. water)x(7.48 gal./cu. Ft water)=15,798 gal

4. It is strongly recommended that no other drainwater sytems tie into the French Drain system, ie gutter flows or overflow systems.

5. Upgrade/repair the existing French Drain systems;

    a. one on the north side of the barn and shelters should be increased in depth & width and upgraded with filter fabric between soil and drain rock with perforated pipes connected to a solid walled drainpipe tightline that daylights to a filter strip near the south property line
    b. the second existing French Drain along toe of cut bank on the NW side of the round pen with a perforated pipe. The perforated pipe can be connected to a solid walled pipe crossing the paddock and day-lighting to a filter strip along the SE fence line. This will significantly reduce subsurface upland water(s) from saturating the roundpen area and may reduce downslope seepages.

6. Prep and Seed the cut bank along the upper slope of the cut bank on the NW side of the round pen, keep it in permanent vegetation to control erosion and slumping. Seasonal maintenance of hand mowing with a trimmer may be required on this bank.

7. Consider exclusionary fencing along the upper slope of the cut bank on the NW side of the round pen to keep livestock off of the cut bank and to protect the upgraded French Drain system at the toe of this cut bank. Also consider fencing around the black walnut tree or it is strongly recommended that removal of the tree be undertaken due to the high toxicity of all parts of the tree to horses.

8. It is strongly recommended that a hardened paddock/sacrifice area be developed and strictly used in conjunction with a rotational grazing plan.

9. It is strongly recommended that the existing paddocks be cross fenced, prepared and seeded to establish vegetation on all bare surfaces except the hardened/sacrifice paddocks to reduce erosion of soils.

10. Converting stalls runs to heavy use protection/hardened footing paddocks is also strongly recommended for mud, erosion/sediment and nutrient management. This conversion will also assist with the ease of equine manure management practices/cleanup.

11. Add drain and drainpipe to wash-rack area. Daylight graywater at a permanently vegetated area away from septic or vegetable garden areas, armor outlet if at top of slope or consider creating a biofiltration garden to process graywater.

12. Manure Management should be done on a daily basis. This will extend the useable life of the hardened footing/sacrifice areas, improve pasture health and reduce nutrient runoff from these areas.

13. Manure Bunker system options; one that can be built on site or a smaller, portable manufactured system were discussed with you and various locations were discussed as well (see map). Each location had pro's and con's associated with it.
    - Where existing equipment is near residence:
        - Pro's:
            - hard surfaces exist
            - no additional grading required
            - level area, easy of working with equipment around facility
        - Con's
            - Vicinity to water well, if leachate escaped hard surfaces water well could be at risk
            - Farthest away from source of manure
            - Uphill from manure sources
            - Relocation of equipment and materials from this area required
    - Above Barn in nearly level area:
        - Pro's:
            - Little to minimal grading required for bunker system
            - Adjacent to greatest source of manure (stalls)
        - Con's
            - Additional grading or surfacing from driveway to facility required
            - Slope of driveway at this location may be a concern
            - Uphill from manure sources
    - Below Barn in nearly level area:
        - Pro's
            - Little to minimal grading required for bunker system
            - Adjacent to greatest source of manure (stalls)
            - Downhill from manure sources
            - Minimal surfacing from driveway to facility required
            - Driveway slope minimal at this location
        - Con's
            - Adjacent to neighbor access point
            - Closer to property lowpoint
            - Leachate, if escaped, could have significant impact to adjacent waterway

14. Composting may be a viable option for your facility to be able to utilize the compost on the vegetated pastures. You still may have excess materials to be hauled off site, due to an imbalance of the number of

horses to area of lands you can spread composted materials on.

15. Consider reducing the number of permanent stock on the facility. It is strongly recommended that the current stock number on this facility not be increased.

SPECIAL NOTES

First flush downspout devices are important to keep debris from entering, contaminating or clogging of drainpipes or water storage tanks. The combination of the French drain and rain gutter/catchment systems are both vital components to reducing the generation of mud on your facility for your soil type and profile.

ADDITIONAL NOTES

The Natural Resources Conservation Service (NRCS) is one of the oldest government agencies of its kind. It is an agency that was essentially initiated by landowners during the "Dust Bowl" era of the 1930s. NRCS helps private landowners and land users throughout the United States and Pacific Trust territories to voluntarily conserve soil, water, air, plant, animal, wildlife and related resources.

The NRCS provides conservation technical assistance, administers conservation programs and is a non-regulatory federal agency under the U.S. Department of Agriculture (USDA). All NRCS services are made available to land users, without service fees. In xxxxxxxxx County, NRCS works closely with, and is co-located with the Resource Conservation District (RCDxxx) of xxxxxxxxxx County. The RCDxxx is a local special district organized under California Public Resource Code Division 9. The NRCS is an equal opportunity provider and employer.

The NRCS does not enforce laws or ordinances, issue permits, or respond to complaints in a regulatory manner. Individuals who receive advice and council from NRCS are responsible for compliance with all laws, ordinances and permit requirements.

The NRCS protects the confidentiality of its clients, customers and of the public according to agency policy and by the protections stipulated by the Freedom of Information Act.

The Natural Resources Conservation Service makes no representation on the existence or non-existence of any utilities. It is the property owner's or land user's responsibility to contact the Underground Service Alert Office (USA) at 1-800-642-2444 for information regarding location of underground utilities when conducting any activity that involves soil disturbances and excavations.

Information provided on practices that are structural in nature is advisory and should not be considered as complete construction specifications. The property owner/land user is responsible for any further technical assistance that might be necessary.

For more information regarding NRCS and RCDxxx services and programs you can contact the Salinas Service Center: 831-424-1036 ext 122 (NRCS my extension); xxx-xxx-xxxx ext xxx (xxxxxxxxx, RCDxxx); or visit us on line at: www.ca.nrcs.usda.gov .

If you have any questions regarding my field summary, visit, or any of the enclosures then please don't hesitate to contact me.

Sincerely,

USDA NATURAL RESOURCES CONSERVATION SERVICE

Susan Hoey Lees
Civil Engineering Technician
Ph: 831-424-1036 ext:122

744A La Guardia Street
Salinas, CA 93905

Enclosures

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

COMPOSTING FACILITY

(No.)

CODE 317

DEFINITION

A structure or device to contain and facilitate the controlled aerobic decomposition of manure or other organic material by micro-organisms into a biologically stable organic material that is suitable for use as a soil amendment.

PURPOSE

To reduce the pollution potential and improve the handling characteristics of organic waste solids; and produce a soil amendment that adds organic matter and beneficial organisms, provides slow-release plant-available nutrients, and improves soil condition.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies where:

- Organic waste material is generated by agricultural production or processing.
- The facility is a component of a planned waste management system;
- The facility can be constructed, operated and maintained without polluting air and/or water resources; and,
- The compost can be applied to the land or marketed to the public.

CRITERIA

General Criteria Applicable to All Purposes

Laws and Regulations. Install and operate the facility in compliance with all federal, state and local laws, rules and regulations.

Safety. Incorporate safety and personal protection features and practices into the facility and its operation as appropriate to minimize the occurrence of equipment and biosecurity hazards during the composting process.

Facility Siting. Locate on a base of low permeability soils, concrete, or other liner material that will not allow contamination of ground water. The floor of the composting facility shall be at least two feet above the seasonal high water table.

Locate outside of floodplains when practical; otherwise protect the facility from inundation or damage from a 25-year flood event.

Locate so that prevailing winds and landscape elements minimize odors and protect visual resources.

Direct surface runoff away from the compost facility. Direct contaminated runoff from the composting operation to an appropriate storage or treatment facility for further management.

Locate so that water is available to the facility during dry periods to ensure proper moisture and acceptable curing times to meet the management goals.

Facility Type. Select the type of composting facility or method based on the type and availability of raw material, the desired quality of finished compost, equipment, labor, time and land available.

Meet the structural requirements of conservation practice standard 313, Waste Storage Facility when designing slabs, walls, and support structures. Meet the requirements of conservation practice standard 367, Roofs and Covers when designing roofs.

Facility Size. Size the composting facilities to accommodate the amount of raw material planned for active composting, with a capacity consistent with the composting processes that will be used to produce the desired compost product, and with sufficient finishing time as required to achieve the desired characteristics. Space for compost storage may be included in the finishing space or in a separate facility. Select dimensions to accommodate handling and processing.

A facility for manure and other agricultural organic waste that is to be used on the farm shall have the capacity to produce compost that can be safely stored without undesirable odors. This requires the temperature of the compost to be maintained above 104°F for five days with at least four hours above 130°F during that time period.

A facility to produce compost for use off the farm or for sale shall have the capacity to significantly reduce pathogens. For a static pile or within vessel facility this requires the temperature of the compost to be maintained above 130°F for three days. The total compost period shall include time for the initial primary stage of composting and time for secondary stage composting. For a windrow system this requires the temperature of the compost to be above 130°F for 15 days with a minimum of five turnings of the compost.

If the facility is to be used to compost animal carcasses it shall have the capacity to maintain the compost temperature greater than 130° F for at least 5 days as an average throughout the compost mass followed by a compatible time for secondary composting. For a windrow system the temperature of the compost shall be above 130°F for 15 days with a minimum of five turnings of the compost. Size animal mortality composting facilities according to the methods provided in the National Engineering Handbook Part 637, Chapter 2 – Composting (NEH 637.0213, Dead Animal Composting), National Engineering Handbook Part 651, Agricultural Waste Management Field Handbook, Chapter 10 Mortality Management (NEH 651.1007), NRCS or comparable extension publication. Base the size of dead animal composting facilities on normal mortality loss records for the operation. If these data are not available use locally established mortality rates for the type of operation. Ensure that the final product of the composting process has no visible pieces of soft tissue remaining.

Use of Finished Compost. Land application of finished compost shall be in accordance with conservation practice standard 590, Nutrient Management; or conservation practice standard 633, Waste Utilization.

CONSIDERATIONS

To reduce offensive odors increase the carbon nitrogen ratio. A carbon nitrogen ration of 30:1 in the initial mix should have minimal odors.

Minimize odors and nitrogen loss by selecting carbonaceous material that, when blended with the nitrogenous material, provides a balance of nutrients and porous texture for aeration.

A chemical neutralizing or other additive agent should be used if structural components do not provide adequate odor reduction.

Maximize solar warming by aligning piles north to south configured with moderate side slopes.

Orient windrows to prevent ponding of surface runoff.

Protect compost facilities from the wind in cold or dry climates. Wind protection may help prevent excess drying of the compost.

Minimize blown in rain by providing roof overhang.

For facilities that are organic producers or that sell compost to organic producers, ensure that the treated lumber used in the stacking facility meets the requirements for organic production. It may be best to have the producer consult with the organic certifier as to the use and acceptability of treated lumber for litter and compost storage.

PLANS AND SPECIFICATIONS

Prepare plans and specifications in accordance with the criteria of this standard and describe the requirements for applying

the practice to achieve its intended use, including:

- Layout and location of livestock facilities, waste collection points, and/or waste transfer
- Size, type and number of animals or other sources of organic feedstock
- Grading plan showing excavation, fill, and drainage, as appropriate
- Size and capacity needed
- Design requirements
- Safety requirement for operation

OPERATION AND MAINTENANCE

Develop an operation and maintenance plan that is consistent with the purposes of this practice and the life of the composting facility. Recipe ingredients and the sequence that they are to be layered and mixed shall be given in the plan.

Compost Mix. Develop a compost mix that encourages aerobic microbial decomposition and avoids nuisance odors.

Carbon-Nitrogen Ratio. The initial compost mix shall result in a carbon to nitrogen (C:N) ratio between 25:1 and 40:1. Compost with a lesser carbon to nitrogen ratio can be used if nitrogen mobilization is not a concern.

Carbon Source. Store a dependable source of carbonaceous material with a high C:N ratio to mix with nitrogen rich waste materials.

Bulking Materials. Add bulking materials to the mix as necessary to enhance aeration. The bulking material may be the carbonaceous material used in the mix or a non-biodegradable material that is salvaged at the end of the compost period. Make provision for the salvage of any non-biodegradable material used in the composting process.

Moisture Level. Maintain adequate moisture in the compost mix throughout the compost period within the range of 40 to 65 percent (wet basis). Prevent excess moisture from accumulating in the compost in high precipitation climatic regions. This may require the facility to be covered.

Temperature of Compost Mix. Manage the compost to attain and then maintain the internal temperature for the duration required to meet management goals. It may be necessary for the compost to reach 145°F to adequately destroy weed seeds. Closely monitor temperatures above 165°F. Take action immediately to cool piles that have reached temperatures above 185°F.

Turning/Aeration. The frequency of turning/aeration shall be appropriate for the composting method used, and to attain the desired amount of moisture removal and temperature control while maintaining aerobic degradation.

Monitoring: The operation and maintenance plan shall state that composting is a biological process that needs monitoring and management throughout the composting period to insure proper composting processes. The operation may need to undergo some trial and error in the start-up of a new composting facility. Manage the compost piles for temperature, odors, moisture, and oxygen, as appropriate. Test the finished compost as appropriate to assure that the required decomposition has been reached.

REFERENCES

USDA, NRCS. 2000. National Engineering Handbook, Part 637, Chapter 2, Composting. Washington, D.C.

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NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

SUBSURFACE DRAIN

(Ft.)

CODE 606

DEFINITION

A conduit installed beneath the ground surface to collect and/or convey excess water.

PURPOSE

This practice may be applied as part of a resource management system to achieve one or more of the following purposes:

- Remove or distribute excessive soil water.
- Remove salts and other contaminants from the soil profile.

CONDITIONS WHERE PRACTICE APPLIES

This standard applies to agricultural land where a shallow water table exists and where a subsurface drainage system can mitigate the following adverse conditions caused by excessive soil moisture:

- Poor health, vigor and productivity of plants.
- Poor field trafficability.
- Accumulation of salts in the root zone.
- Health risk and livestock stress due to pests such as flukes, flies, or mosquitoes.
- Wet soil conditions around farmsteads, structures, and roadways.

This standard applies where a suitable outlet is available considering the quantity and quality of collected excess water.

CRITERIA

Capacity. Design capacity shall be based on the following, as applicable:

- Application of a locally proven drainage coefficient for the acreage drained.
- Yield of groundwater based on the expected deep percolation of irrigation water from the overlying fields.
- Comparison of the site with other similar sites where subsurface drain yields have been measured.
- Measurement of the rate of subsurface flow at the site during a period of adverse weather and groundwater conditions.
- Application of Darcy's law to lateral or artesian subsurface flow.
- Contributions from surface inlets based on hydrologic analysis or flow measurements

Size. The size of subsurface drains shall be computed by applying Manning's formula, using roughness coefficients recommended by the manufacturer of the conduit. The size shall be based on the maximum design flow rate and computed using one of the following assumptions:

- The hydraulic grade line parallel to the bottom grade of the subsurface drain with the conduit flowing full at design flow (normal condition, no internal pressure).
- Conduit flowing partly full where a steep grade or other conditions require excess capacity.
- Conduit flowing under internal pressure with hydraulic grade line set by site conditions, which differs from the bottom grade of the subsurface drain.

All subsurface drains shall have a nominal diameter that equals or exceeds 3 inches.

Internal Hydraulic Pressure. Drains are normally designed to flow with no internal pressure, and the flow is normally classified as open channel. The design internal pressure of drains shall not exceed the limits

Conservation practice standards are reviewed periodically and updated if needed. To obtain the current version of this standard, contact your Natural Resources Conservation Service State Office or visit the Field Office Technical Guide.

recommended by the manufacturer of the conduit.

Horizontal Alignment. A change in horizontal direction of the subsurface drain shall be made by one of the following methods:

1. The use of manufactured fittings.
2. The use of junction boxes or manholes.
3. A gradual curve of the drain trench on a radius that can be followed by the trenching machine while maintaining grade.

Location, Depth, and Spacing. The location, depth, and spacing of the subsurface drain shall be based on site conditions including soils, topography, groundwater conditions, crops, land use, outlets, saline or sodic conditions, and proximity to wetlands.

The minimum depth of cover over subsurface drains may exclude sections of conduit near the outlet or through minor depressions, providing these sections of conduit are not subject to damage by frost action or equipment travel.

In mineral soils, the minimum depth of cover over subsurface drains shall be 2.0 feet.

In organic soils, the minimum depth of cover after initial subsidence shall be 3.0 feet. If water control structures are installed and managed to limit oxidation and subsidence of the soil, the minimum depth of cover may be reduced to 2.5 feet.

For flexible conduits, maximum burial depths shall be based on manufacturer's recommendations for the site conditions, or based on a site-specific engineering design consistent with methods in NRCS National Engineering Handbook (NEH), Part 636, Chapter 52, Structural Design of Flexible Conduits.

For computation of maximum allowable loads on subsurface drains of all materials, use the trench and bedding conditions specified, and the compressive strength of the conduit. The design load on the conduit shall be based on a combination of equipment loads, trench loads, and road traffic, as applicable.

Equipment loads shall be based on the maximum expected wheel loads for the equipment to be used, the minimum height of cover over the conduit, and the trench width.

Equipment loads on the conduit may be neglected when the depth of cover exceeds 6 feet. Trench loads shall be based on the type of backfill over the conduit, the width of the trench, and the unit weight of the backfill material.

Minimum Velocity and Grade. In areas where sedimentation is not a hazard, minimum grades shall be based on site conditions and a velocity of not less than 0.5 feet per second. If a sedimentation hazard exits, a velocity of not less than 1.4 feet per second shall be used to establish the minimum grades. Otherwise, provisions shall be made for preventing sedimentation by use of filters or by collecting and periodically removing sediment from installed traps, or by periodically cleaning the lines with high-pressure jetting systems or cleaning solutions.

Maximum Velocity. Design velocities for perforated or open joint pipe shall not exceed those given in Table 1, unless special protective measures are installed. Design velocities with protective measures shall not exceed manufacturer's recommended limits.

Table 1. Maximum Flow Velocities by Soil Texture.

Soil Texture	Velocity, ft./sec.
Sand and sandy loam	3.5
Silt and silt loam	5.0
Silty clay loam	6.0
Clay and clay loam	7.0
Coarse sand or gravel	9.0

Ref: NEH 624, Chapter 4, Subsurface Drainage.

On sites where topographic conditions require drain placement on steep grades and design velocities greater than indicated in Table 1, special measures shall be used to protect the conduit or surrounding soil.

Protective measures for high velocities shall include one or more of the following, as appropriate:

1. Enclose continuous perforated pipe or tubing with fabric type filter material or properly graded sand and gravel.

2. Use non-perforated continuous conduit or a watertight pipe, and sealed joints.
3. Place the conduit in a sand and gravel envelope, or initial backfill with the least erodible soil available.
4. Select rigid butt end pipe or tile with straight smooth sections and square ends to obtain tight fitting joints.
5. Wrap open joints of the conduit with tar-impregnated paper, burlap, or special fabric-type filter material.
6. Install larger diameter drain conduit in the steep area to help assure a hydraulic grade line parallel with the conduit grade.
7. Install open air risers for air release or entry at the beginning and downstream end of the high velocity section.

Releases from drainage water management structures shall not cause flow velocities in perforated or open joint drains to exceed allowable velocities in Table 1, unless protective measures are installed.

Thrust Control. Follow pipe manufacturer's recommendations for thrust control or anchoring, where the following conditions exist:

- Axial forces that tend to move the pipe down steep slopes.
- Thrust forces from abrupt changes in pipeline grade or horizontal alignment, which exceed soil bearing strength.
- Reductions in pipe size.

In the absence of manufacturer's data, thrust blocks shall be designed in accordance with NEH, Part 636, Chapter 52, Structural Design of Flexible Conduits.

Outlets. Drainage outlets shall be adequate for the quantity and quality of water to be discharged.

Outlets to surface water shall be designed to operate without submergence under normal conditions.

For discharge to streams or channels, the outlet invert shall be located above the elevation of normal flow and at least 1.0 foot above the channel bottom.

Outlets shall be protected against erosion and undermining of the conduit, entry of tree roots, damaging periods of submergence, and entry of rodents or other animals into the subsurface drain.

A continuous section of pipe without open joints or perforations, and with stiffness necessary to withstand expected loads, shall be used at the outlet end of the drain line. Minimum lengths for the outlet section of conduit are provided in Table 2. Single-wall Corrugated Plastic Pipe is not suitable for the section that outlets into a ditch or channel.

For outlets into sumps, the discharge elevation shall be located above the elevation at which pumping is initiated.

Table 2. Minimum Length of Outlet Pipe Sections.

Pipe Diameter, in.	Min. Section Length, ft.
8 and smaller	10
10 to 12	12
15 to 18	16
Larger than 18	20

The use and installation of outlet pipe shall conform to the following requirements:

- If burning vegetation on the outlet ditch bank is likely to create a fire hazard, the material from which the pipe is fabricated must be fireproof.
- At least two-thirds of the pipe section shall be buried in the ditch bank, and the cantilever section must extend to the toe of the ditch side slope, or the side slope shall be protected from erosion.
- If ice or floating debris may damage the outlet pipe, the outlet shall be recessed to the extent that the cantilevered part of the pipe will be protected from the current of flow in the ditch or channel.
- Headwalls used for subsurface drain outlets must be adequate in strength and design to avoid washouts and other failures.

Protection from Biological and Mineral Clogging. Drains in certain soils are subject to clogging of drain perforations by bacterial action in association with ferrous iron, manganese, or sulfides. Iron ochre can clog

drain openings and can seal manufactured (fabric) filters. Manganese deposits and sulfides can clog drain openings.

Where bacterial activity is expected to lead to clogging of drains, access points for cleaning the drain lines shall be provided.

Where possible, outlet individual drains to an open ditch to isolate localized areas of contamination and to limit the translocation of contamination throughout the system.

Protection from Root Clogging. Problems may occur where drains are in close proximity to perennial vegetation. Drain clogging may result from root penetration by water-loving trees, such as willow, cottonwood, elm, soft maple, some shrubs, grasses, and deep-rooted perennial crops growing near subsurface drains.

The following steps may reduce the incidence of root intrusion:

- Install a continuous section of non-perforated pipe or tubing with sealed joints, through the root zone.
- Remove water-loving trees for a distance of at least 100 feet on each side of the drain, and locate drains a distance of 50 feet or more from non-crop tree species.
- Provide for intermittent submergence of the drain to limit rooting depth by installing a structure for water control (e.g. an inline weir with adjustable crest) that allows for raising the elevation of the drain outlet.

Water Quality. Septic systems shall not be directly connected to the subsurface drainage system, nor shall animal waste be directly introduced into the subsurface drainage system.

Materials. Subsurface drains include flexible conduits of plastic, bituminized fiber, or metal; rigid conduits of vitrified clay or concrete; or other materials of acceptable quality.

The conduit shall meet strength and durability requirements for the site. All conduits shall meet or exceed the minimum requirements of the appropriate specifications published by the American Society for Testing and Materials (ASTM), American Association of State Highway Transportation Officials (AASHTO), or the American Water Works Association (AWWA).

Foundation. If soft or yielding foundations are encountered, the conduits shall be stabilized and protected from settlement. The following methods are acceptable for the stabilization of yielding foundations:

- Remove the unstable material and provide a stable bedding of granular envelope or filter material.
- Provide continuous cradle support for the conduit through the unstable section.
- Bridge unstable areas using long sections of conduit having adequate strength and stiffness to ensure satisfactory subsurface drain performance.
- Place conduit on a flat, treated plank. This method shall not be used for flexible (e.g. Corrugated Plastic Pipe) without proper bedding between the plank and conduit.

Filters and Filter Material. Filters shall be used around conduits, as needed, to prevent movement of the surrounding soil material into the conduit. The need for a filter shall be determined by the characteristics of the surrounding soil material, site conditions, and the velocity of flow in the conduit. A suitable filter shall be used if any of the following conditions exist:

- Local experience with soil site conditions indicates a need.
- Soil materials surrounding the conduit are dispersed clays, silts with a Plasticity Index less than 7, or fine sands with a Plasticity Index less than 7.
- The soil is subject cracking by desiccation.
- The method of installation may result in inadequate consolidation between the conduit and backfill material.

If a sand-gravel filter is specified, the filter gradation shall be designed in accordance with NEH, Part 633, Chapter 26, Gradation Design of Sand and Gravel Filters.

Specified filter material must completely encase the conduit such that all openings are covered with at least 3 inches of filter material, except where the top of the conduit and side filter material are be covered by a sheet of plastic or similar impervious material to reduce the quantity of filter material required. In all cases, the resulting flow pattern through filter

material shall be a minimum of 3 inches in length.

Geotextile filter materials may be used, provided that the effective opening size, strength, durability, and permeability are adequate to prevent soil movement into the drain throughout the expected life of the system. Geotextile filter material shall not be used where the silt content of the soil exceeds 40 percent.

Envelopes and Envelope Material. Envelopes shall be used around subsurface drains if needed for proper conduit bedding or to improve flow characteristics into the conduit.

Materials used for envelopes do not need to meet the gradation requirements of filters, but they must not contain materials that will cause an accumulation of sediment in the conduit, or materials that will render the envelope unsuitable for bedding of the conduit.

Envelope materials shall consist of sand-gravel, organic, or similar material. 100 percent of sand-gravel envelope materials shall all pass a 1.5-inch sieve; not more than 30 percent shall pass a Number 60 sieve; and not more than 5 percent shall pass the Number 200 sieve.

Organic or other compressible envelope materials shall not be used below the centerline of flexible conduits. All organic or other compressible materials shall be of a type that will not readily decompose.

Placement and Bedding. Placement and bedding requirements apply to both excavation trenching and plow type installations.

Place the conduit on a firm foundation to ensure proper alignment.

Conduits shall not be placed on exposed rock, or on stones greater than 1½ inches for conduits 6 inches or larger in diameter, or on stones greater than ¾ inch for conduit less than 6 inches in diameter. Where site conditions do not meet this requirement, the trench must be over-excavated a minimum of 6 inches and refilled to grade with a suitable bedding material.

If installation will be below a water table or where unstable soils are present, special equipment, installation procedures, or bedding materials may be needed. These special requirements may also be necessary to prevent soil movement into the drain or plugging of the envelope, if installation will be made in materials such as soil slurries.

For the installation of Corrugated Plastic Pipe with diameters of 8 inches or less, one of the following bedding methods shall be specified:

1. A shaped groove providing an angle of support of 90 degrees or greater shall be provided in the bottom of the trench for tubing support and alignment.
2. A sand-gravel envelope, at least 3 inches thick, to provide support.
3. Compacted bedding material beside and to 3 inches above the conduit.

For the installation of Corrugated Plastic Pipe with diameters larger than 8 inches, the same bedding requirements shall be met except that a semi-circular or trapezoidal groove shaped to fit the conduit with a support angle of 120 degrees will be used rather than a V-shaped groove.

For rigid conduits installed in a trench, the same requirements shall be met except that a groove or notch is not required. For trench installations where a sand-gravel or compacted bedding is not specified, the initial backfill for the conduit shall be selected material containing no hard objects (e.g. rocks or consolidated chunks of soil) larger than 1.5 inches in diameter. Initial backfill shall be carried to a minimum of 3 inches above the conduit.

Auxiliary Structures and Protection. The capacity of any structure installed in the drain line shall be no less than that of the line or lines feeding into or through them.

Structures for water table management, with provisions to elevate the outlet and allow submergence of the upstream drain, shall meet applicable design criteria in NRCS Conservation Practice Standards, Structure for Water Control (587), and Drainage Water Management (554).

If the drain system is to include underground outlets, the capacity of the surface water inlet shall not be greater than the maximum design flow in the downstream drain line or lines. Covers or trash racks shall be used to ensure that no foreign materials are allowed in the drain lines. Inlets shall be protected from entry

of animals or debris. If sediment may pose a problem, sediment traps shall be installed.

The capacity of a relief well system shall be based on the flow from the aquifer, the well spacing, and other site conditions, and shall be adequate to lower the artesian water head to the desired level. Relief wells shall not be less than 4 inches in diameter.

Junction boxes, manholes, catch basins, and sand traps must be accessible for maintenance. A clear opening of not less than 2.0 feet will be provided in either circular or rectangular structures.

The drain system shall be protected against turbulence created near outlets, surface inlets or similar structures. Continuous non-perforated or closed-joint pipe shall be used in drain lines adjoining the structure where excessive velocities will occur.

Junction boxes shall be installed where three or more lines join or if two lines join at different elevations. If the junction box is buried, a solid cover should be used, and the junction box should have a minimum of 1.5 feet of soil cover. Buried boxes shall be protected from traffic.

If not connected to a structure, the upper end of each subsurface drain line will be closed with a tight-fitting cap or plug of the same material as the conduit, or other durable materials.

Watertight conduits designed to withstand the expected loads shall be used where subsurface drains cross under irrigation canals, ditches, or other structures.

CONSIDERATIONS

When planning, designing, and installing this practice, the following items should be considered:

- Protection of shallow drains, auxiliary structures, and outlets from damage due to freezing and thawing.
- Proper surface drainage to reduce the required intensity of the subsurface drainage system.
- Designs that incorporate drainage water management practices (or facilitate its future incorporation) to reduce nutrient loading of receiving waters.
- Drainage laterals oriented along elevation contours to improve the effectiveness of drainage water management structures.
- The effects of drainage systems on runoff volume, seepage, and the availability of soil water needed for plant growth.
- Confirmation of soil survey information with site investigation, including auguring and shallow excavations to identify soil profile hydraulic characteristics, soil texture layering, water table depth, etc.
- The effects of drainage systems on the hydrology of adjacent lands.
- Subsoiling or ripping of soils with contrasting texture layers to improve internal drainage.
- Installations in dry soil profile to minimize problems of trench stability, conduit alignment, and soil movement into the drain.
- The effects to surface water quality.
- Use of temporary flow blocking devices to reduce risk of drain water contamination from surface applications of manure.

PLANS AND SPECIFICATIONS

Plans and specifications for installing subsurface drains shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose.

At a minimum, plans specifications shall include, as applicable: location of drainage system; wetland delineation(s); conduit lengths, grades, sizes, and type of materials; structure locations, dimensions, and elevations; outlet locations, elevations, and protection required; and normal water level elevations in outlet ditches or streams.

OPERATION AND MAINTENANCE

The Operation and Maintenance (O&M) Plan shall provide specific instructions for operating and maintaining the system to insure proper function as designed. At a minimum, the O&M Plan shall address:

- Necessary periodic inspection and prompt repair of system components (e.g. structures for water control, underground

outlets, vents, drain outlets, trash and rodent guards).

- Winterization protection from freezing conditions for drainage systems in cold climates.

REFERENCES

USDA-NRCS, National Engineering Handbook, Part 624, Chapter 4, Subsurface Drainage.

USDA-NRCS, National Engineering Handbook, Part 633, Chapter 26, Gradation Design of Sand and Gravel Filters.

USDA-NRCS, National Engineering Handbook, Part 636, Chapter 52, Structural Design of Flexible Conduits.

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

FENCE

(Ft.)

CODE 382

DEFINITION

A constructed barrier to animals or people.

PURPOSE

This practice facilitates the accomplishment of conservation objectives by providing a means to control movement of animals and people, including vehicles.

CONDITIONS WHERE PRACTICE APPLIES

This practice may be applied on any area where management of animal or human movement is needed.

CRITERIA

General Criteria Applicable to All Purposes

Fencing materials, type and design of fence installed shall be of a high quality and durability. The type and design of fence installed will meet the management objectives and site challenges. Based on need, fences may be permanent, portable, or temporary.

Fences shall be positioned to facilitate management requirements. Ingress/egress features such as gates and cattle guards shall be planned. The fence design and installation should have the life expectancy appropriate for management objectives and shall follow all federal, state and local laws and regulations.

Height, size, spacing and type of materials used will provide the desired control, life expectancy, and management of animals and people of concern.

CONSIDERATIONS

The fence design and location should consider: topography, soil properties, livestock management and safety, livestock trailing, wildlife class and movement, location and adequacy of water facilities, development of potential grazing systems, human access and safety, landscape aesthetics, erosion problems, moisture conditions, flooding potential, stream crossings, and durability of materials. When appropriate, natural barriers should be utilized instead of fencing.

Where applicable, cleared rights-of-way may be established which would facilitate fence construction and maintenance. Avoid clearing of vegetation during the nesting season for migratory birds.

Fences across gullies, canyons or streams may require special bracing, designs or approaches.

Fence design and location should consider ease of access for construction, repair and maintenance.

Fence construction requiring the removal of existing unusable fence should provide for the proper disposal of scrap materials to prevent harm to animals, people and equipment.

This practice is likely to occur in areas where cultural resources or endangered species habitat may be found. Follow NRCS Planning Policy to address these concerns.

PLANS AND SPECIFICATIONS

Plans and specifications are to be prepared for all fence types, installations and specific sites. Requirements for applying the practice to achieve all of its intended purposes shall be described.

Conservation practice standards are reviewed periodically and updated if needed. To obtain the current version of this standard, contact your Natural Resources Conservation Service State Office or visit the Field Office Technical Guide.

OPERATION AND MAINTENANCE

Regular inspection of fences should be part of an ongoing maintenance program. Inspection of fences after storms and other disturbance events is necessary to ensure the continued proper function of the fence. Maintenance and repairs will be performed in a timely manner as needed, including tree/limb removal and water gap replacement.

Remove and properly discard all broken fencing material and hardware. All necessary precautions should be taken to ensure the safety of construction and maintenance crews.

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NRCS, CA

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NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

FILTER STRIP

(Ac.)

CODE 393

DEFINITION

A strip or area of herbaceous vegetation that removes contaminants from overland flow.

PURPOSE

- Reduce suspended solids and associated contaminants in runoff.
- Reduce dissolved contaminant loadings in runoff.
- Reduce suspended solids and associated contaminants in irrigation tailwater.

CONDITIONS WHERE PRACTICE APPLIES

Filter strips are established where environmentally-sensitive areas need to be protected from sediment, other suspended solids and dissolved contaminants in runoff; in areas situated below cropland, grazing land, or disturbed land (including forest land); and in areas where permanent vegetative establishment is needed to enhance wildlife and beneficial insects, or maintain or enhance watershed function.

This practice applies when planned as part of a conservation management system.

CRITERIA

General Criteria Applicable to All Purposes

Filter strips shall be designated as vegetated areas to treat runoff and are not part of the adjacent cropland rotation.

Overland flow entering the filter strip shall be uniform sheet flow. Concentrated flow shall be dispersed before entering the filter strip.

State listed noxious weeds will not be established in the filter strip and will be controlled if present. Filter strips shall not be used as a travel lane for equipment or livestock.

Filter strip establishment shall comply with local, state and federal regulations.

Additional criteria to reduce sediment, particulate organics and sediment-adsorbed contaminant loadings in runoff

Filter strip flow length shall be determined based on field slope percent and length, and filter strip slope percent, erosion rate, amount and particle size distribution of sediment delivered to the filter strip, density and height of the filter strip vegetation, and runoff volume associated with erosion producing events. The minimum flow length for this purpose shall be 20 feet.

Filter strip location requirements:

- The filter strip shall be located along the downslope edge of a field or disturbed area. To the extent practical it shall be placed on the approximate contour. Variation in placement on the contour should not exceed a 0.5% longitudinal (perpendicular to the flow length) gradient.
- The drainage area above the filter strip shall have greater than 1% but less than 10% slopes.
- The filter strip will be designed to have a 10-year life span, following the procedure in the Agronomy Technical Note No. 2 (Using RUSLE2 for the Design and Predicted Effectiveness of Vegetative Filter Strips (VFS) for Sediment), based on the sediment delivery in RUSLE2 to the upper

edge of the filter strip and ratio of the filter strip flow length to the length of the flow path from the contributing area.

- The ratio of the drainage area to the filter strip area shall be less than 70:1 in regions with RUSLE-R factor values 0-35, 60:1 in regions with RUSLE-R factor values 35-175, and 50:1 in regions with RUSLE-R factor values of more than 175.
- The average annual sheet and rill erosion rate above the filter strip shall be less than 10 tons per acre per year

Vegetation. The filter strip shall be established to permanent herbaceous vegetation.

Species selected shall be:

- able to withstand partial burial from sediment deposition and
- tolerant of herbicides used on the area that contributes runoff to the filter strip.

Species selected shall have stiff stems and a high stem density near the ground surface.

Species selected for seeding or planting shall be suited to current site conditions and intended uses. Selected species will have the capacity to achieve adequate density and vigor within an appropriate period to stabilize the site sufficiently to permit suited uses with ordinary management activities.

Species, rates of seeding or planting, minimum quality of planting stock, such as PLS or stem caliper, and method of establishment shall be specified before application. Only viable, high quality seed or planting stock will be used.

Site preparation and seeding or planting shall be done at a time and in a manner that best ensures survival and growth of the selected species. What constitutes successful establishment, e.g. minimum percent ground/canopy cover, percent survival, stand density, etc. shall be specified before application.

Planting dates shall be scheduled during periods when soil moisture is adequate for germination and/or establishment.

The minimum seeding and stem density shall be equivalent to a high quality grass hay seeding rate for the climate area or the density of vegetation selected in RUSLE2 to determine trapping efficiency, whichever is the higher seeding rate.

Additional Criteria to Reduce Dissolved Contaminants in Runoff

The criteria given in “Additional criteria to reduce sediment, particulate organics and sediment adsorbed contaminant loadings in runoff” for location, drainage area and vegetation characteristics also apply to this purpose.

Filter strip flow length required to reduce dissolved contaminants in runoff shall be based on management objectives, contaminants of concern, and the volume of runoff from the filter strip’s drainage area compared with the filter strip’s area and infiltration capacity.

The flow length determined for this purpose shall be in addition to the flow length determined for reducing sediment, particulate organics and sediment-adsorbed contaminant loadings in runoff.

The minimum flow length for this purpose shall be 30 feet.

Additional Criteria to Serve as Zone 3 of a Riparian Forest Buffer, Practice Code 391

Except for the location requirements, the criteria given in **“Additional criteria to reduce sediment, particulate organics and sediment adsorbed contaminant loadings in runoff”** also apply to this purpose.

If concentrated flows entering Zone 3 are greater than the filter strip’s ability to disperse them, other means of dispersal, such as spreading devices, must be incorporated.

Additional Criteria to Reduce Sediment, Particulate Organics and Sediment-adsorbed Contaminant Loadings in Surface Irrigation Tailwater

Filter strip vegetation may be a small grain or other suitable annual with a plant spacing that does not exceed 4 inches.

Filter strips shall be established early enough prior to the irrigation season so that the vegetation can withstand sediment deposition from the first irrigation.

The flow length shall be based on management objectives with a minimum flow length of 20 feet.

Additional Criteria to Restore, Create or Enhance Herbaceous Habitat for Wildlife and Beneficial Insects

If this purpose is intended in combination with one or more of the previous purposes, then the minimum criteria for the previous purpose(s) must be met.

Additional filter strip flow length devoted to this purpose must be added to the length required for the other purpose(s).

Any addition to the flow length for wildlife or beneficial insects shall be added to the downhill slope of the filter strip.

Vegetation to enhance wildlife may be added to that portion of the filter strip devoted to other purposes to the extent they do not detract from its primary functions.

Plant species selected for this purpose shall be for permanent vegetation adapted to the wildlife or beneficial insect population(s) targeted.

If this is the only purpose, filter strip width and length shall be based on requirements of the targeted wildlife or insects. Density of the vegetative stand established for this purpose shall consider targeted wildlife habitat requirements and encourage plant diversity. Dispersed woody vegetation may be used to the extent it does not interfere with herbaceous vegetative growth, or operation and maintenance of the filter strip.

The filter strip shall not be mowed during the nesting season of the target wildlife.

Livestock and vehicular traffic in the filter strip shall be excluded during the nesting season of the target species.

Additional Criteria to Maintain or Enhance Watershed Functions and Values

Filter strips shall be strategically located to enhance connectivity of corridors and non-cultivated patches of vegetation within the watershed.

Filter strips shall be strategically located to enhance aesthetics of the watershed.

Plant species selected for this purpose shall be for establishment of permanent vegetation.

CONSIDERATIONS

Filter strips should be strategically located to reduce runoff, and increase infiltration and ground water recharge throughout the watershed.

Filter strip width (flow length) can be increased as necessary to accommodate harvest and maintenance equipment.

Filters strips with the leading edge on the contour will function better than those with a gradient along the leading edge.

Seeding rates that establish a higher stem density than the normal density for a high quality grass hay crop will be more effective in trapping and treating contaminants.

Creating, Restoring or Enhancing Herbaceous Habitat for Wildlife and Beneficial Insects and Pollinators. Filter strips are often the only break in the monotony of intensively-cropped areas. The wildlife and pollinator benefits of this herbaceous cover can be enhanced by:

- Increasing the width beyond the minimum required, and planting this additional area to species that can provide food and cover for wildlife and pollinators. This additional width should be added on the downslope side of the filter strip.
- Adding herbaceous plant species to the filter strip seeding mix that are beneficial to wildlife and pollinators and be compatible for one of the listed purposes. Changing the seeding mix should not detract from the purpose for which the filter strip was established.
- Filter strips for the single purposes of wildlife/beneficial insect habitat or to enhance watershed function should be strategically located to intercept contaminants thereby enhancing air and water quality.

To avoid damage to the filter strip consider using vegetation that is somewhat tolerant to herbicides used in the up-slope crop rotation.

Consider using this practice to enhance the conservation of declining species of wildlife,

including those that are threatened or endangered.

Consider using this practice to protect National Register listed or eligible (significant) archaeological and traditional cultural properties from potential damaging contaminants.

Select grass species that sequester more carbon. Increasing the width of filter strip will increase the potential for carbon sequestration.

PLANS AND SPECIFICATIONS

Based on this standard, plans and specifications shall be prepared for each specific field site where a filter strip will be installed. A plan includes information about the location, construction sequence, vegetation establishment, and management and maintenance requirements.

Specifications shall include:

a) Length, width, and slope of the filter strip to accomplish the planned purpose (length refers to flow length across the filter strip).

b) Species selection and seeding or sprigging rates to accomplish the planned purpose

c) Planting dates, care and handling of the seed to ensure that planted materials have an acceptable rate of survival

d) A statement that only viable, high quality and regionally adapted seed will be used

e) Site preparation sufficient to establish and grow selected species

OPERATION AND MAINTENANCE

For the purposes of filtering contaminants, permanent filter strip vegetative plantings should be harvested as appropriate to encourage dense growth, maintain an upright growth habit and remove nutrients and other contaminants that are contained in the plant tissue.

Control undesired weed species, especially state-listed noxious weeds.

Prescribed burning may be used to manage and maintain the filter strip when an approved burn plan has been developed.

Inspect the filter strip after storm events and repair any gullies that have formed, remove unevenly deposited sediment accumulation that will disrupt sheet flow, reseed disturbed areas and take other measures to prevent concentrated flow through the filter strip.

Apply supplemental nutrients as needed to maintain the desired species composition and stand density of the filter strip.

To maintain or restore the filter strip's function, periodically regrade the filter strip area when sediment deposition at the filter strip-field interface jeopardizes its function, and then reestablish the filter strip vegetation, if needed. If wildlife habitat is a purpose, destruction of vegetation within the portion of the strip devoted to that purpose should be minimized by regrading only to the extent needed to remove sediment and fill concentrated flow areas.

Grazing shall not be permitted in the filter strip unless a controlled grazing system is being implemented. Grazing will be permitted under a controlled grazing system only when soil moisture conditions support livestock traffic without excessive compaction.

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NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

HEAVY USE AREA PROTECTION

(Ac.)

CODE 561

DEFINITION

The stabilization of areas frequently and intensively used by people, animals or vehicles by establishing vegetative cover, surfacing with suitable materials, and/or installing needed structures.

PURPOSE

- To provide a stable, non-eroding surface for areas frequently used by animals, people or vehicles
- To protect and improve water quality

CONDITIONS WHERE PRACTICE APPLIES

This practice applies to agricultural, urban, recreational and other frequently and/or intensively used areas requiring treatment to address one or more resource concerns.

CRITERIA

General Criteria Applicable to All Purposes

Plan and design heavy use areas to comply with federal, state, and local laws and regulations.

Design Load. Base the design load on the type and frequency of traffic, (vehicular, animal, or human) anticipated on the heavy use area.

Foundation. Evaluate all site foundations for soil moisture, permeability, texture and bearing strength based on the design load and planned frequency of use.

Where necessary, prepare the foundation by removal and disposal of materials that are not adequate to support the design loads.

Use a base course of gravel, crushed stone, other suitable material and/or geotextile on all sites that need increased load bearing strength, drainage, separation of material and soil reinforcement. Refer to Natural Resources Conservation Service (NRCS), National Engineering Handbook, Parts 642 and Design Note 24, Guide for Use of Geotextiles, for guidance on geotextile selection.

On sites with porous foundations (high permeability rate), with a need to protect ground water from contamination, provide an impervious barrier.

Surface Treatment. Select a surface treatment that is stable and appropriate to the purpose of the heavy use area. Surface treatments must meet the following requirements according to the material used.

Concrete. Design the thickness and compressive strength of concrete according to the expected loading and use. For installations where it is necessary to limit the permeability of the concrete, refer to NRCS NRCS Conservation Practice Standard, Waste Storage Facility (313) and ACI 360R-06, Design of Slabs-on-Ground, for design criteria for slabs on grade.

Bituminous Concrete Pavement. Refer to *AASHTO Guide for Design of Pavement Structures* or the applicable state department of highway's specification for design criteria for bituminous concrete paving.

In lieu of a site specific design, for areas that will be subject to light use, pave with a minimum of 4 inches of compacted bituminous concrete over a subgrade of at least 4 inches of well compacted gravel. Use bituminous

concrete mixtures commonly used for road paving in the area. Compact the surface with a heavy steel wheel roller until the bituminous concrete is thoroughly compacted and roller marks are eliminated.

Other Cementitious Materials. Other cementitious materials such as soil cement, roller compacted concrete, and coal combustion by-products (flue gas desulphurization sludge and fly ash) can be used to provide a durable, stable surfacing material. Develop site specific mix designs based on the properties of the material with compressive strengths necessary for the expected use and loading on the heavy use area.

Aggregate. Design fine or coarse aggregate surfaces at least 4-inches thick. If the surface will be compacted, choose a well graded aggregate.

Sprays and Artificial Mulches. When utilizing sprays of asphalt, oil, plastic, manufactured mulches, and similar materials, follow the manufacturer's recommendations for design requirements.

Other. Surfacing materials, such as limestone screenings, cinders, tanbark, bark mulch, brick chips, shredded rubber and/or sawdust, shall have a minimum layer thickness of 4 inches.

Structures. Design any structures associated with the heavy use area including roofs, according to appropriate NRCS standards**.** Where NRCS standards do not exist, design structures according to the requirements of the particular construction material and accepted engineering practice. Base environmental design loads for buildings associated with heavy use areas on criteria in ASCE 7 - Minimum Design Loads for Buildings and Other Structures: ASCE/SEI 7-05.

Drainage and Erosion Control. Include provisions in the design for surface and subsurface drainage, as needed. Include provisions for disposal of runoff without causing erosion or water quality impairment. To the extent possible, prevent runoff from entering the heavy use area.

Vegetative Measures. Where appropriate, stabilize all areas disturbed by construction with vegetation as soon as possible after construction. Refer to NRCS Conservation Practice Standard, Critical Area Planting (342). If vegetation is not appropriate for the site, use other measures to stabilize the area.

Additional Criteria for Livestock Heavy Use Areas

The treated area can include all areas where livestock congregate and cause surface stability problems. This includes feeding areas, portable hay rings, watering facilities, feeding troughs, mineral boxes and other facilities where livestock concentrations cause resource concerns.

Use NRCS Conservation Practice Standards Wastewater Treatment Strip (635), Manure Transfer (No.) (634), Critical Area Planting (342); Fencing (382); Prescribed Grazing (528); Filter Strip (393); Vegetated Treatment Area (635); Access Control (472) or other similar standards as companion practices, when needed to meet the intended purpose of the heavy use area protection.

Include provisions in the design of the heavy use area to collect, store, utilize and/or treat manure and contaminated runoff.

Additional Criteria for Recreation Areas

Heavy use protection in recreation areas that are accessible to the public must meet the requirements of the Americans with Disabilities Act.

CONSIDERATIONS

Heavy use areas can have a significant impact on adjoining land uses. These impacts can be environmental, visual and cultural. Care should be taken when selecting the type of treatment to ensure that it is compatible with adjoining areas. Consider such things as proximity to neighbors, utilities, cultural resources, environmentally sensitive areas and the land use where the stabilization will take place. Stabilization techniques used in a cattle feeding area may not be appropriate for a recreation area.

By its very nature, a heavy use area will be subject to intensive use. If vegetation will be part of the stabilization technique, consider the durability of the vegetation. Choose plant species that can withstand the expected use. Additional techniques such as geogrids, other

reinforcing techniques or planned periods of rest and recovery may need to be employed to ensure that vegetative stabilization will succeed.

Heavy use areas will be intensely used by animals, people or both. Consider the safety of the users both human and animal during the design. Avoid slippery surfaces, sharp corners or surfaces and structures that might entrap users. For heavy use areas used by livestock avoid the use of sharp aggregates that might injure livestock hooves.

For livestock heavy use areas, provide positive drainage to prevent ponding of water. Such wet areas can have adverse affects on animal health and comfort.

Heavy use area protection often involves paving or otherwise reducing the permeability of the heavily used area. This can reduce infiltration and increase surface runoff. Depending on the size of the heavy use area, this can have an impact on the water budget of the surrounding area. During the planning and design, consider the effects to ground and surface water.

Heavy use areas are places where animals, people or vehicles are concentrated. The resulting manure, sediments, bacteria, petroleum products and trash that might accumulate on the heavy use area can result in degraded runoff water quality. During planning and design consider how these pollutants will be handled to reduce offsite impacts.

To reduce the negative water quality impact of heavy use areas consider locating them as far as possible from waterbodies or water courses. In some cases this may require relocating the heavily used area rather than just armoring an area that is already in use.

Surface erosion can be a problem on large heavy use areas that do not use a hard surface such as concrete. In these cases the designer may need to include measures on the area that reduce the flow length of runoff to reduce erosion problems.

To reduce the potential for air quality problems from particulate matter associated with heavy use areas, consider the use of NRCS Conservation Practice Standards Windbreak/Shelterbelt Establishment (380), Herbaceous Wind Barriers (603) or the use of palliative treatments such as lignosulfonate, synthetic polymers, organic oils, or chloride compounds to control dust from bare heavy use areas.

Heavy use areas for livestock can vary widely in size depending on how the operator manages his livestock. Because heavy use areas can be expensive to construct and maintain, a significant consideration should be to reduce the size of the heavy use area as much as possible. This may require changes in how the livestock are managed but in the long run may result in less maintenance and a more efficient operation.

For areas that will need to be cleaned frequently by scraping, loose aggregate or other non-cementitious materials may not be the best choice. Consider a more durable surface such as concrete.

Byproducts from coal fired power plants such as fly ash and sludge from scrubbers can vary significantly. Therefore, their toxicity and cementation characteristics should be known to ensure they are compatible with the intended use.

PLANS AND SPECIFICATIONS

Prepare plans and specifications for Heavy Use Area Protection that describe the requirements for installing the practice according to this standard. As a minimum the plans and specifications shall include:

1. A plan view showing the location and extent of the practice.
2. Where appropriate, cross-sections showing the type and required thickness of paving or stabilization materials.
3. Where appropriate, plans for required structural details.
4. Where appropriate, vegetation establishment requirements.
5. Construction specifications that describe in writing site specific installation requirements for the heavy use area protection.

OPERATION AND MAINTENANCE

Prepare an operation and maintenance (O&M) plan for the operator. The minimum requirements to be addressed in the O&M plan are:

1. Periodic inspections, especially immediately following significant rainfall events.
2. Prompt repair or replacement of damaged components especially surfaces that are subjected to wear or erosion.
3. For livestock heavy use areas include requirements for the regular removal and management of manure.
4. Where vegetation is specified, periodic mowing, fertilization and control of vegetation.

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LIVESTOCK AND LAND

Healthy Management of Land and Livestock

Required Load Reduction Information

1. Date: _____

2. Site / Facility Reference Name: _____

3. Watershed: _____

4. Nearest Creek (name): _____

5. Size of Facility: _____ acres

6. Facility / Storage distance from creek: _____ ft

7. Stable / Covered Stalls or Roofed Areas:

Area: _____ ft^2

8. Pastures / Non-hardened Turnouts

A. Area: _____ ft^2

B. Soil type [1]

☐ Fine Sand ☐ Very Fine Sand ☐ Loamy Sand
☐ Sandy Loam ☐ Very Fine Sandy Loam ☐ Silt Loam
☐ Clay Loam ☐ Silty Clay Loam ☐ Silty Clay
☐ Compacted Base

C. Organic Matter [2]

☐ <0.5% ☐ 2% ☐ 4%

D. Slope: _____ %

E. Type of Cover:

☐ None ☐ Native Vegetation ☐ Grasses

F. Soil Loss[3]: _____ tons/year

9. Paddock / Hardened turnout areas and pens

A. Area: _____ ft^2

B. Soil type [1]

☐ Fine Sand ☐ Very Fine Sand ☐ Loamy Sand
☐ Sandy Loam ☐ Very Fine Sandy Loam ☐ Silt Loam
☐ Clay Loam ☐ Silty Clay Loam ☐ Silty Clay
☐ Compacted Base

C. Organic Matter [2]

☐ <0.5% ☐ 2% ☐ 4%

D. Slope: _____ %

E. Type of Cover:

☐ None ☐ Native Vegetation ☐ Grasses

F. Soil Loss[3]: _____ tons/year

10. Best Management Practices (BMPs)

A. Manure Management [4]

☐ 0% ☐ 20% ☐ 40% ☐ 60% ☐ 80% ☐ 100%

B. Exclusionary Fencing [5]

☐ 0% ☐ 20% ☐ 40% ☐ 60% ☐ 80% ☐ 100%

C. Pasture Management [6]

☐ 0% ☐ 20% ☐ 40% ☐ 60% ☐ 80% ☐ 100%

D. Roof Drainage Controls

☐ 0% ☐ 20% ☐ 40% ☐ 60% ☐ 80% ☐ 100%

11. Notes:

_____

_____

_____

_____

_____

Notes:

[1] Parameter may be derived from the Soil Survey (USDA 1980) for specific county of orgin

[2] Table 1. Universal Soil Loss Equation Soil Erosion Factor

Soil Type	Percent Organic Matter		
	<0.5	2	4
Fine Sand	0.16	0.14	0.1
Very Fine Sand	0.42	0.36	0.28
Loamy Sand	0.12	0.1	0.08
Sandy Loam	0.27	0.24	0.19
Very Fine Sandy Loam	0.47	0.41	0.33
Silt Loam	0.48	0.42	0.33
Clay Loam	0.28	0.25	0.21
Silty Clay Loam	0.37	0.32	0.26
Silty Clay	0.25	0.23	0.19
Compacted Base	0.14	0.12	0.1

[3] Table 2. Universal Soil Loss Equation Cover Factor

Type of Cover	C factor	Soil loss reduction (%)
None	1	0
Native Vegetation	0.01	99
Grasses	0.1	90

[4] Table 3. Manure Management Percent Implementation Guidelines

Percent Management	Manure Removal Practices	Manure Storage Features*
0%	Infrequent removal	No cover on a pervious surface
20%	2 times / week	Tarp cover on a pervious surface
40%	2 times / week	No cover on impervious surface
60%	Every other day	Tarp cover on impervious surface
80%	1 time / day	Permanent roof on pervious surface
100%	> 1 time / day	Permanent roof on impervious surface

*Assumes tarp or roof feature cover > or = 100% of footprint of manure pile

[5] Table 4. Exclusionary Fencing Percent Implementation Guidelines

Percent Management	Site Conditions
0%	No fencing
20%	Exclusion w/fenced stock crossing in water
40%	Fenced buffer to water way: 10' or less
60%	Fenced buffer to water way: >30' buffer
80%	Exclustion w/ fenced stock crossing over culvert
100%	No access to water: >50' setback / buffer

[6] Table 5. Pasture Management Percent Implementation Guidelines

Percent Management	Site Conditions
0%	No vegetation and no drainage controls
20%	Drainage controls with no vegetation
40%	Patchy / sparse vegetation with no drainage controls
60%	Vegetation with no drainage controls
80%	Patchy / sparse vegetation with proper drainage controls
100%	Significant vegetation year round and proper drainage controls

Equestrian Facility Best Management Practices
Predictive Analysis
User Guide

for

Manure and Erosion Pollution Prevention Program
Ecology Action
Santa Cruz, California

Prepared for:

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Appendix C: Equestrian BMPs Demonstration Sites Predictive Analysis Results

1. INTRODUCTION

1.1. Project Description

This predictive analysis is a spreadsheet model prepared by Fall Creek Engineering (FCE) for Ecology Action to be used by Ecology Action staff, Santa Cruz County agencies, and groups concerned with the water quality impacts of equestrian facilities. Ecology Action received grant funding from the Regional Water Quality Control Board for the Livestock and Land Program (LLP). This program partnered with local Resource Conservation Districts to help achieve water quality and watershed improvements by educating livestock owners in Santa Cruz, San Benito, South Santa Clara and Monterey Counties on best management practices (BMPs). Along with providing educational materials and workshops regionally, the LLP also provides cost share assistance to selected equestrian facilities that implement best management practices to reduce the export of non-source pollutants to nearby waterways. These facilities also agree to be used as demonstration sites, which provide a valuable resource for the community to see the management practices working.

The spreadsheet model was designed to help the LLP understand the impact of equestrian facility sites in Santa Cruz County and the effectiveness of implementing specific best management practices to improve water quality. This tool may also assist in determining which proposed projects should be granted funding, based on which projects can most effectively use BMPs.

This year, four demonstration sites were selected in Santa Cruz County. FCE analyzed the sites and estimated the annual pollutant loads that each site would have produced prior to and after implementing the management practices. Section 4 discusses these results.

1.2. Predictive Analysis Background

The predictive analysis is designed to be a user-friendly method to document and calculate the estimated effectiveness of best management practices. Manure management, exclusionary fencing, pasture management, drainage controls, and other equestrian BMPs can be implemented to reduce sediment, nutrients, pathogens, and other potential contamination of nearby waterways. This model also allows different runoff treatment options to be selected and analyzed to predict how they will reduce the impacts from equestrian facilities. The treatment BMPs include bioretention swales, filter strips, and vegetated swales. The model uses site specific information to compute annual loads for the amount of manure produced, as well as the primary constituents of concern, nutrients, pathogens, and sediment.

The annual loading of contaminants is calculated first using existing and proposed site conditions to quantify the sediment, pathogen, and nutrient generation at the site. Then, management practices are taken into consideration, applying removal efficiency from published studies to predict the effectiveness of best management practices at the respective site.

1.3. Constituents of Concern

The primary source of waterway pollution from equestrian facilities is from equine defecation, urination, and soil erosion. Manure and urine contains nutrients and pathogens that can affect water quality and intensive equine activities can contribute to soil erosion. The amount of manure and urine produced from an average 1000 pound horse is 50 pounds per day (MWPS, 2000).

1.3.1. Nutrients

Manure contains nitrogen and phosphorus, which can runoff to creeks stimulating algae blooms that consume the limited oxygen in the water, making it unavailable for fish. Ammonia found in horse urine can be toxic to aquatic life. The model uses nutrient loading values based on published data (MWPS, 2000) and represent average values reported for horses. Each day, an average adult horse can defecate approximately 0.28 pounds of nitrogen and 0.11 pounds of phosphorus.

1.3.2. Pathogens

Manure from horses contains bacteria and viruses that may impact water quality. Fecal coliform is generally used in water quality analysis as an indicator of potential pathogenic organisms. Streptococcus is bacteria also found in feces, which, depending on the species can cause strep throat, pneumonia, meningitis and many other infectious diseases. Published data from equestrian facilities show that 2.6×10^{11} and 4.2×10^{8} colonies of total streptococcus and fecal coliform are produced per day, respectively (EPA, 2008), respectively.

1.3.3. Sediment

Intensive confined animal facilities, heavy grazing, or pasture use can remove the vegetation, exposing the soil's surface. This can lead to increased soil erosion, transporting soil through rain, wind, and water runoff to streams and waterways where the sediment can adversely affect many aquatic habitats.

Poorly managed manure can also increase the solids loading, however, this additional load is considered to be negligible and in the model manure is not considered a contribution of sediment in the analysis.

The total amount of sediment lost is calculated based on the Universal Soil Loss Equation (USLE), which estimates the annual rate of erosion based on climatic data, soil characteristics, topography, and management practice or type of cover at each site. The *Erosion and Sediment Control Handbook* (Goldman, et. al., 1986) was used as the primary reference for the USLE and may provide the user with additional information if needed. In the spreadsheet a rainfall erosivity factor is calculated using a synthetic rainfall distribution for Type I storms for Santa Cruz County.

2. PREDICTIVE ANALYSIS INPUT DATA

The data used in the model calculations is derived from two sources: 1) the user input data based on site-specific information and 2) published data. This section describes the information needed to complete the spreadsheet for a specific site and provides some of the background data used in the model.

The model is designed on a Microsoft Excel spreadsheet with a tab labeled "Worksheet Calculations". On this worksheet, the user will input the data and be able to print out the sheet containing site information and the calculated annual loads for the site. See Appendix A for a sample of this print out.

The light blue highlighted areas in the "Worksheet Calculations" tab are the cells that require user input. The other cells in the worksheet are locked to prevent the user from altering or deleting important information in the form. There are drop down menus in some of the cells which allow the user to select from a list rather than entering arbitrary values. Comments are provided to the right of the spreadsheet, which do not print with the results. The information to be inputted is site specific, and therefore each new site should be saved under a different file name.

2.1. Facility Information

Each form requires input of the equestrian facility's basic contact information as well as specific site information that is likely presented in the initial review of projects. The facility information provides the user a reference of which facility the predictive analysis results are for, which should facilitate tracking data compiled using this model. There is also some information which is used in the equations to generate the results.

2.1.1. Watershed and Nearest Creek

This information identifies the nearest waterway and the watershed in which the facility is located.

2.1.2. Size of Facility

This value is a reference value that is used to calculate the number of horses per acre. For a facility to manage the site in an open range configuration, generally as a "rule of thumb", seven acres of grassland are needed for each horse. Most facilities in Santa Cruz County will not meet these requirements, and therefore other management practices may be needed to reduce the equine impacts.

2.1.3. Precipitation

The precipitation is found using the 2-year, 6-hour storm specific to each site. The user can extrapolate the precipitation (in inches) from the Figure 1 by finding the approximate site location in the County of Santa Cruz and the nearest isopluvial line(s) to extrapolate the precipitation. The map was prepared using the National Oceanic and Atmospheric Administration (NOAA) published Precipitation-Frequency Atlas, which is commonly used for precipitation information. The precipitation value is used in the USLE and can also give the user a relative idea of how much rainfall impacts the site, which may alter

the management practices selected. Since there is little or no snow in Santa Cruz County, the precipitation value given is sufficient to calculate runoff and no factor is used to account for snowmelt.

2.1.4. Facility/Storage Distance from Creek

This distance is used to calculate the amount of sediment that can be deposited or caught upland on the site before reaching the creek as part of the USLE and can also be considered the slope length across the site. To calculate the distance from the creek or drainage channel, the user should select the longest distance water flows across the equestrian facilities (eventually into a waterway).

2.1.5. Quantity of Horses

The number of horses at the facility can greatly affect the amount of manure generated, as well as, the management practices selected given the land available for each horse. If a site is too small for the existing quantity of horses, reducing the amount of horses could be considered a management practice and thus the user must input the present and proposed quantity of horses at the site. (The predictive analysis uses an average value of 50 pounds of manure per day per horse.)

2.2. Management Areas

The management areas are divided into three main categories: covered areas, non-hardened areas, and hardened areas. The covered areas include stables, covered stalls or manure bunkers, or other areas with roofs. These areas can contribute to erosion and sediment loss if proper drainage controls are not used. The pastures are categorized as non-hardened areas and should be vegetated year round, and are considered to have some residual dry matter or vegetation with an established root structure. Paddocks are categorized as hardened areas and are divided to distinguish differences in area, soil type, soil organic matter, slope or type of cover. For larger sites, with multiple soil types and different management areas throughout the site, multiple spreadsheets can be used to quantify the different areas and the management practices in each area.

Below are the descriptions for the input for these management areas. Two values are required for each input option; the present (existing) value and the proposed (after the improvements are implemented) value.

2.2.1. Area

This parameter describes the area in square feet of the various management areas and is used in the Universal Soil Loss Equation (USLE) to estimate the loss of soil (on annual basis) from erosion.

2.2.2. Soil Type and Organic Matter

These parameters describe the soil characteristics in the management areas. A drop down menu allows the user to choose from nine general soil types, as well as compacted base material, as listed in Table 1. The compacted base would be selected for areas, such as,

arenas or paddocks that were excavated and filled with a compacted course aggregate or compacted fill that would not allow for good infiltration of rainfall.

The second drop down menu allows the user to choose the percent of organic matter. Organic matter would occur in vegetated areas, such as grassed pasture. Typically, soil with less than 0.5% (<0.5) organic matter is considered to have a low organic matter and having 4 percent is considered to a have a relatively high organic content.

Soil type and percent organic matter are used to determine the soil erosion factor in the USLE, as seen in the Table 1 (adapted from US DOE, 2008). Compacted base was added to this information due to the fact that many sites use compacted base to harden the soil and values are approximated.

If the user is not familiar with soils on the site, these parameters can be derived from the Soil Survey for Santa Cruz County (USDA, 1980), which provide the soil type and the erosion factor. The user can choose the soil type which matches the site to the table below, or the user can find the erosion factor and select the nearest erosion factor to determine the soil type and percentage organic matter.

Table 1. Universal Soil Loss Equation Soil Erosion Factor

Soil Type	**Percent Organic Matter**		
	<0.5	**2**	**4**
Fine sand	0.16	0.14	0.1
Very fine sand	0.42	0.36	0.28
Loamy sand	0.12	0.1	0.08
Sandy loam	0.27	0.24	0.19
Very fine sandy loam	0.47	0.41	0.33
Silt loam	0.48	0.42	0.33
Clay loam	0.28	0.25	0.21
Silty clay loam	0.37	0.32	0.26
Silty clay	0.25	0.23	0.19
Compacted base	0.14	0.12	0.1

2.2.3. Slope

The site topography has a large influence on erosion and sediment transport. This parameter describes the slope at the site and the user can input the percent slope at the site using any number from 1 to 100, however, using land with slopes greater than 30 percent should be avoided because steep grades are difficult to manage and control runoff and erosion. In cases of varying slope, the average across the management area should be used. Slope and the distance from the creek (Section 2.1.4) are used to determine the topographic factor in the USLE.

2.2.4. Type of Cover

This parameter describes the type of vegetative cover established in the management areas. A drop down menu allows the user to choose from these cover types: none, native

vegetation, or grasses. The type of cover contributes to the soil loss reduction as seen in Table 2.

Table 2. Universal Soil Loss Equation Cover Factor

Type of Cover	C factor	Soil loss reduction (%)
None	1.0	0
Native Vegetation	0.01	99
Grasses	0.1	90

2.3. Equestrian Best Management Practices

For equestrian facilities, the most effective way to reduce nutrient and pathogen impacts to waterways is through manure management. Efficient collection and proper storage of manure can effectively control the waste and minimize the export of pollutants. Other effective management practices include exclusionary fencing, pasture management, and site drainage controls, which also reduce the export of pollutants for an equestrian facility.

Background information for these best management practices, assumptions and studies used to compute the effectiveness of each management practice are discussed for each management practice. Each practice allows the user to select the percentage (in 20 percent increments) of implementation for both the existing and proposed scenarios. Selection of zero percent would indicate there is no management practice, and selection of 100 percent would indicate the practice is properly implemented throughout the entire site. Appendix B provides the user with additional guidelines in selecting the most appropriate effective percentage for manure management, exclusionary fencing, and pasture management. Each site can vary greatly; and so the guidelines describe some common characteristics that may be useful in classifying the percentage of management at each site. LLP staff prepared the guidelines and may provide updates or revisions periodically.

2.3.1. Manure Management

Manure management is the practice of removing manure regularly from paddocks, stalls, corrals and wash areas and ensuring that the manure stockpiles do not come in contact with runoff. The manure should be temporarily stored on an impervious surface and under cover to prevent contact with rainfall or runoff. The manure then can either be converted to compost onsite or hauled offsite for disposal.

Manure management assumes that manure is collected and stored in a covered area for either hauling offsite or composting purposes. Collection of manure does not eliminate urine from potentially exiting the site and it is assumed that 20 percent of the urine and residual manure can not be collected. Manure management at 100% effectiveness, will only remove 80% of the manure and urine generated during the year. It is important to indicate that in large pastures or areas where access is difficult (i.e. trees, bushes, or other

obstructions), manure is more difficult to collect and should be reflected in the percentage selected.

2.3.2. Exclusionary Fencing

Exclusionary fencing restricts horses from entering waterways and can be used to create a buffer in order to protect stream banks and other environmentally sensitive areas. Fencing is very important in sites where there is the potential for horses to be in direct contact with a waterway, trampling stream banks and defecating or urinating in the water.

Exclusionary fencing assumes that horses do not have access to waterways or areas that drain directly to waterways. Data from Lake Champlain Basin Watershed Project was used for calculating the pollutant reductions projected by installing exclusionary fencing. This study occurred over a three year period and focused on various management practices including exclusionary fencing. The percent reduction in pollutants for exclusionary fencing is presented in Table 3.

2.3.3. Pasture Management

Pasture management practices can include tilling (discing), drainage improvements (which may include non-pasture areas with non-roof controls), rotational grazing, regular clipping, weed control, pasture renovation, reseeding, or any combination of these management techniques. These techniques can improve pasture productivity and reduce the impacts from overgrazing and runoff, which leads to contamination of nearby waterways. If non-roof drainage controls are installed, they are accounted for in an increase in the percentage of pasture management implemented, not in roof drainage controls.

Pasture management is generally used on larger pastures where manure management is not quite as feasible. Pastures management can help ensure that the pasture is vegetated (at least residual dry matter or dead grass with a root-structure) year-round and never completely down to the dirt, which would make it no longer a functional pasture area. It is assumed that pasture management and exclusionary fencing have comparable effects on reducing pollutants. Therefore, the results of the Lake Champlain Basin Watershed Project study are also used for calculating the pasture management reductions, as presented in Table 3.

Table 3: Pollutant Reductions Estimates for Exclusionary Fencing and Pasture Management Practices (after Meals, 2000)

Constituent of Concern	Reduction
Total Nitrogen	38%
Total Phosphorus	49%
Total Streptococcus	40%
Fecal Coliform	38%
Sediment	28%

2.3.4. Drainage Controls

Proper drainage controls on rooftops or on a site can prevent or minimize runoff from concentrating, minimizing erosion and sedimentation. Roof drainage controls can include the installation of rain gutters and downspouts that divert drainage away from areas that are prone to erosion or convey runoff to water storage tanks or cisterns, to allow runoff to be reused for irrigation or dust control.

Controlling site runoff can also minimize erosion potential on a site. Site runoff controls may include reshaping of paddocks or pastures to redirect runoff around confined animal areas, diverting runoff to BMPs, or redirecting usage and establishing cover crops or using permeable materials in intensive areas, such as sand or gravel aggregate bases in arenas.

Drainage controls includes directing rooftop runoff to drainage areas not impacted by equestrian facilities. In the model the rooftop runoff contributes to the overall sediment load (using the pastures characteristics) if it is not properly directed away from areas that can cause erosion and runoff. If non-roof drainage controls are installed, they should be accounted for in an increase in the percentage of pasture management implemented.

2.4. Treatment Best Management Practices

Treatment best management practices (BMP) are practices in which runoff filters through the treatment system(s) to remove pollutants. There are three treatment control best management practices that are commonly used and incorporated into the model. These include bioretention swales, filter strips, and vegetated swales. Each site can use different treatment system(s), which would be designed depending on site conditions, constraints, and desired removal efficiencies. Table 4 summarizes the estimated removal efficiencies for constituents of concern using the selected treatment control best management practices.

Table 4. Treatment Best Management Practices
Percent Removal from Published Data

Treatment BMP	Total Nitrogen	Total Phosphorus	Total Streptococcus	Fecal Coliform	Sediment
Bioretention[1]	46%	5%	0%	0%	59%
Filter Strip[2,3]	15%	-52%	71%	83%	74%
Vegetated Swale[2]	73%	38%	0%*	0%*	80%

*Note: There is insufficient published data to determine bacteria removal effectiveness for bioretention and vegetated swales, therefore, the removal efficiency is assumed to be zero.

Sources:
[1] Center for Watershed Protection, 2007
[2] CASQA 2003
[3] Spiehs, et al. 2007

Treatment BMPs can take two to three years to become fully established. The values above are used in the model and assume that the treatment BMP is fully established. The model allows for two treatment BMPs to be selected per site in the proposed scenario. The drop down menu for treatment best management practices include: none, bioretention, filter strip, or vegetated swale. It is assumed that treatment BMPs are not implemented prior to project improvements because an equestrian facility seeking management assistance generally does not have existing treatment BMPs, therefore the "Present" column does not have drop down menus in this section. Below are the descriptions of the treatment management practice options used in the model.

2.4.1. Bioretention Swales

Bioretention swales are stormwater control BMPs that remove contaminant and nutrients by using soil and plants to filter runoff. As water filters through the soil, pollutants are removed or degraded by a combination of biochemical and physical processes and have been found to be one of the most effective treatment systems for nonpoint source pollutants. The United States Environmental Protection Agency (US EPA) (9/2008) and the California Stormwater Quality Association (CASQA) (2003) recommend the size of the bioretention system should be at least 15 feet by 40 feet, with an excavated depth of 4 feet. Bioretention swales should not be placed in areas with high groundwater (within 6 feet of ground surface), or areas with slopes greater than 20 percent. High sediment loads may cause clogging in bioretention swales. Data on bacterial removal efficiencies was not available for bioretention systems, so the removal is assumed to be 0% for both total streptococcus and fecal coliform.

Figure 2. Bioretention Swale

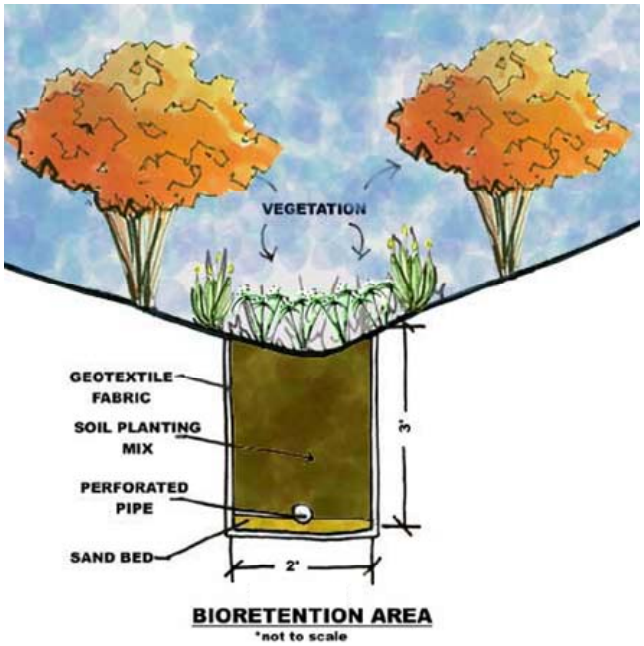

Image from Abbey and Associates

In order to clarify any confusion between the nomenclature of bioretention and biodetention, the primary difference is described below. Bioretention generally is installed with an underdrain (as seen in Figure 2), or perforated pipe at the bottom of the swale to allow the water to drain out from the bottom. Biodetention does not have an underdrain and will have an overflow for when ponding (detention) occurs. There may be cases in which biodetention systems act like bioretention system without an underdrain, because the soil allows sufficient percolation through the existing subsurface. Therefore, if a biodetention system is installed, the user may select the bioretention best management practice, due to their similarities.

2.4.2. Filter Strips

Filter strips are vegetated areas, generally with herbaceous plantings, that are established on the lower edge of pastures, paddocks, or other equestrian facilities, adjacent to waterways or streams. Filter strips are also known as buffer strips, vegetated buffer strips, and streamside management zones and provide relatively high pollutant removal, especially for pathogens and sediment. Although filter strips are effective at removing pathogens and sediment; the removal of nutrients is uncertain and likely due to the amount of loading, soil conditions and amount of area used. Although, the model does not account for filter strip length, the longer the runoff has to flow, the greater the removal efficiencies. The minimum recommended length is 15 feet in the direction of flow (CASQA, 2003).

Figure 3. Filter Strip

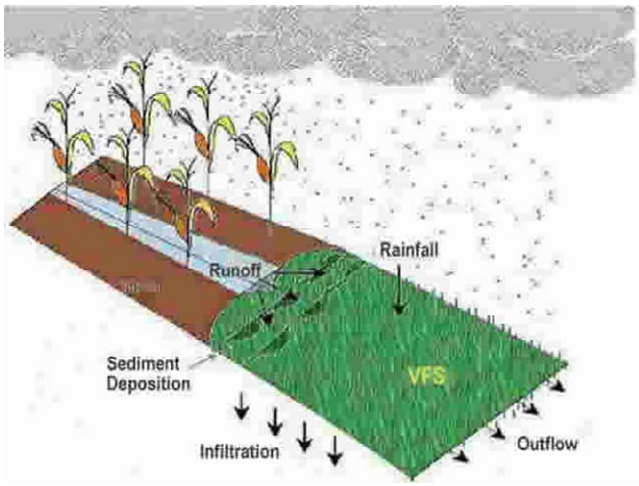

Image from University of Florida (Dr. Munoz-Carpena)

2.4.3. Vegetated Swales

Vegetated swales are shallow sloping, vegetated channels designed to trap suspended solids, nutrients, and other particulate pollutants and promote infiltration. These vegetated channels are typically sited along the natural grade draining flows from equestrian management areas to provide filtration prior to discharging to waterways and may include an underdrain to prevent flooding. Sizing of vegetated swales depends on

the runoff flow rate and Manning's equation, however a simplified method is to use one percent of the area draining to the swale as the total surface area of the swale area. Vegetated swales should not be placed on very flat grades, steep topography, or poorly drained soils, which may erode during high flow situations. Vegetated swales should be designed to have a minimum hydraulic residence time of 9 minutes and should not have a length less than 100 feet (CASQA, 2003).

Figure 4. Vegetated Swale

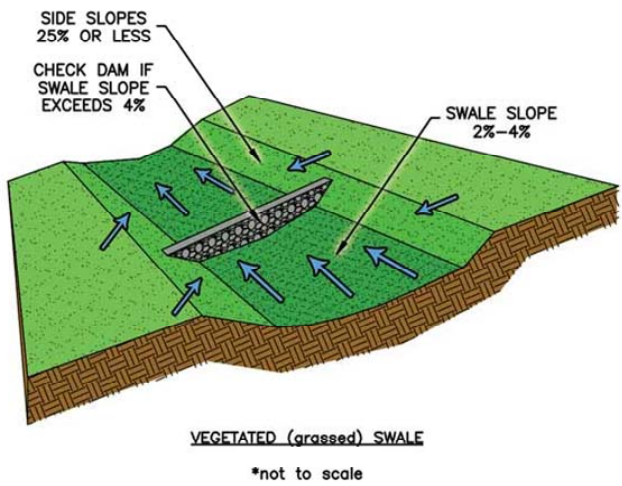

Image from Abbey and Associates

The results from the CASQA studies were averaged to estimate the removal efficiencies of vegetated swales. In general vegetated swales provide high removal rates for nitrogen and sediment; however, there is conflicting and insufficient data related to pathogen removal efficiencies, so the removal is assumed to be 0% for both total streptococcus and fecal coliform.

2.5. Best Management Practices Costs

The user can also input the cost per each best management practice into the spreadsheet. This information is used to calculate a cost per unit removed for each constituent of concern. Please note that the cost information does not print out in the data output sheet, however the information is still available for analysis.

3. PREDICTIVE ANALYSIS OUTPUT DATA

3.1. Present and Proposed Annual Loads

The final section of the predictive analysis tabulates the results of the model using the data entered in previous sections. The annual loads in pounds per year for manure, nutrients, pathogens (colonies per year) and sediment are calculated automatically in the spreadsheet model. These cells are locked to prevent the user from changing the equation.

Annual load reductions are based on management practices and are designed to give the user an estimate of the total potential load reductions resulting from the implementation of the practices as compared to the existing or unmitigated project.

3.2. Percent Effectiveness

The percent effectiveness or percent reduction is a value that takes the difference between the initial and proposed loads, divided by the initial load. It is important to note that in rare cases, phosphorus loads may increase due to only using a filter strip, resulting in a negative percent effectiveness. However, in most cases, using a combination of equestrian and treatment management practices results in an overall reduction in pollutants indicating an improvement in water quality for constituents of concern.

3.3. Use of Model Output

This predictive model was created to provide the Livestock and Land Program a tool to estimate and document the effectiveness of best management practices, and possibly assist in the selection of demonstration sites each year they are funded. Treatment BMPs generally take a couple of years to be established and be effective in improving water quality. To accurately determine the improvements in water quality, long-term monitoring and testing is required, which increases the cost of the management practice substantially. Thus, most projects cannot afford to get an accurate value of nutrients, pathogens, and sediment exported from the site due to equine activities. However for purposes of selecting equestrian BMPs, evaluating effectiveness, and selecting demonstration sites; this model provides sufficient information as a planning, screening and predictive tool. Each site varies greatly and due to the limitations of the equations and input data, the model may not give an accurate illustration of the site in all cases.

4. 2008 SELECTED DEMONSTRATION SITES

The Livestock and Land Program provided technical and financial assistance to implement best management practices and improvements at existing equestrian facilities. Typically, the selected sites are demonstration projects for the program.

In 2008, four facilities in Santa Cruz County were selected as demonstration sites. At each site, the model was used to estimate of the effectiveness of the projects to improve water quality. A summary of the percent effectiveness for each site is presented in Table 5. A print out of the model data and results and detailed information for each site can be found in Appendix C. The following sections discuss the pre- and post-conditions of each project.

Table 5. Summary of BMPs Percent Effectiveness at Demonstration Sites

Facility	Manure	Nutrients		Pathogens		Sediment
		Total Nitrogen	Total Phosphorus	Total Streptococcus	Fecal Coliform	
Aptos Academy	48%	69%	49%	89%	94%	97%
Coale Property	NA	85%	41%	0%	0%	92%
Millan Property	76%	86%	77%	95%	97%	82%
Swanton Pacific	64%	96%	92%	84%	83%	99%

NA – Not Applicable

4.1. Aptos Academy

The Aptos Academy is a private elementary and middle school with an existing equestrian facility. There are four horses at this site year round. The area was transformed from a cow pasture to a horse pasture in 2004. This site initially had a round pen and a pasture area that included a section of seasonal drainage that conveys water from Highway 1 and surrounding hills adjacent to the facility to the ocean.

Prior to the project, the horses were allowed to cross the drainage to access a small section of the pasture with apple trees. This action not only provided a direct route for manure to enter the drainage that outlets at La Selva Beach, but also destroyed sections of a berm that ran parallel to the drainage, allowing runoff to drain directly from the pasture into the waterway.

The main project highlights entailed installing exclusionary fencing to keep the horses out of the seasonal drainage and small section across the drainage from the pasture area; installing covered manure management bins where manure is converted to compost for use in their garden adjacent to the equestrian facilities; regrading the property and restoring berms; adding drainage controls including a filter strip; and installing stalls and paddocks, with rain gutters and downspouts for both the manure bunker and the paddocks, which will outlet into a water catchment tank.

The model results indicate that pathogens and sediment will effectively be removed by the proposed management practices at the site. The model predicts that 89 percent or higher removal efficiencies should be obtained for pathogens and sediment by these activities. Nutrients will also be removed with the management practices implemented. The planned site improvements are expected to substantially reduce potential water quality impacts at the site.

4.2. Coale Property

The Coale property is a private residence with an existing facility that has been previously selected as a demonstration site. There are three horses at this one-acre facility. The initial demonstration project, the Coales implemented manure management to contain the manure onsite, so additional removal credits for the current project have not been applied. Also the existing stables already have proper gutters and downspouts. Runoff from the paddocks and arena area currently drains via sheet flow along the stable down the slope, into the nearest waterway, Wilder Creek, located approximately 800 feet downstream from the property.

This year, as a second demonstration project, the project will divert runoff away from confinement areas, thus reducing the transport or export of sediments, nutrients and pathogens to Wilder Creek. Contaminated runoff will be conveyed to a vegetated swale and bioretention swale for treatment prior to discharging to Wilder Creek.

The modeling indicates that sediment removal will be approximately 92 percent and the nitrogen removal is 85 percent. The proposed BMPs should substantially improve runoff water quality, reducing impacts to Wilder Creek from the site.

4.3. Millan Property

The Millan property is a private residence with an existing facility for four horses. The property is 3.5 acres; however, the horses are limited to a much smaller area. The slope where the horse facility sits is only about 1 to 2 percent, however surrounding the site has much steeper slopes and poor drainage control measures. The steep slopes and historic intensive use of the site has caused severe erosion.

The main project highlights entailed diverting runoff around the coral and through culverts to the seasonal drainage; collecting manure in a covered area for a trailer, so that it can be hauled to the dump; installing rain gutters and downspouts for both the manure bunker and the stable; and adding drainage controls including a filter strip.

The existing annual load of sediment from the model is about 30 tons per year per acre. Based on the type of soils (sandy soils) encountered at the site, USLE could potentially underestimate the amount of soil loss at the site. Implementing the proposed management practices will reduce manure, nutrient and pathogen loads substantially. Installing drainage controls vegetated swales will likely reduce sediment loads by 82%.

4.4. Swanton Pacific Ranch

Swanton Pacific Ranch (SPR) is an existing cattle and agriculture ranch operated by California Polytechnic State University San Luis Obispo as an educational facility. SPR proposed to convert an area previously used as grazing land, to maintain four horses and provide a space for visiting horses. The area would also be used to maintain the birthing cows during calving season. The area is approximately two acres and runs adjacent to Queseria Creek. The hillside adjacent the site has springs and seeps during the wet season, which drains through this proposed pasture area into the creek.

This project includes diverting hillside drainage through a vegetated swale around the pasture area and into Queseria Creek, minimizing the transport of pollutants and sediment from confined areas. The ranch will also install a covered manure bunkers, new paddocks, and stalls for the horses, with proper runoff controls.

The management practices are estimated to remove 99 percent of the sediment that would have been contributed to the site if the pastures were established without management practices. All the other practices are projected to remove at least 83 percent of the sediment, nutrients and pathogens.

5. REFERENCES

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6. Miller, J.F., Frederick, R.H. and Tracey, R.J. National Oceanic and Atmospheric Administration (NOAA) Atlas 2, Precipitation-Frequency Atlas of the Western United States, Volume XI-California. Silver Spring, MD. 1973.

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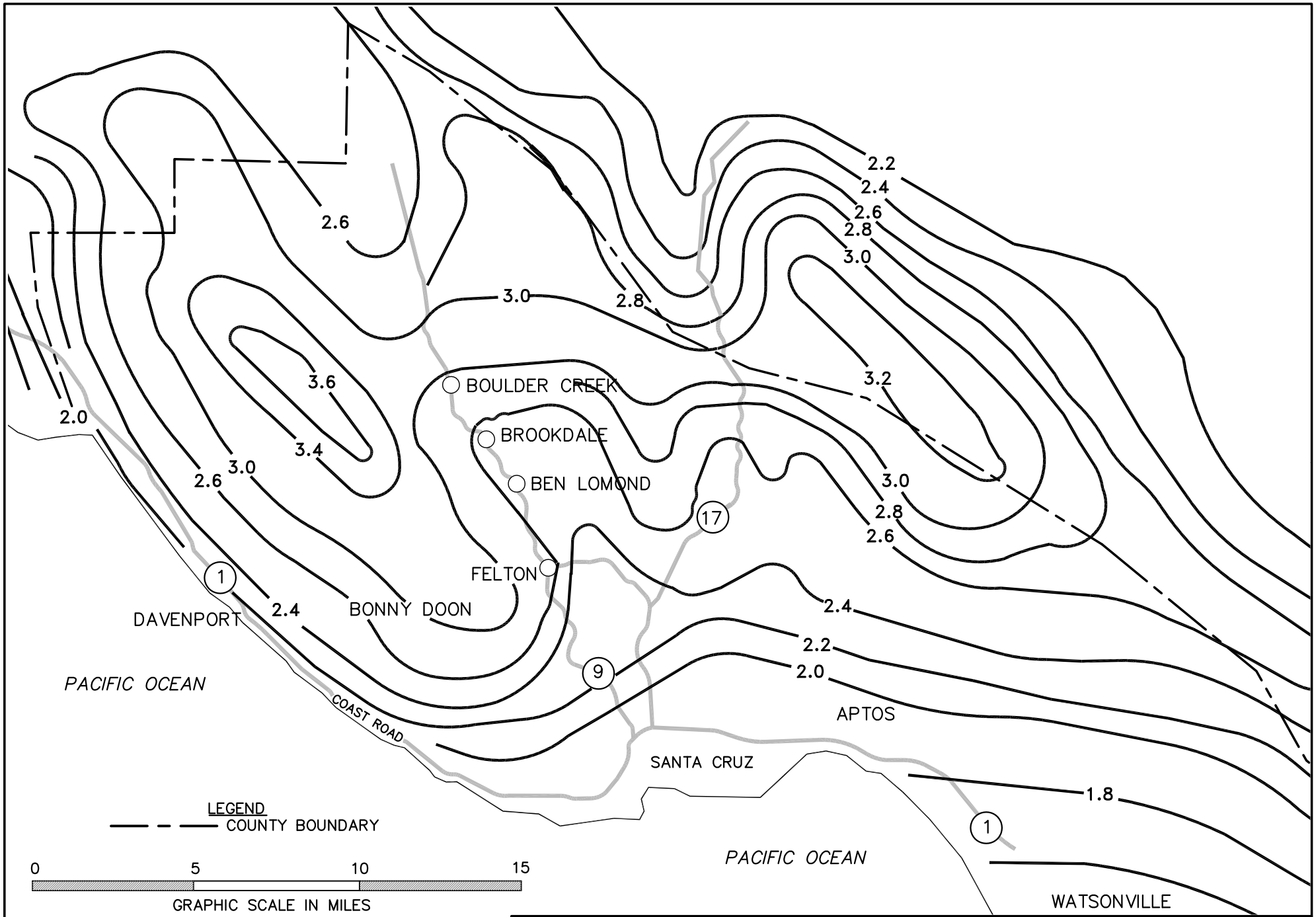

FALL CREEK ENGINEERING, INC.
Civil • Environmental • Water Resources Engineering

FIGURE 1. PRECIPITATION (INCHES)
2 YEAR – 6 HOUR ISOPLUVIALS
FOR SANTA CRUZ COUNTY

APPENDIX A

BLANK
EQUESTRIAN BMPS PREDICTIVE ANALYSIS FORM

Data Analysis Form for Equestrian Facilities Best Management Practices

Manure and Erosion Pollution Prevention Program

Ecology Action, Santa Cruz, California

Facility Information

Facility Name:		Operator/Contact:	
Address:		Owner (if different):	
		Telephone:	
		Email	
Watershed:			
Nearest Creek:		Facility/storage distance from creek:	ft
Size of Facility:	acres		
Precipitation:	inches (2-yr, 6-hr)	Note: extrapolate value from Figure 1	

	Present	Proposed	
Quantity of Horses:	horses	horses	
Management Areas			
Stable/Covered Stalls or Roofed Areas			
Area	ft^2	ft^2	
Pastures/Non-hardened Turnouts			
Area	ft^2	ft^2	
Soil Type	Fine sand	Fine sand	
Organic Matter	<0.5 %	<0.5 %	
Slope	%	%	
Type of Cover	None	None	
Soil Loss	0.00 tons/year	0.00 tons/year	
Paddock/Hardened Turnout Areas and Pens			
Area	ft^2	ft^2	
Soil Type	Fine sand	Fine sand	
Organic Matter	<0.5 %	<0.5 %	
Slope	%	%	
Type of Cover	None	None	
Soil Loss	0.00 tons/year	0.00 tons/year	
Best Management Practices (BMP)			
Manure Management	0%	0%	
Exclusionary Fencing	0%	0%	
Pasture Management	0%	0%	
Roof Drainage Controls	0%	0%	
Treatment BMP 1		None	
Treatment BMP 2		None	

Annual Loads	Present	Proposed	% Effectiveness
Manure	0.00 tons	0.00 tons	#DIV/0!
Nutrients			
Total Nitrogen	0.00 lbs	0.00 lbs	#DIV/0!
Total Phosphorus	0.00 lbs	0.00 lbs	#DIV/0!
Pathogens			
Total Streptococcus	0.00E+00 colonies	0.00E+00 colonies	#DIV/0!
Fecal Coliform	0.00E+00 colonies	0.00E+00 colonies	#DIV/0!
Sediment	0.00 tons	0.00 tons	#DIV/0!

APPENDIX B

ADDITIONAL GUIDANCE FOR EQUESTRIAN BEST MANAGEMENT PRACTICES

Manure Management
Percent Implementation Guidelines

The following guidelines have been prepared to assist in selecting the most appropriate percent implementation of manure management at the site for both before and after scenarios.

For each site, select the scenario in the table below that most accurately describes the site conditions for both manure removal practices and manure storage features and then select the lowest percentage between the two.

Percent Management	Manure Removal Practices	Manure Storage Features*
0%	Infrequent removal	No cover on a pervious surface
20%	2 times/week	Tarp cover on a pervious surface
40%	2 times/week	No cover on impervious surface
60%	Every other day	Tarp cover on impervious surface
80%	1 time/day	Permanent roof on pervious surface
100%	> 1 time/day	Permanent roof on impervious surface

* Assumes tarp or roof feature covers > or = 100% of footprint of manure pile.

Using the value selected from the table, the user should also evaluate any other conditions that may increase or decrease the risk of manure impacting the site due to the management or site conditions. The following are other considerations that may (or may not) impact the percent management selected:

- Manure storage percent coverage (i.e. reduce percentage appropriately if only partially covered)
- Distance of storage from creek
- Vegetated drainage or drainage patterns
- Percent of site where manure is collected
- Removal techniques
- Other*

* Please identify and notify the Livestock and Land Program of any factors that other users may encounter for future revisions of these guidelines.

Example: A site picks up manure every other day and has a permanent roof on a pervious surface. However the manure bunker is only 5 feet from the creek.

Start with 60% because the manure storage feature gives the lowest percent management and decrease to 40% because the impacts to the creek due to its proximity.

Exclusionary Fencing
Percent Implementation Guidelines

The following guidelines have been prepared to assist in selecting the most appropriate percent implementation of exclusionary fencing at the site for both before and after scenarios.

For each site, select the scenario in the table below that most accurately describes the site conditions to determine the initial percent implementation of the management practice.

Percent Management	Site Conditions
0%	No fencing
20%	Exclusion w/ fenced stock crossing in water
40%	Fenced buffer to water way: 10’ or less
60%	Fenced buffer to water way: >30’ buffer
80%	Exclusion w/ fenced stock crossing over culvert
100%	No access to water: >50’ setback/buffer

Using the value selected from the table, the user should also evaluate any other conditions that may increase or decrease the risk of the horses impacting the waterways or areas that drain directly to waterways due to the management practices existing or proposed. The following are other considerations that may (or may not) impact the percent management selected:

- Vegetation in buffer zone
- Type of fencing
- Continuity of fencing
- Type of crossing
- Other*

* Please identify and notify the Livestock and Land Program of any factors that other users may encounter for future revisions of these guidelines.

Example: A site has a fenced buffer greater than 30 feet, but the area is sparsely vegetated.

Start with 60% management and decrease to 40% because sparsely vegetated buffer is less effective than a vegetated buffer.

Pasture Management
Percent Implementation Guidelines

The following guidelines have been prepared to assist in selecting the most appropriate percent implementation of pasture management at the site for both before and after scenarios.

For each site, select the scenario in the table below that most accurately describes the site conditions to determine the initial percent implementation of the management practice.

Percent Management	Site Conditions
0%	No vegetation and no drainage controls
20%	Drainage controls with no vegetation
40%	Patchy/sparse vegetation with no drainage controls
60%	Vegetation with no drainage controls
80%	Patchy/sparse vegetation with proper drainage controls
100%	Significant vegetation year round and proper drainage controls

Using the value selected from the table, the user should also evaluate any other conditions that may increase or decrease the risk of the pasture conditions impacting the waterways due to the management practices existing or proposed. The following are other considerations that may (or may not) impact the percent management selected:

- Tilling (discing) soil
- Rotational grazing
- Reseeding frequency
- Other*

* Please identify and notify the Livestock and Land Program of any factors that other users may encounter for future revisions of these guidelines.

Example: A site has sparse vegetation with no drainage controls, but the owner has agreed to reseed the site annually.

Start with 40% management and increase to 60% because reseeding will increase the vegetation at the site.

APPENDIX C

EQUESTRIAN BMPS
DEMONSTRATION SITES
PREDICTIVE ANALYSIS RESULTS

Data Analysis Form for Equestrian Facilities Best Management Practices

Manure and Erosion Pollution Prevention Program

Ecology Action, Santa Cruz, California

Facility Information

Facility Name:	Aptos Academy	Operator/Contact:	Cori Altman
Address:	1940 Benito Drive	Owner (if different):	Not Known
	Aptos, CA	Telephone:	(831) 688-1080
		Email	calt8@sbcglobal.net
Watershed:	San Lorenzo-Soquel		
Nearest Creek:	La Selva Beach Drainage	Facility/storage distance from creek:	600 ft
Size of Facility:	1.25 acres		
Precipitation:	1.8 inches (2-yr, 6-hr)	Note: extrapolate value from Figure 1	

	Present	Proposed	
Quantity of Horses:	4 horses	4 horses	
Management Areas			
Stable/Covered Stalls or Roofed Areas			
Area	0 ft^2	800 ft^2	
Pastures/Non-hardened Turnouts			
Area	49500 ft^2	39000 ft^2	
Soil Type	Clay loam	Clay loam	
Organic Matter	4 %	4 %	
Slope	1.2 %	1.2 %	
Type of Cover	None	Grasses	
Soil Loss	3.50 tons/year	0.28 tons/year	
Paddock/Hardened Turnout Areas and Pens			
Area	2000 ft^2	3150 ft^2	
Soil Type	Clay loam	Clay loam	
Organic Matter	4 %	4 %	
Slope	1.2 %	1.2 %	
Type of Cover	None	None	
Soil Loss	0.14 tons/year	0.22 tons/year	
Best Management Practices (BMP)			
Manure Management	0%	60%	
Exclusionary Fencing	0%	40%	
Pasture Management	0%	40%	
Roof Drainage Controls	0%	60%	
Treatment BMP 1		Filter Strip	
Treatment BMP 2		None	

Annual Loads	Present	Proposed	% Effectiveness
Manure	36.50 tons	18.98 tons	48%
Nutrients			
Total Nitrogen	408.80 lbs	127.49 lbs	69%
Total Phosphorus	160.60 lbs	82.05 lbs	49%
Pathogens			
Total Streptococcus	3.80E+14 colonies	4.04E+13 colonies	89%
Fecal Coliform	6.13E+11 colonies	3.90E+10 colonies	94%
Sediment	3.64 tons	0.10 tons	97%

Data Analysis Form for Equestrian Facilities Best Management Practices

Manure and Erosion Pollution Prevention Program

Ecology Action, Santa Cruz, California

Facility Information

Facility Name:	Coale Property	Operator/Contact:	Susan Coale
Address:	2309 Empire Grade	Owner (if different):	
	Santa Cruz, CA	Telephone:	(831) 429-9604
		Email	slcoale@ucsc.edu
Watershed:	Wilder Creek		
Nearest Creek:	Wilder Creek	Facility/storage distance from creek:	800 ft
Size of Facility:	1 acres		
Precipitation:	2.2 inches (2-yr, 6-hr)	Note: extrapolate value from Figure 1	

	Present	Proposed	
Quantity of Horses:	3 horses	3 horses	
Management Areas			
Stable/Covered Stalls or Roofed Areas			
Area	11250 ft^2	11250 ft^2	
Pastures/Non-hardened Turnouts			
Area	6000 ft^2	6000 ft^2	
Soil Type	Silty clayloam	Silty clayloam	
Organic Matter	<0.5 %	<0.5 %	
Slope	1 %	1 %	
Type of Cover	None	None	
Soil Loss	3.31 tons/year	3.31 tons/year	
Paddock/Hardened Turnout Areas and Pens			
Area	9000 ft^2	9000 ft^2	
Soil Type	Silty clayloam	Silty clayloam	
Organic Matter	<0.5 %	<0.5 %	
Slope	1 %	1 %	
Type of Cover	None	None	
Soil Loss	1.73 tons/year	1.73 tons/year	
Best Management Practices (BMP)			
Manure Management	80%	80%	
Exclusionary Fencing	0%	0%	
Pasture Management	0%	0%	
Roof Drainage Controls	0%	0%	
Treatment BMP 1		Vegetated Swale	
Treatment BMP 2		Bioretention	

Annual Loads	Present	Proposed	% Effectiveness
Manure	9.86 tons	9.86 tons	0%
Nutrients			
Total Nitrogen	110.38 lbs	16.09 lbs	85%
Total Phosphorus	43.36 lbs	25.54 lbs	41%
Pathogens			
Total Streptococcus	1.02E+14 colonies	1.02E+14 colonies	0%
Fecal Coliform	1.66E+11 colonies	1.66E+11 colonies	0%
Sediment	5.03 tons	0.41 tons	92%

Data Analysis Form for Equestrian Facilities Best Management Practices

Manure and Erosion Pollution Prevention Program

Ecology Action, Santa Cruz, California

Facility Information

Facility Name:	Millian Property	Operator/Contact:	Doug & Aniko Millan
Address:	1145 Weston Road	Owner (if different):	
	Scotts Valley, CA	Telephone:	(831) 438-2035
		Email	sheranger@aol.com
Watershed:	San Lorenzo Creek		
Nearest Creek:	Unnamed drainage	Facility/storage distance from creek:	50 ft
Size of Facility:	3.5 acres		
Precipitation:	2.8 inches (2-yr, 6-hr)	Note: extrapolate value from Figure 1	

	Present	Proposed	
Quantity of Horses:	4 horses	4 horses	
Management Areas			
Stable/Covered Stalls or Roofed Areas			
Area	1400 ft^2	ft^2	
Pastures/Non-hardened Turnouts			
Area	7500 ft^2	7500 ft^2	
Soil Type	Very finesand	Very finesand	
Organic Matter	<0.5 %	<0.5 %	
Slope	1 %	1 %	
Type of Cover	None	None	
Soil Loss	1.43 tons/year	1.21 tons/year	
Paddock/Hardened Turnout Areas and Pens			
Area	3500 ft^2	3500 ft^2	
Soil Type	Fine sand	Fine sand	
Organic Matter	<0.5 %	<0.5 %	
Slope	2 %	2 %	
Type of Cover	None	None	
Soil Loss	0.33 tons/year	0.33 tons/year	
Best Management Practices (BMP)			
Manure Management	20%	100%	
Exclusionary Fencing	0%	40%	
Pasture Management	0%	40%	
Roof Drainage Controls	0%	80%	
Treatment BMP 1		Filter Strip	
Treatment BMP 2		None	

Annual Loads	Present	Proposed	% Effectiveness
Manure	30.66 tons	7.30 tons	76%
Nutrients			
Total Nitrogen	343.39 lbs	49.04 lbs	86%
Total Phosphorus	134.90 lbs	31.56 lbs	77%
Pathogens			
Total Streptococcus	3.19E+14 colonies	1.55E+13 colonies	95%
Fecal Coliform	5.15E+11 colonies	1.50E+10 colonies	97%
Sediment	1.77 tons	0.32 tons	82%

Data Analysis Form for Equestrian Facilities Best Management Practices

Manure and Erosion Pollution Prevention Program

Ecology Action, Santa Cruz, California

Facility Information

Facility Name:	Swanton Pacific Ranch	Operator/Contact:	Sue Burges
Address:	125 Swanton Road	Owner (if different):	Cal Poly SLO
	Davenport, CA	Telephone:	(831) 458-5410
		Email	slburges@calpoly.edu
Watershed:	Queseria Creek		
Nearest Creek:	Queseria Creek	Facility/storage distance from creek:	400 ft
Size of Facility:	2 acres		
Precipitation:	2.0 inches (2-yr, 6-hr)	Note: extrapolate value from Figure 1	

	Present	Proposed	
Quantity of Horses:	4 horses	4 horses	
Management Areas			
Stable/Covered Stalls or Roofed Areas			
Area	0 ft^2	900 ft^2	
Pastures/Non-hardened Turnouts			
Area	54750 ft^2	52700 ft^2	
Soil Type	Clay loam	Clay loam	
Organic Matter	<0.5 %	<0.5 %	
Slope	1 %	1 %	
Type of Cover	None	Grasses	
Soil Loss	5.23 tons/year	0.50 tons/year	
Paddock/Hardened Turnout Areas and Pens			
Area	0 ft^2	1150 ft^2	
Soil Type	Clay loam	Clay loam	
Organic Matter	<0.5 %	<0.5 %	
Slope	0.5 %	0.5 %	
Type of Cover	None	None	
Soil Loss	0.00 tons/year	0.07 tons/year	
Best Management Practices (BMP)			
Manure Management	0%	80%	
Exclusionary Fencing	0%	100%	
Pasture Management	0%	60%	
Roof Drainage Controls	0%	100%	
Treatment BMP 1		Vegetated Swale	
Treatment BMP 2		None	

Annual Loads	Present	Proposed	% Effectiveness
Manure	36.50 tons	13.14 tons	64%
Nutrients			
Total Nitrogen	408.80 lbs	18.12 lbs	96%
Total Phosphorus	160.60 lbs	12.91 lbs	92%
Pathogens			
Total Streptococcus	3.80E+14 colonies	6.23E+13 colonies	84%
Fecal Coliform	6.13E+11 colonies	1.06E+11 colonies	83%
Sediment	5.23 tons	0.07 tons	99%

Data Analysis Form for Equestrian Facilities Best Management Practices

Manure and Erosion Pollution Prevention Program

Ecology Action, Santa Cruz, California

Facility Information

Facility Name:		Operator/Contact:	
Address:		Owner (if different):	
		Telephone:	
		Email	
Watershed:			
Nearest Creek:		Facility/storage distance from creek:	ft
Size of Facility:	acres		
Precipitation:	inches (2-yr, 6-hr)	Note: extrapolate value from Figure 1	

	Present	Proposed	
Quantity of Horses:	horses	horses	
Management Areas			
Stable/Covered Stalls or Roofed Areas			
Area	ft^2	ft^2	
Pastures/Non-hardened Turnouts			
Area	ft^2	ft^2	
Soil Type	Fine sand	Fine sand	
Organic Matter	<0.5 %	<0.5 %	
Slope	%	%	
Type of Cover	None	None	
Soil Loss	0.00 tons/year	0.00 tons/year	
Paddock/Hardened Turnout Areas and Pens			
Area	ft^2	ft^2	
Soil Type	Fine sand	Fine sand	
Organic Matter	<0.5 %	<0.5 %	
Slope	%	%	
Type of Cover	None	None	
Soil Loss	0.00 tons/year	0.00 tons/year	
Best Management Practices (BMP)			
Manure Management	0%	0%	
Exclusionary Fencing	0%	0%	
Pasture Management	0%	0%	
Roof Drainage Controls	0%	0%	
Treatment BMP 1		None	
Treatment BMP 2		None	

Annual Loads	Present	Proposed	% Effectiveness
Manure	0.00 tons	0.00 tons	#DIV/0!
Nutrients			
Total Nitrogen	0.00 lbs	0.00 lbs	#DIV/0!
Total Phosphorus	0.00 lbs	0.00 lbs	#DIV/0!
Pathogens			
Total Streptococcus	0.00E+00 colonies	0.00E+00 colonies	#DIV/0!
Fecal Coliform	0.00E+00 colonies	0.00E+00 colonies	#DIV/0!
	0.00 tons	0.00 tons	#DIV/0!

APPENDIX 3-B-5

TUOLUMNE COUNTY RESOURCE CONSERVATION DISTRICT

Technical Documentation

Tuolumne County Stream Team

Water Quality Monitoring Report 2007-08

Tuolumne County Resource Conservation District

P.O. Box 4394
Sonora, CA 95370
(209) 533-8866
www.tcrcd.org

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Table 1: List of Abbreviated Terms & Symbols

cm	centimeters
CWRCB	California Water Resources Control Board
DO	Dissolved oxygen
EC	Electrical conductivity (or Conductivity)
µS	Microsiemens
mg/l	Micrograms per liter
NRCS	Natural Resources Conservation Service
NTU	Nephelometric Turbidity Units
ppm	Parts per million
RCD	Resource Conservation District
SNC	Sierra Nevada Conservancy
USDA	United States Department of Agriculture
WRCB	Water Resources Control Board (see also CWRCB)

Table 2: Conversion Table – Centigrade (Celsius) to Fahrenheit

Degrees Centigrade/a/	Degrees Fahrenheit	Degrees Centigrade/a/	Degrees Fahrenheit
0	32	20	68
1	33.8	21	69.6
2	35.6	22	71.6
3	37.4	23	73.4
4	39.2	24	75.2
5	41	25	77
6	42.8	26	78.8
7	44.6	27	80.6
8	46.4	28	82.4
9	48.2	29	84.2
10	50	30	86
11	51.8	31	87.8
12	53.6	32	89.6
13	55.4	33	91.4
14	57.2	34	93.2
15	59	35	95
16	60.8	36	96.8
17	62.6	37	98.6
18	64.4	38	100.4
19	66.2	39	102.2
		40	104

/a/ ^{0}Fahrenheit – 32 ÷ 1.8 = ^{0}Celsius or C= 5/9 F -17.777

Table 3: Conversion Table – Centimeters to Inches

Centimeters	Inches	Centimeters	Inches
1	0.4	21	8.3
2	0.8	22	8.7
3	1.2	23	9.1
4	1.6	24	9.4
5	2.0	25	9.8
6	2.4	26	10.2
7	2.8	27	10.6
8	3.1	28	11.0
9	3.5	29	11.4
10	3.9	30	11.8
11	4.3	31	12.2
12	4.7	32	12.6
13	5.1	33	13.0
14	5.5	34	13.4
15	5.9	35	13.8
16	6.3	40	15.7
17	6.7	45	17.7
18	7.1	50	19.7
19	7.5	55	21.7
20	7.9	60	23.6

/a/ cm X 0.3937008 = inches

Chapter 1. Introduction

1.1. Project History & Purpose

The Tuolumne County Stream Team was formed in 2006 through the Tuolumne County Department of Public Works and Engineering Services in conjunction with the preparation and adoption of the *Tuolumne County Water Quality Plan* (2007) which was prepared through a grant from Proposition 13 through the State Water Resources Control Board and CALFED. The Plan identified two primary threats to the county's water quality: Sedimentation and bacterial contamination.

The *Tuolumne County Water Quality Plan* includes recommended programs to improve these and other water quality parameters through implementation of multiple programs (e.g., improved erosion control, public education and outreach). The Tuolumne County Stream Team was charged with collecting information on the health of surface waters countywide as a means of assessing the effectiveness of the *Tuolumne County Water Quality Plan*'s various programs in improving water quality. In January, 2007, the Tuolumne County Stream Team was transferred from Tuolumne County to the Tuolumne County Resource Conservation District to ensure continued program oversight.

Members of the Tuolumne County Stream Team are volunteers from the community that have attended (or been trained by a member that has attended) training sessions provided through the State Water Resources Control Board Clean Water Team. Collection and analysis of water samples by the Tuolumne County Stream Team occurs in compliance with the protocols established pursuant to the Tuolumne County Water Quality Plan's Quality Assurance Project Plan (QAPP) reviewed and approved by the State Water Resources Control Board. These protocols have been summarized in a Water Quality Field Manual used by the members of the Tuolumne County Stream Team.

The Tuolumne County Stream Team strives to meet quarterly, but meets a minimum of once yearly, to discuss sampling protocols, problems encountered and sampling results with other members of the team. Special training sessions are added from time to time to expand the parameters measured by the members of the Tuolumne County Stream Team. In 2007, the Stream Team received training in the use of IDEXX testing equipment for total coliform, *Enterococcus* and *E. coli* testing.

1.2. Monitoring Locations

Table 4: Monitoring Locations 2007-2008 Tuolumne County Stream Team

County Code	Site #	Location Description	Notes
MM-01	1	Mormon Creek @ VonKleiben Road and Hwy 49	
MM-02	2	Mormon Creek @ Columbia Airport	Eliminated 2007/08 due to low or no flows
PMT-01	3	Peppermint Creek @ Pulpit Rock Road	Downstream side of Pulpit Rock Road Bridge
WD-01	4	Woods Creek @ Rawhide Road Bridge	Upstream of Rawhide Bridge on Woods Creek
WD-02	5	Woods Creek @ Bell Mooney	Downstream side of crossing
WD-03	6	Woods Creek @ Rotary Park	Upstream of bridge @ drainpipe @ entrance to park
SRA-01	7	Sonora Creek @ Southgate Drive	Upstream from bridge @ fairgrounds
--	*8*	*Reserved*	--
--	*9*	*Reserved*	--
--	*10*	*Reserved*	--
CRT-01	11	Curtis Creek @ Lime Kiln Rd.	
CRT-02	12	Curtis Creek @ Tuolumne Road	
STD-01	13	Tributary to Curtis Creek @ Standard Rd.	
--	*14*	*Reserved*	--
TBK-01	15	Turnback Creek @ Tuolumne Road	
TBK-02	*16*	*Reserved*	--
TBK-03	17	Turnback Creek @ Yosemite Road	
MED-01	18	Mt. Eaton Ditch @ Buchanan Mine Rd.	
TBK-04	19	Turnback Creek @ Old Buchanan Mine Rd	
GC-01	20	Groveland Creek @ GCSD Driveway	
BC-01	21	Big Creek @ Ferretti Road	
--	*22*	*Reserved*	--
TH-01	23	Twain Harte Creek @ Eproson Park	
SV-01	24	Sullivan Creek @ Longeway Road	
TH-02	25	Twain Harte Creek @ Crystal Falls Drive	
SV-02	26	Sullivan Creek @ Creekside/Crestview	
SV-03	27	Sullivan Creek @ Creekside opposite Fern Lane	
SV-04	28	Sullivan Creek @Buena Vista Avenida	
SV-05	29	Sullivan Creek @Potato Ranch Road	
SV-06	30	Sullivan Creek @Bergel Road-SR 108	

1.3. Monitoring Dates 2007-2008

Monitoring is scheduled for the first Saturday morning of each month during the "wet" season (normally October/November through June).

Table 5: Monitoring Dates 2007-2008

Monitoring Dates	Exceptions/Notes
November 3, 2007	Mormon Creek (both sites): November 4, 2008
December 1, 2007	Groveland Creek: December 8, 2007 Big Creek: December 8, 2007
January 5, 2008	Groveland Creek: January 12, 2008 Big Creek: January 12, 2008
February 2, 2008	Groveland Creek: February 1, 2008 Big Creek: February 1, 2008
March 1, 2008	--
March 16, 2008	Sullivan Creek and Twain Harte Creek only
April 5, 2008	--
May 3, 2008	Sonora Creek: May 2, 2008 Woods Creek @ Rotary Park: May 2, 2008
June 7, 2008	--

1.4. Executive Summary of 2007/2008 Season

Twenty-four (24) sites were monitored by forty (40) volunteers in the 2007-2008 season. Highlights of monitoring results include:

- Lowest water temperatures were found along all Sullivan Creek locations, some Turnback Creek locations and both Twain Harte Creek locations. The lowest temperature reading for the season came from Turnback Creek @ Old Buchanan Mine Road at 2.4^0 Celsius (approximately 36^0 Fahrenheit) followed closely by 2.7^0 Celsius at Twain Harte Creek/Eproson Park and 2.8^0 Celsius at Sullivan Creek @ Longeway. These readings occurred in December, 2007 and January, 2008.

- Highest water temperature was detected at the Curtis Creek Tributary @ Standard Road reading 20.6^0 Celsius (more than 68^0 Fahrenheit) followed closely by Twain Harte Creek @ Crystal Falls Drive reading 20^0 Celsius (68^0 Fahrenheit).

- The shallowest sampling locations were at Mormon Creek @ Columbia Airport which was frequently dry (leading to the eventual elimination of the site for sampling). The second shallowest site was Mormon Creek @ VonKleiben measuring 1.3".

- The deepest sampling locations were found in January, 2008 at the Sullivan Creek @ Creekside, Sullivan Creek across from Fern Lane, Sullivan Creek @ Potato Ranch, Sullivan Creek @ Bergel/SR 108 and Twain Harte Creek @ Eproson Park where depths exceeded 100 cm (1 meter)

- Lowest electrical conductivity was detected at the Mount Eaton Ditch @ Old Buchanan Mine Road near Tuolumne (20-40 μS). This is consistent with findings in the 2006-2007 season where the same location also yielded the lowest overall electrical conductivity readings (30-40 μS). Sullivan Creek @ Longeway Road also displayed relatively low electrical conductivity readings (60-80 μS).

- The highest electrical conductivity was found at Woods Creek @ Rotary Park (640 μS) with other high readings found at Curtis Creek @ Limekiln road (560 μS)

- The lowest dissolved oxygen reading was found at Curtis Creek Tributary @ Standard measuring 1.8 ppm dissolved oxygen

- The highest dissolved oxygen reading was found at the Mount Eaton Ditch @ Old Buchanan Mine Road measuring 12.1 ppm dissolved oxygen.

- The lowest turbidity readings for the season were collected at Mormon Creek @ VonKleiben road (0.2 NTU) with the highest readings collected at Turnback Creek @ Yosemite Road (72 NTU). Other high turbidity readings were found at Curtis Creek at Limekiln (64 NTU), Curtis Creek @ Tuolumne Road (64.1 NTU) and Sullivan Creek @ Bergel Road/SR 108 (65.5 NTU)

- The highest turbidity samples for all locations were collected in February, 2008. February turbidity readings ranged from those at Big Creek/Ferretti Road reading 17 times the site's lowest turbidity to a turbidity reading 126 times the site's lowest turbidity reading at the Curtis Creek/Limekiln road

sampling location. February 2007 also yielded the highest turbidity sample readings for the 2006-2007 season.

- The lowest variation in pH occurred at Groveland Creek @ Groveland Community Services District Driveway (7.4-7.8) and at Big Creek @ Ferretti Road in Groveland where pH varied through the entire sampling season from 7.0-7.7. Lower pH variations occurred at Mormon Creek@ Columbia Airport, Peppermint Creek @ Pulpit Rock Road, Woods Creek @ Rawhide and Woods Creek @ Bell Mooney; however, the slight variations of only 0.1 – 0.6 units are attributed to the fewer sampling events at these locations.

- The highest pH variation occurred at all Sullivan Creek and Twain Harte Creek sampling locations (pH variation ranged from 3.3 to 5.2 units). However, unusually high pH readings occurring on March 16, 2008 at all sites using the same pH meter indicate a possible meter error. Curtis Creek @ Limekiln also had a wide variation in pH (3.3 units) after accounting for possible pH meter errors. Special attention to pH meter readings will be given at these locations in the 2008-2009 sampling season.

- Bacterial sampling was undertaken by the Tuolumne County Stream Team for the first time during a single sampling event in June, 2008 at four locations in the Tuolumne area (3 sites along Turnback Creek and 1 on the Mt. Eaton Ditch). All bacterial samples collected were within the EPA's recommended safety ranges for coliforms and *Enterococcus*. Lowest *Enterococcus* levels were 4.1MPN at Turnback Creek @ Old Buchanan Mine Road. That site also registered the lowest total coliform levels (45.9 MPN). The highest *Enterococcus* levels were measured at 25.3 at the Mt. Eaton Ditch @ Buchanan Mine Road. That site also registered the highest total coliform levels (74.3 MPN). *E. coli* was not detected at any of the sampling sites. The Stream Team is uncertain if this is due to the IDEXX reagent selected (Colisure), a failure of the sealer to seal quanti-trays, or actual absence of *E. coli*. Working with IDEXX, the Stream Team coordinator is attempting to resolve this issue prior to commencing sampling in the 2008-2009 season.

1.5. Suggestions/Recommendations Based on Findings; Future Plans/Issues/Opportunities

- Undertake a Stream Clean-Up day for trash focusing on the Turnback Creek @ Old Buchanan Mine Road site
- Consider adding garbage bags and gloves to monitoring kits to pick up litter observed at sites
- Follow-up on highly acidic readings in Curtis Creek and tributary sites
- Follow-up on consistently high electric conductivity readings at SV-04/ Sullivan Creek @ Buena Vista Avenida (readings there reach 300s and 400s -- high in comparison to other readings in the Phoenix Basin ranging up to the 100s)
- Swap sampling sites for Stream Teams for at least one sampling event
- Have water quality coordinator accompany each Stream Team at least once each season
- Photograph all monitoring sites – obtain a digital camera that can be checked out for use by Stream Teams that don't already have one
- Expand sampling parameters to include nitrate sampling
- Acquire poles/stakes marked in cm for all teams to measure depth @ station and adopt cm as preferred unit of measure to avoid mixing inches and cm on data sheets
- Do a "first flush" sampling including bacterial collection
- Also do bacterial sampling after first major rain after soils have become saturated
- Follow-up on low conductivity readings at the Mt. Eaton Ditch
- Work with the Twain Harte Community Services District to see what alternatives are available to trace the source of recurring gas/petroleum smells at Twain Harte Creek/Eproson Park
- Test for coliforms at Eproson Park to determine if these may be related to septic smell
- Pursue coliform testing for Sullivan Creek at Fern Lane to follow-up on septic smell

- Pursue coliform testing at Twain Harte Creek @ Crystal Falls Drive based on septic/sulphur smell
- Investigate securing low-cost accurate flow meters and learn to calculate stream cross sections and volumes
- Revise data sheets to include specific entry box for depth @ station (measured in cm)
- Revise data sheets to re-locate water temp and pH next to each other (same meter used)
- Revise data sheets to facilitate entering time of collection, time of fixing, time of readings
- Investigate feasibility of Stream Team receiving one day aquatic plant identification training for commonly occurring plants
- List Stream Team results on the RCD website
- Include graphic representation of data in next annual report
- Include mean, median, averages in next annual report

1.6. Training and Meetings

The Stream Team held its annual kick-off meeting October 26, 2007 at the Sonora, CA Fire Station in anticipation of the 2007-2008 seasons and discussed consistency with various protocols for parameter tests.

On April 24, 2008 Stream Team members participated in training on IDEXX equipment to sample E. coli, total coliforms and enterococcus. Ten participants attended the training at the Sonora, CA Fire Station. Erik Burres of the Water Resources Control Board Clean Water Team conducted the training.

1.7. Funding

In 2007-2008, the Tuolumne County Resource Conservation District:

- Received $1,000.00 and water quality monitoring equipment from Tuolumne County in conjunction with assuming oversight of the Tuolumne County Stream Team

- Received a Sierra Nevada Conservancy Grant for $48,500, to expand volunteer water quality monitoring to better define the locations and sources of fecal coliform (in particular, *E. coli*) contamination thereby assisting multiple agencies in directing their limited resources towards remedial actions with the highest likelihood of success in reducing and eliminating fecal coliform contamination in the Upper Stanislaus and Upper Tuolumne River waterways.

- Received a California Department of Conservation Watershed Coordinator Grant $171,590. A portion of this grant will be used to hire a watershed coordinator. The watershed coordinator will oversee and direct the Stream Team activities.

- Received assistance from the United States Department of Agriculture Natural Resources Conservation Service to purchase additional water quality monitoring supplies (calibration solutions, reagents) and additional dissolved oxygen kits to assist in the 2007-2008 sampling season.

1.8. Equipment & Supplies - Needs

In the 2006/2007 and 2007/2008 sampling seasons, some Stream Team members (sampling at sites widely scattered throughout the county) shared turbidimeters. As a result, hold times for turbidity samples sometimes exceeded recommended protocols while members awaited the return and availability of turbidimeters. In response, the Tuolumne County Resource Conservation District sold its YSI meter to Columbia Community College at the end of the 2007/2008 sampling season to raise funds for the purchase of an additional turbidimeter. The addition of a sixth turbidimeter during the 2008/2009 season is expected to eliminate excessive hold times for turbidity samples and increase the accuracy of all turbidity samples collected and analyzed by the Stream Team.

In addition to the preceding, the following equipment and supply needs were identified:

- Research alternative pH and temperature meters. Per recommendations, consider Oakton instead of Hanna meters. Lifespan and accuracy of the Hanna meters is questionable

- Obtain disposable pipettes for processing bacterial samples using the IDEXX system

- Obtain a certified thermometer for calibrating the incubators for bacterial sampling

- Inventory and order supplies for the 2007-2008 sampling season no later than August 1, 2008 (e.g., pH and EC calibration solutions, Dissolved oxygen reagents)

- Future needs are expected to include – expanding the total available equipped monitoring kits for expanded Stream Team membership; obtaining nitrate sampling equipment, obtaining accurate/low cost flow meters, obtaining labeled poles for measuring depth @ station (in cm).

Chapter 2. Monitoring Parameters (Indicators)

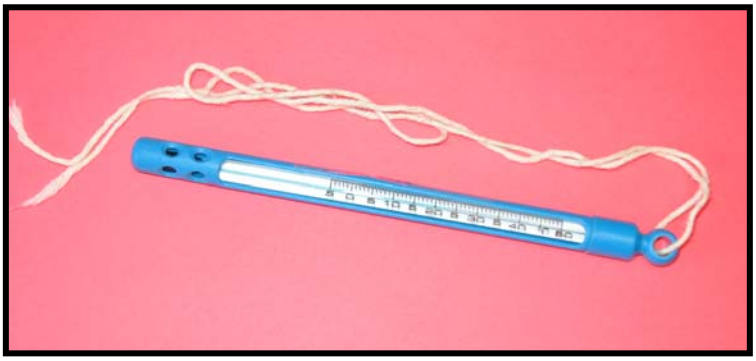
Much of the following is excerpted from the Tuolumne County Stream Team Monitoring Handbook (4th Edition, Terry Strange, Strange Aquatic Resources with information complied from the US Environmental Protection Agency and California State Water Resources Control Board Clean Water Team).

The following parameters are measured by members of the Tuolumne County Stream Team. These parameters were selected for measurement because they are common indicators of stream health. Measurements for turbidity and fecal coliforms also are included as monitoring parameters based on the recommendations of the Tuolumne County Water Quality Plan (2007) and Tuolumne County Foothill Watershed Assessment (2007). Both documents can be found online at http://www.tcrcd.org/index_files/Page284.htm

2.1. Temperature – Air

Air temperature can affect water temperate. The importance of water temperature is described in Section 2.2.

Figure 1: LaMotte Model 1066 Thermometer- Air Temperature



2.2. Temperature – Water

Importance of Water Temperature

Temperature is one of the most important water quality parameters. Aquatic organisms from microbes to fish are dependent on certain temperature ranges for their optimal health. Optimal temperatures for fish depend on the species: some survive best in colder water, whereas others prefer warmer water. If water temperatures are outside this optimal range for a prolonged period of time, organisms are stressed and can die. Temperature affects the oxygen content of the water (oxygen levels become lower as temperature increases); the rate of photosynthesis by aquatic plants; the metabolic rates of aquatic organisms; and the sensitivity of organisms to toxic wastes, parasites, and diseases.

Factors Affecting Water Temperatures

Natural Factors

- Sunlight energy such as seasonal and daily changes, effects of shade (cover), and air temperature
- Wind speed at water surface
- Stream flow
- Depth of water
- Inflow of groundwater which is usually colder than creek water
- Inflow of surface water including a drainage ditch or another creek
- Color and turbidity of water (suspended sediment absorbs heat)

Human Factors

- Removal of riparian vegetation
- Soil erosion, filling in deep pools that were once cold, dark refugia for fish
- Stormwater runoff from hot impervious surfaces
- Alterations to stream morphology, substrate and flow
- Cooling water discharges from power plants
- Water diversion or storage resulting in decreased flows
- Water originating from surface or bottom of reservoir

Acceptable Water Temperature Ranges

Acceptable ranges cannot be assigned without understanding the aquatic ecosystem. The maximum tolerable temperature depends on the species.

Species	Growth	Maxima	Spawning*	Embryo Survival**
Bluegill	32^0C (90^0F)	35^0C (95^0F)	25^0C (77^0F)	34^0C (93^0F)
Carp		21^0C (70^0F)	33^0C (91^0F)	
Channel catfish	32^0C (90^0F)	35^0C (95^0F)	27^0C (81^0F)	29^0C (84^0F)
Largemouth bass	32^0C (90^0F)	34^0C (93^0F)	21^0C (70^0F)	27^0C (81^0F)
Rainbow trout	19^0C (66^0F)	24^0C (75^0F)	9^0C (48^0F)	13^0C (55^0F)
Sockeye salmon	18^0C (64^0F)	22^0C (72^0F)	10^0C (50^0F)	13^0C (55^0F)
Coho Salmon	16.5^0C (62^0F)	22^0C (72^0F)		
Steelhead	20.5^0C (69^0F)	24^0C (75^0F)		
Chinook		24^0C (75^0F)	6-13^0C (43-55^0F)	5-13^0C (41-55^0F)

* The optimum or mean of the range of spawning temperatures reported for the species.
** The upper temperature for successful incubation and hatching reported for the species

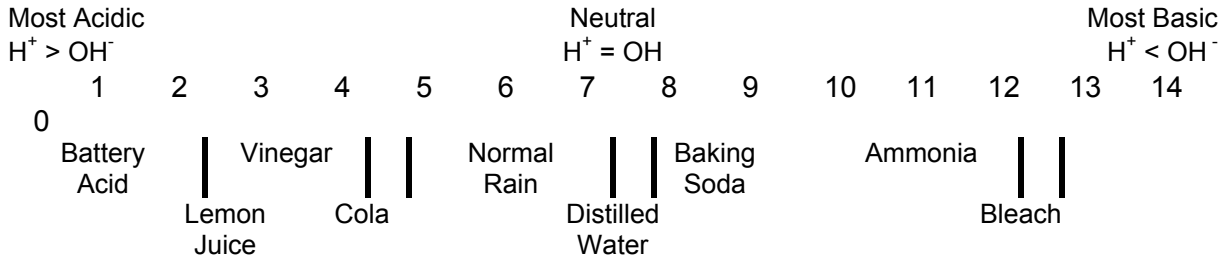
Maximum weekly average temperature for growth and short-term maximum temperatures for selected fish Adapted from EPA's *Draft Volunteer Stream Monitoring: A Method Manual. An Analysis of the Effects of Temperature on Salmonids of the Pacific Northwest with Implications for Selecting Temperature Criteria.* Sullivan, K., D.J. Martin, R.D. Cardwell, J.E. Toll, and S. Duke. 2000

2.3. pH

pH is a term used to indicate the alkalinity or acidity of a substance as ranked on a scale from 1.0 to 14.0. As acidity increases the pH gets lower. The pH scale measures the logarithmic concentration of hydrogen (H+) and hydroxide (OH-) ions, which make up water (H+ + OH- = H2O). When both types of ions are in equal concentration, the pH is 7.0 or neutral. Below 7.0, the water is acidic (there are more hydrogen ions than hydroxide ions). When the pH is above 7.0, the water is alkaline, or basic (there are more hydroxide ions than hydrogen ions). Since the scale is logarithmic, a drop in the pH by 1.0 unit is equivalent to a 10-fold increase in acidity. So, a water sample with a pH of 5.0 is 10 times as acidic as one with a pH of 6.0, and a pH of 4.0 is 100 times as acidic as a pH of 6.0.

Figure 2: Hanna pHep (Measures pH and Water Temperature)

pH Scale Showing the Value of Some Common Substances



Source: U.S. Fish and Wildlife Service

Importance of pH

pH affects many chemical and biological processes in the water. For example, different organisms flourish within different ranges of pH. The largest variety of aquatic animals prefers a range of 6.5-8.0. pH outside this range reduces the diversity in the stream because it stresses the physiological systems of most organisms and can reduce reproduction. Low pH can also allow toxic elements and compounds to become mobile and "available" for uptake by aquatic plants and animals. This can produce conditions that are toxic to aquatic life, particularly to sensitive species like rainbow trout. Changes in acidity can be caused by atmospheric deposition (acid rain), surrounding rock, and certain wastewater discharges.

Input of basic or acidic substances (man-made or natural)

pH can change because of external inputs. You might measure a difference in pH along a stream due to:

- Changes in tree types surrounding the water, for example conifer needles are acidic and maple leaves are basic
- Changes in adjacent soils or rock types and erosion events
- Changes in the stream bottom material, for example the difference between gravel, silt, and bedrock
- Large changes in temperature affecting the CO_2/O_2 (carbonic acid) cycle in the water.
- Changes in human activity affecting the stream.

Other Factors

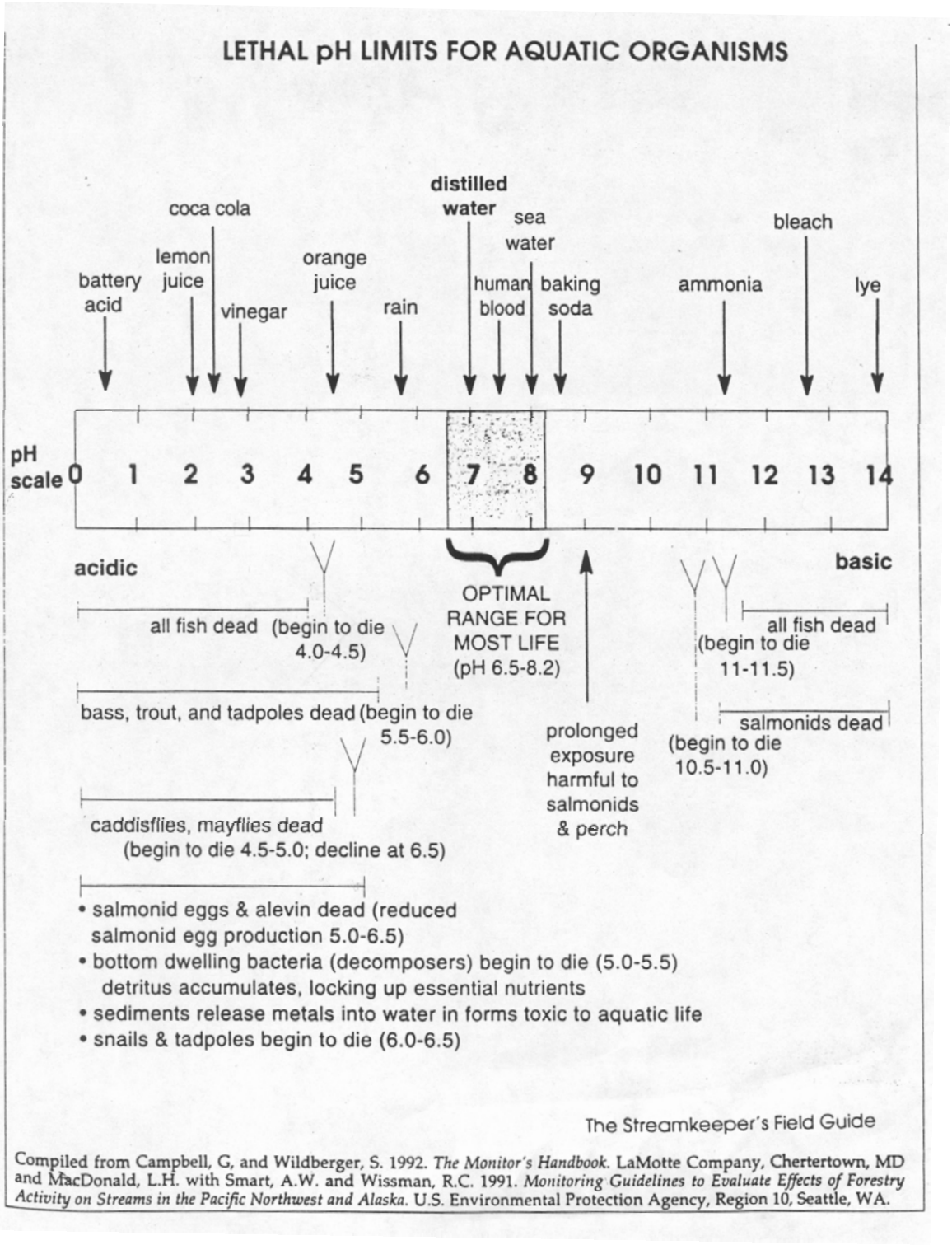
- In fresh water, increasing temperature decreases pH.

- Waters with high algal growth can show a diurnal change in pH. When algae grow and reproduce they use carbon dioxide. This reduction causes the pH to increase. Therefore, if conditions are favorable for algal growth (sunlight, warm temperatures), the water will be more alkaline. Maximum pH usually occurs in late afternoon, pH will decline at night. Because algal growth is restricted to light penetrating zones, pH can vary with depth in lakes, estuaries, bays and ocean water.

- High levels of bacterial activity in sediments can cause associated water to become acidic.

- Manmade inputs that reduce pH include acid rain (from automobiles or industrial sources) and acid mine drainage. Nutrients con indirectly affect pH by stimulating algal growth.

Aquatic Organism Tolerances



2.4. Dissolved Oxygen

The amount of oxygen dissolved in water, and is measured in micrograms per liter or parts per million (ppm).

Importance of Dissolved Oxygen (DO)

The creek system both produces and consumes oxygen. It gains oxygen from the atmosphere and from plants as a result of photosynthesis. Running water, because of its churning, dissolves more oxygen than still water, such as that of a reservoir behind a dam. Most aquatic organisms need oxygen to survive and grow. Some species, such as trout and stoneflies require high levels of DO, while other species such as catfish, worms and dragonflies, do not.

If there is not enough oxygen in the water, the following may result: death of adults and juveniles; reduction in growth; failure of fish eggs/insect larvae to survive; change in species present; and/or growth of toxic or smothering bacteria, fungi, or algae.

Factors Affecting Dissolved Oxygen Levels in Water

Pollution

If organic material (e.g. algae) or waste (e.g. septic leaks) is present in water, bacteria quickly move in to decay the material. As they respire and feed on the decaying material, they use up oxygen and generate CO_2 in the water. Large algae blooms (caused by events like people dumping lawn clippings or leaves, or fertilizer runoff) can create near-zero oxygen conditions in creeks.

Temperature

As temperature increases, less oxygen can be dissolved in water. When water holds all the DO it can at a given temperature, it is said to be 100 percent saturated with oxygen. Water can be supersaturated with oxygen under certain conditions (e.g. below large dams where discharging flows are very turbulent).

The following table shows the concentration of dissolved oxygen that is equivalent to the 100 percent saturation for the noted temperature (and normal barometric pressure). For fresh water only!

Dissolved Oxygen 100% Saturation at Sea Level

Temperature (degrees Celsius)	Dissolved Oxygen (mg/L)	Temperature (degrees Celsius)	Dissolved Oxygen (mg/L)
0	14.6	16	9.9
1	14.2	17	9.7
2	13.8	18	9.6
3	13.5	19	9.3
4	13.1	20	9.1
5	12.8	21	8.9
6	12.5	22	8.7
7	12.1	23	8.6
8	11.8	24	8.4
9	11.6	25	8.3
10	11.3	26	8.1
11	11.0	27	8.0
12	10.8	28	7.8
13	10.5	29	7.7
14	10.3	30	7.6
15	10.1	31	7.5

Sources of Dissolved Oxygen (DO)

Oxygen is added to water by:

Re-aeration

Oxygen from air is dissolved in water at its surface, mostly through turbulence. Examples of this include water tumbling over rocks (rapids, riffles, curves in the waterway) and wave action.

Photosynthesis (during daylight)

Plants produce oxygen when they photosynthesize. DO is generally highest in the late afternoon, and lowest in the early morning hours before sunrise.

Consumption of Dissolved Oxygen (DO)

Dissolved oxygen is used in two major ways—both of which contribute to the Biological Oxygen Demand (BOD) of the creek system:

Respiration

- Aquatic organisms breathe and use oxygen.
- Large amounts of oxygen are consumed by algae and aquatic plants at night (when large masses of plants are present).
- Large amounts of oxygen are consumed by decomposing bacteria (when there are large amounts of dead material to be decomposed, there will be significant numbers of bacteria).

Substances

Examples of substances that breakdown and use oxygen in the process are generally biodegradable and include dead organic matter, algae, sewage/feed lot waste, yard clippings/yard waste, oil/grease, and fertilizer runoff.

Causes of Low Dissolved Oxygen (DO) Levels

- Increases in water temperature
- Algal blooms
- Human waste
- Animal waste (especially from feedlots/dairy farms)
- Depletion near the bottom of reservoirs by bacteria

Other Factors

- Altitude—water holds less oxygen at higher altitudes
- Salinity—dissolved oxygen decreases, as salinity increases
- Mineral content--dissolved oxygen decreases, as the mineral content and concentration of the water increases

Figure 3: LaMotte Dissolved Oxygen Kit Model 5860

(Stand designed by Stream Team member Pat Stone)

Acceptable Dissolved Oxygen (DO) Ranges

The following table gives specific DO values for the survival of different species:

Biologic Effects of Decreasing Dissolved Oxygen (DO) Levels on Salmonids, Non-Salmonids Fish, and Aquatic Invertebrates

	DO (mg/mL)	
	Instream	Intergravel
I Salmonid waters		
A. Embryo and larval stages		
No production impairment	11	8
Slight production impairment	9	6
Moderate production impairment	8	5
Severe production impairment	7	4
Limit to avoid acute mortality	6	3
B. Other life stages		
No production impairment	8	
Slight production impairment	6	
Moderate production impairment	5	
Severe production impairment	4	
Limit to avoid acute mortality	3	
II. Non-Salmonid waters		
A. Early Life stages		
No production impairment	6.5	
Slight production impairment	5.5	
Moderate production impairment	5	
Severe production impairment	4.5	
Limit to **avoid** acute mortality	4	
B. Other life stages		
No production impairment	6	
Slight production impairment	5	
Moderate production impairment	4	
Severe production impairment	3.5	
Limit to avoid acute mortality	3	
III. Invertebrates		
No production impairment	8	
Some production impairment	5	
Limit to avoid acute mortality	4	

2.5. Turbidity

Turbidity is a measure of water clarity and how much the material suspended in the water decreases the passage of light through the water. Suspended materials include soil particles (clay, silt, and sand), algae, plankton, microbes, and other substances. These materials are typically in the size range of 0.004 mm (clay) to 1.0 mm (sand). Turbidity can affect the color of the water. Higher turbidity increases water temperatures because suspended particles absorb more heat. This, in turn, reduces the concentration of dissolved oxygen (DO) because warm water holds less DO than cold. Higher turbidity also reduces the amount of light penetrating the water, which reduces photosynthesis and the production of DO. Suspended materials can clog fish gills, reducing the resistance to disease in fish, lowering growth rates, and affecting egg and larval development. As particles settle, they can blanket the stream bottom, especially in slower waters, and smother fish eggs and benthic macroinvertebrates.

Sources of Turbidity

- Soil erosion
- Waste discharge
- Urban runoff
- Eroding stream banks
- Large numbers of bottom feeders (such as carp), which stir up bottom sediments
- Excessive algal growth (e.g. phytoplankton)

Why Measure for Turbidity

Turbidity can be useful as an indicator of the effects of runoff from construction, agricultural practices, logging activity, discharges, and other sources. Turbidity often increases sharply during a rainfall, especially in developed watersheds, which typically have relatively high proportions of impervious surfaces. The flow of storm water runoff from impervious surfaces rapidly increases stream velocity, which increases the erosion rates of stream banks and channels. Turbidity can also rise sharply during dry weather if earth-disturbing activities are occurring in or near a creek without erosion control practices in place.

Regular monitoring of turbidity can help detect trends that might indicate increasing erosion in developing watersheds. However, turbidity is closely related to stream flow and velocity and should be correlated with these factors. Comparisons of the

change in turbidity over time, therefore, should be made at the same point at the same flow.

Turbidity is not a measurement of the amount of suspended solids present or the rate of sedimentation of a stream since it measures only the amount of light that is scattered by suspended particles. Measurement of **Total Suspended Solids (TSS)** is a more direct measure of the amount of material suspended and dissolved in water.

Figure 4: Hach 2100 P Turbidimeter

2.6. Electrical Conductivity

Conductivity is the ability of water to conduct an electrical current. Dissolved ions in the water are conductors. The major positively charged ions are sodium (Na^+) calcium (Ca^{2+}), potassium (K^+) and magnesium (Mg^{2+}). The major negatively charged ions are chloride (Cl^-), sulfate (SO_4-2), carbonate (CO_3-2), and bicarbonate (HCO_3-). Nitrates (NO_3-2) and phosphates (PO_4-3) are minor contributors to conductivity, although very important biologically.

Salinity is a measure of the amount of salts or ions in the water. Because dissolved ions increase salinity as well as conductivity, the two values are related. The salts in sea water are primarily sodium chloride (NaCI). However, other saline waters, such as Mono Lake, owe their high salinity to a combination of dissolved ions including sodium, chloride, carbonate and sulfate.

Figure 5: Oakton EC Tester

Importance of Conductivity (TDS)

Conductivity can affect the quality of water used for irrigation or drinking. Most aquatic biota tolerate a range of conductivity. However, the ionic composition of the water can be critical. For example, cladocerans (water fleas) are far more sensitive to potassium chloride than sodium chloride at the same concentration.

Conductivity will vary with water source such as ground water, water drained from agricultural fields, municipal wastewater and rainfall. Therefore, conductivity can indicate groundwater seepage or a sewage leak.

What Affects Conductivity of Water

- Soil and rocks release ions into the waters that flow through or over them. The geology of a certain area will determine the amount and type of ions.
- Salinity and conductivity of coastal rivers is influenced by tides. Sea spray can carry salts into the air that then fall back into the rivers with rainfall.
- De-icing salt used on roads and driveways can easily end up in nearby streams and affect salinity until diluted by large volumes of low salinity water.
- Flow of rivers into estuaries can greatly affect salinity as well as the location of the estuarine mixing zone. This is very important to the survival of estuarine organisms.
- Fresh water lost by evaporation will increase the conductivity and salinity of the waterbody. Warm weather can increase ocean salinity.
- As temperature increases, conductivity increases. Salinity is the amount of salt actually present in the water; therefore, it is not dependent on temperature.

Acceptable Conductivity Ranges

Here are some values of conductivity and salinity to give you an idea of possible data ranges you might encounter in the field. Waters that might have higher conductivity than reported here are rivers or drainage ditches dominated by subsurface agricultural return flows; ephemeral streams or pools late in the season; tidally influenced coastal waters; and naturally saline lakes or ponds.

Conductivity of Water

Water Type	Conductivity (mhos/cm or μS)
Distilled Water	0.5 - 3.0
Melted snow	2 - 42
Potable water in U.S.	30 - 1500
Irrigation Supply Water	< 750

2.7. Stream Flow[1]

Figure 6: Global Water Flow Meter (measuring flow velocity)

Stream flow or discharge is the volume of water that moves through a specific point in a stream during a given period of time. Discharge is usually measured in units of cubic feet per second (cfs). To determine discharge, a cross-sectional area of the stream or river is measured. Then, the velocity of the stream is measured using a Flow Rate Sensor. The discharge can then be calculated by multiplying the cross-sectional area by the flow velocity.

Stream flow is an important factor in the stream ecosystem and is responsible for many of the physical characteristics of a stream. Stream flow can also modify the chemical and biological aspects of a stream. Aquatic plants and animals depend upon stream flow to bring vital food and nutrients from upstream, or remove wastes downstream.

Stream flow has two components. The first is flow velocity, and the second is the volume of water in the stream. Flow velocity is influenced by the slope of the surrounding terrain, the depth of the stream, the width of the stream, and the roughness of the substrate or stream bottom. If the surrounding terrain is steep, then rain water and snow melt will have less time to soak into the ground and runoff will be greater. In an area with level terrain, the rain water has plenty of time to soak into the ground and there is less runoff. The flow velocity will also vary as the width or depth of a stream changes. For instance, if you squeeze a water hose with your

[1] All stream flow information from: http://www.msstate.edu/dept/geosciences/CT/TIG/WEBSITES/LOCAL/Spring2002/Mark_Harsha/STREAM_FLOW_TEST.htm

hand, the flow velocity of the water increases. This is because you have reduced the area that the water must flow through, while the volume of water passing through the hose remained constant. The same thing happens in a stream when the stream channel changes in its width or depth. The substrate of the stream bottom also affects the flow velocity since water moves faster over a smooth surface than a rough surface. Flow velocity is greater when the stream bottom is comprised of sand and clay and lower when it is cobble, rock, and boulders.

The volume of water in the stream is affected by the climate of the region. Areas with more rain and snow have more water draining into surrounding streams and rivers. Seasonal changes affect stream volume as well. In the summer there will be less water in the stream compared to the winter. The number of tributaries that merge with a stream or river contribute more water to the system, increasing the stream volume. Human activities can also influence the volume of water in streams. Water removal for consumption can reduce water volumes. Road and parking lot construction can increase water volume by covering large surfaces and preventing rain-water from soaking into the ground (i.e., creating impermeable surfaces). The resulting runoff from parking lots and roads often enters surrounding streams without the benefit of filtration through the ground. This allow minimally diluted contaminants collected in parking lots and roadways a direct route to waterways.

2.8. Coliforms & Other Bacteria

Coliform bacteria are found in the environment, in soils, degrading leaves, and other sources, and is no longer commonly used as a water quality indicator. Fecal bacteria are used as indicators of possible sewage contamination because they are commonly found in human and animal feces. *E. coli* is a species of fecal coliform bacteria that is specific to fecal material from humans and other warm-blooded animals. *Enterococcus* is another fecal bacteria indicator (albeit not coliform) used to monitor water quality.

Figure 7: IDEXX Colilert and Enterolert/Quanti-Tray Coliform Testing Equipment (Partial)

Importance of Bacteria

E.coli and *Enterococcus* bacteria are generally not harmful by themselves, but do indicate the possible presence of pathogenic (disease-causing) bacteria, viruses, and protozoans that also live in human and animal digestive systems. Elevated levels of these bacteria can cause health problems (including ear infections, stomach upset and urinary tract infections in women), cloudy water, unpleasant odors, and an increased oxygen demand (the amount of oxygen consumed by microorganisms in breaking down waste). The EPA recommends *E. coli* and *Enterococcus* as the best indicators of health risk from water contact in recreational waters.

Sources of Fecal Coliform

- Wastewater treatment plants
- On site septic systems
- Domestic and wild animal manure
- Storm runoff

Acceptable Fecal Bacteria Ranges

Coliform ranges typically found in surface water are <1 to 80,000 colonies per 100 mL, while coliform ranges typically found in fecal-contaminated surface water are 1,200 to >4,000,000 colonies per 100 mL.

The "advised safe level" for *E. coli* in freshwater used for bathing is a concentration of less than 126 *E. coli* per 100 mL. The advised safe level for *Enterococcus* in freshwater is 61 Enterococci per 100 ml.

2.9. General Stream Conditions:

In addition to measuring general water quality indicators, the Stream Team members also observe and record general physical stream characteristics including: water murkiness (ranging from clear to cloudy to murky based on the depth in inches below the surface that is visible), percent canopy (percentage of tree cover), presence of algae or water plants, presence or absence of an oily sheen, presence or absence of foam or suds, presence or absence of litter (generally defined as small scattered pieces of garbage) or trash (generally defined as larger and more concentrated garbage), and the depth of water at the monitoring station (generally measured at centerline of the stream). Recording these general stream conditions may assist in interpreting monitoring results by providing indications as to why a particular water quality parameter is occurring outside the expected range while providing a record of stream changes over time.

2.10. WEATHER CONDITIONS

Stream Team members also record general weather conditions including cloud cover, precipitation and wind because these conditions directly affect water and air temperatures, the volume of water in-stream, and may affect the volume of run-off from the surrounding watershed into streams.

Chapter 3. Big Creek (Groveland)

3.1. Big Creek @ Ferretti Road - *Site #21, BC-01*

3.1.1. INDICATORS: Big Creek @ Ferretti Road 2007-2008 Results

Site #21 BC-01	Depth @ station	Air temp (^{0} Celsius)	Water Temp (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
November 2007	--	--	--	--	--	--	--
December 2007	10 cm	17.0	13.0	210	8.8-9.2	7.6	1.04-1.12
January 2008	12 cm	13.0	5.7	230	11.4-11.6	7.2-7.3	0.55-0.65
February 2008	25 cm	8.0	6.1	90	11.5-11.6	7.6-7.7	6.83-6.94
March 2008	20 cm	9.0	8.0	80	11.2	7.6	9.28-9.38
April 2008	--	16.0-16.5	9.5	110	10-10.6	7.4	2.15-2.24
May 2008	--	20-20.5	11.9	220	7.0-7.4	6.9	0.58-0.83
June 2008	10 cm	21.0-21.5	14.8	340	3.5-3.6	7.0	2.98-3.11
Overall Range	10-25 cm	8.0 – 21.5	5.7-14.8	80-340	3.5-11.6	7-7.7	0.55-9.38

In comparison, 2006-2007 results for this site were as follows:

Site #21 BC-01	Depth @ station	Air temp (^{0} Celsius)	Water Temp (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
2006-2007 (November – June)	10-12 cm	6.0-22.00	1.6-16.1	90-290	7.6-10.8	6.1-7.8	0.73-2.78

3.1.2. GENERAL STREAM CONDITIONS: Big Creek @ Ferretti Road 2007-2008 Results

Site #21 BC-01	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	--	--	--	--	--	--	--
December 2007	Clear	Less than 50%	No	No	No	No	
January 2008	Clear	Less than 50%	No	No	No	No	
February 2008	Murky (<4" visibility)	--	No	No	No	No	Creek 20-30 feet wide
March 2008	Clear	Less than 50%	No	No	No	No	Slight milkiness
April 2008	Clear	Less than 50%	Algae	No	No	No	
May 2008	Clear	Less than 50%	Algae	No	No	No	
June 2008	Clear	Less than 50%	No	No	No	No	Milkiness, not turbidity; mostly stagnant
Overall Condition	Clear to Murky	Less than 50%	See above	No	No	No	

3.1.3. WEATHER CONDITIONS: Big Creek @ Ferretti Road 2007-2008 Results

Site #21 BC-01	Cloud Cover	Precipitation	Wind
November 2007	--	--	--
December 2007	None	None	Calm
January 2008	None	None	Calm
February 2008	Cloudy	None	Calm
March 2008	Cloudy	None	Calm
April 2008	None	None	Calm
May 2008	None	None	Calm
June 2008	None	None	Calm

Chapter 4. Curtis Creek

4.1. Curtis Creek @ Limekiln Road - *Site #11/CRT-01*

4.1.1. INDICATORS: Curtis Creek @ Limekiln 2007-2008 Results

Site #11 CRT-01	Depth @ station	Air temp (^{0} Celsius)	Water Temp (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
November 2007	--	--	--	--	--	--	--
December 2007	12”	9.9-10.1/b/	9.0-9.8	320-330	5.2-9.0	5.0	0.51-0.69
January 2008	8”	9.5-10.0	7.6-7.7	130	9.8-11.0	~~4.5~~/a/	51.2-64.5
February 2008	25 cm (9.8”)	7.0-7.5	5.0-5.9	150	9.9-10.2	7.7	12.4-13.3
March 2008	18”	14.0-14.5	11.9-12.3	190-200	2.6-2.8	4.9-5.3	3.48-3.64
April 2008	8”	15.0	12.6-13.0	530-560	7.3-7.6	~~4.1~~/a/	1.39-1.84
May 2008	15 cm (5.9”)	20.0-21.0	13.2	260	8.4-8.7	8.1-8.3	1.43-1.78
June 2008	6”	23-25.0	18.6-18.9	200	7.2-7.4	6.3	1.74
Overall Range	5.9” – 18”	7.0-25.0	5.0-18.9	130-560	2.6 – 11.0	~~4.1~~ 5 - 8.3	0.51-64.5

/a/ Indicates meter error or suspected meter error
/b/ Different field thermometer used for air - "Sybron", calibrated to be accurate from -50 to 120 degrees F, with 2 degree divisions.

In comparison, 2006-2007 results for this site were as follows:

Site #11 CRT-01	Depth @ station	Air temp (^{0} Celsius)	Water Temp (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
2006-2007 (November – May)	10" – 18"	8.0-25.0	5.8-14.2	110-270	4.1-8.8	6.2-9.0*	1.58-141**

*4.4 pH reading in February recorded as meter error
**High reading to be monitored for reoccurrence

4.1.2. GENERAL STREAM CONDITIONS: Curtis Creek @ Limekiln 2007-2008 Results

Site #11 CRT-01	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	--	--	--	--	--	--	--
December 2007	Cloudy (>4" visibility)	Greater than 50%	No	No	No	Yes	Low flow
January 2008	Murky (<4" visibility)	Greater than 50%	No	No	Yes (foam and suds)	Yes	
February 2008	Cloudy (>4" visibility)	Less than 50%	No	No	Yes (foam and suds)	Yes	
March 2008	Cloudy (>4" visibility)	Greater than 50%	No	No	Yes (foam and suds)	Yes	
April 2008	Cloudy (>4" visibility)	Greater than 50%	Algae & Water plants	No	No	No	
May 2008	Clear	Less than 50%	No	No	No	No	
June 2008	Clear	Greater than 50%	Algae & water plants	No	No	Yes	Fish fingerlings, no rain past week
Overall Condition	Clear to Murky	See above	See above	No	See above	See above	See above

4.1.3. WEATHER CONDITIONS: Curtis Creek @ Limekiln 2007-2008 Results

Site #11 CRT-01	Cloud Cover	Precipitation	Wind
November 2007	--	--	--
December 2007	None	None	Calm
January 2008	Cloudy sky	Rain	Breezy
February 2008	Cloudy sky	None	Calm
March 2008	Partly cloudy	None	Breezy
April 2008	None	None	Breezy
May 2008	None	None	Calm
June 2008	None	None	Calm

4.2. Curtis Creek @ Tuolumne Road - *Site #12, CRT-02*

4.2.1. INDICATORS: Curtis Creek @ Tuolumne Road: 2007-2008 Results

Site #12 CRT-02	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l	pH	Turbidity (NTU)
November 2007	--	--	--	--	--	--	--
December 2007	12”	7.1-7.3/b/	7.2-7.3	390-410	4.8-5.6	~~4.3-4.9/a/~~	2.18-2.89
January 2008	18”	7.5-8.0	6.9-7.3	140-150	9.8-10.8	~~4.5~~/a/	54.0-64.1
February 2008	25 cm (9.8”)	4.8-5.0	5.0-5.1	150	10.2-10.5	7.3	11.7-12.8
March 2008	6”	12.5-14.0	12.1-12.5	190-200	3.0-3.8	~~4.6~~/a/	3.61-3.77
April 2008	8”	17.0-17.5	12.0-14.0	310-380	6.8-7.2	~~4.1~~/a/	1.67-2.02
May 2008	25 cm (9.8”)	19.4-20.5	13.7	210	7.4-8.6	7.6-7.7	2.09-2.38
June 2008	6”		16.3-17.7	130-140	5.9-6.4	6.1	6.8
Overall Range	6” – 18”		5.0-17.7	130-410	3.0-10.8	~~4.1~~/a/– 7.7	2.02 – 64.1

/a/ Indicates meter error or suspected meter error
/b/ Used different field thermometer "Sybron", calibrated to be accurate from -50 to 120 degrees F, with 2 degree divisions.

In comparison, in 2006-2007:

Site #12 CRT-02	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l	pH	Turbidity (NTU)
2006-2007 (Nov – May)	8" – 18"	8-26.2	8.4-14.5	110-280	4.6-11.0	6.3-8.3*	2.28-161**

*4.4 pH reading in February recorded as meter error
** High reading to be monitored for reoccurrence

4.2.2. GENERAL STREAM CONDITIONS: Curtis Creek @ Tuolumne Road, 2007-2008 Results

Site #12 CRT-02	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	--	--	--	--	--	--	--
December 2007	Cloudy (>4" visibility)	Greater than 50%	No	No	No	Yes	--
January 2008	Murky (>4" visibility)	Greater than 50%	No	No	Yes	Yes	Stormy night before
February 2008	Cloudy (>4" visibility)	Greater than 50%	No	No	Yes	No	
March 2008	Cloudy (>4" visibility)	Greater than 50%	No	No	Yes	Yes	
April 2008	Cloudy (>4" visibility)	Greater than 50%	Algae & water plants	No	No	No	
May 2008	Clear	Greater than 50%	No	No	No	No	Strong manure odor
June 2008	Cloudy (>4" visibility)	Greater than 50%	Algae & water plants	No	No	No	No rain past week
Overall Condition	Clear to Murky	Greater than 50%	See above	No	See above	See above	See above

4.2.3. WEATHER CONDITIONS: Curtis Creek @ Tuolumne Road, 2007-2008 Results

Site #12 CRT-02	Cloud Cover	Precipitation	Wind
November 2007	--	--	--
December 2007	None	None	Breezy
January 2008	Cloudy	Misty	Breezy
February 2008	Cloudy	Drizzle	Calm
March 2008	Partly cloudy	None	Breezy
April 2008	None	None	Breezy
May 2008	None	None	Breezy
June 2008	None	None	Calm

4.3. Curtis Creek Tributary @ Standard Road – *Site #13, STD-01*

4.3.1. INDICATORS: Curtis Creek Tributary @ Standard Road 2007-2008 Results

Site #13 STD-01	Depth @ station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
November 2007	--	--	--	--	--	--	--
December 2007	12”	6.8-7.2/c/	7.9-8.3	110/b/	4.0-7.6	~~4.5~~/a/	2.10-2.13
January 2008	12”	7.0-8.0	8.5	230	9.5-10.2	~~4.5~~/a/	32.0-32.8
February 2008	12 cm (4.7”)	4.0-4.5	5.2	210	10.3-10.6	7.5	6.95-7.61
March 2008	4”	12.5-13.0	13.8-13.9	250	4.2-6.2	~~4.6~~	1.17-1.33
April 2008	6”	15.0-17.0	14.1-15.3	310-320	4.9-5.0	~~4.1~~	0.38-0.51
May 2008	8 cm (3.1”)	22.2-22.4	16.7-17.1	430	4.9-5.7	7.8	0.58-1.03
June 2008	4”	21.0-22.5	20.2-20.6	370	1.8-2.0	5.9	6.2
Overall Range	3.1” – 12”	4.0-22.5	5.2-20.6	110-430	1.8 – 10.6	~~4.1~~-7.8	0.58-32.8

/a/ Indicates meter error or suspected meter error
/b/ Data corrected from recorded 1110
/c/ Used different field thermometer for air - "Sybron", calibrated to be accurate from -50 to 120 degrees F, with 2 degree divisions.

In comparison, in 2006-2007:

Site #13 STD-01	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
2006-2007 (Nov – May)	6" – 12"	10-24.8	7.5-15.0	110-620	1.1-10.0	6.2-8.4*	0.46-145**

*4.4 pH reading in February recorded as meter error
** High reading to be monitored for reoccurrence

4.3.2. GENERAL STREAM CONDITIONS - Curtis Creek Tributary @ Standard Road 2007-2008 Results

Site #13 STD-01	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	--	--	--	--	--	--	--
December 2007	Cloudy (>4" visibility)	Greater than 50%	No	No	No	Yes	Drought, standing pool of water
January 2008	Murky (<4" visibility)	Greater than 50%	No	No	Yes	Yes	Heavy storm night before
February 2008	Clear	Less than 50%	No	No	Yes	Yes	--
March 2008	Cloudy (>4" visibility)	Greater than 50%	Algae & water plants	No	No	Yes	
April 2008	Cloudy (>4" visibility)	--	Heavy algae	No	No	No	--
May 2008	Clear	Greater than 50%	Algae & water plants	No	No	No	--
June 2008	Murky (<4" visibility)	Greater than 50%	No	Yes	No	Yes	Decomposing plant matter; no rain past week
Overall Condition	See above	See above	See above	See above	See above	See above	See above

4.3.3. WEATHER CONDITIONS: Curtis Creek Tributary @ Standard Road 2007-2008 Results

Site #13 STD-01	Cloud Cover	Precipitation	Wind
November 2007	--	--	--
December 2007	None	None	Calm
January 2008	Cloudy	Misty	Breezy
February 2008	Cloudy	Drizzle	Calm
March 2008	Partly cloudy	None	Breezy
April 2008	None	None	Breezy
May 2008	None	None	Calm
June 2008	None	None	Calm

Chapter 5. Groveland Creek

5.1. Groveland Creek @ Groveland Community Services District Driveway - *Site #20, GC-01*

5.1.1. INDICATORS: Groveland Creek @ Groveland Community Services District Driveway 2007-2008 Results

Site #20 GC-01	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
November 2007	--	--	--	--	--	--	--
December 2007	12 cm	13.5-14	11.8	210	8.2-9.4	7.7	1.29-1.33
January 2008	12 cm	12-12.5	6.8	220-230	10.6-11.2	7.5-7.7	2.71-2.73
February 2008	10 cm	8.0-8.5	5.8-5.9	130	10.8-11.1	7.6-7.8	32.9-33.1
March 2008	10 cm	9.5-10	8.0	160	11.0-11.4	7.8	7.65-7.71
April 2008	8.0 cm	4.0	7.1	200	10.4-10.5	7.6	0.35-0.42
May 2008	10 cm	12.0	9.2	200	9.5-9.8	7.4	0.42-0.45
June 2008	10 cm	15.5-16.5	12.2	200	8.3-8.5	7.5	0.29-0.31
Overall Range	8.0-12.0 cm	4.0-16.5	5.8-12.2	130-230	8.2-11.4	7.4-7.8	0.29-33.1

In comparison, in 2006-2007:

Site #20 GC-01	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
2006-2007 (Nov – June)	8-10 cm	8-25	4.6-16.1	170-410	3.2-11.0	6.8-8.0	1.29-12.6

5.1.2. GENERAL STREAM CONDITIONS: Groveland Creek @ Groveland Community Services District Driveway 2007-2008 Results

Site #20 GC-01	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	--	--	--	--	--	--	--
December 2007	Clear	Less than 50%	No	No	No	No	
January 2008	Clear	Greater than 50%	Algae	No	No	No	
February 2008	Murky (<4" visibility)	Less than 50%	No	No	Foam, suds	No	Water milky, sudsy – like sewage
March 2008	Clear	Less than 50%	No	No	No	No	Slight milkiness
April 2008	Clear	Less than 50%	Algae	No	No	No	
May 2008	Clear	Less than 50%	Algae	No	No	No	
June 2008	Clear	Less than 50%	Algae	No	No	No	Two algal types
Overall Condition	Clear to Murky	See above	See above	No	See above	No	See above

5.1.3. WEATHER CONDITIONS: Groveland Creek @ Groveland Community Services District Driveway

Site #20 GC-01	Cloud Cover	Precipitation	Wind
November 2007	--	--	--
December 2007	None	None	Calm
January 2008	None	None	Calm
February 2008	Cloudy (high, thin)	None	Calm
March 2008	Cloudy	None	Calm
April 2008	None	None	Calm
May 2008	None	None	Calm
June 2008	None	None	Calm

Chapter 6. Mormon Creek

6.1. Mormon Creek @ VonKleiben Road - *Site #1, MM-01*

6.1.1. INDICATORS: Mormon Creek @ VonKleiben Road 2007-2008 Results

Site #1 MM-01	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen ppm, mg/l	pH	Turbidity (NTU)
November 2007	--	6-7	10.9-11.1	480	8.8-0.0	7.9	0.5-0.8
December 2007	--	6	7.9-8.0	480	--	8.1-8.2	0.2
January 2008	--	7-7.2	9.2-9.3	230-290	8.5-9.0	7.9	--
February 2008	4”	0.0-2.0	7.4-7.5	380	9.0-9.3	8.1	12.2-12.9
March 2008	--	8.5-10.0	11.4	440	8.4-8.9	8.5	1.37-1.47
April 2008	--	--	--	--	--	--	--
May 2008	6-8”	15.0-15.5	12.4-12.5	490	9.3-9.5	8.5	0.39-0.41
June 2008	1’3”/a/	23	14.7-14.8	480-490	8.6	8.3	0.80-1.07
Overall Range	4” – 1’3”	0.0-23.0	7.4-14.8	230-490	8.4-9.5	7.9-8.5	0.2-12.9

/a/ Monitoring downstream of bridge – normal location is upstream of bridge

In comparison, in 2006-2007:

Site #1 MM-01	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen ppm, mg/l	pH	Turbidity (NTU)
2006-2007 (Nov-May)	9”-10”	0-15.0	6.6-13.5	310-530	8.7-10.8	8.3-8.5	0.37-34.5

6.1.2. GENERAL STREAM CONDITIONS: Mormon Creek @ VonKleiben Road 2007-2008 Results

Site #1 MM-01	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	Clear	Greater than 50%	No	No	No	No	--
December 2007	Clear	Greater than 50%	No	No	No	No	--
January 2008	Murky <4” visibility	Greater than 50%	No	No	No	No	--
February 2008	Clear	Greater than 50%	No	No	Yes	No	--
March 2008	Clear	Greater than 50%	No	No	Yes	No	--
April 2008	--	--	--	--	--	--	
May 2008	Clear	Greater than 50%	No	No	No	No	
June 2008	Clear	Greater than 50%	Heavy algae	No	No	No	Sampled downstream of bridge – normal sampling is upstream
Overall Condition	Clear to Murky	Greater than 50%	None to heavy algae	No	Sometimes foam, suds	No	

6.1.3. WEATHER CONDITIONS: Mormon Creek @ VonKleiben Road 2007-2008 Results

Site #1 MM-01	Cloud Cover	Precipitation	Wind
November 2007	None	None	Calm
December 2007	None	None	Calm
January 2008	Cloudy sky	Rain	Breezy
February 2008	Cloudy sky	None	Calm
March 2008	Cloudy sky	None	Calm
April 2008	--	--	--
May 2008	None	None	Calm
June 2008	None	None	Breezy (light)

6.2. Mormon Creek @ Columbia Airport - *Site #2, MM-02*

6.2.1. INDICATORS: Mormon Creek @ Columbia Airport 2007-2008 Results

Site #2 MM-02	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
November 2007	Dry	Dry	Dry	Dry	Dry	Dry
December 2007	Dry	Dry	Dry	Dry	Dry	Dry
January 2008	Dry	Dry	Dry	Dry	Dry	Dry
February 2008	Dry	Dry	Dry	Dry	Dry	Dry
March 2008	Removed from monitoring list due to lack of flow					
April 2008						
May 2008						
June 2008						
Overall Range						

In comparison, in 2006-2007

Site #2 MM-02	Depth @ Station	Air temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm;mg/l)	pH	Turbidity (NTU)
2006-2007	Dry – 4.5”	2-13.0	10.6-13.0	20-50	7.8-10.4	7.2-7.8	3.02-23.5

Chapter 7. Mt. Eaton Ditch

7.1. Mt. Eaton Ditch @ Buchanan Mine Road - *Site #18, MED-01*

7.1.1. INDICATORS: Mt. Eaton Ditch @ Buchanan Mine Road 2007-2008 Results

Site #18 MED-01	Depth @ station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
November 2007	9 cm	15-16	9.3-9.4	20	6-9.2	7.5	2.26-2.48
December 2007	7.5 cm	6.5-7	3.7-3.9	20	8.2-11.0	7.4-7.7	1.58-2.00
January 2008	4 cm	5.5	5.0-5.1	40	6.6-9.1	7.1-7.3	14.5-14.7
February 2008	10 cm	3	6.7-7.0*	30	7.9-12.1	2.3-2.4*	4.44-4.48
March 2008	9.5 cm	9-9.5	7.5	40	3.8-7.2	6.6-6.7	4.39-5.32
April 2008	8 cm	13-14	7.1-7.2	40	8.5-8.9	6.4	2.16-6.33
May 2008	6 cm	19-20	11.19-11.39	30-40	4.8-5.7	6.1-6.2	3.53-4.13
June 2008	10.5 cm	19.5	11.9-12.0	20	3.9-4.6	6.0-6.1	4.56-4.73
Overall Range	4 – 10.5 cm	3-20	3.7-12.0	20-40	3.9-12.1	6.0-7.7	1.58-14.7

* Subject to change pending confirmation that pH and temperature readings were not inadvertently switched

Table 6: Mt. Eaton Ditch @ Buchanan Mine Road Bacterial Sampling Test Run, June 2008

	Most Probable Number (MPN)
Enterococci	25.3
Total coliforms	74.3

In comparison, in 2006-2007:

Site #18 MED-01	Depth @ station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
2006-2007 (Nov – May)	8 – 13 cm	6.5-20.0	6.0-13.4	30-40	4-11	6.8-7.8	2.3-28.4

7.1.2. GENERAL STREAM CONDITIONS: Mt. Eaton Ditch @ Buchanan Mine Road 2007-2008 Results

Site #18 MED-01	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	Clear	Less than 50%	No	No	No	No	
December 2007	Clear	Less than 50%	No	No	No	No	
January 2008	Clear	Less than 50%	No	No	No	No	
February 2008	Clear	Greater than 50%	No	No	No	No	
March 2008	Clear	Greater than 50%	No	No	No	No	
April 2008	Clear	Greater than 50%	No	No	No	No	
May 2008	Clear	Greater than 50%	No	No	No	No	
June 2008	Clear	Greater than 50%	No	No	No	No	
Overall Condition	Clear	See above	No	No	No	No	

7.1.3. WEATHER CONDITIONS: Mt. Eaton Ditch @ Buchanan Mine Road 2007-2008 Results

Site #18 MED-01	Cloud Cover	Precipitation	Wind
November 2007	None	None	Calm
December 2007	Partly Cloudy	None	Calm
January 2008	Cloudy	None	Breezy
February 2008	Cloudy	None	Calm
March 2008	Cloudy	None	Calm
April 2008	None	None	Breezy
May 2008	None	None	Calm
June 2008	None	None	Calm

Chapter 8. Peppermint Creek

8.1. Peppermint Creek @ Pulpit Rock Road - *Site #3, PMT-01*

Figure 8: Peppermint Creek @ Pulpit Rock Road

Figure 9: Algae at Peppermint Creek

8.1.1. INDICATORS: Peppermint Creek at Pulpit Rock Road 2007-2008 Results

Site #3 PMT-03	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
November 2007	--	--	--	--	--	--	--
December 2007	--	--	--	--	--	--	--
January 2008	--	--	--	--	--	--	--
February 2008	--	--	--	--	--	--	--
March 2008	--	--	--	--	--	--	--
April 2008	6”	14.5-15.0	12.1-12.2	340	8.6-9.0	8.0	0.62-0.91/a/
May 2008	<2”	19.5-20.5	14.6	340	8.7-8.8	7.9-8.0	0.46-0.50
June 2008	4.25 – 9.5”/b/	23 – 24.0	17.0-17.2	350-360	8.8-9.2	8.0	5.0-5.35
Overall Range	<2” – 9.5”	14.5-24.0	12.1-17.2	340-360	8.6-9.2	7.9-8.0	0.62-5.35

/a/ Read after 12 hour hold
/b/ Moved station further downstream to pool due to extreme turbidity kicked up from algae from frogs and crayfish movements

In comparison, in 2006-2007:

Site #3 PMT-03	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
2006-2007 (Nov – April)	6-40.6 cm (2.4" - approx. 16.0")	9.5-17	5.7-18.3	150-770	4.8-10.4	7.9-8.6	0.72-39.4

8.1.2. GENERAL STREAM CONDITIONS: Peppermint Creek @ Pulpit Rock Road 2007-2008 Results

Site #3 PMT-03	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	--	--	--	--	--	--	--
December 2007	--	--	--	--	--	--	--
January 2008	--	--	--	--	--	--	--
February 2008	--	--	--	--	--	--	--
March 2008	--	--	--	--	--	--	--
April 2008	Clear	Less than 50%	Algae & Water Plants	No	No	Yes - heavy trash (beer, soft drink cups, grocery plastic bags)	Water striders Vegetation clearing (blackberries, heavy equipment stored with piles of vegetation on east bank)
May 2008	Clear	Greater than 50%	No	No	No	Yes	--
June 2008	Cloudy (>4" visibility)	Less than 50%	Algae (heavy)	No	No	Yes	Frog, peppermint (dense), water strider, crayfish; Movement of frogs and crayfish kicked up thick algae creating turbidity
Overall Condition	Clear to Cloudy	See above	See above	No	No	Yes	See above.

8.1.3. WEATHER CONDITIONS: Peppermint Creek @ Pulpit Rock Road 2007-2008 Results

Site #3 PMT-03	Cloud Cover	Precipitation	Wind
November 2007	--	--	--
December 2007	--	--	--
January 2008	--	--	--
February 2008	--	--	--
March 2008	--	--	--
April 2008	None	None	Breezy
May 2008	None	None	Calm
June 2008	None	None	Breezy (light)

Chapter 9. Sonora Creek

9.1. Sonora Creek @ Southgate Drive - *Site #7, SRA-01*

Figure 10: Sonora Creek @ Southgate Drive

9.1.1. INDICATORS: Sonora Creek @ Southgate Drive 2007-2008 Results

Site #7 SRA-01	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
November 2007	8”	10	11.6-11.7	360	9.2-9.3	7.8	0.78-0.87
December 2007	10”	4.5-5.0	6.7-6.8	450-470	7.8-11.0	8.0	0.42-0.62
January 2008	10”	7.0	7.7-7.8	180	8.8-10.0	7.6	32.4-33.5
February 2008	11.5”	6.0-6.5	6.3	210	10.4-11.0	7.8	9.3-9.75/a/
March 2008	10”	9.0	10	330	6.2-8.6	8.5	--
April 2008	10”	9.5-10.0	10.2-10.3	410-420	9.7-10.0	8.6	0.78-0.94
May 2008	10”	19.0	12.7	420	8.4-10.0	8.5	0.92-1.66
June 2008	12”	24.5	17.9-18.0	420	8.9-9.4	8.5	1.21—1.63
Overall Range	8”-12”	4.5 – 19.0	6.3-18.0	180-470	6.2-11.0	7.6-8.6	0.42-33.5

/a/ Read @ 24 hours

In comparison, in 2006-2007:

Site #7 SRA-01	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
2006-2007 (Nov – May)_	6” – 12”	5-18.5	4.1-14.5	120-380	8.8-13.6	7.8-9.2	0.96-26.4

9.1.2. GENERAL STREAM CONDITIONS: Sonora Creek @ Southgate Drive 2007-2008 Results

Site #7 SRA-01	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	Clear	Less than 50%	Yes	No	No	Yes	--
December 2007	Clear	Less than 50%	Yes	No	No	No	--
January 2008	Murky (<4" visibility)	Less than 50%	Yes	No	Yes	Yes	--
February 2008	Cloudy (>4" visibility)	Less than 50%	Yes	No	No	Yes (water bottle, paper)	Cloudy especially below falls and @ bank
March 2008	Clear	Less than 50%	Yes	No	No	Yes (tire)	--
April 2008	Clear	Less than 50%	Yes	No	No	Yes (beer bottle)	--
May 2008	Clear	Less than 50%	Yes	No	No	No	Abundant vegetation growth since previous sampling
June 2008	Clear	Less than 50%	Yes	No	No	Yes	Peppermint abundant, small fish, very dense grasses and veg required moving upstream slightly for sampling
Overall Condition	Clear to Cloudy	Less than 50%	Yes	No	See above	See above	See above

9.1.3. WEATHER CONDITIONS: Sonora Creek @ Southgate Drive 2007-2008 Results

Site #7 SRA-01	Cloud Cover	Precipitation	Wind
November 2007	None	None	Calm
December 2007	None	None	Calm
January 2008	Cloudy sky	None (recent torrent)	Calm
February 2008	Cloudy sky	None	Breezy (light)
March 2008	Cloudy sky	None	Calm
April 2008	None	None	Calm
May 2008	None	None	Calm
June 2008	None	None	Breezy (light)

Chapter 10. Sullivan Creek

10.1. Sullivan Creek @ Longeway Road - *Site #24, SV-01*

10.1.1. INDICATORS: Sullivan Creek @ Longeway Road 2007-2008 Results

Site #24 SV-01	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Flow (ft/sec)	Turbidity (NTU)	Notes
November 2007	10 cm	16.8-16.9	10.1-10.2	70-80	9.3-9.7	6.8-6.9	--	9.0-9.5	--
December 2007	10 cm	3.0	8.6-8.7	70	9.3-9.5	6.8-6.9	--	15.5-16.0	--
January 2008	40 cm	1.4	2.8	60-70	10.5-11.1	8.0-8.1	--	20.4-21.5	--
February 2008	--	1.0-1.5	4.3	60	10.0-10.75	8.4-8.5	--	6.82-6.99	snow
March 1, 2008	5.5 * (14 cm)	9-10.5	7.9-8.0	60	10.2-10.6	8-8.1	1.0	9.98-10.6	--
March 16, 2008	--	10-11	8.5-9.2	60	--	9.8-10.1**	--	2.99-3.74	
April 2008	6* (15.5 cm)	12	10	60	4.5	7.5	--	5.1-5.4	--
May 2008	30 cm	17.5	12.0	70	9-10	6.0	--	1.4-1.6	--
June 2008	--	18.5-19.0	13.5	70	8.1	7-7.9	--	2.18-2.42	--
Overall Range	10 – 40 cm	1.0-19.0	2.8-13.5	60-80	4.5-11.1	6.8-10.1	1.0	1.4-21.5	--

*units not specified, assumed inches

**all pH readings at all Sullivan Creek locations (same temp meter) read high – meter may have been in error?

In comparison, in 2006-2007:

Site #24 SV-01	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Flow (ft/sec)	Turbidity (NTU)
2006-2007 (Dec – May)	15-40 cm	7-17.1	5.3-15.2	60-80	8.0-9.9	7.2-7.8	--	6.18-58.2

10.1.2. GENERAL STREAM CONDITIONS: Sullivan Creek @ Longeway Road 2007-2008 Results

Site #24 SV-01	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	Clear	Greater than 50%	Algae, water plants	No	No	No	
December 2007	Clear	Greater than 50%	Algae, water plants	No	No	No	
January 2008	Cloudy (>4" visibility)	Greater than 50%	No	No	Foam, suds	No	
February 2008	Cloudy (>4" visibility)	Greater than 50%	No	No	No	No	Snowing heavy, water flowing from 3 pipes, horse field drains above on other side of pipes; dogs, horses
March 1, 2008	Clear	Greater than 50%	Algae on rocks	No	No	No	Rocks very slippery
March 16, 2008	Cloudy (> 4" visibility)	Greater than 50%	Algae, water plants	No	Foam, suds	No	
April 2008	Clear	Greater than 50%	No	No	No	Yes	
May 2008	Clear	Greater than 50%	No	No	No	Yes	
June 2008	Clear	Greater than 50%	No	No	No	No	--
Overall Condition	Clear to Cloudy	Greater than 50%	See above	No	See above	See above	See above

10.1.3. WEATHER CONDITIONS: Sullivan Creek @ Longeway Road 2007-2008 Results

Site #24 SV-01	Cloud Cover	Precipitation	Wind
November 2007	None	None	Calm
December 2007	Partly Cloudy	None	Calm
January 2008	Cloudy sky	Drizzle	Breezy
February 2008	Cloudy	Snowing heavy	Calm
March 1, 2008	Cloudy	None	Calm
March 16, 2008	Partly Cloudy	None	Breezy
April 2008	None	None	Calm
May 2008	Partly Cloudy	None	Calm-Breezy
June 2008	No clouds	None	Breezy

Figure 11: Sullivan Creek @ Longeway Road

10.2. Sullivan Creek @ Creekside/Crestview - *Site #26, SV-02*

10.2.1. INDICATORS: Sullivan Creek @ Creekside/Crestview 2007-2008 Results

Site #26 SV-02	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Flow ft/sec	Turbidity (NTU)
November 2007	20 cm	17.2-17.3	12.4-12.5	80-90	9.5-9.7	7.2-7.3	--	15.5-16.5
December 2007	20 cm	3.2	10.1	90	9.4-9.7	6.9-7.0	--	15.0-16.0
January 2008	100 cm	1.7	3.2	100-110	10.4-10.5	8.1	--	37.8-40.1
February 2008	--	4.0-4.5	4.2-4.3	100	10.75	8.2	--	10.3-10.4
March 1, 2008	22 in (approx 58 cm)	10.0	8.2-9.0	90	9.8-10.2	8.6-9.2	0.5	7.58-7.86
March 16, 2008	--	11.0-11.5	7.4-7.5	100	--	10.3*-10.4*	--	3.32-3.93
April 2008	14 (abt. 38 cm)	18-19	7-8	100	7.5	7.5	--	7.5
May 2008	<50 cm	16.0	12.0	110	9-10	7.0	--	1.2-1.3
June 2008	--	19.5-21.0	14.5-15.0	120	9.0	7-8.6	--	1.33-1.47
Overall Range	20-100 cm	3.2-21.0	3.2-15.0	80-120	7.5 – 10.75	6.9-10.4*	0.5	1.2-40.1

*Possible meter error

In comparison, in 2006-2007:

Site #26 SV-02	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Flow ft/sec	Turbidity (NTU)
2006-2007 (Dec – May)	20 – 100 cm	8.4-23.5	4.3-16.6	90-130	7.0-10.6	7.3-7.8	--	1.66-31.1

10.2.2. GENERAL STREAM CONDITIONS: Sullivan Creek @ Creekside/Crestview 2007-2008 Results

Site #26 SV-02	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	Clear	Greater than 50%	Algae, water plants	No	No	Yes	
December 2007	Clear	Greater than 50%	Algae, water plants	No	No	Yes	
January 2008	Cloudy (>4" visibility)	Greater than 50%	No	No	Foam, suds	Yes	
February 2008	Cloudy (>4" visibility)	Less than 50%	No	No	No	Yes (cans, potato chip bags, bottles)	Heavy population, water cloudy
March 1, 2008	Cloudy (> 4" visibility)	Less than 50%	Water plants	No	Foam, suds	Yes (moderate trash)	
March 16, 2008	Cloudy (> 4" visibility)	Less than 50%	Algae, water plants	No	Foam, suds	No	
April 2008	Clear	Less than 50%	No	No	No	No	Area looks clean
May 2008	Clear	Greater than 50%	Yes	No	No	Yes	--
June 2008	Clear	Greater than 50%	No	No	No	Yes	--
Overall Condition	Clear to Cloudy	See above	See above	No	See above	See above	See above

10.2.3. WEATHER CONDITIONS: Sullivan Creek @ Creekside/Crestview 2007-2008 Results

Site #26 SV-02	Cloud Cover	Precipitation	Wind
November 2007	None	None	Calm
December 2007	Partly Cloudy	None	Calm
January 2008	Cloudy sky	Drizzle	Breezy
February 2008	Cloudy	Light rain	Calm
March 2008	Cloudy	None	Calm
March 16, 2008	None	None	Breezy
April 2008	None	None	Calm
May 2008	Partly cloudy	None	Calm
June 2008	No clouds	None	Breezy

Figure 12: Sullivan Creek @ Creekside/Crestview

10.3. Sullivan Creek Opposite Fern Lane - *Site #27, SV-03*

10.3.1. INDICATORS: Sullivan Creek Opposite Fern Lane 2007-2008 Results

Site #27 SV-03	Depth @ Station (inches, average)	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Flow (ft/sec)	Turbidity (NTU)
November 2007	20 cm	17.1-17.2	12.3-12.4	80-90	9.2-9.7	7.3	--	13.9-15.0
December 2007	30 cm	3.1	10.1	90	9.0-9.5	6.9-7.0	--	15.2-15.8
January 2008	100 cm	1.7	3.2	90-100	10.5-10.7	8.1	--	40.1-42.3
February 2008	--	4.0	4.5	110	10.0-10.25	8.3-8.4	--	9.37-9.5
March 1, 2008	16.8 in (abt 43 cm)	13.0-13.5	9.1	90-100	9.6-11.2	8.1-8.2	1.5	7.01-7.38
March 16, 2008	--	10.4	7.3-8.4	110	--	10.2*-10.3*	--	3.94-4.01
April 2008	14** (abt. 38 cm)	20-21	11-12	120	9	6.0	--	1.2
May 2008	Approx 50 cm	16.0	12.0	120-130	9-11	6.5	--	1.1-1.2
June 2008	--	20.5	14.5	130	8.6	7-8.4	--	1.25-1.75
Overall Range	20-100 cm	1.7-21.0	3.2-14.5	80-130	8.6-11.2	6.0-10.3*	1.5	1.1-42.3

**Units not specified, assumed inches
*Possible meter error

In comparison, in 2006 – 2007:

Site #27 SV-03	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Flow (ft/sec)	Turbidity (NTU)
2006-2007 (Dec – May)	15 – 100 cm	6.5-24.0	4.6-17.0	90-130	6.4-10.0	7.3-7.8	--	0.88-30.7

10.3.2. GENERAL STREAM CONDITIONS: Sullivan Creek Opposite Fern Lane 2007-2008 Results

Site #27 SV-03	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	Clear	Greater than 50%	Algae, water plants	No	No	Yes	
December 2007	Clear	Greater than 50%	Algae, water plants	No	No	Yes	
January 2008	Cloudy water (>4" visibility)	Greater than 50%	No	No	Foam, suds	Yes	
February 2008	Cloudy water (>4" visibility)	Less than 50%	No	No	No	No	Some bubbles on surface, heavy population
March 1, 2008	Cloudy water (>4" visibility)	Less than 50%	Water plants	No	Suds	Yes (light litter)	No leaves on trees
March 16, 2008	Cloudy water (>4" visibility)	Less than 50%	Algae, water plants	No	No	Yes	
April 2008	Clear	Less than 50%	No	No	No	Yes	--
May 2008	Clear	Greater than 50%	Algae, water plants	No	No	No	--
June 2008	Clear	--	Algae, water plants	No	No	No	Septic smell
Overall Condition	Clear to cloudy	See above	See above	No	See above	See above	See above

10.3.3. WEATHER CONDITIONS: Sullivan Creek Opposite Fern Lane 2007-2008 Results

Site #27 SV-03	Cloud Cover	Precipitation	Wind
November 2007	None	None	Calm
December 2007	Partly cloudy	None	Calm
January 2008	Cloudy sky	Drizzle	Breezy
February 2008	Cloudy	Drizzle (light rain)	Calm
March 1, 2008	Partly cloudy	None	Calm
March 16, 2008	None	None	Breezy
April 2008	Partly cloudy	None	Calm
May 2008	None	None	Calm
June 2008	None	None	Breezy

Figure 13: Sullivan Creek @ Opposite Fern Lane

10.4. Sullivan Creek Tributary @ Buena Vista Avenida - *Site #28, SV-04*

10.4.1. INDICATORS: Sullivan Creek Tributary @ Buena Vista Avenida 2007-2008 Results

Site #28 SV-04	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Flow (ft/sec)	Turbidity (NTU)
November 2007	10 cm	16.9	11.0-11.1	210	9.4-9.5	7.4-7.5	--	9.6-10.5
December 2007	5 cm	3.0	8.2-8.3	210	9.5	6.8	--	10.2-10.8
January 2008	30 cm	1.6	3.0	180-190	10.7-10.8	8.3	--	30.5-31.2
February 2008	--	3.0	5.0	180	10.25-10.75	8.9-9.0	--	6.74-6.75
March 1, 2008	3.4 in. (Abt. 8.5 cm)	16	10.6-10.7	210	10.2-11.0	8.5-8.8	0.5	1.38-1.46
March 16, 2008	--	13.5-14.5	7.5-7.7	--	--	11.1*-11.2*	--	0.48-0.74
April 2008	12** (Abt 30.5 cm)	25	10	120	9.0	7.0	--	1.9
May 2008	<20 cm	16.5	12.5	320-330	9-10	7.0	--	0.5-0.6
June 2008	--	20-21.0	15.5	410	7.8	7.0-7.6	--	1.77-2.26
Overall Range	5 – 30.5 cm	1.6-25.0	3.0-15.5	120-410	7.8-11.0	6.8-11.2*	0.5	0.48-31.2

*Possible meter error
** units not specified, assumed inches

In comparison in 2006-2007:

Site #28 SV-04	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Flow (ft/sec)	Turbidity (NTU)
2006-2007 (Dec – May)	15-30 cm	7-23.5	5.1-18.4	160-280	7.7-9.9	8.1-8.5	--	0.71-19.0

10.4.2. GENERAL STREAM CONDITIONS: Sullivan Creek Tributary @ Buena Vista Avenida 2007-2008 Results

Site #28 SV-04	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	Clear	Greater than 50%	Algae, water plants	No	No	No	
December 2007	Clear	Greater than 50%	Algae, water plants	No	No	Yes	
January 2008	Cloudy (> 4" visibility)	Greater than 50%	No	No	No	No	
February 2008	Cloudy (> 4" visibility)	Less than 50%	Water plants (moss)	No	No	No	Cul-de-sac, lots of moss, raging water falls
March 1, 2008	Clear	Less than 50%	Algae, water plants	No	No	Yes (light litter)	
March 16, 2008	Clear	Less than 50%	Algae, water plants	No	No	No	
April 2008	Clear	Greater than 50%	No	No	No	No	--
May 2008	Clear	Greater than 50%	Yes	No	No	Yes	
June 2008	Clear	Less than 50%	Yes	No	No	No	Tadpoles, mosquito fish, waterbugs, poison oak; very low flow; sampling pool approaching stagnant; lots of floaties; willow roots in pond; water walking fly, monkey flower; neighbors watching – reports of oil dumping
Overall Condition	Clear to cloudy	See above	See above	No	No	See above	See above

10.4.3. WEATHER CONDITIONS: Sullivan Creek Tributary @ Buena Vista Avenida 2007-2008 Results

Site #28 SV-04	Cloud Cover	Precipitation	Wind
November 2007	None	None	Calm
December 2007	Partly cloudy	None	Calm
January 2008	Cloudy	Drizzle	Breezy
February 2008	Cloudy	Drizzle	Calm
March 1, 2008	Cloudy	None	Calm
March 16, 2008	None	None	Breezy
April 2008	Partly cloudy	None	Calm
May 2008	None	None	Calm
June 2008	No clouds	None	Breezy

Figure 14: Sullivan Creek @ Buena Vista Avenida

10.5. Sullivan Creek @ Potato Ranch Road - *Site #29, SV-05*

10.5.1. INDICATORS: Sullivan Creek @ Potato Ranch Road 2007-2008 Results

Site #29 SV-05	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Flow (ft/sec)	Turbidity (NTU)	Notes
November 2007	10 cm	16.7-16.8	12.0	90	9.4-9.5	7.1-7.2	--	15.4-15.5	--
December 2007	20 cm	3.1	10.2	90	9.3-9.5	6.8	--	15.3-15.8	--
January 2008	100 cm	1.6	3.4	70	10.5-11.0	8.1-8.2	--	53.6-55.2	--
February 2008	--	3	4.5-4.6	120	10.25-11.0	8.9	--	12.2-12.4	--
March 1, 2008	8.66 in. (21.5 cm)	13-15.0	9.6-9.8	110	9.8-10.0	8.4-8.5	3.5	6.86-6.92	--
March 16, 2008	--	9-10.5	7.0-7.9	120	10.6-11.0	10.3*-10.4*	--	6.93-8.16	
April 2008	12** (Abt 30.5 cm)	25-26	10	130	9.5	7.0	--	1.8	Minimal variation in data collected for each parameter
May 2008	<50 cm	15.5	12.0	130-140	8-9	7.0	--	1.0-1.1	--
June 2008	--	18.5-19.0	13.5	150	9.5	7-9.0	--	0.85-1.02	--
Overall Range	10 – 100 cm	3-26.0	3.4-13.5	70-150	8.0-11.0	7.1-10.4*	3.5	0.85-55.2	--

** units not specified, assumed inches
*Possible meter error

In comparison, in 2006-2007:

Site #29 SV-05	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Flow (ft/sec)	Turbidity (NTU)
2006-2007 (Dec - May)	15-30 cm	5-24	3.9-17	100-160	7.5-12.2	7.5-7.9	--	0.98-47.0

10.5.2. GENERAL STREAM CONDITIONS: Sullivan Creek @ Potato Ranch Road 2007-2008 Results

Site #29 SV-05	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	Clear	Greater than 50%	Algae, water plants	No	No	Yes	
December 2007	Clear	Greater than 50%	Algae, water plants	No	No	Yes	
January 2008	Cloudy (>4" visibility)	Greater than 50%	No	No	Foam, suds	Yes	
February 2008	Cloudy (>4" visibility)	Less than 50%	No	No	No	No	Golf course, cloudy water
March 2008	Cloudy (>4" visibility)	Less than 50%	Water plants (grass)	No	No	No	Wild berries, lots of dead leaf accumulation; both slopes sandy supported by (leaves?)
April 2008	Clear	Less than 50%	No	No	No	Yes	--
May 2008	Clear	Greater than 50%	Algae, water plants	No	No	Yes	--
June 2008	Clear	Greater than 50%	Algae	Yes	No	No	--
Overall Condition	Clear to cloudy	See above	See above	See above	See above	See above	See above

10.5.3. WEATHER CONDITIONS: Sullivan Creek @ Potato Ranch Road 2007-2008 Results

Site #29 SV-05	Cloud Cover	Precipitation	Wind
November 2007	None	None	Calm
December 2007	Partly cloudy	None	Calm
January 2008	Cloudy	Drizzle	Breezy
February 2008	Cloudy sky	Drizzle	Calm
March 1, 2008	Partly cloudy	None	Calm
March 16, 2008	None	None	Breezy
April 2008	Partly cloudy	None	Calm
May 2008	None	None	Calm
June 2008	None	None	Calm

Figure 15: Sullivan Creek @ Potato Ranch Road

10.6. Sullivan Creek @ S.R. 108/Bergel Road - *Site #30, SV-06*

10.6.1. INDICATORS: Sullivan Creek @ SR 108/Bergel Road 2007-2008 Results

Site #30 SV-06	Depth @ Station (inches, average)	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Flow (ft/sec)	Turbidity (NTU)
November 2007	30 cm	16.5	12.4-12.5	90	8.4-8.5	7.0-7.1	--	15.5-15.8
December 2007	20 cm	3.1	10.5	100-110	9.3-9.5	6.5	--	15.5-15.8
January 2008	100 cm +	1.5	3.5	70	9.4-9.5	8.0-8.1	--	63.2-65.5
February 2008	--	4.0	4.5-4.6	90	9.5-10.0	8.9-9.0	--	17.6-17.7
March 1, 2008	20.3 in. (Abt. 53 cm)	13.0-14.0	10.3-10.7	80	10.0-10.6	9.0-9.1	2.0	10.3-11.0
March 16, 2008	--	9.0-11.0	6.1	70	10.2-11.2	10.0*-10.5*	--	3.91-4.38
April 2008	12** (30.5 cm)	19-20	8	60	7.0-7.5	7.5	--	3.5
May 2008	< 50 cm	15.0-16.0	13.5	70	9	7.0	--	--
June 2008	--	17.5	15.5-16.0	50	8.3-9.0	7	--	2.69-3.25
Overall Range	20-100+cm	1.5-20.0	3.5 – 16.0	50-110	7.0-11.2	6.5-10.5*	2.0	3.5-65.5

*Possible meter error
** No units, assumed inches

In comparison, in 2006-2007:

Site #30 SV-06	Depth @ Station (inches, average)	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Flow (ft/sec)	Turbidity (NTU)
2006-2007 (Dec – May)	15-50 cm	9.5 – 25.0	4.5-18.8	90-120	7.2-11.3	7.4-8.0	--	1.41-60.5

10.6.2. GENERAL STREAM CONDITIONS: Sullivan Creek @ SR 108/Bergel Road 2007-2008 Results

Site #30 SV-06	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	Clear	Greater than 50%	Algae, water plants	No	No	Yes	
December 2007	Clear	Greater than 50%	Algae, water plants	No	No	Yes	
January 2008							
February 2008	Cloudy (>4" visibility)	Less than 50%	No	No	Suds	No	Bubbles on surface, cloudy water under freeway
March 1, 2008	Cloudy (>4" visibility)	Less than 50%	Algae on rocks	No	Suds	Yes (broken bottles)	Under bridge large rocks on slopes; no leaves on trees
March 16, 2008	Cloudy (>4" visibility)	Less than 50%	Algae, water plants	No	No	Yes	
April 2008	Clear	Greater than 50%	No	No	No	Yes	
May 2008	Clear	Greater than 50%	Yes	No	No	Yes	
June 2008	Clear	Greater than 50%	No	No	No	Yes	Dead crawfish
Overall Condition	Clear to cloudy	See above	See above	No	See above	See above	See above

10.6.3. WEATHER CONDITIONS: Sullivan Creek @ SR 108/Bergel Road 2007-2008 Results

Site #30 SV-06	Cloud Cover	Precipitation	Wind
November 2007	None	None	Calm
December 2007	Partly cloudy	None	Calm
January 2008			
February 2008	Cloudy	Drizzle	Calm
March 1, 2008	Partly cloudy	None	Breezy
March 16, 2008	None	None	Breezy
April 2008	Partly cloudy	None	Breezy
May 2008	None	None	Calm
June 2008	None	None	Calm

Chapter 11. Turnback Creek

11.1. Turnback Creek @ Tuolumne Road - *Site #15, TBK-01*

11.1.1. INDICATORS: Turnback Creek @ Tuolumne Road 2007-2008 Results

Site #15 TBK-01	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
November 2007	18 cm	14-14.5	8.6	110	5.7-7.0	7.3-7.5	0.79-0.97
December 2007	26 cm	6.0-6.5	3.5-3.6	110	5.9-8.1	7.7-7.8	0.62-0.69
January 2008	29 cm	6.5-7.5	5.1	100	7.7-8.2	7.3-7.4	25.8-26.0
February 2008	25 cm	4-5.5	3.5-3.6	100	9.2-9.75	7.2-7.3	6.33-6.43
March 2008	16 cm	11.5	7.2-7.3	100	6.4-9.5	6.9-7.1	3.39-3.62
April 2008	8 cm	14-15	7.9	130	8.6-9.0	7.1	1.75-3.79
May 2008	15 cm	21-23	10.9-11.1	120	9.0 – 10.0	7.1	1.2-1.62
June 2008	20 cm	19.3-19.5	12.3	120	3.8-11.4	6.9-7.1	1.00-1.11
Overall Range	8 – 29 cm	6.0-23.0	3.5-12.3	100-130	3.8-11.4	6.9-7.8	0.62-26.0

Table 7: Bacterial Sampling Test Run Turnback Creek @ Tuolumne Road, June, 2008

	Most Probable Number (MPN)
Enterococci	**7.3***
Total coliforms	**59.1***

*Coliform ranges typically found in surface water are <1 to 80,000 colonies per 100 mL, while coliform ranges typically found in fecal-contaminated surface water are 1,200 to >4,000,000 colonies per 100 mL. The "advised safe level" for *E. coli* in freshwater used for bathing is a concentration of less than 126 *E. coli* per 100 mL. The advised safe level for *Enterococcus* in freshwater is 61 Enterococci per 100 ml. The above sample indicates a "safe" level of coliforms.

In comparison, in 2006-2007:

Site #15 TBK-01	**Depth @ Station**	**Air Temperature (^{0} Celsius)**	**Water Temperature (^{0} Celsius)**	**Conductivity µS**	**Dissolved Oxygen (ppm; mg/l)**	**pH**	**Turbidity (NTU)**
2006-2007 (Nov – May)	10.2-20 cm	7 – 20	5.9-12.7	110-130	4.2-10.0	7.1-7.8	0.68-113

11.1.2. GENERAL STREAM CONDITIONS: Turnback Creek @ Tuolumne Road 2007-2008 Results

Site #15 TBK-01	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	Cloudy (>4" visibility)	Greater than 50%	Algae, water plants	No	Foam, suds	Yes	
December 2007	Clear	Less than 50%	Algae, water plants	No	No	Yes	
January 2008	Murky <4" visibility	Greater than 50%	No	No	Foam, suds	No	Pockets of foam
February 2008	Cloudy >4" visibility	Greater than 50%	Water plants	No	Foam, suds	Yes	
March 2008	Cloudy >4" visibility	Greater than 50%	Algae, water plants	No	Foam, suds	Yes	
April 2008	Clear	Greater than 50%	Algae, water plants	No	No	No	
May 2008	Cloudy >4" visibility	Greater than 50%	Algae, water plants	No	No	Yes (soiled toilet paper)	
June 2008	Clear	Greater than 50%	No	No	Foam, suds	Yes	
Overall Condition	Clear to Murky	See above	See above	No	See above	See above	

11.1.3. WEATHER CONDITIONS: Turnback Creek @ Tuolumne Road 2007-2008 Results

Site #15 TBK-01	Cloud Cover	Precipitation	Wind
November 2007	None	None	Calm
December 2007	None	None	Calm
January 2008	Cloudy	None	Breezy
February 2008	Cloudy	None	Calm
March 2008	Cloudy	None	Calm
April 2008	None	None	Calm
May 2008	None	None	Calm
June 2008	None	None	Calm

11.2. Turnback Creek @ Yosemite Road - *Site #17, TBK – 03*

11.2.1. INDICATORS: Turnback Creek @ Yosemite Road 2007-2008 Results

Site #17 TBK-03	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
November 2007	23.5 cm	13	9.6	120	6.9-8.1	7.3-7.4	1.4-1.65
December 2007	19 cm	6-7	3.9	130	6.6-10.45	7.4-7.6	1.31-1.45
January 2008	29 cm	6.5-7	5.7	100	6.7-11.8	7.1-7.3	70.1-72.0
February 2008	20 cm	3-4	3.8-3.9	110	9.6-11.0	7.3	10.6-10.7
March 2008	30 cm	10-11	8.8	120	9.4-10.0	6.9	5.48-5.8
April 2008	26 cm	14-15	11.4	160	8.4-9.8	7.0-7.1	2.3-2.67
May 2008	20 cm	21-22	14.8-14.9	180	4.9-5.9	7.3-7.4	3.4-3.58
June 2008	--	19.5	13.2-13.4	180	6.6-8.1	7.1-7.2	3.35-3.5
Overall Range	19-30 cm	3-19.5	3.8-14.9	100-180	4.9-11.8	6.9-7.6	1.31-72.0

In comparison, in 2006 – 2007:

Site #17 TBK-03	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
2006-2007 (Apr/May)	11-13 cm	7 – 18.5	11.1 – 16.7	160-170	4.5-7.6	7.5-7.8	4.04-6.95

Table 8: Bacterial Sampling Test Run Turnback Creek @ Yosemite Road, June, 2008

	Most Probable Number (MPN)
Enterococci	18.7*
Total coliforms	65.7*

*Coliform ranges typically found in surface water are <1 to 80,000 colonies per 100 mL, while coliform ranges typically found in fecal-contaminated surface water are 1,200 to >4,000,000 colonies per 100 mL. The "advised safe level" for *E. coli* in freshwater used for bathing is a concentration of less than 126 *E. coli* per 100 mL. The advised safe level for *Enterococcus* in freshwater is 61 Enterococci per 100 ml. The above sample indicates a "safe" level of coliforms.

11.2.2. GENERAL STREAM CONDITIONS: Turnback Creek @ Yosemite Road 2007-2008 Results

Site #17 TBK-03	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	Clear	Greater than 50%	No	No	Foam, suds	Yes	
December 2007	Clear	Greater than 50%	No	No	Foam, suds	No	
January 2008	Murky (<4" visibility)	Less than 50%	No	No	Foam, suds	No	More than 2" rain in past 24 hours
February 2008	Murky (<4" visibility)	Greater than 50%	No	No	Foam, suds	Yes	
March 2008	Cloudy (>4" visibility)	Greater than 50%	Algae, water plants	No	No	Yes	
April 2008	Cloudy (>4" visibility)	Greater than 50%	Algae, water plants	No	Foam, suds	Yes	
May 2008	Cloudy (>4" visibility)	Greater than 50%	Algae, water plants	No	Foam, suds	Yes	Private party pumping water just under bridge from stream
June 2008	Cloudy (>4" visibility)	Greater than 50%	Algae, water plants	No	Foam, suds	No	
Overall Condition	Clear to Murky	See above	See above	No	Normally foams, suds	See above	See above

11.2.3. WEATHER CONDITIONS: Turnback Creek @ Yosemite Road 2007-2008 Results

Site #17 TBK-03	Cloud Cover	Precipitation	Wind
November 2007	None	None	Calm
December 2007	None	None	Calm
January 2008	Cloudy	None/a/	Breezy
February 2008	Cloudy	None	Calm
March 2008	Cloudy	None	Calm
April 2008	None	None	Breezy
May 2008	None	None	Calm
June 2008	None	--	Calm

/a/ Over 2” rain in past 24 hours

11.3. Turnback Creek @ Old Buchanan Mine Road - *Site #19, TBK-04*

11.3.1. INDICATORS: Turnback Creek @ Old Buchanan Mine Road 2007-2008 Results

Site #19 TBK-04	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
November 2007	23 cm	4	6.5-6.6	100	5.4-7.2	7.6-7.7	1.97-2.50
December 2007	21 cm	1-2	2.4-2.5	100	4.1-5.9	7.6-7.7	0.81-0.87
January 2008	26 cm	4	4.7	80	6.1-8.0	7.2-7.3	17.5-19.2
February 2008	22 cm	1.5-2	3.4-3.5	80	8.8-10.5	6.9-7.0	3.63-3.71
March 2008	20 cm	9-9.5	6.4-6.6	80	5-7.2	7.0-7.1	3.17-3.27
April 2008	18 cm	11-13	5.5-5.6	100	4.4-5.4	6.9-7.0	1.59-1.98
May 2008	20 cm	17	8.7-8.8	90-100	5.4-7.8	6.8-6.9	1.45-2.2
June 2008	14.5 cm	14	9.5-9.7	90	4.2-4.7	6.8-7.0	1.22-1.23
Overall Range	14.5 - 26	1-17	2.4-9.7	80-100	4.1-10.5	6.8-7.7	0.81-19.2

In comparison in 2006-2007:

Site #19 TBK-04	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
2006-2007 (Dec – May)	11.8 – 25 cm	7.2-16	5.9-10.8	80-100	5.4-10.2	7.4 – 8.0	2.16 – 81.6

Table 9: Bacterial Testing Practice Run Turnback Creek @ Old Buchanan Mine Road June 7, 2008 Results

	Most Probable Number (MPN)
Enterococci	4.1
Total coliforms	45.9

*Coliform ranges typically found in surface water are <1 to 80,000 colonies per 100 mL, while coliform ranges typically found in fecal-contaminated surface water are 1,200 to >4,000,000 colonies per 100 mL. The "advised safe level" for *E. coli* in freshwater used for bathing is a concentration of less than 126 *E. coli* per 100 mL. The advised safe level for *Enterococcus* in freshwater is 61 Enterococci per 100 ml. The above sample indicates a "safe" level of coliforms.

11.3.2. GENERAL STREAM CONDITIONS: Turnback Creek @ Old Buchanan Mine Road 2007-2008 Results

Site #19 TBK-04	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	Clear	Greater than 50%	No	No	No	Yes	
December 2007	Clear	Less than 50%	No	No	No	Yes (3 tires within 8 feet of water)	
January 2008	Murky (> 4" visibility)	Less than 50%	No	No	Foam, suds	No	Over 2" rain in past 24 hours
February 2008	Cloudy (>4" visibility)	Greater than 50%	No	No	Foam, suds	Yes (tires)	
March 2008	Cloudy (>4" visibility)	Greater than 50%	Algae	No	Foam	Yes (tires, car battery)	
April 2008	Clear	Greater than 50%	Algae, water plants	No	No	Yes (tires, sheet metal)	
May 2008	Clear	Greater than 50%	No	No	No	Yes	
June 2008	Clear	Greater than 50%	No	No	No	Yes (4 tires, large aluminum sheet, car battery within 40 ft. of water)	
Overall Condition	Clear to Murky	See above	See above	No	See above	Yes – normally	See above

11.3.3. WEATHER CONDITIONS: Turnback Creek @ Old Buchanan Mine Road 2007-2008 Results

Site #19 TBK-04	Cloud Cover	Precipitation	Wind
November 2007	None	None	Calm
December 2007	None	None	Calm
January 2008	Cloudy	Snow/a/	Breezy
February 2008	Cloudy	None	Calm
March 2008	Cloudy	None	Calm
April 2008	None	None	Calm
May 2008	None	None	Calm
June 2008	None	None	Calm

/a/ Over 2" rain in past 24 hours

Chapter 12. Twain Harte Creek

12.1. Twain Harte Creek @ Eproson Park - *Site #23, TH-01*

12.1.1. INDICATORS: Twain Harte Creek @ Eproson Park 2007-2008 Results

Site #23 TH-01	Depth @ Station (inches, average)	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Flow (ft/sec)	Turbidity (NTU)	Notes
November 2007	10 cm	17.0-17.1	10.8-11.0	80	8.7-9.1	6.8	--	12.1-12.9	--
December 2007	30 cm	2.8	8.5	100-110	8.0-8.4	6.7-6.8	--	20.2-21.0	--
January 2008	100 cm +	1.3	2.7-2.8	150	10.5-10.7	8.1	--	30.5-32.4	--
February 2008	--	2	4.3-4.5	170	10.00-10.25	7.6-7.7	--	7.81-8.11	snowing
March 1, 2008	22.1 in. (Abt 58 cm)	8.5-9.1	8.0-8.1	160-161	7.6-8.2	7.3-8.2	0.5	7.10-7.35	--
March 16, 2008	--	7.75-9.8	8.2-8.3	170-180	--	9.9*-10.0*	--	4.53-5.00	
April 2008	10** (25.5 cm)	12	8-9	170	6.0	6.0	--	6.4	--
May 2008	<50 cm	18.0	13.0	170-180	8-9	6.0	--	4.5-5.6	--
June 2008	--	22-22.5	15-16	170-180	8-9.2	6.5-7.2	--	3.84-4.24	--
Overall Range	10 – 100+ cm	1.3-22.5	2.7-16.0	80-180	6.0-10.7	6.0-10.0*	0.5	3.84-32.4	--

*Possible meter error
**Assumed inches

In comparison, in 2006-2007:

Site #23 TH-01	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Flow (ft/sec)	Turbidity (NTU)
2006-2007 (Dec – May)	20-60 cm	6.0-23.0	7.2-14.3	170-200	7.1-9.2	7.2-7.4	--	7.14-18.2

* Hydrocarbon, petroleum odor and brown scum were noted in the 2006-2007 sampling season

12.1.2. GENERAL STREAM CONDITIONS: Twain Harte Creek @ Eproson Park 2007-2008 Results

Site #23 TH-01	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	Clear	Greater than 50%	Algae, water plants	No	No	Yes	Gas odor
December 2007	Clear	Greater than 50%	Algae, water plants	Yes	No	Yes	Smells like gas
January 2008	Cloudy (>4" visibility)	Greater than 50%	No	No	Foam, suds	Yes	--
February 2008	Cloudy (>4" visibility)	Less than 50%	No	No	No	No	Raging water, snowing, snow on ground, no trash, water cloudy
March 1, 2008	Cloudy (>4" visibility)	Greater than 50%	No	No	Foam, suds	Yes (scum, murky)	Conifers mixed, copper colored leachate present in between culvert pipes and on left side of culver (dissolved iron or sewage?)
March 16, 2008	Cloudy (>4" visibility)	Less than 50%	Algae, water plants	Yes	Foam, suds	Yes	Strong petroleum smell – worse than last visit
April 2008	Cloudy (>4" visibility)	Less than 50%	Yes	Yes	Yes	Yes	Toxic area
May 2008	Clear	Greater than 50%	Yes	Yes	Yes	Yes	Smells of petroleum products; brown scum on stream bottom
June 2008	Cloudy (>4" visibility)	<50%	Yes	No	No	Yes	Gas, sulfur; septic; nasty looking pond
Overall Condition	Clear to cloudy	See above	See above	See above	See above	See above	See above

12.1.3. WEATHER CONDITIONS: Twain Harte Creek @ Eproson Park 2007-2008 Results

Site #23 TH-01	Cloud Cover	Precipitation	Wind
November 2007	None	None	None
December 2007	None	None	None
January 2008	Cloudy	Drizzle	Breezy
February 2008	Cloudy	Snowing	Breezy
March 1, 2008	Cloudy	None	Calm
March 16, 2008	Partly cloudy	None	Windy
April 2008	None	None	Calm
May 2008	None	None	Breezy
June 2008	None	None	Breezy

Figure 16: Twain Harte Creek @ Eproson Park

12.2. Twain Harte Creek @ Crystal Falls Drive - *Site #25, TH-02*

12.2.1. INDICATORS: Twain Harte Creek @ Crystal Falls Drive 2007-2008 Results

Site # 25 TH-02	Depth @ Station (inches, average)	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Flow (ft/sec)	Turbidity (NTU)	Notes
November 2007	5 cm	17.5	12.3-12.4	80-90	8.9-9.5	7.1	--	15.4-16.5	--
December 2007	5 cm	3.2	10.0	100	9.4-9.7	7.1-7.2	--	18.0-19.5	--
January 2008	50 cm	1.7	3.0	110	10-10.5	8.1-8.2	--	35.0-37.1	--
February 2008	--	4.5-5.0	3.6	120	10.75-11.0	8.0-8.1	--	29.2-29.7	--
March 1, 2008	10 cm	9.0-10.0	8.4-9.2	90	9.8-10.4	7.9-8.0	1.0	22.6-23.1	--
March 16, 2008	--	11.5-12.5	9.6-10.8	110-120	--	10*-10.2*	--	10.1-10.6	
April 2008	6** (Abt 15.5 cm)	19-20	12	130	9	7.0	--	2.8	--
May 2008	<20 cm	17.0	17.0	130-140	8-9	6.5	--	2.4-2.6	--
June 2008	--	21.0-21.5	20	170	5.3	5.0-6.5	--	2.53-3.82	--
Overall Range	5 – 20 cm	1.7-21.5	3.0-20.0	80-170	5.3-11.0	5.0-10.2*	1.0	3.82-37.1	--

**Assumed inches
*Possible meter error

In comparison, in 2006 – 2007:

Site # 25 TH-02	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Flow (ft/sec)	Turbidity (NTU)
2006-2007 (Dec – May)	15-40 cm	8.5-23.5	4.7-20.6	90-150	7 – 10.4	7.6-8.0	--	1.64-59.5

12.2.2. GENERAL STREAM CONDITIONS: Twain Harte Creek @ Crystal Falls Drive 2007-2008 Results

Site # 25 TH-02	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	Clear	Greater than 50%	Algae,water plants	No	Foam, suds	Yes	
December 2007	Clear	Greater than 50%	Algae, water plants	No	Foam, suds	Yes	
January 2008	Cloudy (>4" visibility)	Greater than 50%	No	No	Foam, suds	Yes	
February 2008	Cloudy (>4" visibility)	Less than 50%	No	No	Foam, suds	No	Raging water, lots of foam and suds, water murky, heavy population
March 1, 2008	Murky (<4" visibility)	Less than 50%	Algae	No	Suds	Yes (moderate litter)	Trees - no leaves
March 16, 2008	Cloudy (>4" visibility)	Less than 50%	Algae, water plants	No	Foam, suds	Yes	
April 2008	Clear	Less than 50%	No	No	No	No	
May 2008	Clear	Greater than 50%	Yes	No	Yes	Yes	
June 2008	Clear	Greater than 50%	Algae	No	No	Yes – tennis shoe, burger container	Smell of septic/sulphur; Small fish present (mosquito fish?)
Overall Condition	Clear to Murky	See above	See above	No	See above	See above	See above

12.2.3. WEATHER CONDITIONS: Twain Harte Creek @ Crystal Falls Drive 2007-2008 Results

Site # 25 TH-02	Cloud Cover	Precipitation	Wind
November 2007	None	None	Calm
December 2007	Partly cloudy	None	Calm
January 2008	Cloudy	Drizzle	Breezy
February 2008	Cloudy	Drizzle	Calm
March 1, 2008	Partly cloudy	None	Calm
March 16, 2008	Partly cloudy	None	Breezy
April 2008	None	None	Calm
May 2008	None	None	Calm
June 2008	None	None	Breezy

Figure 17: Twain Harte Creek @ Crystal Falls Drive

Chapter 13. Woods Creek

13.1. Woods Creek @ Rotary Park - *Site # 6, WD-03*

Figure 18: Woods Creek @ Rotary Park (June, 2008)

13.1.1. INDICATORS: Woods Creek @ Rotary Park 2007-2008 Monitoring Results

Site #6 WD-03	Depth @ Station (inches)	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity (µS)	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
November 2007	6”	14.0-16.0	11.8	530	8.2-9.4	7.7	0.4-0.52
December 2007	8”	6.5-7.5	6.6-6.7	630-640	7.7-9.8	7.8	0.63-0.70
January 2008	5”	7.5-8.0	8.2-8.3	390	7.7	9.4-10.0	17.9-18.0
February 2008	7.5”	5.5-8.0	7.6-7.7	400-410	9.6-11.2	8.0	1.39-1.8/a/
March 2008	4”	9.0	10.3-10.4	510	9.5-9.8	8.5	--
April 2008	8”	10.5-13.5	10.2-10.5	550	9.8	8.7	0.74-1.0
May 2008	8”	20-21.0	13.0-13.1	550-560	9-9.4	8.5	1.48-1.62/a/
June 2008	7.5”	--	17.8-17.9	540-550	7.0-8.4	8.1	2.81-3.18
Overall Range	4” – 8”	5.5-21.0	6.6-17.9	390-640	7.0-11.2	7.7-10.0	0.4-18.0

/a/ Read results after or at 24 hour holding time

In comparison, in 2006-2007:

Site #6 WD-03	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity (µS)	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
2006-2007 (Nov – May)	5-10”	10.5 – 26.5	5.7-14.5	270-550	7.8-13.2	8.0-9.1	0.65-13.4

13.1.2. GENERAL STREAM CONDITIONS: Woods Creek @ Rotary Park

Site #6 WD-03	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	Clear	Less than 50%	Yes	No	No	Yes	--
December 2007	Clear	Less than 50%	No	Yes	No	No	Oily sheen nearby sampling site
January 2008	Murky (<4” visibility)	Less than 50%	Yes	No	No	Yes	--
February 2008	Clear	Less than 50%	Yes	No	No	Yes (garbage bag, soft drink lid, bottle cap, soda can)	--
March 2008	Clear	Less than 50%	Yes	No	No	Yes	--
April 2008	Clear	Less than 50%	Yes	No	No	Yes (a few aluminum soda cans, cardboard, plastic cups)	--
May 2008	Clear	Less than 50%	No	No	No	No	Abundant vegetation growth along banks (new since last sampling)
June 2008	Clear	Less than 50%	Yes	No	No	Yes	--
Overall Condition	Clear to Murky	Less than 50%	See above	See above	No	See above	See above

13.1.3. WEATHER CONDITIONS: Woods Creek @ Rotary Park

Site #6 WD-03	Cloud Cover	Precipitation	Wind
November 2007	None	None	Calm
December 2007	None	None	Calm
January 2008	Cloudy sky	None (recent torrents of rain)	Calm
February 2008	Cloudy sky	None	Breezy
March 2008	Cloudy sky	None	Calm
April 2008	None	None	Calm
May 2008	None	None	Calm
June 2008	None	None	Breezy (light)

13.2. Woods Creek @ Rawhide Road - *Site #4, WD-01*

Figure 19: View Looking West from Collection Site to Rawhide Road Bridge

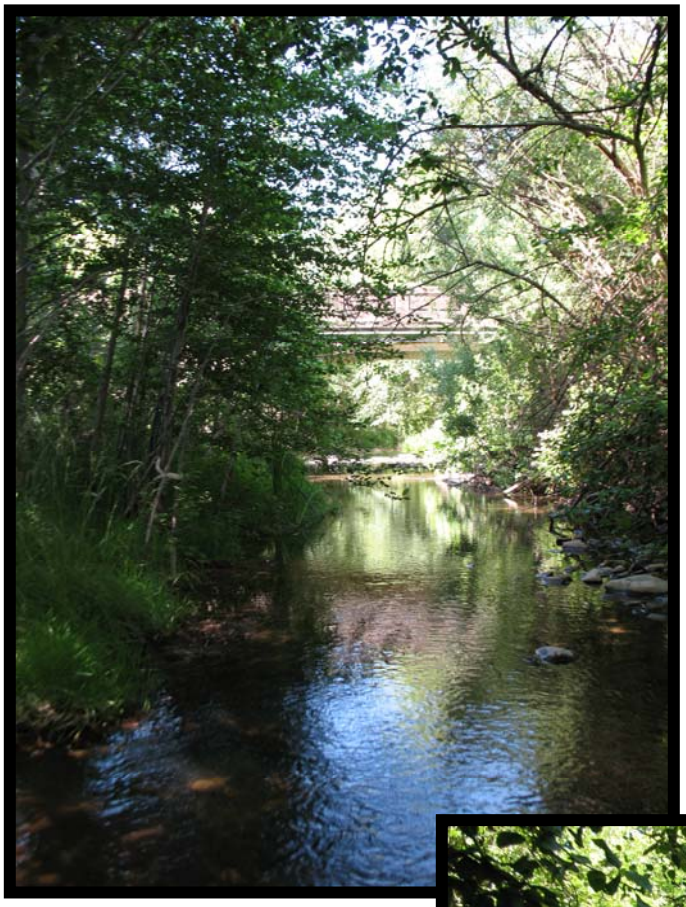
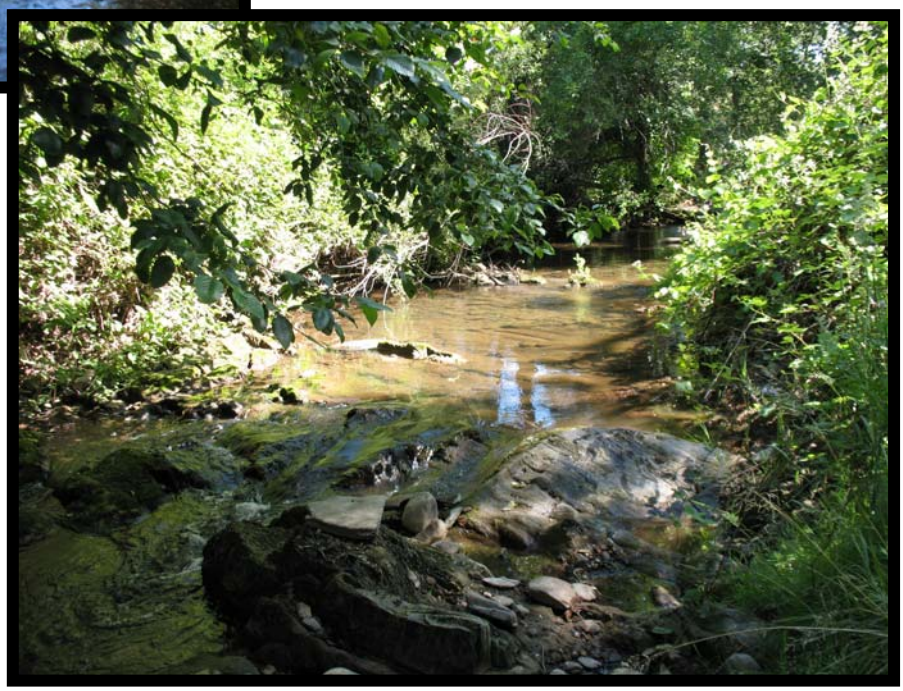


Figure 20: View Looking East from Sampling Site (June, 2008)



13.2.1. INDICATORS: Woods Creek @ Rawhide Road Bridge 2007-2008 Results

Site #4 WD-01	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity (µS)	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
November 2007	--	--	--	--	--	--	--
December 2007	--	--	--	--	--	--	--
January 2008	--	--	--	--	--	--	--
February 2008	--	--	--	--	--	--	--
March 2008	--	9.5	10.4	465	10.0	8.4	2.16-2.24
April 2008	8.5”	11-12.5	10.5	520	9.1-9.6	8.4	1.42-1.52/a/
May 2008	6-8”	19.5-20.5	12.7	510	9.3-9.5	8.4	1.77-2.14
June 2008	7.5”	20.0	14.4-14.5	520	9.1-9.3	8.3	2.32-2.58
Overall Range	6.0-8.5”	9.5-20.0	10.4-14.5	465-520	9.1-10.0	8.3-8.4	1.42-2.58

/a/ Read results after 12 hour holding time

In comparison, in 2006 – 2007:

Site #4 WD-01	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity (µS)	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
2006-2007 (Nov – May)	10.16 – 45.7 cm	5.5-25.0	5.7-19.3	160-490	5.2-10.1	7.9-8.9	1.28-59.2

13.2.2. GENERAL STREAM CONDITIONS: Woods Creek @ Rawhide Bridge 2007-2008 Results

Site #4 WD-01	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	--	--	--	--	--	--	--
December 2007	--	--	--	--	--	--	--
January 2008	--	--	--	--	--	--	--
February 2008	--	--	--	--	--	--	--
March 2008	Clear	Greater than 50%	No	No	No	Yes	--
April 2008	Clear	Greater than 50%	Algae, Yes	No	Foam (sides of banks)	Yes (wrapper)	Vinca blooming
May 2008	Clear	Greater than 50%	No	No	No	Yes	--
June 2008	Clear	Greater than 50%	Algae and water plants, yes	Yes (on shoreline)	No	Yes (uplands, cardboard etc)	Water gliders
Overall Condition	Clear	Greater than 50%	Algae & Water Plants	Occasionally	Occasionally	Normally present	See above

13.2.3. WEATHER CONDITIONS: Woods Creek @ Rawhide Bridge 2007-2008 Results

Site #4 WD-01	Cloud Cover	Precipitation	Wind
November 2007	--	--	--
December 2007	--	--	--
January 2008	--	--	--
February 2008	--	--	--
March 2008	Cloudy sky	None	Calm
April 2008	Partly cloudy (light cloud cover)	None	Breezy
May 2008	None	None	Calm
June 2008	None	None	Breezy

13.3. Woods Creek @ Bell Mooney - *Site #5, WD-02*

Figure 21: Woods Creek @ Bell Mooney Sampling Site (June, 2008)

13.3.1. INDICATORS: Woods Creek @ Bell Mooney Road 2007-2008 Results

Site #5 WD-02	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
November 2007	--	--	--	--	--	--	--
December 2007	--	--	--	--	--	--	--
January 2008	--	--	--	--	--	--	--
February 2008	--	--	--	--	--	--	--
March 2008	--	10.0-11.0	10.2-10.3	420-430	10.5	8.4	1.67-1.74
April 2008	9”	20.5	12-12.1	510	9.3-9.5	8.4	2.09-2.48
May 2008	--	--	--	--	--	--	--
June 2008	9.75”	24.5 – 27.0	15.9-16.1	480	7.3-8.2	8.0	1.61-1.99
Overall Range	9-9.75”	10.0 – 27.0	10.2-16.1	420-510	7.3-10.5	8-8.4	1.61-2.48

In comparison, in 2006 – 2007:

Site #5 WD-02	Depth @ Station	Air Temperature (^{0} Celsius)	Water Temperature (^{0} Celsius)	Conductivity µS	Dissolved Oxygen (ppm; mg/l)	pH	Turbidity (NTU)
2006-2007 (Nov – May)	20.3 – 45.7 cm	10 – 25	5 – 18.2	180-490	5.2-11.0	8.0-9.0	1.35 – 37.8

13.3.2. GENERAL STREAM CONDITIONS: Woods Creek @ Bell Mooney 2007-2008 Results

Site #5 WD-02	Water Murkiness	Canopy Cover (%)	Algae, Water Plants	Oily sheen	Foams, suds	Litter, Trash	Other
November 2007	--	--	--	--	--	--	--
December 2007	--	--	--	--	--	--	--
January 2008	--	--	--	--	--	--	--
February 2008	--	--	--	--	--	--	--
March 2008	Clear	Less than 50%	No	No	No	No	--
April 2008	Clear	Less than 50%	Yes	No	Yes	No	Foam from water falling over road; road closed, water flowing over road
May 2008	--	--	--	--	--	--	--
June 2008	Clear	Less than 50%	Yes	No	Yes	No	Scum present, crayfish, spearmint, cottonwood "cotton" very thick, algae very thick
Overall Condition	Clear	Less than 50%	Yes, normally	No	Normally Yes	No	See above

13.3.3. WEATHER CONDITIONS: Woods Creek @ Bell Mooney 2007-2008 Results

Site #5 WD-02	Cloud Cover	Precipitation	Wind
November 2007	--	--	--
December 2007	--	--	--
January 2008	--	--	--
February 2008	--	--	--
March 2008	Cloudy sky	None	Calm
April 2008	None	None	Breezy (slight)
May 2008	--	--	--
June 2008	None	None	Breezy (light)

Final

TUOLUMNE COUNTY

Foothill Watershed Assessment

Prepared for:
Tuolumne County

February 2007

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Final

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Report Acronyms

BMPs	best management practices
CALFED	California Bay-Delta Authority
CAMMR	California's Management Measures for Polluted Runoff
CGS	California Geological Survey
CGU	Channel Geomorphic Unit
CLS	California Laboratory Services
COC	Chain of Custody forms
CT-1	Curtis Creek Monitoring Location 1
CVRWQCB	Central Valley Regional Water Quality Control Board
DEM	Digital Elevation Model
DOQQ	digital ortho quarter quadrangle
ELAP	Environmental Laboratory Accreditation Program
ESA	Environmental Science Associates
GIS	Geographic Information System
GV-1	Garrotte Creek Monitoring Location 1
HA	Hydrologic Area
HGU	Hillslope Geomorphic Unit
HU	Hydrologic Unit
MEP	maximum extent practicable
mg/L	milligram per liter
mL	milliliter
MM-1	Mormon Creek Monitoring Location 1
MPN	most probable number
MRP	Monitoring and Reporting Plan
NA	Not Applicable
NAD 83	North American Datum 1983
NPDES	National Pollution Discharge Elimination System
NRCS	Natural Resources Conservation Service
NTU	nephelometric turbidity unit
PSA	Primary Study Area

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QA/QC	Quality Assurance / Quality Control
QAPP	Quality Assurance Project Plan
RL / IAL	Reporting Limit / Instrument Accuracy Level
RPD	Relative Percent Difference
SNEP	Sierra Nevada Ecosystem Project
SV-1	Sullivan Creek Monitoring Location 1
SV-2	Sullivan Creek Monitoring Location 2
SWAMP	Surface Water Ambient Monitoring Program
SWRCB	State Water Resources Control Board
TB-1	Turnback Creek Monitoring Location 1
TDS	total dissolved solids
TMDL	Total Maximum Daily Load
TSS	total suspended solids
UCCE	University of California Cooperative Extension
USEPA	U.S. Environmental Protection Agency
USGS	United States Geological Survey
WD-1	Woods Creek Monitoring Location 1
WQC	Water Quality Committee
WQP	Water Quality Plan
µg/L	microgram per liter
µS/cm	microSiemen per centimeter

Chapter 1
Introduction

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CHAPTER 1
Introduction

1.1 Overview

This Watershed Assessment (Assessment) was undertaken to evaluate current water quality conditions within the foothill region of the Upper Tuolumne and Stanislaus River watersheds.[1] In support of this objective, this Assessment provides a description of existing conditions at a reconnaissance level in an effort to identify factors influencing water quality and, more importantly, to capture the spatial extent of those influences. The findings and recommendations developed as part of this Assessment will form a scientific basis for the preparation of a Water Quality Plan (WQP) for Tuolumne County (County). In this context, this Assessment focuses on hydrologic areas within the foothill region of the County and their interactions with the larger Upper Tuolumne and Upper Stanislaus River watersheds.

1.2 Assessment Background and Context

Similar to many foothill watersheds within the Sierra Nevada, little information in terms of hydrology and surface water quality is available for smaller hydrologic areas that drain into the larger, well-known river systems (e.g., Tuolumne and Stanislaus Rivers). Until recently, much of the attention in the Upper Tuolumne and Stanislaus River watersheds has been directed toward their upper reaches due to water supply, hydroelectric, timber, and recreational interests. Consequently, much of the existing information is limited to these areas. However, as growth within the Central Valley continues to expand east, its effects are being felt in numerous foothill communities, including those within the County. This trend has prompted the need for a better understanding of foothill watershed dynamics and how continued urbanization will affect the structure and functionality of foothill watersheds in addition to corresponding implications to surface water quality.

The purpose of preparing this Assessment is to support the CALFED drinking water quality objective by assessing source water quality within the County and developing a planning framework that responds to the assessed conditions. This Assessment looks broadly at surface water resources within the County based on existing information and places specific emphasis on surface water quality within the foothill region where limited information exists and urbanization is actively occurring. For these foothill watersheds, this Assessment is supported by a surface water quality-monitoring program and a sediment characterization component developed for a smaller sub-unit that yielded data that may be extrapolated to the larger, developed foothill region (see Chapter 4, Foothill Geomorphology and Sediment Transport Dynamics).

[1] A "watershed" is defined as the region draining into a river, river system, or other body of water above a particular point.

By virtue of the applied beneficial uses to these downstream water-bodies (e.g., drinking water and cold water habitat), the County is interested in further understanding how the various land use activities occurring within its jurisdiction affect watershed function and, more importantly water quality, in the context of each watershed. Just as important is how future water quality regulations may be applied in the County. For these reasons, this Assessment identifies and broadly evaluates those influences to downstream water impoundments to better understand the function of the foothill watershed in the context of the overall hydrologic unit (e.g., Upper Tuolumne River). Just as important is the understanding of how these functions have changed as a consequence of urbanization, agricultural practices, timber harvesting and management, and water diversions and/or impoundments in unincorporated sections of the County.

The County recognizes that there are numerous valued components and processes in a given watershed and could spend an enormous amount of time and money studying them. With this understanding, it becomes clear that it is necessary to identify and prioritize a few characteristics that are critical to evaluating relative watershed health and, most importantly, surface water quality. The constituents of most concern in water bodies that drain to the Sacramento-San Joaquin Delta with respect to drinking water include microbial pathogens, organic carbon, salinity, turbidity, and nutrients. These constituents in addition to other common urban and agricultural contaminants, as identified in Chapter 5, Surface Water Quality, were chosen as the primary water quality indicators for this Assessment. A general evaluation of ecosystem processes, local geomorphology, and land use history was necessary to link the water quality data acquired from the County water quality program in efforts to determine if and where cumulative or mass loading of pollutants is impairing surface water quality. More importantly, it is necessary to know the extent to which watershed conditions have been altered by land use within the County's jurisdiction.

1.3 Land Ownership and Jurisdictional Context

Tuolumne County is almost exclusively contained within the Upper Stanislaus and Tuolumne River watersheds in the central Sierra Nevada (see Figure 1-1). The County comprises just less than 1.5 million acres; the Stanislaus National Forest and Yosemite National Park comprise the eastern two-thirds of the land area. With federal lands comprising such a large proportion of the County, the primary geographic scope of the Assessment is focused to the foothill regions of the two watersheds where urban growth is actively occurring and where the County maintains primary land use authority.

This Assessment is driven by the need to develop a WQP that focuses on the County's concerns for surface water quality based on observed risks. At the same time, the WQP needs to assist CALFED in achieving its primary mission by protecting major sources of drinking water for the Sacramento-San Joaquin Delta and the San Francisco Bay. To this end, the objectives of this Assessment are twofold: (1) assessing foothill watershed conditions in terms of cumulative surface water quality conditions and sediment production, and (2) identifying the priorities and preliminary content of the WQP.

This Assessment was prepared with the intent of establishing a baseline for foothill watersheds within the Upper Tuolumne and Stanislaus River watersheds, specifically lands within County jurisdiction. An attempt to assess cumulative watershed effects (CWEs) was undertaken as part of this Assessment to better understand watershed processes and the impacts that result from human activities. To the extent possible, the relationship between human activities, watershed processes, sources of stress ("stressors"),[2] and the ecological endpoints are also considered.

1.4 Watershed Scale and Study Area Focus

By virtue of the expansive drainage areas within the Upper Stanislaus and Upper Tuolumne watersheds, it is not practical to provide a detailed assessment of the entire watersheds. Additionally, the County is not interested in studying land areas where it does not have discretionary authority over land use decisions. For these reasons, the Assessment only provides an evaluation of watershed conditions at two distinct, but inter-related, watershed scales. These watershed scales are based on smaller watershed units delineated in the 1999 California Interagency Watershed Map (CalWater Version 2.2.1) for portions of the Big Oak Flat, Clavey River, and Copperopolis Hydrologic Areas.

To determine the appropriate scales of analysis, a jurisdictional overlay was completed to eliminate watershed areas outside the County's jurisdiction. For those watersheds within the County's jurisdiction, focus was placed on watersheds that are experiencing development pressures, supply drinking water to downstream reservoirs, and contain waterways exhibiting water quality concerns. Five planning watershed areas were identified for the reconnaissance-level scale of the Assessment. These include the Sullivan Creek, Woods Creek, North Don Pedro, and Big Creek watersheds within the Upper Tuolumne watershed and the Rawhide Flat watershed within the Upper Stanislaus watershed. These watershed areas are contained along the foothill margin of the County and comprise the primary study area (PSA) of the Assessment. The reconnaissance-level watershed scale was chosen to assess cumulative, mass-loading conditions within local foothill watersheds in conjunction with their interactions with unit-wide watershed conditions, with emphasis placed on surface water quality.

The second and more detailed watershed scale evaluated in this Assessment correlates with the highest priority tributaries within the PSA and the County's interest in understanding the dynamics of sediment transport. Based on discussions with County staff, the public, and agency staff, the Sullivan Creek watershed, a tributary to Don Pedro Reservoir, was identified as one such priority watershed. This watershed scale was chosen to allow for stratification of the Sullivan Creek watershed into units with shared attributes for more detailed characterization of sediment production and transport through the watershed. Fluvial geomorphologic measurements generated as part of this Assessment provide insight on sediment loading to Phoenix Reservoir and Don Pedro Lake from the Sullivan Creek watershed.

[2] "Stressor" refers to anything, natural or human-induced, that could cause harm to components and processes within the watershed.

1.5 Constraints to the Assessment

Access proved to be the single, most constraining factor to the preparation of this Assessment in that the field reconnaissance conducted was generally restricted to public road right-of-ways (ROW). The level of disturbance in these locations is expected to be higher than that of other reaches, where road crossings do not exist. This factor left much of the river channels studied unobservable and limited to aerial photographs for interpretation. Another factor is the presence of engineered water imports and exports. Aqueducts, canals, penstocks, storm drains, and pipelines can interfere with the otherwise-clean delineation of a watershed and, more importantly, interpretation of water quality data.

1.6 Public Involvement

This Assessment has been conducted under the auspices of the County, with funding provided by the California State Water Resources Control Board and CALFED, through a Proposition 13 grant (Costa-Machado Water Act of 2000). This Assessment, including the scope of work, the Quality Assurance Project Plan (QAPP), Monitoring and Reporting Plan (MRP), and Project Assessment and Evaluation Plan (PAEP), have been overseen by a Water Quality Committee (WQC), who have helped to guide the study and review draft documents (see Chapter 7 for the WQC's membership).

The Upper Tuolumne (USGS Cataloging Unit No. 18040009) and Stanislaus River (Cataloging Unit No. 18040010) watersheds have been designated as Category I watersheds by the California Unified Watershed Assessment (CUWA). Watersheds with high values (e.g., water quality), high risks to maintaining those values (e.g., stresses from human population growth, wildfire hazards, and loss of habitat), and high opportunity for achieving improvements (e.g., the presence of local working groups) are considered the highest priority of the Category 1 watersheds. The Upper Tuolumne and Stanislaus watersheds generally meet the first two criteria, but are lacking in the third in terms of a working group that can manage issues at a watershed scale. For this reason, both watersheds are not identified as priority watersheds in the 1997 CUWA; however, the County is optimistic that the program developed as part of the WQP will increase public involvement and agency coordination.

Public outreach and informational exchange during the preparation of this Assessment will be accomplished in several ways. Three public scoping sessions were held in 2005 to solicit public input on current water quality problems within the County, their respective locations, and the constituents of concern (e.g., sediment). Informational exchange and stakeholder involvement continues to evolve within the County through staff coordination and a web link on the County's new website.

1.7 Previous Studies

The Upper Stanislaus and Tuolumne River watersheds have been the subject of several past studies, as well as actions and efforts by local residents to investigate and solve problems associated with the river systems, including impaired water quality. This Assessment in support

of the County's WQP builds on past studies, and includes new studies, such as the hillslope and channel geomorphology assessment and a surface water quality monitoring program. This Assessment synthesizes the results of past studies that are applicable to the PSA and provides a context for regional surface water quality conditions. In support of this objective, data acquired for this Assessment consist of a combination of GIS layers, aerial photography (USGS digital ortho-quarter quadrangle [DOQQs]), and various written reports, which are referenced in Chapter 7.

1.8 Report Outline

Following the introduction provided in Chapter 1, Chapter 2 presents a synopsis of watershed conditions from both a regional and local perspective. Chapter 3 briefly summarizes the local landscape history with emphasis on those activities that led to major changes to the physical watershed environment (e.g. road development, mining, urban development, etc.). Chapter 4 describes the initial observations and findings of ESA's geomorphic assessment and sediment characterization study conducted for the Sullivan Creek sub-hydrologic area. Chapter 5 provides a synopsis of surface water quality data obtained as part of this project along with other sources. Principal findings and conclusions of the Assessment are synthesized and presented in Chapter 6. Chapter 7 provides lists of the report authors, the persons consulted, and references.

Chapter 2
Physical Watershed Characteristics

ESA

CHAPTER 2
Physical Watershed Characteristics

This chapter presents an overview of the physical watershed attributes that characterize the foothill region of the Upper Stanislaus River and Upper Tuolumne River watersheds; and more specifically, the primary study area (PSA) of the Assessment. Emphasis is placed on providing an understanding of those physical watershed features that influence, in part, the movement and fate of nonpoint source (NPS) pollutants within the foothill region of the two watersheds. This information is framed in the context of how these attributes interact within the larger San Joaquin River Hydrologic Basin to supplement other CALFED drinking-water programs.

From a classical watershed perspective, the PSA is characterized as a hydrologic sub-basin, which includes five large watershed units, comprising a total of 224.8 square miles (143,847 acres). The first portion of this chapter provides a general description of the PSA in the overall context of the Upper Stanislaus River and Upper Tuolumne River watersheds. The second portion of this chapter provides a more detailed description of the five watershed units that comprise the PSA, which include all or portions of the Sullivan Creek, Woods Creek, North Don Pedro, Big Creek, and Rawhide flat watersheds. Due to the large area involved and topographic complexity of the five watersheds in conjunction with limitations on access and available funding, the level of investigation is more variable at the sub-watershed level. This variability is further noted under the description for the individual watershed units in the later section.

2.1 Watershed Characteristics

2.1.1 Structural Geology

Tuolumne County resides within the central portion of the Sierra Nevada geomorphic province and is characterized by geology dating back to the Paleozoic Era (570 million years ago [mya]). A majority of the County's geology is composed of Mesozoic plutons[1] that are overlain by continental volcanic and sedimentary rock from the Cenozoic Era[2] (CDC, 1997). The eastern two-thirds of the County exhibit intrusive contacts and volcanic/sedimentary cover, whereas the western third is comprised of metamorphic terranes, deformed by folding and faulting. The western-most exposures of the intrusive contact occur in the Phoenix Basin and near Tuolumne City. Further west, metamorphic terranes trend generally north-northwest along fold axes that dip steeply to the east and were formed during the Mesozoic. The vertical orientation of the unit is

[1] Intrusive igneous rocks dating back to 66 to 208 mya. .
[2] The Cenozoic Era refers to the last 66 mya.

readily visible in horizontal road cuts, for example along Jacksonville Road near Sullivan Creek. Locally, the Calaveras and Shoo Fly complexes exhibit strikes that trend more strongly west-northwest. A general geologic map for the PSA is illustrated in **Figure 2-1**.

The Tuolumne Table Mountain geologic unit is the principal drainage divide between the Upper Tuolumne and Upper Stanislaus Rivers. This geologic feature is clearly visible from State Route (SR) 108 near Chinese Camp and resembles a tabletop from the road (See **Figure 2-2**). Table Mountain is the remnants of an ancient stream canyon cut in a broad flat sheet of volcanic ash and filled by lava that extends for 60 miles from the high Sierra Nevada to its terminus at a bluff of sedimentary andesitic beds near Knights Ferry. Over time, the soft ash was eroded away as the Sierra Nevada was raised and tilted westward. This left the resistant lava flow exposed, creating the appearance of a table. The resistant latite lava flow overlies andesitic tuffs, gravels, Eocene quartz gravels and boulders (Geologic Guidebook, 1949).

2.1.2 Soils Resources

In general terms, the distribution of soil resources across the County is mainly representative of coarse-grained materials overlaying a granitic and/or granodiorite parent material in the eastern two-thirds and finer-grained materials overlaying a metasedimentary and metabasic (or metavolcanic) parent material in the western third. In the upper reaches of the foothill region, the surface soils are highly weathered and often resemble a reddish brown, coarse-textured sandy clay loam with differing quantities of organic matter. North-facing aspects typically have higher contents of organic matter as a consequence of denser vegetation, lower evapotranspiration, and are greater in depth as compared to south-facing locations. In the upper elevations, the subsurface consists of a yellowish red, sandy clay loam that grades to weathered gabbrodiorite at depth (NRCS, 2003). At lower elevations, the soil resource consists of shallow to moderately deep materials comprised of higher fractions of clay and formed in vertically tilted material weathered from metamorphic rock (NRCS, 2002).

Throughout the PSA the depth to bedrock is typically dependent on the degree of slope, but may range from less than 10 inches along hill-slopes and ridgelines to greater than 60 inches in narrow gulches and small alluvial plains. The contact with the bedrock is generally abrupt, although some slightly weathered fracture planes are randomly scattered in many areas. Soils within the PSA are usually well-drained with medium to very rapid runoff, depending on slope angle and ground cover (NRCS, 2003). The rock fragment content ranges from <5 to 50 percent throughout the profile (NRCS, 2002); increasing along hill-slopes and ridgelines. Soil infiltration and permeability is highly variable depending on surface cover, soil depth, and slope.

Numerous medium to very large rock outcrops blanket portions of the foothill region. This rock is generally highly resistant metamorphic or granitic rock that extends to variable depths around the exposed outcrop. In some locations, the rock outcrop unit covers over an acre of land. The plant cover in these locations consists of sparse grasses and stunted trees. In isolated areas, a thin mantle of soil material may be present; however, the depth is typically less than five inches with surface runoff occurring rapidly.

Figure 2-1

Figure 2-2

Within the local stream corridors, bar units that occur in and along these channels consist of highly stratified[3] stony and/or boulder sand that is typically barren, except for isolated areas containing riparian areas, which are subject to inundation during high flows during significant rainfall events (e.g., >10 year, 24 hour). These soils are subject to frequent scouring or cutting as well as to deposition, depending on creek flow and bed load.[4] Typically the surface runoff is moderate and the drainage is variable.

2.1.3 Climate

Tuolumne County is characterized by warm, dry summers with little to no precipitation, and cold, wet winters with moderate to heavy precipitation. At elevations above 5,000 feet, this precipitation is generally in the form of snow. The majority of annual precipitation falls as rain from November through April. However, when subtropical air masses move into the Sierra Nevada in summer and early autumn, sufficient moisture is available to generate extreme rainfall. Intense convective storms occurring over a period of three or four days can generate local flooding. In the foothill region, the total annual rainfall averages approximately 35 inches. By virtue of the orographic uplift created by the presence of the Sierra Nevada, precipitation is highly influenced by elevation. General precipitation zones are illustrated in **Figure 2-3**. Within the foothill region, the 10-year, 24-hour estimated precipitation amount is approximately 5.5 inches and the 100-year, 24-hour precipitation amount is approximately 8.0 inches (WRCC, 1973).

About half the recorded precipitation in the major river basins of the west slope of the Sierra Nevada becomes stream flow (**Table 2-1**) (Kattelmann et al., 1983). Stream flow, both in absolute magnitude and as a proportion of precipitation, increases with elevation. In a 1-square-kilometer (250-acre) research basin in Sequoia National Park at 2,800 to 3,400 meters (9,200 to 11,100 feet), 75 to 90 percent of the annual precipitation became stream flow (Kattelmann and Elder, 1991).

TABLE 2-1
APPROXIMATE DISPOSITION OF PRECIPITATION IN MAJOR RIVERS

River	Gauging Station	Precipitation (Centimeters)	Stream Flow (Centimeters)	Losses (Centimeters)
Stanislaus	(New Melones Reservoir)	115	75	40
Tuolumne	(Don Pedro Reservoir)	110	55	55

SOURCE: Kattelmann et al., 1983

[3] The term refers to geologic deposits or soil layers that result from processes of soil formation through layering.
[4] Rock particles rolled or pushed along the bottom of a stream by moving water.

Figure 2-3

2.1.4 Regional Surface Water Hydrology

Tuolumne County is almost exclusively contained within the Upper Stanislaus and Tuolumne River watersheds (U.S. Geological Survey Catalog No. 1804009 [Upper Tuolumne River] and No. 1804010 [Upper Stanislaus River]) located in the central Sierra Nevada (see **Figure 2-4,** Hydrology). These hydrologic units span the entire western slope of the Sierra Nevada, extending approximately 90 linear miles from large dam impoundments in the lower foothills east to the crest; rising over 12,000 vertical feet. The North Fork and mainstem Stanislaus River delineate the northern boundary of the Upper Stanislaus River watershed, which defines the boundary between Tuolumne and Calaveras Counties. This drainage divide is a result of the Calaveras Table Mountain sequence situated along the southwestern boundary of Calaveras County and Summit Level Ridge further east. As indicated in Section 2.1.1, a similar Table Mountain sequence forms the division between the Upper Tuolumne and Stanislaus Rivers systems. To the south, a series of ridgelines delineate the drainage divide between the Upper Tuolumne River watershed and the Merced River watershed. These ridgelines include the Piney Ridge, Penon Blanco, Warner, Pilot Ridges, and the Cathedral Range further east.

Several dam systems regulate flows within the middle and lower reaches of both river systems. Don Pedro Reservoir along the Tuolumne River and New Melones Reservoir along the Stanislaus River are the largest impoundments within each watershed with 2,030,000 acre-feet (AF) and 2,420,000 AF of capacity, respectively (USGS, 2003). These two impoundments disconnect each waterway from its lower reaches within the Central Valley. Below each reservoir, each river flows west, southwest before converging with the San Joaquin River. Once in the San Joaquin River, flows travel northwest towards the City of Antioch where they converge with the Sacramento River prior to empting into Suisun Bay, which drains into San Pablo Bay. A schematic depicting the Upper Stanislaus and Upper Tuolumne River's connection to the Sacramento-San Joaquin Delta is depicted in **Figure 2-5**.

The PSA is situated near the base of the two watersheds and represents a small fraction of the total watershed area. Within the Upper Stanislaus River watershed, the PSA accounts for a very small fraction (approximately 3 percent) of the total watershed area. Within the Upper Tuolumne River watershed, the PSA accounts for a larger, but still relatively minor portion (approximately 11.5 percent) of the total watershed area. Numerous contributing waterways are located upstream of the PSA within both river systems (see Figure 2-4). These waterways generally traverse U.S. Forest Service or National Park Service land and, thus are outside the County's land use authority and not the focus of this study. For this reason, a brief description of these waterways is provided to the extent necessary to compare their integrity and evaluate their overall interaction with the waterways within the PSA.

Gages on these waterways are more available and comprehensive due to their importance as drinking water sources as compared to waterways within the PSA. Unregulated (often called unimpaired) streams within the PSA lack complete datasets and are generally improperly sited for use in this Assessment. Stream gaging stations in the County are operated by the U.S. Geological Survey (USGS), local utilities, irrigation districts in the Central Valley, and a few other federal agencies (e. g., U.S. Bureau of Reclamation).

Figure 2-4

Figure 2-5

Upper Tuolumne River Watershed (Hydrologic Unit)

The Upper Tuolumne River Watershed (Hydrologic Unit 18040009) is drained by the Tuolumne River, which originates in Tuolumne Meadows at the confluence of streams descending from the slopes of Mt. Lyell (13,100 feet) and Mt. Dana (13,155 feet). The Tuolumne River is the largest river flowing into the San Joaquin Valley, draining approximately 1616 square miles (1,033,947 acres), and, on average produces approximately 1.8 million AF of runoff per year. Precipitation largely influences the seasonal flow. The watershed is comprised of 1,944 miles of waterways with 80 percent of the watershed unobstructed by impoundments (ICE, 1997). Approximately 35 percent of the watershed is located on slopes in excess of 15 percent (ICE, 1997). All flows within the watershed drain into Don Pedro Reservoir. Portions of the Tuolumne River are classified as a Wild and Scenic River. This provides additional protection to the river by prohibiting improvements or additions to facilities within the one-quarter-mile corridor on each side of the river until the Wild and Scenic River Management Plan is complete. The corridor is managed by the Stanislaus National Forest Service.

From Tuolumne Meadows the river descends through the steep Yosemite wilderness, before its flow is impounded by the O'Shaughnessy Dam in Hetch Hetchy Valley (3,500 feet). At this point, a portion of the water from O'Shaughnessy Dam is diverted towards the Kirkwood Powerhouse. Above O'Shaughnessy Dam, the river drains a land area of approximately 459 square miles and is located entirely within Yosemite National Park. Just below Yosemite National Park, Cherry Creek enters the river. Further downstream, the Tuolumne River's South and North Forks, as well as the Clavey River, join the main stem above Don Pedro Reservoir.

There are three major reservoirs within the watershed above Don Pedro Reservoir: Hetch Hetchy, Lake Eleanor, and Cherry Valley Reservoirs. Their storage capacities are 360,000, 273,000, and 27,000 AF, respectively (USGS, 2003). These reservoirs are used primarily as water supplies for surrounding counties and any surplus is supplied to San Francisco. Discharge from these reservoirs flows down into the Lower Tuolumne River watershed through Don Pedro Reservoir, which is a major water source for the Cities of Turlock, Modesto and San Francisco.

The North Fork of the Tuolumne River is similar to the sub-watershed units within the PSA and converges with the main stem Tuolumne River, approximately 1 mile upstream from Don Pedro Reservoir. The North Fork is about 10 miles long and drains an area of 114 square miles between Duckwall Mountain, Murphy Peak, and Marble Mountain on the east, and SR 108 to the west. Its major tributaries include Sugarpine and Wrights Creeks, as well as Basin, Duckwall, and Hunter Creeks. The North Fork watershed is small, at a low elevation, and most of its runoff is associated with winter rainfall (FERC No. 10081-002, Turlock Irrigation District, DEIS/EIR Clavey River Project 1994). **Figure 2-6** illustrates the terrain of the North Fork.

Figure 2-6

Don Pedro Reservoir (USGS Cataloging Unit 11287500) is formed by an earthfill dam, which was completed in 1971. It is located 500 feet downstream from Mexican Gulch, and 3.4 miles northeast of La Grange. Storage began on November 3, 1970. The mutually agreed-upon minimum storage is 309,000 AF below, which occurs at an elevation of 600.0 feet. Water passes through a powerplant at the dam and then down the Tuolumne River to La Grange Dam, 2.5 miles downstream, where it is diverted into the Turlock and Modesto Canals for irrigation. The reservoir is owned and operated jointly by Turlock and Modesto Irrigation Districts. Prior to June 1971, the reservoir was formed by a concrete gravity-type dam completed in 1923 with a capacity of 290,400 AF. Extremes for the period of record (September 1923 to 2003) include maximum contents of 2,044,000 AF on January 2, 1997 at an elevation of 831.11 feet. The minimum storage since the reservoir was first filled to its current levels is 302,600 AF, which occurred on October 14 and 15, 1977, at an elevation of 598.2 feet. (USGS, 2003)

Upper Stanislaus River Watershed

The Upper Stanislaus River Watershed (USGS Cataloging Unit 18040010) is composed of 1,660 miles of waterways, with approximately 85 percent of the watershed unobstructed by impoundments (ICE, 1997). There are 32 dams within the watershed and an estimated 1,215 stream crossings (ICE, 1997). Approximately 35 percent of the watershed is situated on slopes in excess of 15 percent slope (ICE, 1997). All flows within the watershed ultimately drain into the federally owned New Melones Reservoir.

The Upper Stanislaus River drains an area of about 997 square miles (638,066 acres). In normal water years, the regulated runoff in the Stanislaus River at New Melones Dam is 1,050,000 AF of water. New Melones Reservoir was formed by an earth rockfill dam and completed in November 1978. It is located 0.1 mile downstream from the old Melones Dam, and 7.6 miles southwest of Sonora. The dam is downstream from the original concrete dam, which was completed in December 1926. When the elevation is above 808.0 feet, water is released through New Melones Powerplant to Tulloch Reservoir where it is used for irrigation. Extremes for the period of record (1926-2003) include maximum contents of 2,400,000 AF for July 8 through 10, 1983 at an elevation of 1,086.42 feet. The minimum since the reservoir was first filled in July 1983 was 83,630 AF on October 1, 1992 at an elevation of 721.15 feet (USGS, 2003).

The 39-mile North Fork Stanislaus River flows through 35 miles of the Stanislaus National Forest from Mosquito Lake to the Middle Fork Stanislaus. McKays Point Reservoir, Lake Alpine, Utica Reservoir, Union Reservoir, and New Spicer Meadows Reservoir all lay within the North Fork. The Middle Fork Stanislaus River flows southwesterly from the Emigrant Wilderness Area (elevation 9,650 feet); joining the North Fork Stanislaus River, approximately 50 miles downstream (elevation 1,230 feet); to form the main stem of the Stanislaus River. The terrain is characterized by 67.5 miles of National Forest (2 miles of the river are outside the forest) from the headwaters to the North Fork Stanislaus. The tributaries that feed into the Middle Fork Stanislaus River include Kennedy Creek in the Emigrant Wilderness Area, Summit Creek, and the Clark Forks of the Stanislaus River.

The South Fork Stanislaus River also flows southwesterly from the Emigrant Wilderness Area near Bay Meadow (elevation 8,800 feet) to the New Melones Reservoir, approximately 35 miles downstream. The only major tributary to the South Fork is Herring Creek. Three storage dams lie along the South Fork Stanislaus River, including Strawberry Dam, which impounds Pinecrest Lake, as well as the Philadelphia Diversion and Lyons Dams and are operated by Tri-Dam. The combined storage capacity for the three dams is 24, 541 AF, which is about 12 percent of the 200,000 AF estimated unimpaired runoff of the South Fork Stanislaus River in a normal water year (Tri-Dam, 2002). The Tuolumne Utilities District (TUD) delivers water supplies to much of unincorporated Tuolumne County from Lyons Reservoir, below Pinecrest Lake on the South Fork Stanislaus River.

2.1.5 Groundwater

Tuolumne County is contained within the portion of the Sierra Nevada geomorphic province where groundwater is primarily located in fractured hard rock fissures. As a result, the County contains no large, well-defined groundwater basins. The highest groundwater yields typically occur at shallow depths where fracturing is greatest. The depth and location of groundwater within the County is highly variable due to the influence of fractures, foliation, faults, or man-made structures such as wells or ponds, and groundwater gradients are likely to be shallower near perennial streams and ponds. According to Delineation of Wellhead Protection Areas in Fractured Rock (USEPA, 1991) and Groundwater Resources and Water Supply Alternatives in the Wawona Area of Yosemite National Park (Borchers, 1986), groundwater flow in fractured-rock aquifers occurs mainly through discrete fracture conduits (Tuolumne County Groundwater Protection Grant Final Report, 2000).

2.1.6 Terrestrial Vegetation

Regional natural plant communities in the PSA include those that are common to the Sierra Nevada Foothills (Upper Foothills Metamorphic Belt Ecological Unit), such as mixed oak, interior live oak woodland, mixed chaparral, and ponderosa pine. Typical elevations within this ecological subsection range from 800 to 5,000 feet above sea level. The PSA contains a diverse assemblage of plant communities and wildlife habitats, from closed canopied, multi-tiered woodlands to open grasslands, ponds, and wetlands. While native plant species dominate most plant communities in the PSA, their structure and composition has been substantially altered over time by resource extraction (including mining and logging), grazing, development, and fire suppression (see Chapter 3.0, Influences from Land Management and Population Growth). In general, these anthropogenic influences have fragmented some habitats, while fire suppression has resulted in most plant communities succeeding into later seral stages that contain high levels of biomass. For example, many of the oak woodland plant communities are both denser, and have a smaller mean polygon size, than what was likely present over 100 years ago.

Plant Communities and Wildlife Habitats

Plant communities are assemblages of plant species that occur together in the same area. They are defined by species composition and relative abundance. The plant community descriptions and nomenclature described in this section generally follows the classification system provided in Sawyer and Keeler-Wolf (1995). **Figure 2-7** illustrates the plant communities found within the PSA. In general these plant communities include:

- Black Oak Series/Montane Hardwood;
- Black Oak Series/Blue Oak Woodland;
- Interior Live Oak Series/Montane Hardwood;
- Mixed Oak Series/Montane Hardwood;
- Ponderosa Pine Series/Montane Hardwood-Conifer;
- Wedgeleaf Ceanothus Series/Montane Chaparral; and
- California Annual Grassland Series/Annual Grassland.

2.1.7 Riparian and Aquatic Ecosystems

Riparian areas are the focal point of many resource conflicts in the Sierra Nevada because they are a critical ecological link between land and water. Although scarcity of quantitative information and unaltered reference sites currently limit the development of quantitative conclusions about riparian health across the entire Sierra Nevada, a few generalities were identified as part of the Sierra Nevada Ecosystem Project (SNEP, 1996).

In the SNEP Report, the term “riparian area” refers to the transition zone between the upslope terrestrial ecosystem and the adjacent aquatic ecosystem. Similarly, the term riparian corridor refers to the land on either side of the stream and including the stream. An emerging concept of riparian (or streamside) management zones has been used by agencies as a management tool to include some upland areas that may influence or buffer the riparian corridor (SNEP, 1996).

Riparian areas are water-dependent lands along streams and lakes where transitions occur between terrestrial and aquatic parts of a watershed. They may be best described as the zone of direct interaction between land and water (Swanson et al., 1982; Gregory et al., 1991; Cummins, 1992). Riparian corridors connect the headwaters to the valley and facilitate transfer of materials (Gregory et al., 1991). Water, energy, and organic matter move downstream through a continuum of changing ecological processes along each stream (Vannote et al., 1980). The continuity of riparian areas is one of their critical characteristics, which is readily disrupted by human activities.

Riparian areas do not have precise boundaries because of temporal fluctuations of stream levels and intermixed vegetation types on the upland side. During most of the year, riparian areas are clearly separate from (though intimately connected to) their adjacent stream. However, during periods of high water, the topographically-lower sections of a riparian area that constitute a floodplain become part of the stream. Riparian communities usually contain a gradient in soil moisture from the stream through the floodplain and sometimes up into the lower terraces, depending on geomorphology and hydrology of the particular site. Typical riparian vegetation requires the high soil moisture usually found along streams, and some can even tolerate saturated soils and occasional inundation.

Figure 2-7

Riparian systems are distinct in mountain areas because they traverse broad vegetation belts that are arranged largely by elevation. At variable distances away from the stream, riparian vegetation grades into upland vegetation. In some cases, there is little obvious difference in the composition of vegetation between the streamside area and the adjacent hillslopes. Elsewhere, there are marked contrasts between deciduous species in the riparian area and conifers or chaparral on the hillsides. The thin, linear nature of riparian areas in the Sierra Nevada limits their total area to a small fraction of any watershed. Because habitat elements associated with riparian areas are relatively rare compared to the entire landscape, modification of even small areas has a proportionally greater impact in riparian areas than elsewhere in the watershed (SNEP, 1996).

In general, riparian areas are the most productive and diverse parts of the landscape (Risser, 1995). Microclimates and soil moisture regimes found along streams are highly favorable for plant growth to be sustained for longer periods of each year than in other geographic locations. The frequent disturbance by floods and variety of physical habitats promotes much greater diversity of species than on more uniform hillslopes (Odum, 1978; Gregory et al., 1991). Under natural flow regimes, frequent disturbance by various levels and durations of flooding results in riparian vegetation with a patchy distribution of species and ages (Swanson et al., 1990). The diversity of species and habitat structure may be reduced by human impacts that tend to simplify ecological processes and components. Riparian communities identified in the PSA include (Sawyer and Keeler-Wolf, 1995) the following:

- White Alder Series/Valley-Foothill Riparian;
- Creeks and Ponds/Aquatic Habitats; and
- Spikerush Series/Seasonal Wet Meadows and Swales.

2.1.8 Existing Land Use

The major population center in the PSA is the City of Sonora with a population of about 4,500. The nearest major population center outside Tuolumne County is the City of Stockton, located about 65 miles to the west. The physical distribution of the County's defined communities within the PSA is shown in **Figure 2-8**. As depicted, Groveland, Big Oak Flat, the Don Pedro Subdivision, and Pine Mountain Lake are located in the southern section of the PSA. Moccasin, owned and operated by the City and County of San Francisco, is also located at the southern end of Don Pedro Reservoir at the confluence of Moccasin Creek. Due to its physical separation from the remainder of the County, the land use patterns tend to be more rural and service needs are generally supported by the central portion of the PSA (e.g., Sonora). This portion of the PSA is commonly referred to as gateway to the Yosemite National Park and a large portion of the area's economy caters to park visitors (Tuolumne County General Plan, 1996).

Figure 2-8

The central and northern portions PSA are characterized by highly urbanized areas with agricultural operations and rural development at the edges of, and between, the individual communities. The central portion of the PSA is relatively rural, extends from Jamestown eastward to Twain Harte, and is the center to the majority of the County's population and the bulk of the County's development since the Gold Rush. This area provides the majority of the County's shopping centers, public services, and industrial facilities. Other urbanized areas in-between and to the north and south include the communities of Columbia, East Sonora, Phoenix Lake, Mono Vista, Soulsbyville, Sonora, Tuolumne City, Tuttletown, Standard, and numerous residential subdivisions located in and around these communities. The Standard Lumber Company and West Side Lumber Company left behind the communities of Standard and Tuolumne City. While few residential structures remain in Standard, a large section of the residential district in Tuolumne City remains intact (Tuolumne County General Plan, 1996).

2.2 Foothill Watershed Characteristics

This section provides a general description of the five watershed units that comprise the PSA. In certain instances, and in the interest of efficiency, particular emphasis is placed on specific sub-watershed units within each of the five watershed units based on the level of urbanization. **Figure 2-8** illustrates the PSA and the location of the five watershed units within the PSA. In addition, Figure 2-8 illustrates the local hydrologic connections of the PSA to the larger Upper Stanislaus River and Upper Tuolumne River watersheds.

To enable enhanced analysis of the five major watersheds comprising the PSA, numerous drainage catchments were delineated within each of the watersheds through surface interpolation of 10-meter Digital Elevation Models (DEM) for the USGS 7.5-minute quadrangles for New Melones Dam, Sonora, Standard, Tuolumne, Columbia, Columbia SE, Twain Hart, Keystone, Chinese Camp, Duckwall Mountain, Moccasin, Groveland, and Jawbone Ridge. The 10-meter DEM was used rather than the recently produced California Watersheds (CalWater 2.2) Geographic Information System (GIS) dataset, due to its finer detail in recognition of the topographic complexity of the PSA. The modeled drainage catchments are illustrated within each of the context of the larger five watersheds in the following sub-sections.

2.2.1 Rawhide Flat Watershed

Mormon Creek and Bear Creek are the principal drainage features within the Rawhide Flat watershed and drain some 16,287 acres (25.4 square miles). The Rawhide Flat watershed is located in the southern section of the Copperopolis Hydrologic Area (Calwater 2.2), south of New Melones Reservoir. Mormon Creek is the principal drainage feature south of the community of Columbia, west of the Tuolumne County Table Mountain divide, and extends approximately 8.1 miles (see **Figure 2-9**). Bear Creek originates to the south of Rawhide Flat and extends 3.1 miles southwesterly towards New Melones Reservoir. The lower reaches, roughly two miles, of both waterways are inundated by New Melones Reservoir.

Figure 2-9

Based on the level of urbanization within the Mormon Creek sub-watershed, this sub-watershed is the focus of this Assessment for the larger Upper Stanislaus River Watershed. Mormon Creek originates in a small alluvial fan at the eastern base of Union Hill, south of the Columbia Airport, and trends south from Columbia along the western side of Table Mountain. Mormon Creek abruptly bends to the west in response to Rawhide Flat uplands and trends towards New Melones Reservoir (see **Figure 2-9**). Above the town of Springfield, flows within Mormon Creek are intermittent and largely controlled by surface runoff from rainfall events. Below Springfield, flows within Mormon Creek are regulated by a series of small dam impoundments. The impoundments generally sustain base flows year-round. Unfortunately, no public gages are located along Mormon Creek, and therefore, no seasonal flow data are currently available.

The stream corridor itself is highly modified with rural and low-density residential development comprising much of the riparian corridor and approximately 18 major road crossings. Riparian cover ranges from <10 percent to >90 percent depending on the reach. Vegetation within the watershed is dominated by the Blue Oak-Foothill Pine plant community, which comprises over 50 percent of the land area. Other characteristic plant communities include Annual Grassland, Blue Oak Woodland, Montane Chaparral, and Ponderosa Pine. The upper section of the watershed houses a majority of the urbanized development (14 percent).

Upper reaches of Mormon Creek are characterized by a combination of step-pool and cascade alluvial-channel morphologies (Montgomery and Buffington, 1998), while lower grade channel morphologies are generally inundated by New Melones Reservoir. In the vicinity of the Columbia Airport, Mormon Creek consists of a modified channel that is more-or-less routed along the southern boundary of the airport (see **Figures 2-9** and **Figure 2-10**, Photograph M-A). In the vicinity of Springfield, Mormon Creek begins to resemble an intermediate step-pool channel morphology that continues south and west along SR 49. Photograph M-B in **Figure 2-10** illustrates the channel upstream of Mormon Creek Road.

Stream gradients with step-pool channels are such that larger bed materials (rock fragments, large organic debris, etc.) only become mobile during relatively infrequent hydrologic events. As a result, movement of larger grain sizes occurs only during large events when flows reach flood-prone widths[5] and step-pool morphology is reestablished at the tail of the hydrograph (Montgomery and Buffington, 1998). Flood-prone widths in the vicinity of Mormon Creek Road are readily distinguishable below Rawhide Road (see Photograph M-C, **Figure 2-11**). During more average discharges, finer materials are stored in pools and along banks providing some level of sediment storage. In contrast, reaches below Sheppard's Ranch Road grade to an intermediate cascade channel morphology, which is characterized as a sediment transport zone ((see Photograph M-D, **Figure 2-12)**. One of the dam impoundments along Mormon Creek is located just up-gradient of this channel reach (see Photograph M-E in **Figure 2-12)**.

[5] Flood-prone width is defined as the width of the horizontal surface at an elevation twice the "bankfull" depth. Bankfull flow corresponds to flow levels that occur at recurrence intervals of two years or less.

Figure 2-10

Figure 2-11

Figure 2-12

The geology of the Mormon Creek watershed is very complex. The most dominant geologic unit within the watershed is the Calaveras Complex and it is interspersed with small areas of marble-dominated units such as those viewable from SR 49, near the intersection of Shaws Flat Road. The Calaveras Complex usually consists of undifferentiated argillite, phyllite, fine-grained schist, and metachert, with local exposures of marble and amphibolite (CDC, 1997). These lithologies represent the metamorphosed equivalents of sedimentary rocks that were deposited by submarine slides in an ocean basin as a chaotic assemblage (sedimentary melange). The assemblage was later accreted to the North American continent during the Mesozoic (CGS, 1997). The marble may represent limestone originally deposited on a seamount, which was then tectonically emplaced into the chaotic assemblage during this accretion (CDC, 1997). Phyllite-dominant and greenschist-dominant Sullivan Creek terranes are also prominent. **Table 2-2** presents geochemical information for each of the major geologic units and percentage of the watershed coverage to provide a base context for potential surface water chemistry.

2.2.2 Woods Creek Watershed

The Woods Creek watershed encompasses some 18,588 acres (29.0 square miles) with the Upper Woods sub-watershed comprising approximately 12,403 acres and the Lower Woods sub-watershed 6,185 acres, respectively. The watershed has experienced significant land use alteration with approximately 66 major road crossings within the watershed and highly variable riparian habitat. Riparian cover ranges from non-existent to more than 90 percent. The Upper Woods Creek sub-watershed is composed of stands of Blue Oak-Foothill Pine (28 percent), Ponderosa Pine (20 percent), Montane Hardwood-Conifer (5 percent), and Montane Hardwood (21 percent). The lower section of the upper watershed is mainly composed of urban development (16 percent) and scattered patches of Annual Grassland, Blue Oak Woodland, and Blue Oak-Foothill Pine. The Lower Woods Creek sub-watershed is less urban and is composed of Annual Grassland (25 percent), Blue Oak-Foothill Pine (47 percent), Chamise-Redshank Chaparral (16 percent), and scattered areas of Cropland, Montane Hardwood, and urban development.

The headwaters of Woods Creek start at the base of the northern slopes of Yankee Hill and the southern slopes of Biewetts Point. From Yankee Hill, Woods Creek meanders to the south and traverses through the towns of Martinez, Squabbletown, and Browns Flat along the western base of Bald Mountain. At Browns Flat, Woods Creek parallels SR 49 and traverses the western edge of downtown Sonora near Sonora High School, where it is channelized before its confluence with Dragon Gulch. Base flows within Woods Creek become year-round in Sonora and are partly attributed to irrigation-return flows from the City during the summer months. Below Sonora, Woods Creek roughly parallels SR 49 to the south-southwest and along the western edge of Jamestown. South of Bell Money Road, Woods Creek traverses back to the south and into a steep gorge before emptying into Don Pedro Reservoir.

TABLE 2-2
GEOCHEMISTRY OF MORMON CREEK GEOLOGIC UNITS

Rock Unit	Percentage of Area	Dominant Rock Type	Derived From	Geochemistry
Precambrian and Paleozoic Metasedimentary Rock	7 %	schist	Fine-grained sedimentary rock such as shale*	silica (SiO_2) and others dependent on type of schist

TABLE 2-2
GEOCHEMISTRY OF MORMON CREEK GEOLOGIC UNITS

Rock Unit	Percentage of Area	Dominant Rock Type	Derived From	Geochemistry
Calaveras Complex	20%	argillite	shale, mudstone, siltstone, claystone*	SiO_2
		phyllite	foliated, metamorphosed shale or fine-grained sandstone, with muscovite (mica)*	SiO_2, SiO_4, Al, K, Fe, Mg, H_20
		fine-grained schist	fine-grained sedimentary rock such as shale*	SiO_2 and others dependent on type of schist
		metachert	fine-grained metasedimentary rock with main mineral being quartz*	SiO_2
		marble (local)	metamorphic recrystallization of limestone*	$CaCO_3$
		amphibolite (local)	amphibole, plagioclase feldspar*	Fe, Mg, Ca, Al, H_20, SiO_4, K, Na, Si
Ultramafic Rock (*mostly serpentinized*)	6 %	dunite	igneous rock with coarse-grained olivine; some with chromite, magnetite, ilmenite, pyrrhotite, pyroxene††	Cr, SiO_4, Fe, Mg, Fe_3O_4, $FeTiO_3$, FeS, Ca‡
		peridotite	olivine; may contain pyroxene‡‡	SiO_2, SiO_4 Fe, Mg
Sullivan Creek terrane	22 %	turbidite	water-driven sediment§	SiO_2 and others
		phyllite (local belt)	foliated, metamorphosed shale or fine-grained sandstone, with muscovite (mica)*	SiO_2, SiO_4, Al, K, Fe, Mg, H_20
		greenschist (local belt)	metamorphized to produce chlorite crystals with schistose foliation; also includes epidote and actinolite§§	SiO_2, SiO_4, Mg, Fe, Al, H_20, Ca*
Jurassic Melange	2 %	diverse lithology within argillite and serpentinite matrix; may contain carbonate rock (local)	exotic blocks of metamorphic and igneous rock suspended in argillaceous or serpentinitic material	SiO_2, SiO_4, Mg, H_20, $CaCO_3$ and others
Plutonic Rock *(including Granitics)*	8%	silicic or mafic igneous rock	intrusive igneous rock (cools beneath surface)*	SiO_2, Mg, Fe
Quartz-Vein Systems and Hydrothermally Altered Rock	<1 %	quartz vein	quartz	SiO_2
		calcite vein	calcite	$CaCO_3$
		ankerite	carbonate mineral‡	$Ca(Fe, Mg, Mn)(CO_3)_2$

TABLE 2-2
GEOCHEMISTRY OF MORMON CREEK GEOLOGIC UNITS

Rock Unit	Percentage of Area	Dominant Rock Type	Derived From	Geochemistry
		sericite	fine-grained white mica[§§§]	SiO_4
		talc	fine-grained silicate mineral[*]	$Mg_3Si_4O_{10}(OH)_2$
		mariposite	chrome-bearing mica	Cr, SiO_4
Tertiary and Quaternary Volcanic Rock:		silicic composition		SiO_2
Miocene-Pliocene Mehrten Formation	4 %	intermediate composition	volcanic complex of tuff, mudflows, lava flows, volcaniclastic sediment, and shallow intrusions	intermediate
Quaternary flows and hypabyssal intrusions	7 %	mostly mafic composition		Fe, Mg
Quaternary Sedimentary Deposits	1 %	alluvium, colluvium (local, at low and high elevations)	sand, gravel, and silt deposited by rivers and streams or gravity into the valley below[*]	SiO_2 and others
	2 %	mine tailings (local, at low elevations)	diverse mineralogy	diverse chemistry

Note: 20 percent of the watershed is inundated by New Melones Reservoir and/or is unclassified.
SOURCE: CGS, 1997

Woods Creek extends approximately 8.6 miles from its headwaters to Don Pedro Reservoir (see **Figure 2-13**). Various reaches of Woods Creek exhibit a combination of cascade, step-pool, plane bed, and pool riffle alluvial channel-reach morphologies. North of Sonora, Woods Creek exhibits an intermediate step-pool channel morphology, prior to entering the City of Sonora where it becomes channelized along the eastern border of Sonora High School. To the south of the high school, Woods Creek exhibits varying levels of modification (see Photographs W-A and W-B, **Figure 2-14)**. Further south, Sonora Creek joins Woods Creek near the intersection of Stockton Street (SR 49) and Southgate Road. Sonora Creek is a major contributing drainage that runs through the heart of Sonora and extends approximately 5.7 miles from the north and is a highly modified waterway and channeled underneath portions of Sonora (Photographs S-A and S-B, **Figure 2-15**).

To the south of the City of Sonora and Jamestown, Woods Creek begins to transition into a more level terrain and exhibits intermediate plane bed channel morphology (see Photograph W-B, **Figure 2-14** and Photograph W-C, **Figure 2-16**). Plane-bed channels differ morphologically from both step-pool channels in that they are characterized by long stretches of a relatively featureless bed (Montgomery and Buffington, 1998). To the west of Bell Mooney Road, the channel gradient of Woods Creeks increases to the extent that step-pool channel morphologies dominate the lower reaches prior to encountering Don Pedro Reservoir (see Photograph W-D, **Figure 2-16**).

Figure 2-13

Figure 2-14

Figure 2-15

Figure 2-16

A 2004 drainage study prepared for the City of Sonora indicates that peak flows within Woods Creek, below the confluence with Sonora Creek (south of the Fairgrounds), can range from 379.8 cubic feet per second (cfs) for a 2-year event and up to 3,351.1 cfs during a 100-yr event (Weatherby-Reynolds Consulting Engineers, Inc., 2004).

The upper reaches in the northern sections of the Woods Creek watershed are underlain by mafic plutonic rocks with small inclusions of auriferous[6] gravels. The western edge of the watershed is lined by Table Mountain latite and undifferentiated Mehrten Formations. The central and southern portions of the watershed units are underlain by a melange of meta-volcanic, ultramafic, and/or meta-sedimentary rocks. Smaller units of the Penon Blanco (Logtown Ridge) Formation[7] are also delineated in the southern sections of the watershed. **Table 2-3** presents geochemical information for each of the major geologic units and the percentage of the watershed covered to provide a basis for potential surface water chemistry.

TABLE 2-3
GEOCHEMISTRY OF WOODS CREEK GEOLOGIC UNITS

Rock Unit	Percentage of Area	Dominant Rock Type	Derived From	Geochemistry
Precambrian and Paleozoic Metasedimentary Rock	8.5%	See Table 2-2		
Calaveras Complex	33 %	See Table 2-2		
Mesozoic Metasedimentary and Metavolcanic Rock	23 %	See Table 2-2		
Jurassic Melange	< 1%	See Table 2-2		
Plutonic Rock	20%	See Table 2-2		
Quartz-Vein Systems and Hydrothermally Altered Rock	< 1 %	See Table 2-2		
Tertiary and Quaternary Volcanic Rock: *Oligocene-Miocene Valley Springs Formation*	10 %	See Table 2-2		
Ultramafic Rock *(mostlyerpentinized)*	5%	See Table 2-2		
Quaternary Sedimentary Deposits	< 1 %	See Table 2-2		

SOURCE: CGS, 1997

2.2.3 Sullivan Creek Watershed

The Sullivan Creek watershed is the largest drainage area within the PSA, comprising 62.7 square miles (40,118 acres). The watershed is comprised of two major water features, Sullivan Creek and Curtis Creek (see **Figure 2-17)**. This watershed is the focus of the geomorphic assessment and sediment transport study and is extensively described in Chapter 4.0, Foothill Geomorphology and Sediment Transport Dynamics.

6 Sand and gravel composed mainly of pre-Tertiary rock (CGS, 1997)
7 Mafic metavolcanic rock formed as pyroclastic deposits and flows (CGS, 1997).

Figure 2-17

The headwaters of Sullivan Creek originate just south of Sugar Pine east of Twain Harte and flow along the eastern portion of the Phoenix Basin before entering Phoenix Lake; a small water supply reservoir constructed near the turn of the 20th century (see Photographs SV-1 and SV-2, **Figure 2-18**). Several smaller waterways drain into Sullivan Creek above Phoenix Lake and are described in Chapter 4.0, Foothill Geomorphology and Sediment Transport Dynamics. Sullivan Creek drains an area of approximately 15,488 acres above Phoenix Reservoir and stretches approximately 7.7 miles (see **Figure 2-17**). Below Phoenix Reservoir Sullivan Creek drains an area of approximately 9,696 acres and extends roughly 10.8 miles before empting into Don Pedro Reservoir (see Photographs SV-3 and SV-4, **Figure 2-19**).

The Sullivan Creek watershed is a highly modified unit with approximately 113 major roadway crossings. The riparian cover is generally good with >90 percent in many rural locations. The exception occurs in more urbanized locations, where bank-side and riparian vegetation can be non-existent. Photographs SV-5 and SV-6 in **Figure 2-20** illustrate the riparian stands along Sullivan Creek above Lime Kiln Road and below Algerine Road. Vegetation stands within the Phoenix Basin are dominated by Ponderosa Pine (52 percent); intermixed with Blue Oak-Foothill Pine and Montane Hardwood depending on moisture availability. The lower sections of the watershed show marked increases in the coverage of Blue Oak-Foothill Pine (50 percent) and the addition of Annual Grassland and Chamise-Redshank Chaparral.

The section of Sullivan Creek just below Phoenix Lake is modified and serves a portion of the Phoenix Ditch. Above Phoenix Lake, the TUD's Main Ditch imports water into the watershed from three storage reservoirs along the South fork Stanislaus River, Pinecrest Lake, and Philadelphia and Lyons Reservoirs. These flows are diverted into the Phoenix Ditch, which traverses the western side of the Phoenix Basin. The regulated flows are diverted by TUD below Phoenix Lake back into the Phoenix Ditch and Shaws Flat Pipeline. No continuous flow data were available for this Assessment for Sullivan Creek above Phoenix Reservoir or above Don Pedro Reservoir.

Curtis Creek is a major contributing drainage that converges with Sullivan Creek, just north of Jacksonville Road. Curtis Creek drains an area of approximately 14,934 acres and extends roughly 11.1 miles. Photographs CT-1 and CT-2 in **Figure 2-21** provide illustrations of the channel of Curtis Creek below the Town of Standard at Algerine and Lime Kiln Roads. Upstream of Standard, Curtis Creek is highly altered as a result of the movement of timber during old logging practices with only a few stands of Valley Oak remaining within the riparian zone. A portion of the waterway is utilized as the Soulsbyville Ditch for water conveyance. Stands of Blue Oak-Foothill Pine (65 percent) dominate the landscape up-gradient of Standard with scattered patches of Annual Grassland, Blue Oak Woodland, Montane Hardwood, Ponderosa Pine, and scattered development. Below Standard, the composition is similar with higher proportions of Montane Hardwood and scattered plots of irrigated agricultural land. No flow data are available for Curtis Creek.

Figure 2-18

Figure 2-19

Figure 2-20

Figure 2-21

Plutonic rock formations dominate the upper reaches of the Sullivan Watershed. Shoo Fly Complex and Calaveras Complex reside in the northern end, while the Miocene-Pliocene Mehrten Formation lies along the northeastern edge. In the south, mafic plutonic rock is accompanied by marble-dominant Calaveras Complex, ultramafic rock, phyllite and greenschist Sullivan Creek Terranes, Tertiary sand and gravel deposits, and mine tailings. The Tertiary sand and gravel deposits are erosional remnants of ancient stream channels (CDC, 1997). **Table 2-4** presents geochemical information for each of the major geologic units and the percentage of the watershed area covered to provide a baseline for potential surface water chemistry.

2.2.4 North Don Pedro Watershed

The North Don Pedro watershed covers 63.1 square miles (40,394 acres) and includes lands that extend from the north shore of Don Pedro Reservoir up to areas just west of Twain Hart, near the intersection of SR 108 and Confidence Road. Sub-watershed units within the watershed include Turnback Creek (11,693 acres), Blanket Creek (9,332 acres), Kanaka Creek (6148 acres), Deer Creek (8,796 acres), and North of Moccasin (4425 acres). This Assessment focuses on the Turnback Creek sub-watershed due to the extensive land use alteration that has occurred within this unit and the level of future growth expected. **Figure 2-22** illustrates the location of the Turnback Creek sub-unit in the context of the North Don Pedro watershed.

The Turnback Creek sub-watershed comprises roughly 11,693 acres and flows through a long, narrow canyon for approximately 15.9 miles. Turnback Creek is a perennial stream below the mill pond on the Westside-Cherry Valley site in Tuolumne, which is impounded by a concrete dam, originally constructed to float and maneuver logs for lumber production. The dam, constructed in 1912, is a concrete gravity dam approximately 22-feet high, 450 long (including side retaining walls). The crest elevation is approximately 2556 feet above mean sea level; the storage capacity is approximately 120 AF of water at operating capacity (G.L. Gritz Engineering, 2005). No continuous flow data are available for Turnback Creek below the dam impoundment.

Currently, there are 37 major road crossings on Turback Creek, including its contributing drainages. The land use alterations along Turnback Creek are extensive; however, portions of the creek have some natural features, including almost complete riparian cover, such as areas just north of Tuolumne Road; just north of the new bypass (see Photograph T-A, **Figure 2-23**). This is in contrast to the highly altered channel forms just downstream of the dam (see Photograph T-B, **Figure 2-23**) and along Box Factory Road (see Photograph T-C**, Figure 2-24**). Below Yosemite Road, Turnback Creek begins to exhibit some natural channel features along with high densities of canopy cover (see Photograph T-D, Figure 2-24).

The upper portion of the Turnback Creek watershed is composed of stands of Ponderosa Pine, which correlates to roughly 26 percent of the watershed. The center sections contain much of the urban development, 27.6 percent of the total watershed. The vegetation within the middle and lower sections of the watershed is composed of dominantly Blue Oak-Foothill Pine (29 percent) intermixed with Montane Hardwood (11 percent). Lower and middle sections of the watershed also include patches of Annual Grassland, Blue Oak Woodland, and Cropland.

TABLE 2-4
GEOCHEMISTRY OF SULLIVAN CREEK GEOLOGIC UNITS

Rock Unit	Percentage of Area	Dominant Rock Type	Derived From	Geochemistry
Precambrian and Paleozoic Metasedimentary Rock	2%	See Table 2-2		
Shoo Fly Complex	7 %	quartzite	metamorphosed quartz sandstone and chert*	SiO_2*
		quartzofeldspathic gneiss	metamorphosed, foliated granite, diorite, or schist with minerals: quartz, feldspar, hornblende, and biotite mica**	SiO_2, K, Na, Ca, Al, Si, Fe, Mg*
		gneissic granitoids	foliated portions and porphyroclasts of quartz, feldspar, mica, amphibole, and granitic aggregates†	SiO_2, SiO_4, K, Na, Al, Fe, Mg, Ca, H_20*
Calaveras Complex	6 %	See Table 2-2		
Sullivan Creek terrane	4 %	See Table 2-2		
Mesozoic Metasedimentary and Metavolcanic Rock	<1 %	See Table 2-2		
Jurassic Melange		See Table 2-2		
Plutonic Rock *(including Granitics)*	60%	See Table 2-2		
Quartz-Vein Systems and Hydrothermally Altered Rock	< 1 %	See Table 2-2		
Tertiary and Quaternary Volcanic Rock: *Oligocene-Miocene Valley Springs Formation*	10 %	See Table 2-2		
Ultramafic Rock *(mostlyerpentinized)*	5%	See Table 2-2		
Quaternary Sedimentary Deposits		mine tailings (local, at low elevations)	sand, gravel, and silt deposited by rivers and streams or gravity into the valley below*	SiO_2 and others*
	< 1 %	schist	diverse mineralogy	diverse chemistry
		quartzite		
		quartzofeldspathic gneiss		

SOURCE: CGS, 1997

Figure 2-22

Figure 2-23

Figure 2-24

The northern section of the watershed is characterized by geologic units composed of granitic plutonic rocks and the Shoo Fly Complex and Mehrten Formation. The southern section of the watershed is composed of phyllite-dominant and greenschist-dominant Sullivan Creek terranes, as well as small amounts of melange and ultramafic rock. The Calaveras Complex is also abundant within this section of the watershed. **Table 2-5** presents geochemical information for each of the major geologic units and the percentage of the watershed area covered to provide a base context for potential surface water chemistry.

TABLE 2-5
GEOCHEMISTRY OF TURNBACK CREEK GEOLOGIC UNITS

Rock Unit	Percentage of Area	Dominant Rock Type	Derived From	Geochemistry
Shoo Fly Complex	20 %	See Table 2-4		
Calaveras Complex	13 %	See Table 2-2		
Plutonic Rock *(including Granitics)*	51 %	See Table 2-2		
Tertiary and Quaternary Volcanic Rock:	16 %	See Table 2-2		
Miocene-Pliocene Mehrten Formation	<1 %	See Table 2-2		

SOURCE: CGS, 1997

2.2.5 Groveland Watershed

The Groveland watershed is located in the southern portion of the PSA and covers roughly 44.5 square miles (28,460 acres). The watershed is located at the western end of the Clavey River Hydrologic Area (Calwater 2.2.1) and is comprised of three major watershed units: Big Humbug Creek (9,759 acres), Pine Mountain Lake (8,064 acres), and Hells Hollow Creek (10,637 acres). The Groveland Creek sub-unit of the Pine Mountain Lake sub-watershed is the focus of this Assessment since it supports much of the development in the south County and is entirely contained within the County's jurisdiction. The Groveland Creek watershed is illustrated in **Figure 2-25** in the context of the larger Big Creek watershed.

The entire Big Creek watershed includes a total of 35 major road crossing with nine of the major crossings occurring along Groveland Creek. Big Creek is approximately 15.7 miles (82,802.9 feet) with Pine Mountain Lake impounded near its mid-point. Groveland Creek, approximately 4.2 miles in length, drains into the southern end of Pine Mountain Lake. Groveland Creek parallels SR 120 and Ferretti Road down to the Pine Mountain Lake subdivision. Riparian habitat in the vicinity of Groveland is marginal, but improves downstream (see Photographs G-A and G-B, **Figure 2-26**). Ponderosa Pine is the dominant vegetation stand in the Pine Mountain Lake watershed, with small inclusions of Blue Oak-Foothill Pine, Mixed Chaparral, and Montane Hardwood.

Figure 2-25

Figure 2-26

Flow in Groveland Creek is seasonal; however, no flow data are available for the winter months. However, flows within Big Creek above Whites Gulch, 2.5 miles east of Groveland, have been recorded from May 1969 to 2003. Extremes for the period of record include a maximum discharge of 2,620 cfs on February 17, 1986, with a gage height of 7.03 feet. This measurement was based on the slope-area measurement at gage height 6.51 feet. No flow occurred for many days in most years (USGS, 2003). Typically, the flow is highest during the winter and spring months and lowest in late summer and early fall.

The geology of the Big Creek Watershed is mostly composed of Calaveras Complex (70 percent), with a small portion dominated by marble. In addition to the Calaveras Complex, exposures of the Mehrten Formation (2.5 percent), Sullivan Creek terrane, made up of a phyllite belt, (23 percent), and granitic rock (4.5 percent) underlie the remaining sections of the watershed. **Table 2-2** provides geochemical information for each of these geologic units to provide a base context for potential surface water chemistry.

Chapter 3

Land Management and Population Growth Influences

ESA

CHAPTER 3
Land Management and Population Growth Influences

3.1 Overview

In an effort to produce a comprehensive watershed assessment, the County and its consultants determined that research and discovery into the historic land uses of the PSA should be conducted. The key driver of this decision was the common knowledge that the County has a unique history on at least four fronts. First, the area was part of the gold mining industry of the region, which at the time used invasive techniques to mine gold (i.e., placer, hydraulic, sluice and dredging). Logging, which began around the turn of the 20th century and agriculture and ranching (beginning around the 1920s) led to the development of an extensive roadway and rail system, much of which exists today and forms the base of the expanded road network. With a corresponding increase in state-wide water demand following the 1940s, both watersheds have been tapped by regional water interests, resulting in an extensive network of water diversion canals, dam impoundments, and pipelines, which have significantly altered natural hydrology at a basin-wide scale. Finally, the continuing urbanization within the foothill region is expected to further alter natural drainage patterns with corresponding surface water quality implications.

The following sections provide an overview of these occurrences with emphasis placed on those actions that resulted in alterations to the physical hydrologic conditions of the foothill margin of the County.

3.1.1 Pre-1850s

Current evidence suggests that people have lived in the Sierra Nevada region for about 12,000 years (Tri-Dam Project, Beardsley/Donnells Project, 2002). Archeological research suggests that the Central Sierra Miwok were the most recent Native American occupants to inhabit portions of the range that now includes portions of Tuolumne County. The severity of winter in the upper elevations of the Sierra Nevada precluded permanent villages, with aboriginal populations generally inhabiting the foothill zones below 4,000 feet, where a more moderate winter climate prevailed (Barrett and Gifford, 1933). Due to the complexity of the foothill terrain, most villages were situated on ridges or terraces above the streams (Beardsley Hydroelectric Project, FERC Project, 2002).

Frequent mention is made in the ethnographic literature of the Miwok use of fire for environmental modification, i.e., as an aid in hunting and to increase the yield of a wide variety of edibles and encourage the growth of desirable plants. These annual fires destroyed seedlings but did not harm established trees such as valley and interior live oaks, whose scattered method of growth is attributed to this repeated annual burning.

Impacts of Native Americans on the hydrologic system appear to have been minor, largely because of the comparatively small population in the mountains and limited technology (Central Stanislaus Watershed Analysis, June 2002). Their deliberate use of fire as a vegetation-management tool would have been the primary agent in altering local hydrology. To the extent that intentional fires removed vegetation, evapotranspiration was reduced, water yields were increased, and surface erosion was increased. The geographical extent, intensity, and frequency of such fires cannot be quantified. Therefore, the conclusions that may be drawn regarding the hydrologic consequences of this activity are limited. Areas near population centers were probably impacted to a greater degree than remote areas (SNEP, 1996).

3.2 Mineral Extraction

In Tuolumne County, the first major industry that significantly modified the landscape was gold mining, which began around 1848 with the discovery of gold near the confluence of Woods and Moccasin Creeks. Since the 1848 discovery, this region of the Mother Lode has produced greater than 4 million tons of processed ore tailings (Wagner, 1970). Most of the gold deposits formed within a folded and faulted metamorphic belt often referred to as the Melones Fault Zone (MFZ). Within the Tuolumne County portion of the MFZ, many of the lode gold ores are associated with quartz veins and carbonate rocks formed by metasomatic reactions of mineralizing fluids with greenschist rocks at very high temperatures (SNEP, 1996).

Mining in the Sierra Nevada was intimately connected to the development of lumber and water resources and promoted the development of camps and towns to supply the needs of miners and loggers (SNEP, 1996). Water was necessary for gold production, and in later times it provided power for mining activities. Lumber was required to carry water in flumes, to support excavations, to provide fuel for steam engines and pumps, and to support tunnels. Lumber was also needed for housing and business structures. Camps and towns were often consumed by fires, requiring further timber harvest. Contemporary sketches and photographs of northern and central Sierran communities show barren environments around mining settlements (SNEP, 1996).

Hillsides became pockmarked from mining operations. Channels and tunnels were cut to divert water so that streambeds could be mined. Flumes were constructed of wood to divert water from streambeds, requiring the cutting of adjoining forests. This water was used and reused farther downstream. Rivers became filled with sand. Boulders were moved out of streambeds to expose placer gold and were placed elsewhere, creating new riverine environments. Flumes leaked or collapsed, creating erosion gullies. Water storage dams burst, generating great surges of water that pushed mud, stones, and trees before the flood (Ziebarth 1984; Beesley, 1994). Mercury was used to assist in the recovery of fine gold particles in placer, hydraulic, and hardrock mining during this period. Its release into stream systems stretching all the way to the San Francisco Bay was measured in tons before 1940 (Meals,1995).

At that time, diversions and flumes were also built to supply water to off-channel claims for separating gold and for ground sluicing where diverted water was used to erode ancient stream deposits. Natural channels were often totally dewatered to supply maximum flow in an artificial waterway. The erosive power of water was used with great effectiveness by containing water

within pipes and hoses under high pressure and then directing it at hillslopes composed of gold-bearing gravels (SNEP, 1996). Remnant hill-slope scars, which are now vegetated, are still visible at many locations within the County. As an example of power and hydraulic water use, flumes and pipes with 120 meters (400 feet) of head could deliver about one million gallons of water per hour through a 10-inch nozzle at a speed of about 120 miles per hour (Logan, 1948; SNEP, 1996). Sediment-laden runoff from the eroded hillslopes was directed into long sluice boxes, often in tunnels, to extract the gold and then discharged into the nearest creek (SNEP, 1996).

Quartz gold mining grew in importance after 1900. Permanent communities such as Sonora reflected the relatively stable nature of this industry (Clark 1963, 1980; Sinnott, 1976). The extent of impact this industry had on water and other Sierran elements has not been completely determined. During World War II, most of these hardrock gold mining operations were closed so that the iron, fuel, and wood they consumed could be redirected into the war effort. Few reopened after 1945.

As depicted in **Figure 3-1**, many of the mines within the PSA are concentrated along the Moccasin and Sullivan Creek drainages, which are now partially inundated by the Don Pedro Reservoir on the Tuolumne River. Waste materials produced during mining operations are heterogeneous piles of rocks that have undergone varying degrees of crushing, granulation, and chemical processing. They are mineralogically complex chemical reactors that interact with the atmosphere and with the waters of Don Pedro Reservoir, which seasonally floods many of the mines and mill sites of the Tuolumne River Canyon (Savagea et al., 1999).

Many other mineral commodities have been produced in Tuolumne County, mostly in small quantities and in a sporadic manner. These include asbestos, clay, chromite, construction aggregate (crushed stone, sand and gravel), copper, decorative rock (mariposite rock, dolomite, serpentinite), diatomite, dimension stone (marble, slate granite), dolomite, graphite, lead, limestone, magnesite, manganese, platinum (placer), silver (by-product of gold mining), talc, tungsten, uranium, and zinc. Most important among these in tonnage and value have been construction aggregate, dimension stone (marble), dolomite, limestone, and silver.

Next to gold, carbonate rock (limestone and dolomite) has been the most valuable mineral commodity produced in the County. Quarrying of such rock for dimension stone began at least as early as 1860 at the Columbia Marble Quarry, northwest of Columbia. This mine was once the largest marble quarry in California; subsequently, the rock was quarried for other uses. Recently, two large operations have been quarrying in this immediate area: Blue Mountain Minerals, mainly for limestone for diverse uses, and Marine Magnesium Company, for dolomite for use in the magnesium chemicals industry. More recently, the Blue Mountain Minerals Company purchased the Marine Magnesium quarry currently operates both quarries. Other smaller quarries have been developed in carbonate rock for dimension stone and decorative rock throughout the belt of carbonate rocks of the Calaveras Complex. South of Sonora, along Lime Kiln Road, U.S. Lime Products operated one of the most important high-calcium limestone mines in northern California for many decades. Now closed, it was notable for being an underground mine rather than a quarry.

Figure 3-1

Production of crushed stone for use as construction aggregate has increased as Tuolumne County has grown over the last several decades. Currently, the two main mines in operation, Table Mountain Quarry and Sierra Rock Products Quarry, produce crushed stone from sources near the main population centers (see **Figure 3-1**). Sand and gravel have been produced at very few sites, mainly because of the scarcity of high-quality deposits of this commodity. The scarcity is a result of both geologic conditions and because two potential sources, the Tuolumne and Stanislaus Rivers, have been dammed, flooding most of their canyons at lower elevations. An important deposit along the Tuolumne River near the now-inundated Town of Jacksonville was mined for many years. Small borrow pits have been used around the County, mostly for road maintenance (CDC, 1997).

3.3 Timber Production and Grazing

By 1900, timber and agricultural grazing, which were initially support industries for the mining operations in Tuolumne County and the region, had become established local industries. The forests in the vicinity of the PSA could not be efficiently harvested until the expansion of the Sugar Pine Railway system in the mid-1920s. At this time, the system allowed the transportation of the logs from remote portions of the forest directly to the mills for processing. Produce and later beef production became important in the County's economy in the latter half of the 20th century. More recently, the production of turkeys and small viticulture operations have become important agricultural enterprises in the County (Tuolumne County, 1997).

Steam engines called steam donkeys damaged young trees and disturbed forest soils as they dragged logs to chutes or loading pads, where they were loaded on wagons or railcars for transport to the mills. Saws at the mills generated large quantities of sawdust, which was often dumped into nearby rivers, killing fish and creating health hazards and reduced water quality for those living downstream. Felled logs were frequently cut at the point where limbs began, leaving the rest behind to serve as fuel when fires started, often damaging nearby merchantable timber. Large quantities of potentially marketable trees were cut to build V flumes to transport cut lumber (SNEP, 1996). These V flumes consumed 135,000 board feet per mile (SNEP, 1996).

By 1890, some forest and scenic resource issues were addressed by the creation of two national parks (Sequoia and Grant Grove, and Yosemite) and several Sierra Nevada forest reserves (Sierra, Stanislaus, and Tahoe). While federal legislation was passed, no overall policy was developed to administer these new federal responsibilities (Runte, 1987). The Sierra Club was founded at the same time to help shape policies for these areas (Jones, 1965).

More recently, timber production is regulated on public lands by the federal government through the Stanislaus National Forest, which mainly comprises lands east of the PSA, although small in-holdings are located in the upper reaches of Sullivan, Woods, and Turnback Creeks. On State and private lands, the State Board of Forestry regulates timber harvesting through the use of Timber Harvest Plans. County staff provides limited guidance through Section 17.52.170 of the Tuolumne County Ordinance Code, which addresses local rules for commercial timber harvesting on parcels less then three acres in size (Tuolumne County, 1997). As of March 1, 1995, Tuolumne County

was assessing 84,449 acres of private land zoned TPZ (Timberland Production Zone) (Tuolumne County, 1997). According to the 2004 Tuolumne County Crop and Livestock Report, the timber industry in Tuolumne County harvested 23.5 million board feet of timber worth $5,038,500 (Tuolumne County, 2005).

Rangeland use within the County started with the sheep industry, which developed in two distinct periods before 1900. The first period (1848–1860) involved driving animals from New Mexico and southern California to mining camps and towns in the western foothills for consumption. This phase did not result in much actual grazing in the Sierra Nevada. The second phase (after 1860) depended on grazing Sierran pastures. The number of sheep that foraged on Sierran meadows before the Forest Service and County regulations began can only be guessed at. There was no limit to the size or the number of bands that entered the Sierra before 1900, nor was there a limit on the length of time they could utilize a specific area.

Gradually during this same period, and through the remainder of century, cattle replaced sheep on many Sierran ranges, resulting in more soil compaction and increased effects on vegetation in riparian zones (SNEP, 1996). It has been documented that heavy grazing patterns over a short time period will reduce infiltration rates on porous soils by about 50 percent, while longer term light and moderate grazing decreased rates to about 75 percent of their original values (SNEP, 1996). However, without information regarding the frequency, duration, and quantities of animals grazed, it is difficult to determine the exact level of disturbance caused by grazing. Today, a majority of the west County agricultural land base within the PSA continues to be used for rangeland. Photos A and B in **Figure 3-2** illustrate the variability in grazing intensity that commonly occurs from one property to the next. Where more productive soils are present in combination with available irrigation water, the production of numerous other crops is feasible, including field crops, fruit and nuts, and small-scale vineyards.

3.3.1 Fire Suppression and Vegetation Conversion

Years of aggressive fire protection and timber management have dramatically changed the character of the County's forests, brush, and grassland communities, including those that characterize the upper reaches of the PSA. The California Department of Forestry and Fire Protection (CDF) utilizes a Fire Hazard Severity Classification System to assess the wildland fire potential of a site (Stanislaus Forest Service Fire Plan, 2004). The classification system is based upon factors of slope, fuel, and summer weather patterns. In general terms, the wildland fire hazard within the PSA varies from moderate, in the relatively level annual grasslands in the west County, through high to extreme, in the dense brush and tree covered slopes in the upper reaches of the watersheds.

Figure 3-2

Portions of the PSA overlap with the Stanislaus Forest Service's Fire Management Unit (FMU) No. 2, which covers low elevations with the National Forest. Approximately 992 wildfires (244,100 acres) have originated in FMU No. 2 between 1970 and 2002; 26 percent of the total fires on the Stanislaus National Forest during that time period (Stanislaus Forest Service Fire Plan, 2004). This FMU includes land not included in FMU No. 1, which is characterized by historically frequent fire (fire regimes I and II). The PSA is located at elevations below 6,000 feet in elevation and is represented by fire regime I, which is one of frequent, low severity surface fires. The majority of the fires and area burned in the PSA are caused by lightning. Of the human-caused fires, discarded cigarettes, sparks from mechanized equipment, and escaped campfires and controlled burns are generally the culprits. Following a fire, burned areas are exposed to the effects of erosion oduring rainfall events. Indirect affects of this accelerated erosion to affected water ways may include measurable increases in pH, nitrates, and phosphorus. However, the largest, most observable increase is generally in the form of increased turbidity.

Notwithstanding the alteration of the natural fire regime, the intense grazing of sheep in the latter half of the 19th century significantly impacted meadow systems in the County. Some observers attribute the reduction of some native perennials and their replacement by more aggressive annual species in upper-elevation grassy hillsides and higher-elevation meadow systems to these unregulated activities (SNEP, 1996). In the foothill region, the period between 1945 and 1975 was especially important in the development of range and forest management practices using controlled burning, herbicides, range seeding, and fertilization practices to optimize selected species. More recently, residential and commercial landscaping practices have introduced numerous plant species that are very successful at out-competing natives. Table 3-1 lists a number of documented invasive plants that have been observed within the PSA. Although the introduction and spread of non-native plants is well-documented, it is not clear how these changes have altered localized hydrology in the context of more physical alterations, such as road construction.

3.4 Development of the Transportation Network

Economic development in the mid-1850s in the central Sierra produced foothill road systems in the most accessible areas (e.g., stream terraces, intermittent channels, etc.). Access to Yosemite was well established by the 1870s through Big Oak Flat near present-day Groveland. This route includes parts of the original SR 120, which enters the Sierra foothills near Knights Ferry. Sections of SR 120 were added to the state highway system in 1899 (Sierra Nevada Photos, 2005) with the local roadway network constructed off the main route. Much of the Sierra Nevada Range further south remained isolated during this time (SNEP, 1996).

Trail alignments of what eventually became SR 49 were established by the 1860s to provide access to and from Columbia and Sonora. Sections of SR 49 were added to the state highway system in 1909, while other sections were not added until 1964 (Sierra Nevada Photos, 2005).

TABLE 3-1
OBSERVED INVASIVE PLANT SPECIES WITHIN THE PSA

Plant Species (Common/Scientific)	Habitat
Himalayan blackberry (*Rubus discolor*)	Found in riparian areas, seasonally wet areas
Yellow starthistle (*Centaurea solstitialis*)	Abundant; especially in disturbed areas in grasslands and woodland understory
Medusahead (*Taeniatherum caput-medusae*)	Found in grasslands, open fields
Perennial pepperweed (*Lepidium latifolium*)	Seasonal and permanent wetlands or low spots in grasslands
Oblong spurge (*Euphorbia oblongata*)	Disturbed areas, roadsides, fields/pastures
Rush skeletonweed (*Chondrilla juncea*)	Disturbed areas, roadsides, fields/pastures
Smooth distaff thistle (*Carthamus baeticus*)	Disturbed, open sites of grasslands and pastures
Spotted knapweed (*Centaurea maculosa*)	Fields, roadsides, disturbed open sites, grasslands, and logged area.
Scotch broom (*Cytisus scoparius*)	Disturbed areas, roadsides
Tree of heaven (*Ailanthus altissima*)	Disturbed areas, riparian areas, disturbed woodlands
Puncture vine (U*lus terrestris*)	Roadsides, vacant lots, other dry disturbed areas
Canada thistle (*Cirsium arvense*)	Roadsides, vacant lots, other dry disturbed areas
Klamathweed (*Hypericum perforatum)*	Pastures, abandoned fields, disturbed places
Vetch (*Vicia sativa*)	Disturbed areas, fields
Field hedge-parsley (*Torilis arvensis*)	Disturbed areas, grasslands, woodlands
Fennel (*Foeniculum vulgare*)	Roadsides, waste places, ditches
Periwinkle (*Vinca major*)	Riparian areas, wet woodlands
Italian thistle (*Carduus pycnocephalus*)	Roadsides, pastures, waste areas, grasslands
Bull thistle (*Cirsium vulgare*)	Disturbed areas, grasslands

Parts of the original emigrant's trail follow the current SR 108/120, which enters the Sierra foothills near Knights Ferry and passes through the south edge of Sonora (Sierra Nevada Photos, 2005). Similar to the Groveland area, much of the local roadway networks extend off SR 49 and SR 108.

Similar to the major highways, the need for railroads was generated by the logging and mining industries. More widespread use came with advancements in timber extraction, which was able to provide the ties, timbers, fuel, and planking necessary to build the railroads. In 1897, the Sierra Railway Company of California was formally incorporated, with grading beginning in Oakdale. The Sierra Railroad, completed in 1897, was constructed along a right-of-way that included alternate sections of land on either side. A year later, the railroad's terminus was moved to Sonora. Much of the lumber to build the railroad came from these adjacent lands. Extensive cut and fill was necessary in conjunction with long trestles and bridges crossings were necessary to maintain a low grade for the railroad alignment.

The combination of trail, road, and railroad development, vegetation removal, and the frequency of disturbance resulted in significant alternation of the natural drainage pattern in the PSA. The installation of large structures and parking areas, driveways, trails and horizontal road cuts

between the late 1920s and 1990s has concentrated sheet wash down-gradient through engineering drainage systems and roadways ascents, modified stream channel morphology by the accumulation of sediment, and diverted natural flow to other locations.. Gullies often form where drainage is diverted onto unprotected slopes by roadside ditches and culverts, where culverts block and divert flow over roadbeds and fill slopes, or where ruts form above road cuts and driveways thereby concentrating runoff. The phenomenon is exhibited in numerous locations within the PSA (see Photographs C and D, **Figure 3-3** and Photos E and F, **Figure 3-4)**.

Other topographic modifications may divert runoff from one stream to another. Road and trail crossings obstruct and channelize small contributing drainage-ways and, in some instances, may divert runoff away from the natural drainage channels. In these cases, flow is reduced in the original channel while the new, engineered or pre-existing channels must accommodate higher flow volumes. Any change in runoff volume, its mode and timing of production, and its rate of transport through a channel system all affect both the rate of water delivery to any point and its ability to transport sediment.

3.5 Water Resource Management and Conveyance

3.5.1 Early Surface Water Conveyance

The County's extensive ditch and reservoir system, as depicted in Figure 2-8, had its origin in the Gold Rush days of the 1850s. The first canal infrastructure supplied water power to the mines and placer claims and water for domestic uses in mining camps. The Tuolumne County Water Company, incorporated in September 1852 for more than half a century, was the main entity responsible for the development of dams, reservoirs, and ditches and the delivery of water to a large part of the County (PG&E Canal History, 1947).

In 1898, the Tuolumne County Water Company was reincorporated as the Tuolumne County Water and Electric Power Company, which constructed the Phoenix Powerhouse in 1898 prior to merging into the Sierra and San Francisco Power Company in 1909 (PG&E Canal History, 1947). The properties of the Sierra and San Francisco Power Company were leased on January 1, 1920, to the Pacific Gas and Electric Company (PG&E) and were purchased in 1927 by PG&E. As a result, the reservoirs and ditches built originally to serve the mines and camps became a part of the PG&E system that today serves nearly all of the PSA. Many of the old ditches and reservoirs identified in Figure 2-8 that comprise PG&E's water system in Tuolumne County are still in existence and utilized as part of the Tuolumne Utilities District's (TUD) water distribution system (see Figure 3-5). Major dam impoundments and water conveyance features constructed within the County are listed in Tables 3-2 and 3-3. TUD is contracted with PG&E for transfers of water from the South Fork Stanislaus River, below Lyons Dam through the Main Tuolumne Canal for consumptive use in the PSA and power generation at Phoenix Powerhouse.

Figure 3-3

Figure 3-4

Figure 3-5
11x17

Back of 11x17

TABLE 3-2
PG&E RESERVOIR SYSTEM

Name	Use	Year Built	Capacity (acre-feet)
Blue Gulch (Bought in February 1876 by Tuolumne County Water Company from Tuolumne Hydraulic Mining Company.)	Irrigation	Prior to 1876	0.7
Jamestown	Domestic	Rebuilt 1932	0.55
Kincaid (Purchased in November 1896 by Tuolumne County Water Company from W.I. Morgan Estate.)	Irrigation	Prior to 1866	48.3
Lyons (Land for the Lyons Flat Reservoir was bought by Tuolumne County Water Company on March 29, 1881, from Gardner Grey. The dam was built in 1897-1898 and later reconstructed by PG&E.)	Phoenix	1930	5,508
Matelot	Irrigation	1853	12
O'Neill (Purchased by Tuolumne County Water Company in February 1856 from Allen Oliver.)	Irrigation	Prior to 1856	12
Phoenix (Purchased by Tuolumne County Water Company on February 24, 1876, from its builder, the Tuolumne Hydraulic Mining Company.)	Irrigation	1852	850
Relief	Stanislaus Powerhouse	1909	15,554
Sand Bar	Stanislaus Powerhouse	Rebuilt 1939	51
San Diego (Bought by Tuolumne County Water Company from Erwin Davis, July 7, 1860.)	Irrigation	Prior to 1860	40
Slum Dam (Rebuilt in 1900)	Irrigation	1853	0.5
Sonora	Domestic	1929	4.7
Stanislaus Forebay	Stanislaus Powerhouse	1908	320
Main Strawberry (Originally there were two Strawberry Reservoirs, Upper and Lower, both built by the Tuolumne County Water Company in 1856-1857. The present reservoir was built in 1916.)	Electric Power	1856	18,266
Tuolumne	Domestic	Rebuilt 1931	2.1
Wolfling (Purchased in May, 1878, by Tuolumne County Water Company from John Wolfling. Rebuilt by PG&E in 1930.)	Domestic	Prior to 1878	2.0

Source: PG&E Canal History, 1947

TABLE 3-3
PG&E'S CANAL SYSTEM

Name	Construction Date/Information	Diverts From	Discharges Into	Length (Miles)	Use
Algerine	Algerine Ditch was constructed about 1852 by the Tuolumne Hydraulic Mining Co.	Curtis Creek	Blue Gulch Res.	9.5	Irrigation
Columbia	The original Columbia ditch was purchased from the Columbia and Stanislaus River Water Company by the Tuolumne County Water Company in 1860. It extended from the Middle Fork of the Stanislaus above Donnell's Flat 23 miles to a 3,000-foot tunnel that emptied into the South Fork and thence to the vicinity of Columbia, a total distance of 50 miles. The ditch was completed in 1850 but was used only three or four years.	Main Canal at Big Hill Camp	Junction of Matelot and San Diego Canals	4.04	Domestic & Irrigation
Eureka	Constructed in 1888-1889 to Carter's and vicinity.	Section Four	Tuolumne Res.	8.06	Domestic & Irrigation
Jamestown	The Jamestown Ditch, built in 1896, extended from the Golden Gate Mine on Wood's Creek to Jamestown.	Sonora Canal	Jamestown Res.	4.45	Domestic
Kincaid	Constructed by the W.I. Morgan Estate about 1866.	Curtis Creek	Kincaid Res.	0.51	Irrigation
Main	Constructed in 1851-1852.	South Fork Stanislaus River below Lyons	Columbia Canal at Big Hill Camp	18.81	Phoenix Ph. Domestic & Irrigation
Matelot		Columbia Canal	Sec. 14, T. 2 N. R. 14 E.	1.52	Irrigation
Philadelphia		South Fork Stanislaus River	Spring Gap Powerhouse	4.67	Electric Power
Phoenix	Constructed by the Tuolumne Hydraulic Mining Company to serve the Standard Lumber Company at Standard City in 1852. A bypass, 1.66 miles long, extends from Sullivan Creek to Phoenix Canal.	Phoenix Res.	Curtis Creek	3.12	Domestic
Racetrack		Shaw's Flat Canal	Racetrack Res.	1.18	Irrigation
Roach's Camp	The original ditch constructed in 1900 by the Tuolumne County Water Company extended from Tuolumne to Ajax and Free Lance Mines, a distance of 7.30 miles.	Eureka Canal	Turnback Creek	2.04	Irrigation
San Diego		Columbia Canal	Byrd's Res. Site	3.74	Irrigation
Section Four		Main Canal	Eureka and Soulsbyville Canals	2.74	Domestic & Irrigation
Shaw's Flat	Shaw's Flat ditch has been known as Street's Ditch and sometimes as Phoenix Ditch. It originally took water from Phoenix Lake to Sonora and Shaw's Flat. It was built by the Tuolumne Hydraulic Mining Company about 1852.	Phoenix Canal	Slum Dam Res.	10.50	Irrigation

TABLE 3-3
PG&E'S CANAL SYSTEM

Name	Construction Date/Information	Diverts From	Discharges Into	Length (Miles)	Use
Soulsbyville	Constructed in 1888-1889 by Tuolumne County Water Company from Eureka Camp to head of Black Oak mine.	Section Four Canal	Jamestown Canal	4.73	Irrigation
Sonora	Constructed about 1855 by the Tuolumne Hydraulic Mining Company.	Shaw's Flat Canal	Jamestown Canal	3.81	Domestic & Irrigation
Stanislaus	Stanislaus Powerhouse was built in 1908 by the Stanislaus Electric Power Co., which soon afterward transferred the property to the Sierra and San Francisco Power Co. Water to operate the plant was diverted from the Middle Fork of the Stanislaus River at Sand Bar Dam and transported 16 miles to the forebay above the powerhouse through a wooden flume built along the precipitous wall of the canyon. In 1941, the flume was replaced by a tunnel that now carries the flow through solid rock through most of its 11-mile length. The flow diverted from the Middle Fork comes from storage in Relief Reservoir and from Lake Strawberry on the South Fork, from which it is carried by ditch over the divide to Spring Gap Power House and thence into the Middle Fork.	Middle Fork of the Stanislaus River	Stanislaus Forebay	11.20	Power
Table Mountain	Constructed by the Tuolumne County Water Company in 1851-1852 from Springfield Weir to O'Neill Reservoir, a distance of 5.55 miles.	Slum Dam	O'Neill Res.	5.45	Irrigation

SOURCE: PG&E Canal History, 1947

Due to the linear nature of the diversions and earthen canal features, the alterations to the localized drainage patterns and stream hydrology within the PSA is similar to those associated with the early roadway system. In contrast, however, while the canal system has remained relatively unchanged from its early days, the roadway system has and continues to expand in response to continued population growth. Another significant alteration to the hydrologic system resulted from the installation of smaller dam impoundments that still exist today and have acted as sediment traps for much of the coarser sediment generated by previously-mentioned topographic alterations. Although these features are capable of capturing coarse sediment (e.g., sands), finer materials such as silts and clays are likely to pass through these smaller impoundments due to the settling time required to remove these materials from suspension. Today reservoir sedimentation is receiving increased attention due to the associated reductions in reservoir capacity, thereby necessitating costly dredging practices, and the accumulation of certain contaminants and heavy metals that bind readily to sediments.

3.5.2 Regional Water Conveyance Facilities

In 1926, the Oakdale and South San Joaquin Irrigation Districts built the Melones Dam and Powerplant. The peak of construction by irrigation districts came in the 1950s with construction of the Tri-Dam Project, which consists of the Donnells and Beardsley Dams on the upper Stanislaus River, Tulloch Dam on the lower Stanislaus River, and the enlargement of Goodwin Dam, also on the lower river (Reclamation, 2005). In 1978, New Melones Reservoir was formed by an earth and rockfill dam, downstream from the old Melones Dam, 7.6 miles southwest of Sonora. The New Melones Unit was officially transferred to the U.S. Bureau of Reclamation in November 1979 for integrated operation with the Central Valley Project.

The Don Pedro Reservoir is formed by an earthfill dam, which was completed in 1971. It is located 500 feet downstream from Mexican Gulch, and 3.4 miles northeast of La Grange. Storage began November 3, 1970. Water passes through a powerplant at the dam and then down the Tuolumne River to La Grange Dam, 2.5 miles downstream, where it is diverted into the Turlock and Modesto Canals for irrigation. The reservoir is operated jointly by the Turlock and Modesto Irrigation Districts. Prior to June 1971, the reservoir was formed by a concrete gravity-type dam completed in 1923 with a capacity of 290,400 AF (USGS, 2003).

Under state law, the Turlock and Modesto Irrigation Districts hold “senior” water-rights to base flows within the Tuolumne River. The San Francisco Public Utilities Commission (SFPUC) holds “junior” rights, in which the exact distribution is determined daily by a calculated estimate of what the flow would be at La Grange (located just below Don Pedro Reservoir), absent any dams on the river. Most of the year, all of the river’s flows below 2,416 cfs belong to the two districts. Over the 60-day period from mid-April to mid-June, typically the period of highest river flow due to melting snow, that threshold is raised to 4,066 cfs.

The SFPUC does not divert water directly from Don Pedro Reservoir, but owns the right to store up to 740,000 AF in Don Pedro Reservoir (more than twice the total volume of Hetch Hetchy Reservoir (SFPUC, 2004)). The SFPUC uses its storage in Don Pedro Reservoir as a water bank and is still able to divert river flows upstream by using its bank in three “upcountry” reservoirs, Hetch Hetchy, Lake

Eleanor, and Cherry Valley Reservoir. In accordance with State law, the SFPUC spills a portion of the river flow as it impounds the upstream flow or diverts it to the San Francisco Bay Area. Water storage in Don Pedro Reservoir is also managed to prevent the Tuolumne from flooding Modesto and the surrounding areas. Consequently, neither San Francisco nor the irrigation districts are allowed to fill their portions of the reservoir until the end of the spring snowmelt.

3.5.3 Groundwater Management

Currently, approximately 30 percent (16,500) of Tuolumne County's 55,000 residents depend on groundwater either from private wells or one of the small or large public water systems. As the primary non-public water source, wells continue to be drilled for new development, particularly for rural residents (an average of 114 wells per year during the past five years). Since the adoption of the Tuolumne County Water Well Ordinance in 1986 (Chapter 13.16 Tuolumne County Ordinance Code [TCOC]), the Environmental Health Division had issued approximately 1,900 water well drilling permits as of 1999 (Tuolumne County, 1999).

Public water systems with more than 200 service connections are regulated by the State Department of Health Services (DHS). There are 16 such systems in Tuolumne County. The largest water provider in Tuolumne County is TUD, with the majority of its customers served by surface water (e.g., the Stanislaus River and associated impoundments) and only about 5 percent served with well water (300 connections with about 720 users). TUD maintains 45 wells, some of which are used to supply make-up water during droughts and ditch outages (Tuolumne County, 1999).

Other large water providers, such as the Groveland Community Services District and Twain Harte Community Services District also use surface sources. However, several others such as Mi Wuk Mutual, Cold Springs and Odd Fellows Sierra Park, and many of the smaller public water systems in the County depend on a groundwater for at least part of their water supply. There are 106 small water systems regulated by the County's Environmental Health Division (EHD). Eighty-two of these systems rely exclusively on groundwater (Tuolumne County, 1999).

3.5.4 Wastewater Treatment

Historically, Tuolumne County communities from Jamestown to Twain Harte have discharged sewage effluent directly to Woods or Sullivan Creeks (Tuolumne County, 1997). With the adoption of the Clean Water Act in 1972 and, shortly thereafter, the establishment of the State Water Resources Control Board and Regional Water Quality Control Boards, these practices were ended. At that time, a Regional Wastewater Plan was developed, and treatment plants at Sonora and Jamestown were upgraded to treat the wastewater to a level of quality suitable for discharge to surface waters. Interceptor lines were constructed to bring primary treated sewage from Twain Harte and untreated sewage from other communities throughout the area to the Sonora treatment plant. The upgraded regional collection and treatment system has been in operation since April 1976 (Tuolumne County, 1997). TUD is the major provider of wastewater service within northern sections of the PSA; with other smaller providers servicing more isolated urban cores within the central and southern portions of the PSA. Table 3-4 lists the major wastewater service providers within the PSA.

TABLE 3-4
PRIMARY SEWAGE DISPOSAL – TUOLUMNE COUNTY

Agency	Location of Treatment Collection Facilities	Capacity (Gallons per Day)	Average Throughput (Gallons per Day)	Maximum Possible Connections (Number)	Disposition of Effluent
Tuolumne Utilities District (TUD)	End of Southgate Drive, Sonora	5,200,000 [1]	2,800,000–3,000,000 [1]	20,800 – 24,186 [1]	Storage at Quartz Reservoir, and used for agricultural irrigation
Groveland Community Services District (GCSD)	At the main GCSD Office, Ferretti Road, Groveland.	400,000	188,000	1,300	Complex of spray fields and ponds for evaporation and a portion is used at the Pine Mountain Lake gold course for irrigation, although salt concentrations are reducing this use.
Tuolumne Sanitary District	Near Box Factory Road, North of Turnback Creek and south of RR, Tuolumne City.	360,000 gpd (dry weather)	65,000 (dry weather)	850	Spray evaporation ponds downstream from Tuolumne along Turnback Creek
Jamestown Sanitary District	Plant alongside Wood's Creek, Jamestown	280,000 gpd (dry weather)	180,000	1,250	Effluent pumped to Quartz treated-wastewater reservoir and used for agricultural irrigation
Grand Total		**6,240,000**	**3,233,000–3,433,000**	**24,200–27,586**	

[1] Facility is currently built to handle 2,600,000 gallons per day, but the facility is designed to begin expansion to 5,200,000 gallons per day once the facility hits 80 percent capacity. The facility currently serves between 10,400 and 12,093 connections based on TUD's guidelines of 215 to 250 gallons per day residential household. Current average throughput is 1.4 to 1.5 million gallons per day. Source: Gary Egger, TUD, August 1, 1986.

SOURCE: Tuolumne County General Plan EIR, 1996

Today, TUD's Sonora Regional wastewater treatment plant (WWTP) and Jamestown Sanitary District's (JSD) WWTP treat wastewater to a disinfected secondary standard. The TUD plant is regulated by Waste Discharge Requirements (WDR) Order No. 94-192; the JSD plant is regulated by WDR Order No. 5-01-062. These WDRs are regulated by the Central Valley Regional Water Quality Control Board (CVRWQCB). In addition to centralized wastewater treatment facilities, it is estimated that approximately 40 percent of Tuolumne County residents (about 22,000 people) do not have available sewer service and therefore must use on-site sewage treatment and disposal systems (Tuolumne County, 1999). This has resulted in the installation of an estimated 7,500 septic tank-leachfield systems county-wide (Tuolumne County, 1999). Of this total, it is not clear how many of these septic tank-leachfield systems reside within the PSA; however, given that the PSA includes a large fraction of the development within the County it is presumed that it includes a large proportion of the total systems. Many of these operate without problems, but others suffer from poor design or increased use.

The EHD regulates underground disposal using individual or common tank and leach field systems. Because the volume of wastewater introduced to a septic tank system from a typical household unit ranges from 40 to 45 gallons per day per person (Canter and Knox, 1985), it is estimated that about 880,000 gallons of sewage are discharged into the ground per day in the

County (Tuolumne County, 1999). The most problematic systems are generally located in older communities with high septic system densities and lots with inadequate leachfield area. Some of these subdivisions were developed primarily for use as vacation cabins but now have a high rate of year-round occupancy.

Most of the septic systems were installed prior to the adoption of Chapters 13.04 and 13.08 of the Tuolumne County Ordinance Code (TCOC) (in 1975 and 1981, respectively), which now require a health review and soil investigations to demonstrate feasibility and long-term operation prior to approval (Tuolumne County, 1999). Additionally, the County notes that some of these systems were installed in fractured rock and are potentially a threat to groundwater quality and local water wells. Those wells of most concern are generally associated with older residences drilled prior to the adoption of the local well construction ordinance in 1986 (Chapter 13.16 TCOC), which mandates minimum separation between leachfields and other sources of pollution (Tuolumne County, 1999). In other instances if local bedrock fractures are oriented laterally, problematic septic systems may pose a potential hazard to surface water.

3.6 Population Growth

3.6.1 Demographic Trends

Prior to 1900, the County's population varied from 16,229 in 1860 to 6,082 in 1890 in response to the decades marked by California's Gold Rush. Only since 1930 has Tuolumne County experienced a steady growth rate (Tuolumne County, 1997). From the 1950s to the 1960s, the growth rate of the unincorporated area of Tuolumne County increased from 1.5 to 6.3 percent per year and remained at a high level through 1990 (Table 3-5). The population of the unincorporated area of Tuolumne County grew by 44.4 percent during the 1980s and slowed to 13.0 percent during the 1990s (Tuolumne County, 1997). The State Department of Finance projects the County to reach a population of about 65,452 by 2020 and 70,537 by 2040 (Department of Finance, 2000).

In 2000, the per capita income in the County was $20,910; approximately 70 percent of the State average and ranking 45th in the State (Department of Finance, 2000). In March 2003, the County had a civilian labor force of 22,360 persons. Of these, 20,920 persons were employed.

TABLE 3-5
HISTORICAL POPULATION GROWTH, 1900-2000

		Change from Preceding Year/Census		
Year	Population	No. of Persons	Percentage (10 Year)	% Average Annual Change
1900	9,244			
1910	7,950	-1,294	-14.0%	-1.4%
1920	6,084	-1,866	-23.5%	-2.3%
1930	6,993	909	14.9%	1.5%
1940	8,630	1,637	23.4%	2.3%
1950	10,136	1,506	17.5%	1.7%
1960	11,679	1,543	15.2%	1.5%
1970	19,069	7,390	63.3%	6.3%
1980	30,681	11,612	60.9%	6.1%
1990	44,303	13,622	44.4%	4.4%
2000	50,078	5,775	13.0%	1.3%

Source: Tuolumne County General Plan, (Source: U.S. Census, City of Sonora 2001-2008 Housing Element)

This corresponds with an unemployment rate in of 6.5 percent; slightly higher than the national average, which is currently around 5 percent. The major employment sectors are government (28.5 percent), retail trade (26.7 percent) and services (25.2 percent). The 2000 Census indicates those employed within the County were employed in the following industries:

- Agriculture, Forestry, Fishing, and Hunting
- Mining
- Construction
- Manufacturing
- Wholesale trade
- Retail trade
- Transportation and Warehousing
- Utilities
- Information
- Finance and Insurance
- Real Estate, Rental and Leasing
- Professional, Scientific, and Technical Services
- Administrative, Support and Waste Management
- Educational Services
- Health Care and Socia1 Assistance
- Arts, Entertainment and Recreation
- Accommodation and Food Services
- Public Administration
- Other Services

Current employment trends suggest that the economy of the County is changing from the historic industries of agriculture, mining, and timber to more of a service based economy. Current growth trends indicate that continued residential growth threatens oak woodland habitats in the County, since these habitats are where much of the growth is occurring. The current housing boom is fueled by the County's proximity to the rapidly growing cities in the Central Valley, which are generally within commuting distance. Based on current population projections, the lower reaches of the PSA are expected to experience additional growth through 2040, especially above the shoreline of Don Pedro Reservoir.

Chapter 4

Foothill Geomorphology and Sediment Transport Dynamics

ESA

CHAPTER 4
Foothill Geomorphology and Sediment Transport Dynamics

4.1 Purpose, Scope, and Methods

ESA conducted a Hillslope and Channel Geomorphic Assessment to provide an indication of total sediment volume within the Sullivan Creek Hydrologic Area and to produce a preliminary sediment budget to identify the portion of the existing sediment load that may be potentially controllable.

4.2 Approach to Quantifying Sediment Sources

ESA's work focused on broadly quantifying the volume and extent of hillslope and streamside erosion and the associated ratios of sediment delivery occurring in the watershed. This information is then used in estimating the relative proportion of sediment delivery from erosion, which is potentially controllable or preventable.

Data collection methods for this task primarily consist of (1) unit-wide, aerial photographic interpretation; (2) field mapping, data collection and analyses on selected portions of the hillslopes and stream channels in the Sullivan Creek Hydrologic Area; (3) GIS analysis of the area; and (4) preparing a simple sediment budget for the Sullivan Creek watershed. All of these elements rely on sound professional judgment in identifying, measuring, and quantifying erosional features and sediment sources, in determining whether the erosion is natural or associated with past land use activities in the watershed, and applying field observations and literature information to the analysis.

4.2.1 General Limitations

Any form of estimate is generally complicated by the difficulties of predicting the amount of sediment eroded, the delivery of eroded sediment into the stream network, and the downstream transport of the introduced sediment, sediment storage in stream channels or flood areas, and the potential secondary effects that result from the initial introduction of sediment into a stream channel. The small scale of the aerial photographs in conjunction with an extensive canopy cover limited the amount of erosional features that could be identified remotely. Minimal access to private property also limited ESA's ability to identify or measure erosional features on the hillslopes or make stream observations beyond public ROW stream crossings. Further, estimates

of erodability are based on published literature for similar geologic units and do not have the benefit of site-specific erosion measurements. Sediment transport measurements could not be verified by virtue of a of lack continuous flow data to enable correlation for the quantities of sediment believed to be held in storage and the transport potential based on specific rainfall or flow intensities (e.g. 5-year, 24-hour; 50-year, 24 hour; etc.).

4.3 Hillslope Geomorphology

4.3.1 Physical Setting

The Sierra Nevada mountain range is generally described as a westward-tilted mountain block (Bateman and Wahrhaftig, 1966). The uplift is greatest along the eastern mountain front where the elevations are highest and elevations generally decline toward the Central Valley. Various episodes of uplift and river incision have occurred over its long history. The most important episodes to consider here are those since the deposition of the early Tertiary gold-bearing (auriferous) gravels. These Eocene age deposits relate to a regional uplift, the development of major river systems, and the deposition of the alluvial (river-deposited) gold-bearing gravels. The next major event was the inundation and burial of the landscape by volcanic mudflows, volcanic lava flows, and volcanic ash flows in Miocene-Pliocene time (Huber, 1990; Higgins, 1997). In the central to northern Sierra Nevada these materials completely buried the pre-existing river landscape forming a broad plateau surface; afterwards a new drainage system developed by incising into that plateau. These volcanic materials are assigned to the Mehrten Formation (predominantly volcanic debris flows) and other distinctive lava flows such as the Table Mountain Latite along the former path of the Stanislaus River.

Central and southern Tuolumne County is the zone in which the plateau-forming Mehrten Formation and other flows become substantially less dominant. Huber (1990, p. 102) notes that the Tuolumne River, which lies immediately south of the Sullivan Creek watershed, “is the northernmost of the major rivers draining the west slope of the Sierra Nevada whose course is not totally disrupted by the voluminous lahars[1] that buried most of the northern Sierra.” The Tertiary Stanislaus River to the north of the Sullivan Creek watershed was inundated by the Table Mountain Latite (see Section 2.1.1 Structural Geology). The current course of the Stanislaus River was incised into the adjacent non-volcanic rocks leaving the Tuolumne Table Mountain as a remnant marking the Tertiary course of the river.

The Sullivan Creek drainage is an interfluve[2] area between the Tuolumne River to the south and the Stanislaus River to the north. Whereas the Tuolumne and Stanislaus rivers have large watersheds which extend long distances into the high Sierra, the Sullivan Creek watershed drains a much smaller area in the western foothills. It has a watershed area of approximately 40,100 acres and has a watershed length of approximately 17 miles. Although its location is in the western foothills the maximum relief in the watershed is 4,100 feet (between Elizabeth Peak on the northern rim

1 Volcanic debris flows
2 An interfluve is the ridge line separating two drainages. In the case of Sullivan Creek this “ridge line” is sufficiently large to have its own drainage system.

and the surface of Don Pedro Reservoir). This northern ridge is above the elevation of the Mehrten Formation and was not buried by it. Despite the substantial overall relief in the watershed there is only a small area with slopes greater than 50 percent.

The watershed geology is described in Section 2.1.3 Sullivan Creek Hydrologic Area. It consists of the 16 geologic mapping units shown in Table 4-1:

TABLE 4-1
GEOLOGIC UNITS IN THE SULLIVAN WATERSHED

Mapping Unit	Name	Age	Rock Types
Qal	Alluvium	Quaternary	Sand and gravel, also includes colluvium, landslide debris, and tailings locally
Qt	Tailings	Quaternary (modern)	Various rock debris, formed from mining operations
Tm	Mehrten Formation (undifferentiated)	Miocene-Pliocene	Volcanic flows, mudflows, plugs, and sediment of andesite composition, includes some mafic and silicic rock
Tvs	Valley Springs Formation	Oligocene-Miocene	Volcanic and sedimentary rock (mainly silicic tuff)
Tg	Auriferous (gold-bearing) gravel	Eocene	Sand and gravel composed mostly of pre-Tertiary rock
Js	Metasedimentary rocks	Jurassic	Slate with subordinate metagraywacke, minor metaconglomerate and tuff, formed as turbidites
Jm	Melange	Jurassic or older	Complex of incoherent lithologies including metavolcanic rock, chert, serpentine, schist, and marble
Jsp	Sullivan Creek terrane (phyllite belt)	Jurassic (?)	Mainly phyllite and stretched conglomerate derived from argillaceous and coarser-grained sediment
Jsg	Sullivan Creek terrane (greenschist belt)	Jurassic (?)	Metavolcanic rock including pyroclastic deposits and pillow basalt
Jv	Metavolcanic rocks (undifferentiated)	Jurassic	Metavolcanic rock, generally andesitic to basaltic composition
Mzg	Granitic rocks (undifferentiated)	Mesozoic	Granite to quartz diorite, includes main Sierran batholith and isolated plutons
Mzpm	Mafic plutonic rocks (undifferentiated)	Mesozoic	Diorite to gabbro, includes pyoxenite and hornblendite locally
Pzc	Calaveras Complex (undifferentiated)	Paleozoic-Triassic	Marine metasedimentary rock with minor metavolcanic rock, mainly chaotic argillite and subordinate chert
Pzcm	Calaveras Complex (marble)	Paleozoic-Triassic	Marine limestone and dolomite metamorphosed to marble
Pzs	Shoo Fly Complex (undifferentiated)	Paleozoic	Marine metasedimentary rock, mainly quartzite with minor schist and marble, may include masses of gneiss locally
um	Ultramafic rock	Paleozoic-Mesozoic	Dunite and peridotite partially or completely altered to serpentine

SOURCE: CGS, 1997

The detailed geology can be generalized into three broad lithologic (rock) groups. The first lithologic group is the volcanic plateau formed by the Mehrten Formation with a very small exposure of the underlying Valley Springs Formation. This plateau-forming deposit may have originally extended over most of the Sullivan Creek watershed but has since been eroded away. It now underlies only a very small area to the northeast and south of Twain Harte and to the southeast of Soulsbyville. Indications of the former extent of the Mehrten plateau in the area are shown by the elongated narrow ridges that separate the upper Sullivan Creek drainage from the Curtis Creek drainage to the southeast. These elongated ridges suggest that the Mehrten Formation formerly extended at least this far and formed a continuous surface at least from southeast of Soulsbyville to these ridges. It is likely that the Mehten Formation also continued to the north through the upper Sullivan Creek watershed. Virtually all of this former extent has been eroded away exposing the second, and underlying, lithologic group.

The second lithologic group is the area underlain by intrusive igneous rocks (granitic and mafic in composition) which are referred to as granitic in this section and some of the metamorphic rocks. This is the dominant rock type in the Sullivan Creek watershed. This rock underlies the upper two-thirds of the watershed as well as some area in the southwestern-most part of the watershed. In the upper watershed these granitic rocks underwent a relatively deep weathering which produced a moderately-deep to deep weathering zone. This weathering zone is shown throughout much of the watershed by reddish surface soil horizons underlain by more pale materials. In places these pale weathering zones can be observed to transition into the underlying granitic bedrock with boulders (corestones) weathering out between the bedrock joints (see **Figure 4-1**). Throughout the upper two-thirds of the watershed remnant granitic boulders up to approximately 10 feet in longest dimension are exposed in stream beds, stream banks, hillsides, and road cuts. These granitic boulders are found at all elevations in the upper watershed underlain by the granitic rocks. They occur at the highest elevations immediately beneath the Mehrten Formation in Twain Harte (see **Figure 4-2**), on hillslopes on upper Phoenix Lake Road and along Middle Camp Road (see **Figure 4-3**), on low elevation surfaces in Standard (see **Figure 4.4**), and in valley bottoms along Curtis Creek in Standard and in Twain Harte Creek where it crosses Crystal Falls Drive. In addition, there are two areas where well-developed exfoliation sheets formed in the granitic rocks occur. One is along Phoenix Lake Road (see **Figure 4-4**) and the other is along Sullivan Creek above Crystal Falls Drive (see **Figure 4-5**).

As noted in Section 2.1.2 Soil Resources the upper soil horizons in this area tend to be sandy clay loams. Below the soil profile these deeply weathered granitic rock materials produce predominantly sand-size material (called grus). The less weathered granite also produces gravel-sized sediment. When exposed in natural stream cuts, road cuts, or other disturbed areas this range of fine-grained to sandy to gravel sediment is very erodible. The sandy grus forms a substantial portion of the sediment contribution in the watershed.

Figure 4-1

Figure 4-2

Figure 4-3

Figure 4-4

Figure 4-5

The third lithologic group is the metamorphic rocks, which are dominated by metamorphic sedimentary and volcanic rocks. These rocks outcrop in a narrow zone at the upper rim of the northern watershed and in the lower one-third of the watershed. These metamorphic rocks tend to be dense and hard and have a shallower weathering zone and soil column as compared to the granitic rocks (see **Figure 4-6**). They do not contribute substantial amounts of sediment from soil erosion except in areas immediately adjacent to streams (see **Figure 4-6**). These metamorphic rocks also form a northwest-southeast trending zone of bedded rocks in the lower portion of the watershed. Sullivan Creek and Curtis Creek have eroded steep canyons where they pass through them. In these sites coarse rock materials produced predominantly by physical weathering on the canyon walls can be contributed directly to the streams by slope processes (see **Figure 4-6**).

4.3.2 Geomorphic Terrains

Hillslope Geomorphic Units (HGUs) are the basic unit for analysis of rates of erosion and sediment production rates to stream channels. The concept of HGUs assumes that hillslopes with similar characteristics will be dominated by similar erosional processes and similar mechanisms by which eroded material is delivered to stream channels. The development of HGUs serves as the basis for a sampling of hillslopes, to measure (through use of aerial photographs and field mapping) erosion and sediment production rates. Once determined, these rates can then be extrapolated to all areas in the larger watershed that fall within the same HGU. Development of the HGUs for the Sullivan Creek watershed was accomplished primarily through the use of existing GIS data.

Because each HGU type is defined as possessing a unique combination of attributes, it was necessary to limit the number of layers that would be used in the definition. In addition, some “lumping” of attributes within a layer was necessary to reduce the number of possible combinations. In the end, three primary layers were used to characterize natural HGUS and include a 10-meter DEM, geology,[3] and vegetation. To model alterations in the natural HGUs, the County’s roads GIS layer was utilized since local observation suggest these features in conjunction with contributing driveways constitute the largest fracture of hillslope alteration. The following describes how each of these layers were used in the analysis.

A 10-meter DEM was used to calculate slope angles, expressed in terms of percent slope. The slope categories were then generalized into areas of steeper and less steep terrain through the use of a “nearest neighbor” function of the GIS. With this function, the region (or “neighborhood”) around each point on a 10-meter grid in the watershed was examined to determine the steepness of all points in the neighborhood. The slope steepness categories used included 0 to 15 percent, 15 to 50 percent, and greater than 50 percent based on Ellen and Wentworth (1995). These slope categories relate to both the potential for erosion and slope alteration for development purposes (Ellen and Wentworth, 1995).

[3] Soil/vegetation maps for Tuolumne County were produced by the Soil Conservation Service in 1968; and have been digitized and attributed for use in a GIS by the Tuolumne County’s Farm Advisor’s Office. The mapping, however, does not extend to the developed areas. Consequently, the geologic mapping of Curtis (1999) was used in placed of the soil coverage because it provides completed coverage of the entire Sullivan Creek watershed.

Figure 4-6

Slopes in the first category are gentle and present little to no constraint to road alignment and require minimal grading for development. Slopes in the 15 to 50 percent category are steep enough to require grading for flat space but sufficiently gentle to allow grading by standard means. Slopes greater than 50 percent are steeper than the standard 2:1 (horizontal:vertical) cut and fill slopes and they cannot support development requiring flat surfaces unless fills steeper than 2:1 can be sustained. In the Sullivan Creek watershed slopes are generally in the first two categories and slopes greater than 50 percent only occur in areas within canyons or small-localized areas.

Several dozen geologic units are shown as polygons in geologic maps prepared by the CGS for Tuolumne County (Higgins, 1997) and 16 of these geologic units occur in the Sullivan Creek watershed (**Table 4-1**). These units were combined into generalized categories with shared characteristics of resistance to erosion based on field observations and comparisons to work in the Yuba River watershed (Curtis et al., 2005) as described in Section 4.3.1 Physical Setting. Elsewhere in the Sierra Nevada the Mehrten Formation is notable for the occurrence of landslides, which often originate at the interface between the base of the formation and the underlying bedrock (Curtis et al., 2005). It is also considered an erosive unit along its margins (Curtis et al., 2005). However, field observations in the Sullivan Creek watershed did not identify significant landslides, and the surface erosion seen along exposed margins of the Mehrten Formation (**Figure 4-7**) was not more than that observed in the weathered granitic material. Consequently, the geologic units were grouped into two broad groups: granitic and Mehrten (moderately erodible) and metamorphics (low erodibility).

The vegetation layer includes many vegetation types converted into a grid file. These were combined into similar categories based on cover protection to reduce the number of possible HGUs. The two vegetative types used were forest (including conifer and oak woodland) and grassland.

The final HGUs were therefore defined by the combination of the three slopes classes, the two geologic erodibility classes, and the two vegetation classes or 12 separate HGUs. These HGUs are presented in **Figure 4-8**.

4.3.3 Deviations from Sampling Protocol

All aerial photograph interpretation was limited to stitched-digital ortho-photographs provided by the County. To the extent feasible, ESA utilized this aerial coverage (ten-meter resolution) to identify larger sediment sources throughout the entire Sullivan Creek watershed. Because this imagery is not available in stereo, its use in identifying small- to medium-sized features was limited due to the ten-meter resolution and further complicated by the uniform canopy cover that characterized much of the watershed. These two factors made the determination of a feature's certainty[4] minimal, even for larger features. As a consequence, ESA was unable to determine the average length, width, and depth of larger features on the aerial photo. Further, features that were identified were unable to be field-checked due to access restrictions. These limitations made transferring individual features into an ArcGIS shape file format impractical. (1:24,000 scale).

[4] This is the certainty of the analyst's interpretation of the feature type and provides information necessary for field checking of sites.

Figure 4-7

4.4 Sediment Source Assessment Results

The sediment source assessment involved roadside evaluation of the different HGUs. The 12 terrains defined by the three slope gradient classes, the two geologic erodibility classes, and the two vegetation classes were examined by observing their characteristics along the Sullivan Creek Hydrologic Area road system. While access to the actual hillslopes was very limited, numerous useful observations could be made from the roadside with respect to overall vegetative cover, the general character and amount of natural and human disturbance, and estimates of the scale of sediment production and delivery from the road systems themselves. The road system traverse included all areas within the Sullivan Creek watershed including:

- Approximate northwest to southeast transects in the lower watershed for the Lower Sullivan Creek and Curtis Creek subwatersheds including Jacksonville Road, Algerine Road, Lime Kiln Road, Wards Ferry Road, and Outback Trail.
- The upper Curtis Creek and Soulsbyville subwatersheds along Tuolumne Road, Curtis Drive, Black Oak Road, and Soulsbyville Road.
- The Lower Sullivan Creek subwatershed in Sonora Hills and along Campo Seco Road, and Avenida Bonita.
- The Upper Sullivan Creek subwatershed along Phoenix Lake Road, Old Phoenix Lake Road, Potatoe Ranch Road, Montgomery Road, El Lobo Center, Creekside Drive, American River Drive, Crystal Falls Drive, Kewin Mill Road, Longway Middle Camp Road, Road N5602, Hunts Road, Bald Mountain Road, and Big Hill Road.
- A number of the road-stream crossing evaluated for the Channel Morphology and Sediment Transport Assessment (Section 4.4) were also observed to provide context for the HGUs.

A portion of the lower watershed that is being developed as rural residential home sites was not traversed because access is by private roads. Similarly, the larger rural land ownership of grazing land could only be observed at some distance. In the northern portion of the Upper Sullivan subwatershed north of Phoenix Lake rural residential development was not directly observed because access is also by private road. In this area some general observations could be made at a distance from Big Hill Road. Overall the coverage was sufficient to be able to generally characterize, or extrapolate, the condition of the sediment sources in the watershed.

Although some locations exhibited features associated with extreme soil erosion (e.g., extensive gully systems), their extent was limited and/or unobservable due to access limitations. Observed erosion was primarily associated with human disturbance and the two primary disturbances identified were associated with roads (road cuts, road side ditches, road embankments, native or gravel surface roads) and home sites (unpaved driveways, pastures, correls, and unvegetated portions of the lot).

Figure 4-8
11x17

Back of 11x17

To simplify the sediment budget analysis, the HGUs were also combined in the GIS into three erodibility rankings. The HGUs were combined using procedures in ArcGIS spatial analyst (ESRI, 2004). That is, the derived datasets (slope, geologic erodibility, vegetation) were first reclassified into a common scale. The three slope classes were scaled at 3 (0 to 15 percent), 5 (15 to 50 percent), and 8 (greater than 50 percent). The geologic erodibility categories were scaled at 2 for low erodibility and 6 for moderate erodibility. Vegetation was scaled at 7 for forest and 10 for grassland. The next step was to weight and combine the datasets. Because field observations indicate that natural vegetation does not have a substantial differentiating effect on erodibility it was weighted at 0.1. Geologic erodibility was considered next in importance and it was weighted at 0.4. Slope was considered the most important and weighted at 0.5. These weighting factors were applied within spatial analyst and generated three erodibility classes based on the defined parameters. The three general erodibility classes were low erodibility (1), moderate erodibility (2), and high erodibility (3). The distribution of these erodibility classes in the Sullivan Creek Watershed Area are shown in Figure 4-9(A) Erodibility.

Figure 4-9 also shows the other analysis layers used in the Sediment Budget, which is described in detail in the following section. These layers include a stream layer generated in the ArcHydro component of ArcGIS (Figure 4-9(B) Streams); a road layer (Figure 4-9(C) Roads) and a simplified developed area (i.e., areas of concentrated development; Figure 4-9(D) Developed Area), which was developed by applying a buffer to the road layer. Using the HGUs as a base, the sediment budget estimated sediment production for natural conditions and developed conditions. The developed conditions individually accounted for the roads and "Developed Area." The process is described in detail in the following section.

4.4.1 Sediment Budget

A simplified sediment budgeting approach was developed to evaluate the sediment source and delivery to the stream channel systems in the Sullivan Creek watershed. Sediment budgets evaluate the sediment production from a variety of sources and their delivery to the stream system. Detailed sediment budgets consider hillslope surface erosion, road erosion, mass wasting (e.g., landslides), and streambank erosion among other items. The simplified sediment budgeting approach used here includes hillslope surface erosion (under natural and developed conditions) and road erosion. Mass wasting contributions are not included because of the limitations of the available aerial photography to recognize landslide scars and general absence of landslide units identified in available geologic maps. Streambank erosion is not included because of the limitations of the aerial photography to allow identification of streamside erosion and the lack of access to conduct erosion transects along streams.

Figure 4-9

The sediment budget methodology was simplified from that done by McGurk et al. (1996) in the Camp and Clear Creek watersheds in El Dorado County; tributary to the Cosumnes River. The Sullivan Creek watershed sediment budget considered the potential for sediment production and delivery from hillslopes to the stream channels for each of the four subwatersheds. In brief, the methodology created buffer zones around the stream system subdivided by the erodibility category; assigned erosion values (tons per acre per year) from the literature for each of the erodibility categories and condition categories (i.e., natural, developed, roads); and then reduced the total tons of sediment produced by an estimate of how much of the eroded sediment would be trapped on the hillslope rather than actually being delivered to a stream. The latter approach is based on the observation that the further away from a stream that sediment is produced, the less likely that sediment is to actually reach, i.e., be delivered to, a stream. The values are totaled for each of the four subwatersheds considered, i.e., Upper Sullivan Creek (all the drainage contributing to Phoenix Lake), Lower Sullivan Creek, Soulsbyville, and Curtis Creek. The process is described in more detail below.

First, the ArcHydro component of ArcGIS was used to generate a detailed stream layer [see Figure 4-9(B)]. This stream layer was compared to the U.S. Geological Survey 7.5 minute topographic quadrangle and seen to be in reasonable agreement with the contour crenulations on the maps that denote the location of streams or drainages. Then these streams were buffered by distance producing four separate buffer zones around the streams. The buffer distances used are 0 to 164 feet, 164 to 328 feet, 329 to 492 feet, and greater than 493 feet (i.e., 50-meter intervals). The assumption here is the closer a hillside segment is to a stream channel the more likely it is that any eroded sediment is to reach a stream channel (see the discussion of sediment delivery below). These buffer zones were then overlain onto the hillslope erodibility layer. This analysis generated a database that showed the acreage in each of the three erodibility categories for each of the four buffer zones for each of the four subwatersheds. That is, the analysis quantifies how the erodibility categories are spatially arranged around the stream system.

The next step was to provide estimates for the amount of erosion that would occur in the individual erodibility categories and condition categories. These values were derived from a literature review with selections made based on the field observations within the watershed and on professional judgment. The erodibility values used were in tons per acre per year of sediment that would be produced under the given conditions. The sources used for estimating the erodibility values included those from natural and disturbed conditions in the Sierra Nevada (Euphrat, 1992; Kattleman, 1996; McGurk et al., 1996; Snyder et al., 2004; Curtis et al., 2005) and from granitic terrains in the Klamath Mountains of California (Sommarstrom et al., 1990) and the Idaho batholith (Rice et al., 1972). The erodibility values are multiplied by the acres in each erodibility category for each stream buffer zone to generate a value for the total tons of sediment eroded within each of the buffer zones per year. The values are then added to provide a value for the entire subwatershed. These values are the amount of sediment movement on the hillslopes. The potential for this eroded sediment to actually reach, i.e., be delivered to, a stream is evaluated by considering the distance of each buffer zone from the stream and then applying a sediment delivery ratio.

A sediment delivery ratio is the ratio of sediment delivered from a point to the total erosion that could occur upslope of the delivery point. For example, if 7 tons of sediment is delivered to a stream when 10 tons of sediment was produced from a specific source area, the sediment delivery ratio for that site is 7 divided by 10 or equivalently 70 percent. Sediment delivery ratios reflect the fact that some portion of eroded sediment is stored on the hillslope. Sediment eroded at a great distance from a stream (e.g., from a ridge top) may not be delivered at all, thereby having a sediment delivery ratio of 0 percent. The sediment delivery ratios used for natural conditions were 25 percent for the 0 to 164-foot buffer zone, 15 percent for the 164 to 328-foot zone, 10 percent for the 329 to 492-foot zone, and 0 percent for the greater than 493-foot zone. These values are similar to those used by McGurk et al. (1996).

To evaluate the changes in sediment production and delivery that have occurred in association with existing development, two other subsets of the Sullivan Creek watershed were also developed: a simplified development area and a roads area. The intent of the development area was to identify a reasonable spatial representation of the area that has undergone substantial development thereby resulting is significant alterations to the geomorphic terrain. It was produced by buffering the existing road system and visually comparing the result with the maps and field observations of the area. Initially roads were buffered at 500 feet. Then the buffers on roads that transect less developed areas were reduced to 50 or 100 feet to generally represent the amount of development associated with them and/or road cuts that extend off the actual road alignment. This produced an area of approximately 17,000 acres of developed land within the 40,100 acre watershed. Another alteration was made within the sediment budget spreadsheet to address the fact that certain areas are more urbanized than others. Specifically, an area correction factor was applied to address the degree of development in Twain Harte and Sonora Hills. The acreage covered by these two areas was estimated from land use maps. Twain Harte was assumed to have 70 percent impermeability and Sonora Hills was assumed to have 100 percent impermeability. These values were used as sediment delivery ratios to reduce the amount of potential sediment delivered from these sites. Sediment delivery ratios were assumed to be higher for the developed areas than natural areas. The sediment delivery ratios used were 60 percent for the first buffer zone, 40 percent for the second buffer zone, 20 percent for the third buffer zone, and 0 percent for the fourth buffer zone. This developed area was assumed to have an overall impermeable area of 16 percent (Minor and Cablk, 2001) and the sediment delivery ratios were reduced as a means of estimating the area that does not produce sediment.

Next the acres of road were identified by buffering the road system by 11 feet on each side of the centerline. This generated an area of approximately 800 acres in roads. Roads are considered separately because they often produce a large amount of sediment (McGurk et al., 1996). The sediment delivery ratios used for the roads were 80 percent for the first buffer zone, 50 percent for the second buffer zone, 20 percent for the third buffer zone, and 0 percent for the fourth buffer zone. The final area under current conditions is approximately 22,350 acres in relatively undeveloped conditions, i.e., forest or grassland. Some of the grasslands are used for grazing but the areas are still similar to natural conditions and are evaluated as such in the sediment budget.

Table 4-2 summarizes the results of the sediment budget. The sediment values, in tons and tons per acre per year, are shown for sediment produced and sediment delivered. The values are also shown for completely natural conditions and then for developed conditions. The developed condition values are derived from three datasets: the current area under "natural" conditions, the developed area, and the roads area. Natural conditions are considered to have very low sediment production and sediment delivery rates based on data from the Klamath Mountains (Sommarstrom et al., 1990) and the Idaho batholith (Rice et al., 1972). Sediment production rates for developed conditions in low erodibility are taken from values from Euphrat (1992); the moderate erodibility values are taken from a Sierra-wide value reported in Kattleman (1996); and the high erodibility value is simply scaled up from the moderate value. The sediment production rate for roads is taken from McGurk et al. (1996) and scaled up for moderate and high erodibility.

TABLE 4-2
SEDIMENT BUDGET FOR THE SULLIVAN CREEK WATERSHED

Watershed Condition	Sediment Produced	Sediment Delivered	Sediment Delivery Ratio
Natural Conditions			
Upper Sullivan (tons)	421	81	0.19
Upper Sullivan tons per acre	0.027	0.005	
Lower Sullivan (tons)	229	43	0.19
Lower Sullivan tons per acre	0.024	0.004	
Soulsbyville (tons)	181	33	0.18
Soulbyville tons per acre	0.026	0.005	
Curtis Creek (tons)	195	36.5	0.19
Curtis Creek tons per acre	0.025	0.005	
Entire Watershed (tons)	1,025	193	**0.19**
Entire Watershed tons per acre	0.026	0.005	
Developed Conditions - Entire Watershed			
Undeveloped Area (tons)	564	109	0.19
Developed Area (tons)	8,655	3,417	0.39
Roads (tons)	736	462	0.63
Subtotal (tons)	9,955	3,987	0.40
Tons per acre	0.248	0.099	
Times > natural, tons/ac	9.7	20.6	
Developed Conditions - Upper Sullivan Creek			
Undeveloped Area (tons)	202	40	0.20
Developed Area (tons)	4,210	1,695	0.40
Roads (tons)	345	212	0.61
Subtotal (tons)	4,758	1,947	0.41
Tons per acre	0.307	0.126	
Times > natural, tons/ac	11.3	**24.0**	
Developed Conditions - Lower Sullivan Creek			
Undeveloped Area (tons)	138.2	26.6	0.19
Developed Area (tons)	1710.7	641.1	0.37
Roads (tons)	163.0	100.8	0.62
Subtotal (tons)	2011.9	768.5	0.38
Tons per acre	0.2	0.1	
Times > natural, tons/ac	**8.8**	**18.0**	
Developed Conditions - Soulsbyville Creek			
Undeveloped Area (tons)	72.7	13.6	0.19
Developed Area (tons)	1997.9	788.3	0.39
Roads (tons)	162.8	106.3	0.65
Subtotal (tons)	2233.4	908.3	0.41
Tons per acre	0.3	0.1	
Times > natural, tons/ac	**12.4**	**27.4**	
Developed Conditions - Curtis Creek			
Undeveloped Area (tons)	151.2	28.8	0.19
Developed Area (tons)	769.9	304.4	0.40
Roads (tons)	65.4	42.5	0.65
Subtotal (tons)	986.5	375.8	0.38
Tons per acre	0.1	0.05	
Times > natural, tons/ac	**5.1**	**10.3**	

See Appendix A for detailed calculations
SOURCE: ESA, 2006

Under natural conditions the values for sediment production and delivery are very low reflecting the low erodibility (Table 4-2). The subwatershed wide sediment delivery ratios are 0.18 or 0.19, which is in line with values reported for watersheds of this size in Walling (1994) and similar to the value 0.21 from Sommarstrom et al. (1990).

Under developed conditions both sediment production and sediment delivery increase. These values reflect the connectivity of the predominantly paved road system to streams and the connectivity of home sites, namely driveways, to roads which are connected to streams. Overall deliverability increases to 0.4 and there is an increase of 20 times in the tons per acre delivered for the entire watershed compared to natural conditions. The increase in tons per acre delivered to Phoenix Lake (i.e., the Upper Sullivan Creek Watershed) is 23 times that of natural conditions. McGurk et al. (1996) report an average annual increase of 53 times the natural rate of erosion compared to natural conditions in the residentially-influenced Clear Creek basin in El Dorado County.

Based on information provided in a newspaper article on Phoenix Lake (Wolfson, 2005), during the period from 1890 to 2005, 227 acre-feet of sediment were deposited over 115 years (including an assumption that an additional 20 acre-feet of sediment was removed by dredging in the 1980s). For comparison purposes, the acre-feet values were converted to tons based on the density of the sediment taken from reservoir cores in Englebright Lake on the Yuba River (Snyder et al., 2004). The total tons were converted to tons per acre per year. Finally, a correction factor was applied for the sediment trapping efficiency of Phoenix Lake. That is, reservoirs do not trap all the sediment that is delivered to them; specifically some amount of the fine-grained suspended sediment (e.g. clays and silts) passes through the reservoir and are transported downstream. A simple sediment trapping efficiency of 75 percent was calculated for Phoenix Lake based on the capacity-watershed ratio method (Verstraeten and Poesen, 2000). Using the above values a maximum average sediment amount of about 0.3 tons per acre per year has been delivered to Phoenix Lake. If the reported values for the acre-feet of sedimentation in Phoenix Lake are reasonably accurate then the estimated sediment delivery to the lake from the reported sedimentation is greater than the estimate from the sediment budget. However, the sediment budget does not include estimates of delivery from mass wasting, stream bank erosion, or changes in storage of sediment in the stream channel itself.

Although these are preliminary values, the simple sediment budget indicates that a large amount of controllable sediment is associated with developed conditions in the watershed including unpaved driveways, road side ditches, road embankments, pastures, corrals, and unvegetated, bare ground portions of home lots.

4.5 Channel Morphology and Sediment Transport

The amount of sediment yielded to a particular point is largely dependant upon the ability of the channels within the watershed to transport sediment. At any given instant, channels are typically transporting sediment from two distinct sources: (1) sediment delivered directly from the surrounding hillslopes and (2) sediment that is stored within the channel network itself.

In the latter case, transport is generally manifest in bed and bank erosion.[5] The ability of a channel to move sediment is termed the sediment transport capacity, which depends mainly on channel slope and discharge; the actual rate of transport, given similar slope and discharge, depends upon a third factor: the size distribution of mobile sediments. In general, sediment transport is a function of slope, discharge (flow velocity and depth) and the size distribution of mobile sediments. Further, the general morphology of a channel is usually a good indicator of transport capacity and efficiency. A planning-level analysis of channel slope and morphology, and their relation to sediment transport capacity and rate, is presented below.

4.5.1 General Approach

As noted earlier (**Section 4.3.1**), the Sullivan Creek watershed is an interfluve area between the much larger and deeper basins of the Tuolumne River (to the south) and the Stanislaus River (to the north). Soils within this watershed are generally shallow, underlain by plutonic and metamorphic bedrock, and runoff processes in response to rainfall are generally rapid. Based on 118 years of record, Goodridge (2005) calculated the average annual rainfall for the Sonora Ranger Station to be 32.4 inches. The Sullivan Creek watershed receives little to no snowmelt runoff. The hydrologic and geologic characteristics of the Sullivan Creek watershed are described in further detail in **Section 2.2.3.**

The Sullivan Creek system generally functions as more of a headwater-type system as opposed to a meandering, lowland alluvial system. Within this system, valley (or channel) segment slope and morphology is useful for distinguishing dominant sediment transport processes (fluvial versus mass wasting), inferring general long-term sediment flux characteristics (transport- versus supply-limited), and providing insight into the spatial linkages that govern watershed response to disturbance (this concept is summarized by Montgomery and Buffington [1998]). However, depending on the extent of alluvial material, segments that appear functionally similar at the valley-scale may respond differently at the reach-scale to similar perturbations in sediment loading and discharge. Thus, to the extent possible, reach-scale morphology should be used to verify or augment the description and characteristics of representative valley or channel segments.

A planning-level Channel Geomorphic Assessment was conducted to assess general sediment transport characteristics within the Sullivan Creek watershed and to supplement the sediment budget presented in **Section 4.4.** The general approach to this assessment involved Geographic Information System (GIS) analysis and a rapid field survey and inventory. Slope delineations made using ArcGIS and channel characteristics observed at the reach-scale, by means of the channel system survey of the Sullivan Creek Hydrologic Area, were used to classify channel segments into six general categories and qualitatively evaluate sediment transport capacity and characteristics. The methodologies and results of this assessment are presented below.

[5] For our conceptual purposes, bank erosion is considered to be an in-channel sediment source, though in many cases it can be considered a hillslope input (i.e., soil creep).

4.5.2 Channel Segment Slope Delineation

Channel slopes were delineated using ArcGIS and various data layers. USGS blueline stream delineations were taken from the National Hydrograph Dataset (NHD) (USGS, 2005) and are shown in **Figure 4-10**. Manmade conveyance structures moving local or imported water from the Sullivan Creek watershed were excluded from the set of streams (i.e., the Phoenix Ditch). The stream layer was superimposed onto a 10-meter DEM and slope values were generated for each channel reach. For the most part, channel reaches comprised the entire length of a particular channel between an upstream and downstream confluence with another channel. In some cases the channel reaches were segmented further; modification of the segment delineation was based upon observations made during field reconnaissance (below) and generation of a denser, artificial stream network based exclusively upon drainage area.[6] For example, if a portion of a channel transitions dramatically from a moderate gradient to plunging down through a bedrock exposure, and this segment is not bracketed by a confluence at either extreme, then the segmentation of this channel would be modified to reflect this feature.

Once the channel reaches and their associated slope values were delineated, the reaches were grouped into classes according to slope. Channel slope is a principal determinant of both morphology and sediment transport capacity. Slope classes were delineated according to channel classifications presented by Montgomery and Buffington (1997, 1998) and further summarized by Kondolf et al (2003). The three slope classes are: < 0.02, 0.02 to 0.04, and 0.041 to 0.30; herein referred to as Slope Class 1, Slope Class 2, and Slope Class 3, respectively (**Figure 4-10**). Generally, no slopes over 30 percent were observed for the principal tributaries and channels. These slope classes are also associated with, and used to generalize, a probable channel form, which was verified and expanded upon through the field reconnaissance (below).

4.5.3 Stream Channel Morphology and Observations

In order to characterize channel morphology, a general survey of the channel system was conducted for the Sullivan Creek watershed. The channel survey was essentially a road-system traverse, generally limited to stream crossings and reaches that were in close proximity to the roads. A series of observations and, in some cases, quantified measurements were made and noted at each station for a consistent set of parameters; a number of photographs were also taken for each station. For each station, all observations and measurements are summarized in **Table 4-3,** and a representative set of photographs and accompanying descriptions are presented in **Appendix B**.

[6] The artificial stream network was generated using the 10-meter DEM and the HEC-GeoHMS program for watershed and stream delineation. Delineations were made using a contributing area threshold of 20 acres. The HEC-GeoHMS program is described in detail by USACE (2000).

Figure 4-10
11x17

Back of 11x17

Table 4-3. Summary Notes for Channel System Survey.

Station ID	Channel Segment Slope [3] (ft/ft)	Confinement [4]	M&B (1997) Classification [5]	Bankfull Dimensions (ft) width	Bankfull Dimensions (ft) depth	Entrenchment [6]	Riparian/Bank Vegetation	Erosion	Deposition	Bedrock Exposure
SCR-6	0.043	UC	NA	NA	NA	LOW	grassland	NA	NA	No
TWH-1	0.050	MC	ALT	9.0	2.0	MODERATE	sparse forest/blackberries	bank undercut	much sand	No
SCR-5	0.190	WC	CA	6.0	1.5	MODERATE	dense blackberries	none	pool/obstruction accumulaition	No
SCR-7	0.078	UC	SP	10.5	3.0	HIGH	sparse forest (young trees)	severe, highly incised	none	No
SCR-3	0.030	MC	PB/PR	10.0	2.5	LOW	dense forest/shrubs	none	minor clay/silt	No
SCR-2 [1]	0.014	MC	PR	12.0	2.5	LOW	sparse forest/shrubs	minor bank erosion	normal bars	No
SCR-1 [1,2]	0.006	UC	PR/PB	15.0	3.0	LOW	sparse forest/dense shrubs	bank erosion	sands over armor bed	No
SCR-18	0.146	WC	CA	3.0	0.5	MODERATE	dense shrubs	none	pool/obstruction accumulaition	No
SCR-9	0.024	UC	PB	NA	NA	LOW	sparse forest	near large culvert	none	No
SCR-10	0.086	WC	SP/CA	6.0	1.5	MODERATE	sparse forest/dense shrubs	none	pool/obstruction accumulaition	Yes
SCR-11	0.031	UC	SP/PB/PR	25.0	2.5	LOW	forest/dense shrubs/blackberries	none	none	Yes
SCR-12	0.030	WC	SP/BDRK	NA	NA	NA	sparse forest/shrubs	none	pool deposition	Yes
SCR-15	0.030	UC	PB	6.0	1.0	LOW	sparse forest/grassland	bank erosion	accumulation near road	No
SCR-16	0.038	UC	PB	4.0	1.5	LOW	grassland	none	none	No
SCR-13	0.008	UC	PB/PR	35.0	4.0	LOW	sparse forest/shrubs	none	none	No
SCR-14	0.025	UC	NA	NA	NA	LOW	grassland/pasture	none	aggraded channel	No
SCR-19	0.026	WC	SP/BDRK	NA	NA	NA	forest/dense shrubs	none	none	Yes
CCR-4	0.050	UC	CA	8.0	1.0	LOW	shrubs/blackberries	none	none	No
CCR-3	0.013	UC	PB	NA	NA	LOW	sparse forest/grassland	none	aggraded channel	No
CCR-2	0.008	UC	PB/PR	21.0	3.0	MODERATE	sparse forest/dense shrubs/blackberries	minor bank erosion	aggraded channel	Yes
CCR-1	0.024	MC	SP/PB/PR	25.0	2.5	MODERATE	dense forest/dense shrubs	none	none	No
CCR-6	0.035	UC	PB	NA	NA	LOW	forest/grassland	none	eddy downstream of bridge	No
CCR-7	0.021	UC	PB/ALT	5.0	1.5	MODERATE	grassland	channel incision	none	No
CCR-5	0.024	UC	NA	6.0	0.5	LOW	grassland/pasture	none	aggraded channel	No
CCR-9	0.027	UC	PB/PR	NA	NA	LOW	sparse forest/shrubs	none	none	No
CCR-10	0.015	UC	PB/PR	30.0	3.5	LOW	grassland/pasture	minor bank erosion downstream	aggraded channel	No

NOTES:

1 A pebble-count was conducted at this station.

2 A cross-section was surveyed at this station.

3 Slope derived from 10-meter DEM in ArcGIS.

4 UC = unconfined (valley width is generally > 4 times the channel width), MC = moderately confined (valley width is generally 2-4 times the channel width), WC = well confined (valley width is generally < 2 times the channel width). Note: confinement is characterizing the valley width compared to the channel, whereas entrenchment is comparing floodprone width to the channel. These two parameters are typically related but not always (i.e., a highly entrenched channel can occur within an unconfined valley).

5 Morphology classfied according to concepts presented by Montgomery and Buffington (1997).

6 Visual estimate of floodprone width vs. bankfull channel width. Generally, if floodprone width/bankfull width < 1.4 (highly entrenched), between 1.4 and 1.6 (moderately entrenched), and > 1.6 (low, not entrenched). After Rosgen (1994).

Confinement

Channel confinement strongly influences channel response (Montgomery and Buffington, 1998) and largely determines if, during large flows, sediment will be transported through the valley or stored within the floodplain. Confinement (as opposed to entrenchment) typically refers to the geometry of the channel above the bankfull stage (i.e., the valley width compared to the channel width) and is a measure of the space available for the channel to move laterally. Unconfined channels possess extensive floodplains across which over-bank flows spread, which limits the effect of peak discharges on channel morphology. In contrast, confined channels efficiently translate high flows into increased basal shear stress (Montgomery and Buffington, 1998). Channel confinement was qualitatively assessed for each station and, in the context of the CGU categories, is discussed further below.

Sediment Size and Storage Characteristics

Given a discharge and slope, sediment size distribution and channel confinement generally determine how the channel will respond in terms of sediment transport and form adjustment.[7] Of the two, sediment size distribution is generally more important because it is relevant for a wide range of flow conditions (confinement becomes more important only during flood events). Under similar flow conditions, a channel bed comprised of larger particles (e.g., cobbles) will remain more stable and transport less sediment compared to a channel bed comprised of small particles (e.g., sands). Further, the gradation (or sorting) of the bed material is also important; in other words, are the size classes evenly distributed or is the distribution bi-modal (e.g., lots of fine sand and lots of small boulders, with nothing in between). Hassan et al. (2005) summarized multiple studies that showed distinct phases of transport of bed material depending on the sediment size. Further, Wilcock and McArdell (1997) demonstrate that the presence of sand-sized material can enhance the transport of the larger particles on the channel bed. Significant sand deposits were noted at or near stations SCR-1, SCR-10, TWH-1, and CCR-2.

In order to obtain some quantitative sense of sediment size distribution within the Sullivan Creek watershed, pebble counts following the methodology described by Wolman (1954) were conducted at stations SCR-1, SCR-2, and CCR-2 (**Figure 4-11**). A heel-to-toe method was used to traverse the bed or bar and randomly select particles. An effort was made to avoid distinct sand deposits and only capture the separate gravel/cobble population; however, this was not practical at station SCR-1 due to the layer of sand that had been rather uniformly deposited over the bed (the bed material was more embedded and less armored at SCR-1 as a result). Regardless, the largest grain size (65mm) actively transported is similar among the three stations. The sand layer at SCR-1 is notable and becomes fully mobilized under much smaller flows compared to the underlying large gravels and cobbles. Considering the three pebble-counts and bankfull dimension estimates at the same stations, and using the stream power vs. bedload transport relation illustrated by Dunne and Leopold (1978; Figure 17-4), Sullivan Creek is likely more competent at transporting its available bedload. This conclusion is supported by field observations of notable accumulations of bed and bar sediments as provided in photos of CCR-2, CCR-3, and CCR-10. Curtis Creek tends to be wider at these locations.

[7] Large woody-debris (LWD) also plays an important role in this respect (i.e., considered together with sediment size distribution and confinement). However, LWD was not prevalent among the channel stations surveyed, and a comprehensive inventory was beyond the scope of this report and would likely be inhibited by property-access issues.

Figure 4-11

Channel and floodplain sediment storage is another important characteristic of fluvial sediments and can have important implications regarding the calculation and interpretation of sediment budgets. Periods of significant sediment transport in small to medium channels are interspersed with much longer periods of low transport, during which most of the transportable sediment is held in temporary storage in the channel bed, bars, and floodplains (Hicks and Gomez, 2003). Sediment accumulates in, and is released from, channels and valley floors over periods that range from days to millennia (Reid and Dunne, 1996). This follows the principle of active sediment (i.e., moving once every few years), semi-active sediment (i.e., moved every 5-20 years), and inactive sediment, which only mobilizes during extreme events (Kelsey et al. (1987, *cited in* Curtis et al., 2005).

In terms of sediment yield to a particular location, the channel itself is often times the greatest source of sediment. For example, studies conducted in the Lake Tahoe basin by Nolan and Hill (1991) showed that in-stream sediment sources constituted approximately 95 percent of the suspended load delivered to Lake Tahoe from the study basins. The volume of sediment being stored within the channel network, at any given time, typically is far greater than the volume yielded at the mouth of a basin. Short-term storage typically is manifested in gravel bar formations or local accumulations behind channel obstructions such as logs or boulders. In contrast, long-term storage usually occurs within aggrading or active floodplains. Sediment characteristics and storage elements were noted for each station and, in the context of the CGU categories, which are discussed further below.

Montgomery and Buffington (1997) Classification

One of the main objectives of the channel system survey was to classify the reach at each station according to the classification scheme described by Montgomery and Buffington (1997). The slope classes were derived using this classification and with an understanding of the probable channel form that the slope classes imply. It was important to verify this relationship in the field, note any significant deviations, and expand upon the general characteristics, if necessary.

Montgomery and Buffington (1997) recognize three primary channel-reach substrates: bedrock, alluvium, and colluvium. Bedrock reaches lack a contiguous alluvial bed and reflect high transport capacities relative to sediment supply; they are typically confined by valley walls and have steep slopes (Montgomery and Buffington, 1997). Alluvial channels, on the other hand, exhibit a wide variety of morphologies that vary with slope and position within the watershed, and they may have a well-established floodplain or little to no associated floodplain features. The five alluvial reach morphologies are: cascade, step-pool, plane-bed, pool-riffle, and dune-ripple (or regime). The Sullivan Creek watershed generally lacks the last morphology (regime) all together, as this is more characteristics of larger, lowland alluvial systems. Colluvial channels are normally small headwater streams that pass over a colluvial valley and exhibit weak or ephemeral fluvial transport; identification and assessment of colluvial channels within the Sullivan Creek Hydrologic Area was not within the scope of this report.

Table 4-4 presents a brief description of the channel morphologies applicable to this assessment and their relevant Slope Class.

Other Field Observations and Measurements

In addition to the morphology classification and the sediment and confinement characteristics, the following channel characteristics were measured (where feasible) or described: bankfull dimensions (width and depth), floodprone width, entrenchment ratio, bank vegetation, bed and bank erosion, sedimentation and disturbance, and bedrock exposure. The following is a brief description of the measurement or estimate of each parameter (recorded measurements and observations for all parameters, when applicable, are presented in **Table 4-3** for each station):

TABLE 4-4
CHANNEL REACH MORPHOLOGIES

Channel Type	Description	CGU Slope Class
Cascade	**.30 > s > .10** – Tumbling flow. Energy dissipation is dominated by continuous, tumbling flow over and around individual large clasts. Generally occur on steep slopes, are confined, and exhibit disorganized bed material typically consisting of cobbles and boulders. Large particle size relative to flow depth. Low sediment supply relative to transport capacity.	3
Step-pool	**.10 > s > .04** – Characterized by longitudinal steps formed by large clasts spanning the channel width and separating pools containing finer material. Pool spacing roughly one to four channel widths. Steep gradients, small width to depth ratios, and pronounced valley confinement. Low sediment supply relative to transport capacity.	3
Plane-bed	**.04 > s > .02** – Usually refers to planar gravel and cobble-bed channels. Lack discrete bars. Moderate to high slopes and confinement varies. Moderate to Low sediment supply relative to transport capacity.	2
Pool-riffle	**.02 > s > .001** – Undulating bed that defines sequence of bars, pools, and riffles. Pool spacing roughly five to seven channel widths in self-formed channels. Moderate to low gradients and generally unconfined. Bar formation in natural channels typically limited to slopes < 0.02. Moderate to High sediment supply relative to transport capacity.	1
Bedrock	Variable slopes – Exposed rock. Lack a continuous alluvial bed and there is little, if any, valley fill. Generally confined. Low sediment supply relative to transport capacity.	Varies

SOURCE: Montgomery and Buffington (1997), ESA; s = slope

Bankfull Dimensions. The bankfull discharge is considered to be the maximum discharge that can be contained within the channel without overtopping the banks and is commonly accepted to represent the flow that occurs, on average, once every 1 to 2.5 years. The bankfull width, usually defined by high-water marks indicated by strand lines, fluvial sediment deposits, and the boundary formed by vegetation at the channel margin, was measured or visually estimated for most stations. Similarly, the bankfull depth, the average depth corresponding to the bankfull width, was measured or visually estimated for each station. The top of the bankfull channel is normally lower than the obvious top of bank observed in the field, which is often the elevation of a low terrace.

Flood-Prone Width. Unless the delineation was obvious (i.e., drift-line, debris), the flood-prone width was measured or estimated as the width of the floodplain at an elevation that was approximately twice the bankfull depth.

Entrenchment Ratio. Entrenchment is a good indicator of the channel's shear stress sensitivity, and the entrenchment ratio is a measure of how much the channel is entrenched into the valley floor. The entrenchment ratio for each station was estimated using the approach developed by Rosgen (1994), where the flood-prone width is divided by the bankfull width. Thus, the lower the ratio the more entrenched the channel.

Bank Vegetation. Description of bank vegetation provides an estimate of the resistance to lateral erosion (i.e., more heavily vegetated banks are usually less likely to erode). Bank vegetation for each station was classified in the field according to generalized vegetation categories (i.e., grassland, shrubs, dense riparian, bare, etc.).

Bank and Bed Erosion. Active bed or bank erosion is usually an indicator of vulnerability to future erosion and may indicate channel instability. Indications of active bank erosion or channel incision include: exposed bare soil, recently scoured gullies, prevalence of slumps or slides along the banks, or recently scoured bed or banks. This parameter was qualitatively assessed as being low (i.e., no evidence), moderate (i.e., patches of exposed soil; limited areas of recent erosion), or high (i.e., extensive areas of exposed soil; evidence of chronic sediment input from bank failures; evidence of active channel incision).

Sedimentation and Disturbance. Active sedimentation or disturbance (e.g., landslide) provides an approximation of the amount of sediment supplied to the channel and may be an indication of channel instability. Indications of active sedimentation within the channel include: multiple channel threads, poorly defined channel margins, sediment deposits that have not been re-worked into bar formations, or evidence of recent sediment input from bank failures. Sedimentation was qualitatively assessed as being low, moderate, or high.

The nature and extent of any observed disturbance and/or obvious sediment input processes was recorded and, where possible, quantified to the extent practical. Sediment input to channels occurs either through discrete (episodic) processes, chronic processes, or the general process of soil creep (which may manifest in either a discrete or chronic manner). Significant anthropogenic disturbances could include channel modification (i.e., rip-rap or levees), grading and excavation, vegetation modification, and road construction. Fire, naturally or artificially induced, can also have a significant effect on sediment input and overall hillslope and channel condition. Such disturbances can significantly affect, or exacerbate, either discrete or chronic sediment input processes. Evidence of discrete sediment input processes (e.g., mass wasting) includes: landslide scars, debris flows, gullies, tree-throw, and bank erosion (driven primarily by gravitational forces); evidence of chronic sediment input processes includes: sheet erosion from hillslopes, ravel/road-cut erosion, and bank erosion (driven primarily by the shearing force of flow).

Bedrock Exposure. Because most of the Sullivan Creek watershed is underlain by relatively shallow plutonic (mostly granite) or metamorphic bedrock, exposures and remnant boulders of these structures can exert much control on channel morphology. Channels flowing over bedrock typically have a high sediment transport capacity relative to the sediment supply. Bedrock exposures or prominent features (i.e., boulders) were noted at each station if present.

SCR-1 Survey

A cross-section and longitudinal profile was surveyed for Sullivan Creek at station SCR-1 using an auto-level and stadia rod (**Figure 4-12**). This station was chosen because of its relative accessibility, general morphology, and location within the Sullivan Creek watershed. Pool-riffle morphology dominates at this station and, as a result, this station is likely to exhibit a measurable change in form in response to a significant shift in sediment input or flow characteristics. Further, this station is about 3,000 feet upstream of Phoenix Lake, with no significant tributaries in between, making this location an ideal candidate for monitoring future sediment supply to the lake. Because of access restrictions, all other channel measurements were made using a stadia rod and tape measures or were visually estimated.

4.5.4 Deviations from Sampling Protocol

ESA deviated from the sampling protocol concerning calculation of the Unit Stream Power Index (SPI) and the quantitative survey of gravel bars. The Unit SPI can be approximated as the product of the cross section-averaged bankfull depth and the channel slope. As only two variables are used for this value, the Unit SPI is highly sensitive to both variables used. Access and mere magnitude of area under consideration did not permit a cross-section survey at each station accurate enough to estimate the *cross section-averaged* bankfull depth. Estimates of the absolute bankfull depth were made at most stations but this parameter is not sufficient for calculating the Unit SPI (i.e., a wide shallow channel, a wide entrenched channel, and a narrow entrenched channel may all have the same absolute bankfull depth but dramatically different *cross section-averaged* bankfull depths). Further, access restrictions prevented an accurate clinometer reading of slope for some stations. As such, the Unit SPI was not calculated for the CGU stations.

4.6 Sediment Transport Implications

Based upon the channel segment slope delineation and stream channel morphology observations, six CGU classifications were derived with regards to sediment transport characteristics and implications. Three primary classifications (Slope Class), based mainly on channel segment slope, were created for all channel segments; and three secondary classifications were derived, only for particular segments, to supplement the information provided by the primary classifications. The secondary classifications were derived for the instances where observed confinement, sediment characteristics, and/or morphology were notably different than that associated with the given Slope Class or were notable features of an expected morphology. Channel segments and CGU classifications are presented in **Figure 4-10**.

Figure 4-12

Channel Geomorphic Units (CGU)

Primary Classification

Slope Class 1 (Response)

For this CGU (Slope Class 1), channel segment slopes range from 0.1 to 2 percent. Channel segments described by this unit tend to be moderately confined to unconfined and generally exhibit a pool-riffle (with some plane-bed) morphology. Expanding on confinement, channels within this unit tend to be in valleys that are greater than two times the width of the bankfull channel. Sediment supply is greater than the sediment transport capacity for these channels and thus, on average, they are usually experiencing a net storage of sediment. Within the channel, storage is manifested in bar formations which, based on field observations, are likely in equilibrium in the Sullivan Creek watershed; but are thought to be accumulating in areas within the Curtis Creek watershed [see below]). Based upon measurements made at stations SCR-1 and SCR-2, the volume of *active* sediment (i.e., sand and gravel bars) currently stored within these segments (for the Upper Sullivan Creek watershed) is approximately 2.0 cubic meters per meter of channel. Yet, segments within the lower portion of the Sullivan Creek Hydrologic Area and within the Curtis Creek watershed were undoubtedly storing more total sediment, though it was not clear what fraction of this sediment could be considered active and comparable to the estimates made for the Upper Sullivan Creek watershed.

Longer-term storage occurs within the floodplains of these channel segments. However, floodplain development was not significant within many of these segments; those segments that had well developed, more classic floodplain features are singled out in the secondary classification below (Floodplain Storage). Segments within this CGU are considered response segments, in that, according to Montgomery and Buffington (1998), reach-level morphology is likely to change given a moderate change in sediment supply or discharge. **Figure 4-13** is a photograph from a representative station for this CGU.

Slope Class 2 (Transport and Response)

For this CGU (Slope Class 2), channel segment slopes range from 2 to 4 percent. Channel segments described by this unit tend to be moderately confined and generally exhibit a plane-bed (with some step-pool and pool-riffle) morphology. Expanding on confinement, channels within this unit tend to be in valleys that are two to four times the width of the bankfull channel. Sediment supply is generally less than the sediment transport capacity for these channels and thus, on average, they are usually transporting most of the sediment supply. However, some of the pool-riffle segments within this CGU do not transport all of the available sediment; but this is generally the exception to the rule for this CGU. There is some degree of storage within these segments, typically in localized pools, backwater areas, or sporadic bar formations.

Figure 4-13

Based upon observations made amongst the stations within this CGU, the volume of *active* sediment (i.e., sand and gravel) currently stored within these segments (for the Upper Sullivan Creek watershed) is approximately 1.0 cubic meter per meter of channel. Longer-term storage occurs within the floodplains of these channel segments. There was generally no floodplain development within these segments. Those few segments that had well developed, more classic floodplain features are singled out in the secondary classification below (Floodplain Storage). Segments within this CGU are considered both transport and response segments, in that the morphology of most stations could be considered a transitional form between transport and response reaches. In a given year, whether a particular reach is accumulating or transporting sediment is largely dependent upon the magnitude and duration of peak discharges for that year. **Figure 4-14** is a photograph from a representative station for this CGU.

Slope Class 3 (Transport and Source)

For this CGU (Slope Class 3), channel segment slopes ranged from 4 to 30 percent. Channel segments described by this unit tend to be highly to moderately confined and exhibit a cascade and step-pool morphology. Expanding on confinement, channels within this unit tend to be in valleys that are less than four times the width of the bankfull channel. Sediment supply is typically far less than the sediment transport capacity for these channels and thus, on average, they are usually actively transporting all of their sediment supply. Storage is not a factor for many of these channels; however, those segments in which notable accumulation of sediment were observed are singled out in the secondary classification below (Obstruction Storage). Further, in the upper headwaters, where the channels in this unit become colluvial (vs. alluvial), they serve as continuous sources of sediment by means of gullying or debris flows; these are a natural functions.

Segments within this CGU are considered transport segments, in that, according to Montgomery and Buffington (1998), reach-level morphology is only possible or unlikely to change given a moderate change in sediment supply or discharge. Most of the segments within this CGU occur in the northern section of the Upper Sullivan Creek watershed. The channel network is relatively more dense in this area and the soils tend to be more deeply weathered (i.e., along Big Hill Road) and subject to incision by the channel network. **Figure 4-15** is a photograph from a representative station for this CGU.

Secondary Classification

As stated above, the secondary classifications were derived for the instances where observed confinement, sediment characteristics, and/or morphology were notably different than that associated with the given Slope Class or were notable features of an expected morphology. These classifications were derived, only for particular segments, to supplement the information provided by the primary classifications.

Figure 4-14

Figure 4-15

Floodplain Storage and Channel Aggradation (Unconfined)

Classic floodplain development was not present in many of the Slope Class 1 segments. However, floodplain development and, in some cases, channel aggradation was noted in some of the lower reaches of the Sullivan Creek Hydrologic Unit and these segments comprise this CGU. Aggradation, as it applies to this CGU, refers to a long-term process, based upon field observations, where storage occurs within the floodplains and channels of these segments and, in some cases, the channels have almost been completely filled-in (see **Figure 4-16**). Dietrich and Dunne (1978) describe the residence time of valley floor and floodplain sediments as being on the order of thousands of years.

Channels described by this CGU tend to be wide and shallow and generally incompetent at transporting their bed material load; these segments likely serve as sediment sinks during moderate to large flood events. However, along these same lines, during an extreme flood these segments may be susceptible to significant scour of channel or valley fill. Further, the process of channel incision would be readily apparent in these segments and likely signal a longer-term shift in discharge or sediment loads. In some cases, such as the *downstream* side of Curtis Creek at the Algerine Road bridge, a slight degree of incision is currently evident, in which case the channel may be shifting to one side serving as a net source of sediment rather than a net sink. **Figure 4-17** is a photograph from a representative station for this CGU (the *upstream* side of Curtis Creek at the Algerine Road bridge). Segments within this CGU are considered response segments, in that, according to Montgomery and Buffington (1998), reach-level morphology is likely to change given a change in sediment supply or discharge. Yet, compared to the other units in Slope Class 1, segments within this CGU would likely require a larger change in sediment supply or discharge in order to illicit a measurable response.

Obstruction (Boulder) Storage

This CGU is intended, specifically, to supplement the Slope Class 3 channels in the northern half of the Upper Sullivan Creek watershed. Though segments within this CGU are still supply-limited over time, much more accumulation (typically behind in-stream boulders) of fine to sandy sediments were noted for these segments compared to the other Slope Class 3 channels. Local storage of gravel and finer material is not uncommon to this general type (i.e., all Slope Class 3 channels), but it was more pronounced for segments singled-out for this CGU. Yet, compared to the Floodplain Storage CGU, the sediments held in storage within these channel segments are flushed much more frequently. Montgomery and Buffington (1997) point to a study that showed material in such depositional sites was completely mobilized during a seven-year flood event, whereas no movement was observed during flows of less than the annual recurrence interval. Megahan (1982), in studies within basins draining the granitic bedrock of the Idaho batholith, found the change in sediment stored behind obstructions was highly variable from year to year and a function (on an inter-annual basis) of annual instantaneous peak flows.

Figure 4-16

Figure 4-17

In most local storage sites, the sediment was reddish-brown in color and comprised mainly of silt and silty-sands (see right photo in **Figure 4-18**). Thus, the source of much of the stored sediment within this unit was the deeply weathered granite on the northern slopes of the Upper Sullivan Creek watershed. A number of road-cuts and road-side ditches observed on Big Hill Road (particularly in the vicinity of stations SCR-17 and SCR-18) were obvious candidates for generation of the sediment supply to these segments. Based upon measurements made at various stations, the volume of *active* sediment currently stored behind these obstructions is approximately 0.5 cubic meters per meter of channel.

Bedrock Reach (Transport and Confined)

This CGU is intended, primarily, to supplement two Slope Class 2 segments within the lower reaches of Sullivan Creek. In these two areas, the channel has incised down to the bedrock (metamorphic rock units) and scoured-out much of the valley fill or historic channel deposits. Unlike the typical Slope Class 2 channel segments, the bedrock reaches identified by this CGU are highly confined, generally supply-limited, and very efficient at transporting their sediment loads (i.e., they are solely transport reaches). These channel segments are the most stable of all the CGUs, and reach-level morphology is unlikely to change given a moderate change in sediment supply or discharge. **Figure 4-19** is a photograph from a representative station for this CGU

4.7 Preliminary Conclusions

The 62 square mile Sullivan Creek watershed is estimated to have produced an average of 0.248 tons/acre/year with 0.099 tons/acre/year delivered to the stream network (see **Table 4-2**). This rate of erosion is 9.7 times greater than natural conditions. Including our estimate of chronic road surface erosion, the average quantity of eroded sediment delivered to the stream network is 20.6 times greater as opposed to natural conditions. These findings suggest that there is a large fraction of controllable sediment within the watershed. The relative amounts of both erosion and sediment delivery from the various terrain types in the watershed quantified in this study are in line with expectations, with more highly erodible geologic units, distributed areas, and steeper areas generally producing the largest quantities of sediment.

Erosional features associated with land management account for by far the greatest sediment delivery volumes from the watershed. In order of importance, roads, property ground coverage, and unpaved driveways account for the largest percentage of the total sediment delivery. Intensive land use practices have contributed to accelerated, human-caused erosion throughout the watershed, resulting in increased sediment loading of the streams. Over the past 90 years, subsequent sediment transport within the upland stream channels has, in all likelihood, contributed to downstream, lowland aggradation and sedimentation issues. Field observations indicate that there may be substantial quantities of sediment stored in smaller streams in areas inaccessible to filed investigators. Consequently, the granitic and Mehrten (moderately erodible) HGUs that underlie much of the forested area in the upper sections of the watershed may continue to produce relatively large quantities of sediment for some time.

Figure 4-18

Figure 4-19

In terms of sediment sources derived from the channels, the *Slope Class 1* CGU is likely the most important is terms of a chronic source of sediment to the basin outlets (particularly in terms of sand). To some degree this process is natural and expected for these channel types; however, the fraction of sand being actively stored and mobilized (annually) appears to be high. For the Upper Sullivan Creek watershed, the *Obstruction Storage* CGU is likely the second most important in-channel sediment source; though the movement of sediment is more episodic (i.e., just during large events, or once every year or two at most). This process is likely controllable to some degree, in that some of the sediment stored within this CGU is probably derived from road-cuts and ditches found on the northern slopes of the Upper Sullivan Creek watershed. For the Lower Sullivan Creek and Curtis Creek watersheds, the *Floodplain Storage* CGU is the second most important in-channel sediment source. However, this unit is highly variable in terms of its supply potential (i.e., some channels are almost completely filled and not incising, whereas others have incised slightly into the valley). The significance of these units in terms of supply could increase dramatically under a catastrophic flood or a regional shift in the flow regime. The *Slope Class* 2, *Slope Class 3*, and *Bedrock Reach* CGUs generally seem to be efficient at transporting the available sediment supply and likely do not serve as in-channel sediment sources in any significant manner.

The aerial photo analysis of these areas was performed at a scale that did not allow for a specific attribution of erosion to land management activities other than to observe a broad land use category. Further, the lack of a sequential set of historic air photographs did not allow for ESA to assess changes in land use practices over time, which was further limited by inaccessibility (e.g. private property restrictions) and time limitations.

In general, discussions with County staff and local landowners indicate that land use practices have been steadily improving in the Sullivan Creek watershed. Timber harvest practices within the watershed are generally small in scale (e.g. < three acres). Farmers and ranchers in the lower sections of the watershed have been working with the Natural Resources Conservation Service and the Farm Bureau to prevent erosion and improve both water quality protection measures and road maintenance practices in cultivated, rangeland and forest settings. While erosion and sediment delivery resulting from past management will likely continue for some time, there should be an overall decrease in sediment delivery to stream channels as land use practices continue to improve and as degraded lands recover both naturally and through proactive treatments. This trend coupled with road system improvements and landowner education, mainly in terms of groundcover reestablishment, will help to further improve conditions.

4.7.1 Recommendations for Future Study

Specific recommendations can be made with regard to improving the sediment budget in terms of the sediment transport component by performing watershed-scale drainage modeling. This form of modeling would be necessary to establish a realistic SPI for varying rainfall intensities. Site-specific erosion plots should be established to verify the erodibility rates used in the sediment budget. In particular, such plots should be established along road cuts in grus soil materials, natural areas (as a control), below culvert outfalls, and on disturbed bare ground. A more detailed classification of the road system and percent distribution of the various erosion sources based on a road sampling scheme combined with more detailed estimates of sediment deliverability should also be established to refine the sediment production and the sediment delivery values.

Chapter 5
Surface Water Quality

ESA

CHAPTER 5
Surface Water Quality

5.1 Overview

Chapter 5.0 presents the results for Phase 1 of the County's Surface Water Monitoring and Reporting Program (MRP) and compares that data with other available data within the PSA and for the larger Upper Stanislaus and Upper Tuolumne River watersheds. Much of the preexisting data are limited to watershed sanitary surveys for water diversions and compliance monitoring for point-source discharges. As a consequence, there is a well-established dataset for the main waterways within each watershed; however, minimal data exists for many sections of the PSA. Existing datasets were reviewed and are summarized to the extent possible to assess and characterize the interactions between the smaller foothill watersheds that comprise the PSA and the larger river system as a whole.

To understand how current regulatory goals and standards apply to this Assessment, it is critical to understand the basic premise of water resources, which as a public trust resource is subject to an extensive legislative and regulatory history within California. Today, the basis for water quality regulation within the United States is the Federal Pollution Control Act Amendments of 1972 and 1986, known as the Clean Water Act (CWA)(33 USC 1251-1376). The objective of the CWA is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." California's Porter-Cologne Water Quality Control Act (Porter-Cologne Act, California Water Code Section 13000 et seq.) in conjunction with the CWA provides the basis for water quality regulation within California. The Porter Cologne Act requires a "Report of Waste Discharge" for any point discharge of waste (liquid, solid, or otherwise) to land or surface waters that may impair a beneficial use of surface or groundwater of the state. In practice, these requirements are typically integrated with the CWA Section 402 National Pollutant Discharge Elimination System (NPDES) permitting process[1] and implemented at the regional level by Regional Water Quality Control Boards (RWQCB) and overseen by the State Water Resources Control Board (SWRCB) and U.S. Environmental Protection Agency (USEPA) Tuolumne County is located in the east-central portion of California and lies within the jurisdiction of the Central Valley RWQCB (Region 5).

1 Section 402 establishes the National Pollutant Discharge Elimination System (NPDES), a permitting system for the discharge of any pollutant (except for dredge or fill material) into waters of the United States. This permit program is administered by the U.S. Environmental Protection Agency (USEPA) in most states (not in California) and on Native American lands.

The SWRCB carries out water quality protection authority through the adoption of specific Water Quality Control Plans[2] (Basin Plans). The Central Valley RWQCB is responsible for the Water Quality Control Plan covering the west slope of the Sierra Nevada (RWQCB, 1998). The RWQCB implements management plans to modify and adopt standards under provisions set forth in Section 303(c) of the CWA and California Water Code (Division 7, Section 13240). Under Section 303(d) of the 1972 CWA, the State is required to develop a list of waters with segments that do not meet water quality standards. The law requires the RWQCB to establish priority rankings for waters on the lists and develop action plans and/or establish Total Maximum Daily Loads (TMDL) to improve water quality.

Except for Don Pedro Reservoir, no waterbodies within the Upper Stanislaus River and Upper Tuolumne River hydrologic units are identified as impaired on the 303(d) List and TMDL (SWRCB, 2003). Don Pedro Reservoir is listed on the 2002 California Section 303(d) list and TMDL Priority Schedule for mercury contamination associated with historic mining activities with many of the mines now inundated by Don Pedro Reservoir. In addition to mercury other heavy metals, such as arsenic, may also be present; however, no data were collected for Don Pedro Reservoir as part of the County's MRP to confirm this possibility. The lower reaches of the Stanislaus and Tuolumne Rivers are also listed under the federal CWA as impaired water bodies for diazinon, Group A pesticides (aldrin, dieldrin, endrin, chlordane, heptachlor expoxid, hexachlorocyclohexane, endosulfan, and toxaphene), and unknown toxicity. The Lower Stanislaus River is also listed for mercury.

The SWRCB also adopted the Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California (SWRCB, 2000). This policy provides implementation measures for numerical criteria contained in the California Toxics Rule (CTR), promulgated in May 2000 by the USEPA. When combined with the beneficial use designations in the Basin Plan, these documents establish statewide standards for surface and groundwater quality.

Beneficial Uses and Water Quality Objectives

Existing beneficial uses applied to the Upper Stanislaus and Upper Tuolumne Rivers include agricultural supply, cold freshwater habitat, municipal and domestic supply, hydropower generation, water contact recreation, non-water contact recreation, warm freshwater habitat, and wildlife habitat (RWQCB, 1998). By virtue that many of the waterways within the Upper Stanislaus and Upper Tuolumne watersheds are not specifically prescribed beneficial uses in the Basin Plan, the Basin Plan requires the application of the "Tributary Rule" in regulating point-discharges; whereby beneficial uses identified for major waterways (e.g., Tuolumne River) apply to all contributing drainages (e.g., Sullivan Creek). In evaluating the data acquired during the Phase 1 of the MRP, those beneficial uses with the lowest numerical limits, based on Basin Plan objectives include:

2 Basin Plans establish water quality standards for particular bodies of water. California water quality standards are composed of three parts: the designation of beneficial uses of water, water quality objectives to protect those uses, and implementation programs designed to achieve and maintain compliance with the water quality objectives.

- **Cold Freshwater Habitat.** Uses of water that support cold water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.
- **Municipal and Domestic Supply.** Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply.
- **Water Contact Recreation.** Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, white-water activities, or fishing.
- **Warm Freshwater Habitat.** Uses of water that support warm water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.

Based on the applied beneficial use, the RWQCB has set water quality objectives for all surface waters in the Central Valley. These water quality objectives include bacteria, biostimulatory substances, chemical constituents, color, dissolved oxygen, floating material, oil and grease, pH, pesticides, radioactivity, salinity, sediment, settleable material, suspended material, sulfide, tastes and odors, temperature, toxicity, and turbidity (RWQCB, 1998). In addition, objectives for specific chemical constituents have been set depending on the beneficial uses designated for each waterbody (RWQCB, 1998). Constituent limits identified in the Basin Plan in conjunction with CTR criteria were used to determine the magnitude of any water quality impairment within each of the monitored waterways (RWQCB 1998).

The CWA Section 303(d) list identifies water bodies with impaired beneficial uses, the parameters of concern within each water body that are thought to be responsible for the impairment, and the likely sources of the parameters of concern. The Section 303(d) list contains only parameters of concern for which there are water quality objectives for surface waters. Much of the regulation for drinking water applies to the treated water available for consumption and does not apply to the surface water source. Therefore, the Section 303(d) list does not contain all parameters of concern for drinking water. **Table 5-1** identifies additional parameters of concern to CALFED in terms of drinking water supplies.

5.2 Regional Watershed Water Quality

The Upper Stanislaus River and Upper Tuolumne River Watersheds are generally regarded as producing surface water of excellent quality, meaning the water is suitable for almost any use and contains low concentrations of contaminants (at least below state and federal standards). Most of the literature reviewed for this Assessment Report suggests that runoff generated from the upper reaches of the two watersheds is suitable for human consumption except for the risk of pathogens, which is generally associated with livestock grazing and wildlife. Sediment is also considered a pervasive pollutant because its production may be increased above natural background levels by almost any human or animal activity that disturbs the soil or reduces vegetation cover.

TABLE 5-1
WATER QUALITY PARAMETERS OF CONCERN TO BENEFICIAL USES

Metals	Organics/Pesticides	Disinfection By-Product Precursors	Other
Cadmium	Carbofuran	Bromide	Dissolved Oxygen
Copper	Chlordane[a]	Total Organic Carbon	Salinity (TDS, EC)
Mercury	Chlorpyrifos	Chloride	Temperature
Selenium	DDT[a]		Turbidity
Zinc	Diazinon		Toxicity of unknown origin[b]
	PCBs[a]		Pathogens
	Toxaphene[a]		Nutrients[c]
	Dioxins[d]		pH (Alkalinity)
	Dioxin-like compounds[d]		Boron
			Sodium adsorption ratio

Notes: EC = Electrical conductivity; TDS = Total dissolved solids; TOC = Total organic carbon
[a] These compounds are no longer used in California. Toxicity from these compounds is remnant, from past use.
[b] Toxicity of unknown origin refers to observed aquatic toxicity, the source of which is unknown.
[c] Nutrients includes nitrate, nitrite, ammonia, organic nitrogen, total phosphorus, and soluble reactive phosphorus.
[d] These compounds may be added after review by an appropriate group of stakeholders.

SOURCE: CALFED, 2000

Upper Tuolumne River

No water quality monitoring stations are located at the confluence of the North Fork and mainstem of the Tuolumne River, which in theory, would provide the best representation of surface water quality from the entire watershed above the PSA. In general, the vast majority of water entering Don Pedro Reservoir is thought to be well oxygenated, high quality cold water. As water flows through the Don Pedro Reservoir, it may be impacted by various sources of contaminants, similar to those thought to affect contributing waterways within the PSA. Primary water quality problems include excessive sediment inflow from development in local runoff, nutrient inflow, mercury from abandoned mining tailings, and bacterial contamination from septic systems. Additionally, seasonal temperature stratification processes in Don Pedro Reservoir are also thought to play an important role in water quality conditions. Sections of Don Pedro Reservoir are deep enough to be subject to seasonal temperature stratification; whereby, the Reservoir becomes thermally stratified each spring through fall and maintains a separation between the warmer waters of the top layer and the cold water below.

The most comprehensive water quality data for the upper reaches of the Tuolumne River available for comparison purposes come from the San Francisco Public Utilities Commission (SFPUC). The SFPUC conducts extensive microbiological and chemical monitoring throughout the upper watershed and its transmission system, including daily sampling for coliform bacteria (total and fecal coliform bacteria and *E. coli*) at its Tesla Portal and three other supplemental locations (Priest Reservoir, West Portal, and Moccasin Reservoir). The SFPUC also conducts periodic monitoring for inorganic chemicals (e.g., metals), volatile organic compounds (VOCs) (e.g., methyl tertiary butyl ether [MTBE]), synthetic organic chemicals (e.g., atrazine, 2,4-D, etc.), and water quality parameters such as pH, hardness, and nutrients (e.g., nitrate) (SFPUC, 2004).

The SFPUC's source water quality assessment for 2004 indicates that its unfiltered water supply meets all federal and state filtration avoidance criteria, including watershed protection, disinfection treatment, bacteriological quality, and operational standards; thereby providing an exceptionally high quality drinking water source (SFPUC, 2004). The SFPUC has identified pollutants sources of high concern, which include those that have the potential to contribute fecal contamination to the current water supply (livestock corrals, grazing, and small wastewater systems). From January 1 through December 31, 2004, there were 2 fecal coliform and 276 total coliform measurements that exceeded 20 and 100 MPN/100mL, respectively, at SFPUC's four monitoring sites (SFPUC, 2004). Of the 276 total coliform occurrences, 51 of them occurred at Tesla Portal. For the same period, all fecal coliform measurements taken at Tesla Portal were below 20 MPN/100mL (SFPUC, 2004).

In addition to the high concern category, the SFPUC has identified a medium concern category that includes those potential contaminants that may contribute other contaminants to the current water supply, such as sediment, ash, organic material, or groundwater discharges from leaking underground fuel tanks (USTs). The potential contaminant sources of medium concern are indicative of localized erosion and sedimentation, previous wildfires (e.g., the 2,310-acre Hetch Hetchy fire near Tiltill and Rancheria Creeks in October 2004), and a groundwater remediation project at Tuolumne Meadows Service Station (SFPUC, 2004).

Upper Stanislaus River

The most recent evaluation of the overall water quality in the upper reaches of the Stanislaus River, has been conducted by Brown and Caldwell (1995) and Tetra Tech EM, Inc. (2001) (Tri-Dam, Beardsley/Donnells Project, FERC Project No. 2005). These studies were undertaken to satisfy the requirements of the California Surface Water Treatment Rule. Although limited, the data collected by entities including the U. S. Geological Survey (USGS), Pacific Gas & Electric (PG&E), and the California Department of Fish and Game (CDFG) suggest that water quality within the Upper Stanislaus River is good to excellent. In general, water temperatures are generally low, dissolved oxygen (DO) readings are usually 7.0 milligrams per liter (mg/L) or greater, concentrations of organic chemicals such as nitrate and phosphate are low, and most metals occur at undetectable levels (Tri-Dam, Beardsley/Donnells Project, FERC Project No. 2005).

Based on an extensive review of available water quality data, Brown and Caldwell (1995) reached the conclusion that the water in the Stanislaus River is low in nitrogen. The maximum nitrate concentration recorded was 0.27 mg/L, which is well below the 1.0 mg/L nitrate standard used to characterize source waters that can stimulate algae growth (Tri-Dam, Beardsley/Donnells Project, FERC Project No. 2005). Stanislaus River water is soft, with hardness readings ranging from 3 to 65 mg/L as calcium carbonate; alkalinity levels indicate a very high buffer capacity. The water is basic to slightly alkaline with pH readings ranging from about 7 to 8 units (Tri-Dam, Beardsley/Donnells Project, FERC Project No. 2005). Brown and Caldwell also concluded that, based on expected land use changes in the watershed, it was unlikely that water quality would significantly change in the next 20 years (Tri-Dam, Beardsley/Donnells Project, FERC Project No. 2005).

Brown and Caldwell (1995) and Tetra Tech (2001) concluded that grazing, recreation (body contact recreation), and wildfires pose a low to moderate threat to water quality similar to the upper Tuolumne River, and that all other contaminant sources pose a low threat to water quality. However, this report noted that lower sections of the watershed may be susceptible to increases in nutrient levels, bacteria, pesticides, herbicides, surfactants, solids, and turbidity. The literature review conducted in support of this Assessment suggests that water quality within the upper reaches of the watershed more than likely meets or exceeds all water quality objectives stated in the Basin Plan.

5.3 Foothill Surface Water Quality

5.3.1 Methods

Within the PSA, the vast majority of water quality data available prior to the initiation of this project are associated with compliance monitoring for point-source discharges, such as the Tuolumne Utilities District's (TUD) wastewater treatment plants (WWTP). In addition, TUD's 2002 watershed sanitary survey (2002) to assess the source quality of drinking water supplies and a 1999 groundwater study prepared by the County's Environmental Health Department provide information relevant to the Assessment. In addition, a review of the USEPA's STORNET database was also performed; however, the most recent data for the PSA date back to the early 1970s and were not considered appropriate for comparison purposes. These reports are integrated to the extent necessary to augment the water quality data collected as part of the Assessment.

Due to the expansive area contained within the PSA and the range of possible contaminants that could be present in foothill waterways, the County developed a MRP that consists of a two-phased approach to monitoring implementation. Phase 1 involved the establishment of a water quality baseline for the five watersheds that comprise the PSA. The monitoring locations in Phase 1 were selected to assess cumulative or mass loadings within each of the five watersheds and provide an indication of total pollutant loadings into downstream water supply reservoirs (i.e., New Melones and Don Pedro Reservoirs). These monitoring locations are depicted in **Figure 5-1** and described in **Table 5-2**. Phase 2 of the MRP has yet to be initiated and will consist of a more focused monitoring effort that will largely be driven by the findings in this Assessment.

Phase 1 of the MRP included the collection of grab samples at seven monitoring locations. The parameters sampled include: flow, pH, total suspended solids (TSS), specific conductance, oil and grease, temperature, priority pollutant metals, DO , turbidity, and nitrate + nitrite as N. Other analytical tests included EPA 8151A for herbicides, EPA 8260B for volatile organics compounds (VOCs), and total and fecal coliform bacteria. **Table 5-3** presents the analytical parameters sampled at each of the seven monitoring locations and the laboratory methods employed as part of the MRP. Concurrent with collection of the above grab samples, visual observations for the presence of floating and suspended materials, films or sheens, discoloration, turbidity, potential nuisance conditions (e.g., odor), and aquatic life were also recorded and photo-documented. Due to funding limitations, no formal bioassessment or acute and/or chronic toxicity monitoring were conducted in support of this monitoring effort. Phase 2 of the MRP may include this form of monitoring at specific locations if funding becomes available.

Figure 5-1

11x17

Back of 11x17

Surface Water Monitoring Results

Monitoring was conducted on November 8, 2005, December 1, 2005, and January 18, 2006 according to methods outlined in the County's MRP. Samples requiring analytical analysis were submitted to the appropriate analytical laboratory within the required holding times. Each monitoring event was characterized by a 24-hour rainfall of differing intensities with the November 8, 2005 event totaling 0.08 inches, the December 1, 2005 event totaling 0.66 inches, and the January 18, 2006 event totaling 0.56 inches as measured at the Sonora Weather Station (elevation 1,749 feet) (CDEC, 2006). The 24-hour precipitation amounts that occurred over this three month sampling period are graphically depicted in **Figure 5-2** and provide further indication of the rainfall events leading up to or preceding each of the three events. Creek flows, measured in velocity, were recorded to provide additional correlation with the water quality data (e.g., turbidity, TSS, etc.).

TABLE 5-2
DESCRIPTIONS OF SAMPLING LOCATIONS

Sample Site Designation[a]	Sample Site Location (Latitude/Longitude)	General Land Uses Assessed[b] (Percent of Watershed Area)
Turnback Creek (TB-1)	37 deg 57' 0.0 "	Rural, Estate, and Low-Density Residential; General Commercial; Timber Production; Light Industrial
Lower Sullivan Creek (SV-1)	37 deg 55' 12.0"	Rural, Estate and High and Low-Density Residential; General and Heavy Commercial; Grazing; Heavy and Light Industrial; Business Park
Upper Sullivan Creek (SV-2)	38 deg 0' 36.0"	Rural, Estate and High and Low-Density Residential; General Commercial; Grazing; Timber Production
Mormon Creek (MM-1)	37 deg 59' 24.0"	Rural, Estate and High and Low-Density Residential; General and Heavy Commercial; Light Industrial ; Airport (Mixed Use)
Groveland Creek (GV-1)	37 deg 51' 0.0"	Rural, Estate and High and Low-Density Residential; General and Heavy Commercial; Mixed Use
Woods Creek (WD-1)	37 deg 56' 24.0"	Rural, Estate and High and Low-Density Residential; General and Heavy Commercial; Grazing; Light Industrial; Business Park
Curtis Creek (CT-1)	37 deg 57' 0.0"	Rural, Estate, High and Low-Density Residential; General and Heavy Commercial; Grazing; Heavy and Light Industrial; Business Park

[a] Ambient Surface Water Sampling Sites – Water samples were collected and analyzed for constituents list in Table 5-3.
[b] Upstream land uses were determined based on interpretation of the County's zoning coverage.

SOURCE: ESA, 2006

Figure 5-2

TABLE 5-3
SURFACE WATER SAMPLING PARAMETERS AND CONSTITUENTS

				Monitoring Location						
Analysis	**Method**	**Units**	**RL/IAL**	**SV-1**	**SV-2**	**GV-1**	**MM-1**	**TB-1**	**CT-1**	**WD-1**
Flow	Field	Cubic feet per second	--	x	x	x	x	x	x	x
pH	Field	Standard Unit	pH Unit	x	x	x	x	x	x	x
Specific Conductance	Field	µS/cm	± 0.5%	x	x	x	x	x	x	x
Temperature	Field	deg. F	± 0.5	x	x	x	x	x	x	x
Dissolved Oxygen	Field	mg/L	± 2%	x	x	x	x	x	x	x
Turbidity	Field	NTU	± 2%	x	x	x	x	x	x	x
Oil and Grease	EPA 1664	mg/L	5.0	x	x	x	x	x	x	x
Total Suspended Solids	EPA 160.2	mg/L	5.0	x	x	x	x	x	x	x
Priority Pollutant Metals	EPA 200.8[(A)]	µg/L	variable	x	x	x	x	x	x	x
Low-Level Mercury	EPA 1631	ng/L	0.5	x			x	x	x	x
Total & Fecal Coliform	STDM 9221	MPN/100 mL	N/A	x	x	x	x	x	x	x
Nitrate/Nitrite as N	EPA 300.0	mg/L	0.500	x	x	x	x	x	x	x
Volatile Organics	EPA 8260B	ug/L	variable	x		x	x	x	x	x
Herbicides	EPA 8151A	ug/L	variable	x	x	x	x	x	x	x

Notes: SV-1 (Lower Sullivan Creek); SV-2 (Upper Sullivan Creek); GV-1 (Groveland Creek); MM-1 (Mormon Creek); TB-1 (Turnback Creek); CT-1 (Curtis Creek); WD-1 (Woods Creek).
uS/cm – microsiemens per centimeter; mg/L – milligrams per liter; RL/IAL – Reporting Limit/Instrument Accuracy Level; µg/L – micrograms per liter
EPA Method 200.8 is designed to obtain analytical results for numerous metals with differing detection limits.

Because the County did not to receive formal approval of its Quality Assurance Project Plan (QAPP) until early November, the first rainfall event was not collected. The first rainfall, commonly referred to as the "first flush" event, occurred on September 21, 2005 (CDEC, 2006). This rainfall event was associated with a monsoonal weather pattern, whereby a moisture-rich air mass moved into the southern Sierra from the south; producing nearly an inch (0.99) of rainfall in the vicinity of the PSA. With the approval of the QAPP in early November, the next rainfall event that occurred on November 8, 2005 was sampled, but produced less than forecasted. This event did not produce rainfall sufficient to generate surface flow within Groveland Creek and, therefore, GV-1 was not sampled on November 8, 2005. The next measurable precipitation fell on December 1, 2005, and was collected at all seven sampling locations. This event best-characterizes an early winter second major flush rainfall event. The next significant rainfall occurred on January 18, 2006, and was sampled to characterize mid-winter conditions.

Figures 5-3 through **5-9** illustrate a more localized vantage point for each of the monitoring locations depicted in **Figure 5-1** to provide additional context for the monitoring data. Site MM-1 is located downstream of Columbia along SR 49 and just upstream of the Mormon Creek Road Bridge (see **Figure 5-3**). As shown in **Figure 5-4**, site WD-1 is located southwest of Jamestown

along SR 108 and upstream of the Bell Money Road crossing. Site SV-1 is located at the Algerine Road Bridge crossing where samples were grabbed downstream of the bridge due to poor access upstream (see **Figure 5-5**). As shown in **Figure 5-6**, site SV-2 is located just east of Phoenix Lake on Potato Ranch Road. Sampling at SV-2 occurred upstream of the bridge at the western end of the Phoenix Lake Country Club. Site CT-1 is located upstream of the Lime Kiln Road Bridge to the west of Standard (see **Figure 5-7**). As shown in **Figure 5-8**, site TB-1 is located at the end of Box Factory Road and west of the Tuolumne WWTP. Site GV-1 is located downstream of the town of Groveland, along Ferretti Road, and upstream of the Groveland CSD access road bridge (see **Figure 5-9**).

Table 5-4 provides the minimum and maximum values acquired for the constituents sampled at each of the seven monitoring locations. The discussion that follows presents an evaluation of the constituents sampled in the context of the results summarized in **Table 5-4** and other available local datasets.

TABLE 5-4
SUMMARY OF MONITORING RESULTS FOR GENERAL WATER QUALITY CONSTITUENTS

Analysis	Units	RL/IAL	SV-1		SV-2		WD-1		CT-1		TB-1		MM-1		GV-1	
			Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
pH	units	+/- 0.2	5.2	6.9	5.3	6.5	5.9	7.2	6.0	6.7	4.9	6.2	6.4	7.8	4.8	5.9
Temperature	deg. F	+/- 0.27	45.9	54.9	44.8	52.5	46.9	54.4	45.2	54.2	44.7	53.1	45.4	54.8	45.3	49.8
Dissolved Oxygen	mg/L	+/- 2%	8.6	10.4	9.2	10.9	9.3	10.9	9.4	11.3	7.7	10.3	9.3	10.4	9.7	10.7
Specific Conductance	uS/cm	+/- 0.5%	84	239	89	112	207	380	116	269	98	137	373	408	102	127
Turbidity	NTU	+/- 2%	0.80	25.90	2.34	85.40	1.48	29.50	2.06	70.70	2.68	70.40	4.45	13.60	30.20	30.30
TSS	mg/L	5.0	20.0	53.0	20.0	110.0	18.0	25.0	ND	44.0	17.0	42.0	6.2	8.0	6.2	56.0
Hardness	mg/L	1.0	38.0	120.0	35.0	44.0	91.0	210.0	49.0	120.0	43.0	61.0	200.0	240.0	47.0	68.0
Oil and Grease	mg/L	5.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.1	ND	ND	ND	ND
Nitrate and Nitrite (as N)	mg/L	0.500	ND	0.46	ND	0.41	ND	0.50	ND	0.41	ND	ND	ND	0.61	ND	ND
Fecal Coliform	MPN/100 mL	2	27	500	600	1600	170	1700	130	1100	17	1600	240	500	70	1600
Total Coliform	MPN/100 mL	2	240	1600.	1600	16000	1600	9000	300	16000	1600	16000	900	1600	1400	1600

Note: Complete dataset is included in Appendix C.

mg/L milligrams per liter; uS/cm microsiemens per centimeter; MPN most probable number; NTU = nephelometric turbidity units

Source: ESA, 2006

Figure 5-3

Figure 5-4

Figure 5-5

Figure 5-6

Figure 5-7

Figure 5-8

Figure 5-9

Temperature

Water temperature is an important influence on water chemistry as rates of chemical reactions generally increase with increasing temperature. For example, temperature helps to regulate of the solubility of gases and minerals (solids); thereby determining how much of these materials can be dissolved in water. The solubility of important gases, such as oxygen and carbon dioxide increases as temperature decreases. Inversely the solubility of most minerals increases as the water temperature increases.

During the period of monitoring, water temperature exhibited a downward trend at all monitoring locations, which coincided with decreasing air temperatures. Surface water temperatures were in the mid to low 50s in late fall at all monitoring locations and trended downward through January into the mid 40s. Of all the monitoring locations sampled, Groveland Creek was the only one to go dry during the summer of 2005. This trend suggests that the other waterways would be subject to warming in the summer when flows are lower. In shallower reaches of Mormon, Sullivan, Curtis, and Turnback Creeks, there is insufficient natural slope to keep the mainstem flowing rapidly. Therefore, these creeks are subject to warming by high summer temperatures. This occurrence is intensified along unvegetated stream banks and below small storage reservoirs.

Dissolved Oxygen

Dissolved oxygen (DO) is gaseous oxygen dissolved in water. It is generated by diffusion from the surrounding air, as a byproduct of photosynthesis and from turbulence in the water column. Dissolved oxygen is largely controlled by biotic processes, mainly photosynthesis and plant respiration. The difference in these two processes alone can account for the large daily variations in dissolved oxygen concentrations, especially during the summer months. However, diurnal variations were not the focuses of this analysis and, therefore, additional sampling would be required to establish trends for diurnal fluctuations.

During the period of sampling, DO levels experienced an upward trend coinciding with colder water temperatures. The relatively high DO levels suggest that the contributions of oxygen-demanding substances (e.g., organics) are not depleting the oxygen levels, at least during the period of monitoring. The Basin Plan standard for DO is based on the application of the cold water habitat beneficial use, which is 7.0 milligrams per liter (mg/L). The values measured at all the sampling locations, during the period of sampling, exceeded this standard. However, future monitoring under Phase 2 of the MRP will be critical to augment the current dataset to support this conclusion, especially during the summer. Continued monitoring at CT-1 during the summer should be emphasized, as large algal blooms were noted during the summer of 2005. It is well-documented that if a sufficient nutrient supply is available during the summer months to stimulate algal blooms, DO levels can be depleted leading to anoxic conditions.

pH

The pH is a conventional parameter used to express the acid or alkaline condition of a water sample. The pH of natural waters tends to range between 6 and 9. The RWQCB uses a range from 6.5 to 8.5 in regulating discharges to local receiving waters. This standard provides a buffer to lower and higher pH levels that may adversely affect the ability of aquatic organisms to complete life cycles, especially as the pH becomes >9.0 or <5.0.

As water flows, it dissolves mineral substances it contacts, picks up aerosols and dust from the air, receives inputs of man-made substances, and supports photosynthetic organisms, all of which affect pH. As noted in **Table 5-4**, several of the sampling locations recorded pH levels that were well below 6.5. During the sampling period, sites SV-1, TB-1, and GV-1 all exhibited pH values below 6.5; whereby sites TB-1 and GV-1 recorded pH measurements of 4.9 and 4.8, respectively, on December 1, 2005. In light of the limited sampling duration, the exact reasons for these low pH values are not well understood. Potential influences could include the local geology [iron (Fe) and aluminum (Al) oxides], the addition of organic materials which tend to be acidic, and potentially acid rain influences. All sites measured on January 18, 2006 exhibited a gradual increase in pH suggesting that the above influences may all be contributing to this phenomenon. However, given that pH values in the upper reaches of the Upper Stanislaus and Upper Tuolumne River watersheds tend to be more neutral (e.g., 7.0) compared to data for this Assessment, continued monitoring is warranted to establish long-term trends.

Specific Conductance

Electrical conductivity is a measure of the ability of water to conduct electricity, and therefore, a measure of the water's ionic activity and content. In general terms, with an increase in the concentration of ionic (dissolved) constituents in solution, there is a corresponding increase in the solution's electrical conductivity. Specific conductance (SC) is simply the conductivity normalized to a temperature of 25º C. SC is generally found to be a good measure of the concentration of total dissolved solids (TDS)[3] and salinity. Elements whose ionic forms contribute the most to these measures include: calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), bicarbonate (HCO_3^{-}), sulfate (SO_4^{2-}), and chloride (Cl^{-}).

SC within the Sierra Nevada is generally low as a consequence of the associated lithology; which is composed dominantly of plutoic rocks [silicon dioxide (SiO_2), Mg, Fe}. A more diverse geology within the foothill region contains exposures of marble and amphibolite (CDC, 1997), especially in the Woods Creek and Mormon Creek watersheds, which contain differing quantities of Ca, Mg, Cl, and Na. Both Mormon Creek and Woods Creek had the highest SC measurements. WD-1 had a maximum reading of 380 µS/m; while MM-1 recorded a maximum of 408 µS/m. The readings recorded at Woods Creek are likely associated with the presence of two wastewater treatment facilities upstream of WD-1. For example, TUD has measured TDS readings of 340 mg/L at its Sonora WWTP and 260 mg/L at the Jamestown WWTP (RWQCB Monitoring and Reporting Program No. R5-2002-0202). Additionally, reclaimed water produced consistent with Title 22 California Code of Regulations (CCR) Section 60301 et seq., (Title 22) by TUD is used for irrigation proposes within the Woods Creek watershed and stored in Quartz Reservoir, downstream of site WD-1. This activity also represents a possible contribution of TDS to the Woods Creek watershed.

The readings in Mormon Creek are less obvious, but could be associated with improperly functioning septic systems. Additionally, the presence of the Roll-In Mobilehome Park wastewater treatment facility upstream of MM-1, which consists of two 1,500-gallon septic tanks that are pumped into a series of six ponds, may contribute to the elevated conductivity (RWQCB

3 For comparison purposes, TDS is generally equal to 0.68 multiplied by SC.

Order R5-2002-0069). However, as no monitoring plan has been submitted, there are no data available to support this. Nonetheless, the owners of the Mobilehome Park have submitted a proposal to connect the facility's wastewater collection system to TUD's sewer system. Once connected, the six existing wastewater ponds would be closed, thereby eliminating any potential subsurface discharge to Mormon Creek.

The remaining sites recorded a SC of less than 140 µS/m, except at SV-1 (239 µS/m) and CT-1 (269 µS/m). The higher SC values at these locations are thought to be attributed to the numerous intermittent contributing drainages that traverse through grazing lands, horse corrals, and feed lots. The data suggest that flows from upstream locations contribute some level of dilution in terms of SC. The California secondary maximum contaminant level (MCL) for SC is 900 µS/m; none of the sites sampled encroach near this limit (see Appendix C).

Turbidity

Turbidity is a measure of the degree of suspended particles, including organic matter (e.g. algae) and inorganic particles (e.g. silt and clay) that scatter light passing through a water column. Light scattering increases with increasing sediment load. Turbidity is commonly measured in nephelometric turbidity units (NTU) and is simply stated as the measure of relative clarity of a liquid. The most frequent causes of turbidity in rivers are soil and bank erosion and contributions of organic materials. The predominant contributing factor to seasonal turbidity in the PSA appears to be peak flows in the winter, when bare soils are eroded and are carried downstream as suspended load, which also may be measured as total suspended solids (TSS). The RWQCB standard for turbidity is based on comparing upstream to downstream NTU levels (see **Appendix C**). Therefore, since this Assessment focuses only on receiving waters, the compliance standard is not applicable. The RWQCB generally sets standards for TSS, which range from 50 to 100 mg/L; depending on the discharge.

As provided in **Table 5-4**, the maximum NTU values were substantially higher than the minimum values collected; with the exception of site MM-1, which is believed to be affected by a series of small storage reservoirs that act as sediment traps. The increased NTU values, along with the correlating increases in TSS values, are mainly attributed to higher rainfall intensities and associated flow velocities recorded on December 1, 2005 and January 18, 2006. Higher rainfall intensities are more erosive on bare soils, while higher flow velocities are more erosive to un-protected banks. The highest recorded values were obtained at SV-2, TB-1, and CT-1. Sites CT-1 and TB-1 are located below areas where new development, and hence construction, is occurring in the County. However, in the case of site CT-1, measurements were taken considerably downstream from developing areas. For this reason, the NTU values acquired at CT-1 should be taken in the context of the probable dilution effect from less-developed areas. Similarly, NTU values obtained at TB-1 were taken below the Westside Pond, which acts as a sediment basin or trap. In this context, contributions of sediment to Turnback and Curtis Creeks at upstream locations could have considerably higher NTU values than those provided in **Table 5-4** and Appendix C.

In contrast, the measurements recorded at SV-2 are believed to be associated with pre-existing development for reasons discussed in Chapter 4.0. Site SV-2 is located at the base of Upper Sullivan Creek, just east of Phoenix Lake, and provides a sample of all drainage flows that originate from the central and eastern section of the Phoenix Basin. Prior land use activities in the Phoenix Basin have modified natural hillslope drainage by altering topography and removing ground cover. Road cuts, water delivery features, and other excavated faces have increased overland flow by intercepting subsurface flow, concentrating it, and redirecting it downslope and efficiently routing it into natural waterways. Further, compacted surfaces[4], including road embankments, unpaved driveways, and housing pads, lead to a loss in aggregate stability, which in turn, results in decreased surface infiltration of water and increased runoff. Increasing slope steepness and length further intensifies this effect. Compacted surfaces not only affect the susceptibility of soil surfaces to erosion, but also limit the reestablishment of protective groundcover by inhibiting root penetration and decreasing the amount of aeration and available water. These chronic conditions are suspected to be the major cause of turbidity at SV-2.

In interpreting the turbidity data, it is important to note that the available dataset includes only three discrete samples and does not include data from larger storm events. For example, as depicted in **Figure 5-2**, a significant rainfall event occurred over the 2005/2006 New Years Day weekend, but was not collected. However, local observations during this period indicated that bankfull flows occurred and, in some instances, flows extended beyond the banks and into low-lying floodplains. High turbidity levels were more than likely associated with this event, but are not reflected in the data presented in **Table 5-4** and Appendix C.

Further, TUD staff have stated that NTU readings in the Phoenix Ditch, above Phoenix Lake, which drains western portions of the Phoenix Basin, have been recorded at much higher levels than those measured as part of this study (see **Table 5-4**). For example, TUD has recorded turbidity levels of 160 NTU at its Scenic View Water Treatment Plant (WTP) and 300 NTU at its Sonora WTP, which both are below Phoenix Lake (TUD, 2002). It is assumed that the NTU readings upstream of Phoenix Lake would be even higher due to the settling of large particles (e.g., sand) in Phoenix Lake. In addition, TUD has noted that its raw water turbidity tends to increase as water flows through its ditch systems away from Lyons Reservoir (TUD, 2002).

Synthetic Compounds

For the purposes of this Assessment, synthetic compounds represent a potential range of urban pollutants chosen for sampling under the MRP and include oil and grease, VOCs, and chlorinated herbicides. The following discussion provides an evaluation of the data collected as part of the MRP and, where available, provides an expanded discussion based on other data sources reviewed as part of this Assessment.

Oil and grease measurements were included in the MRP to provide an indication of the level of petroleum and associated by-products entering local waterways from roadways, fueling stations, etc. During the three sampling events, no oily sheens were observed at the seven monitoring

4 Soil compaction occurs when soil particles are pressed together, thereby reducing pore space between them. This increases the weight of the solids per unit volume of soil (bulk density). Soil compaction occurs in response to pressure (weight per unit area) exerted by humans, off-highway vehicles, etc.

locations. As provided in **Table 5-4**, oil and grease was not detected at any of the sampling sites, except at TB-1 on December 1, 2005. The California public health goal for drinking water for oil and grease is 2.0 mg/L. However, the California primary MCL is 15.0 mg/L. The concentration of oil and grease at TB-1 was just above the method detection limit at 5.1 mg/L. Given that TB-1 is in close proximity to Tuolumne City and oils tend to float at the surface, thereby not being removed by the Westside Pond, it is reasonable to conclude that small quantities of oil and grease are being discharged into foothill waterways from urbanized areas. However, given that a majority of the monitoring sites were located a substantial distance downstream of urbanized areas, the dilution factor provided by undeveloped lands generally maintains concentrations of oil and grease at undetectable levels. An expanded dataset would be desirable to support this conclusion.

VOCs are chemicals of an organic nature, which readily volatilize or travel from the water into the air. Most of these substances are industrial chemicals and solvents. They include light alcohols, acetone, trichloroethylene, dichloroethylene, benzene, vinyl chloride, xylenes, and MTBE. These potentially toxic chemicals are used as solvents, degreasers, paints, thinners, and fuels. Because of their volatile nature, they readily evaporate into the air, increasing the potential exposure to humans. Due to their low water solubility, environmental persistence, and widespread industrial use, they are commonly found in soil and water.

Table 5-5 provides the water quality standards and method detection limits for all VOCs sampled on November 8, 2005. None of the constituents listed in **Table 5-5** were detected in samples collected for using EPA Method 8260B. This result includes duplicate samples taken on the same day.

TABLE 5-5
LABORATORY ANALYTICAL METHODS AND WATER QUALITY STANDARDS FOR VOLATILE ORGANIC COMPOUNDS AND CHLORINATED HERBICIDES

Analyte	Matrix	Reporting Units	Analytical Method	Method Reporting Limit	Water Quality Standards
Volatile Organic Compounds (VOCs)					
1,1-Dichloroethane	water	µg/L	*EPA 8260B*	1.0	5 (a)
1,1-Dichloroethylene	water	µg/L	*EPA 8260B*	0.5	6 (a)
1,1,1-Trichloroethane	water	µg/L	*EPA 8260B*	2.0	200 (a)
1,1,2-Trichloroethane	water	µg/L	*EPA 8260B*	0.5	5 (a)
1,1,2,2-Tetrachloroethane	water	µg/L	*EPA 8260B*	0.5	1 (a)
1,2-Dichlorobenzene	water	µg/L	*EPA 8260B*	2.0	600 (a)
1,2-Dichloroethane	water	µg/L	*EPA 8260B*	0.5	0.5 (a)
cis-1,2-Dichloroethene	water	µg/L	*EPA 8260B*	0.5	6 (a)
1,2-Dichloropropane	water	µg/L	*EPA 8260B*	0.5	5 (a)
1,2,4-Trichlorobenzene	water	µg/L	*EPA 8260B*	5.0	5 (a)
1,3-Dichlorobenzene	water	µg/L	*EPA 8260B*	2.0	600 (e)
1,3-Dichloropropene	water	µg/L	*EPA 8260B*	0.5	0.5 (a)
1,4-Dichlorobenzene	water	µg/L	*EPA 8260B*	2.0	5 (a)
Benzene	water	µg/L	*EPA 8260B*	0.5	1.0 (a), 0.15 (c)
Bromoform	water	µg/L	*EPA 8260B*	2.0	100 (a), 80 (b)
Bromomethane	water	µg/L	*EPA 8260B*	2.0	510 (d)
Carbon tetrachloride	water	µg/L	*EPA 8260B*	0.5	0.5 (a), 0.1 (c)
Chlorobenzene (mono chlorobenzene)	water	µg/L	*EPA 8260B*	2.0	--
Chloroethane	water	µg/L	*EPA 8260B*	2.0	16 (d)
Chloroform	water	µg/L	*EPA 8260B*	0.5	100 (a), 80 (b)
Chloromethane	water	µg/L	*EPA 8260B*	2.0	2400 (d)
Dibromochloromethane	water	µg/L	*EPA 8260B*	0.5	10 (a), 80 (b)
Dichlorobromomethane	water	µg/L	*EPA 8260B*	0.5	--

TABLE 5-5
LABORATORY ANALYTICAL METHODS AND WATER QUALITY STANDARDS FOR VOLATILE ORGANIC COMPOUNDS AND CHLORINATED HERBICIDES

Analyte	Matrix	Reporting Units	Analytical Method	Method Reporting Limit	Water Quality Standards
Dichloromethane	water	µg/L	*EPA 8260B*	2.0	5 (a)
Ethylbenzene	water	µg/L	*EPA 8260B*	2.0	300 (a), 300 (c)
Hexachlorobutadiene	water	µg/L	*EPA 8260B*	1.0	--
Naphthalene	water	µg/L	*EPA 8260B*	10.0	170 (e)
Tetrachloroethene	water	µg/L	*EPA 8260B*	0.5	5 (a), 0.06 (c)
Toluene	water	µg/L	*EPA 8260B*	2.0	150 (a)
trans-1,2-Dichloroethylene	water	µg/L	*EPA 8260B*	1.0	10 (a)
Trichloroethene	water	µg/L	*EPA 8260B*	2.0	5 (a)
Vinyl chloride	water	µg/L	*EPA 8260B*	0.5	0.5 (a), 0.05 (c)
Methyl-tert-butyl ether (MTBE)	water	µg/L	*EPA 8260B*	3.0	13 (a)
Trichlorofluoromethane	water	µg/L	*EPA 8260B*	5.0	150 (a)
1,1,2-Trichloro-1,2,2-Trifluoroethane	water	µg/L	*EPA 8260B*	10.0	1,200 (a)
Styrene	water	µg/L	*EPA 8260B*	0.5	100 (a)
Xylenes	water	µg/L	*EPA 8260B*	0.5	1,750 (a)
Chlorinated Herbicides					
Bentazon	water	µg/L	*EPA 8151A*	2.0	18.0 (a)
2,4-D	water	µg/L	*EPA 8151A*	10.0	70 (a)
Dalapon	water	µg/L	*EPA 8151A*	10.0	200 (a)(b)
Dinoseb	water	µg/L	*EPA 8151A*	2.0	7 (a)
Picloram	water	µg/L	*EPA 8151A*	1.0	500 (a)(c)
2,4,5-TP (Silvex)	water	µg/L	*EPA 8151A*	1.0	50 (a), 25 (c)
Pentachlorophenol	water	µg/L	*EPA 8151A*	1.0	1 (a), 0.4 (c)

(a) California primary MCL
(b) USEPA primary MCL
(c) California public health goal for drinking water
(d) California Secondary MCL
(e) DHS Action Level for Drinking Water

mg/L = milligram per liter; µg/L = microgram per liter; mL = milliliter; MPN = most probable number; ng/L = nanograms per liter; ppt = parts per trillion

Source: RWQCB Water Quality Goals, 2003; Tuolumne County Quality Assurance Project Plan, 2005.

Leaking USTs are documented as having caused localized soil and water contamination in Tuolumne County (Tuolumne County, 1999). As of 1999, there were 46 sites where groundwater contamination has been attributed to hazardous waste spills or leaking tanks. Because no agency database searches were conducted as part of this Assessment, it is assumed that an undetermined number of sites have been added since that time. Compounds associated with gasoline, such as benzene, toluene and xylene and additives such as MTBE, are considered the most problematic and have been detected in close proximity to USTs. However, none of these contaminants were detected during Phase 1 of the MRP at the method reporting limits, which are below regulatory standards provided in **Table 5-5**. This finding is attributed to the considerable dilution that is thought to occur at the cumulative monitoring sites as a result of runoff from undeveloped lands.

In addition to the VOCs associated with USTs, the dry cleaning solvents such as tetrachloroethene (TCE), perchloroethene (PCE) and their decay products cis 1,2-dichloroethene (cis 1,2-DCE) and vinyl chloride are mobile in groundwater, and were detected in monitoring wells at Sierra Launderers and Cleaners. The monitoring wells, originally drilled as part of an UST investigation, obtained samples that contained up to 12,000 µg/L of PCE, 1,700 µg/L of TCE, 4,500 µg/L of cis

1,2-DCE and 300 µg/L of vinyl chloride (RWQCB Resolution No. R5-2002-0109). The source area is immediately adjacent to Woods Creek and about 600 feet from Sonora Union High School (RWQCB Resolution No. R5-2002-0109). To date, the extent of pollution is undefined. TUD and the RWQCB are currently requesting funds from the State Water Pollution Cleanup and Abatement Account to assist in responding to this water quality problem.

The results of the analytical analysis completed as part of this Assessment indicates that the constituents covered by EPA Method 8260B were not detectable at the cumulative loadings sites identified in **Figure 5-1**. As these compounds were not detected at the method reporting limit, it may be concluded that sufficient dilution is occurring from the remainder of the watershed, to the extent, that downstream water supply reservoirs are not at significant risk. Further discussion on these constituents is provided in Chapter 6.0. It is expected that these constituents may be detectable at more site specific locations within the PSA. In addition, an expanded dataset would be appropriate to further support this conclusion. Further discussion is provided in Chapter 6.0.

In addition to VOCs, chlorinated herbicides have been used wide-spread in the past decades for landscaping, agriculture, forestry, and vegetation control applications. These compounds have high to very high acidity, low to high water solubility, and very low to moderate volatility. Both water solubility and soil retention are dependent on soil pH. Overall soil retention is generally low. Breakdown of these herbicides is typically associated with microbial decomposition. As an example, the average active half life of 2,4-D is approximately 11 years. In contrast, chlorinated pesticides, such as DDT, which were not sampled during Phase 1 of the MRP, are more persistent for many years after application.

As provided in **Table 5-5**, samples collected for chlorinated herbicides analyzed under EPA Method 8151A had undetectable concentrations for all constituents. These results suggest that chlorinated herbicides are not present at detectable levels in major waterways draining from the PSA. However, this conclusion should be taken in the context of the limited datasets available for this Assessment and the cumulative loading sites sampled. Further, the County acknowledges that Phase 1 of the MRP did not include analysis of other herbicides that may be used within the PSA. For example, following the preparation of the MRP, additional discussions with staff from the Central Sierra Environmental Resource Center (CSERC) and Tuolumne County have indicated that other herbicides are commonly used within the County, depending on the target plant species and include Pronone and Velpar, Round Up Pro, Aqua Master, Garlon, Gallery, and pre-emegents, such as Telar and Payload.

The active ingredient in Pronone and Velpar is hexazinone, which is water-soluble and readily mobilized due to adsorption to soil particles (Weed Control Methods Handbook, 2001). Round Up Pro and Aqua Master are contact herbicides, containing the active ingredient glyphosate, and are generally non-selective. Round Up Pro is used in the control annual weeds, woody brush and trees, while Aqua Master is used to control emergent vegetation in and around bodies of water. The active ingredient in Garlon is triclopyr, which is used to control of woody vegetation and broadleaf weeds (Weed Control Methods Handbook, 2001). Gallery is chiefly composed of isoxaben and is used as a selective pre-emergence herbicide that prevents the growth of broadleaf weeds, such as poison oak and Himalayan blackberry. The active ingredient in Telar is a

chlorosulfuron, which is mainly used along railroads, highway rights of way, and around power distribution poles. Payload is composed on flumioxazin, which is used to maintain bareground and control invasive plants, such as Russian and Canada thistle, crabgrass, Bromus species, ryegrass and foxtails.

These herbicides were not sampled for as part of Phase 1 of the MRP and, thus additional sampling would be required under Phase 2 of the MRP to verify their relative absence or presence in the water column at the cumulative sampling locations. Chapter 6.0 provides additional discussion on this issue in terms of additional forms of investigation that should be considered in future planning.

Trace Metals

Sources of trace metals in waterways are influenced by various factors including industrial processes occurring in upstream locations, corroding metal surfaces, combustion processes, natural deposits (e.g., mining), etc. Trace metals (especially copper, lead, and zinc) are by far the most prevalent priority pollutant constituents found in urban runoff. For this reason, trace metals were sampled at each of the seven monitoring locations to determine if County land uses are contributing significant concentrations of trace metals to downstream water supply reservoirs. Additionally, influxes of metals, including arsenic, mercury, copper, etc, from abandoned and/or inactive mines are also thought to contaminate local surface waters.

As previously indicated, the focus of this Assessment was to assess potential impacts to water supply reservoirs, namely in terms of drinking water. For this reason, trace metals were analyzed using EPA Method 200.8, due to its cost-effectiveness and ability to detect trace metal concentrations below drinking water standards for arsenic, cadmium, chromium (total), copper, lead, mercury, nickel, selenium, silver, and zinc. This approach is important to note given that other analytical methods are available to detect trace metals at lower concentrations based on their effects on aquatic organisms. However, these methods are generally much more expensive both in terms of the analytical equipment required and staff resources needed to acquire the sample.

Under Phase 1 of the MRP three sampling events were conducted for each of the seven sites, except at GV-1, using EPA Method 200.8 for trace metals analysis. The results indicated that trace metals were at undetectable levels at the method reporting limits provided in **Table 5-6**. The exception to this finding occurred at sites MM-1 and GV-1, where selenium was detected at concentrations of 5.5 µg/L and 7.3 µg/L, respectively; just above the method reporting limit. The presence of selenium is thought to be attributed to the associated geology and/or aerial deposition. In addition to those constituents identified in **Table 5-6**, TUD makes mention in its 2002 Watershed Sanitary Survey that raw water periodically exhibits elevated concentrations of iron at levels substantially lower than the secondary MCL for iron (5000 µg/L) (TUD, 2002). Iron was not sampled during Phase 1 of the MRP, since it is not identified as a priority pollutant and is associated with the local geology.

Based on the historic mining activity that occurred within the PSA, the County included one additional round of sampling for mercury using EPA Method 1631, which provides a low detection limit, down to 0.5 nanograms per liter (ng/L). The results show that very low levels of mercury were detected at sites SV-1, WD-1, MM-1, CT-1, and TB-1. Site TB-1 recorded the highest

concentration of 3.43 ng/L. These concentrations are very low and likely represent background levels. Additionally, with the presence of the former Jamestown Mine upstream of WD-1, the values obtained under both EPA Method 200.8 and 1631 would suggest that onsite stormwater controls at the mine are functioning properly and providing the necessary containment. Based on the water quality standards provided in **Table 5-6** in conjunction with the method report limits for metals analyzed using EPA Methods 200.8, it is reasonable to conclude that contributions of trace metals do not represent a significant hazard to downstream water supply reservoirs. Further, the existing mercury TMDL for Don Pedro Reservoir is thought to be attributable to the heterogeneous piles of rocks that are frequently inundated by Don Pedro Reservoir.

Nutrients

Nutrients are generally identified as a water quality concern due to their association with the biostimulation of algal growth. Nutrients are typically introduced into the watershed through agricultural and residential land uses, which use soluble forms of phosphorus and nitrogen, as fertilizer. Algal growth is largely limited due to the availability of phosphorus and nitrogen. In the absence of a controlling or limiting growth factor, algal blooms will eventually cloud the water and block the sunlight exhibited in reaches of Curtis Creek below Lime Kiln Road (see **Figure 5-10**).

TABLE 5-6
ANALYTICAL METHODS AND WATER QUALITY STANDARDS FOR TRACE METALS

Analyte	Matrix	Reporting Units	Analytical Method	Reporting Limit	Basin Plan Standard or CA Toxics Rule
Arsenic	water (salinity <0.5 ‰)	µg/L	EPA 200.8	1.0	10 (a), 0.004 (b)
Cadmium	water	µg/L	EPA 200.8	0.25	5.0 (c), 0.07 (b)
Chromium	water	µg/L	*EPA 200.8*	2.0	50 (c)
Copper	water	µg/L	EPA 200.8,	0.5	1300 (c), 170 (b)
Lead	water	µg/L	EPA 200.8	0.5	12.0 (b), 100 (c)
Mercury (inorganic0	water (low level, parts per trillion)	ng/L (ppt)	EPA 1631	0.5	2.0 µg/L (a,c), 1.2 µg/L (b)
Nickel	water	µg/L	EPA 200.8	5.0	10 (a)
Selenium	water (salinity >0.5 ‰)	µg/L	EPA 200.8	5.0	50.0 (e)
Silver	Water	µg/L	EPA 200.8	1.0	100 (d)
Zinc	Water	µg/L	EPA 200.8	10.0	5000 (d)

(a) USEPA primary MCL
(b) California public health goal for drinking water
(c) California primary MCL
(d) California secondary MCL
(e) Title 22 – California Toxics Rule

µg/L = microgram per liter; ng/L = nanograms per liter; ppt = parts per trillion

Figure 5-10

Excess nitrates (NO_3) in drinking water is a health concern and has caused the closure of more public water supply wells in California than any other contaminant (Bachman, 1997; Tuolumne County, 1999). Nitrate can also be a source of toxicity, which can cause methemoglobinemia[5], but is generally limited to children less than six months old. Nitrates were chosen for monitoring under the MRP due to the numerous potential sources within the PSA such as septic tank effluent, fertilizers, decomposing organic matter, and industrial and agricultural wastes. Nitrate is very soluble in water, is not readily absorbed by soil, and is therefore mobile in surface and groundwater. The USEPA has recently lowered the maximum contaminant level (MCL) for nitrate in drinking water down to 10 mg/L (as nitrate ion). The State is expected to adopt the 10 mg/L or stricter standard, based on USEPA's revision.

This Assessment found no obvious trends in nutrient concentrations; expect that there may be a surplus of nitrate in local creeks, to the extent, that enables abundant algal growth. However, the period of the dataset does not allow for observation of seasonal trends in nutrients except that nitrate concentrations were somewhat higher in winter as compared to the fall. **Table 5-4** provides dissolved nitrate data for each of the seven sites within the PSA. The highest measurement of 0.61 mg/L was obtained at site MM-1 on January 18, 2006. This measurement is substantially lower than the USEPA's MCL for drinking water. As provided in **Table 5-4**, the method reporting limit for nitrate is 0.500 mg/L. As the vast majority of the samples collected contained levels of nitrate that were not detectable, it can be reasonably assumed that waterways within the PSA are not contributing significant concentrations of nitrates to drinking water reservoirs. However, in recognition of the limited datasets to support this conclusion, additional discussion on nitrates is provided in Chapter 6.0.

Coliform Bacteria

Bacteriological sampling was conducted as part of Phase 1 of the MRP to verify the presence of coliform bacteria within waterways draining the PSA, based on concerns raised by local residents and the County's 1999 Groundwater Protection Report. Total coliform bacteria are microorganisms that live in large numbers in the intestines of warm- and cold-blooded animals, including humans. A specific subgroup of this collection is referred to as fecal coliform bacteria, the most common member being *Escherichia coli*. These organisms are differentiated from the total coliform bacteria by their ability to grow at elevated temperatures and are associated with the fecal material of warm-blooded animals.

The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the fecal material from animals and/or humans. The presence of fecal coliform bacteria may also provide an indication that source waters may have been contaminated by other pathogens or disease-producing bacteria or viruses which can also exist in fecal matter. Some waterborne pathogenic diseases include typhoid fever, viral and bacterial gastroenteritis, and hepatitis A. The presence of fecal coliform bacteria provides evidence that ambient waters have come into contact with human and/or animal waste and may be directly linked to overflow of domestic sewage or nonpoint sources of human and animal waste.

5 Process where excess nitrate in the bloodstream can prevent red blood cells from taking up sufficient oxygen.

Based on concerns raised by the general public and County staff, total and fecal coliform samples were grabbed at each of the seven monitoring locations during the three sampling events. The analytical results confirm the presence of fecal coliform at all the sampling sites. Even with limited data, fecal coliform bacteria levels were consistently reported at levels greater than 400 MPN/100 mL. At several sites fecal coliform were detected at levels in excess of 1,600 MPN/100 mL (SV-2, TB-1, WD-1, and GV-1).

The RWQCB applies a standard of 400 MPN/100mL[6] fecal coliform for waterways and/or bodies where the body-contact recreation beneficial use is applied. A stricter standard for fecal coliform may be applied when the geometric mean for five samples collected over a 30 day period exceeds 200 MPN/100mL. For this Assessment five samples were not available. Nonetheless, the values obtained during the December 2005 and January 2006 sampling events and summarized in **Table 5-4**, indicate that the maximum levels of fecal coliform detected were well above the applied standard.

The County's 1999 Ground Water Protection Report suggests that improperly functioning septic systems and grazing practices may be a probable cause for levels of fecal coliform bacteria recorded within all of the monitored waterways. The County inventoried a total of 497 problematic septic systems within the PSA as part of the County's Groundwater Protection Report (1999). However, with over 7,500 inventoried septic systems within the County, the number of undocumented problematic septic systems is likely greater than the total number inventoried as part of the Groundwater Protection Report (1999).

In the lower foothill sections of the PSA, grazing practices are also likely to contribute fecal coliform bacteria to the monitored waterways. This conclusion is supported by the fewer number of problematic septic systems within the lower sections of the Woods Creek, Sullivan Creek, and Curtis Creek watershed sub-units. Further, the fecal coliform levels recorded at the effluent discharge points for the Sonora and Jamestown WWTPs would suggest that these facilities are not major contributors to the levels of fecal coliform recorded at WD-1 (RWQCB Monitoring and Reporting Program No. R5-2002-0202).

In the lower foothill sections of the PSA, grazing practices are also likely to contribute fecal coliform bacteria to the monitored waterways. Grazing animals were observed near local waterways and, in some instances, within the actual channel as depicted in **Figure 5-11**. As a consequence, current unobstructed grazing practices result in the distribution of manure in and near waterways, thereby contributing to the fecal coliform levels recorded in the lower reaches of Woods, Sullivan, and Curtis Creeks.

6 Geometric Mean-10% of Samples for 30 days

Figure 5-11

5.4 General Conclusions

The results of the baseline monitoring under Phase 1 of the MRP in conjunction with other field studies suggest that waterways that drain the PSA currently do not exhibit detectable levels of typical urban pollutants. Rather, the data collected as part of the MRP suggest that pollutants (e.g. sediments and pathogens) found within local waterways are more commonly associated with rural forms of development and legacy land use practices. This conclusion is not to be taken out of context by broadly concluding that urban-type pollutants are not discharged within the watershed. Rather, a more appropriate conclusion would be that urban forms of pollutants are currently not detectable at the analytical method detection limits employed as part of this Assessment and at the monitoring locations identified in **Figure 5-1** and **Table 5-2**, which are indicative of all sources within the five watersheds that comprise the PSA.

By virtue that concentrations of urban pollutants were below detectable levels, it is appropriate to conclude that these pollutants are well below regulatory action levels and currently do not represent a significant threat to drinking water quality in downstream reservoirs. However, the County cautions that this conclusion should be taken in the context of the limited data available for this Assessment Report (e.g. three sampling events). Further, the implementation of Phase 1 was difficult from a logistical standpoint due to the number of sampling locations monitored and the substantial distances between each location. This factor resulted in the collection of samples at different points on the hydrograph[7] for each of the assessed waterways. Every attempt was made to collect samples prior to the peak on the hydrograph for each waterway. However, due to the varying sizes of the contributing drainage areas for each sampling location and the lack of continuous flow data for the assessed waterways, this proved to be unattainable. In light of these circumstances, these conclusions are subject to further refinement pending future monitoring efforts at more, site-specific monitoring locations in conjunction with Phase 2 of the MRP and additional monitoring goals set forth in the County's WQP.

7 Hydrographs are charts that display the change of a hydrologic variable (e.g., stream flow, rainfall, etc.) over time.

Chapter 6

Principal Findings and Recommendations

ESA

CHAPTER 6
Principal Findings and Recommendations

6.1 Principal Findings

An evaluation of surface water quality conditions within the foothill region of Tuolumne County reveals that prior land use management activities and their associated legacies are the leading causes of surface water quality degradation in the PSA. Based on the land use history summarized in Chapter 3.0, the most significant landscape alteration has occurred within the last 150 years as a result of road construction, the development of water supply infrastructure, mining, grazing and continued population growth. Observations within the PSA suggest that localized hydrology has been particularly influenced by the additions of impervious surfaces, as a result of the construction of roads, parking lots, and buildings. Although net increases in runoff were not quantified as part of this Assessment, there is sufficient evidence indicating that these increases have mobilized sediment within the upper, transport-oriented reaches of the PSA and re-deposited it in lower-gradient, transport-limited segments of each watershed.

Based on the limited data acquired in conjunction with this Assessment, water quality parameters or constituents identified as a concern or in need of further investigation are those generally associated with the legacies of prior land use activities. Contamination sources include residential and commercial on-site sewage disposal systems, leaking underground fuel tanks, and unobstructed grazing practices. Continued sedimentation to local waterways within the PSA is also a concern that requires the management of chronic erosion sources, such as unpaved driveways, and better controls on new development and construction. In this context, the primary focus of future water quality planning efforts and monitoring programs should be directed towards the following:

- Total and fecal coliform bacteria and other potential pathogens from on-site sewage disposal systems and unobstructed grazing. Nutrients (e.g. nitrates) may also be associated with these activities with additional contributions from fertilizer applications;

- Unknown causes for pH levels within receiving waters (e.g. levels lower than Basin Plan standards) and the potential for increased solubility of trace metals;

- Determination of the extent and impact from non-point sources (NPS) of urban pollutants (e.g. leaking USTs, improper disposal, etc.), namely in terms of isolating affected reaches; and

- Sedimentation to local water supply reservoirs, sediment accumulation in lower-gradient reaches, and potential transport of rural and/or urban-pollutants.

6.2 Watershed Catchment Vulnerability

The preliminary findings of this Assessment suggest that considerable dilution is occurring within the PSA, at least to the extent that typical urban pollutants are not detectable at cumulative loading sites. This finding suggests that some level of assimilative capacity exists within the lower reaches of the monitored waterways. With this understanding, the County is in a position to be proactive in terms of addressing future sources of urban pollutants by planning at a watershed scale. This level of planning will help the County to minimize adverse affects to surface water quality from existing sources identified in this Assessment and new ones that can be reasonably anticipated as build-out continues under the County's currently adopted General Plan.

To accomplish this, the five major watersheds that comprise the PSA were further delineated into drainage catchments, as described in Chapter 2.0 and depicted in **Figures 2-9**, **2-13**, **2-17**, **2-22**, and **2-25**. These drainage catchments were given unique identifiers (e.g. US01 – Upper Sullivan Creek, Catchment Unit No. 1) to allow for further analysis using geographic information systems (GIS). This delineation enables the County to identify specific drainage catchments where urban development will be the most concentrated at build-out; thereby providing an indication of each catchment's potential vulnerability to urban pollutants and, more importantly, enabling the prioritization of specific reaches within the PSA based on the associated vulnerability.

It is well documented that runoff from urbanized areas is generated from a number of sources including residential areas, commercial and industrial areas, roads, highways, and bridges. Essentially, any surface that does not have the capability to pond and infiltrate water will produce runoff with the timing and quantity of flow largely determined by a given storm event and the percentage of the drainage area covered by impervious surfaces. With additional impervious surface cover, such as rooftops, streets, parking lots, rainfall is no longer able to infiltrate into the soil column. As a result, the timing of peak flow is generally reduced and the quantity of flow is increased. A generally accepted method to measure watershed risk is to measure the level of impervious surface area increases in a given watershed unit or catchment, since it can be reasonably assumed that more rainfall will be converted to direct runoff. This phenomenon allows for a more rapid discharge of urban pollutants directly to receiving waters and, ultimately, could lead to cumulative water effects in higher order receiving waters.

Historically, as urbanization occurred and storm drainage infrastructure systems were developed the conventional reasoning was to limit the nuisance of increased runoff volumes by conveying the runoff off-site in the most efficient manner possible. As a result, streams that receive storm water runoff frequently cannot convey the large volumes of water generated during runoff events without degradation of the receiving stream. In addition to the problems associated with excess water volume, the levels of toxic or otherwise harmful pollutants in storm water runoff can cause significant water quality problems in receiving waters, which in the case of the PSA, drain to water supply reservoirs. It is also important to note that although typical urban pollutants were not detected during Phase 1 of the MRP, this finding may not hold true as future monitoring occurs and as build-out continues and further limits assimilative capacity of local waterways.

In recognition of the well-established correlation between impervious surfaces and water quality degradation, an estimation of impervious surface cover was considered an appropriate method for assessing the relative vulnerability of the numerous catchments that comprise the PSA. More over, it was considered necessary to further isolate those drainage catchments that would be the most vulnerable to urban development in order to enable prioritization from a planning perspective. This technique included the estimation of future impervious cover based on a County zoning build-out scenario. This was performed in conjunction with a road density analysis to isolate potentially chronic sources of sedimentation. Although the use of the zoning coverage carries the potential to over-estimate impervious cover, at least in the interim, it provides the best practical information to enable accurate watershed planning in terms of non-point sources of pollution and the large land area that comprises the PSA (224.8 square miles). Other methods, such as direct measurement which entails directly measuring individual components of impervious cover, were simply impractical by virtue of the limited time and funding available.

In order to assess relative vulnerability for individual drainage catchments that comprise the PSA, it was necessary to categorize County zones based on allowable development intensities as defined in Title 17 of the County's Zoning Ordinance and summarized in **Table 6-1**. Four development intensity categories (1 through 4) were developed to cover the range of development intensities present within the County. Category 1 includes all zones where the ultimate build-out would result in less than 5 percent of the property containing impervious surface cover. Zones in Category 2 have maximum development intensities that range from 5 to 25 percent impervious surface area. Development intensities in Category 3 range from 25 to 75 percent; while Category 4 development intensities are greater than 70 percent. The exception to these categories occurs where no zone is applied to the County's parcel coverage, which is generally limited to the City of Sonora. This classification scheme provided the best opportunity for isolating the highest concentrations of urbanized development (e.g. areas with greater than 70 percent impervious surface area), as shown in **Figure 6-1**.

The delineations illustrated in **Figure 6-1** provide an indication of where specific pollutant loadings could occur based on the types of land uses present in conjunction with maximum extent of impervious surface cover. For example, Category 4 includes a majority of the commercial and industrial uses and the highest densities of residential development. Likewise, Category 3 includes lower densities of residential and commercial development and major day-use recreational areas. Category 1 includes all agricultural lands, timber production zones, and extensions of public lands (e.g. National Forest) into the PSA.

TABLE 6-1
DEVELOPMENT INTENSITY CATEGORIES

Zone	Use Density (a)	cover (b)	Impervious Class (c)
R-1	6units/ac	up to 35%	3
R-2	12units/ac	up to 70%	4
R-3	15units/ac	up to 85%	4
RE-1	FAR = 0.5	50%	3
RE-2	FAR = 0.5	50%	3
RE-3	FAR = 0.5	50%	3
MU	15units/ac	up to 85%	4
K	1 unit/5000 ft2	50%	3
C-K	FAR=0.5	50%	3
C-O	1unit/2,500 ft2	up to 100%	4
C-1	1unit/2,500 ft2	up to 100%	4
C-2	1unit/2,500 ft2	up to 100%	4
M-1	1unit/7,500 ft2	up to 80%	4
M-2	1unit/7,500 ft2	up to 80%	4
BP	1unit/2,500 ft2	up to 100%	4
P	Variable	<5% assumed	1
AE-37	2units/37ac	<1%	1
A-20	1unit/10ac	<1%	1
A-10	1unit/5ac	1.1%	1
O	n/a	<1%	1
O-1	n/a	<1%	1
RE-5	FAR =0.2	20%	2
RE-10	FAR=0.2	20%	2
C-S	FAR=0.1	10%	2
TPZ	1unit/37ac	<1%	1
MPZ	1unit/20ac	<1%	1
Undefined	N/A	N/A	0(D)

(A) From Title 17, Zoning Code
(B) Assumptions: Indust. 1 unit 6,000 square feet
Res/Com 1 unit 2,500 square feet
(C) Cover classes - 1 = <5%;2 = 5-25%; 3 = 25-50%; 4 = >50%
(D) 0 – Applies to the undefined zones; most of which are limited to the City of Sonora.

Source: Tuolumne County, 1997; ESA, 2006

Figure 6-1

As previously indicated, water quality monitoring conducted in support of this Assessment did not sample site-specific reaches that drain one main land use. This approach was considered appropriate in the context of the numerous studies conducted by the U.S. EPA to characterize the nature of urban storm water runoff in conjunction with the need to obtain supporting evidence of whether County land uses are contributing significant concentrations of major pollutants. Data sources available from the EPA include the National Urban Runoff Program (NURP); the USGS Urban Stormwater Database; and the Federal Highway Administration (FHWA) study of storm water runoff loadings from highways. In addition to these federal sources, there is a great deal of information in the technical literature, as well as data collected by the State of California (e.g., Caltrans).

The most comprehensive study of urban runoff was the NURP, conducted by the EPA between 1978 and 1983. NURP was conducted in order to examine the characteristics of urban runoff and similarities or differences between urban land uses, the extent to which urban runoff is a significant contributor to water quality problems nationwide, and the performance characteristics and effectiveness of management practices to control pollution loads from urban runoff (U.S. EPA, 1983). Sampling was conducted for 28 NURP projects which included 81 specific sites and more than 2,300 separate storm events (U.S. EPA, 1983). NURP focused on the following ten constituents:

- Total Suspended Solids (TSS)
- Biochemical Oxygen Demand (BOD)
- Chemical Oxygen Demand (COD)
- Total Phosphorus (TP)
- Soluble Phosphorus (SP)
- Total Kjeldahl Nitrogen (TKN)
- Nitrate + Nitrite (N)
- Total Copper (Cu)
- Total Lead (Pb)
- Total Zinc (Zn)

Since the NURP, other important studies have been conducted that characterize stormwater. The University of Alabama and the Center for Watershed Protection were awarded an EPA Office of Water 104(b)3 grant in 2001 to collect and evaluate stormwater data from a representative number of NPDES (National Pollutant Discharge Elimination System) MS4 (municipal separate storm sewer system) stormwater permit holders. The initial version of this database, the National Stormwater Quality Database Version 1.1 (NSQD) is currently being compiled (Center for Watershed Protection, 2004). Preliminary data results for the NSQD are included in **Table 6-2**.

TABLE 6-2
MEDIAN VALUES AND EVENT MEDIAN CONCENTRATIONS FOR SELECTED PARAMETERS IN THE NSDQ, VERSION 1.0

Parameter	Overall	Residential	Commercial	Industrial	Freeways	Open Space
Area (acres)	56	57.3	38.8	39	1.6	73.5
% Imperv.	54.3	37	83	75	80	2
Precip. Depth (in)	0.47	0.46	0.39	0.49	0.54	0.48
TSS (mg/L)	58	48	43	77	99	51
BOD (mg/L)	8.6	9	11.9	9	8	4.2
COD (mg/L)	53	55	63	60	100	21
Fecal Coliform MPN/100mL)	5,081	7,750	4,500	2,500	1,700	3,100
NH3 (mg/L)	0.44	0.31	0.5	0.5	1.07	0.3
NO2+NO3 (mg/L)	0.6	0.6	0.6	0.7	0.3	0.6
Nitrogen, Total Kjeldahl (mg/L)	1.4	1.4	1.6	1.4	2	0.6
Phos., total (mg/L)	0.27	0.3	0.22	0.26	0.25	0.25
Cd, total (ug/L)	1	0.5	0.9	2	1	0.5
Cu, total (ug/L)	16	12	17	22	35	5.3
Pb, total (ug/L)	16	12	18	25	25	5
Ni, total (ug/L)	8	5.4	7	16	9	ND
Zn, total (ug/L)	116	73	150	210	200	39

ND = not detected, or insufficient data to present as a median value.

Source: Center for Watershed Protection, 2004

A major goal of the NSQD project is to provide a benchmark for comparison with locally collected data. The NSQD provides typical values for associated land use classes that enable comparisons with local monitoring data (e.g. Phase 2 of the MRP). **Table 6-3** provides a comparison of the NURP and NSQD studies in order to show current Event Median Concentrations (EMCs) for key constituents (Center for Watershed Protection, 2004). In general, the results from NURP and the NSQD indicate that there is not a significant difference in pollutant concentrations in runoff from different urban land use categories. However, the studies do show that there is a significant difference in pollutant concentrations in runoff from urban sources as compared to runoff produced from more rural, non-urban areas, such as those areas that characterize a vast majority of the PSA.

TABLE 6-3
COMPARISON OF NURP AND NSQD DATA

	Overall		Residential		Commercial		Open Space	
Parameter	NSQD Median	NURP Median	NSQD Median	NURP Median	NSQD Median	NURP Median	NSQD Median	NURP Median
Area (acres)	56	68.5	57.3	57.5	38.8	27.5	73.5	3775
TSS (mg/L)	58	100	48	101	43	69	51	70
Pb, total (ug/L)	16	144	12	144	18	104	5	30
Cu, total (ug/L)	16	34	12	33	17	29	NA	NA
Zn, total (ug/L)	116	160	73	135	150	226	39	195
Nitrogen, Total Kjeldahl (mg/L)	1.4	1.5	1.4	1.9	1.6	1.18	0.6	0.97
NO2+NO3 (mg/L)	0.6	0.68	0.6	0.74	0.6	0.57	0.6	0.54
Phos., total (mg/L)	0.27	0.33	0.3	0.38	0.22	0.20	0.25	0.12

Source: EPA, 1983; Center for Watershed Project, 2004

A slight deviation during the last event of Phase 1 of the MRP, included the acquisition of more, site-specific runoff data for two urbanized sections of the County. These site locations were sampled to provide initial comparisons with the NURP and NSQD datasets. For comparison purposes, the data that was acquired provided TSS values that ranged from 46 to 100 mg/L. The turbidity values were notably higher at 66.3 and 183 NTUs. Similar to the pH results for the seven monitoring sites, the pH at the discharge locations were 5.7 and 5.68, respectively. Oil and grease were not detected at either location at the method reporting limit (5.0 mg/L). From these preliminary datasets, the TSS, turbidity, and pH values would suggest that additional site-specific testing is warranted.

Impervious Surface and its Effects

As shown in **Figure 6-1** and supported by the data provided in **Appendix D**, the total land area within the PSA expected to be covered by 70 percent or more impervious area at build-out is approximately 2.4 percent, while 18.4 percent of the PSA land area would be covered by 25 percent or more of impervious surface cover. Lands within the Deer Creek, Kanaka Creek, and Rough and Ready Creek sub-watershed units are planned for minimal development and do not receive drainage flows from more urbanized sections of the PSA. Therefore, these sub-watershed units are considered to have low vulnerability in terms of receiving substantial inputs of urban-type pollutants. In this context, these areas may represent viable mitigation lands.

Watershed units with the greatest vulnerability to urban runoff within the PSA include specific catchments contained within the Curtis Creek, Lower Sullivan, Mormon Creek, Turnback Creek, Upper Sullivan Creek, and Upper Woods Creek sub-watersheds. To a lesser extent, certain catchments within the Bear Creek and Big-Oak Flat-Groveland watershed units would also be moderately vulnerable. Although not reflected by the percentage of total sub-watershed area, the Curtis Creek sub-watershed unit and, more specifically, catchment CC04 contains the highest concentration of lands classified Category 4 (63.8 percent) at build-out (see **Figure 6-**1 and **Appendix D**). Further, more than 35 percent of the land base within catchments CC01A (35.6 percent), CC02 (54.7 percent), and CC03 (37.5 percent) is classified as Category 3 or 4. Given these findings, the upper reaches of the Curtis Creek sub-watershed unit would be considered highly vulnerable to urban pollutant loading and should receive prioritization for future NPS programs.

Likewise portions of the Woods Creek, Upper and Lower Sullivan Creek, Mormon Creek, Big-Oak Flat-Groveland, and Turnback Creek watershed units are vulnerable to additions of impervious surfaces, as shown in **Figure 6-1**. More specifically, catchments within the Lower Sullivan Creek sub-watershed unit that would contain large areas within Categories 3 and 4 include LS02 (58.6 percent), LS03 (79.4 percent), and LS06 (41.8 percent). Within the Upper Sullivan Creek sub-watershed unit, catchments delineated as containing large areas of Categories 3 and 4 include US01 (48.7 percent), US03 (56.9 percent), and US04 (49.2 percent), US12 (69.4 percent), US13 (39.2 percent), and US14 (43.9 percent). Other catchments within the PSA that would be rated as having moderate to high vulnerabilities include: BG04 (78.7 percent), BG12 (79.0 percent), BG13 (58.7 percent), MC01A (42.1 percent) MC01B (66.2 percent), MC01C (69.9 percent), TC04 (44.1 percent), TC05 (40.8 percent), WC03B (35.4 percent), and (WC12 (42.7 percent). It is also important to note that the City of Sonora was not rated and, therefore, Appendix D underrates the potential impervious cover for catchments WC04, WC05, WC07, and US05.

In the context of the high fraction of Categories 3 and 4 within the above-identified catchments, a direct relationship may be demonstrated between the level of impervious surface cover within each watershed catchment and increased bank scour within receiving waters. A direct-relationship between urbanization (i.e. % watershed imperviousness) and the number of bankfull flows occurring annually is well-established (Leopold, 1968; EPA, 1999); whereby it has been estimated that a watershed with 25% impervious surfaces is subjected once every five years to an event of peak volume equivalent to the 100-year storm under completely forested conditions. At 38% imperviousness, this same event occurs every 2.5 years, and at 65% imperviousness it occurs annually (Klein 1979; EPA, 1999). These processes also contribute direct increases in contaminant loadings, such as petroleum byproducts, pesticides, industrial solvents, which partition strongly to fine particles with high ratios of surface area to volume. This phenomenon demonstrates the need for a comprehensive drainage ordinance that requires new projects to maintain runoff volumes and peak timing to pre-project levels.

In many instances, the impacts on receiving streams due to high storm water flow rates or volumes may be more significant than those attributable to the contaminants found in storm water discharges. The discussion provided in Chapter 4.0 of this Assessment generally supports this hypothesis, in that at a broad scale, there is a large fraction of controllable sediment (see **Table 4-2**). Impacts of urbanization and increased storm water discharges to receiving streams documented in this Assessment include:

1. Evidence of increases in the number of bankfull events and increased peak flow rates;
2. Sedimentation and increased sediment transport;
3. Increased siltation (burial of stable habitats);
4. Stream bed scouring (e.g., undercutting);
5. Aesthetic degradation (e.g., loss of shade); and;
6. Changes in stream morphology (e.g., channelization, reduced depth).

6.3 Response to the Findings

The principal findings of the Assessment Report would suggest that the County's Water Quality Plan place emphasis on addressing three principal water quality concerns. This section provides additional discussion on the principal findings and identifies potential actions that could be taken in response to the principal water quality concerns including (1) fecal coliform bacteria and nutrients, (2) urban non-source point pollutants (e.g. leaking USTs, disposal practices, pH uncertainties, etc.), and (3) sedimentation. These three topics are covered under the following subheadings.

Fecal Coliform Bacteria and Nutrients

As described in Chapter 5.0, fecal coliform levels in all the monitored waterways were above Basin Plan standards at one or more times during the first phase of the MRP. The two primary non-point sources thought to contribute to these elevated levels include concentrated areas of failing individual septic systems and unobstructed grazing practices. Alterations in natural drainage patterns within the PSA, mainly from roadways, likely create additional pathways that enable coliform bacteria to enter waterways; similar to that of sediment transport.

Nutrient inputs are also generally associated with these septic tank effluent and grazing practices and are further influenced by applications of various fertilizers. Due the complexity of the nutrient cycle (e.g. plant uptake, etc.) for various macro-nutrients[1], specific nutrients may be detected at higher concentrations at more, site-specific reaches within the PSA. The low concentrations detected at the Phase 1 monitoring sites are likely attributed to higher level dilution from less-affected land areas and, thus may be less-representative of more-specific reaches.

The County has identified three primary factors that limit the performance of on-site waste water systems. These include shallow depths to bedrock, coarse-textured soils, and restrictive lot sizes and/or configurations. Unobstructed grazing practices become problematic at a point when livestock congregate in close proximity to or within creek channels and/or contributing drainages where manure accumulates. The preferable method for mitigating grazing affects is to establish riparian buffer standards, which outline minimum setback requirements.

Corrective measures for failing septic systems are more problematic in that each system in need of replacement may require expensive on-site improvements and/or specially engineered systems. In some instances on-site restrictions may only be corrected through an extension of sewer service, which would only be cost-effective for clusters of development. However, regardless of the corrective action taken, water quality improvements in terms of fecal coliform reductions would not be expected immediately following the corrective action due to the preexisting contamination and the extent of its down-slope migration.

Due to the diffuse nature of NPS loadings from grazing practices and differing management practices employed on a property-by-property basis, it is difficult to isolate specific areas that should receive priority. In general, the County's Agricultural Commissioner and/or Farm Advisor would need to have the ability to document and map problematic areas verses non-problematic areas on a parcel-by-parcel basis; similar to the approach of identifying problematic septic systems. Such an effort, however, would be both time consuming and costly as it would be labor intensive. As a result, the idea of establishing buffer standards would likely be more cost-effective in the context that grazing operations blanket the entire land area within the lower reaches of the PSA.

1 Essential elements used by plants in relatively large amounts for plant growth are called macronutrients. The major macronutrients are nitrogen (N), phosphorous (P), and potassium (K). Calcium (Ca), magnesium (Mg), and sulfur (S) are also macronutrients.

Urban Non-Point Source Pollution

Data collected through Phase 1 of the MRP indicates that urban land uses are currently not discharging high concentrations of urban pollutants (e.g. trace metals, VOC, etc.) into downstream water supply reservoirs. The leading factor thought to contribute to these non-detectable levels (see Tables 5-5 and 5-6) is attributed to the existing land development pattern. In general terms, urban and residential areas are concentrated in the middle to upper reaches of the PSA while agricultural and grazing uses comprise much of the PSA within the lower reaches. This development pattern is thought to provide considerable dilution to upper, more developed reaches in the PSA (e.g. East Sonora) prior to flows entering Don Pedro Reservoir. However, this dilution effect is likely less influential within the Mormon Creek Watershed, due to the closer proximity of residential development to New Melones Reservoir. Further, the actual quantities of dilution provided in the lower reaches of the PSA have not been quantified as part of this Assessment and, therefore, even gross drainage calculations would be desirable to support this finding.

Based on the analytical results and work completed as part of this Assessment, the County is in an advantageous position to manage the watersheds that comprise the PSA in a way that minimizes adverse water quality effects to local waterways and, more importantly, downstream water supply reservoirs. The WQP can be developed in a way that minimizes polluted runoff by incorporating a watershed or drainage catchment scale planning methodology and employing a sensible combination of pollutant source control and site specific treatment control measures. Watershed planning at the catchment scale enables the prioritization of smaller drainage units containing high concentrations of existing or planned forms of urban development. As some of these areas could have runoff similar in quality to the data provided in Table 6-2 and 6-3, this planning methodology will allow the County to focus outreach efforts, potential grant funding opportunities, and testing preferred best management practices (BMPs) at these locations.

This concept is illustrated in **Figure 6-2**; whereby localized drainage catchments are rated based on the level of impervious surface area provided in **Figure 6-1** and the ratings based on the maximum allowable building intensity as provided in **Table 6-1**. Prioritized watershed catchments should be the primary focus of urban stormwater controls and future monitoring activities. Monitoring activities should be focused to those catchments with the highest priority ratings. Due to large capital expenditures associated with the construction and maintenance of treatment-oriented BMPs, the first step in planning the location and type of treatment BMP is to understand that large reductions in treatment BMP size and investment can be made by (1) reducing the runoff volumes that need to be captured, infiltrated, or treated, and (2) controlling sources of pollutants. These two strategies are the most cost-effective in managing urban runoff.

Figure 6-2

There are four basic strategies for treating runoff prior to it entering a waterway and include (1) infiltrating runoff into the soil, (2) retaining runoff for later release with the detention providing treatment, (3) conveying runoff slowly through vegetation (e.g. bioretention[2]), and (4) treating runoff on a flow-through basis using various treatment technologies (e.g. oil and grease separators). Incorporating these design features into new development is generally less difficult as opposed to existing development. In existing developments the County is limited in terms of options for the placement of structural water quality BMPs, such as detention facilities, since these facilities can not be cost-effectively integrated at a site-specific level. For new development, the California Stormwater BMP Handbook identifies general gross-area thresholds for the inclusion of treatment-oriented BMPs (CASQA, 2003):

- Residential ≥ 10 units
- Commercial ≥ 1 acre
- Parking lots, road project ≥ 5,000 square feet
- Redevelopment ≥ 5,000 square feet impervious
- Retail Gasoline Outlets
- New and Redevelopment projects above 1 acre or 10,000 square feet of impervious area.

There are many factors that may affect runoff discharge from a particular site; some of these include: precipitation, soil permeability, watershed area, ground cover, antecedent moisture, storage in the watershed, and time parameters. Given the varying influences to runoff at any one site, it is often difficult to obtain an accurate prediction of the amount of runoff to ensure the integrity of a particular treatment. However, too partially account for this problem control measures should be designed based on anticipated runoff velocities from smaller, more discrete catchments within the drainage network. The drainage catchments delineated in **Figure 6-2** provide insight as to possible drainage influences for future engineering applications based on localized hydrology. Newly prescribed BMPs should be designed based on the maximum expected runoff volumes (e.g. 50-year, 24-hour rainfall intensity) from both on- and off-site influences. Modeling efforts should also include an accurate characterization of land use and soil type to determine an appropriate Runoff Curve Number (RCN). These concepts and more specific BMPs are expected to be more thoroughly evaluated and integrated into the County planning process as part of the WQP.

In addition to planning for increased runoff, the County's objective of controlling urban non-point sources of pollution includes isolating specific drainage catchments containing contaminated sites. As part of the County's Groundwater Protection Report (1999), a database of sites was created. Currently, the database documents 58 sites with Class V injection wells[3], 45 sites with WDRs issued by the Regional Water Quality Control Board, 67 sites with underground fuel storage tanks, and 74 active commercial sites with on-site sewage disposal. Although designed to be GIS compatible, to date, much of this data has not been integrated into the GIS. The ability to overlay these data with drainage catchments would further enhance the prioritization ratings depicted in **Figure 6-2**.

2 Bioretention basins direct sheet flow across a grass buffer strip to a ponding area for infiltration. They utilize soils and both woody and herbaceous plants to remove pollutants from stormwater runoff (EPA, 1999).

3 Typically, Class V injection wells are shallow "wells," such as septic systems and drywells, used to place nonhazardous fluids directly below the land surface. Some examples of Class V wells are agricultural drainage wells, storm water drainage wells, large capacity septic systems, sewage treatment effluent wells, mine backfill wells, special drainage wells, heat pump/air conditioning return flow wells, and industrial wells. For facilities that generate nonhazardous wastes, Class V wells provide for disposal when there is no access to a sewer system.

Due to various complexities in treating NPS pollution from urban sources, emphasis within the WQP should be placed on approaches that minimize existing on-site effects (e.g., erosion control, good housekeeping, etc.) and combining this effort with a well-focused education and outreach program and limited site-specific monitoring program (e.g., outfall sampling). The County's MRP provides the initial framework for future monitoring and should be adjusted to enable site-specific monitoring at the base of the prioritized catchments. In addition to those parameters identified in Table 5-2, more site-specific water quality testing may also include the following constituents based on the plausible range of localized land uses:

1. Polycyclic Aromatic Hydrocarbons [PAHs] (EPA 610).
2. Organochlorine Pesticides (EPA 8081A).
3. Organophosphorus Pesticides (EPA 8141B).
4. Semi-Volatile Organic Compounds (EPA 8316, EPA 8270C).
5. PCBs (EPA 8082).

In addition to the collection of grab samples from site-specific urban runoff locations, which will require the use of an analytical laboratory, the County has allocated funding associated with this grant project for the purchase of field monitoring equipment. The instrumentation available will allow County staff and local citizen monitors to track pH, specific conductance, temperature, turbidity, and flow at the existing monitoring sites and new monitoring sites that will be identified in the WQP. The existing monitoring sites that should be carried forwarded into Phase 2 of the MRP include SV-2, CT-1, TB-1, GV-1, and WD-1. The tracking of pH is considered especially critical due to the low pH values recorded during the first phase of the MRP and the need to establish trends and further isolate potential influences.

Erosion and Sedimentation

As provided in Chapter 4.0, the coarse-scale sediment budget suggests that there is a controllable fraction of current sediment production within the Sullivan Creek watershed. Conservative estimates indicate that erosional processes are generating sediment volumes almost 10 times greater as compared to natural conditions. Further, based on the extent of topographic alteration, primarily from road development, the average quantity of eroded sediment delivered to the stream network is more than 20 times greater as opposed to natural conditions. Based on local observations, roads, property ground coverage, and unpaved driveways are thought to account for the largest fraction of the total sediment and associated delivery. Based on limited observations outside the Sullivan Creek watershed, these concepts are also applicable to the other four watershed units that comprise the PSA.

In the context of the cumulative sediment sources identified in Chapter 4.0, the County's ability to manage erosion is best focused on the existing roadway system, which has altered local drainage pathways, thereby enhancing the delivery of eroded sediment. In general terms, roads efficiently intercept surface runoff and subsurface flow, concentrate it within roadside ditches, and redirect it toward natural drainages and creeks through culverts and/or over-side drains. Increasing slope steepness and length further intensifies this effect. Due to this association, prioritization of individual catchments by road density was considered an appropriate method to isolate those drainage

catchments with the highest potential risks for enhanced sediment delivery. **Figure 6-3** illustrates the relative rankings. As shown, drainage catchments US03, US04, US12, LS02, LS05, and BG13 exhibit the highest rankings; while several other catchments are identified as a moderately high priority. In the future, to further enhance the prioritization ratings provided in **Figure 6-3**, the inclusion of construction sites would be ideal to further enable correlation between sediment production and relative delivery.

By virtue that roads in themselves are expensive to construct and important to the County's economic base, road realignments and/or decommissioning are not considered feasible options for the management of sediment delivery. Rather, the control of sediment delivery from roadways needs to work within the confinements of the existing roadways system. To accomplish this, it is important that improvements be focused at minimizing high runoff velocities along roadway conveyance ditches and enhancing soil protection below over-side drains and culverts. As commonly observed throughout the PSA, even if roadside embankments are well-vegetated and actively eroding, the enhanced connectivity provided by roadside ditches to local waterways effectively conveys runoff from adjacent properties, which in many instances is highly turbid (see **Figure 6-4**, Photographs A and B). This connectively is further enhanced by roadways that are oriented parallel or diagonally along the dominant slope angle and more so in instances where slope lengths exceed 100 feet. At points where runoff is diverted away from the roadway, the increased velocity may result in the formation of larger erosion features (e.g. gullies) in down-slope locations. In instances where its impractical to minimize the length of roadside ditches, emphasis should be placed on providing down-slope erosion protection measures such as riprap for initial energy dissipation and bioengineering[4] methods further down-slope to maintain slower runoff velocities (see **Figure 6-4**, Photograph B).

Since inputs of sediment into roadside ditches are highly contingent upon adjacent land use practices, alterations in natural drainage patterns from roadways is considered only part of the problem. As discussed in Chapter 4.0, local observations indicate that management of residential and commercial properties is highly variable from a soil erodability perspective. The principal factor contributing to the removal of sediment on adjacent properties, which leads to enhanced delivery into roadside ditches, is the exposure of bare ground to the erosive effects of precipitation and its subsequent runoff. For this reason, the maintenance of some form of groundcover (e.g. plant cover, leaf litter, gravel, etc.) to limit the exposure of bare ground is critical to controlling these sources of sediment. Due to the frequent disturbance and direct connection to roadside ditches, unpaved driveways will be more problematic in terms of sediment control. Short of requiring the paving of entire driveway segments, solutions may include adding a gravel base, installing down-slope sediment traps, waterbars, and/or a combination thereof.

4 Bioengineering uses plants and structures together in mutually reinforcing or complimentary roles. The structural components initially protect and stabilize the site and create a stable zone for the plants to grow. Bioengineering techniques are used to prevent erosion on upland slopes, to protect streambanks and channels against erosion, and provide slope stability.

Figure 6-3

Figure 6-4

In terms of the erosive forces affecting waterways within the PSA, the contributing sources of sediment are the most practical means at which to control additional inputs. However, as previously indicated, the increased flows produced by both the roadway system and additions of impervious surface cover, have resulted in channel widening and aggradation in lower gradient segments of the stream network and channel incision and bank scouring in higher gradient segments. This phenomenon has resulted in excessive contributions of sediment that has overwhelmed lower gradient reaches, due to the waterway's inability to transport it.

By virtue that the movement of sediment within channels is more episodic (e.g., just during large events), options for controlling sediment within the channels are limited, short of manually removing the sediment in sections exhibiting excessive accumulation. Rather, the most practical route would be allow the channel to naturally flush the sediment out over time and, in limited instances, identifying riparian enhancement projects in efforts to stabilize banks, minimize undercutting and bank scour, and increasing channel roughness (e.g. introduction of large-woody debris, boulders, etc.). Improvements within riparian zones should also be focused at increasing structural complexity in contributing drainages below urbanized areas in efforts to slow flow velocities and to limit their erosive power. Further, since development in many instances occurs up to the edge of natural waterways and/or contributing drainages, riparian enhancement projects should also focus on the removal of invasive plant species through the reintroduction of native forms of groundcover and mid-level tree canopies to enhance natural filtering processes.

The restoration of riparian communities are critical to maintaining good water quality within the five watersheds that comprise the PSA, since the physical and biological processes in the riparian area can modify water and its constituents in route from upland hillslopes to waterways as well as from upstream to downstream areas (Karr and Schlosser, 1978). Streamside soils and vegetation regulate the entry of groundwater, surface runoff, nutrients, sediments and other particulates, and fine and coarse organic matter to streams. During significant rainfall events, plant roots and fallen trees help stabilize the soil and streambanks. Vegetative protection of streambanks against erosion effectively reduces sediment delivery to downstream reaches. This role as a buffer and filter is often relied upon to limit stream degradation from land use activities in the uplands and should be integrated with current planning practices (e.g. approval of tentative maps, etc.).

In the context of the above-mentioned concepts, the following monitoring, planning, and BMP recommendations should be integrated into the WQP to the extent feasible to control excessive erosion and sedimentation and minimize the effects of continued urbanization within the PSA:

- As erosion control planning progresses, the County should isolate those priority watershed catchments that contain high proportions of the granitic and Mehrten (moderately erodible) HGUs that underlie much of the forested area in the upper sections of the PSA. Where feasible, the County should establish erosion test plots to confirm the validity of the values used in Table 4-2. Such plots should be established along road cuts in grus soil materials, natural areas (as a control), below culvert outfalls, and on distributed bare ground. A more detailed classification of the road system and percent distribution of the various erosion sources based on a road sampling scheme combined with more detailed estimates of sediment deliverability should also be established to refine the sediment production and the sediment delivery values.

- New development projects should be required to calculate pre- and post-project runoff volumes for affected watershed catchments. This approach would focus on changes to runoff in terms of timing, velocity, and attenuation requirements.
- Photo-document the mouth of Lower Sullivan Creek from the Jacksonville Road turn-out to track bar deposits over the next 10 years; measuring width and length of major deposits, their movement, and changes in vegetation
- The County should investigate the use of various erosion control techniques (e.g. erosion control blankets and mats, fiber roles, riprap, hydraulic plantings, mulching, biofilters, and cellular confinement systems) to identify preferable control methods, especially for steep roadway cutbanks and embankments that are exhibiting chronic forms of erosion.
- The County should develop and identify a preferred native plant list to provide direction for local landowners and developers to facilitate the establishment of a permanent vegetative cover in addition to temporary erosion control.
- A riparian and aquatic inventory should be conducted for the Woods, Sullivan, Mormon and Turnback Creek Watersheds to establish an indication of the relative health. Riparian enhancement projects should be prioritized for urbanized areas (see Figure 6-3) and areas immediately downstream. Additionally, an invasive species eradication program should be developed and implemented with willing landowners.
- Develop a road drainage and conveyance database to enable the tracking and isolation of chronic erosion and/or sedimentation sources (e.g. lack of down-slope protection) within the roadway system. Figure 6-2 should be used in prioritizing these investigations. All sources should be logged with a GPS and entered into a GIS.
- Inventory current construction projects according to APNs and overlay with drainage catchments in a GIS to aid in SWPPP monitoring. Figure 6-3 should be used in prioritizing these investigations.
- Initiate an annual, long-term monitoring program at Station SCR-1 (Upper Sullivan Creek below Potato Ranch Road) to track changes in the channels cross-section. Additionally, work with TUD to conduct a second bathometric survey for Phoenix Reservoir to provide additional comparison to values provided in Table 4-2 (see Chapter 4.0)
- As sediment production in up-slope locations is largely influenced at the property ownership level, the County should develop a technical assistance program to help landowner's better manage sediment production.
- As part of the WQP, develop a County-suggested list of site-specific BMPs to encourage uniform implementation and maintenance practices throughout the County.
- Watershed-scale drainage modeling should be conducted to establish a realistic SPI for varying rainfall intensities within each of the five watersheds that comprise the PSA.
- Using information provided in Figures 6-2 and 6-3 the County should identify several more site-specific water quality monitoring locations to enable comparisons between runoff generated from highly urbanized areas and those values provided in Tables 6-2 and 6-3.
- The County should coordinate with TUD in studying the feasible of extending sewer service into those areas identified as high priority in by the County Department of Environmental Health.

6.4 Limitations of this Report

This assessment provides useful and valuable information and represents a considerable effort of the involved agencies, contractors, and public. It was limited in duration, scope, detail, and analysis level due to constraints in budget, time, access, and overall resources. Where data are limited, hypotheses were developed along with recommendations to test or improve the understanding of watershed processes. Specific limitations are presented below to put the Assessment in the necessary context.

- This report does not seek to predict drainage within the foothill watersheds.
- Sediment delivery values provided in this report were derived from a combination of research and professional judgment. Values obtained were derived from gross estimates in the context of the assumption provided in Chapter 4.0. The calculations are not intended for site specific application. Coarse-scale sediment delivery budgets do a poor job rating site-specific erosion hazards as observed from properties with differing land covers and roadways. The input data required by the model is aimed at assessing the potential for sediment delivery based on a generalization of locally observed conditions. As a monitoring tool, the model is misaligned with what appears to be the primary source of erosion from roadways, unpaved driveways, and tracts with high proportions of bare soil.
- The analysis of fluvial and hillslope conditions is limited, ongoing, and incomplete. Data collection has been abbreviated at many locations due to access restrictions. Although the best available data were used in this study, the predicted sediment rates should be used with caution. No assessment of potential erosion and sediment delivery were conducted to determine what changes would occur as a result of catastrophic wildfire.
- Evaluation of aquatic and riparian habitat within the PSA was limited to roadway crossings and therefore is not considered representative of the entire stream length.
- There was only time to compare the broadest contrasts between land use impacts and habitat conditions. More subtle analysis of habitat changes to properly characterize recent land use activities requires a larger and more detailed database to make significant conclusions.
- The water chemistry analysis was limited to three sampling events, with supplemental data acquisition anticipated through, at minimum, 2009. Nonetheless, the sampling frequency remains limited and discontinuous and does not allow temporal analysis.
- The absence of sequential data for suspended loads, specific conductance and turbidity are limitations in this report. However, the monitoring framework established in the County's MRP provides a means for acquiring this data over the longer term and throughout the implementation of the WQP.

Chapter 7

Report Authors, Citations, and Persons Consulted

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CHAPTER 7

Report Authors, Citations, and Persons Consulted

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Justin Gragg, Hydrologist
Solomon McCrea, Geographic Information Systems (GIS)
Linda Huff, Environmental Scientist
Jamie Galos, Biologist
Joshua Boldt, Botanist
Tom Wyatt, Graphic Artist

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7.3 Other Persons Consulted

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Appendix A

Sediment Budget Calculations

ESA

Entire Sullivan Creek Hydrologic Area – Natural Conditions

SDR = Sediment Delivery Ratio

Sum of acres		GRIDCODE				**Natural Conditions**											
PWSNAME	ToBufDist	1	2	3	Grand Total	Low Erod	Mod Erod	High Erod	1	2	3	SUM	**SDR**	1	2	3	SUM
Curtis Creek	164	2,349	1,473	46	3,868	0.020	0.030	0.050	47.0	44.2	2.3	93.5	0.25	11.7	11.0	0.6	23.4
	328	1,329	1,320	37	2,685	0.020	0.030	0.050	26.6	39.6	1.8	68.0	0.15	4.0	5.9	0.3	10.2
	492	483	621	12	1,116	0.020	0.030	0.050	9.7	18.6	0.6	28.9	0.1	1.0	1.9	0.1	2.9
	493	63	117	2	182	0.020	0.030	0.050	1.3	3.5	0.1	4.9	0	0.0	0.0	0.0	0.0
Curtis Creek Total		4,224	3,530	97	7,851							195.2					36.5
Lower Sullivan Creek	164	3,234	1,401	70	4,706	0.020	0.030	0.050	64.7	42.0	3.5	110.2	0.25	16.2	10.5	0.9	27.6
	328	2,135	1,102	40	3,277	0.020	0.030	0.050	42.7	33.1	2.0	77.7	0.15	6.4	5.0	0.3	11.7
	492	925	493	12	1,429	0.020	0.030	0.050	18.5	14.8	0.6	33.9	0.1	1.8	1.5	0.1	3.4
	493	160	116	4	280	0.020	0.030	0.050	3.2	3.5	0.2	6.9	0	0.0	0.0	0.0	0.0
Lower Sullivan Creek Total		6,454	3,111	127	9,692							228.8					42.6
Soulsbyville Creek	164	2,019	1,455	30	3,505	0.020	0.030	0.050	40.4	43.7	1.5	85.6	0.25	10.1	10.9	0.4	21.4
	328	974	1,269	38	2,282	0.020	0.030	0.050	19.5	38.1	1.9	59.5	0.15	2.9	5.7	0.3	8.9
	492	318	674	24	1,015	0.020	0.030	0.050	6.4	20.2	1.2	27.8	0.1	0.6	2.0	0.1	2.8
	493	55	212	7	274	0.020	0.030	0.050	1.1	6.4	0.3	7.8	0	0.0	0.0	0.0	0.0
Soulsbyville Creek Total		3,366	3,611	99	7,076							180.6					33.1
Upper Sullivan Creek	164	3,017	4,883	244	8,144	0.020	0.030	0.050	60.3	146.5	12.2	219.0	0.25	15.1	36.6	3.1	54.8
	328	1,587	3,437	153	5,177	0.020	0.030	0.050	31.7	103.1	7.7	142.5	0.15	4.8	15.5	1.1	21.4
	492	553	1,254	40	1,847	0.020	0.030	0.050	11.1	37.6	2.0	50.7	0.1	1.1	3.8	0.2	5.1
	493	94	215	5	313	0.020	0.030	0.050	1.9	6.4	0.2	8.6	0	0.0	0.0	0.0	0.0
Upper Sullivan Creek Total		5,251	9,788	443	15,481							420.8					81.2
Grand Total		19,295	20,040	766	40,100							1025.4	total tons				193.4 total tons
												0.026	total tons per acre				0.005 total tons per acre

Undeveloped Area Outside of the Developed Area

Undeveloped area outside of the "developed area."

Sum of acres		GRIDCODE															
PWSNAME	ToBufDist	1	2	3	Grand Total	Low Erod	Mod Erod	High Erod	1	2	3	SUM	**SDR**	1	2	3	SUM
Curtis Creek	164	1764	1203	36	3003	0.020	0.030	0.050	35.3	36.1	1.8	73.2	0.25	8.8	9.0	0.4	18.3
	328	1028	1099	26	2153	0.020	0.030	0.050	20.6	33.0	1.3	54.8	0.15	3.1	4.9	0.2	8.2
	492	380	506	9	895	0.020	0.030	0.050	7.6	15.2	0.5	23.2	0.1	0.8	1.5	0.0	2.3
	493	42	99	2	143												
Curtis Creek Total		3213	2907	74	6194							151.2					28.8
Lower Sullivan Creek	164	1847	973	56	2875	0.020	0.030	0.050	36.9	29.2	2.8	68.9	0.25	9.2	7.3	0.7	17.2
	328	1229	746	31	2005	0.020	0.030	0.050	24.6	22.4	1.5	48.5	0.15	3.7	3.4	0.2	7.3
	492	534	324	7	865	0.020	0.030	0.050	10.7	9.7	0.4	20.8	0.1	1.1	1.0	0.0	2.1
	493	109	71	2	183												
Lower Sullivan Creek Total		3718	2114	96	5928							138.2					26.6
Soulsbyville Creek	164	560	730	16	1306	0.020	0.030	0.050	11.2	21.9	0.8	33.9	0.25	2.8	5.5	0.2	8.5
	328	295	598	26	919	0.020	0.030	0.050	5.9	17.9	1.3	25.1	0.15	0.9	2.7	0.2	3.8
	492	135	336	18	489	0.020	0.030	0.050	2.7	10.1	0.9	13.7	0.1	0.3	1.0	0.1	1.4
	493	27	111	4	142												
Soulsbyville Creek Total		1018	1774	63	2856							72.7					13.6
Upper Sullivan Creek	164	1142	2603	143	3888	0.020	0.030	0.050	22.8	78.1	7.2	108.1	0.25	5.7	19.5	1.8	27.0
	328	648	1765	84	2497	0.020	0.030	0.050	13.0	53.0	4.2	70.1	0.15	1.9	7.9	0.6	10.5
	492	229	610	23	862	0.020	0.030	0.050	4.6	18.3	1.2	24.0	0.1	0.5	1.8	0.1	2.4
	493	30	95	2	127												
Upper Sullivan Creek Total		2048	5073	253	7374							202.2					39.9
Grand Total		9998	11868	486	22352							564.3	total tons				109.0 total tons
												0.025	total tons per acre				0.005 total tons per acre

Developed Area

Developed area defined by road buffer.

Sum of acres 1		GRIDCODE 1																		
PWSNAME 1	ToBufDis 1	1	2	3	Grand Total	Low Erod	Mod Erod	High Erod	1	2	3	SUM	**SDR**	1	2	3	SUM	SDR	SDR	Erosion
Curtis Creek	164	555	260	10	825	0.360	0.700	0.100	199.7	181.7	1.0	382.5	0.5	99.9	90.9	0.5	191.2			
	328	288	213	10	512	0.360	0.700	0.100	103.7	149.2	1.0	254.0	0.34	35.3	50.7	0.4	86.3			
	492	100	113	2	215	0.360	0.700	0.100	35.9	78.9	0.2	115.1	0.17	6.1	13.4	0.0	19.6			
	493	20	18	0	38															
Curtis Creek Total		963	603	23	1,589							751.5					297.2			
Lower Sullivan Creek	164	1,310	414	14	1,738	0.360	0.700	0.100	471.5	289.6	1.4	762.5	0.5	235.7	144.8	0.7	381.3			
	328	861	343	9	1,213	0.360	0.700	0.100	309.9	240.2	0.9	551.1	0.34	105.4	81.7	0.3	187.4			
	492	373	164	4	541	0.360	0.700	0.100	134.1	240.2	0.4	374.8	0.17	22.8	40.8	0.1	63.7			
	493	48	43	2	93															
Lower Sullivan Creek Total		2,591	963	30	3,584							1688.4					632.3	0.98	619.7	1654.6
Soulsbyville Creek	164	1,383	698	14	2,095	0.360	0.700	0.100	497.7	488.6	1.4	987.8	0.5	248.9	244.3	0.7	493.9			
	328	646	652	12	1,310	0.360	0.700	0.100	232.4	456.4	1.2	690.1	0.34	79.0	155.2	0.4	234.6			
	492	177	329	6	511	0.360	0.700	0.100	63.6	230.4	0.6	294.5	0.17	10.8	39.2	0.1	50.1			
	493	25	99	3	127															
Soulsbyville Creek Total		2,230	1,778	35	4,043							1972.3					778.6			
Upper Sullivan Creek	164	1,786	2,190	97	4,073	0.360	0.700	0.100	642.8	1533.3	9.7	2185.9	0.5	321.4	766.7	4.9	1092.9			
	328	888	1,597	67	2,552	0.360	0.700	0.100	319.8	1117.8	6.7	1444.3	0.34	108.7	380.0	2.3	491.1			
	492	306	617	17	940	0.360	0.700	0.100	110.2	431.6	1.7	543.5	0.17	18.7	73.4	0.3	92.4			
	493	60	114	2	177															
Upper Sullivan Creek Total		3,040	4,518	184	7,742							4173.7					1676.4	0.978	1639.5	4081.8
Grand Total		8,824	7,863	272	16,958							8460.3	total tons				3334.9			
												0.50	total tons per acre				0.20			

Reduced for Twain Harte
Reduction factor is 0.978

Reduced for Sonora Hills
Reduction factor is 0.98

Roads

						Roads												
Sum of acres		GRIDCODE																
PWSNAME	ToBufDist	1.00	2.00	3.00	Grand Total	Low Erod	Mod Erod	High Erod	1	2	3	SUM	**SDR**	1	2	3	SUM	
Curtis Creek	164	31.57	10.46	0.23	42.26	0.900	1.000	1.100	28.4	10.5	0.3	39.1	0.8	22.7	8.4	0.2	31.3	
	328	13.10	8.00	0.15	21.25	0.900	1.000	1.100	11.8	8.0	0.2	20.0	0.5	5.9	4.0	0.1	10.0	
	492	3.65	2.99	0.04	6.68	0.900	1.000	1.100	3.3	3.0	0.0	6.3	0.2	0.7	0.6	0.0	1.3	
	493	0.71	0.30		1.01													
Curtis Creek Total		49.03	21.76	0.42	71.21							65.4					42.5	
Lower Sullivan Creek	164	78.83	15.46	0.15	94.43	0.900	1.000	1.100	70.9	15.5	0.2	86.6	0.8	56.8	12.4	0.1	69.3	
	328	45.84	12.74	0.12	58.70	0.900	1.000	1.100	41.3	12.7	0.1	54.1	0.5	20.6	6.4	0.1	27.1	
	492	18.56	5.38	0.16	24.11	0.900	1.000	1.100	16.7	5.4	0.2	22.3	0.2	3.3	1.1	0.0	4.5	
	493	3.03	1.70	0.12	4.86													
Lower Sullivan Creek Total		146.27	35.28	0.55	182.11							163.0					100.8	
Soulsbyville Creek	164	77.06	27.71	0.55	105.32	0.900	1.000	1.100	69.4	27.7	0.6	97.7	0.8	55.5	22.2	0.5	78.1	
	328	33.58	20.17	0.16	53.91	0.900	1.000	1.100	30.2	20.2	0.2	50.6	0.5	15.1	10.1	0.1	25.3	
	492	6.14	8.91	0.08	15.13	0.900	1.000	1.100	5.5	8.9	0.1	14.5	0.2	1.1	1.8	0.0	2.9	
	493	1.92	2.98		4.90													
Soulsbyville Creek Total		118.70	59.76	0.79	179.25							162.8					106.3	
Upper Sullivan Creek	164	90.29	90.46	3.91	184.67	0.900	1.000	1.100	81.3	90.5	4.3	176.0	0.8	65.0	72.4	3.4	140.8	
	328	51.92	75.66	2.25	129.83	0.900	1.000	1.100	46.7	75.7	2.5	124.9	0.5	23.4	37.8	1.2	62.4	
	492	18.49	27.19	0.39	46.07	0.900	1.000	1.100	16.6	27.2	0.4	44.3	0.2	3.3	5.4	0.1	8.9	
	493	3.35	5.84	0.09	9.28													
Upper Sullivan Creek Total		164.05	199.15	6.64	369.85							345.2					212.1	
Grand Total		478.05	315.95	8.41	802.41							736.3	total tons				461.7	total tons
												0.92	total tons per acre				0.58	total tons per acre

Values Used for Sediment Loading

Values for Sullivan Creek Sediment Budget

	Natual Erosion Rate tons per acre per year	Rationale	Developed Erosion Rate - tons per acre per year	Rationale	Road Erosion Rate - tons per acre per year	Rationale
High	0.05	3	0.9	6	1.1	9
Medium	0.03	2	0.7	5	1	8
Low	0.02	1	0.36	4	0.9	7

1, 2 & 3. Based on values of 0.02-0.04 tons/acre/year for Scott River from Sommarstrom et al. (1990); 0.04 tons/acre/year reported by Euphrat (1992); and 0.04 tons/acre/year in Idaho Rice et al. (1972).

4. Based on Euphrat's (1992) non-reservoir erosion rate of 0.1 acre-ft/mi2/yr, used 2,308 tons per ac-foot/yr which is 0.36 tons/acre/year.

5. Based on Kattleman's (1996) report of California Department of Forestry and Fire Protection Sierra Nevada-wide value of 0.2 acre-ft/mi2/yr, non-reservoir value, using 2,308 tons/ac-ft/yr the value is 0.72 tons/acre/year.

6. Value is scaled up from the Kattleman (1996) value indicated in number 5 above.

7. McGurk et al. (1996) use 0.9 T/acre-yr for paved roads after 3rd yr. Value is for acreage of paved road (22-24') + 8' for shoulder. Our road acreage is based on 22 foot road bed without shoulder so it should be a reasonable conservative estimate.

8. Scaled up from number 7 above.

9. Scaled up from number 8 above.

Phoenix Lake Sedimentation Rate Estimate

Based on values reported in Union Democrat newspaper article Wolfson (2005)
Lake created in 1852 and is approximately 88 acres in size.
Average depth is 10 to 15 feet but 5 feet or less in silt clogged areas.
Phoenix Lake dredged once in the 1980s but this did not remove much sediment (assume 20 acre-feet for this analysis).

	Estimate 1 (low)	**Estimate 2**	**Estimate 3** (maximum)
End Year	2005	2005	2005
Start Year	1852	1880	1890
207 acre-feet of Sedimentation in 'X' Years	153	125	115
acre-feet/year of sedimentation	1.35	1.66	1.80

20	Acre-feet dredged in 1980s (Assumed)
227	Total a-f of sed in 115 yrs
1.97	acre-feet/year

tons per year	2,484.1	3,040.5	3,624.2
Acres in Upper Sullivan Creek	15,481	15,481	15,481
Tons per acre per year delivered to Phoenix Lake	**0.16**	**0.20**	**0.23**

Phoenix Lake Trapping Efficiency (TE) 1 cubic feet = 0.028317 cubic meters

Need volume of Phoenix Lake in m3		ft3/ac-ft	ft3	m3/ft3	m3
Original volume =	825 acre-feet	43560	35,937,000	0.028317	1,017,623
Current volume =	618 acre-feet	43560	26,920,080	0.028317	762,292

Capacity-watershed ratio (C/W) (m3 capacity per km2 catchment area)	C/W	Trap Effec	t/ac-yr low value	**t/ac yr total w TE low value**	t/ac yr high value	**t/ac yr total w TE high value**
Original C/W	15,874	0.75	0.16	**0.21**	0.23	**0.31**
Current C/W	11,891	0.7	0.16	**0.23**	0.23	**0.33**

Based on the numbers reported in the Union Democrat article (Wolfson, 2005):
the minimum sedimentation rate would be from 1852-2005 or 0.16 tons per acre per year (0.21 tons/ac-yr including trapping efficiency);
the maximum sedimentation rate would be from 1890-2005 + what was removed by dredging in the 1980s or about 0.23 tons per acre per year (or 0.31 tons/ac-yr including trapping efficiency).

Phoenix Lake Sedimentation Rate Estimate, continued

Values for converting acre-feet to tons	
tons per cubic foot 10%(gr), 60%(s), 25%(si), 5%(cl)	0.04215
square feet per acre or cubic feet per acre-foot	43560
tons per acre-foot of sediment	**1,836**

Maximum Phoenix Lake Capacity	
88	acres
15	feet deep
1,320	acre-feet

Therefore, 825 acre-feet capacity seems reasonable

Capacity late 1800s	825	acre-feet
Current capacity	618	acre-feet
Total Amount of Sedimentation	207	acre-feet

References

Snyder, N.P., D.M. Rubin, C.N. Alpers, J.R. Childs, J.A. Curtis, L.E. Flint, and S.A. Wright, Estimating Accumulation Rates and Physical Properties of Sediment Behind a Dam: Englebright Lake, Yuba River, Northern California, Water Resources Research, Volume 40, Paper W11301, 19 pp., 2004.

Verstraeten, G. & J. Poesen, Estimating Trap Efficiency of Small Reservoirs and Ponds: Methods and Implications for the Assessment of Sediment Yield, Progress in Physical Geography, Volume 24 (2), pp. 219-251, 2000.

Wolfson, J., Shrinking Lake a Growing Concern, Union Democrat, September 30, 2005.

Appendix B

Channel Reach Photo-Documentation

(See Figures Folder)

ESA

Appendix C

Phase 1 MRP
Data Summary Report

ESA

ESA Water

8950 Cal Center Drive
Building 3, Suite 300
Sacramento, CA 95826
916.564.4500 phone
916.564.4501 fax

www.esassoc.com

March 24, 2006

Mark Houghton
Tuolumne County Public Works Department
2 South Green Street
Sonora, CA 95370

Subject: Monitoring Report for Phase 1 of the Tuolumne County Surface Water Monitoring and Reporting Program

Dear Mr. White:

Environmental Science Associates (ESA) is pleased to present the attached Monitoring Report for Phase 1 of the County's Surface Water Monitoring and Reporting Program (MRP), which meets requirements of the County's Quality Assurance and Project Plan (QAPP).

Field samples were collected and analyzed with pre-calibrated field sampling equipment utilizing standard protocols to eliminate the chance for error and cross-contamination. Post-field calibration checks were performed for all field samples. Samples requiring laboratory analysis were stored in a chilled cooler and delivered under chain of custody to California Laboratory Services (CLS) and AquaLab Water Analysis (AquaLab) for sample analysis and processing. Frontier Geosciences Inc.(Frontier) conducted laboratory low-level mercury analysis.

An analytical summery report is included as Exhibit A. Full laboratory results; including QA/QC data have been included as attachments to the summery report.

ESA appreciates the opportunity to provide our services to Tuolumne County. If you have any questions regarding this report, please call me at (916) 564-4500.

Sincerely,

Clint Meyer
Project Manager

204254-2.0

ESA Water

EXHIBIT A
ANALYTICAL SUMMERY REPORT

FALL/WINTER (2005-06)
ANNUAL SURFACE WATER MONITORING SUMMARY REPORT – PHASE 1
TUOLUMNE COUNTY WQP

Sample ID:	SV-1		
Sample Location:	Algerine Road Bridge	Sampling Dates:	11/8/2005, 12/1/2005, 1/18/2006
Sample Matrix:	Water	Lab Received Dates:	AquaLab: 11/8/2005, 12/1/2005, 1/18/2006 CLS, Labs: 11/9/2005, 12/9/2005, 1/19/2006
Sampler(s):		Report Date:	3/15/2006

Sampling Results

Analysis	Method	Sample	Units	RL/IAL	Sampling Dates 11/8/05	12/1/05	1/18/06	Min.	Max.
Flow	Field	Grab	feet/second		<1.0	4.8	5.7		
pH	Field	Grab	units	+/- 0.2	6.89	5.2	6.27	5.20	6.89
Temperature	Field	Grab	Deg. F	+/- 0.27	54.89	50.58	45.9	45.90	54.89
Dissolved Oxygen	Field	Grab	mg/L	+/- 2%	8.58	9.64	10.39	8.58	10.39
Specific Conductance	Field	Grab	uS/cm	+/- 0.5%	239	84	118	84.00	239.00
Turbidity	Field	Grab	NTU	+/- 2%	0.8	25.9	25.2	0.80	25.90
TSS	EPA 160.2	Grab	mg/L	5.0	ND	53	20	20.00	53.00
Hardness	SM-2340B	Grab	mg/L	1.0	120	38	49	38.00	120.00
Oil and Grease	EPA 1664	Grab	mg/L	5.0	ND	ND	ND	ND	ND
Nitrate and Nitrite (as N)	EPA 300.0	Grab	mg/L	0.500	ND	ND	0.46	ND	0.46
Microbiological									
Fecel Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	27	500	300	27.00	500.00
Total Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	240	1600	1100	240.00	1600.00
Volatile Organics									
1,1-Dichloroethane	EPA 8260B	Grab	ug/L	1.0	ND				
1,1-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND				
1,1,1-Trichloroethane	EPA 8260B	Grab	ug/L	2.0	ND				
1,1,2-Trichloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
1,1,2,2-Tetrachloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
1,2-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
1,2-Dichloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
cis-1,2-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND				
1,2-Dichloropropane	EPA 8260B	Grab	ug/L	0.5	ND				
1,2,4-Trichlorobenzene	EPA 8260B	Grab	ug/L	5.0	ND				
1,3-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
1,3-Dichloropropene	EPA 8260B	Grab	ug/L	0.5	ND				
1,4-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
Benzene	EPA 8260B	Grab	ug/L	0.5	ND				
Bromoform	EPA 8260B	Grab	ug/L	2.0	ND				
Bromomethane	EPA 8260B	Grab	ug/L	2.0	ND				
Carbon tetrachloride	EPA 8260B	Grab	ug/L	0.5	ND				
Chlorobenzene (mono chlorobenzene)	EPA 8260B	Grab	ug/L	2.0	ND				
Chloroethane	EPA 8260B	Grab	ug/L	2.0	ND				
Chloroform	EPA 8260B	Grab	ug/L	0.5	ND				
Chloromethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dibromochloromethane	EPA 8260B	Grab	ug/L	0.5	ND				

Report Approved By: _____

Dichlorobromomethane	EPA 8260B	Grab	ug/L	0.5	ND		
Dichloromethane	EPA 8260B	Grab	ug/L	2.0	ND		
Ethylbenzene	EPA 8260B	Grab	ug/L	2.0	ND		
Hexachlorobutadiene	EPA 8260B	Grab	ug/L	1.0	ND		
Naphthalene	EPA 8260B	Grab	ug/L	10	ND		
Tetrachloroethene	EPA 8260B	Grab	ug/L	0.5	ND		
Toluene	EPA 8260B	Grab	ug/L	2.0	ND		
trans-1,2-Dichloroethylene	EPA 8260B	Grab	ug/L	1.0	ND		
Trichloroethene	EPA 8260B	Grab	ug/L	2.0	ND		
Vinyl chloride	EPA 8260B	Grab	ug/L	0.5	ND		
Inorganic Analysis (Metals)							
Arsenic	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Cadmium	EPA 200.8	Grab	ug/L	0.25	ND	ND	ND
Mercury	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Antimony	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Beryllium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Chromium (total)	EPA 200.8	Grab	ug/L	2.0	ND	ND	ND
Copper	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Lead	EPA 200.8	Grab	ug/L	100.0	ND	ND	ND
Nickel	EPA 200.8	Grab	ug/L	20.0	ND	ND	ND
Selenium	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Silver	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Thallium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Zinc	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Low Level Mercury	EPA 1631	Grab	ng/L	0.50	1.23		
Herbicides							
Bentazon	EPA 8151A	Grab	ug/L	2.0	ND		
2,4-D	EPA 8151A	Grab	ug/L	1.0	ND		
Dalapon	EPA 8151A	Grab	ug/L	2.0	ND		
Dinoseb	EPA 8151A	Grab	ug/L	1.0	ND		
Picloram	EPA 8151A	Grab	ug/L	1.0	ND		
2,4,5-TP (Silvex)	EPA 8151A	Grab	ug/L	1.0	ND		
Pentachlorophenol	EPA 8151A	Grab	ug/L	1.0	ND		

RL/IAL: Reporting Limit/Instrument Accuracy Level
nd: Not detected

Report Approved By: _____

FALL/WINTER (2005-06)
ANNUAL SURFACE WATER MONITORING SUMMARY REPORT – PHASE 1
TUOLUMNE COUNTY WQP

Notes on Receiving Water Conditions at SV-1

Floating or suspended matter Y☒ N☐

If yes, describe: Plant Debris (11/8/05, 12/1/05, 1/18/06); Sediment (12/1/05, 1/18/06)

Visible films, sheens, or coatings Y☐ N☒

If yes, describe:

Discoloration Y☒ N☐

If yes, describe: Turbid (12/1/05, 1/18/06)

Algae, fungi, slimes, or objectionable growths Y☒ N☐

If yes, describe: Algae visible on rocks (11/8/05)

Odor/Other nuisance conditions Y☐ N☒

If yes, describe:

Aquatic life: None observed.

Report Approved By: _____

PHOTO DOCUMENTATION FOR SV-1

FALL/WINTER (2005-06)
ANNUAL SURFACE WATER MONITORING SUMMARY REPORT – PHASE 1
TUOLUMNE COUNTY WQP

Sample ID: SV-2
Sample Location: Potato Ranch Road Bridge
Sample Matrix: Water
Sampler(s):

Sampling Dates: 11/8/2005, 12/1/2005, 1/18/2006
Lab Received Dates: AquaLab: 11/8/2005, 12/1/2005, 1/18/2006
CLS, Labs: 11/9/2005, 12/9/2005, 1/19/2006
Report Date: 3/15/2006

Sampling Results

Analysis	Method	Sample	Units	RL/IAL	Sampling Dates 11/8/05	12/1/05	1/18/06	Min.	Max.
Flow	Field	Grab	feet/second						
pH	Field	Grab	units	+/- 0.2	1.75	5.9	5.1	5.27	6.48
Temperature	Field	Grab	Deg. F	+/- 0.27	6.48	5.27	5.76	44.80	52.48
Dissolved Oxygen	Field	Grab	mg/L	+/- 2%	52.48	47.946	44.8	9.20	10.85
Specific Conductance	Field	Grab	uS/cm	+/- 0.5%	9.2	10.42	10.85	89.00	112.00
Turbidity	Field	Grab	NTU	+/- 2%	112	102	89	2.34	85.40
TSS	EPA 160.2	Grab	mg/L	5.0	ND	110	20	20.00	110.00
Hardness	SM-2340B	Grab	mg/L	1.0	44	43	35	35.00	44.00
Oil and Grease	EPA 1664	Grab	mg/L	5.0	ND	ND	ND	ND	ND
Nitrate and Nitrite (as N)	EPA 300.0	Grab	mg/L	0.500	ND	ND	0.41	ND	0.41
Microbiological									
Fecel Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	1600	1600	600	600.00	1600.00
Total Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	1700	1600	16000	1600.00	16000.00
Volatile Organics									
1,1-Dichloroethane	EPA 8260B	Grab	ug/L	1.0	NS				
1,1-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	NS				
1,1,1-Trichloroethane	EPA 8260B	Grab	ug/L	2.0	NS				
1,1,2-Trichloroethane	EPA 8260B	Grab	ug/L	0.5	NS				
1,1,2,2-Tetrachloroethane	EPA 8260B	Grab	ug/L	0.5	NS				
1,2-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	NS				
1,2-Dichloroethane	EPA 8260B	Grab	ug/L	0.5	NS				
cis-1,2-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	NS				
1,2-Dichloropropane	EPA 8260B	Grab	ug/L	0.5	NS				
1,2,4-Trichlorobenzene	EPA 8260B	Grab	ug/L	5.0	NS				
1,3-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	NS				
1,3-Dichloropropene	EPA 8260B	Grab	ug/L	0.5	NS				
1,4-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	NS				
Benzene	EPA 8260B	Grab	ug/L	0.5	NS				
Bromoform	EPA 8260B	Grab	ug/L	2.0	NS				
Bromomethane	EPA 8260B	Grab	ug/L	2.0	NS				
Carbon tetrachloride	EPA 8260B	Grab	ug/L	0.5	NS				
Chlorobenzene (mono chlorobenzene)	EPA 8260B	Grab	ug/L	2.0	NS				
Chloroethane	EPA 8260B	Grab	ug/L	2.0	NS				
Chloroform	EPA 8260B	Grab	ug/L	0.5	NS				
Chloromethane	EPA 8260B	Grab	ug/L	0.5	NS				
Dibromochloromethane	EPA 8260B	Grab	ug/L	0.5	NS				
Dichlorobromomethane	EPA 8260B	Grab	ug/L	0.5	NS				
Dichloromethane	EPA 8260B	Grab	ug/L	2.0	NS				
Ethylbenzene	EPA 8260B	Grab	ug/L	2.0	NS				
Hexachlorobutadiene	EPA 8260B	Grab	ug/L	1.0	NS				

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Naphthalene	EPA 8260B	Grab	ug/L	10	NS		
Tetrachloroethene	EPA 8260B	Grab	ug/L	0.5	NS		
Toluene	EPA 8260B	Grab	ug/L	2.0	NS		
trans-1,2-Dichloroethylene	EPA 8260B	Grab	ug/L	1.0	NS		
Trichloroethene	EPA 8260B	Grab	ug/L	2.0	NS		
Vinyl chloride	EPA 8260B	Grab	ug/L	0.5	NS		
Inorganic Analysis (Metals)							
Arsenic	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Cadmium	EPA 200.8	Grab	ug/L	0.25	ND	ND	ND
Mercury	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Antimony	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Beryllium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Chromium (total)	EPA 200.8	Grab	ug/L	2.0	ND	ND	ND
Copper	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Lead	EPA 200.8	Grab	ug/L	100.0	ND	ND	ND
Nickel	EPA 200.8	Grab	ug/L	20.0	ND	ND	ND
Selenium	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Silver	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Thallium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Zinc	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Low Level Mercury	EPA 1631	Grab	ng/L	0.50	NS		
Herbicides							
Bentazon	EPA 8151A	Grab	ug/L	2.0	ND		
2,4-D	EPA 8151A	Grab	ug/L	1.0	ND		
Dalapon	EPA 8151A	Grab	ug/L	2.0	ND		
Dinoseb	EPA 8151A	Grab	ug/L	1.0	ND		
Picloram	EPA 8151A	Grab	ug/L	1.0	ND		
2,4,5-TP (Silvex)	EPA 8151A	Grab	ug/L	1.0	ND		
Pentachlorophenol	EPA 8151A	Grab	ug/L	1.0	ND		

RL/IAL: Reporting Limit/Instrument Accuracy Level
nd: Not detected
NS: Not Sampled

Report Approved By: _____

Notes on Receiving Water Conditions at SV-2

Floating or suspended matter Y☒ N☐

If yes, describe: Plant Debris (11/8/05, 1/18/06); Sediment (12/1/05, 1/18/06)

Visible films, sheens, or coatings Y☐ N☒

If yes, describe:

Discoloration Y☒ N☐

If yes, describe: Turbid (12/1/05, 1/18/06)

Algae, fungi, slimes, or objectionable growths Y☐ N☒

If yes, describe:

Odor/Other nuisance conditions Y☐ N☒

If yes, describe:

Aquatic life: Small fish on 11/8/05

Report Approved By: _____

PHOTO DOCUMENTATION FOR SV-2

FALL/WINTER (2005-06)
ANNUAL SURFACE WATER MONITORING SUMMARY REPORT – PHASE 1
TUOLUMNE COUNTY WQP

Sample ID: WD-1
Sample Location: Bell Mooney Crossing
Sample Matrix: Water
Sampler(s):

Sampling Dates: 11/8/2005, 12/1/2005, 1/18/2006
Lab Received Dates: AquaLab: 11/8/2005, 12/1/2005, 1/18/2006
CLS, Labs: 11/9/2005, 12/9/2005, 1/19/2006
Report Date: 3/15/2006

Sampling Results

Analysis	Method	Sample	Units	RL/IAL	Sampling Dates 11/8/05	12/1/05	1/18/06	Min.	Max.
Flow	Field	Grab	feet/second		<1.0	5.5	5.5	5.93	7.24
pH	Field	Grab	units	+/- 0.2	7.24	5.93	6.27	46.85	54.36
Temperature	Field	Grab	Deg. F	+/- 0.27	54.36	51.66	46.85	9.26	10.95
Dissolved Oxygen	Field	Grab	mg/L	+/- 2%	9.26	9.44	10.95	207.00	380.00
Specific Conductance	Field	Grab	uS/cm	+/- 0.5%	380	273	207	1.48	29.50
Turbidity	Field	Grab	NTU	+/- 2%	1.48	29.5	29.1	5.93	7.24
TSS	EPA 160.2	Grab	mg/L	5.0	ND	25	18	18.00	25.00
Hardness	SM-2340B	Grab	mg/L	1.0	210	150	91	91.00	210.00
Oil and Grease	EPA 1664	Grab	mg/L	5.0	ND	ND	ND	ND	ND
Nitrate and Nitrite (as N)	EPA 300.0	Grab	mg/L	0.500	ND	ND	0.5	ND	0.50
Microbiological									
Fecel Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	170	1600	1700	170.00	1700.00
Total Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	1600	1600	9000	1600.00	9000.00
Volatile Organics									
1,1-Dichloroethane	EPA 8260B	Grab	ug/L	1.0	ND				
1,1-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND				
1,1,1-Trichloroethane	EPA 8260B	Grab	ug/L	2.0	ND				
1,1,2-Trichloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
1,1,2,2-Tetrachloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
1,2-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
1,2-Dichloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
cis-1,2-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND				
1,2-Dichloropropane	EPA 8260B	Grab	ug/L	0.5	ND				
1,2,4-Trichlorobenzene	EPA 8260B	Grab	ug/L	5.0	ND				
1,3-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
1,3-Dichloropropene	EPA 8260B	Grab	ug/L	0.5	ND				
1,4-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
Benzene	EPA 8260B	Grab	ug/L	0.5	ND				
Bromoform	EPA 8260B	Grab	ug/L	2.0	ND				
Bromomethane	EPA 8260B	Grab	ug/L	2.0	ND				
Carbon tetrachloride	EPA 8260B	Grab	ug/L	0.5	ND				
Chlorobenzene (mono chlorobenzene)	EPA 8260B	Grab	ug/L	2.0	ND				
Chloroethane	EPA 8260B	Grab	ug/L	2.0	ND				
Chloroform	EPA 8260B	Grab	ug/L	0.5	ND				
Chloromethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dibromochloromethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dichlorobromomethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dichloromethane	EPA 8260B	Grab	ug/L	2.0	ND				
Ethylbenzene	EPA 8260B	Grab	ug/L	2.0	ND				

Report Approved By: _____

Hexachlorobutadiene	EPA 8260B	Grab	ug/L	1.0	ND		
Naphthalene	EPA 8260B	Grab	ug/L	10	ND		
Tetrachloroethene	EPA 8260B	Grab	ug/L	0.5	ND		
Toluene	EPA 8260B	Grab	ug/L	2.0	ND		
trans-1,2-Dichloroethylene	EPA 8260B	Grab	ug/L	1.0	ND		
Trichloroethene	EPA 8260B	Grab	ug/L	2.0	ND		
Vinyl chloride	EPA 8260B	Grab	ug/L	0.5	ND		
Inorganic Analysis (Metals)							
Arsenic	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Cadmium	EPA 200.8	Grab	ug/L	0.25	ND	ND	ND
Mercury	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Antimony	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Beryllium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Chromium (total)	EPA 200.8	Grab	ug/L	2.0	ND	ND	ND
Copper	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Lead	EPA 200.8	Grab	ug/L	100.0	ND	ND	ND
Nickel	EPA 200.8	Grab	ug/L	20.0	ND	ND	ND
Selenium	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Silver	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Thallium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Zinc	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Low Level Mercury	EPA 1631	Grab	ng/L	0.50	1.48		
Herbicides							
Bentazon	EPA 8151A	Grab	ug/L	2.0	ND		
2,4-D	EPA 8151A	Grab	ug/L	1.0	ND		
Dalapon	EPA 8151A	Grab	ug/L	2.0	ND		
Dinoseb	EPA 8151A	Grab	ug/L	1.0	ND		
Picloram	EPA 8151A	Grab	ug/L	1.0	ND		
2,4,5-TP (Silvex)	EPA 8151A	Grab	ug/L	1.0	ND		
Pentachlorophenol	EPA 8151A	Grab	ug/L	1.0	ND		

RL/IAL: Reporting Limit/Instrument Accuracy Level
nd: Not detected

Report Approved By: _____

FALL/WINTER (2005-06)
ANNUAL SURFACE WATER MONITORING SUMMARY REPORT – PHASE 1
TUOLUMNE COUNTY WQP

Notes on Receiving Water Conditions at WD-1

Floating or suspended matter Y☒ N☐

If yes, describe: Plant Debris (11/8/05); Sediment (12/1/05, 1/18/06)

Visible films, sheens, or coatings Y☒ N☐

If yes, describe: Rock crevices on 12/1/05

Discoloration Y☒ N☐

If yes, describe: Turbid (12/1/05, 1/18/06)

Algae, fungi, slimes, or objectionable growths Y☒ N☐

If yes, describe: Algae visible on rocks (11/8/05)

Odor/Other nuisance conditions Y☒ N☐

If yes, describe: Sulfur smell on 11/08/05

Aquatic life: Beaver (?) crossing Bell Mooney on 1/18/06

Report Approved By: _____

PHOTO DOCUMENTATION FOR WD-1

FALL/WINTER (2005-06)
ANNUAL SURFACE WATER MONITORING SUMMARY REPORT – PHASE 1
TUOLUMNE COUNTY WQP

Sample ID: MM-1
Sample Location: Mormon Creek Road Bridge
Sample Matrix: Water
Sampler(s):

Sampling Dates: 11/8/2005, 12/1/2005, 1/18/2006
Lab Received Dates: AquaLab: 11/8/2005, 12/1/2005, 1/18/2006
CLS, Labs: 11/9/2005, 12/9/2005, 1/19/2006
Report Date: 3/15/2006

Sampling Results

Analysis	Method	Sample	Units	RL/IAL	Sampling Dates 11/8/05	12/1/05	1/18/06	Min.	Max.
Flow	Field	Grab	feet/second		1	3.5	4.5	6.40	7.76
pH	Field	Grab	units	+/- 0.2	7.76	6.4	6.61	45.35	54.75
Temperature	Field	Grab	Deg. F	+/- 0.27	54.75	52.3	45.35	9.29	10.39
Dissolved Oxygen	Field	Grab	mg/L	+/- 2%	9.29	9.45	10.39	373.00	408.00
Specific Conductance	Field	Grab	uS/cm	+/- 0.5%	408	373	400	4.45	13.60
Turbidity	Field	Grab	NTU	+/- 2%	9.97	4.45	13.6	6.40	7.76
TSS	EPA 160.2	Grab	mg/L	5.0	6.2	ND	8	6.20	8.00
Hardness	SM-2340B	Grab	mg/L	1.0	240	220	200	200.00	240.00
Oil and Grease	EPA 1664	Grab	mg/L	5.0	ND	ND	ND	ND	ND
Nitrate and Nitrite (as N)	EPA 300.0	Grab	mg/L	0.500	ND	ND	0.61	ND	0.61
Microbiological									
Fecel Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	240	500	500	240.00	500.00
Total Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	900	1600	1400	900.00	1600.00
Volatile Organics									
1,1-Dichloroethane	EPA 8260B	Grab	ug/L	1.0	ND				
1,1-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND				
1,1,1-Trichloroethane	EPA 8260B	Grab	ug/L	2.0	ND				
1,1,2-Trichloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
1,1,2,2-Tetrachloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
1,2-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
1,2-Dichloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
cis-1,2-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND				
1,2-Dichloropropane	EPA 8260B	Grab	ug/L	0.5	ND				
1,2,4-Trichlorobenzene	EPA 8260B	Grab	ug/L	5.0	ND				
1,3-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
1,3-Dichloropropene	EPA 8260B	Grab	ug/L	0.5	ND				
1,4-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
Benzene	EPA 8260B	Grab	ug/L	0.5	ND				
Bromoform	EPA 8260B	Grab	ug/L	2.0	ND				
Bromomethane	EPA 8260B	Grab	ug/L	2.0	ND				
Carbon tetrachloride	EPA 8260B	Grab	ug/L	0.5	ND				
Chlorobenzene (mono chlorobenzene)	EPA 8260B	Grab	ug/L	2.0	ND				
Chloroethane	EPA 8260B	Grab	ug/L	2.0	ND				
Chloroform	EPA 8260B	Grab	ug/L	0.5	ND				
Chloromethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dibromochloromethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dichlorobromomethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dichloromethane	EPA 8260B	Grab	ug/L	2.0	ND				
Ethylbenzene	EPA 8260B	Grab	ug/L	2.0	ND				

Report Approved By: _____

Hexachlorobutadiene	EPA 8260B	Grab	ug/L	1.0	ND		
Naphthalene	EPA 8260B	Grab	ug/L	10	ND		
Tetrachloroethene	EPA 8260B	Grab	ug/L	0.5	ND		
Toluene	EPA 8260B	Grab	ug/L	2.0	ND		
trans-1,2-Dichloroethylene	EPA 8260B	Grab	ug/L	1.0	ND		
Trichloroethene	EPA 8260B	Grab	ug/L	2.0	ND		
Vinyl chloride	EPA 8260B	Grab	ug/L	0.5	ND		
Inorganic Analysis (Metals)							
Arsenic	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Cadmium	EPA 200.8	Grab	ug/L	0.25	ND	ND	ND
Mercury	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Antimony	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Beryllium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Chromium (total)	EPA 200.8	Grab	ug/L	2.0	ND	ND	ND
Copper	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Lead	EPA 200.8	Grab	ug/L	100.0	ND	ND	ND
Nickel	EPA 200.8	Grab	ug/L	20.0	ND	ND	ND
Selenium	EPA 200.8	Grab	ug/L	5.0	5.5	ND	ND
Silver	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Thallium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Zinc	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Low Level Mercury	EPA 1631	Grab	ng/L	0.50	1.91		
Herbicides							
Bentazon	EPA 8151A	Grab	ug/L	2.0	ND		
2,4-D	EPA 8151A	Grab	ug/L	1.0	ND		
Dalapon	EPA 8151A	Grab	ug/L	2.0	ND		
Dinoseb	EPA 8151A	Grab	ug/L	1.0	ND		
Picloram	EPA 8151A	Grab	ug/L	1.0	ND		
2,4,5-TP (Silvex)	EPA 8151A	Grab	ug/L	1.0	ND		
Pentachlorophenol	EPA 8151A	Grab	ug/L	1.0	ND		

RL/IAL: Reporting Limit/Instrument Accuracy Level
nd: Not detected

Report Approved By: _____

FALL/WINTER (2005-06)
ANNUAL SURFACE WATER MONITORING SUMMARY REPORT – PHASE 1
TUOLUMNE COUNTY WQP

Notes on Receiving Water Conditions at MM-1

Floating or suspended matter Y☒ N☐

If yes, describe: Plant Debris on 12/1/05

Visible films, sheens, or coatings Y☐ N☒

If yes, describe:

Discoloration Y☒ N☐

If yes, describe: Turbid on 1/18/06

Algae, fungi, slimes, or objectionable growths Y☐ N☒

If yes, describe:

Odor/Other nuisance conditions Y☐ N☒

If yes, describe:

Aquatic life: None observed.

Report Approved By: _____

PHOTO DOCUMENTATION FOR MM-1

FALL/WINTER (2005-06)
ANNUAL SURFACE WATER MONITORING SUMMARY REPORT – PHASE 1
TUOLUMNE COUNTY WQP

Sample ID: CT-1
Sample Location: Lime Kilm Road Bridge
Sample Matrix: Water
Sampler(s):

Sampling Dates: 11/8/2005, 12/1/2005, 1/18/2006
Lab Received Dates: AquaLab: 11/8/2005, 12/1/2005, 1/18/2006
CLS, Labs: 11/9/2005, 12/9/2005, 1/19/2006
Report Date: 3/15/2006

Sampling Results

Analysis	Method	Sample	Units	RL/IAL	Sampling Dates 11/8/05	12/1/05	1/18/06	Min.	Max.
Flow	Field	Grab	feet/second		<1.0	4.5	8.6	6.04	6.73
pH	Field	Grab	units	+/- 0.2	6.73	6.04	6.07	45.23	54.23
Temperature	Field	Grab	Deg. F	+/- 0.27	54.23	50.54	45.23	9.37	11.34
Dissolved Oxygen	Field	Grab	mg/L	+/- 2%	9.37	9.85	11.34	116.00	269.00
Specific Conductance	Field	Grab	uS/cm	+/- 0.5%	158	269	116	2.06	70.70
Turbidity	Field	Grab	NTU	+/- 2%	2.29	2.06	70.7	6.04	6.73
TSS	EPA 160.2	Grab	mg/L	5.0	ND	ND	44	44.00	44.00
Hardness	SM-2340B	Grab	mg/L	1.0	73	120	49	49.00	120.00
Oil and Grease	EPA 1664	Grab	mg/L	5.0	ND	ND	ND	ND	ND
Nitrate and Nitrite (as N)	EPA 300.0	Grab	mg/L	0.500	ND	ND	0.41	ND	0.41
Microbiological									
Fecel Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	300	130	1100	130.00	1100.00
Total Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	300	1600	16000	300.00	16000.00
Volatile Organics									
1,1-Dichloroethane	EPA 8260B	Grab	ug/L	1.0	ND				
1,1-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND				
1,1,1-Trichloroethane	EPA 8260B	Grab	ug/L	2.0	ND				
1,1,2-Trichloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
1,1,2,2-Tetrachloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
1,2-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
1,2-Dichloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
cis-1,2-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND				
1,2-Dichloropropane	EPA 8260B	Grab	ug/L	0.5	ND				
1,2,4-Trichlorobenzene	EPA 8260B	Grab	ug/L	5.0	ND				
1,3-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
1,3-Dichloropropene	EPA 8260B	Grab	ug/L	0.5	ND				
1,4-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
Benzene	EPA 8260B	Grab	ug/L	0.5	ND				
Bromoform	EPA 8260B	Grab	ug/L	2.0	ND				
Bromomethane	EPA 8260B	Grab	ug/L	2.0	ND				
Carbon tetrachloride	EPA 8260B	Grab	ug/L	0.5	ND				
Chlorobenzene (mono chlorobenzene)	EPA 8260B	Grab	ug/L	2.0	ND				
Chloroethane	EPA 8260B	Grab	ug/L	2.0	ND				
Chloroform	EPA 8260B	Grab	ug/L	0.5	ND				
Chloromethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dibromochloromethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dichlorobromomethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dichloromethane	EPA 8260B	Grab	ug/L	2.0	ND				
Ethylbenzene	EPA 8260B	Grab	ug/L	2.0	ND				

Report Approved By: _____

Hexachlorobutadiene	EPA 8260B	Grab	ug/L	1.0	ND		
Naphthalene	EPA 8260B	Grab	ug/L	10	ND		
Tetrachloroethene	EPA 8260B	Grab	ug/L	0.5	ND		
Toluene	EPA 8260B	Grab	ug/L	2.0	ND		
trans-1,2-Dichloroethylene	EPA 8260B	Grab	ug/L	1.0	ND		
Trichloroethene	EPA 8260B	Grab	ug/L	2.0	ND		
Vinyl chloride	EPA 8260B	Grab	ug/L	0.5	ND		
Inorganic Analysis (Metals)							
Arsenic	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Cadmium	EPA 200.8	Grab	ug/L	0.25	ND	ND	ND
Mercury	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Antimony	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Beryllium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Chromium (total)	EPA 200.8	Grab	ug/L	2.0	ND	ND	ND
Copper	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Lead	EPA 200.8	Grab	ug/L	100.0	ND	ND	ND
Nickel	EPA 200.8	Grab	ug/L	20.0	ND	ND	ND
Selenium	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Silver	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Thallium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Zinc	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Low Level Mercury	EPA 1631	Grab	ng/L	0.50	2.61		
Herbicides							
Bentazon	EPA 8151A	Grab	ug/L	2.0	ND		
2,4-D	EPA 8151A	Grab	ug/L	1.0	ND		
Dalapon	EPA 8151A	Grab	ug/L	2.0	ND		
Dinoseb	EPA 8151A	Grab	ug/L	1.0	ND		
Picloram	EPA 8151A	Grab	ug/L	1.0	ND		
2,4,5-TP (Silvex)	EPA 8151A	Grab	ug/L	1.0	ND		
Pentachlorophenol	EPA 8151A	Grab	ug/L	1.0	ND		

RL/IAL: Reporting Limit/Instrument Accuracy Level
nd: Not detected

Report Approved By: _____

Notes on Receiving Water Conditions at CT-1

Floating or suspended matter Y☒ N☐

If yes, describe: Plant Debris, foam on 12/1/05; Sediment 1/18/06

Visible films, sheens, or coatings Y☐ N☒

If yes, describe:

Discoloration Y☒ N☐

If yes, describe: Turbid (12/1/05, 1/18/06) – Reddish hue on 1/18/06

Algae, fungi, slimes, or objectionable growths Y☒ N☐

If yes, describe: Algae visible on rocks (11/8/05)

Odor/Other nuisance conditions Y☐ N☒

If yes, describe:

Aquatic life: None observed.

Report Approved By: _____

PHOTO DOCUMENTATION FOR CT-1

FALL/WINTER (2005-06)
ANNUAL SURFACE WATER MONITORING SUMMARY REPORT – PHASE 1
TUOLUMNE COUNTY WQP

Sample ID: TB-1
Sample Location: Box Factory Road Bridge
Sample Matrix: Water
Sampler(s):

Sampling Dates: 11/8/2005, 12/1/2005, 1/18/2006
Lab Received Dates: AquaLab: 11/8/2005, 12/1/2005, 1/18/2006
CLS, Labs: 11/9/2005, 12/9/2005, 1/19/2006
Report Date: 3/15/2006

Sampling Results

Analysis	Method	Sample	Units	RL/IAL	Sampling Dates 11/8/05	12/1/05	1/18/06	Min.	Max.
Flow	Field	Grab	feet/second		<1.0	6.5	8.4	4.88	6.24
pH	Field	Grab	units	+/- 0.2	6.24	4.88	5.55	44.73	53.09
Temperature	Field	Grab	Deg. F	+/- 0.27	53.09	47.85	44.73	7.65	10.31
Dissolved Oxygen	Field	Grab	mg/L	+/- 2%	7.65	8.87	10.31	98.00	137.00
Specific Conductance	Field	Grab	uS/cm	+/- 0.5%	137	113	98	2.68	70.40
Turbidity	Field	Grab	NTU	+/- 2%	2.68	28.4	70.4	4.88	6.24
TSS	EPA 160.2	Grab	mg/L	5.0	ND	17	42	17.00	42.00
Hardness	SM-2340B	Grab	mg/L	1.0	61	50	43	43.00	61.00
Oil and Grease	EPA 1664	Grab	mg/L	5.0	ND	5.1	ND	ND	5.10
Nitrate and Nitrite (as N)	EPA 300.0	Grab	mg/L	0.500	ND	ND	ND	ND	ND
Microbiological									
Fecel Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	17	1600	1300	17.00	1600.00
Total Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	1600	1600	16000	1600.00	16000.00
Volatile Organics									
1,1-Dichloroethane	EPA 8260B	Grab	ug/L	1.0	ND				
1,1-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND				
1,1,1-Trichloroethane	EPA 8260B	Grab	ug/L	2.0	ND				
1,1,2-Trichloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
1,1,2,2-Tetrachloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
1,2-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
1,2-Dichloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
cis-1,2-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND				
1,2-Dichloropropane	EPA 8260B	Grab	ug/L	0.5	ND				
1,2,4-Trichlorobenzene	EPA 8260B	Grab	ug/L	5.0	ND				
1,3-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
1,3-Dichloropropene	EPA 8260B	Grab	ug/L	0.5	ND				
1,4-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
Benzene	EPA 8260B	Grab	ug/L	0.5	ND				
Bromoform	EPA 8260B	Grab	ug/L	2.0	ND				
Bromomethane	EPA 8260B	Grab	ug/L	2.0	ND				
Carbon tetrachloride	EPA 8260B	Grab	ug/L	0.5	ND				
Chlorobenzene (mono chlorobenzene)	EPA 8260B	Grab	ug/L	2.0	ND				
Chloroethane	EPA 8260B	Grab	ug/L	2.0	ND				
Chloroform	EPA 8260B	Grab	ug/L	0.5	ND				
Chloromethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dibromochloromethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dichlorobromomethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dichloromethane	EPA 8260B	Grab	ug/L	2.0	ND				
Ethylbenzene	EPA 8260B	Grab	ug/L	2.0	ND				

Report Approved By: _____

Hexachlorobutadiene	EPA 8260B	Grab	ug/L	1.0	ND		
Naphthalene	EPA 8260B	Grab	ug/L	10	ND		
Tetrachloroethene	EPA 8260B	Grab	ug/L	0.5	ND		
Toluene	EPA 8260B	Grab	ug/L	2.0	ND		
trans-1,2-Dichloroethylene	EPA 8260B	Grab	ug/L	1.0	ND		
Trichloroethene	EPA 8260B	Grab	ug/L	2.0	ND		
Vinyl chloride	EPA 8260B	Grab	ug/L	0.5	ND		
Inorganic Analysis (Metals)							
Arsenic	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Cadmium	EPA 200.8	Grab	ug/L	0.25	ND	ND	ND
Mercury	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Antimony	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Beryllium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Chromium (total)	EPA 200.8	Grab	ug/L	2.0	ND	ND	ND
Copper	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Lead	EPA 200.8	Grab	ug/L	100.0	ND	ND	ND
Nickel	EPA 200.8	Grab	ug/L	20.0	ND	ND	ND
Selenium	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Silver	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Thallium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Zinc	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Low Level Mercury	EPA 1631	Grab	ng/L	0.50	3.43		
Herbicides							
Bentazon	EPA 8151A	Grab	ug/L	2.0	ND		
2,4-D	EPA 8151A	Grab	ug/L	1.0	ND		
Dalapon	EPA 8151A	Grab	ug/L	2.0	ND		
Dinoseb	EPA 8151A	Grab	ug/L	1.0	ND		
Picloram	EPA 8151A	Grab	ug/L	1.0	ND		
2,4,5-TP (Silvex)	EPA 8151A	Grab	ug/L	1.0	ND		
Pentachlorophenol	EPA 8151A	Grab	ug/L	1.0	ND		

RL/IAL: Reporting Limit/Instrument Accuracy Level
nd: Not detected

Report Approved By: _____

FALL/WINTER (2005-06)
ANNUAL SURFACE WATER MONITORING SUMMARY REPORT – PHASE 1
TUOLUMNE COUNTY WQP

Notes on Receiving Water Conditions at TB-1

Floating or suspended matter Y☒ N☐

If yes, describe: Plant Debris (11/8/05, 12/1/05, 1/18/06); Sediment and trash/18/06; sediment and foam 12/1/05

Visible films, sheens, or coatings Y☐ N☒

If yes, describe:

Discoloration Y☒ N☐

If yes, describe: Turbid (12/1/05, 1/18/06)

Algae, fungi, slimes, or objectionable growths Y☒ N☐

If yes, describe: Algae visible on rocks (11/8/05)

Odor/Other nuisance conditions Y☒ N☐

If yes, describe: Sulfur smell on 12/1/05; Bank-side trash and mulch disposal 1/18/06

Aquatic life: None observed.

Report Approved By: _____

PHOTO DOCUMENTATION FOR TB-1

FALL/WINTER (2005-06)
ANNUAL SURFACE WATER MONITORING SUMMARY REPORT – PHASE 1
TUOLUMNE COUNTY WQP

Sample ID: GV-1
Sample Location: CSD Access Road Bridge
Sample Matrix: Water
Sampler(s):

Sampling Dates: 11/8/2005, 12/1/2005, 1/18/2006
Lab Received Dates: AquaLab: 11/8/2005, 12/1/2005, 1/18/2006
CLS, Labs: 11/9/2005, 12/9/2005, 1/19/2006
Report Date: 3/15/2006

Sampling Results

Analysis	Method	Sample	Units	RL/IAL	Sampling Dates 12/1/05	1/18/06	Min.	Max.
Flow	Field	Grab	feet/second		3	3.8	4.78	5.87
pH	Field	Grab	units	+/- 0.2	4.78	5.87	45.27	49.78
Temperature	Field	Grab	Deg. F	+/- 0.27	49.78	45.27	9.73	10.71
Dissolved Oxygen	Field	Grab	mg/L	+/- 2%	9.73	10.71	102.00	127.00
Specific Conductance	Field	Grab	uS/cm	+/- 0.5%	102	127	30.20	30.30
Turbidity	Field	Grab	NTU	+/- 2%	30.2	30.3	4.78	5.87
TSS	EPA 160.2	Grab	mg/L	5.0	56	6.2	6.20	56.00
Hardness	SM-2340B	Grab	mg/L	1.0	68	47	47.00	68.00
Oil and Grease	EPA 1664	Grab	mg/L	5.0	ND	ND	ND	ND
Nitrate and Nitrite (as N)	EPA 300.0	Grab	mg/L	0.500	ND	ND	ND	ND
Microbiological								
Fecel Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	1600	70	70.00	1600.00
Total Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	1600	1400	1400.00	1600.00
Volatile Organics								
1,1-Dichloroethane	EPA 8260B	Grab	ug/L	1.0	ND			
1,1-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND			
1,1,1-Trichloroethane	EPA 8260B	Grab	ug/L	2.0	ND			
1,1,2-Trichloroethane	EPA 8260B	Grab	ug/L	0.5	ND			
1,1,2,2-Tetrachloroethane	EPA 8260B	Grab	ug/L	0.5	ND			
1,2-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND			
1,2-Dichloroethane	EPA 8260B	Grab	ug/L	0.5	ND			
cis-1,2-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND			
1,2-Dichloropropane	EPA 8260B	Grab	ug/L	0.5	ND			
1,2,4-Trichlorobenzene	EPA 8260B	Grab	ug/L	5.0	ND			
1,3-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND			
1,3-Dichloropropene	EPA 8260B	Grab	ug/L	0.5	ND			
1,4-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND			
Benzene	EPA 8260B	Grab	ug/L	0.5	ND			
Bromoform	EPA 8260B	Grab	ug/L	2.0	ND			
Bromomethane	EPA 8260B	Grab	ug/L	2.0	ND			
Carbon tetrachloride	EPA 8260B	Grab	ug/L	0.5	ND			
Chlorobenzene (mono chlorobenzene)	EPA 8260B	Grab	ug/L	2.0	ND			
Chloroethane	EPA 8260B	Grab	ug/L	2.0	ND			
Chloroform	EPA 8260B	Grab	ug/L	0.5	ND			
Chloromethane	EPA 8260B	Grab	ug/L	0.5	ND			
Dibromochloromethane	EPA 8260B	Grab	ug/L	0.5	ND			
Dichlorobromomethane	EPA 8260B	Grab	ug/L	0.5	ND			
Dichloromethane	EPA 8260B	Grab	ug/L	2.0	ND			
Ethylbenzene	EPA 8260B	Grab	ug/L	2.0	ND			
Hexachlorobutadiene	EPA 8260B	Grab	ug/L	1.0	ND			

Report Approved By: _____

Naphthalene	EPA 8260B	Grab	ug/L	10	ND	
Tetrachloroethene	EPA 8260B	Grab	ug/L	0.5	ND	
Toluene	EPA 8260B	Grab	ug/L	2.0	ND	
trans-1,2-Dichloroethylene	EPA 8260B	Grab	ug/L	1.0	ND	
Trichloroethene	EPA 8260B	Grab	ug/L	2.0	ND	
Vinyl chloride	EPA 8260B	Grab	ug/L	0.5	ND	
Inorganic Analysis (Metals)						
Arsenic	EPA 200.8	Grab	ug/L	1.0	ND	ND
Cadmium	EPA 200.8	Grab	ug/L	0.25	ND	ND
Mercury	EPA 200.8	Grab	ug/L	0.5	ND	ND
Antimony	EPA 200.8	Grab	ug/L	5.0	ND	ND
Beryllium	EPA 200.8	Grab	ug/L	1.0	ND	ND
Chromium (total)	EPA 200.8	Grab	ug/L	2.0	ND	ND
Copper	EPA 200.8	Grab	ug/L	0.5	ND	ND
Lead	EPA 200.8	Grab	ug/L	100.0	ND	ND
Nickel	EPA 200.8	Grab	ug/L	20.0	ND	ND
Selenium	EPA 200.8	Grab	ug/L	5.0	ND	7.3
Silver	EPA 200.8	Grab	ug/L	5.0	ND	ND
Thallium	EPA 200.8	Grab	ug/L	1.0	ND	ND
Zinc	EPA 200.8	Grab	ug/L	1.0	ND	ND
Herbicides						
Bentazon	EPA 8151A	Grab	ug/L	2.0	ND	
2,4-D	EPA 8151A	Grab	ug/L	1.0	ND	
Dalapon	EPA 8151A	Grab	ug/L	2.0	ND	
Dinoseb	EPA 8151A	Grab	ug/L	1.0	ND	
Picloram	EPA 8151A	Grab	ug/L	1.0	ND	
2,4,5-TP (Silvex)	EPA 8151A	Grab	ug/L	1.0	ND	
Pentachlorophenol	EPA 8151A	Grab	ug/L	1.0	ND	

RL/IAL: Reporting Limit/Instrument Accuracy Level
nd: Not detected

Report Approved By: _____

Notes on Receiving Water Conditions at GV-1

Floating or suspended matter Y☒ N☐

If yes, describe: Plant Debris (12/1/05, 1/18/06); Sediment (12/1/05, 1/18/06); Trash 12/1/05

Visible films, sheens, or coatings Y☒ N☐

If yes, describe: Oily sheen visible on 12/1/05

Discoloration Y☒ N☐

If yes, describe: Turbid (12/1/05, 1/18/06)

Algae, fungi, slimes, or objectionable growths Y☐ N☒

If yes, describe:

Odor/Other nuisance conditions Y☐ N☒

If yes, describe: Foam at base of step pools on 1/18/06

Aquatic life: None observed.

Report Approved By: _____

PHOTO DOCUMENTATION FOR GV-1

FALL/WINTER (2005-06)
ANNUAL SURFACE WATER MONITORING SUMMARY REPORT – PHASE 1
TUOLUMNE COUNTY WQP
Quality Control Data for Field Instrumentation

Post-Field Calibration Check		**11/8/05**	**12/01/05**	**1/18/06**
pH (4)	Observed	4.17	4.11	3.97
	Actual	4	4	4
	Difference	-0.17	-0.11	0.03
pH (7)	Observed	7.03	7.08	7.04
	Actual	7	7	7
	Difference	-0.03	-0.08	-0.04
pH (10)	Observed	10.14	10.21	10.18
	Actual	10	10	10
	Difference	-0.14	-0.21	-0.18
Specific Conductance	Observed	1000	996	
(uS/m)	Actual	1002	1000	N/A
	Difference	2	4	
Turbidity	Observed	0.31	0.28	0.45
(NTU) - <0.1	Actual	<0.1	<0.1	<0.1
	Difference	0.21	0.18	0.35
Turbidity	Observed	19.12	21.41	20.65
(NTU) - 20.0	Actual	20	20	20
	Difference	0.88	-1.41	-0.65
Turbidity	Observed	98	102	97
(NTU) - 100	Actual	100	100	100
	Difference	2	2	0

Report Approved By: _____

Insert Quality Control Data for Field Instrumentation

Insert Excel Tabloid Page

ANALYTICAL DATA FOR NOVEMBER 8, 2005

ANALYTICAL DATA FOR DECEMBER 1, 2005

ANALYTICAL DATA FOR JANUARY 18, 2006

FALL/WINTER 2005-06
ANNUAL SURFACE WATER MONITORING REPORT - PHASE 1
QUALITY CONTROL DATA

QC Data

			11/8/2005							12/1/2005							1/18/2006						
Parameter	**Units**	**RL/IAL**	**SV-1**	**SV-2**	**TB-1**	**CT-1**	**MM-1**	**GV-1**	**WD-1**	**SV-1**	**SV-2**	**TB-1**	**CT-1**	**MM-1**	**GV-1**	**WD-1**	**SV-1**	**SV-2**	**TB-1**	**CT-1**	**MM-1**	**GV-1**	**WD-1**
Field																							
pH	units	+/- 0.2			6.26		7.43		7.22	5.2	5.33	4.66	5.9	6.34	4.75	5.84	6.27	5.73	5.66	6.03	6.84	5.9	6.92
Temperature	Deg. F	+/- 0.27			53.13		54.62		54.37	50.22	47.57	48.15	54.36	52.28	49.8	51.66	50	44.78	44.64	45.23	49.37	45.3	46.87
Dissolved Oxygen	mg/L	+/- 2%			7.77		9.25		9.29	9.15	10.37	8.2	9.83	9.42	9.83	10.03	10.62	10.87	10.99	11.35	10.34	10.6	10.92
Specific Conductance	uS/cm	+/- 0.5%			136		409		378	84	102	113	269	373	100	272	117	96	98	116	397	228	208
Turbidity	NTU	+/- 2%								28.2	75	25.1	2.11	5.14	34.8	28.2	25.9	31.5	70	71.4	13	28.8	28.2
Conventual									ND														
TSS	mg/L	5.00	ND	ND	ND	ND	9		200						24								
Hardness	mg/L	1.00	120	45	60	72	240		ND						69								
Oil and Grease	mg/L	5.00	ND	ND	ND	ND	ND		ND						ND								
Nitrate and Nitrite (as N)	mg/L	0.50	ND	ND	ND	ND									ND								
Bacteriaological																							
Fecel Coliform	MPN/100 mL	2.00													500		500	500	1300	2400	900	70	1700
Total Coliform	MPN/100 mL	2.00													>1600		1300	16000	>1600	16000	2100	1100	16000
Volatile Organics																							
1,1-Dichloroethane	ug/L	1.00	ND		ND	ND	ND		ND						ND								
1,1-Dichloroethene	ug/L	0.50	ND		ND	ND	ND		ND						ND								
1,1,1-Trichloroethane	ug/L	2.00	ND		ND	ND	ND		ND						ND								
1,1,2-Trichloroethane	ug/L	0.50	ND		ND	ND	ND		ND						ND								
1,1,2,2-Tetrachloroethane	ug/L	0.50	ND		ND	ND	ND		ND						ND								
1,2-Dichlorobenzene	ug/L	2.00	ND		ND	ND	ND		ND						ND								
1,2-Dichloroethane	ug/L	0.50	ND		ND	ND	ND		ND						ND								
cis-1,2-Dichloroethene	ug/L	0.50	ND		ND	ND	ND		ND						ND								
1,2-Dichloropropane	ug/L	0.50	ND		ND	ND	ND		ND						ND								
1,2,4-Trichlorobenzene	ug/L	5.00	ND		ND	ND	ND		ND						ND								
1,3-Dichlorobenzene	ug/L	2.00	ND		ND	ND	ND		ND						ND								
1,3-Dichloropropene	ug/L	0.50	ND		ND	ND	ND		ND						ND								
1,4-Dichlorobenzene	ug/L	2.00	ND		ND	ND	ND		ND						ND								
Benzene	ug/L	0.50	ND		ND	ND	ND		ND						ND								
Bromoform	ug/L	2.00	ND		ND	ND	ND		ND						ND								
Bromomethane	ug/L	2.00	ND		ND	ND	ND		ND						ND								
Carbon tetrachloride	ug/L	0.50	ND		ND	ND	ND		ND						ND								
Chlorobenzene (mono chlorobenzene)	ug/L	2.00	ND		ND	ND	ND		ND						ND								
Chloroethane	ug/L	2.00	ND		ND	ND	ND		ND						ND								
Chloroform	ug/L	0.50	ND		ND	ND	ND		ND						ND								
Chloromethane	ug/L	0.50	ND		ND	ND	ND		ND						ND								
Dibromochloromethane	ug/L	0.50	ND		ND	ND	ND		ND						ND								
Dichlorobromomethane	ug/L	0.50	ND		ND	ND	ND		ND						ND								
Dichloromethane	ug/L	2.00	ND		ND	ND	ND		ND						ND								
Ethylbenzene	ug/L	2.00	ND		ND	ND	ND		ND						ND								
Hexachlorobutadiene	ug/L	1.00	ND		ND	ND	ND		ND						ND								
Naphthalene	ug/L	10.00	ND		ND	ND	ND		ND						ND								
Tetrachloroethene	ug/L	0.50	ND		ND	ND	ND		ND						ND								

FALL/WINTER 2005-06
ANNUAL SURFACE WATER MONITORING REPORT - PHASE 1
QUALITY CONTROL DATA

Parameter	Units	RL/IAL	SV-1	SV-2	TB-1	CT-1	MM-1	GV-1	WD-1	SV-1	SV-2	TB-1	CT-1	MM-1	GV-1	WD-1	SV-1	SV-2	TB-1	CT-1	MM-1	GV-1	WD-1
Toluene	ug/L	2.00	ND		ND	ND	ND		ND						ND								
trans-1,2-Dichloroethylene	ug/L	1.00																					
			ND		ND	ND	ND		ND						ND								
Trichloroethene	ug/L	2.00	ND		ND	ND	ND		ND						ND								
Vinyl chloride	ug/L	0.50	ND		ND	ND	ND		ND						ND								
Inorganic Analysis (Metals)																							
Arsenic	ug/L	1.00	ND	ND	ND	ND	ND		ND						ND								
Cadmium	ug/L	0.25	ND	ND	ND	ND	ND		ND						ND								
Mercury	ug/L	0.50	ND	ND	ND	ND	ND		ND						ND								
Antimony	ug/L	5.00	ND	ND	ND	ND	ND		ND						ND								
Beryllium	ug/L	1.00	ND	ND	ND	ND	ND		ND						ND								
Chromium (total)	ug/L	2.00	ND	ND	ND	ND	ND		ND						ND								
Copper	ug/L	0.50	ND	ND	ND	ND	ND		ND						ND								
Lead	ug/L	100.00	ND	ND	ND	ND	ND		ND						ND								
Nickel	ug/L	20.00	ND	ND	ND	ND	ND		ND						ND								
Selenium	ug/L	5.00	ND	ND	ND	ND	6.2		ND						ND								
Silver	ug/L	5.00	ND	ND	ND	ND	ND		ND						ND								
Thallium	ug/L	1.00	ND	ND	ND	ND	ND		ND						ND								
Zinc	ug/L	1.00	ND	ND	ND	ND	ND		ND						ND								
Herbicides																							
Bentazon	ug/L	2.00	ND	ND	ND	ND	ND		ND						ND								
2,4-D	ug/L	1.00	ND	ND	ND	ND	ND		ND						ND								
Dalapon	ug/L	2.00	ND	ND	ND	ND	ND		ND						ND								
Dinoseb	ug/L	1.00	ND	ND	ND	ND	ND		ND						ND								
Picloram	ug/L	1.00	ND	ND	ND	ND	ND		ND						ND								
2,4,5-TP (Silvex)	ug/L	1.00	ND	ND	ND	ND	ND		ND						ND								
Pentachlorophenol	ug/L	1.00	ND	ND	ND	ND	ND		ND						ND								

Appendix D

Impervious Surface Cover by Watershed Catchment

ESA

Appendix D - Project Impervious Cover By Catchment

Sub-Watershed Units	Catchment ID	Total Acreage	Impervious Cover (Total) >70 %	>25 %	Road Density (Percent Area)
Bear Creek	**BC01A**	1248.4	1.9	23.9	0.6
	BC01B	855.4	9.2	36.5	1.1
	BC01C	541.7	0.0	24.7	0.3
	BC01D	564.6	0.0	52.9	0.6
	BC02	1704.5	0.3	19.9	0.4
Total		**4914.6**	**2.2**	**28.1**	
Big Oak Flat-Groveland	**BG01**	1603.1	9.5	43.0	3
	BG02	503.6	0.0	0.8	1.2
	BG03	1536.7	0.0	4.3	1.6
	BG04	501.4	0.0	78.7	2.8
	BG05	593.9	0.0	43.3	2.8
	BG06	1234.6	0.0	1.1	0.9
	BG07	2210.6	0.0	1.8	1.2
	BG08	3020.6	0.0	1.6	0.8
	BG09	1441.8	0.0	3.0	1
	BG10	1366.9	0.0	12.1	1.1
	BG11	873.8	0.0	8.7	0.4
	BG12	587.1	0.0	79.0	2.6
	BG13	662.3	4.8	58.7	3.7
	BG14	2272.7	0.0	9.8	0.7
	BG15	2620.7	0.0	35.9	1.3
	BG16A	1032.7	0.0	0.0	0
	BG16B	978.2	0.0	0.0	0
	BG16C	263.2	0.0	0.0	0
	BG16D	911.2	0.0	0.0	0
	BG16E	680.9	0.0	0.0	0
Total		**24895.8**	**0.7**	**15.3**	
Curtis Creek	**CC01A**	1796.5	7.0	35.6	3.1
	CC01B	2151.0	1.7	30.5	1.9
	CC02	988.0	7.4	54.7	3.4
	CC03	664.5	3.4	37.5	2
	CC04	503.3	63.8	73.8	3.5
	CC05	988.8	10.1	25.5	1.8
	CC06	1461.4	7.9	25.5	1.8

Appendix D - Project Impervious Cover By Catchment

	CC07	693.7	0.0	6.6	1.1
	CC08	1530.6	0.0	15.2	1.2
	CC09	635.4	0.0	0.2	1.2
	CC10	630.4	0.0	0.0	0.1
	CC11	1999.5	0.0	0.2	0.5
	CC12	927.1	0.0	0.0	0.4
Total		**14970.2**	**5.3**	**22.5**	
Deer Creek	**DC01**	2537.6	0.0	0.3	0.7
	DC02	1515.3	0.0	0.0	0.6
	DC03	1109.6	0.0	0.0	0.7
	DC04	939.9	0.0	0.0	0.5
	DC06A	1344.7	0.0	0.0	0.6
	DC06B	213.6	0.0	0.0	0.1
	DC06C	1186.0	0.0	0.0	0.2
	DC07	1489.5	0.0	0.0	0.0
	DC08	1054.4	0.0	0.0	0.4
	DC09A	671.7	0.0	0.0	0.2
	DC09B	556.4	0.0	0.7	1.4
	DC09C	1955.1	0.0	0.7	1.2
Total		**14573.9**	**0.0**	**0.2**	
Kanaka Creek	**KC01**	2551.6	0.0	9.7	0.6
	KC02	1105.8	0.0	5.4	1.3
	KC03	991.0	0.0	3.5	0.7
	KC04	2359.8	0.0	5.0	0.7
	KC05A	1029.7	0.0	3.4	0.9
	KC05B	376.4	0.0	0.1	0.6
Total		**8414.3**	**0.0**	**5.9**	
Lower Sullivan Creek	**LS01**	1190.2	5.0	32.2	2.0
	LS02	825.5	13.6	58.6	4.8
	LS03	598.7	32.4	79.4	3.4
	LS04	1148.6	7.2	19.9	2.4
	LS05	530.9	26.1	31.3	4.0
	LS06	1105.8	0.0	41.8	2.3
	LS07	802.2	11.1	26.4	1.0
	LS08	953.6	0.0	0.6	0.4

Appendix D - Project Impervious Cover By Catchment

	LS09	602.5	0.4	3.2	0.6
	LS10	1059.0	0.0	7.0	0.5
	LS11	566.4	0.0	0.4	0.0
Total		**9383.4**	**7.2**	**26.8**	
Mormon Creek	**MC01A**	700.9	19.5	42.1	2.06
	MC01B	551.9	42.3	66.2	2.51
	MC01C	1076.0	15.5	69.9	3.19
	MC02	703.9	14.1	30.3	2.51
	MC03	1836.6	0.1	17.0	1.44
	MC04	746.3	0.4	10.1	1.24
	MC05	1070.7	0.7	14.8	0.77
	MC06	3694.3	0.0	29.9	0.31
Total		**10380.7**	**6.2**	**25.4**	
Rough and Ready Creek	**RR01**	3672.3	0.0	6.5	0.4
	RR02	1166.7	0.0	0.8	0.4
	RR03	1880.1	0.0	0.2	0.0
	RR04	417.5	0.0	0.0	0.0
	RR06	807.3	0.0	6.9	0.0
	RR07	648.5	0.0	0.0	0.0
	RR08	1371.2	0.0	0.3	0.0
	RR09	804.4	0.0	0.2	0.0
Total		**10768.0**	**0.0**	**2.9**	
Turnback Creek	**TC01**	1313.8	0.2	26.8	2.4
	TC02	933.3	0.0	15.9	1.3
	TC03	1308.2	0.0	24.8	2.1
	TC04	1274.4	0.0	44.1	1.7
	TC05	986.4	6.1	40.8	2.1
	TC06	822.2	0.0	19.0	1.3
	TC07	4794.0	1.4	11.7	1.0
Total		**11432.4**	**1.1**	**21.9**	
Upper Sullivan Creek	**US01**	2226.5	0.0	48.7	3.2
	US02	1133.8	0.0	23.0	2.1
	US03	1946.9	3.9	56.9	4.2
	US04	479.9	0.0	49.2	3.7
	US05	967.2	1.7	27.2	2.4

Appendix D - Project Impervious Cover By Catchment

	US06	903.7	0.4	1.5	1.0
	US07	606.9	0.0	9.6	1.7
	US08	1226.3	0.0	4.3	1.2
	US09	703.0	1.5	32.3	1.2
	US10	1302.6	0.0	17.5	1.1
	US11	938.2	0.0	32.1	1.1
	US12	637.6	0.0	69.4	3.8
	US13	510.7	0.0	39.2	1.9
	US14	660.1	0.0	43.9	2.7
	US15	1027.7	0.0	33.5	2.6
Total		**15271.0**	**0.7**	**33.5**	
Woods Creek	**WC01A**	738.2	6.7	14.5	1.8
	WC01B	557.7	0.0	8.2	2.6
	WC01C	351.2	0.4	24.4	1.4
	WC02	1006.7	0.7	30.7	2.5
	WC03A	593.5	0.0	3.4	0.8
	WC03B	313.0	16.4	35.4	2.4
	WC04	1847.0	5.7	24.6	2.8
	WC05	2224.5	3.9	16.2	3.3
	WC07	1565.7	9.4	29.0	3.4
	WC08	2089.0	7.1	34.8	2.4
	WC09	1416.3	0.5	12.4	1.5
	WC10	1519.8	11.3	30.3	3.2
	WC11	862.3	0.0	8.1	1.3
	WC12	648.2	26.3	42.7	0.7
	WC13	1687.6	0.3	10.3	1.1
	WC14	1472.3	2.5	4.0	0.8
	WC15	573.9	0.0	0.2	0.0
Total		**19466.8**	**5.1**	**20.0**	
PSA Total		**149371.3**	**2.4**	**18.4**	

Final

TUOLUMNE COUNTY

Water Quality Plan

Prepared for:
Tuolumne County

February 2007

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CHAPTER 1
Introduction

The Tuolumne County (County) Water Quality Plan (WQP) was initiated by Tuolumne County and emphasizes the foothill regions of the Upper Stanislaus and Tuolumne River watersheds where urban growth is actively occurring and where the County maintains primary land use authority and can, therefore, influence activities undertaken on private lands that may affect water quality. It is recognized that this area represents only a portion of the Upper Stanislaus and Tuolumne River watersheds. Approximately two-thirds of the County is under federal or other public or quasi-public ownership. It is recognized that this WQP must look outside the established WQP Project Study Area and work cooperatively with these other jurisdictions to most effectively address overall watershed health. Further, regional issues (e.g., catastrophic fires, timber harvesting, recreational and other uses) that may affect watershed health will require cooperative efforts with multiple jurisdictions outside the scope of this WQP.

1.1 Plan Overview

Tuolumne County's Water Quality Plan contains a comprehensive program that addresses a wide range of water quality concerns within the County. This WQP emphasizes surface (e.g., lakes, streams) water quality, factors affecting surface water quality, and mechanisms for maintaining and improving surface water quality. Subsurface water quality (e.g., wells) is currently addressed through state regulatory programs, and locally through the County Health Department's Division of Environmental Health. The WQP focuses on two primary objectives:

(1) responding to existing State and Federal regulations and new regulations as they become mandated; and

(2) addressing existing and future water quality issues relevant to Tuolumne County waterways as identified in the County's Foothill Watershed Assessment (Assessment).

The WQP includes both regulatory and non-regulatory components. The regulatory component builds upon many existing environmental programs and activities implemented by various County departments and focuses on land development activities subject to the County's permitting requirements and on County public works projects. The non-regulatory stewardship component of the WQP encourages voluntary community participation in maintaining and improving the County's water quality.

Using this two-pronged approach, the WQP addresses the six program elements of the U.S. Environmental Protection Agency's (USEPA) Phase II National Pollution Discharge Elimination System (NPDES) Program. Within the regulatory component, the WQP addresses:

- Illicit Discharge Detection and Elimination
- Construction and Post-Construction Activities
- New Development and Planning
- County Operations

Within the volunteer watershed stewardship component, the WQP addresses:

- Public Outreach and Education; and
- Community Involvement and County Stewardship Priorities

This WQP is also intended to assist CALFED in achieving its primary mission by protecting major sources of drinking water for the Sacramento-San Joaquin Delta (Delta) and the San Francisco Bay; and addressing cumulative causes of water quality degradation within the County's jurisdiction. Full implementation of the WQP will be a long-term process, over a 20-year planning horizon, and its effectiveness will be evaluated every five years. The WQP will be revised as necessary to address areas identified as deficient during the evaluation process, which is outlined in Chapter 2, Approach to Water Quality Planning.

The WQP is organized as follows:

Chapter 1, Introduction. Chapter 1 lays out the major elements of the WQP, provides the general history of the WQP, describes agencies responsible for plan implementation, provides an overview of the community's role, and explains the legal context for the WQP. This chapter outlines how the WQP is designed to be consistent with Tuolumne County General Plan Water Resources Goals, Policies, and Implementation Programs (Chapters IV, VI, and VII of the General Plan), CALFED Goals and Objectives, and State and Federal NPDES Phase II requirements.

Chapter 2, Approach to Water Quality Planning. Chapter 2 introduces the County's Project Study Area (PSA), describes existing conditions, and outlines the County's overall approach to water quality planning. Major emphasis is placed on strategies for watershed-scale planning and long-term evaluation of management practices through the continued acquisition of surface water quality data and implementation of this information through adaptive management.

Chapter 3, County-Based Programs. Chapter 3 describes the County's approach to maintaining and improving surface water quality with an emphasis on addressing non-point sources (NPS) of pollution that are thought to originate from various land uses within the County's jurisdiction. The WQP includes a set of suggested recommended best management practices (BMPs) with the intent of reducing the concentration of pollutants in urban runoff to the "maximum extent practicable" (MEP). For the purposes of this WQP, MEP emphasizes pollution prevention and source control BMPs.

These control programs address categories of NPS pollution including urban runoff, grading and construction, mining, hydromodification, onsite disposal systems, marina operations, mine site runoff, certain agricultural and forestry practices, and public works projects. Each control measure consists of recommended BMPs, as applicable. Measurable goals for modifying or developing new BMPs are designed to address regulatory requirements or sources of pollutants that are not adequately addressed through existing activities.

Regulatory issues are the main focus of this chapter and include four of the USEPA's six required elements to address NPS pollution:

- Illicit Discharge Detection and Elimination;
- Construction and Post-Construction Activities;
- New Development and Planning; and
- County Operations.

Additional County-based programs contingent upon acquiring additional grant funding include:

- Best Management Practice Evaluation and Guidelines Program;
- Roadway Drainage and Erosion Survey, Recordation, Treatment, and Tracking Program; and
- Drainage Planning Program.

Chapter 4, Community and Voluntary Watershed Stewardship Programs. Chapter 4 describes community-based programs or other programs expected to occur outside of the County's jurisdiction. Programs of a primarily voluntary stewardship context are addressed in this chapter and include two of the six USEPA required elements to address NPS pollution:

- Public Outreach and Education; and
- Community Involvement and County Stewardship Priorities.

Additional programs likely to occur outside the jurisdiction of the County include:

- Landowner Technical Assistance Program;
- Wastewater Regionalization and Connection Study; and
- Pursuing a Watershed Coordinator.

Chapter 5, Grant Funding Opportunities. Chapter 5 lists and describes potential sources and methods for funding the programs identified in Chapters 3 and 4.

Chapter 6, References. Chapter 6 identifies references used in the preparation of the WQP.

1.2 Background and Public Involvement

1.2.1 Background

The WQP is the product of a larger CALFED grant-funded project, which encourages a watershed-based approach to address NPS pollution and involves four primary steps:

(1) assessing and determining if there is a problem,
(2) developing a program to address the problem,
(3) implementing the program as designed, and
(4) evaluating its effectiveness.

The preparation of the County's Assessment report and the WQP denotes the first two steps of this process. Steps 3 and 4 will occur in conjunction with the adoption and implementation of this WQP.

The County Board of Supervisors (Board) authorized the financial commitment and inter-departmental cooperation for the grant-funded project by Resolution 8-02, adopted on January 22, 2002, to support CALFED's objective for long range management. This WQP was prepared under the auspices of the County, with funding provided by the California State Water Resources Control Board (SWRCB) and CALFED through a Proposition 13 grant (Agreement No. 39 - Costa-Machado Water Act of 2000[1]). Funding allocated from the 2000 Water Bond requires that projects include a broad-based NPS component; capable of sustaining water quality benefits for a period of 20 years. In response to this requirement, the WQP was developed to not only implement BMPs, but to also implement a watershed-based planning framework as directed by Policy 4.L.a of the County's General Plan. This framework includes a set of measurable goals to enable County staff to evaluate the WQP's effectiveness in protecting water quality over the 20-year planning horizon.

Prior to the preparation of the Assessment and WQP and in order to support CALFED's objective for a scientific basis for water quality determinations, the County submitted a monitoring and reporting plan (MRP) and Quality Assurance Project Plan (QAPP) to the SWRCB and CALFED consistent with State watershed goals. The MRP and QAPP were prepared in accordance with USEPA requirements for QAPPs developed for Environmental Data Operations and were approved by the Central Valley Regional Water Quality Control Board's (CVRWQCB) Quality Assurance Officer prior to the implementation of baseline monitoring activities in support of the Assessment. Additionally, the QAPP and MRP were prepared under the oversight of a Water Quality Committee (WQC), which consists of County staff from individual departments and representation from the University of California (UC) Cooperative Extension. The WQC has helped to guide the focus of baseline studies and review draft documents consistent with CALFED requirements (see Chapter 6 for the WQC's membership and references for the WQPs supporting documents).

1.2.2 Public Involvement

To meet CALFED's objective for stakeholder involvement, in addition to the 50,000 plus residents within the County, 98 regulatory agencies, local agencies, and organizations were identified as having an interest or stake in the development of the WQP. At the onset of the grant-funded project, public notices were published in the Union Democrat and announced on the radio to encourage all

[1] In March 2000, California voters approved Proposition 13, the Costa-Machado Water Act of 2000 (2000 Water Bond), authorizing the state to sell $1.97 billion in general obligation bonds to support safe drinking water, flood protection, and water reliability projects throughout the State.

stakeholders, including the owners of the 45,500 parcels in the County to participate in public meetings during the Water Quality Planning project. Prior to the preparation of the MRP, three public scoping sessions were held in early to mid-2005 to solicit public and agency input on current water quality problems within the County, their spatial occurrence, and the constituents observed to be a concern (e.g., sediment). Information obtained during these meetings was used to identify the seven monitoring locations sampled during Phase 1 of the MRP.

Following the completion of Phase 1 of the MRP, the analytical results and initial findings of the Assessment were shared with interested members of the community at three additional public information meetings in early 2006. At the same time, the County has been actively soliciting interested community members to participate in its citizen water quality monitoring program in order to implement Phase 2 of the MRP. Staff with the UC Cooperative Extension and the newly formed Resource Conservation District (RCD) may provide management oversight under Phase 2.

In addition to these activities, the County recently circulated a public informational survey through several different venues (e.g., Home & Garden Shows, schools, etc.) to seek further input from the community regarding the County's water resources. The survey sought input regarding the current conditions of the County surface water resources, significant threats to water quality, strategies for protecting and improving water quality, and ways to encourage public participation. Based on the results of the survey, 65 percent of those who participated thought that water quality will get worse in the future. Over half of those who participated thought that the most significant threats to water quality were from stormwater runoff from urban uses, septic systems, contaminated sites, and soil erosion. In responding to these threats, those surveyed (75 percent) overwhelmingly indicated that a mix of voluntary and mandatory approaches were necessary to improve water quality. For those surveyed, the most popular strategies for protecting water quality included improving educational opportunities, increasing enforcement actions, expanding the implementation of BMPs, reducing the application of chemicals, and improving water quality monitoring.

As part of the WQP, informational exchange will continue to be accomplished primarily through staff coordination and a link located on the County's website. The WQP, Assessment, and resulting programs will be available for review and download from the County's website.[2]

1.3 Plan Implementation

1.3.1 Tuolumne County Participation and Coordination

The County Board is the policy and budget setting authority for the County. Under the Board, the County's Public Works Department, Administrator's Office, Fire Prevention Bureau, Agricultural Commissioner's Department, Community Development Department, and the Health Department's Environmental Health Division each play a key role in implementing the County's WQP.

[2] http://www.co.tuolumne.ca.us. Go to "Shortcuts to popular pages" menu (on the left) and select "Public Works Administration," which will bring you to the Public Works menu and "Public Works WQP Info."

Each of the key departments has the primary responsibility for day-to-day implementation of the WQP. The County's lead department for managing the WQP is the Public Works Department (Public Works). The County's Water Quality Plan Administrator (WQP Administrator) is appointed by the department head from within Public Works. Individual department and personnel responsibilities for implementation and enforcement are addressed within Chapter 3.0, County-Based Programs for the County's design/construction and maintenance programs.

Public Works Department

Public Works is responsible for implementing and/or overseeing all improvements and maintenance activities undertaken on County roads and drainage facilities. Further, Public Works is responsible for administering the County's Grading Ordinance (County Code Chapter 12.20) that regulates grading on private property and establishes and enforces standards for the construction of new roads for new development. The Solid Waste Division is housed within Public Works. Its primary mission is to ensure that the County has cost effective solid waste disposal services that comply with State and Federal mandates for integrated waste management and the protection of public health and the environment. The County Surveyor's Office also is within the Public Works Department. The Surveyor's Office is responsible for oversight of Title 16 of the County Ordinance Code (Subdivision Ordinance).

Community Development Department

The Community Development Department is composed of three divisions: Planning, Building and Safety, and Geographic Information Systems (GIS). The Planning Division is responsible for coordinating the review and approval processes for all proposed land development and ensuring consistency with the County's land development regulations, such as the Zoning Ordinance (Title 17). The Planning Division also is responsible for conducting environmental assessments of new development including analysis of impacts to surface waters. The Building and Safety Division is responsible for overseeing the construction of residential, commercial, and industrial structures. The GIS Division generally supports planning functions, including environmental analysis, through map development, database creation, and spatial analysis for such factors including fire hazard, land use, access, roads, slope, geotechnical hazards, cultural resources, and related environmental issues.

County Counsel

Code Compliance is administered through the County Counsel's office. The Code Compliance Division within the County Counsel's office is responsible for receiving all alleged complaints of violations related to land use and has authority to enforce applicable ordinances pertaining to land use and development.

Health Department - Environmental Health Division

The Environmental Health Division is responsible for administering the requirements of Title 13 of the County Ordinance Code as it relates to the approval of parcel or subdivision maps with Private Sewage Disposal Systems (Chapter 13.04), On-Site Sewage Treatment and Disposal

(Chapter 13.08), Water Wells (Chapter 13.16), Groundwater Management (Chapter 13.20), and Hazardous Materials Management (Chapter 13.24). Additionally, the Environmental Health Division is responsible for conducting compliance inspections for restaurants, underground storage tanks, and hazardous waste facilities, managing the County's vector control program, and responding to housing health complaints.

Fire Prevention Bureau

The Fire Prevention Bureau is responsible for enforcing fire codes; conducting fire and life safety plan reviews; providing fire safety education; and inspecting and abating existing and potential fire hazards through public education and code enforcement. The Fire Prevention Bureau also is responsible for assessing the adequacy of new roads to support emergency services.

County Administrator's Office

The County Administrators Office, Facilities Management Division is responsible for implementing and/or overseeing all improvements and maintenance activities undertaken on County facilities or property other than County roads. Additionally the Facilities Management Division is responsible for overseeing all leases of County properties.

Agricultural Commissioner's Department

The Agricultural Commissioner has the mission to protect, enhance, and promote the preservation of agriculture and the environment while sustaining the public health, safety, and welfare of all citizens. This Department is responsible for implementing the weights and measures program, Williamson Act program, invasive/noxious species control program, air pollution control program, and pesticide use program.

Water Quality Committee (WQC)

During 2004, the County established a Water Quality Committee to assist the County in developing the WQP. This committee meets at least annually and has representatives from each of the key responsible departments (Community Development, Public Works, Environmental Health, Agricultural Commissioner, and Administrator Office) and from stakeholder agencies (e.g., UC Cooperative Extension).

1.2.3 Non-County Organizations

In addition to participation on the WQC by the UC Cooperative Extension, the County anticipates participation in WQP implementation by multiple organizations and agencies outside of the County. For example, the recently formed Tuolumne County Resource Conservation District has been identified to possibly oversee the WQP's citizen water quality monitoring program (i.e., Phase II WQP Monitoring).

In addition, numerous local districts are involved in monitoring the County's water quality and in

maintaining facilities that affect the County's water quality. These include, but are not limited to: the Tuolumne Utilities District, Groveland Community Services District, and Twain Harte Community Services District. The County will continue to use water quality data available from these entities and share BMPs, as appropriate, to the implementation of the WQP.

1.3.3 Public Participation

Citizen groups, organizations, and individuals representing the Master Gardner's, Columbia Community College, local high schools, the California Native Plant Society, Phoenix Lake Golf Course and Phoenix Lake County Club Estates Homeowners Association already have volunteered to assist in the WQP's citizen water quality monitoring program.

Programs aimed at increasing public education and participation in the WQP are further described in Chapter 4, Community and Voluntary Watershed Stewardship Programs.

Public information related to the implementation of the WQP will be distributed through the following media sources:

- The water quality link on the County's website;
- Local newspapers;
- Contacts with local civic organizations;
- Local radio stations;
- Participation at County events (e.g., Home and Garden Show); and
- Other mechanisms, as appropriate.

1.4 Regulatory Setting

To understand how current regulatory goals and standards apply to this WQP, it is critical to understand the basic premise of water resources, which as a public trust resource are subject to an extensive legislative and regulatory history within California. The basis for water quality regulation within the United States is the Federal Pollution Control Act Amendments of 1972 and 1986, known as the Clean Water Act (CWA)(33 USC 1251-1376). The objective of the CWA is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." California's Porter-Cologne Water Quality Control Act (Porter-Cologne Act, California Water Code Section 13000 et seq.) in conjunction with the CWA provides the basis for water quality regulation within California. The Porter Cologne Act requires a "Report of Waste Discharge" for any point discharge of waste (liquid, solid, or otherwise) to land or surface waters that may impair a beneficial use of surface or groundwater of the state. In practice, these requirements are typically integrated with the CWA Section 402 NPDES permitting process[3] and implemented at the regional level by the Regional Water Quality Control Boards (RWQCB) and overseen by the

[3] Section 402 establishes the National Pollutant Discharge Elimination System (NPDES), a permitting system for the discharge of any pollutant (except for dredge or fill material) into waters of the United States. This permit program is administered by the U.S. Environmental Protection Agency (USEPA) in most states (not in California) and on Native American lands.

SWRCB and the USEPA. The County is within the jurisdiction of the Central Valley (Region 5) RWQCB (CVRWQCB).

In 1987, amendments to the CWA established a two-phase program to regulate 13 classes of stormwater discharges. Under Phase I, which began in 1990, the RWQCBs adopted NPDES stormwater permits for medium (serving between 100,000 and 250,000 people) and large (serving 250,000 people) municipalities or metropolitan areas (e.g., Sacramento Metropolitan Area). As part of Phase II, the SWRCB adopted a General Permit for the Discharge of Stormwater for Small Municipal Separate Storm Sewer Systems (MS4s) (WQ Order No. 2003-0005-DWQ or General Permit) to provide permit coverage for smaller municipalities, including non-traditional small MS4s (e.g., public campuses). The MS4 permit requires a discharger (e.g., the County) to develop and implement a Stormwater Management Plan/Program with the goal of reducing the discharge of pollutants to the maximum extent practicable (MEP).

As previously indicated, although the County is not currently identified as a small MS4, the WQP represents a proactive approach by the County to address pre-existing water quality issues in terms of the State General Permit. Consistent with the requirements for small MS4s, the WQP provides a framework for consistent, effective, and efficient implementation of stormwater management practices for discharges entering drainage conveyance systems.[4] To this end, regulatory requirements contained in the WQP were developed consistent with the Tuolumne County General Plan Goal 4.L, which directs the County to maintain and conserve the quality and quantity of the County's water resources, while protecting the rights of the land owners. The goal is intended to apply to all of the County’s unincorporated lands. More specifically, the WQP implements the requirements of General Plan Policy 4.L.a, which directs the County to develop a conservation program for water resources that includes the following:

1. Provide for the continued implementation of the NPDES permitting program when required by the CVRWQCB.

2. Maintaining vegetative filters and/or buffers adjacent to water resources to assist in reducing the introduction of sediments and pollutants into surface water resources.

3. BMPs for grading on steep slopes, maintaining sediments onsite, preserving adjacent parcel owner property values by avoiding or reducing substantial runoff over neighboring properties and revegetating and/or terracing on large cut and fill slopes.

4. Flexible development standards for reducing grading, where appropriate.

5. Methods for avoiding and maintaining water resources throughout the construction process for those water resources to be preserved on site and throughout the life of the project.

6. Assignment of responsibility for the maintenance of sedimentation control facilities and revegetating graded areas that are abandoned during construction.

[4] Drainage conveyance systems include roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, manmade channels, or storm drains under County ownership.

In addition to providing a regulatory compliance framework, the WQP also was developed to assist CALFED in achieving its primary mission of protecting major sources of water for the Delta and San Francisco Bay. This approach is consistent with General Plan Policy 4.L.8, which directs the County to participate in the State and Federal sponsored CALFED program to develop comprehensive and long-term solutions to the water quality conditions within the Delta. The WQP supports CALFED drinking water quality objectives by continuing to assess source water quality over the long term and providing a dynamic planning framework that responds to the assessed conditions.

In addition to the regulatory context established under the County's General Plan, CALFED, and the CWA, the WQP describes the procedures and practices used to reduce the discharge of pollutants from drainage conveyance systems owned or operated by the County. In various unincorporated areas of the County, waters of the United States or waters of the State pass through, over, or under the County's property and facilities. Those waters may already contain pollutants at the point at which they enter local waterways. This WQP emphasizes approaches to minimizing and preventing the discharge of non-point source pollutants into contributing drainages of local waterways. The following regulatory mechanisms will assist the County in achieving that goal.

1.4.1 State Codes

The California Government Code, Sections 23000-23027, authorizes the County to own and manage property for public purposes. The California Streets and Highways Code provides the County Board jurisdiction over and responsibility for control and operation of the County Highways.

The County possesses adequate legal authority to disconnect or prohibit point source illicit connections to its storm drain systems pursuant to Streets and Highways Code Section 1450. Thus, illicit connections to the County's storm drainage system are considered encroachments. Streets and Highways Code Section 1460 prohibits placing, changing, or renewing an encroachment without a permit. Any person placing an encroachment without the authority of a permit is guilty of a misdemeanor. Generally, a permit granting an encroachment on a highway constitutes a mere revocable license that may be withdrawn at will (People by and through the Department of Public Works v. DiTomaso, 57 C.A. 2D 741). Encroachment permits may also be conditioned to require compliance with stormwater regulations and the requirements of the County's WQP.

Sections 23112, 23113, 23114 and 23115 of the Vehicle Code provide legal authority to prevent spills, dumping, or disposal of materials on the highways and freeways under the County's jurisdiction. Section 23112 states, "No person shall throw or deposit, nor shall the registered owner or the driver, if such owner is not then present in the vehicle, aid or abet in the throwing or depositing upon any highway any bottle, can, garbage, glass, nail, offal, paper, wire, any substance likely to injure or damage traffic using the highway, or any noisome, nauseous, or offensive matter of any kind, rocks, refuse, garbage, or dirt in or upon any highway, including

any portion of the right-of-way thereof, without the consent of the state or local agency having jurisdiction over the highway."

Section 23113 states, "Any person who drops, dumps, deposits, places or throws, or causes or permits to be dropped, dumped, deposited, placed or thrown, upon any highway or street any material described in Section 23112 or in subdivision (d) of Section 23114 shall immediately remove the material or cause the material to be removed."

If the person fails to comply with subdivision (a), the governmental agency responsible for the maintenance of the street or highway on which the material has been deposited may remove the material and collect, by civil action, if necessary, the actual cost of the removal operation in addition to any other damages authorized by law from the person made responsible under subdivision (a).

Section 23114 states (in pertinent part), "No vehicle shall be driven or moved on any highway unless the vehicle is so constructed, covered, or loaded as to prevent any of its contents or load other than clear water or feathers from live birds from dropping, sifting, leaking, blowing, spilling, or otherwise escaping from the vehicle."

1.4.2 County Codes

The County, by ordinance (County Code Chapter 13.24) authorizes the County Health Department, Division of Environmental Health to manage the handling, storage, transport, and use of hazardous material. Additionally, the Division of Environmental Health is authorized to inspect for hazardous materials on private property and oversee clean-up activities.

The County, by ordinance (County Code Chapter 12.20), authorizes the County Department of Public Works to regulate all grading activities, and requires that such activities be undertaken in such a manner that quantities of sediment or other materials substantially in excess of natural levels are prevented from leaving the site.

CHAPTER 2
Approach to Water Quality Planning

This chapter describes how the WQP study area was defined, the condition of watersheds within the study area, and the parameters to be addressed within the WQP. This chapter also identifies the County's approach to prioritizing the watersheds within the study area, minimizing adverse water quality effects to local waterways and downstream water supply reservoirs, and monitoring the results of water quality management efforts and improving those results, where feasible. The resulting approach offers both a watershed level and a more project or parcel-specific level approach to managing water quality to best address short-term, long-term, and cumulative effects on the County's water resources. Following this approach, Chapter 3, County-Based Programs, describes specific actions and programs to be undertaken to address activities affecting water quality within the County's jurisdiction. Chapter 4, Community and Voluntary Stewardship Programs, identifies actions and programs addressing activities outside the County's regulatory jurisdiction.

2.1 Primary Study Area

The County contracted with Environmental Science Associates (ESA) to conduct baseline water quality studies in support of the Assessment for prioritized watershed and sub-watershed units within the Upper Stanislaus River (USGS Cataloging Unit [CU] 1804010) and Upper Tuolumne River (CU 1804009) watersheds (Figure 2-1). The highest priority watershed units within the County's jurisdiction include those under development pressure that supply drinking water reservoirs and include all or portions of the Big Oak Flat, Clavey River, and Copperopolis Hydrologic Areas as identified in the 1999 California Interagency Watershed Map (CalWater Version 2.2.1).

Due to the expansive area contained within the County's jurisdiction and the range of possible contaminants that could be present in foothill waterways, the County's MRP consists of a two-phased approach to monitoring. Phase 1 involved the establishment of a water quality baseline data for five watersheds that comprise the County's Primary Study Area (PSA). The five watershed units include all or portions of the Sullivan Creek, Woods Creek, North Don Pedro, Big Creek, and Rawhide Flat watersheds and sub-watersheds of the Upper Stanislaus River and Upper Tuolumne River watersheds (Figure 2-2). The PSA, located near the base of the two watersheds, represents a small fraction of the total watershed area, but contains a majority of the existing and planned urban development within the County. Within the Upper Stanislaus River watershed, the PSA accounts for a very small fraction (approximately 3 percent) of the total watershed area; whereas within the Upper Tuolumne River watershed, the PSA accounts for a larger, but still relatively small portion (approximately 11.5 percent) of the total watershed area.

Figure 2-1

Figure 2-2

The monitoring locations sampled were selected to assess cumulative or mass loadings within each of the five watersheds and provide an indication of total pollutant loading into downstream water supply reservoirs (i.e., New Melones and Don Pedro Reservoirs). These monitoring locations are illustrated in Figure 2-3. The constituents sampled included flow, pH, total suspended solids (TSS), specific conductance, oil and grease, temperature, priority pollutant metals, dissolved oxygen (DO), turbidity, and nitrate (NO_2) plus nitrite (NO_3)[1]. Other constituents included chlorinated-herbicides, volatile organics compounds (VOCs), and total and fecal coliform bacteria. Concurrent with collection of grab samples, visual observations for the presence of floating and suspended materials, films or sheens, discoloration, turbidity, potential nuisance conditions (e.g., odor), and aquatic life were also recorded and photo-documented. The results of these sampling events are provided in the Assessment and are summarized below in Section 2.2.

Phase 2 of the MRP was initiated in November 2006 and is being implemented monthly by the citizen monitoring group. Future monitoring objectives are more fully described in Chapter 3, County-Based Programs, and Chapter 4, Community and Voluntary Stewardship Programs.

2.2 Existing Conditions

Prior to the preparation of the County's Assessment, much of the preexisting water quality information for the foothill region of the Upper Tuolumne and Upper Stanislaus River watersheds was limited to watershed sanitary surveys for local water supply infrastructure and compliance monitoring for point-source discharges. In contrast, there exists a more-established dataset for the upper reaches of the larger watersheds (e.g., Upper Tuolumne River) due to regional water supply, forestry, and hydroelectric interests. For these reasons, water quality monitoring data collected in support of the Assessment represent the best available information for characterizing current water quality conditions within the PSA and developing a planning framework to address those water quality conditions identified as a concern.

The findings of the County's Assessment specifically note that current water quality conditions within the foothill region of the County are a result of historic land management activities. These conditions are primarily associated with the significant landscape alteration that has occurred within the last 150 years as a result of road construction, the development of local water supply infrastructure, mining and agricultural practices, and population growth. Contaminant sources identified in the Assessment and in prior studies include residential and commercial onsite sewage disposal systems, leaking underground storage tanks (USTs), and unobstructed grazing practices. Chronic sources of soil erosion and enhanced sediment delivery to local waterways are also identified as a concern. Based on the range of potential NPS, the Assessment recommends that the County's WQP prioritize the following concerns:

[1] Bacteria initially convert atmospheric nitrogen, N_2 into forms of ammonia (NH_3) and nitrate (NO_2). Through the process of decomposition, ammonia is then combined with oxygen through the actions of bacteria to produce nitrates and nitrites. Measuring nitrates plus nitrites provides a good indicator of nitrogen levels that, in excess amounts, can result in algal blooms and subsequent oxygen depletion.

RECOMMENDED NON-POINT SOURCE WATER QUALITY PARAMETERS TO BE PRIORITIZED

- ***Soil Erosion and Sediment Delivery to Waterways.***
- ***Total and Fecal Coliform Bacteria, Associated Pathogens, and Nutrients*.**
- ***Urban Contaminants***. (e.g. trace metals, herbicides, hydrocarbons, solvents, etc.)

Figure 2-3

11x17

back of 11x17

2.3 Watershed Prioritization – Catchments

To enable prioritization of the County's limited resources to address these pollution issues, the Assessment report included a vulnerability analysis for smaller watershed catchments that comprise the PSA. This approach allowed for the prioritization of smaller drainage catchments that are potentially vulnerable to the above identified sources of NPS pollutants. For this reason, this planning methodology is incorporated into the WQP and will enable the County to focus outreach efforts, identify potential grant funding opportunities, and evaluate the success of BMPs.

Watershed catchments were delineated for the five major watersheds comprising the PSA through surface interpolation of 10-meter Digital Elevation Models (DEM) for the U.S. Geological Survey (USGS) 7.5-minute quadrangles for New Melones Dam, Sonora, Standard, Tuolumne, Columbia, Columbia SE, Twain Harte, Keystone, Chinese Camp, Duckwall Mountain, Moccasin, Groveland, and Jawbone Ridge. These watershed or drainage catchments were then given unique identifiers (e.g., US01 = Upper Sullivan Creek, Catchment Unit No. 1) to allow for risk analysis using GIS overlay techniques. The watershed vulnerability analysis then used spatial analysis to categorize smaller watershed catchments based on the three major risks identified: (1) urban contaminants, (2) enhanced soil loss and deliverability to the stream network, and (3) problematic septic systems.

In the short-term, this analysis is limited to the watershed units comprising the PSA. However, the County intends to expand the delineation of the drainage catchments to areas outside of the PSA as funding becomes available. As indicated in the preceding section, prioritization of the smaller watershed catchments will allow County staff to better focus outreach efforts, identify and direct potential grant funding opportunities, and evaluate the effectiveness of BMPs to those areas with the highest potential for contamination.

For the purpose of implementing the WQP, prioritization of smaller watershed catchments focused on the three previously identified potential causes of water quality pollution: urban runoff, fecal coliform bacteria and nutrients, and soil erosion and stream sedimentation. Prioritization will be the primary method for implementing watershed rehabilitation projects consistent with General Plan Policy 4.L.n, which provides for such watershed improvements as:

1. A reduction in the presence of contaminants in drinking water by addressing the origins of the contaminants, including, to the maximum extent practicable, the specific activities that affect the drinking water supply of a community or communities.
2. An increase in the quantity of water available from the watershed.
3. The improvement, restoration, or enhancement of fisheries habitat, including riparian habitat, in and along streams and watercourses in the watershed. These projects may address factors which increase sedimentation in streams and watercourses in the watershed.
4. The improvement of overall forest health, including the reduction of factors which may contribute to the severity of wildfires in the watershed.

To prioritize watershed catchments based on potential risks from the wide of range of potential sources of NPS pollution, impervious surface coverage estimates where calculated for each catchment within the PSA. Impervious surface is one of the more commonly used indicators of watershed stress and was considered the most appropriate variable in capturing those catchments at the highest risk to threats from the NPS priorities. Impervious surface cover was estimated by categorizing County zones based on allowable development intensities as defined in Title 17 of the County's Zoning Ordinance. Four development intensity categories were developed to cover the range of development intensities present within the County; these are more thoroughly described in the Assessment report. Although the use of the zoning coverage potentially could over-estimate impervious cover, at least in the interim, it provides the best practical information for watershed planning in terms of NPS pollution for the large land area (224.8 square miles) that comprises the PSA.

Figure 2-4 provides NPS pollutant prioritization ratings for individual drainage catchments based on the maximum allowable building intensities. The highest prioritized watershed catchments are those with the highest concentrations of impervious surfaces at zoning build-out, and therefore, are the primary focus of the stormwater controls and water quality monitoring activities outlined in Chapters 3 and 4 of this document. Watershed units with the greatest vulnerability to urban runoff include specific catchments contained within the Upper Curtis Creek, Lower and Upper Sullivan Creek, Upper Mormon Creek, Upper Turnback Creek, and Big-Oak Flat-Groveland (Pine Mountain Lake) subwatersheds. Urban centers within each of these drainage units include Columbia, Jamestown, East Sonora, Pine Mountain Lake, Standard, Tuolumne, and Twain Harte. It should be noted that zoning information for the City of Sonora (the city limits are excluded from the PSA) is not reflected in Figure 2-4, and therefore, watershed catchments within the Sonora city limits should be incorporated in cooperation with the City as funding allows.

In addition to planning for increased runoff, the County's objective of controlling urban nonpoint sources of pollution includes isolating specific drainage catchments containing contaminated sites. As part of the County's 1999 Groundwater Protection Report, a database of sites was created. Currently, the database documents 58 sites with Class V injection wells,[2] 45 sites with waste discharge requirements (WDRs) issued by the CVRWQCB, 67 sites with underground fuel storage tanks, and 74 active commercial sites with onsite sewage disposal. Although designed to be GIS compatible, much of these datum have not been integrated into the GIS. The ability to overlay these data with specific drainage catchments would further enhance the prioritization ratings depicted in Figure 2-4.

[2] Typically, Class V injection wells are shallow "wells," such as septic systems and drywells, used to place nonhazardous fluids directly below the land surface. Some examples of Class V wells are agricultural drainage wells, stormwater drainage wells, large capacity septic systems, sewage treatment effluent wells, mine backfill wells, special drainage wells, heat pump/air conditioning return flow wells, and industrial wells. For facilities that generate nonhazardous wastes, Class V wells provide for disposal when there is no access to a sewer system.

Figure 2-4
11x17

Back of 11x17

2.4 Response to County-Wide Water Quality Issues

The preparation of the WQP represents an initial attempt to address sources of cumulative watershed effects (CWEs) identified in the County's Assessment report and to proactively respond to the assessed conditions through adaptive management. Based on the County's Assessment (Section 2.2) and the prioritization of catchments (Section 2.3), the County can manage watershed units in its jurisdiction in a way that minimizes adverse water quality effects to local waterways and downstream water supply reservoirs. The WQP emphasizes watershed planning to enable the cost-effective allocation of the County's limited resources to respond to local water quality concerns and maximize opportunities identified in the Assessment report. Further, watershed planning at the catchment level allows for the prioritization of smaller drainage units based on identified vulnerabilities (Section 2.2). Although the County's Assessment concluded that water quality degradation has occurred within each of the five watersheds that comprise the PSA (see Section 2.1), the main forms of degradation, elevated levels of turbidity and fecal coliform bacteria, can be attributed to historical land management practices. Based on these findings, the County can manage sources of urban NPS pollutants both by planning both at a small-scale (individual project) level and at the watershed level. This planning approach will enable the County to cost-effectively focus the implementation of new regulatory requirements on individual projects and public infrastructure while at the same time setting forth a broader, long-range, watershed-level approach to address legacy pollutants while minimizing cumulative water quality effects.

Programs contained in Chapters 3 and 4 of this document are intended to provide the initial framework for complying with the requirements of the Phase II NPDES Program. Although not identified as a Phase II regulated entity, there is a high likelihood that future County regulation may occur; especially as population growth continues. For this reason, the County has developed objectives that can easily be expanded, enhanced, or integrated with other existing programs to satisfy Phase II NPDES Permit requirements for small MS4s. These objectives were developed to address each of the six program elements required for Phase II regulated entities.

SIX PROGRAM ELEMENTS OF PHASE II NPDES PROGRAM

- Illicit Discharge Detection and Elimination
- Construction and Post-Construction Activities
- New Development and Planning
- County Operations
- Public Outreach and Education
- Community Involvement and County Stewardship Priorities

Those program elements largely within the County's regulatory purview (e.g., Illicit Discharge Detection and Elimination; Construction and Post-Construction Activities; New Development and Planning; and County operations) are described in Chapter 3, County-Based Programs. Those program elements more within the public element are likely to be applicable on a watershed level are described in Chapter 4. All programs are intended to demonstrate and sustain improvements to surface water quality over the WQP's 20-year planning horizon and beyond.

Chapters 3 and 4 of this document address both short-term and long-term planning efforts to manage water quality. Generally, remediation of water quality issues resulting from historical practices ("legacy pollutants") requires long-range or broad-scale programs. While a few such programs may be incorporated into County regulations (Chapter 3), the majority of these programs will require a broader effort and the involvement of multiple agencies, the public, and other stakeholders County-wide (Chapter 4).

Programs identified in Chapters 3 and 4 of this document respond to locally assessed conditions to demonstrate a need for grant funding, especially as funding becomes more competitive. Further, these programs emphasize the necessity of demonstrating potentially foreseeable improvements and linking those improvements to water quality objectives for the Delta.

2.5 Adaptive Management

As previously indicated, the overall strategy of the County for reducing pollutants to the maximum extent practicable involves the use of effective management practices and programs through a process of continuous improvement and refinement (adaptive management) focused on source control and pollution prevention activities. Using the WQP as a guide, the County will regularly review its activities, inspect its facilities, and conduct studies to obtain information that supports responsible management and allocation of the resources for improving water quality.

Initial monitoring efforts will focus on the qualitative, and in certain instances, quantitative evaluation of stormwater practices since these practices have the greatest potential to affect the quality of the water being discharged into local receiving waters. As the WQP is implemented, the County expects that monitoring efforts will expand to involve collecting information to:

- Better characterize the composition of stormwater discharges from the County's storm drainage system(s).
- Identify other sources of pollutants.
- Continue to characterize the quality of receiving waters.
- Inventory the storm drainage system(s).
- Develop greater focus on priority pollutants of concern.
- Evaluate the performance of BMPs.

Results from these efforts will be used to assess the effectiveness of the WQP and to develop new or refined programs, including new or improved practices.

The County will continue to work cooperatively with the CVRWQCB and other interested stakeholders during future watershed planning efforts. It is anticipated that the CVRWQCB will provide input on monitoring site selection and sampling and analysis plans in conjunction with these efforts. Results and recommendations of these studies will help refine existing or establish new County-recommended BMPs based on local site conditions and cost-effective implementation. Efforts will continue to emphasize innovative practices that address the specific stormwater constituents expected to cause or contribute to exceedances of applicable water quality objectives.

In addition to evaluating effectiveness of various alternative BMPs, the County or other appropriate entity (e.g., RCD) will investigate the feasibility of developing a Watershed Coordinator position to monitor, research, pursue, propose, refine, and oversee water quality County-wide (see Chapter 4).

2.6 Long-term Monitoring and Response

The WQP includes multiple activities that will require measurement of several surface water quality parameters necessary to evaluate the WQP's performance over the long term and determine whether or not the County's goals and objectives are ultimately achieved.

As more data become available both within the County and elsewhere, the County will be in a better position to assess the actual or threatened effects that runoff from storm drainage systems owned and/or operated by the County may have on local receiving water quality. These data will be used in a variety of ways, including:

- Determining exceedances of water quality objectives
- Developing total maximum daily loadings (TMDLs)
- Refining the WQP
- Watershed planning.

Water quality data collected as part of the WQP will be collected consistent with the County's adopted QAPP. The QAPP documents the requirements and criteria for field and laboratory procedures used during the planning and implementation phases of the County's MRP. The QAPP also discusses water quality objectives and criteria identified for beneficial uses applied to local water resources as prescribed in the Basin Plan. The MRP is a dynamic document that will be amended over time based on changes to sampling parameters and monitoring locations. All amendments to the MRP will be integrated into the most current version and distributed to appropriate County and CVRWQCB staff.

The sampling network for Phase 2 of the MRP will be comprised of some of the cumulative loading sites sampled during Phase 1 and sites that characterize more discrete drainage catchments. Section 2.3 identifies priority watershed catchments determined to be at the highest risk for water quality degradation. Therefore, the WQP will direct more discrete sampling efforts

to these locations as funding becomes available. Potential monitoring sites that may be sampled in the future as part of the WQP are depicted in Figure 2-3. Monitoring parameters at new locations will be contingent on the prioritized risk being assessed. Likewise, monitoring at the Phase 1 monitoring sites will focus on tracking those parameters identified as "constituents of concern," namely turbidity and fecal coliform bacteria, and other standard water quality field parameters (e.g., pH). A citizen-monitoring group under the possible oversight of the County RCD will conduct a majority of the monitoring under Phase 2. Data will be recorded and entered into a master database developed during Phase 1 to track improvements and establish water quality data trends.

In addition to long-term data collection, the WQP encourages acquiring data using protocols outlined in the County's QAPP and MRP to evaluate the effectiveness of BMPs as they are implemented. This approach emphasizes obtaining pre-BMP implementation data for construction and grading projects, and pollution prevention programs to enable actual quantification of their effectiveness. Initially, BMP evaluation will emphasize sediment production and associated transport mechanisms. However, as additional funding becomes available, the evaluation will be expanded to evaluate BMPs aimed at managing other constituents.

Recognizing that the focus area for the County covers a wide range of land uses, the pollutants of concern or target pollutants that will be monitored during the WQP's planning horizon will include a combination of those identified below. These various pollutants are collectively referred to as non-point source (NPS) pollutants in the WQP.

Sediment is soil material transported or deposited by the action of wind, water, ice, or gravity, as a product of erosion. For example, sediment can erode from land when disturbed by a construction activity or heavy rainfall. Sediment can increase turbidity, clog the gills of fish, reduce spawning, smother bottom dwelling organisms, suppress the growth of aquatic vegetation, and transport other pollutants, such as heavy metals.

Oil and grease are characterized as high-molecular weight organic compounds. Primary sources of oil and grease are petroleum hydrocarbon products, motor products, esters, oils, fats, waxes, and high molecular-weight fatty acids. The main sources of oil and grease are leakage from engines, spills at fueling stations, overfilled tanks, leaking under ground storage tanks (USTs), and restaurant waste oil disposal.

Metals (including lead, zinc, cadmium, copper, chromium and nickel) are commonly found in stormwater. Many of the artificial surfaces of the urban environment (e.g., galvanized metal, paint, automobiles, or preserved wood) contain metals, which enter stormwater as the surfaces corrode, flake, dissolve, decay, or leach. Metals are of concern because they are toxic to aquatic organisms, can accumulate to toxic levels in aquatic animals such as fish, and have the potential to contaminate drinking water supplies.

Nutrients are inorganic substances, such as nitrogen and phosphorous. They commonly exist in the form of mineral salts that are either dissolved or suspended in water. The primary source of nutrients in urban runoff has been identified as fertilizer products, but also is associated with organic waste. Excessive use of fertilizer can result in the discharge of nutrients to water bodies and streams, resulting in excessive aquatic algae and plant growth.

Pathogens are agents, usually living microorganisms, or components of these organisms that cause or may cause disease (e.g., viruses, protozoa, fungi, parasites, proteins, various species of bacteria). Water may be contaminated by pathogens such as the bacteria, *E. coli* thereby creating a potentially harmful environment for humans and aquatic life. Sources of these contaminants include animal excrement, sanitary sewer overflow, improperly functioning septic systems, and soil. High levels of indicator bacteria in stormwater have led to the closure of beaches, lakes and rivers to contact recreation such as swimming.

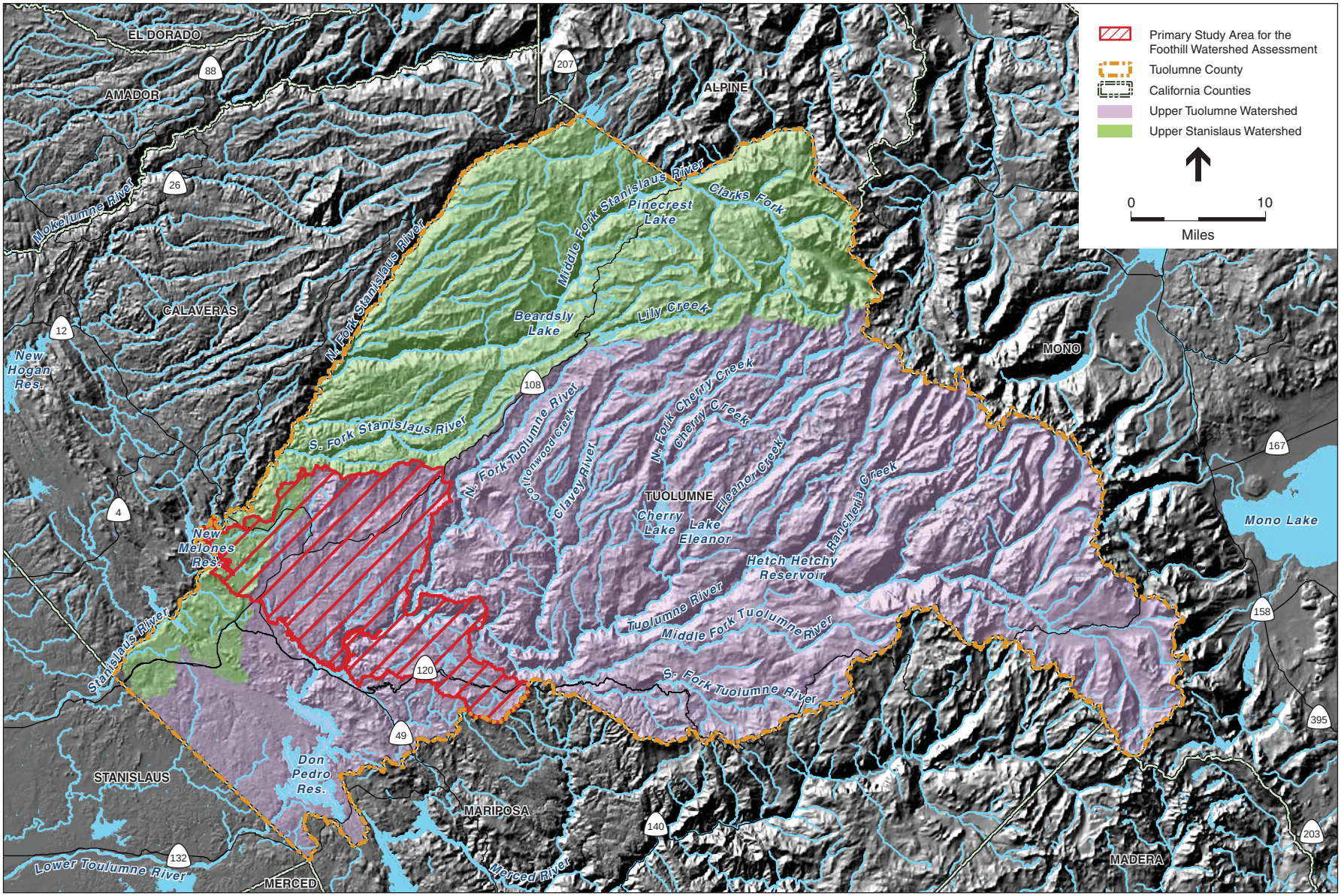
Organic compounds (including toxic synthetic compounds such as adhesives, cleaners, sealants, and solvents) are widely applied and may be improperly stored and disposed. In addition, deliberate dumping of these chemicals into storm drains and inlets causes environmental harm to waterways and adversely affects drinking water supplies. For example, when rinsing off objects, toxic levels of solvents and cleaning compounds can be discharged to the storm drain.

Pesticides (including herbicides, fungicides, rodenticides, and insecticides) are commonly detected in stormwater. As use of pesticides has increased, so have concerns about the potential adverse effects of pesticides on the environment and human health. Accumulation of these compounds in simple aquatic organisms, such as plankton, provides an avenue for biomagnification through the food web, potentially resulting in toxic levels in those organisms that feed on them, such as fish and birds.

Oxygen-Demanding Substances are those substances that require oxygen as part of their natural, biological, or chemical processes. The oxygen demand of a substance can lead to depletion of natural oxygen resources in a waterbody and possibly the development of anoxic conditions. Proteins, carbohydrates, and fats are examples of oxygen-demanding substances. They can also be referred to as “biodegradable organics.” The presence of oxygen-demanding substances in water is measured as the biochemical oxygen demand and the chemical oxygen demand.

Floatable Materials include trash (e.g., paper, plastic, polystyrene packing foam, aluminum materials, etc.) and biodegradable organic matter (e.g., leaves, grass cuttings, food waste, etc.). The presence of floatable materials has a significant impact on the recreational value of a water body and can potentially impact aquatic species habitat. Excess organic matter can create a high biochemical oxygen demand in a stream and thereby, lower the water quality of the stream. Also, in areas where stagnant water exists, the presence of excess organic matter can promote anoxic conditions resulting in the growth of undesirable organisms and the release of odorous and hazardous compounds such as hydrogen sulfide.

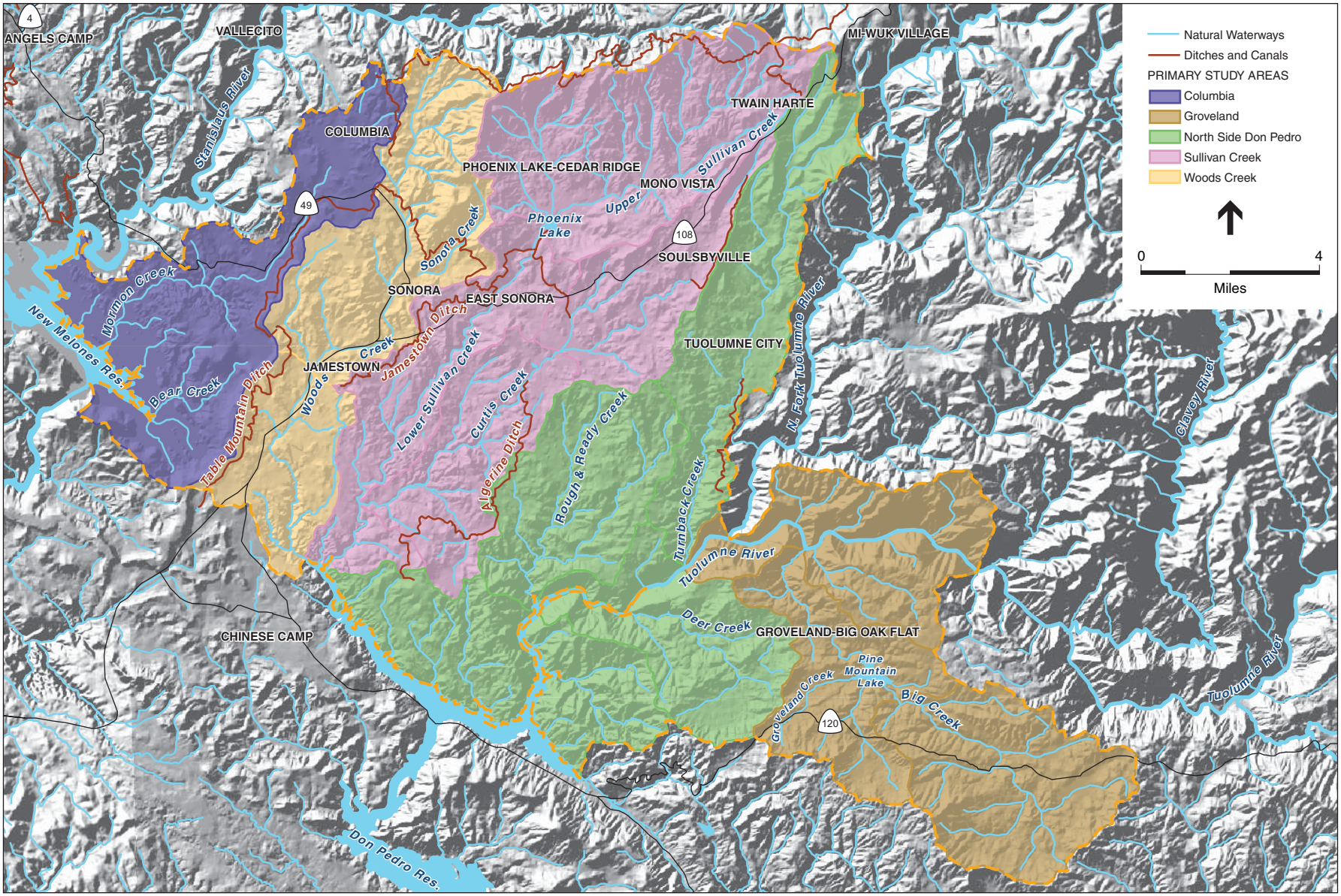
Ecological Indicators include the measurement of certain habitat parameters (e.g., canopy cover, bank vegetation, etc.) and identification of periphyton, benthic macroinvertebrates, and fish assemblages. The measurement of these ecological indicators requires the use of standardized biological monitoring protocols as a way to measure present biological conditions and to provide a means to compare them with the conditions expected in the absence of man-made sources of change. As biological communities reflect overall ecological integrity (i.e., chemical, physical, and biological integrity) and integrate the effects of different stressors, these forms of indicators provide a broad measure of their aggregate impact.



SOURCE: USGS, 1993; ESRI, 2005; and ESA, 2006

Tuolumne County Foothill Watershed Assessment . 204254

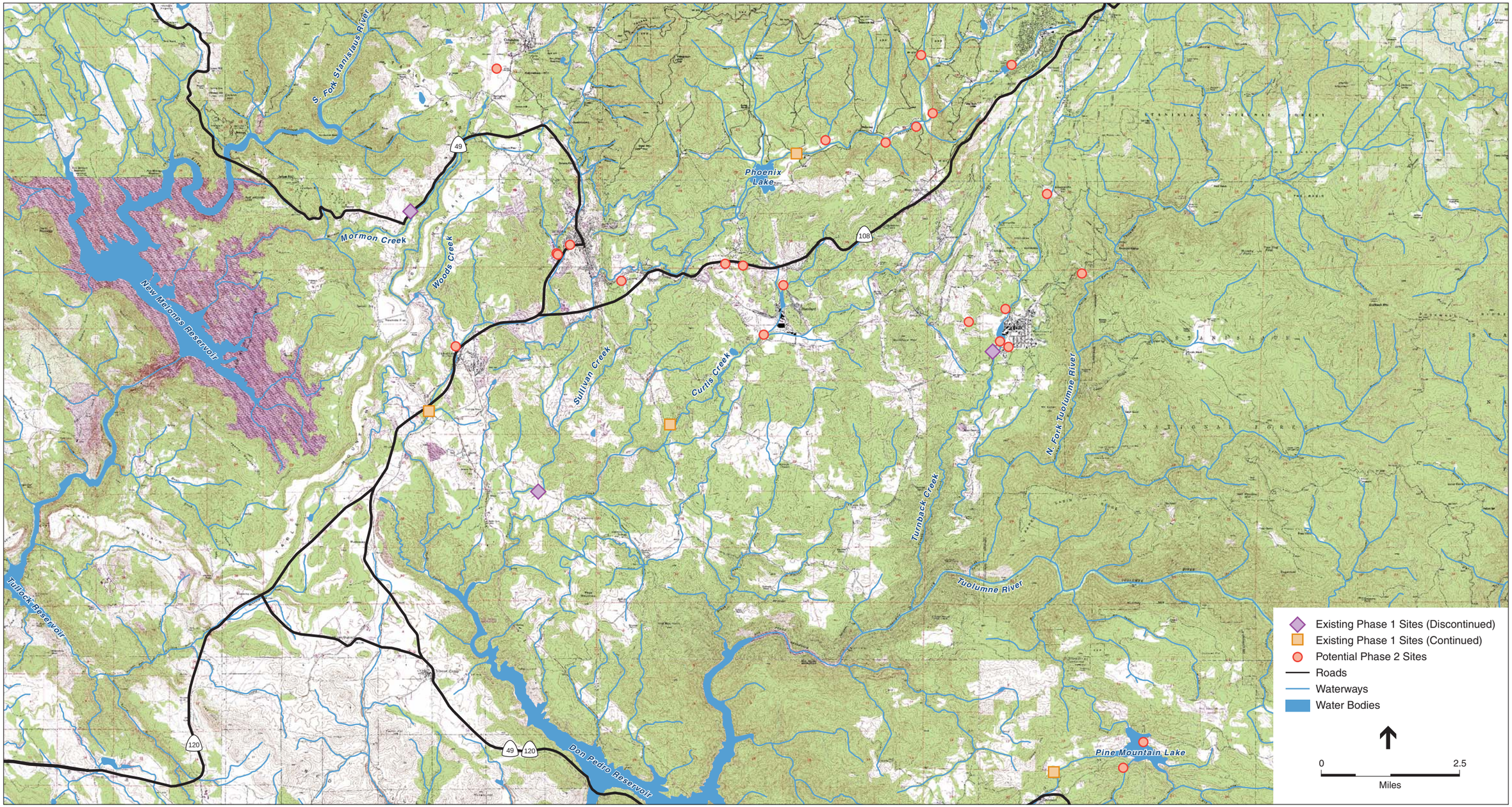
Figure 2-1
County Watersheds



SOURCE: USGS, 1993; CalWater 2.2.1, 1999; and ESA, 2006

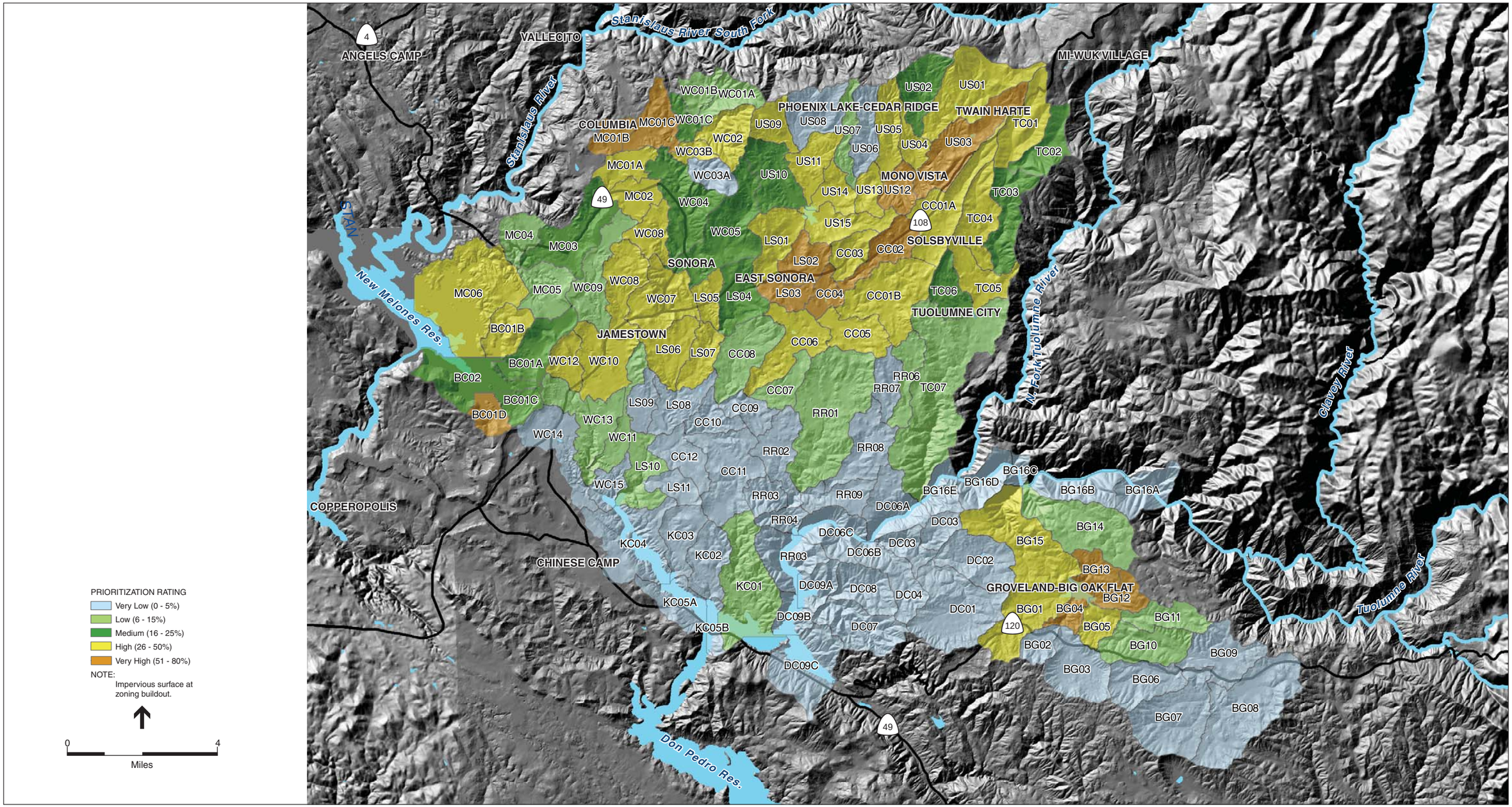
Tuolumne County Foothill Watershed Assessment . 204254

Figure 2-2
Primary Study Area for the
County Foothill Watershed Assessment



SOURCE: Tuolumne County, 2004; and ESA, 2006

Figure 2-3
Existing and Potential Phase 2 Surface Water Monitoring Locations



SOURCE: USGS, 1993; Tuolumne County, 2004; and ESA, 2006

Figure 2-4

Watershed Catchment Prioritization for Urban Non-Point Source Pollutants

CHAPTER 3
County-Based Programs

3.1 Program Overview

The principal findings of the County's Assessment suggest that a range of NPS pollutants, currently or have the potential to impact surface water quality within the foothill region. Further, the Assessment also indicates that foothill watersheds are at risk for further degradation by continuing urbanization and associated drainage modifications. These findings combined with a projected annual growth rate of 0.5 percent and a current population of more than 50,000 suggests that the County meets the criteria for possible regulation under the USEPA's Phase II NPDES Program.

The Phase II NPDES Program is administered by the SWRCB and the California Environmental Protection Agency (Cal EPA) through the California NPS Pollution Control Program. Actually implementation occurs at the RWQCB level. To satisfy USEPA requirements, the SWRCB adopted a General Permit for the Discharge of Stormwater from small municipal separate storm sewer systems or MS4s (WQ Order No. 2003-0005-DWQ) to provide permit coverage for smaller municipalities, including non-traditional small MS4s (e.g., public campuses). The MS4 permit requires a discharger to develop and implement a Stormwater Management Plan/Program with the goal of reducing the discharge of pollutants to the maximum extent practicable (MEP). MEP is the performance standard specified in Section 402(p) of the Clean Water Act and is generally achieved by implementing BMPs that cover the USEPA's six required elements to address NPS pollution in conjunction with assessing their effectiveness during implementation. These six elements include:

- Illicit Discharge Detection and Elimination (Section 3.2)
- Construction and Post-Construction Activities (Sections 3.3)
- New Development and Planning (Section 3.4)
- County Operations (Section 3.5)
- Target User Outreach (Section 3.6) and Public Outreach and Education (Chapter 4)
- Community Involvement and Watershed Stewardship Programs (Chapter 4)

The County is not currently identified as a Phase II entity, but has developed this WQP to address all forms of NPS pollution that are thought to originate from lands within the County's jurisdiction. The program is a comprehensive approach that outlines a range of BMPs with the intent of reducing the concentration of pollutants in stormwater to the MEP. In presenting a range of BMPs and in recognition of localized conditions (e.g., climate), it is necessary to understand the range of preventative and/or treatment BMPs available. Extensive literature is available on various BMPs. BMPs presented in the WQP were chosen based on recognized hydrologic conditions in conjunction with their range of effectiveness and applicability to the various land uses present within the County (Table 3-1).

TABLE 3-1
EXPECTED TARGET POLLUTANTS GENERATED BY LAND-USE CATEGORY

	Target Pollutants								
				Toxic Substances					
Land-Use Category	**Pathogens**	**Heavy Metals**	**Nutrients**	**Pesticides**	**Organic Compounds**	**Sediment**	**Floatables**	**Oxygen-Demanding Substances**	**Oil and Grease**
Detached Residential	X		X	X		X	X	X	X
Attached Residential	P		X	X		X	X	P(1)	P(2)
Commercial/ Industrial	P(3)		P(2)	P(5)	P(2)	P(1)	X	P(5)	X
Automotive		X			X(4)(5)		X		X
Restaurants	X						X	X	X
Hillside Development			X	X		X	X	X	X
Parking Lots		X	P(1)	P(2)		P(1)	X	P	X
Roadways		X	P(1)		X(4)	X	X	P(5)	X

X – Anticipated
P – Potential
(1) Potential pollutant if landscaping exists onsite
(2) Potential pollutant if project includes uncovered parking
(3) Potential pollutant if land use involves food or animal wastes
(4) Including petroleum hydrocarbons
(5) Including solvents

Source: CASQA, 2003

Much of the available literature suggests that multiple BMPs used conjunctively (e.g., source and treatment controls) provide the most effective means to achieving MEP. The WQP distinguishes between the three main BMP categories: preventative, source control, and treatment control. The implementation of these three BMP categories will be approached in a hierarchical manner whereby pollution prevention will be emphasized as the highest priority. The three BMP categories are as follows:

1. **Prevention.** Implementation of practices that use or promote pollution free alternatives (e.g., implementation of practices such as integrated pest management, hazardous materials management plans, educational venues, etc.).

2. **Source control.** Implementation of control measures that focus on minimizing urban runoff from contacting pollutant sources (e.g., controls through land use planning practices or material exposure control practices). Source control measures cover a wide-range of NPS pollutant sources that include a combination of education and outreach, watershed-level planning, identification of illicit (or unauthorized) discharges, soil stabilization and/or modifications to current ministerial procedures.

3. **Treatment controls.** Implementation of practices that require treatment of polluted runoff either onsite or offsite (e.g., extended detention basins). For treatment BMPs it is necessary to distinguish between those BMPs designed for temporary construction applications and those BMPs designed for hydrologic conditions as a result of existing infrastructure and/or new development.

Several County departments are responsible for implementing various BMPs. Many of the prescribed BMPs for each of the program elements are intended to complement existing County programs and are subject to modification throughout the implementation of the WQP. The County Department of Public Works in cooperation with other departments will oversee the implementation of most BMPs and related activities, evaluate their effectiveness based on methods outlined in Section 2.6 of this document, and strive to improve the program over time.

The following describes BMPs addressing five of the USEPA's six required elements to reduce NPS pollution:

- Illicit Discharge Detection and Elimination (Section 3.2)
- Construction and Post-Construction Activities (Section 3.3)
- New Development and Planning (Section 3.4)
- County Operations (Section 3.5)

Chapter 4 of this document addresses the remaining USEPA required element to reduce NPS pollution (Public Education and Outreach, and Stewardship Programs).

3.2 Illicit Discharge Detection and Elimination

Achieving successful source control requires a coordinated approach to detecting unauthorized (illicit) discharges to local waterways and illegal dumping. The goal of this program element is to reduce the discharge of pollutants to storm drainage systems by eliminating connections of wastewater lines, interior drains, and other non-permitted direct connections.

In the absence of specific regulations, the County currently relies on more generic state law (Health & Safety Code) to deter illicit disposal. Options available to the County for discouraging illicit discharges include: (1) development of a structured drainage enforcement policy and guidance procedures, with appropriate monetary penalties and/or cost recovery for violations of related ordinances; (2) mapping of the stormwater conveyance system and identification of high priority drainage areas for targeted investigation/enforcement/correction efforts; and (3) County staff education of illicit discharge identification and reporting procedures and alternatives for proper disposal methods within the County. The County's Illicit Discharge Detection and Elimination program incorporates objectives that address each of these three options as follows:

- Structured Enforcement Policy
- Storm Drain Outfall Mapping and Identification/Evaluation Program
- Illicit Discharge Education Program

The programs are described in detail as follows.

3.2.1 Structured Enforcement Policy – Amend County Ordinance Code

The County currently does not have an adopted drainage ordinance that specifically prohibits non-stormwater discharges into the County's drainage conveyance systems (e.g., roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, manmade channels, or storm drains under County ownership). Currently, drainage is covered under the following chapters of the County Code: Roads (Title 11- Section 11.04.050 (E)), Grading (Title 12 – Sections 12.20.280 and 290), and Subdivisions (Title 16 – Section 16.26.180). Eventually, the County intends to develop and adopt regulations addressing non-stormwater discharges as part of an Ordinance Code update and revision process in the long-term. Short-term amendments to address non-stormwater discharges should be focused on Titles 11 and 12.

Responsible Agency: County Health Department, Division of Environmental Health

Anticipated Timeline: Through December 2012 with updates approximately every five years thereafter

3.2.2 Storm Drain Outfall Mapping and Identification Program

The County in cooperation with other entities operating storm drain facilities and/or conveyance systems within the PSA (e.g., Tuolumne Utilities District [TUD], Groveland Community Services District [GCSD], Twain Harte Community Services District [THCSD]), should develop a Comprehensive Storm Sewer System Map showing the location of all outfalls and the names and locations of receiving waters. To the maximum extent feasible, the County may obtain such information from existing sources (e.g., TUD). Alternatively, the County may pursue a cooperative mapping venture with other agencies. The final map should be compatible with the County's GIS. For those facilities within its jurisdiction, the County should conduct a field inventory of storm drain outfalls for existing development including an inventory of land uses associated with outfalls (e.g., commercial, residential, roadway, industrial and specifying particular type of industry such as automotive, painting etc.). Field inventories should include a general evaluation of water quality at the outfalls.

Responsible Agencies: County Department of Public Works in cooperation with other discharging entities (e.g., TUD, GCSD, THCSD). Mapping assistance and field inventories may be provided by qualified citizen volunteer monitors.

Anticipated Timeline: Commencing in June 2008 through December 2012 with mapping prioritized for watershed catchments identified as high and very high priority in Figure 2-4 of the WQP; updates approximately every five years

3.2.3 Illicit Discharge Education Program

For controlling non-permitted discharges into the County drainage/drainage conveyance system(s), the County should implement an Illicit Discharge Education Program that focuses on educating County staff on the types of illicit discharges. Initially focus will be placed on educating individuals about illicit connections and discharges and illegal dumping. Discharges authorized under a NPDES permit will be exempt from this program. In addition, the following discharges are also exempt because they are not expected to contain pollutants and can therefore be discharged without direct application of control practices. These discharges include:

- water line flushing
- landscape irrigation
- diverted stream flows
- rising ground waters
- uncontaminated ground water infiltration (as defined at 40 CRF §35.2005(20)) to separate storm sewers
- uncontaminated pumped ground water
- discharges from potable water sources
- foundation drains
- air conditioning condensation
- irrigation water
- springs
- water from crawl space pumps
- footing drains
- individual residential car washing
- flows from riparian habitats and wetlands
- dechlorinated swimming pool discharges

The CVRWQCB has issued a general permit for dewatering, Order No. CAG995001. Qualifying dewatering operations are able to obtain permit coverage under this order by submitting a Notice of Intent (NOI) to the CVRWQCB. Allowable discharges must not contain significant quantities of pollutants and be either four months or less in duration, or not exceed 0.25 million gallons per day (mgd) during dry weather. Under the terms of the permit, monitoring and reporting are required. Copies of this permit are available from the CVRWQCB.

Non-potable irrigation water, landscape irrigation, and lawn or garden watering runoff, though minimized, will occur on a regular basis as a result of excess irrigation water running off vegetated and nearby impervious areas and into storm drains. These discharges are not expected to result in the discharge of appreciable pollutants. If these activities subsequently result in an unacceptable level of pollutant discharges, the County will undertake to develop, or require the responsible discharging party to develop, a pollution management plan.

Illicit Connections and Discharges

During routine maintenance of conveyance systems and drainage structures, County staff should look for evidence of illegal discharges or illicit connections. The following steps should be followed:

- Identify spills such as paints, discoloring, etc.
- Identify odors associated with the drainage system.
- Record locations of apparent illegal discharges/illicit connections.
- Track flows back to potential dischargers and conduct aboveground inspections. This can be done through visual inspection of upgradient manholes or alternate techniques including zinc chloride smoke testing, fluorometric dye testing, physical inspection testing, or television camera inspection.
- Once the origin of flow is established, require illicit discharger to eliminate the discharge.

Illegal Dumping

County staff should regularly inspect and clean up hot spots and other storm drainage areas where illegal dumping and disposal occur. They should establish a system for tracking incidents; preferably in a format that is compatible with the County's GIS. The system should be designed to identify the following:

- Illegal dumping hot spots
- Types and quantities (in some cases) of wastes
- Patterns in time of occurrence (time of day, month, or year)
- Mode of dumping (abandoned containers, "midnight dumping" from moving vehicles, direct dumping of materials, accidents/spills)
- Responsible parties

The County will post "No Dumping" signs in problem areas with a phone number for reporting dumping and disposal. Signs should also indicate fines and penalties for illegal dumping.

The State Department of Fish and Game operates a hotline for reporting violations called Cal TIP (1-800-952-5400). The phone number may be used to report any violation of a Fish and Game code (illegal dumping, poaching, etc.).

The California Department of Toxic Substances Control's Waste Alert Hotline, 1-800-69TOXIC, can be used to report hazardous waste violations. Notification of hazardous waste spills and/or dumping should also be directed to the County Environmental Health Department.

Responsible Agency:	Oversight and County staff training by the County Environmental Health Department, Environmental Health Division
Anticipated Timeline:	Ongoing, commencing by December, 2010

3.2.4 Storm Drain Stenciling Program

The County should support a stenciling program to apply messages at storm drain inlets located at key locations and in key facilities (e.g., parks and other areas with notable dumping problems) with the intent of assisting in educating the public about stormwater runoff pollution.

Responsible Agency: County Department of Public Works

Anticipated Timeline: New development projects will require that all new storm drain inlets be stenciled by 2008

3.3 Pre-Construction, Construction, and Post-Construction Activities

This program element describes the controls to reduce the discharge of pollutants associated with construction activities by providing a standardized implementation process and a range of BMPs acceptable to the County. The goal is to control pollutants associated with construction activities by requiring a construction site to implement adequate water quality control measures and by enforcing the implementation of the requirements through adequate construction site inspections. A key factor for the success of this program is contractor education; namely identifying acceptable BMPs and explaining techniques for preparing a stormwater pollution prevention plan (SWPPP). The County is currently providing outreach to private developers, designers, and engineers to raise awareness and inform them of their responsibilities to minimize water quality impacts from construction (Chapter 4.0).

3.3.1 Standardized Practices for Establishing Stormwater Management Measures - Process Checklist

Stormwater pollution control requirements are intended to be implemented on a year-round basis at an appropriate level and in the context of local site conditions. The contractor is expected to deploy measures sufficient to achieve compliance with the County's Grading Ordinance and, as applicable, the NPDES General Permit for Stormwater Discharges Associated with Construction Activity. The following process has been developed to standardize the County's requirements for construction activities and outline a protocol that minimizes on- and/or offsite water quality impacts during construction.

The County should work toward adopting standardized practices addressing and a process checklist for applying stormwater management practices based on the following. The process checklist will be used during field inspections by County staff pursuant to the County's Grading Ordinance and will be made available to contractors and engineers to guide them in preparing County grading plans. Aspects of the following that also address air quality issues may require amendments for consistency with adopted air quality management guidelines.

Scheduling

Construction scheduling shall consider the amount and duration of soil exposed to erosion by wind, rainfall, runoff, and vehicle tracking and shall be scheduled to minimize construction activities in watercourses and the amount of active disturbed soil areas, during the rainy season. A schedule shall be prepared that shows the sequencing of construction activities with the installation of erosion and sediment control practices.

Construction shall be scheduled to minimize construction activities in “high-risk areas” and the amount of actively disturbed soil areas during the rainy season (October 15 to May 15). “High-risk areas” include those areas within 50 feet of watercourses designated on USGS topographic maps, 100-year floodplains, regulated wetlands, and where slopes exceed 15 percent.

Unless specifically authorized by the County’s onsite representative, during the rainy season the contractor shall not schedule construction activities in “high risk areas” or schedule to have more than 5 acres of active disturbed soil area. As an alternative to these restrictions, the contractor may elect to assure that these areas are fully protected by “sediment basins” or “treatment,” in addition to the normally required “effective combination” of soil stabilization, sediment barriers and basins/traps. Where permanent stormwater treatment devices are to be constructed, these devices should, whenever feasible, be constructed as an early work item.

Site Conditions

Existing site characteristics such as vegetation, environmental features, topography, and areas of historic contamination (natural and/or industrial or agricultural) should also be recorded on the project layout. Soil laboratory analyses may be required if prior contamination is suspected. The selection and implementation of construction BMPs will be affected by what existing features need to be protected or mitigated during construction.

Preservation of Existing Vegetation

Preserving existing vegetation to the maximum extent possible (MEP) and for as long as possible on a construction site reduces or eliminates erosion in those areas. To facilitate this practice, on a year-round basis, temporary fencing shall be provided prior to commencement of clearing and grubbing operations or other soil disturbing activities to protect those areas where no construction activity is planned or where construction will occur at a later date. Prior to the commencement of soil disturbing activities, areas of existing vegetation that are to remain and those associated with environmentally sensitive areas (i.e., wetlands, protected habitats, etc) shall be fenced for protection. In general, site designs shall preserve existing vegetation to the MEP; and during construction, existing vegetation shall be preserved (and protected by fencing) for as long as possible to minimize erosion. Vegetation preservation must be accomplished in a manner consistent with basic wildland fire prevention practices and the preservation of defensible space.

Stormwater Run-Off and Concentrated Flows

The diversion of stormwater run-off and conveyance of concentrated flows must be considered in determining the appropriateness of the practices chosen. Practices to divert or manage concentrated flows in a non-erosive fashion may be required on a project-by-project basis to divert offsite drainage through or around the construction site or to properly manage construction site stormwater runoff. Existing watercourses shall be protected; and if diverted, handled in a non eroding fashion. To the extent feasible, all concentrated water flows shall be channeled away from disturbed soil areas / stockpiles. Concentrated water flows shall be conveyed in a non-eroding fashion; and they shall, to the MEP, be channeled away from all disturbed soil areas.

Stockpile Management

Stockpile management is required year round. In addition, the County should require the following:

Soil stockpiles:

- Rainy season (October 15 to May 15): Covered or protected with soil stabilization measures and perimeter sediment barriers.
- Non-rainy season: Covered or protected with perimeter sediment barriers.
- Concrete/asphalt rubble, rock and aggregate base/subbase: Covered or protected with perimeter sediment barriers.
- “Cold mix” asphalt: Covered.

Sediment Tracking Control

Appropriate measures should be deployed to minimize the tracking of sediment offsite by vehicles and/or equipment. These measures include stabilized construction entrances/exits and roadways, and tire washing. Where tracking occurs, streets shall be swept or vacuumed. Sediment tracking control practices are required year round. These measures include:

- Street sweeping
- Stabilization of construction roadways
- Entrance/outlet tire washing

These measures may also include stabilized construction entrance/exit controls; however, frequently this control is not effective and does not suffice as a substitute for tire washing.

Wind Erosion Control

Wind erosion control measures are required year round to minimize dust generated by construction activities. These measures include applying water or other dust palliatives to minimize dust.

Non-Stormwater Management

Non-stormwater discharges shall be minimized to the extent feasible. Sediment laden non-stormwater must be filtered (or equivalent treatment) prior to discharging. Measures to control non-stormwater discharges are required year round. These measures include, but are not limited to:

- Water conservation practices
- Vehicle and equipment operational practices
- Dewatering operational practices
- Waste (including hazardous and septic / sanitary) management practices
- Spill prevention and control practices
- Material handling practices
- Practices for paving, pavement grinding, pile driving, demolition, temporary batch plant and irrigation operations

On construction sites, the Construction Manager and the Contractor shall be alert to and report the potential presence of illicit connections to the County's storm drainage system or illicit discharges. The NPDES permit prohibits the discharge of non-permitted non-stormwater discharges. The County Department of Public Works will coordinate the reporting of prohibited non-storm discharges to the CVRWQCB.

If the non-permitted non-stormwater discharge occurs as a result of the construction activity, the Construction Manager and the Contractor shall immediately halt the discharge and take measures to minimize any potential reoccurrence.

If the non-permitted non-stormwater discharge is not as a result of the construction activity, then the County Department of Public Works will address remediation of the situation with the responsible authorities. The County Department of Public Works will log and track each reported non-permitted non-stormwater discharge to conclusion. The ongoing log will be included within the Annual Report.

Disturbed Soil Area Management

Minimum disturbed soil area management requirements shown in Tables A-1 and A-2 in Appendix A, are based on typical rainfall patterns (i.e., time frames, intensities, and amounts), general soil types, the seasons, slope inclinations, and slope lengths. These same factors must be considered for each site when developing the appropriate levels of soil stabilization and sediment control for a specific site. Disturbed soil areas shall be protected with an effective combination of measures including soil stabilization, sediment barriers, and sediment basins/traps.

BMP Monitoring

The type of BMP monitoring depends on which BMP is implemented. In the case of contractor activity BMPs, the monitoring consists of visual inspection to ensure that the BMP was implemented and maintained according to the SWPPP. Such inspection would include, but is not limited to:

- Identifying spills and resulting clean-up procedures (e.g., supplies of spill cleanup materials)
- Verifying adequacy of trash receptacles
- Verifying waste disposal practices (e.g., recycle vs. hazardous waste bins)
- Examining integrity and use of containment structures
- Verifying use of employee education programs for the various activities
- Noting the location of activity (e.g., outdoor vs. indoor, concrete vs. grass)
- Developing BMPs for any chemicals or fuels not addressed in the SWPPP

In the case of erosion and sediment control BMPs, the monitoring program should consist of regular inspection to determine the following:

- Proper installation of erosion and sediment control BMPs
- Effectiveness of BMPs based on the presence of sediment behind or within control devices, the presence of sediment downstream of the site, and signs of erosion in stabilized areas after a storm event.
- Change in drainage patterns
- Stabilization of areas as quickly as possible after completion of construction activities in an area

Responsible Agency: County Department of Public Works

Anticipated Timeline: Use of checklist to commence by January 1, 2008

3.3.2 Require Implementation of BMPs

The County should prepare a recommended list of BMP's similar to that found in Appendix A, for use by property owners and contractors. Such BMP's will be implemented as required by the revised grading code and other ordinances.

Responsible Agency: County Department of Public Works

Anticipated Timeline: Commencing no later than January 1, 2008

3.3.3 Establish a BMP Effectiveness Evaluation Process

The County should consider developing a Best Management Practices Evaluation and Guidelines Program (BMP Program) to track the effectiveness of local source and treatment control practices in efforts to refine the BMPs identified in Appendix A. Selection of the appropriate BMP for a given situation is a difficult decision that must consider factors such as cost, engineering parameters, and effectiveness in attaining the desired result. This program will facilitate adaptive management objectives by assessing and documenting the development of monitoring procedures to evaluate the implementation and effectiveness of BMPs for a variety of activities in four different program areas: construction, urban NPS pollution, roadway engineering, and vegetation management. This program will require a collaborative process of monitoring and reporting between County and State agencies, landowners, and private developers and contractors that implement BMPs within the County.

3.3.4 BMP Guidelines/Stormwater Control Plan Handbook

The County should explore developing and/or adopting an existing BMP Guidebook to help local businesses, landowners, and contractors comply with the water quality standards enforced by the CVRWQCB. As funding becomes available, the County envisions developing a Guidebook in concert with other foothill counties that includes a step-by-step guide on how to prepare a Stormwater Control Plan that supports the analysis of stormwater impacts under CEQA and includes relevant mitigation requirements. The Guidebook should be supported by schematic designs and a simplified design procedure for stormwater treatment and hydrograph modification management BMPs. In addition, the Guidebook should describe the necessary maintenance agreements (e.g., dedication of fee or easement) or other long-term commitment to provide for operation and maintenance of stormwater treatment facilities in perpetuity.

Responsible Agency: County Department of Public Works

Anticipated Timeline: Within four years of WQP adoption

3.3.5 Amend Title 12 (Grading Ordinance)

Please refer to Section 3.4.1, amend County Ordinance Code and General Plan.

Responsible Agency: County Department of Public Works

Anticipated Timeline: Within four years of WQP adoption

3.4 New Development and Planning

This plan element describes the existing, pending, and proposed new controls to reduce the discharge of pollutants associated with runoff from new development projects after construction is complete. This element also describes existing, pending and proposed new methods to

strengthen zoning requirements and enhance the environmental review process to better address water quality impacts before construction begins. These goals will be achieved through a combination of the following:

- **Amend the County Ordinance Code**, as needed, to provide consistent guidelines for drainage management and/or infrastructure improvements for new developments or major redevelopments in the County through amendments to the County Ordinance Code including identifying BMPs
- **Refining environmental impact analysis** related to water quality pursuant to CEQA including provisions to address both project specific and cumulative stormwater regulatory and permitting issues (Section 3.4.2)
- **Educating County staff** to effectively evaluate water quality and potential threats to water quality (Section 3.4.3)

3.4.1 Amend County Ordinance Code

The Tuolumne County Ordinance Code (TCOC) contains requirements for limiting impacts to water quality from development, such as grading, septic systems, wells, land divisions, residential, agricultural, commercial and industrial land uses designated near surface waters. In the context of the findings of the County's Assessment report, it is uncertain whether existing codes and practices are adequate to mitigate impacts to water quality in the County. Potential modifications to the existing TCOC may include, but are not limited to, new requirements for the preparation of a Stormwater Control Plan; identification of prohibited discharges; establishing an authority to inspect and monitor BMPs; and establishing penalties for violations. The following programs are proposed to standardize, streamline, and improve the County's existing mechanisms for maintaining and improving water quality within County regulations. Beyond these proposals, the County should consider additional modifications to existing ordinances or the establishment of a specific stormwater ordinance.

Title 12 (Grading)

Title 12 of the TCOC governs grading activities within the County (Chapter 12.02). Currently, language contained in Title 12 regulating erosion or sedimentation from stormwater runoff is limited to the following:

> "All drainage facilities shall be designed to carry waters to the nearest practicable drainageway approved by the department as a safe place to deposit such waters. Erosion of ground in the area of discharge shall be prevented by installation of nonerosive downdrains or other devices." (TCOC Section 12.20.290)
>
> "The faces of cut and fill slopes shall be prepared and maintained to control against erosion. This control may consist of effective planting. If, in the opinion of the department, the protection for the slopes is not subject to erosion due to the erosion-resistant character of the materials, such protection may be omitted." (TCOC Section 12.20.310)
>
> "When necessary, check dams, cribbing, riprap or other devices or methods shall be employed to control erosion and provide safety." (TCOC Section 12.20.320)

The Public Works Department is currently in the process of amending Chapter 12.20 to better address erosion from grading and construction operations in efforts to reflect the current base of knowledge. In addition to those changes, the following changes to Title 12 are proposed:

Amend the Grading Ordinance

The County will amend Title 12 to incorporate applicable provisions of Program 3.3.1 (e.g., stockpile management, wind erosion controls, disturbed soil area management, BMPs).

Responsible Agency: County Department of Public Works

Anticipated Timeline: Commencing no later than January 1, 2009

Title 13 (Water and Sewers)

Title 13 of the TCOC governs the installation of individual sewage treatment and disposal systems and water supply wells. This ordinance was the subject of extensive review and revision as part of the 1999 Groundwater Investigation. The current requirements contained in Title 13 are consistent with current State and Federal laws. The requirements for these systems may be reviewed at the following locations in the County Code:

- TCOC Chapter 13.04: Private Sewage Disposal Systems (site and soil requirements for division of land in un-sewered areas).
- TCOC Chapter 13.08: Onsite Sewage Treatment and Disposal (site, soil and construction standards for construction of septic tank-leachfield systems).
- TCOC Chapter 13.12: Abatement of Contamination or Nuisance.
- TCOC Chapter 13.16: Well Ordinance (specifies water well construction and testing standards).

In addition to the above, the County intends to develop a stormwater management ordinance.

Prepare a Stormwater Management Ordinance

The County will develop a Stormwater Management Ordinance through a collaborative process that involves local stakeholders and County leaders. Elements of the Stormwater Management Ordinance should, at minimum, contain the following:

- Requirements for the preparation of a Stormwater Control Plan,
- Identifying prohibited discharges,
- Requiring inclusion of Best Management Practices and Standards as identified in the California Stormwater Best Management Practice Handbook,
- Authority to Inspect and Monitor; and
- Penalties for violations.

Responsible Agencies: County Health Department, Division of Environmental Health and County Department of Public Works

Anticipated Timeline: Complete draft ordinance by December 31, 2012

Tuolumne County General Plan – Watershed Planning

The State defines watershed-based water quality protection as the prevention/control of pollution and management of human activities in a geographically or other defined drainage area to protect, restore, and/or enhance the natural resources and beneficial uses within the watershed. The County intends to achieve this directive through a process of watershed prioritization as discussed in Section 2.3 in conjunction with the implementation of voluntary watershed stewardship programs described in Chapter 4 of this document.

Continue to Implement General Plan Policy Directives to Minimize Water Quality Impacts to Local and Regional Water Supply Reservoirs

The County's General Plan outlines several goals and policies, which through their implementation programs seek to achieve basic watershed protection goals by limiting the encroachment of urbanized land uses near regional drinking water supply reservoirs and encouraging the efficient extension of public infrastructure. For example, Implementation Programs 7.J.a through 7.J.e, 7.K.a through 7.K.d, 1.E.k, 1.F.k, and 1.G.3 direct the County to minimize the use of private onsite sewage disposal systems in favor of extension of public sewer service.

Likewise as revealed in the County's Assessment report, a majority of Community areas are situated in the upper reaches of the Assessment's Primary Study Area and at a substantial distance from regional and Federal water supply reservoirs; thus, providing an urban setback from the reservoirs. The County's General Plan land use diagram reflects this land use pattern and supports the continued concentration of urban and suburban centers in the upper reaches of the foothill margin and rangeland, agricultural, and rural residential areas in the lower reaches (exceptions to this policy are noted to exist—in particular several concentrations of Estate Residential land have been developed along the eastern and southeastern shores of Lake Don Pedro). Policy directives contained within the County's General Plan specifically instruct the County to orient urban forms of development to defined community areas as supported by Implementation Programs 1.A.b, 1.A.c, 1.A.d, 1.A.j, 13.A.d, and 13.B.d of the General Plan.

Responsible Agency: County Community Development Department: Planning Division and GIS Division

Anticipated Timeline: In conjunction with consideration of urban development boundary programs

Future Revisions

Additional revisions to the TCOC will be developed during the first five years of the WQP's implementation. These additions, revisions, and/or modifications will specifically address stream zone protection corridors, post-construction drainage, and NPS runoff controls and will be tailored after California Stormwater Best Management Practice Handbooks (Handbooks). The Handbooks

have provided guidance for municipalities since 1993 and reflect the current practices, standards, and significant amount of knowledge gained since the early 1990s about the effectiveness of BMPs.

3.4.2 Environmental Impact Analysis

CEQA applies to all proposed public and private actions or projects requiring discretionary approval by a State governmental or other public agency (unless an exemption applies; see Articles 18 and 19 of the CEQA Guidelines). A "project" is generally defined as the whole of an action or activity with the potential for resulting in direct or indirect physical effects on the environment. The Community Development Department is the agency within the County responsible for implementing CEQA.

The County has not formally adopted significance standards for hydrology and water quality impacts, but consistent with Appendix G of the CEQA Guidelines, the County considers that implementation of a project would have a significant effect on hydrology (other than flooding) and water quality if it were to:

- Violate any water quality standards or waste discharge requirements,
- Substantially deplete groundwater supplies or interfere substantially with groundwater recharge,
- Substantially alter the existing drainage pattern of a site or area in a manner that would result in substantial erosion or siltation on- or off-site,
- Create or contribute to runoff water that would exceed the capacity of existing or planned stormwater drainage systems,
- Provide substantial additional sources of polluted runoff, or
- Otherwise degrade water quality.

Within unincorporated portions of the County, a development generally includes commercial, industrial, transportation, residential, or mixed use projects involving the creation of new or expanded impervious surfaces, such as roof areas, streets, roadways, parking lots or sidewalks in sufficient quantity to potentially affect water quality. To assist in the County's environmental analysis of a project's potential impacts to water quality, the following programs are proposed:

Update Standardized Mitigation Measures

Amend the County's standardized mitigation measures for CEQA documents to include BMPs for maintaining surface water quality (see Sections 3.3.2 and 3.3.3).

Responsible Agency: County Community Development Department, Planning Division

Anticipated Timeline: Commence by December 31, 2008 and complete no later than June, 2009

Adopt Significance Criteria

In addition to criteria established pursuant to CEQA, adopt significance criteria:

- Establish that a project would have a significant adverse impact on water quality if it fails to maintain nonpoint source pollutants at preconstruction levels, and
- Impair existing beneficial uses and/or conflict with water quality objectives established by the CVRWQCB in the Basin Plan.

Responsible Agency: County Community Development Department, Planning Division

Anticipated Timeline: Commence by December 31, 2008 and complete no later than June, 2009

Evaluate Cumulative Drainage and Water Quality Impacts

The County should establish a minimum threshold (e.g., project size, nature of land use, requirement for an Environmental Impact Report) to determine when these evaluations will be required.

Responsible Agency: County Community Development Department: Planning Division and GIS Division; County Department of Public Works

Anticipated Timeline: Adopt guidelines and procedures by December 31, 2009

Update Field Review Checklists

Update existing field review checklists to incorporate water-quality evaluation criteria (e.g., noting the condition of outflows, existing or potential new sources of NPS pollutants, overall watershed health). The County is encouraged to use existing published checklists to the extent feasible.

Responsible Agency: County Community Development Department, Planning Division

Anticipated Timeline: Amend checklists by December 31, 2009

3.4.3 Educate County Staff

Staff Education and Training

When funding becomes available, the County should organize a field training event for County staff to include, but not limited to:

- Attending a stream walk training session identifying water quality indicators (similar to stream walks provided for the Tuolumne County Stream Team citizen water quality monitors)

- Participating in a cooperative field inspection with planners, public works officials, environmental health staff, and others to increase interdepartmental communications and understanding of field applications of various grading practices, erosion control techniques, soil testing procedures, effectiveness of BMPs and monitoring provisions, and similar field operations affecting water quality.

Responsible Agency: County Community Development Department, Planning Division; County Department of Public Works; County Health Department, Division of Environmental Health; and other agencies involved in applying water quality management measures and evaluations in the field.

Anticipated Timeline: Adopt criteria and/or incentive programs by December 31, 2012

Agency and Local Official Outreach

County Officials. Provide opportunities for County officials to participate in environmental education and the distribution of proclamations for groups, industries, businesses, and individuals who have provided an outstanding contribution to water pollution prevention.

County Department Partnerships. Nurture and maintain opportunities to work with County departments to promote the stormwater message. Incorporate public awareness into County staff training on the Stormwater Program.

Annual Agency and County Supervisors Update. Provide copies of the County's Annual Reports submitted to the CVRWQCB and provide periodic program updates to the County supervisors and other agencies, as appropriate.

Responsible Agency: County Community Development Department, Planning Division; County Department of Public Works; County Health Department, Division of Environmental Health; and other affected agencies

Anticipated Timeline: Ongoing

3.5 County Operations

This program element describes the control measures to reduce pollutants from County activities conducted in public right-of-ways and at publicly operated facilities. The goals of these control measures are to:

1. Reduce the amount and type of pollutants that collect on streets, parking lots, park and recreation areas, and material storage and vehicle maintenance areas

2. Reduce the amount and type of pollutants that result from maintenance of storm drainage systems

3. Set an example for what the County expects on privately-owned lands and facilities

It is critical that the County identify and isolate controllable NPS pollutant sources originating from its own operations. Primary pollutant sources of concern include: high activity parking lots; material (including wastes) storage and handling areas; vehicle and equipment fueling, washing maintenance, repair areas; erodible soils; streets and highways; and handling and application of landscape maintenance products. Reduction or elimination of stormwater pollutants at these sources can be achieved by implementing source control BMPs, which include good housekeeping, employee training, spill prevention and cleanup, preventative maintenance, regular inspections, and record-keeping. These BMPs enhance the effectiveness of engineering, structural, and physical controls (such as impervious containments and covers).

3.5.1 Develop and Implement New Source Reduction Strategies

Training will be essential to ensure that employees are aware of and able to implement pertinent provisions of the stormwater program. Areas of focus should include: (1) equipment maintenance and washing; (2) pesticide application practices; and (3) waste storage and disposal. Fact sheets, performance standards, and procedural worksheets and/or manuals for common activities will help simplify the process and encourage compliance. If operational and source control BMPs are not feasible or adequate, then stormwater treatment BMPs may be necessary (see Appendix A).

A range of source reduction strategies includes:

Vehicle and Equipment Fueling/Cleaning/Maintenance

Reduce potential for pollutant discharge through source control pollution prevention and BMP implementation to prevent or reduce the discharge of pollutants to stormwater during vehicle and equipment fueling, maintenance, and cleaning.

Waste Handling and Disposal

The discharge of pollutants to stormwater from waste handling and disposal can be prevented and reduced by tracking waste generation, storage, and disposal; reducing waste generation and disposal through source reduction, reuse, and recycling; and preventing drainage run-on and runoff.

Spill Prevention, Control and Cleanup

Develop procedures to prevent/mitigate spills to storm drain systems. Develop and standardize reporting procedures, containment, storage, disposal activities, documentation, and follow-up procedures.

Landscape Maintenance

1. The major objectives of this BMP is to minimize the discharge of pesticides, herbicides, and fertilizers to the storm drainage system and receiving waters; prevent the disposal of landscape waste into the storm drain system by collecting and properly disposing of clippings and cuttings, and educating employees and the public.

Drainage System Maintenance

As a consequence of its function, the stormwater conveyance system collects and transports urban runoff that may contain certain pollutants. This BMP focuses on maintaining catch basin/stormwater inlet structures, treatment devices, open channels, pump stations, and other stormwater conveyance structures on a regular basis to remove pollutants, prevent clogging of the downstream conveyance system, restore catch basins' sediment trapping capacity, and ensure the system functions properly hydraulically to avoid flooding.

3.5.2 Roadway Drainage and Erosion Survey Program

Observations documented as part of the County's Assessment report suggest that erosion sites within or connected to the roadway system contribute a large proportion of controllable sediment to local creeks. These sites include road cut slopes, road embankments, road-side cast material, roadside ditches with long slope lengths, and culvert outfalls without sufficient downslope protection. These factors contribute to the road systems ability to efficiently intercept surface runoff and subsurface flow from offsite locations (e.g., adjacent properties), concentrate it within roadside ditches, and redirect it toward natural drainages and creeks through culverts and/or overside drains. Increasing slope steepness and length further intensifies this effect.

This Roadway Drainage and Erosion Survey Program was developed to address these issues by inventorying the roadway system for high priority drainage catchments (Figure 2-4) and prescribing corrective treatments. The purposes of the Roadway Drainage and Erosion Survey Program are to:

- inventory road drainage and erosion features
- identify whether the features do or do not have identifiable problems
- provide treatment recommendation based on the field observations and office evaluations
- develop a treatment priority system
- implement treatments based on the priority system
- establish a tracking and monitoring program for the inventory and instituted treatments

Field Inventory

The field inventory should progressively seek to cover all County road systems. The field inventory should begin in the highest priority watersheds as identified in the Assessment (Figure 2-5) as well as any updated information derived from the on-going inventory or other sources. To the extent possible a mid- and long-term inventory schedule should be developed to determine the range of needs for personnel, equipment, and time to complete the inventory. This schedule will also facilitate budgeting and contribute to grant submittals to assist in funding the inventory and treatment.

Site Prioritization

After the completion of the field inventory, evaluation of the identified sites will be necessary to develop a prioritization scheme for treatment. The site prioritization system should consider the following factors: analysis of inventory results, biological factors, regulatory factors, and management factors. Criteria for each of these categories should be developed. Prioritization discussions in the Five Counties Salmonid Conservation Program (http://www.5counties.org/) *Five Counties Road Erosion Inventory Final Report, Section 7, Treatment Prioritization* (by the Trinity County Planning Department- Natural Resources Division and Mendocino Water Agency, 1999) should be useful in developing criteria for the County to prioritize treatments.

Identify Treatments and Treatment Priority

A series of treatment options for erosion control and engineering improvements of the road drainage system should be developed. This list of treatment options should be based on the experience of other entities (refer to Identification of Revegetation Techniques Suitable for Tuolumne County below), the specific drainage structure and erosion conditions identified in the field inventory, the location of these inventory sites within priority watersheds, the specific cost/benefit ratio of treating a given site, and the budgetary and staffing opportunities and constraints that exist as the program is implemented.

As the program is implemented, new ideas will likely emerge based on experience and new information as well as information developed from monitoring the implemented treatments. These should be integrated into the program as appropriate.

Identification of Revegetation Techniques Suitable for Tuolumne County

Establishing a vegetative cover is often an effective erosion control technique. However, the soils that are exposed in road cuts, road embankments, and other disturbed sites are often difficult sites upon which to establish plant cover. The decomposed granitic soils and shallow soils in the County are particularly difficult to establish vegetation on because they have a low nutrient status; have a low organic matter content; have low water holding capacities that makes them too dry for plants; are shallow making it difficult for plants to establish effective root systems; or are steep and highly erosive which may physically remove any soil nutrients, seeds, or young plants that are placed on them. Investigation of effective means of treating such sites is an on-going process. The following discusses useful information identified during the course of this study; however, a detailed literature review and evaluation of revegetation methods is beyond the scope of this outline. Consequently, a more detailed literature review as well as interviews with knowledgeable professionals and the identification of area-specific revegetation and erosion control techniques would be a useful addition to the treatment options available in the County. Interested professionals would include personnel from Caltrans, Sierra Nevada region Resource Conservation Districts, and the Sierra Nevada National Forests. Identification of sources for vegetative materials will also be useful.

Caltrans has an on-going program of stormwater quality evaluation including soil stabilization, vegetation establishment and maintenance, roadside vegetated treatment, and new erosion technology (www.dot.ca.gov/hq/env/stormwater/ongoing/soil/index.htm) with recent reports available at (www.dot.ca.gov/hq/env/stormwater/special/newsetup/index.htm).

Caltrans also has an online training site on Soil Resource Evaluation – a stepwise process for regeneration and revegetation of drastically disturbed soils (www.dot.ca.gov/hq/LandArch/research/es_site_0522/index.html). This site contains four case studies one of which addresses revegetating a Mehrten Formation deposit along Highway 80 in Placer County and another on decomposed granite in Shasta County. Additional information on the Shasta County site (Buckhorn Summit) is also contained in Claassen and Zasoski (1997a, b).

Additional information and experience with physical and revegetation treatment of erodible decomposed granite soil is contained in Trinity County Resource Conservation District and Natural Resources Conservation Service (1999). The report includes background on the Grass Valley Creek watershed including a history of issues and monitoring information.

Hogan (2005) provides a good overview of sediment source control appropriate to the higher elevation Sierra Nevada. It includes three sections: Part I Guiding Principles, Part II Technical Notes, and Part III Literature Review. Part II contains a review of assessing site conditions, gathering baseline information, soil preparation, fertilizers, soil amendments, plant materials and monitoring. Part III contains a good overview of erosion and variables that influence erosion rates including soil structure and treatments.

The California Department of Fish and Game Salmonid Habitat Restoration Manual (www.dfg.ca.gov/nafwb/manual.html) contains a variety of information on revegetation methods and upslope erosion inventory and sediment control guidance.

The California Geological Survey publication Rehabilitation of Disturbed Lands in California: A Manual for Decision Making (www.conservation.ca.gov/OMR/reclamation/index.htm) addresses restoration of moderately and severely disturbed mining lands some of which is applicable to Difficult To Re-Vegetate Sites Associated With Road Cuts (Newton and Claassen 2003).

Responsible Agencies:	County Department of Public Works; County Administrator's Office, Facilities Management
Anticipated Timeline:	Ongoing. Identify potential funding sources prior to December 31, 2012. If successful, prepare and implement plan for watershed catchments identified as high or very high priority by 2015.

3.5.3 Drainage Planning Program

Based on the findings of the County's Assessment report, alterations to natural drainage patterns as a consequence of continuing urbanization within the County have resulted in degradation of receiving waters (e.g., stream morphology) due to higher stormwater runoff volumes, changes in

peak runoff timing, and the introduction of urban contaminants. The purpose of the County's Drainage Planning Program is to develop supplemental technical information and data necessary to develop master drainage plans for urbanized portions of the County. The ultimate objective of this program is to provide County decision makers with better information regarding cumulative drainage effects from existing and planned development as related to the drainage catchments identified in Figure 2-4.

New requirements contained in Section 3.4.1 of the WQP will require that new development projects maintain pre-project runoff volumes up to a specified design event. As a result, this program will focus on cumulative changes to runoff for existing development in terms of timing and velocity in order to identify attenuation requirements for local drainage areas. This process will help the County in retrofitting older stormwater control devices or installing them where none currently exist. For the purposes of this discussion, retrofitting refers to a process that involves the modification of existing surface water runoff control structures or surface water runoff conveyance systems that were designed to control flooding and will also serve a water quality improvement function. Further, retrofitting should also be considered as an opportunity to improve existing water quality BMPs and/or test new ones.

This Program will follow right after the Storm Drain Outfall Mapping and Identification Program (refer to Section 3.2) and require the delineation of watershed catchments outside of the PSA as identified in the Assessment report. The Program will require the generation of a hydrograph for specific drainage-catchments within larger, yet prioritized drainage basins (e.g., Phoenix Lake Basin). This program will require the use of a hydrologic model to provide insight about the effect of land-management practices on the quantity and quality of runoff, infiltration, lateral flow, both saturated and unsaturated subsurface flow, and deep percolation. The steps in developing local master drainage plans will generally include:

1. Determine issues and prioritize areas of concern (what you want to find out)
2. Determine available data
3. Determine available analytical tools and methods
4. Determine project constraints
5. Determine additional data needs
6. Determine acceptable levels of assurance within project constraints

In selecting a model, the County will consider the following: (1) ease of running the model and interpreting the results, (2) availability of data, (3) availability of models (i.e., considering costs and availability to public entities), (4) applicability to land-use activities, (5) applicability to broad geographic areas, and (6) accuracy of prediction. Federal agencies, such as the U.S. Army Corps of Engineers (Corps), Natural Resources Conservation Service (NRCS; formerly Soil Conservation Service), the U.S. Environmental Protection Agency (USEPA), and the U.S. Geological Service (USGS) have developed a plethora of documentation related to models, methods used, and assumptions involved. Documentation, technical publications and models are electronically available from agency internet sites: http://www.wrc-hec.usace.army.mil/ for the

Corps Hydrologic Engineering Center (HEC) and http://www.wcc.nrcs.usda.gov/ for the NRCS National Water and Climate Center (WCC). Based on preliminary review, the County will use one of the below methods in developing master drainage plans for prioritized basins:

> ***HEC-1.*** All ordinary hydrograph computations associated with a single recorded or hypothetical storm can be accomplished with the Corps' HEC-1, Flood Hydrograph Package.
>
> ***Technical Release 55*** **(Urban Hydrology for Small Watersheds. Graphical or Tabular Method).** The graphical method in Technical Release 55 (TR55) is used to determine the peak discharge for a single storm event on a watershed. The method applies to an urban or a rural watershed or one in transition. The method uses NRCS hydrology as described in National Engineering Handbook Section 4, Hydrology (NEH-4), and was developed from hydrograph analysis using Technical Release 20: Computer Program for Project Formulation–Hydrology. The procedure calculates the runoff curve number and time of concentration based on measured watershed parameters

Responsible Agency: County Department of Public Works

Anticipated Timeline: Ongoing. Identify potential funding sources prior to December 31, 2009. If successful, prepare and implement plan for the PSA by 2012.

3.5.4 Wastewater Regionalization and Connection Study

Water quality monitoring conducted as part of Phase 1 of the County's MRP discovered that fecal coliform levels in all the monitored waterways were above Basin Plan objectives at one or more times. One of the primary non-point sources thought to contribute to these elevated levels includes concentrated areas of failing individual septic systems. The County's 1999 Groundwater Investigation identified three primary factors that limit the performance of onsite wastewater systems, including shallow depths to bedrock, coarse-textured soils, and restrictive lot sizes and/or configurations.

Corrective measures for failing septic systems are problematic and controversial in that each system in need of repair or replacement more than likely requires expensive onsite improvements and/or specially engineered systems. In some instances onsite restrictions may only be corrected through an extension of sewer service, which would only be cost-effective for clusters of development. The County recognizes the need to initiate a comprehensive planning process to address these concerns in coordination with major wastewater service providers within the County, which include the Tuolumne Utilities District (TUD), Groveland Community Services District, Tuolumne Sanitary District, and the Jamestown Sanitary District.

In consultation with these entities, the County should encourage further study of connecting existing development within prioritized watershed catchments to an expanded collection system. In addition, the County will continue to coordinate with the CVRWQCB regarding any applications that include variances to the requirements contained in Chapter 13.04 of the TCOC.

To help fund collection system feasibility studies, the County should take a lead in obtaining project funds in the form of loans from the NRCS and the State Revolving Loan Fund, as well as USEPA Hardship Grants and Community Development Block Grants and the Sierra Nevada Conservancy. Over the long-term, the objectives of the County's Wastewater Regionalization and Connection Study are to:

- Provide sufficient wastewater disposal capacity to meet its short- and long-term growth demands as projected under the County's adopted General Plan
- To site and operate new wastewater collection facilities that minimize adverse environmental effects and eliminate dense clusters of failing onsite wastewater disposal systems
- To achieve the above objectives in a cost-effective manner that limits system capital costs, operations and maintenance costs, and user rates to the extent feasible

Responsible Agency: County Administrators Office; Environmental Health Division; Tuolumne Utilities District

Anticipated Timeline: Ongoing.

CHAPTER 4

Community and Voluntary Stewardship Programs

This chapter describes the current and planned public education and outreach activities that are intended to increase the public's awareness of the County's water resources and the effects of NPS pollution on those resources. In addition, the chapter includes voluntary stewardship programs intended to encourage participation in water quality improvement programs through non-regulatory means throughout the community.

These programs will be implemented contingent on available funding over the course of the planning period. It is anticipated that the majority of these programs will be initiated outside of County regulatory agencies, but with cooperation from those agencies. Specifically, it is anticipated that the Tuolumne County Resource Conservation District and/or similar organization(s) will spearhead efforts to promote community and stewardship-based programs to maintain and improve surface water quality County-Wide.

This chapter describes the current and planned public involvement and participation activities focused on maintaining and improving runoff water quality from urbanized and rural land uses. The primary goal is to identify water quality control measures that the public can implement "in their own backyards."

These activities and programs can be broadly grouped into the following categories:

- Establishing Oversight – Watershed Coordinator (Section 4.1)
- Citizen Monitoring (Section 4.2)
- Landowner Technical Assistance Programs: Erosion Control and Community Source Reduction Programs (Section 4.3)
- Existing County Programs (Section 4.4)
- Public Outreach (Section 4.5)
- Workshops (Section 4.6)
- Community Water Body Cleanup Activities (Section 4.7)
- Recognition Programs (Section 4.8)

4.1 Establishing Oversight - Watershed Coordinator

It is anticipated that the majority of community-based programs will be initiated outside of County regulatory agencies, but with cooperation from those agencies. The County should work with the newly-formed Tuolumne County Resource Conservation District (RCD) to fund a permanent County Watershed Coordinator position. The Watershed Coordinator would establish and promote water quality efforts countywide. Recommended watershed coordinator activities include, but are not limited to:

1. Overseeing citizen and private water quality monitoring efforts, maintaining a master database, and providing direction for making program improvements (Section 4.2)
2. Identifying and distributing educational materials
3. Overseeing implementation of a landowner technical assistance program (Section 4.3)
4. Applying for and administering grants and identifying other funding sources (Chapter 5)
5. Overseeing formation of a watershed stewardship program including educational programs for target stakeholder groups (e.g., ranchers, farmers, and landowners within target watersheds or priority catchments)
6. Overseeing formation of local watershed groups focused on specific catchment areas (refer to Chapter 2, Priorities), identifying and pursuing funding, and implementing stewardship programs to improve water quality within those catchment areas
7. Promoting and overseeing preparation of a Watershed Owner Manual(s) for landowners and/or stakeholder groups, providing common and innovative BMPs, and activities aimed at voluntary landowner implementation countywide
8. Organizing and promoting public outreach programs (Section 4.4)
9. Organizing and promoting educational workshops (Section 4.5)
10. Organizing and promoting community water cleanup activities (Section 4.6)
11. Organizing and promoting source reduction programs (Section 4.7)

4.2 Citizen Water Quality Monitoring

The County Citizen Water Quality Monitoring Group (or Stream Team) was developed to implement a comprehensive monitoring strategy by helping to create integrated, long-term, volunteer-based water quality and watershed monitoring programs within the County's watersheds. The goals of the team are:

- To provide guidance, training, equipment, and support to monitoring groups
- To increase the amount and quality of citizen water quality monitoring data
- To increase public and agency use of, and access to, citizen monitoring data
- To establish communications between citizen monitors and government agencies to ensure that useful information is collected

Water quality monitoring is initially focused at implementing Phase 2 of the County's MRP, but may be expanded, subject to community interest. Expanded activities may include visual assessments of little studied watersheds, measurements of water quality parameters at new monitoring locations, surveys of fish and other aquatic organisms that are indicators of water quality, and measurements of flow and sediment load in the streams. The Stream Team will follow an established sampling protocol, provide equipment, and access to a centralized database.

It is anticipated that the Stream Team will operate under the auspices of the County Resource Conservation District with oversight by the Watershed Coordinator.

4.3 Landowner Technical Assistance: Erosion Control and Community Source Reduction Programs

The connection of individual properties to the County-maintained road system plays an important role in terms of the actual delivery of sediment to natural surface waters. Similarly, watershed planning necessarily involves participation by individual landowners in undertaking practices to prevent NPS pollutants on their properties from entering County surface waters.

The County's Assessment report identified runoff from unvegetated portions of properties, driveways, corrals, and sites under development as contributors of sediment to the stream systems. In addition, animal waste, gardening practices, general maintenance practices, pest control, disposing of household hazardous wastes and related substances, and uses on and from individual properties can contribute to the accumulation of NPS pollutants in streams.

The County should investigate potential grant opportunities to fund the development of a Landowner Technical Assistance Program that would be implemented in conjunction with public education and public outreach programs described in Section 4.6. This program would seek to find and disseminate applicable information for landowners on how they could reduce erosion and sediment and other non-point source pollutant delivery from their individual property. Initially, the Program should consist of the following elements:

- Property Self–Assessment: Watershed Owner's Manual
- Erosion Control Techniques
- Techniques for Managing NPS Pollutants
- Defensible Space/Fuel Modification Areas

4.3.1 Property Self-Assessment: Watershed Owners Manual

This program involves developing a simple to use property self-assessment method to assist landowners in conducting a voluntary runoff, erosion, and NPS pollutant assessment of their property. The property self-assessment should be used for existing properties to identify potential retrofits and for newly developing properties so that effective runoff and erosion control measures can be incorporated. Methods for managing, measuring, and/or reducing NPS pollutants on

individual properties also should be included. Runoff from both impermeable and permeable surfaces should be addressed. Impermeable surfaces would include roofs, paved driveways, and paved patios. Permeable sites will include lawns, gardens, corrals, and park areas.

The property self-assessment will guide landowners through their property and produce an inventory of where runoff occurs and is concentrated, where runoff and sediment and other pollutants may be carried off their property, and where the sediment and other pollutants might be delivered to a local creek. The assessment will produce a simple drawing of the property and the location of runoff and sediment from it. The property self-assessment methodology could be simplified from the more formal procedure used in the Lake Tahoe Basin (Coburn et al., 2003). Examples of other homeowner assessment tools include, but are not limited to:

- Mokelumne River Watershed Owner's Manual (2002) adapted by permission from Home*A*Syst (see below) by the San Joaquin County Resource Conservation District Watershed Coordinator, John Brodie. Available from the San Joaquin County RCD, (209) 9472-7127, online at http://www.sjcrcd.org, or e-mail them at info@ sjcrcd.org.

- Home*A*Syst: An Environmental Risk-Assessment Guide for the Home (1997) by the Regents of the University of Wisconsin System with the cooperation of the Northeast Regional Agricultural Engineering Service (NRAES). Available from NRAES Cooperative Extension, P.O. Box 4557, Ithaca, NY 14852-4557, (607) 255-7564, or online at http://www.nraes.org/publications/nraes87.html

- Lodi Winegrower's Workbook. Guides assessment of farming techniques (specifically winegrape growing), preparation and implementation of action plans to improve soils, water, pest management techniques, and other resources. Published by the Lodi-Woodbridge Winegrape Commission (Ohmart and Matthiasson, 2000). Available from the Lodi-Woodbridge Winegrape Commission, (209) 367-4727 or online at http://www.lodiwine.com

- Healthy Horses for Clean Water – A Guide to Environmentally Friendly Horsekeeping for Equine Businesses. Published by Horses for Clean Water in partnership with Rainier Audubon Society and the King County Department of Natural Resources (Alayne Rneee Blickle, 2000). Available from the Snohomish Conservation District, (425) 335-5634, Ext. 4, or available at http://www.psat.wa.gov/Publications/Pub_Master.htm.

- Tips on Land and Water Management for Small Farm and Livestock Owners in Western Washington also by Horses for Clean Water. The manual addresses mud, manure, pasture, weed, wildlife, woodlot management; compost bins, and more. Copies are available from the King Conservation District, 935 Powell Ave., SW Renton, WA 98055; (206) 764-3410, or may be ordered online at http://www.kingcd.org/pub.htm

Additional resources are listed in Appendix B.

4.3.2 Erosion Control Techniques

The Watershed Owners Manual should address erosion control techniques and treatments and designs that can be implemented at modest cost by the landowners themselves, general laborers, landscapers, or more specialized contractors. These treatment techniques could include items

such as mulching bare soils in open space or around shrubs, installing lawns in larger open spaces, infiltration enhancement using rock-filled trenches or basins (dry wells), downspots and cisterns, flow-through planters, infiltration planters, slotted drains in new driveways, vegetated or grassy swales, or outlet protection where runoff is concentrated. These features are described for the Lake Tahoe Basin in Cobourn et al., 2003; examples are also shown at http://www.tahoebmp.org/examples.aspx) and for the Contra Costa County Clean Water Program (http://www.cccleanwater.org/construction/nd.php#SourceControl). Other descriptions are in The Mountain Driveway Best Management Practices Manual (Wright Water Engineers and Denver Regional Council of Governments, 1999).

NRCS - Backyard Conservation shows how conservation practices used on agricultural lands across the United States to conserve and improve natural resources can be adapted for use on the land around your home. These practices help the environment and can make your yard more attractive and enjoyable (http://www.nrcs.usda.gov/feature/backyard/).

Techniques that may be more suitable for small commercial developments include vegetated and grassy swales, dry wells, infiltration trenches, and infiltration basins (http://www.cccleanwater.org/construction/nd.php#SourceControl).

The Watershed Coordinator will be available to discuss the results of a property self-assessment and help identify suitable treatments that meet the site conditions and the owner's financial and physical capabilities. A list of local supply dealers, who carry the appropriate materials, or local contractors, who have experience installing these treatments will also be assembled and updated as appropriate.

4.3.3 Non-Point Source Pollutant Reduction

The Watershed Owner's Manual also will address techniques for managing NPS pollutants on individual properties. Topics may include, but are not limited to: Landscaping and site management to control runoff; household wastewater, yard and garden care; septic system maintenance; managing household hazardous wastes; safe management of gasoline, heating oil, diesel and other fuels; and recycling, reusing, composting and on-site waste disposal (refer to Section 4.4)

4.3.4 Defensible Space/Fuel Modification Areas

Chapter 15.20 of the TCOC outlines the County's fire safety standards for residential, commercial, and industrial structures. Section 15.20.005 of the TCOC defines "Defensible Space" as the area within the perimeter of a parcel where basic wildland fire prevention practices and measures are to be implemented and maintained, including but not limited to removing brush, flammable vegetation, or combustible growth that is located 30 feet or more from a building or structure measured from the eaves, porches, decks and balconies to the property line, to provide the key point of defense from an approaching wildfire or an escaping structure fire. Additional requirements for defensible space setback distances are provided in Section 15.20.060, Defensible Space and Fuel Modification of the TCOC.

A common misconception is that these fire safety priorities must be weighed against the objectives of erosion control. Rather, the concepts of defensible space and fuel reduction essentially mean arranging trees, shrubs, and other fuel sources in a way that makes it difficult for fire to transfer from one fuel source to another. It does not mean cutting down all trees and shrubs, or creating a bare ring of earth across a specific property (BOF, 2006). An erosion-resistant defensible space involves the maintenance of the existing duff layer, as opposed to its removal, and the use of landscaping with favorable fire performance ratings. The County Watershed Owners Manual should include basic guidelines for common forms of vegetation that are identified as having a favorable fire performance rating.

4.4 Existing County Programs

The County's existing source reduction programs will encourage community members to recycle, reclaim, or reuse materials whenever possible to keep the following items out of streams. Approaches to source reduction may include, but are not limited to:

Recycling. The County's Blue Bag Roadside Recycling Program allows the recycling of specific items by placing them in blue bags, provided by the County, and placing them at the curb on regular trash collection days for free pick-up in their area, whether individuals have collection service or not. Additional information on the program is available at the County's web-site under Living/Environment.

Oil Recycling. Used motor oil can be recycled at certified used oil recycling collection centers throughout the State. Certified used oil collection centers are able to take used motor oil from the public and reimburse individuals at a rate of 16 cents a gallon. The County's Solid Waste Division website provides more information on where the community can recycle used motor oil.

E-Waste. Electronics are a fast-growing portion of America's trash. The "Universal Waste Rule" eliminates these wastes from being commingled in curbside collection services. The County's Solid Waste Division website provides more information regarding the types of E-Wastes that will be accepted at the following locations:

Cal Sierra Transfer Station
19309 Industrial Dr., Sonora, CA
(209) 536-1719
8:00 a.m. - 4:45 p.m.
7 days (except Christmas and New Years)

Groveland Transfer Station
10912 Merrell Road
(End of Merrell Road)
Groveland, CA 95321
(209) 962-4376
8:00 a.m. – 4:00 p.m.
Wednesday and Saturday only (except Christmas and New Years)

The County's Solid Waste Division website provides more information regarding the types of E-Wastes that will be accepted.

Household Hazardous Waste Collection. The absence of routine or affordable pickup service for trash and recyclables in some communities encourages illegal dumping. A lack of understanding regarding applicable laws or the inadequacy of existing laws may also contribute to the problem. Providing a central location for the disposal of household hazardous wastes (e.g., paint, fertilizers, antifreeze, batteries, fluorescent light tubes, products containing batteries, products containing mercury [e.g. thermometers], etc.) will help to protect surface water quality by offering citizens an alternative to disposing of these materials in the storm drain. Disposal costs vary considerably depending on the size of the program, and what types of wastes are collected.

Cal Sierra Transfer Station
19309 Industrial Drive
(Hwy 108 & Industrial Drive)
Sonora, CA 95370-9232
(209) 536-1719

Groveland Transfer Station
10912 Merrell Road
(End of Merrell Road)
Groveland, CA 95321
(209) 962-4376
8:00 a.m. – 4:00 p.m.
Wednesday and Saturday only (except Christmas and New Years)

Businesses that qualify as Conditionally Exempt Small Quantity Generators (CESQG) may participate in the County's CESQG program and take certain hazardous wastes to their disposal/household hazardous waste facilities. A CESQG is defined by law as a business that generates certain hazardous wastes in the course of its regular business in quantities of no more than 27 gallons or 220 pounds in any given monthly period. Businesses that qualify as a CESQG are encouraged to contact the County Solid Waste Division for a CESQG program overview and application at (209) 533-5588.

4.5 Public Outreach

Public education and outreach is generally the cornerstone of an effective water quality program. The goal is to educate the general population about surface water quality and basic steps that they can take to protect it. Public education outreach will be accomplish through several outlets including, but not limited to, civic organizations and clubs, volunteer groups, schools, businesses, the Tuolumne County Resource Conservation District, UC Cooperative Extension, community members, other stakeholder individuals and groups, community services districts, utility districts, utility providers, sanitation districts, and other special districts. It is anticipated that public outreach and education will use local newspapers, radio stations, the internet, organizational newsletters, local events (e.g., Home and Garden Show) public access television and other communication resources.

The primary goal of education and outreach is to generate awareness of surface water pollution prevention by educating people about the storm drainage system, pollutants of concern, and their connections to the health of local waterways and water supply facilities (e.g., reservoirs). Secondly, it is critical to generate public interest and enthusiasm through education and encouragement of active participation in water pollution prevention resulting in changed behavioral patterns benefiting water quality efforts. Outreach activities can be broadly grouped into four categories:

- Outreach to general public and target industries
- Outreach to children and school staff
- Outreach to agency managers and local officials
- Regional partnerships

4.5.1 General Public and Target Industry Outreach Programs:

Clean Water Business Partners. Develop a priority list of businesses that may impact water quality as a result of the services they provide. Enhance efforts to publicly recognize businesses that actively promote activities that reduce or eliminate surface water pollution. Make the program concepts available to businesses that are incorporating water quality protection measures into their operations. Incorporate these businesses in the promotion of clean water awareness and implementing post-construction BMPs (refer to Chapter 3).

Community Events. Partner with environmental and watershed groups to provide material for surface-water pollution prevention information booths at various public events, such as farmer's markets, the County Fair, Home and Garden Shows, and other community events.

Media Campaigns. Develop multimedia materials, campaigns, and partnerships. Look for ways to partner with agencies, businesses, and industries. Increase the use of local and regional media to promote citizens' awareness of the causes of NPS pollution problems and of solutions that they can help implement.

Water Wise Pest Control Program. Coordinate with the County Agricultural Commissioner to form partnerships with nurseries, retailers, landscapers, and pest control operators to encourage less toxic methods of pest control to reduce pesticide toxicity in streams and drainage systems.

4.5.2 School Outreach

Stormwater Classroom Presentations. Support School Board approved stormwater pollution and water quality related presentations suitable for third through sixth grade. Present more technical presentations to seventh through twelfth grade with the idea of integrating such topics into the existing science curriculum. Develop and implement educational materials to tie into science standards by introducing the water cycle, streamside communities and aquatic food chain concepts, and the effects of stormwater pollution.

Water Education for Teachers. Support efforts to develop a Water Education for Teachers Workshop to promote awareness, appreciation, knowledge, and stewardship of water resources through the development of classroom-ready teaching aids (e.g., through

workshop sponsorships, informing local school districts regarding the availability of such programs, assisting in funding to acquire classroom teaching aids).

4.5.3 Statewide and Regional Outreach Activities

California Stormwater Quality Association (CASQA). Join CASQA to enable informational sharing, provide technical support, and identify successful approaches to public education and outreach.

4.6 Workshops

The Watershed Coordinator will organize and hold public workshops that focus on specific stormwater topics. These workshops will be for the purpose of sharing information and facilitating a collective focus on potential solutions for improving surface water quality. The County, the community, and other watershed stakeholders will participate. These workshops will be held on an as-needed basis.

4.7 Community Water Body Cleanup Activities

In conjunction with other watershed planning efforts, it is anticipated that the Watershed Coordinator will organize and promote community water cleanup activities in association with other community organizations including, but not limited, to:

Urban Waterways Beautification Projects. Encourage citizens, school districts, County agencies, and watershed groups to participate in the clean up of different watershed drainage areas. This partnering of governmental and citizen groups will help foster good working relationships throughout the community. “Adopt a Storm Drain” programs encourage individuals or groups to keep storm drains free of debris and to monitor what is entering local waterways through storm drains.

Stenciling Program. The County is proposing to undertake a stenciling program to apply messages at storm drain inlets located at key locations and in key facilities, such as parks and other areas with notable dumping problems, to educate the public about stormwater runoff pollution. The County will develop and distribute information on the storm drain stenciling program and solicit volunteers through schools, community neighborhood associations and clubs, environmental groups, and the Water Quality Planning website. New development projects will require that all new storm drain inlets be stenciled by 2008.

4.8 Recognition Programs

Citizen volunteers performing water quality monitoring or undertaking projects on individual properties to improve the County’s watershed should be recognized. Promoting successful efforts and awarding a “pat on the back” is an effective means for encouraging ongoing efforts and for increasing community involvement, participation and enthusiasm. Successful recognition programs that can serve as a model program include, but are not limited to:

The Lower Mokelumne River Watershed Stewardship Award Program
http://www.sjcrcd.org/involve/2005_Mokelumne_River_Stakeholder_Recognition_Award_FINAL_Jan_2006.pdf

Arcade Creek Project
http://www.arcadecreekproject.org/main.php?content=generalcontent/home

Pit River Watershed Alliance
http://www.pitriveralliance.net/

Dry Creek Conservancy
http://drycreekconservancy.org/

South Yuba River Citizens League
http://syrcl.org/

CHAPTER 5
Grant Funding Opportunities

Funding the County's watershed stewardship priorities over the planning period is one of the more difficult tasks faced by County staff and community groups alike. Because of staffing limitations and financial constraints, the County will continually need to seek both financial and technical assistance to enable implementation of the County's watershed stewardship priorities. This section outlines many of the grant funding mechanisms that may be used to partly or fully fund implementation projects outlined in this chapter. As previously indicated, grant monies are becoming more and more competitive, and therefore, emphasis will be placed on implementation projects. Programs will include a focused water quality monitoring effort to track and evaluate effectiveness. Additionally, in efforts to promote regional partnerships, the County intends to partner with other local public agencies (e.g. utilities), the County Resource Conservation District, tribes, citizen groups, regional agencies (e.g., Turlock Irrigation District), and Federal agencies (e.g., U.S. Bureau of Reclamation) in future grant efforts. A range of potential funding sources include, but are not limited to, the following:

Environmental Quality Incentives Program (EQIP). As part of the reauthorization of the Farm Security and Rural Investment Act of 2002, USEPA and the USDA currently provide funding through the EQIP (current funding is $200 million annually) to enable more rapid support for agricultural producers' actions that will protect water quality. EQIP offers contracts with a minimum term that ends one year after the implementation of the last scheduled practices and a maximum term of ten years. These contracts provide incentive payments and cost-shares to implement conservation practices. Persons who are engaged in livestock or agricultural production on eligible land may participate in the EQIP program. The EQIP may cost-share up to 75 percent of the costs of certain conservation practices. Incentive payments may be provided for up to three years to encourage producers to carry out management practices they may not otherwise use without the incentive. However, limited resource producers and beginning farmers and ranchers may be eligible for cost-shares up to 90 percent. Farmers and ranchers may elect to use a certified third-party provider for technical assistance. An individual or entity may not receive, directly or indirectly, cost-share or incentive payments that, in the aggregate, exceed $450,000 for all EQIP contracts entered during the term of the Farm Bill. Additional information is available at http://www.nrcs.usda.gov/programs/eqip/

Conservation of Private Grazing Land Program. The Conservation of Private Grazing Land (CPGL) Program was authorized by the conservation provisions of the Federal Agricultural Improvement and Reform Act (1996 Farm Bill). The intent of this provision is to provide accelerated technical assistance to owners and managers of grazing land. The CPGL Program

is a voluntary program that helps owners and managers of private grazing land address natural resource concerns while enhancing the economic and social stability of grazing land enterprises and the rural communities that depend on them. Additional information is available at http://www.nrcs.usda.gov/PROGRAMS/cpgl/

Conservation Security Program. The Conservation Security Program is a voluntary program that provides financial and technical assistance for the conservation, protection, and improvement of soil, water, and related resources on Tribal and private lands. The program provides payments for producers who historically have practiced good stewardship on their agricultural lands and incentives for those who want to do more. Additional in formation is available at http://www.nrcs.usda.gov/Programs/csp/

State Revolving Loan Funds. State revolving loan funds (SRFs) are loan programs that are capitalized by federal grants, state appropriations and dedicated revenues. States use the funds to provide a range of financial assistance to local governments, including loans, grants and credit enhancement. The drinking water and wastewater SRF programs provide low-interest loans to local governments and operators of sewer and water facilities. The program has become a major source of water infrastructure financing and is often leveraged with bonds. Additional information is available at http://www.swrcb.ca.gov/funding/srf.html

Proposition 50, Integrated Regional Water Management (IRWM) Grant. The IRWM Grant Program is a joint program between the Department of Water Resources (DWR) and the SWRCB, which provides funding for projects to protect communities from drought, protect and improve water quality, and reduce dependence on imported water. The IRWM Grant Program includes two separate grant types: Planning Grants and Implementation Grants. Additional information is available at http://www.grantsloans.water.ca.gov/grants/integregio.cfm

Small Community Wastewater Grant (SCWG). The SCWG Program provides grant assistance to small communities with financial hardship, needing to install or upgrade failing wastewater treatment facilities. SCWG program funds are some of the most sought after; so funds go quickly. In the last eight years, the program provided assistance totaling $60 million for projects such as installing sewers, upgrading failing treatment plants, and repairing leaking sewer pipes. The SCWG Program offers three types of grants: Planning, Design, and Construction. More information on this program is available at http://www.waterboards.ca.gov/cwphome/scwg/index.html

Safe Drinking Water Act (SDWA) Grant. In California, the responsibility for regulating public water systems and overseeing the allocation of SQWA grant funding resides with the Department of Health Services (DHS). Through an interagency agreement (contract), DWR provides assistance in administering the local financial assistance portion of the Drinking Water State Revolving Fund (DWSRF) program. The federal law provides that a portion of the federal funds may be used for specified activities in addition to providing financial assistance to public water systems for infrastructure improvements. These activities include: (1) administration of the DWSRF financial assistance program, (2) technical assistance to small water systems, (3) source water assessment and protection, and (4) water system capacity development. Federal and State statutes mandate source water assessment and protection, and capacity development. Collectively, funding for these

"set-aside" programs may utilize up to 31 percent of the federal Capitalization Grant. Tribes can also receive grants for public water system infrastructure improvements through a national set-aside. Additional information is available at http://www.grantsloans.water.ca.gov/index.cfm

Clean Water Act (CWA) Section 319(h) Grants. Congress amended the CWA in 1987 to establish the section 319 NPS Management Program, because it recognized the need for greater federal leadership to help focus State and local NPS efforts. Under Section 319, State, Territories, and Indian Tribes are eligible to receive grant money to support a wide variety of activities including technical assistance, financial assistance, education, training, technology transfer, demonstration projects, and monitoring to assess the success of specific NPS implementation projects. Additional information on this grant program is available at http://www.epa.gov/OWOW/NPS/cwact.html

Watershed Coordinator Grants. Information is available at http://www.consrv.ca.gov/DLRP/rcd/grant_program/watershed_grants.htm

Targeted Watershed Grants. The Targeted Watersheds Grant Program is a competitive grant program to encourage the protection and restoration of the country's water resources. The program supports environmental stewardship and action by providing needed funding to watershed organizations for on-the-ground restoration and protection efforts designed to achieve quick, measurable, environmental results. The goal of the Targeted Watersheds program is to build on the successes of existing partnerships and coalitions that have evaluated and assessed their watersheds, devised a technically sound watershed plan, and are ready to embark on steps to implement their plan. More information is available at http://www.epa.gov/owow/watershed/initiative/

CHAPTER 6
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CHAPTER 7
Abbreviations and Acronyms

Assessment	Tuolumne County Foothill Watershed Assessment
Basin Plan	Water Quality Control Plan for the Sacramento River and San Joaquin River Basins
BMP	best management practices
Board	Tuolumne County Board of Supervisors
CEQA	California Environmental Quality Act
County	Tuolumne County
CVRWQCB	Central Valley Regional Water Quality Control Board
CWA	Clean Water Act
CWE	Cumulative Watershed Effects
Delta	Sacramento-San Joaquin Delta
DO	Dissolved Oxygen
DSA	Disturbed soil area
ft/sec	feet per second
ft	feet
GIS	geographic information systems
MEP	Maximum Extent Practicable
mgd	million gallons per day
MRP	Monitoring and Reporting Plan
MS4	small municipal separate storm sewer systems
NPDES	National Pollution Discharge Elimination System
NPS	Nonpoint Source
PSA	Primary Study Area
QAPP	Quality Assurance Project Plan
RCD	Resource Conservation District
RWQCB	Regional Water Quality Control Board
SWPPP	Storm Water Pollution Prevention Plan
SWRCB	State Water Resources Control Board
TCGP	Tuolumne County General Plan
TCOC	Tuolumne County Ordinance Code
TDS	total dissolved solids
TSS	total suspended solids
TUD	Tuolumne Utilities District
UC	University of California
USC	U.S. Code
USEPA	United States Environmental Protection Agency
USTs	Underground Storage Tanks
VOCs	Volatile Organic Compounds
WQP	Water Quality Plan

APPENDIX A
Menu of Best Management Practices

In following the County's Process Checklist (Section 3.3.a), the selection and implementation of BMPs will be driven by the pollution risks associated with the construction activity. The pollution prevention objectives of BMPs are defined based on a review of information gathered during the assessment of the site and planned activities (Process Checklist). Once defined, BMP objectives should be developed in order to encourage the proper selection of BMPs.

The WQP emphasis a distinction between two major categories of treatment measures for construction—erosion control and runoff/sediment control—each of which includes treatment methodologies designed for specific site conditions (e.g., climate, slope gradient, etc.). Erosion control is any practice that protects the soil surfaces and prevents the soil particles from being detached by rainfall or wind. Therefore, erosion control is almost a form of source control that treats the soil surface and protects it from erosive forces. Runoff control involves the use of engineered structures and/or bioengineering to reduce runoff velocities and/or pre-treat runoff prior to discharge offsite. Runoff control often includes some form of sediment control to keep sediment, the product of erosion, onsite and away from waterways. Most importantly, both erosion and runoff control measures have applications both during and flowing construction (e.g., post-construction).

The following terms are used extensively throughout this Appendix and are defined below:

Disturbed Soil Area - Disturbed soil areas (DSAs) are areas of exposed, erosive soil that are within the construction limits and that result from construction activities. The following are not considered DSAs:

- Areas where soil stabilization, erosion control, highway planting, or slope protection are applied and associated drainage facilities are in place and functional.
- Roadways, construction roads, access roads or contractor's yards that have been stabilized by the placement of compacted sub-base or base material or paved surfacing.
- Areas where construction has been completed in conformance with the contract plans and permanent erosion control is in place and functional.
- Erosion control is considered functional when a uniform vegetative cover equivalent to 70 percent of the native background vegetation coverage has been established or equivalent stabilization measures have been employed.

Active and Non-Active Areas - Active areas are construction areas where soil-disturbing activities have already occurred and continue to occur or will occur during the ensuing 21 calendar days. Non-active areas are construction areas (formerly active areas) that will be idle for at least 21 calendar days. The contractor will conduct a review of the existing active areas on a regular basis to determine if a non-active status should be applied to some DSAs.

Slope Length and Terraces - Slope length is measured or calculated along a continuous inclined surface. Each discrete slope is between one of the following: top to toe, top to terrace, terrace to terrace, and terrace to toe. Terraces are drainage facilities that intercept surface flow and convey the resulting concentrated flow away from a slope.

Rainy Season - The rainy season for the County is defined as October 15 through May 15.

Sediment Basin - A sediment basin is a controlled stormwater release structure formed by excavation or by construction of an embankment of compacted soil across a drainage way, or other suitable location. It is intended to trap sediment before it leaves the construction site. The basin is a temporary measure in most cases and is to be maintained until the site area is permanently protected against erosion or a permanent detention basin is constructed. The length of the basin is determined by measuring the distance between the inlet and the outlet and as a rule of thumb is typically more than twice the basin's width to provide sufficient settling time.

Treatment - A combination of basin and treatment engineered to capture and treat (to remove 0.01 mm sized particles and larger) the **10-year, 6-hour rain** event using Q=CxIxA where C=0.5 and I ranges from 1.9 inches (Jamestown) to 2.6 inches (Twain Harte).

This Appendix presents a menu of BMPS for the following two categories, which follow on the accompanying pages:

I. Erosion Control BMPs
II. Runoff Treatment BMPs (II.1 - Flow-Reduction and II.2 - Sediment/NPS Pollutant Reduction Controls)

I. Erosion Control BMPs

When erosion control BMPs are implemented and maintained, the amount of sediment associated with runoff waters can be dramatically reduced. Whenever possible, it is recommended that erosion control measures be emphasized in project planning due to their cost-effectiveness and long term sustainability, especially with the integration of biostabilization[1] measures. Erosion control primarily focuses on the maintenance and reestablishment of a vegetative (or other) cover to protect the soil surface during and following construction or land disturbance. Temporary erosion control is usually achieved by seeding or mulching barren areas with fast growing annual grasses and protecting the soil with mulch or matting. Permanent erosion control usually involves the planting of perennial grasses, shrubs, and trees in a way that resembles native vegetation.

To establish a permanent vegetative cover that will prevent soil detachment, reduce sheet and rill erosion, and stabilize slopes and channels, permanent seeding should be used in conjunction with other erosion control measures. Erosion control blankets and mats, fiber roles, riprap, hydraulic plantings, mulching, biofilters, and cellular confinement systems provide enhanced erosion control by facilitating the establishment of a permanent vegetative cover. Each of these erosion control measures is considered acceptable to the County and is described more thoroughly below. Information regarding the proper installation and design of erosion control measures outlined in the WQP may be reviewed at: http://www.cabmphandbooks.com/

Erosion Control Blankets and Mats

Erosion control blankets (ECBs) and soil stabilization mats (turf reinforcement mats or [TRMs]) can be applied to problem areas to supplement revegetation during its initial establishment. Blankets and matting surfaces temporarily stabilize and protect disturbed soil and enhance water infiltration, decrease compaction and soil crusting, and conserve soil moisture. These temporary surfaces also protect seeds from predators, and reduce desiccation and evaporation by insulating the soil and seed environment. ECBs and TRMs may be used on road-side ditches, construction sites, and drainages channels where water velocities between 3 and 6 feet per second (ft/sec) are likely to wash out new vegetation.

Some types of ECBs and TRMs are specifically designed to stabilize channelized flow areas. These blankets and mats can aid in the establishment of vegetation in waterways and increase the maximum permissible velocity of the given channel by reinforcing the soil and vegetation to resist the forces of erosion during runoff events. Stems, roots, and rhizomes of the associated vegetation become intertwined with the mat, thereby reinforcing the vegetation and anchoring the mat. Conditions where ECBs and TRMs are appropriate may include:

- Slopes and disturbed soils where mulch must be anchored.
- Steep slopes, generally steeper than 3:1(generally not applicable to the County limits).

[1] Biostabilization, also commonly referred to as bioengineering, is a practice that brings together biological, ecological, and engineering concepts to produce living, functioning systems to prevent erosion, to stabilize slopes and to enhance wildlife habitat.

- Critical slopes adjacent to sensitive areas such as streams and wetlands.
- Disturbed soil areas where planting is likely to be slow in providing adequate protective cover.
- Channels with flow exceeding 2 to 4 ft/sec.
- In channels intended to be vegetated and where the design flow exceeds the permissible velocity. Allowable velocity, with turf reinforcement mats after vegetative establishment, is up to 10 ft/sec (3 m/sec).

Hydraulic Plantings

Hydraulic planting is a method of applying erosion control materials to bare soil and establishing erosion-resistant vegetation on disturbed areas and critical slopes. By using hydraulic equipment (hydroseeders and hydromulchers) seed, soil amendments, wood fiber mulch and tackifying agents, bonded fiber matrix and liquid co-polymers can be uniformly broadcast, as a hydraulic slurry, onto the soil. These erosion and dust control materials can often be applied in one operation.

Hydraulic planting techniques are expensive, but provide the most dependable results on steep critical slopes, with limited accessibility and on which mulch must be anchored and on shallow soils which restrict the use of erosion control blankets. Hydraulic machines today are used to spray seed, tack down straw, bind the soil, seal the soil, or apply blanket-like coats of bonded fiber matrix (BFM).

Grass-Lined Channels

Grass-lined channels consist of vegetation lining along a natural or constructed waterway, swale, or dike to protect it from erosion. Grass protection of drainages reduces erosion by lowering water velocity over the soil surface and by binding soil particles with roots. A drainage is any ground surface over which concentrated runoff travels. It is typically a manmade waterway, swale or ditch. Grass-lined channels should be used where:

- A vegetative lining can provide sufficient stability for the channel grade by increasing maximum permissible velocity;
- Slopes are generally less than 5 percent; or
- Site conditions required to establish vegetation, i.e., climate, soils and topography are present.

<u>V-shaped Channels:</u>

Generally used where the quantity of water is relatively small, such as roadside ditches. The V-shaped cross section is desirable because of difficulty stabilizing the bottom, where velocities may be high. A grass or sod lining will suffice where velocities are low or rock or riprap lining may be necessary.

Parabolic Grass Channels:

Often used where larger flows are expected and sufficient space is available. The shape is pleasing and may best fit site conditions. Riprap should be used where higher velocities are expected and where some dissipation of energy (velocity) is desired. Combinations of grass with riprap centers or turf reinforcement mat centers are useful where there is a continuous low flow in the channel.

Trapezoidal Grass Channels:

Used where runoff volumes are large and slope is low so that velocities are non-erosive to vegetated linings. Trapezoidal channels generally have concrete or riprap lined center for low flow.

Mulching

Mulching is an inexpensive method to stabilize the soil surface in locations where the protective vegetation has been removed. The most common use of mulch or plant debris is to provide temporary stabilization of soil, usually until permanent-stabilizing vegetation is established. Where mulches are used to complement vegetation establishment, they should be designed and installed to maximize contact with the ground and last as long as it takes to establish vegetation. On steep slopes, greater than 2.5:1, or where the mulch is susceptible to movement by wind or water, the material should be appropriately anchored. On small sites, where plant material is distributed by hand, it can be anchored by hand punching it into the soil every 1 to 2 feet (0.3 to 0.6 meters) with a dull, round nosed shovel. Mulching effectively complements surface roughening applications.

Cellular Confinement Systems

A cellular confinement system (CCS) is a more expensive three-dimensional, earth-retaining structure used to mechanically stabilize the surface of cut and fill slopes. A CCS is a permanent erosion control practice intended to stabilize infill materials for slope and channel protection, load support, and earth retention applications. The expandable panels create a cellular system that confines topsoil infill, protects and reinforces the plant's root zone, and permits natural subsurface drainage. Slopes as steep as 1:1 can be treated with cellular confinement systems.

A CCS provides durable protection to channels exposed to severe hydraulic or mechanical stresses. The cell structure is a flexible form for distributing a uniform thickness of concrete over a wide range of channel geometry. The erosion-resistant concrete lining system conforms to minor subgrade movement and prevents uncontrolled concrete cracking. The system is used in conjunction with a geotextile underlayer to relieve hydrostatic pressures. The geocell system provides protection to geomembranes in stormwater detention ponds and basins, lagoons, dikes, dam faces, and landfill cover applications. Cell depth of geocell sections is based on the potential tractive and uplift forces.

Fiber Rolls

Fiber rolls consist of straw that is wrapped in tubular black plastic netting. These rolls are used extensively in the construction industry due to their cost-effectiveness. They are approximately 8 inches (200 mm) in diameter and 25 to 30 feet (8 to 9 meters) long. If

installed correctly, straw rolls will capture and keep sediment and minimize sheet and rill erosion until permanent vegetation can get established. Installed, straw rolls shorten the slope length, thereby interrupting the ravelling and rilling processes, and reduce the slope steepness. They catch soil material that moves down the slope by the freeze/thaw processes. Organic matter and native seeds are trapped behind the rolls, which provide a stable medium for germination. Rolls trap fertile topsoil and retain moisture from rainfall, which aids the growth of tree seedlings planted along the upslope side of the rolls.

It is imperative, especially on steeper slopes, that a sufficient trench is constructed to place the roll in. Without it, the roll will not function properly, runoff will scour underneath it, and trees or shrubs planted behind the roll will not have a stable environment in which to become established. Straw rolls will last an average of one to two years and are a relatively low-cost solution to sheet and rill erosion problems. This is an important factor when planning the optimum length of time the slope or construction site will need mechanical stabilization. Fiber rolls can be staked with willow stakes if site conditions warrant, and the moisture retained by the fiber roll will encourage willow establishment. Plastic netting will eventually photo-degrade, eliminating the need for retrieval of materials after the straw has broken down.

Compost Blankets and Berms

Compost blankets are usually used on slopes of 2:1 or gentler, but can be used on slopes as steep as 1:1, with consideration given to the length of slope and depth of application. Compost blankets should not be applied in areas of concentrated flow, and can be used in conjunction with compost berms. Adding components such as a tackifier, or using compost blankets in conjunction with other techniques can increase the allowable steepness of the slope to be treated. Compost blankets should be extended 3 to 6 feet over the top shoulder of the slope to prevent water from getting underneath. Compost blankets can be more effective than ECBs, because they come in better contact with the underlying soil, reducing the chance of rill formation.

RipRap

Riprap is a layer of stone designed to protect and stabilize cut-and-fill slopes subject to seepage or weathering, particularly where conditions prohibit establishment of vegetation. Riprap is a versatile, highly erosion-resistant material that can be used effectively in many locations and in a variety of ways to control erosion on construction sites. Riprap is used extensively along several local creeks (e.g., Woods Creek below Jamestown). Riprap is classed as either graded or uniform. Graded riprap is preferred to uniform riprap in most applications because it forms a dense sub-straight. Uniform riprap is more open and cannot adjust as effectively to movement of the stones.

When considering riprap for surface stabilization, it is important to anticipate visual impacts (including weed control) hazards from snakes and other animals, danger of slides and hazards to areas below steep riprap slopes, damage and possible slides from people moving stones, and general safety. Proper slope selection and surface preparation are essential for successful long term functioning of riprap. Adequate compaction of fill areas and proper use of filter blankets or aggregate foundation is necessary.

Riprap should be a well-graded mixture with 50 percent by weight larger than the specified design size. The diameter of the largest stone size in such a mixture should be 1.5 times the d50 size with smaller sizes grading down to 1 inch (25 millimeters). The designer should

determine the riprap size that will be stable for site conditions. The minimum thickness should be 1.5 times the maximum stone diameter, but in no case less than 6 inches (150 millimeters). The stone should be hard, angular, and of such quality that it will not break down on exposure to water or weathering, and suitable in all other respects for the purpose intended.

Riprap stone for slope stabilization not subject to flowing water or wave action should be sized for stability for the proposed grade. The gradient of the slope to be stabilized should be less than the natural angle of repose of the stone selected. Riprap used for surface stabilization of slopes does not add significant resistance to sliding or slope failure and should not be considered a retaining wall. The inherent stability of the soil must be satisfactory before riprap is used for surface stabilization. Design criteria for sizing stone and determining the dimensions of riprap pads at channel or conduit outlets are presented in NRCS (1992), ABAG (1995), and other engineering design manuals.

Bioengineering

Groundcover serves an instrumental role in controlling surface erosion by shielding soil materials from the impact energy of precipitation, slowing the velocity of runoff, and promoting the aggregation of soil materials. In the County the establishment of permanent vegetative cover should be focused to specific areas where open space uses are planned, within designated setbacks, and in open areas where current revegetation efforts have been unsuccessful or yet to be completed. In this sense, permanent planting will be more associated with rehabilitation of riparian buffer strips for NPS pollution control. In most instances, revegetation will be used to complement and reinforce the primary control measure or structure (e.g., grass-line swales and native-tree re-introduction within road-side ditches).

Bioengineering uses plants and structures together in mutually reinforcing or complimentary roles. The structural components initially protect and stabilize the site and create a stable zone for the plants to grow. Bioengineering techniques are used to prevent erosion on upland slopes, to protect streambanks and channels against erosion, and to provide slope stability. Soil bioengineering generally requires minimal access for equipment and workers and causes relatively minor site disturbance during installation. Therefore, these practices are considered appropriate for environmentally sensitive areas. Bioengineering systems are often more cost effective than the use of vegetation or structural solutions alone. Using indigenous materials accounts for some of the cost effectiveness, since costs are limited to labor for plant harvesting, handling, and transportation to the site.

In bioengineering, the plant material itself may provide both the structural and vegetative components of the design. For example, in willow wattles, live staking and brushlayering the woody material is used to provide initial structural protection and later, vegetative cover. Soil bioengineering is useful on small, highly sensitive or steep sites where the use of machinery is not feasible. However, constraints on planting times or availability of the required quantities of suitable plants during allowable planting times may limit the usefulness of bioengineering methods. Vegetated rock gabions, willow check dams, live stake planting, branchpacking, brushlayering, willow wattles, and coir rolls are all examples of successful bioengineering methods.

The probability of successful plant establishment can be maximized through (1) initial site planning; (2) an understanding of the soil base (i.e., will sediment entrapped promote or hinder stability); (3) selection of appropriate seed blends; (4) careful seedbed preparation; and (5) timely planting. In spite of this, the potential for accelerated erosion will remain during the establishment stage. For this reason and prior to seeding, it will be necessary to install other control structures to minimize runoff velocities, which if left unabated could remove seedlings from their target area and concentrate them at the outlet location. In order to prevent costly maintenance operations on other erosion and sediment control practices, permanent vegetative cover should be established in phases; as work is completed on upslope areas, permanent seedlings should be applied to stabilize these areas.

Slopes or barren areas not amiable to site preparation or erosion control blankets should be treated with mulch and soil binder products such as bonded fiber matrix, acrylic copolymers, or cementitious binders. Nutrient availability will be a primary limitation for vegetation reestablishment within the County since the soil resource is generally deficient in nitrogen and phosphorous. As a consequence, biofertilizers[2] and mycorrhizae[3] are very important to any revegetation effort, as they help to rebuild the living component of the soil that is typically damaged by earthwork. **Table A-1** provides a costs and benefits matrix for several revegetation techniques that may be used for various bioengineering applications.

[2] Biofertilizers are fertilizers containing living microorganisms, which increase microbial activity in the soil. Often, organic food is included to help the microbes get established.

[3] The association, usually symbiotic, of fungi with the roots of seeds plants. There are two major types of mycorrhizae: Ectomycorrhizal Fungi (EM) and Endomycorrhizal Fungi (AM).

TABLE A-1
COSTS AND BENEFITS OF REVEGETATION TECHNIQUES

Technique	Benefits	Drawbacks
Soil stabilization materials		
Rice straw	Provides favorable conditions for plant establishment.	May have some weed seeds; generally few drawbacks.
Native grass straw[1]	Combines seeding and mulching in one step.	Availability can be limited.
Straw wattles[2]	Creates stable areas where vegetation can establish.	Only effective if properly installed and maintained.
Willow wattles[3]	Combines erosion control and revegetation in one step, uses local materials.	Cannot be ordered ready-made. Most useful in wet areas.
Erosion control fabric and netting[4]	Retains soil on steep slopes, promotes plant establishment.	Cost, requires proper installation and maintenance.
Revegetation materials		
Native grass seed, price per pound and per acre[5]	Deep root systems provide excellent erosion control. After they are established, native perennials provide erosion control even during the first fall rains.	Establishment success varies with site conditions, yearly rainfall patterns, and species.
Native grass plugs, price per plug and per acre[6]	Survival of plugs is higher than seeds; plants are larger after one growing season.	Cost of material and labor is higher than seeding. Best for smaller areas.
Cost of collecting seeds onsite and growing local genotypes	Higher survivorship; plants are adapted to local conditions; preserves integrity of local populations.	Cost
Seedlings and saplings of native forbs, shrubs, and trees	Provide long-term erosion control and return the site to original conditions.	Cost, should be planted in areas with stabilized soil. Some species may be limited in availability.
Physical soil stabilization procedures		
Installing water bars along a steep trail	Temporary way to reduce velocity of water along slopes.	Needs constant monitoring maintenance. If improperly placed, may worsen erosion.
Installing a culvert through a dirt road	Reduces erosion associated with access roads.	Cost
Re-contouring slopes	May be the only way to stop erosion on very steep, degraded sites.	Cost, difficult to do on hard-to-access sites.

[1] Recommended application rate varies with amount of seed in hay- varies from 10 to 20 bales per acre.
[2] Costs of installation will vary depending on spacing of straw wattles required on a given slope. Consult manufacturer's guidelines for general recommendations of spacing along a variety of slopes and soil conditions.
[3] Instructions for constructing willow wattles can be found through extension programs or online searches
[4] Quality of netting/erosion control fabric needs to increase as site stability decreases. Estimates from one professional restoration firm are as follows: cost per acre for an all-day crew to seed and blanket a slope with coconut matting is approximately $12,000 to $15,000 per acre, not including cost of plant materials. Cost of using heavy duty matting on a 1:1 slope with hydrology less than 18 cubic feet/second is approximately $28,000/acre.
[5] Recommended seeding rates for broadcast seeding is between 20 to 25 lbs/acre.
[6] Plant on 6- to 12-inch centers, depending on species and conditions. Contact grower for site-specific recommendations.

Source: ESA, 2005

II. Runoff TReatment BMPs

Runoff treatment control measures become necessary in instances where erosion control measures would otherwise prove ineffective in the presence of higher runoff velocities. Additionally, these forms of BMPs are typically integrated into new development to address peak discharges associated with post-construction runoff. In contrast, sediment/NPS control BMPs include those measures that intercept and slow or detain the flow of stormwater to allow sediment to settle and be trapped. Both forms of BMPs must factor existing and/or planned drainage system design in conjunction with considering variables such as local climate, the infiltration rate and erosivity of the soil base and slope.

Due to large capital expenditures associated with the construction and maintenance of treatment-oriented BMPs, the first step in planning the location and type of treatment BMP is to understand that large reductions in treatment BMP size and investment can be made by (1) reducing the runoff volumes that need to be captured, infiltrated, or treated, and (2) controlling sources of pollutants. These two strategies are the most cost-effective in managing post-construction stormwater. The principles and methodologies for incorporating these flow reduction strategies into site facility planning and design are discussed in the following section.

There are four basic strategies for treating runoff prior to it entering a waterway and include (1) infiltrating runoff into the soil, (2) retaining runoff for later release with the detention providing treatment, (3) conveying runoff slowly through vegetation (e.g., bioretention[4]), or (4) treating runoff on a flow-through basis using various treatment technologies. Based on the strategy selected and applicable BMPs, the capacity and primary design sizing criteria must be established using a combination of local hydrology, project drainage characteristics (e.g., percent imperviousness or runoff coefficient), and numerical sizing requirements. BMPs will be either volume-based or flow-based and must be able to effectively treat the design quantity. Peak storm event flows must also be taken into account so the BMP can safely pass the design peak event while maintaining its water quality functions up to the design volume. Information regarding the proper installation and design of runoff and sediment control measures may be reviewed at: http://www.cabmphandbooks.com/

Treatment BMP maintenance arrangements will be developed during the planning phase of development and redevelopment projects. To ensure that BMP maintenance will take place, the County will require evidence that project proponents have executed an approved method of treatment BMP maintenance, repair, and replacement before construction approvals are issued. Mechanisms used by the County to assign responsibility for maintenance to public and private sector project proponents may include, but are not limited, to the following:

- Maintenance agreements
- Conditional use permits
- Other legal agreements

[4] Bioretention basins direct sheet flow across a grass buffer strip to a ponding area for infiltration. They utilize soils and both woody and herbaceous plants to remove pollutants from stormwater runoff (EPA, 1999).

II.1 Flow Reduction BMPs

Estimating Surface Runoff and Pollutant Removal Requirements

There are many factors that may affect runoff discharge from a particular site; some of these include: precipitation, soil permeability, watershed area, ground cover, antecedent moisture, storage in the watershed, and time parameters. Given varying contributions to runoff at any one site, it is often difficult to predict the amount of runoff to ensure the integrity of a particular treatment. However, to account for this problem, control measures should be designed based on anticipated runoff velocities from smaller, more discrete catchments within the drainage network.

As part of the County's Assessment, drainage-catchments were delineated for the drainage network within the Primary Study Area (PSA) using a 10-meter digital elevation model (DEM). The modeled drainage catchments delineated in the County's Foothill Watershed Assessment provide insight as to drainage influences for future engineering applications. It is recommended that entire catchment(s) above the prescribed BMP location be modeled to calculate the maximum expected runoff volumes in order to reduce the chances of failure. The modeling effort should also include an accurate characterization of land use to determine an appropriate Runoff Curve Number (RCN). This approach will allow County staff to identify and actively manage specific up-slope locations that contribute concentrated flow to new and existing drainage systems. For projects outside the PSA, project sponsors and contractors should refer to County Public Works staff for further direction.

The design objectives presented in this program for any new separate stormwater systems are adopted from the Santa Clara Valley MS4 Program. They are paraphrased as follows:

> Numeric Sizing Criteria For Pollutant Removal Treatment Systems: All Dischargers shall require that treatment BMPs be constructed for applicable projects (those projects that create 5,000 square feet or more impervious surface), that incorporate, at a minimum, the following hydraulic sizing design criteria to treat stormwater runoff. As appropriate for each criterion, the Dischargers shall use or appropriately analyze local rainfall data to be used for that criterion.
>
> i. **Volume Hydraulic Design Basis:** Treatment BMPs whose primary mode of action depends on volume capacity, such as detention/retention units or infiltration structures, shall be designed to treat stormwater runoff equal to:
>
> 1. the maximized stormwater quality capture volume for the area, based on historical rainfall records, determined using the formula and volume capture coefficients set forth in Urban Runoff Quality Management, WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87, (1998), pages 175-178 (e.g., approximately the 85th percentile 24-hour storm runoff event); or the volume of annual runoff required to achieve 80 percent or more capture, determined in accordance with the methodology set forth in Appendix D of the California Stormwater Best Management Practices Handbook (CASQA, 2003) using local rainfall data.

ii. **Flow Hydraulic Design Basis:** Treatment BMPs whose primary mode of action depends on flow capacity, such as swales, sand filters, or wetlands, shall be sized to treat:

1. 10 percent of the 50-year peak flow rate; or

2. the flow of runoff produced by a rain event equal to at least two times the 85th percentile hourly rainfall intensity for the applicable area, based on historical records of hourly rainfall depths; or

3. the flow of runoff resulting from a rain event equal to at least 0.2 inches per hour intensity.

Rock-Lined Channels

Rock-lined channels are channels or conveyances (e.g., roadside ditches) lined with rock or riprap and designed to convey concentrated surface runoff without erosion. This is applied in areas where design flow exceeds 2 ft/sec such that channel lining is required, but conditions are not suitable for vegetative protection. This practice is required in locations where a channel will continue to down-cut without protection because of increased flow or a new base line (outlet elevation). Depending on the application, the use of pre-constructed concrete units such as grid pavers, articulated concrete mats, and interlocking concrete blocks may be required to armor stream channels while maintaining porosity and allowing the establishment of vegetation. These structures may be obtained in pre-cast blocks or mats, or may be formed and poured into place. As in any application, these structures should be inspected at regular intervals and after major storms.

Diversion Dike/Continuous Berm

A diversion dike or continuous berm, consists of a ridge of compacted soil constructed immediately above a new cut or soil fill slope or around the perimeter of a disturbed area. These structures typically divert sediment-laden runoff from a disturbed area to a sediment-trapping facility such as a sediment basin. The downslope dike assures that sediment-laden runoff will not leave the area of concern without treatment.

It is very important that a temporary diversion dike be stabilized immediately following installation with temporary or permanent vegetation to prevent erosion of the dike itself. This practice will extend the life of the structure by stabilizing it with a root system. The gradient must have a positive grade to assure drainage, but if the gradient is too great, precautions must be taken to prevent erosion due to high velocity channel flow.

This practice can use material available onsite and can usually be constructed with equipment needed for site grading. Diversion dikes are aesthetically preferable to silt fence and are more durable, less expensive, and require much less maintenance when constructed properly. As a rule of thumb, the channel behind the dike should have a positive grade to a stabilized outlet (e.g., sediment basin). If the channel slope is 2 percent or less, no stabilization is required.

Waterbars And Rolling Dips

Waterbars and rolling dips are defined as ridges or ridge-and-channels constructed diagonally across a sloping road or trail that is subject to erosion. Water bars are used to limit the accumulation of erosive volumes of water on unpaved roads by diverting surface

runoff at pre-designed intervals. Waterbars generally become less effective if driven over by motor vehicles during wet weather. Special consideration must be taken in assessing the cumulative effect of added diversions. The peaks of the water bars and rolling dips should be reinforced for active routes. The Bureau of Land Management and U.S. Forest Service "dog bones" may be the preferred reinforcement. Gravel or concrete may be needed in some locations to stabilize the diversion where significant vehicular traffic is anticipated (e.g., extend downslope from roadway culverts).

Infiltration Techniques

As a stormwater management method, infiltration techniques include a variety of BMPs capable of retaining or detaining water within soils to reduce runoff. Stormwater infiltration methods may be categorized as follows:

A. *Site design practices*, which while having a significant effect on runoff and infiltration, are very much integrated into the overall process of land development. These practices include laying out the site to reduce impervious area, routing drainage from building roofs, and selecting of surface treatments when designing site grading and paving. Site design practices must be integrated with the site's urban design, architecture, landscape architecture, and engineering as part of a multifaceted design solution.

B. *Indirect infiltration* methods, including swales and bioretention areas. These features are expressly designed to hold runoff and allow it to percolate into surface soils. Runoff may reach groundwater indirectly, or may be underdrained into subsurface pipes.

C. *Direct infiltration* methods, which are designed to bypass unsaturated surface soils and transmit runoff directly to groundwater. Devices must be located and designed to limit the potential for stormwater pollutants to reach groundwater. Direct infiltration methods include dry wells and infiltration trenches.

Table A-2 identifies several examples of each infiltration method.

TABLE A-2
DESCRIPTION OF SPECIFIC INFILTRATION METHODS AND FACILITIES

Method / Facility	Description
A. Site Design	
Site Layout Practices	Concentrate development on least sensitive portions of the site; preserve pervious soils and natural drainage features; minimize the amount of impervious area by using shared parking, efficient site circulation and by designing taller buildings with smaller footprints or tuck-under parking,
Green Roofs	May be “extensive” with a 3 to 7 inch lightweight substrate and a few types of low-profile, low-maintenance plants, or may be “intensive” with a thicker substrate, more varied plantings, and a more garden-like appearance.
Disconnected Downspouts	Rather than connecting directly to storm drains, extended leaders direct roof runoff away from the building to nearby landscape detention, pop-up emitters, or infiltration devices.
Amending Soils	Soil amendments and tilling enhance or restore permeability and storage in the top layer of soils, reducing runoff.
Structural Soils	An engineered mix of angular aggregate and clayey loam provides structural support for sidewalks and paving while creating void spaces to support urban tree roots.
Site Grading	Using gentler slopes and concave areas to reduce runoff and encourage infiltration.
Pervious Pavement	Special mixes of concrete and asphalt. Require a base course of crushed aggregate and installation by experienced crews.
Unit Pavers	Traditional bricks, stone, or other pavers on sand or fine crushed aggregate
B. Indirect Infiltration	
Flow-through Planter Box	Contained planter, usually above-ground, holds runoff in a surface reservoir and lets it infiltrate through a layer of soil. Infiltrated runoff collects in a gravel layer below, seeps into a perforated pipe underdrain, and is drained to a storm drain or discharge point.
Infiltration Planter	In-ground planter collects runoff from roofs and paved surfaces and allows it to percolate through permeable soil. May require an underdrain if the underlying native soils are poorly drained.
Bioretention	Discussed under Sediment/NPS Pollutant Reduction Controls subheading
Grassy Swale	Works like bioretention, but also transmits high flows along its length.
C. Direct Infiltration	
Infiltration Basin	An excavation exposes relatively permeable soils and impounds water for rapid infiltration.
Dry Well	Small, deep hole filled with open graded aggregate. Sides may be lined with filter fabric or may be structural (i.e., an open bottom box sunk below grade). Typically receives roof runoff.
Infiltration Trench	Trench, with no outlet, filled with rock or open graded aggregate.

Source: Contra Costa County, 2003

Energy Dissipater

An energy dissipater is a structure designed in a public roadway which reduces the velocity of flow thus dissipating the energy thus controlling erosion at the outlet of a channel or conduit (e.g., trail). This applies when the discharge velocity of an open channel exceeds the permissible velocity of the receiving channel or disposal area. A riprap-lined apron is the most commonly used practice for this purpose because of its relatively low cost and ease of installation. The riprap apron should be extended downstream until stable conditions are reached.

Gabions

Gabions are rectangular wire baskets filled with stones used as pervious, semi-flexible, rock-filled baskets to protect streambanks from the erosive forces of moving water. Rock-filled gabions can be used to armor the bed or banks of channels, or used to divert flow away from eroding channel sections. This practice is applicable where flow velocities exceed 6 ft/sec and where vegetative streambank protection alone is insufficient. Gabions can be used to construct deflectors intended to divert flow away from eroding trail or streambank sections. Gabions are also used to construct retaining walls and grade control structures.

Gabions can provide an important component to a bioengineering solution for streambank or slope erosion because they allow the growth and establishment of natural vegetation. Gabion walls are appropriate where the vertical integrity of a soil bank needs a higher tensile strength to reduce sloughing, excessive sub-surface water is present, or a retaining or toe wall is needed. Additionally, these structures are preferred when riprap is an appropriate practice but the available rock size is insufficient to resist the expected shear stress.

II.2 Sediment/NPS Pollutant Reduction BMPs

Bioretention

Bioretention basins direct sheet flow across a grass buffer strip to a ponding area for infiltration. They utilize soils and both woody and herbaceous plants to remove pollutants from stormwater runoff (USEPA, 1999). The ponding area generally consists of a surface layer containing organics such as mulch, trees, grasses and shrubs, a subsurface layer of planting soil, and a sand bed.

Bioretention areas are used to treat stormwater runoff from impervious surfaces in commercial, residential and industrial developments, but can be just as effective in treating runoff from intensively managed open spaces, such as parks, golf courses, or gardens. Bioretention ponds can be used to filter stormwater prior to discharge to a storm drain or sewer system or as an infiltration device with no outflow. By virtue of the intended purpose (e.g., pollutant removal), the vegetative growth should be routinely maintained via mechanical treatments (e.g., mowed) to remove the various pollutants that have been assimilated by the plant mass. The plant debris should be properly disposed of at a local landfill.

Temporary and Permanent Sediment Basin

A temporary sediment basin is a pond created by excavation in construction of an embankment and designed to retain or detain runoff sufficiently to allow excess sediment to settle. The temporary sediment basin is intended to collect and store sediment from sites that are cleared and/or graded during construction or for extended periods of time before permanent vegetation is re-established or before permanent drainage structures are completed. It is intended to trap sediment before it leaves the construction site. The basin is temporary, with a design life of 12 to 18 months, and is to be maintained until the site area is permanently stabilized.

Basins should be located at the stormwater outlet from the site, not in any natural or undisturbed stream. Use of temporary dikes, pipes and/or channels may be necessary to divert runoff from disturbed areas into the basin and to divert runoff originating from undisturbed areas around the basin. Sediment basins can trap 70 to 80 percent of the sediment which flows into them if designed and constructed appropriately. This design requires a runoff detention time of 24 to 40 hours and is only practically effective in removing sediment down to the medium silt size fraction. Sediment-laden runoff with smaller size fractions, fine silts and clay, will likely pass untreated through the basin. For this reason, basins modified with a "skimmer" device can increase efficiency and reduce turbidity by skimming relatively clear water from the top.

There are inherent problems associated with constructing basins large enough to pond all the sediment-laden runoff long enough to allow all of the fine soil particles to settle out. Therefore, sediment basins must be used in conjunction with other erosion control practices in order to increase effectiveness and trap efficiently. These other concurrent practices include:

- Temporary seeding and/or mulching;
- Minimizing disturbance;

- Scheduling construction operations;
- Diversions to reduce runoff into the basin;
- Frequent use of other, smaller erosion control structures that will capture sediment upslope;
- Frequent inspection and maintenance of all practices.

Straw Bale Dike

- A straw bale dike is a temporary barrier consisting of straw bales installed across a slope, at the toe of a slope, and/or around the perimeter of the construction site. A straw bale dike intercepts and detains small amounts of sediment transported by sheet type runoff. The dikes detain sediment by ponding water and allowing sediment to settle out. Straw bale dikes also slow runoff velocities, thus reducing sheet and rill erosion. They are also useful for erosion and sediment control around the perimeter of a construction site. Straw bale dikes may be used where the following conditions apply: The placement area is not a slope nor likely to receive concentrated runoff;
- The maximum slope gradient above the barrier is 2:1;
- The maximum slope length above the barrier is 100 feet (30.5 m);
- The placement area is suitable for ponding of sheet runoff and sedimentation can occur.

Oil/Grease Separators

Coalescing Oil/Grease Separators are passive, physical separation systems designed for removal of oils, fuels, hydraulic fluids, creosote, pentachlorophenol, turbine oils, mineral oils, and BTEX products from water. The process, in simplified terms, begins when the water/oil mixture enters the separator and is spread out horizontally, distributed through an energy and turbulence diffusing device. As oils accumulate they coalesce into larger droplets, rising upward through pack corrugations until they reach the top of the pack, where they detach and rise to the water's surface. At the same time solids encounter the media and slide down the corrugations, falling into a treatment media. In theory, the oil droplet rise rate and other parameters dictate the surface area required for gravity & coalescent separation. The design will need to satisfy site-specific design criteria as indicated below:

- The hydraulic distribution of the influent flow must assure full usage of the cross-sectional area of the media to fully utilize the available surface area.
- Flow control and direction must be determined to prevent hydraulic short circuiting around, under or over the media pack.
- A laminar flow condition must be maintained (Reynolds "Re" number less than 500) in order to assist droplets to rise. Per the American Petroleum Institute’s (API) Publication 421 of February 1990.

- Horizontal flow through velocities in the separator must not exceed 3 feet per minute or 15 times the rate of rise of the droplets which ever is smaller.

- The media containment chamber design must contain spacing sufficient to facilitate removal of accumulating solids.

Compost Berms

A compost filter berm is a trapezoidal berm that intercepts sheet flow and ponds runoff, allowing sediment to fall out of suspension, and often filtering sediment as well. Compost binds heavy metals and can break hydrocarbons down into carbon, salts and other benign compounds (USEPA, 1997). Compost is organic, biodegradable, renewable, and can be left onsite. This is particularly important near streams. Compost does not generally leach nutrients (Glanville, 2003). Standard specifications for both compost berms have been developed for the American Association of State Highway and Transportation Officials (AASHTO).

Compost berms are more cost-effective than many other erosion/sediment control methods. The invention of the blower truck makes compost an easy to install and reliable method of sediment and erosion control. Most municipal programs are now generating compost as municipal greenwaste programs, thus making it readily available in most areas.

Drop-Inlet and Curb-Inlet Sediment Barriers

Drop-inlet and curb-inlet sediment barriers are temporary barriers constructed from concrete block and gravel or gravel filled sandbags. These forms of sediment barriers are intended to reduce the sediment discharged into storm drains by ponding the runoff and allowing the sediment to settle out. The structures allow for overflow from high runoff events and the gravel allows the ponds to dewater rapidly.

The sandbag curb inlet and block and gravel sediment barrier can be used at curb inlets on gently sloping, paved streets where:

- Water can pond and allow sediment to separate out of suspension;

- Runoff is relatively low, less than 0.5 ft^3/sec (0.01 cubic meters/sec).

- Once the small catchment areas behind the sandbags or block and gravel fill with sediment, future sediment-laden runoff will enter the storm drain without being desilted. Therefore, sediment must be removed from these structures during or after each storm. Additional storage can be obtained by constructing a series of sandbag barriers along the gutter so that each barrier traps small amounts of sediment.

APPENDIX B

Links to Other Organizations and Information

Management Practices Promoting Resource Conservation

Home*A*Syst/Farm*A*Syst Program. These are model stewardship-based programs for homeowners and farmers assisting in the conservation of agricultural and natural resources. The program is a cooperative effort between the Northeast Regional Agricultural Engineering Service (NRAES) and the University of Wisconsin. For more information: NRAES, Cooperative Extension, 152 Riley-Orb Hall, Ithaca, NY 14853-5701; (607) 255-7654.

The San Joaquin County Resource Conservation District in cooperation with the NRAES has adapted the Home*A*Syst model into a watershed owner's manual for the Lower Mokelumne River. For more information: http://www.nraes@cornell.edu or Homeasys@uwis.edu

Horses for Clean Water. Publishes Healthy Horses, Clean Water - Horses for Clean Water - a program developed by horse owners for horse owners to promote horse health and environmental health. http://www.horsesforcleanwater.com

Lodi-Woodbridge Winegrape Commission. Winegrower's Workbook. View on-line and/or order a copy of the groundbreaking Lodi Winegrowers Workbook promoting farm stewardship for vineyard owners and managers. http://www.lodiwine.com

National Stormwater Best Management Practices Database. Database of BMP performance data for over 150 BMP studies. Developed by the Urban Water Resources Research Council. http://www.bmpdatabase.org

San Joaquin County Resource Conservation District Lower Mokelumne River Watershed Stewardship Plan. http://www.sjcrcd.org

University of California, Davis B Rangeland Watershed Program Provides extensive links and information for managing rangelands to conserve resources. http://agronomy.ucdavis.edu/calrng/RWP.html

U.S. Environmental Protection Agency. Stream Monitoring: On-line Guide for Developing a Citizen Water-Quality Monitoring Program, Volunteer Stream Monitoring. http://www.epa.gov/volunteer/stream/index.html

Yolo County Resource Conservation District. Order your copies of these excellent publications: Bring Farm Edges Back to Life!, How to Enhance Your Agriculture and Farm Landscape with Proven Conservation Practices for Increasing the Wildlife Cover on Your Farm; Know Your Natives: A Pictorial Guide to California Native Grasses. http://www.yolorcd.ca.gov

Lower Mokelumne River and Other Watershed Stewardship Information. California Environmental Resources Evaluation System (CERES). Information on San Joaquin County's flood conditions, demographics, land uses, historical and cultural resources, recreation, special status species, water resources, vegetation and habitats with maps, photos and other documents. http://www.ceres.ca.gov/geo_area/counties/San_Joaquin/

California Rivers Assessment. Provides extensive information and links describing the status of California Rivers and their resources. http://www.endeavor.des.ucdavis.edu/newcara/

Central Sierra Watershed Coalition. Grass roots organization for the protection and eco-restoration of the five rivers of the central Sierra Nevada: Mokelumne, Calaveras, Stanislaus, Tuolumne and Merced Rivers. http://www.cswc.org

City of Lodi's Storm Drain Detectives. A citizen volunteer and education program monitoring water quality along the lower Mokelumne River, including Lodi Lake. http://www.lodi.gov/Storm%20Drain%20Detectives/index.htm

Mokelumne-Cosumnes Watershed Alliance. Provides oversight for and links to multiple watershed planning efforts ongoing for the Mokelumne and Cosumnes River watersheds. http://www.mcwatershed.org

National Association of Conservation Districts. Environmental education links. http://www.nacdnet.org/resources/links.htm#EviEd:

City of Sacramento Stormwater Management Program. Good information on stormwater management including information for teachers and programs for volunteers to protect water quality. http://www.sacstormwater.org

Sacramento-San Joaquin Delta Atlas. On-line copies of the Sacramento-San Joaquin Delta Atlas. Extensive photos, history, and resource information for the Delta. http://rubicon.water.ca.gov/delta_atlas.fdr/daindex.html

San Francisco Estuary Project B State of the Estuary Reports. Link is to the Bay/Delta Estuary=s biological resources report. http://www.abag.ca.gov/bayarea/sfep/reports/soe/soe4a.htm

San Joaquin County Resource Conservation District Lower Mokelumne River Watershed Stewardship Plan. http://www.sjcrcd.org

Shodor Education Foundation, Inc.: Surface Water Runoff Modeling. Examining the effect of soil type, ground cover type, and rainfall amount on the quantity of water runoff. http://www.shodor.org/master/environmental/water/runoff/index.html:

UC Davis Information Center for the Environment. A collaboration of UC Davis scientists and private, state, Federal and international resource agencies and efforts. Provides extensive links related to resource conservation and programs. http://www.ice.ucdavis.edu

UC Davis Land, Air, and Water Resources Department. Link to Dr. G. Pasternack's research on the Mokelumne River Salmon Spawning Gravel Restoration project. Includes areal-time and link to stream conditions at Camanche Reservoir.
http://lawr.ucdavis.edu/faculty/gpast/mokelumne.html

U.S. Environmental Protection Agency, Office of Ground Water and Drinking Water Quality. Provides extensive information on water quality and NPS pollutants.
http://www.epa.gov/OGWDW/

U.S. Environmental Protection Agency, Office of Water. Extensive links to all aspects of water quality including laws and regulations, funding opportunities, publications and more.
http://www.epa.gov/ow/

U.S. Environmental Protection Agency, Office of Water Watershed Protection Division. Includes funding, databases, publications, outreach, and other information links for watershed planners.
http://www.epa.gov/owow/watershed/

U.S. Environmental Protection Agency. Surf Your Watershed website site. Excellent source to find out all about your watershed (e.g., size, boundaries, water quality, threats, land uses).
http://www.epa.gov/surf/

U.S. Environmental Protection Agency. Watershed Information Network (WIN). Roadmap to information and services for protecting and restoring water resources. http://www.epa.gov/win/

United States Geological Survey website providing information on water resources of the United States. http://water.usgs.gov

Watershed Management Council. Non-profit educational organization dedicated to the advancement of the art and science of watershed management. Lots of watershed links.
http://www.watershed.org

Flooding and Water Supply – Mokelumne River. California Department of Water Resources, California Data Exchange Center with link to the Division of Flood Management. Provides detailed flow and flood stage information for the Lower Mokelumne River and Cosumnes River.
http://cdec.ca.gov/

California Department of Water Resources, Division of Flood Management, California Data Exchange Center. Provides flow and flood stage information. Listed website is for the Cosumnes River. http://www.cdec.water.ca.gov/river/cosumnesStages.html

East Bay Municipal Utility District. Provides East Bay Municipal Utility District's water supply reports for the Lower Mokelumne River Watershed.
http://www.ebmud.com/info/water_supply_reports/default.htm

East Bay Municipal Utility District, Emergency Preparedness Office (EPO) website. In case of earthquake or flood, the EPO action plan is designed to protect the community. For more information: (510) 287-1259. http://www.ebmud.com/emergency/emergency.html:

Humboldt State University Foundation. The San Joaquin County Resource Conservation District (SJRCD) in cooperation with the East Bay Municipal Utility District and the non-profit Humboldt State University Foundation is funding a geographic information system mapping and research program for one of Humboldt State University's graduate students. The study will provide the SJCRCD with valuable information related to the historic flooding and vegetation patters along the Lower Mokelumne River. http://www.humboldt.edu/~hsuf/

California Department of Conservation, Division of Land Resource Protection Resource Conservation District Assistance Program. This state agency has successfully secured funding for the State's Resource Conservation Districts to assist in watershed planning and implementation. This organization funded a watershed coordinator position for the San Joaquin County RCD. http://www.consrv.ca.gov/dlrp/RCD/index.htm

California Farm Bureau Federation. http://www.cfbf.com

Delta Protection Commission (DPC). State agency with oversight of land use and planning for the Primary Zone of the Sacramento-San Joaquin Delta. The San Joaquin County RCD is working with the DPC to determine the feasibility of establishing a Resource Conservation and Development District (RC&D) http://www.delta.ca.gov

East Bay Municipal Utility District. EBMUD operates Camanche Reservoir and Dam that form the eastern boundary of the Lower Mokelumne River Watershed. EBMUD, in cooperation with the U.S. Fish and Wildlife Service and California Department of Fish and Game, implements the Lower Mokelumne River Partnership Fund which makes small grants available for organizations interested in undertaking projects which promote the health of the Lower Mokelumne River. http://www.ebmud.com

East Bay Municipal Utility District. A Historical Perspective of the Mokelumne River Watershed. http://www.ebmud.com/services/environmental/fwhistory.html:

City of Lodi website promoting tourism and the economy of the City of Lodi. Good links to the wine-tasting region of northern San Joaquin County. http://www.visitlodi.com

City of Lodi website. Provides links to the City of Lodi's Storm Drain Detectives site and to other departments involved in water quality management, solid waste management, and similar resource-related activities. http://www.lodi.gov/

Lodi-Woodbridge Winegrape Commission. View on-line and/or order your copy of the groundbreaking Lodi Winegrowers Workbook promoting farm stewardship for vineyard owners. http://www.lodiwine.com

University of California Cooperative Extension B San Joaquin County office. Provides extensive assistance with farm and ranching operations in San Joaquin County. http://cesanjoaquin.ucdavis.edu

United States Department of Agriculture, Natural Resources Conservation Service, California. http://www.ca.nrcs.usda.gov:

Appendix A

Menu of Best Management Practices

Appendix B
Links to Other Organizations and Information