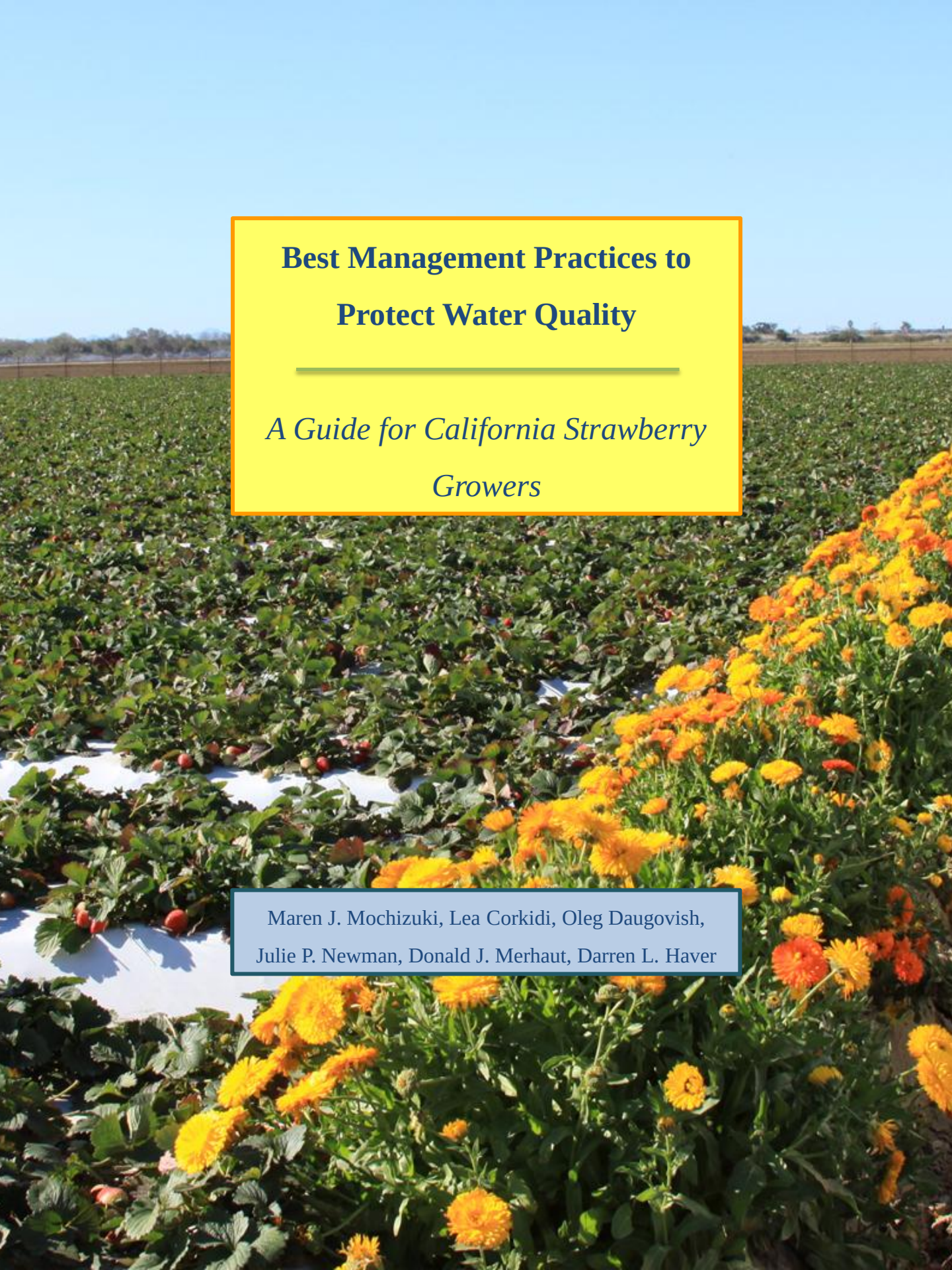

Best Management Practices to Protect Water Quality

A Guide for California Strawberry Growers

Maren J. Mochizuki, Lea Corkidi, Oleg Daugovish, Julie P. Newman, Donald J. Merhaut, Darren L. Haver

California strawberry growers employ numerous practices to protect water quality such as releasing the biological control agent *Persimilis*, thereby reducing pesticide use, and using drip irrigation after plant establishment, thereby reducing water use and runoff. *Best Management Practices to Protect Water Quality – A Guide for California Strawberry Growers* was developed to illustrate relatively low-cost practices that have been successfully employed on some farms but are mostly not yet utilized industry-wide. Our goal is to encourage widespread adoption of cost-effective management practices that minimize pollutants in creeks, rivers, and the ocean.

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Photographs included herein are for the express purpose of demonstrating proper best management practices. Photographs depicting improper practices were staged and no implication should be made that an operation is not in compliance with regulations.

Cover photo: These intentionally-planted flowering buffers maintain the integrity of the ends of each strawberry bed, reducing sediment movement via water and wind. The buffer minimizes dust damage to the crop and reduces movement of pests such as spider mites. Flowering plantings may also attract beneficial insects.

*Courtesy UC Statewide IPM Program

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Water Quality and Potential Agricultural Pollutants

Agricultural pollutants have contributed to impaired water quality in California.

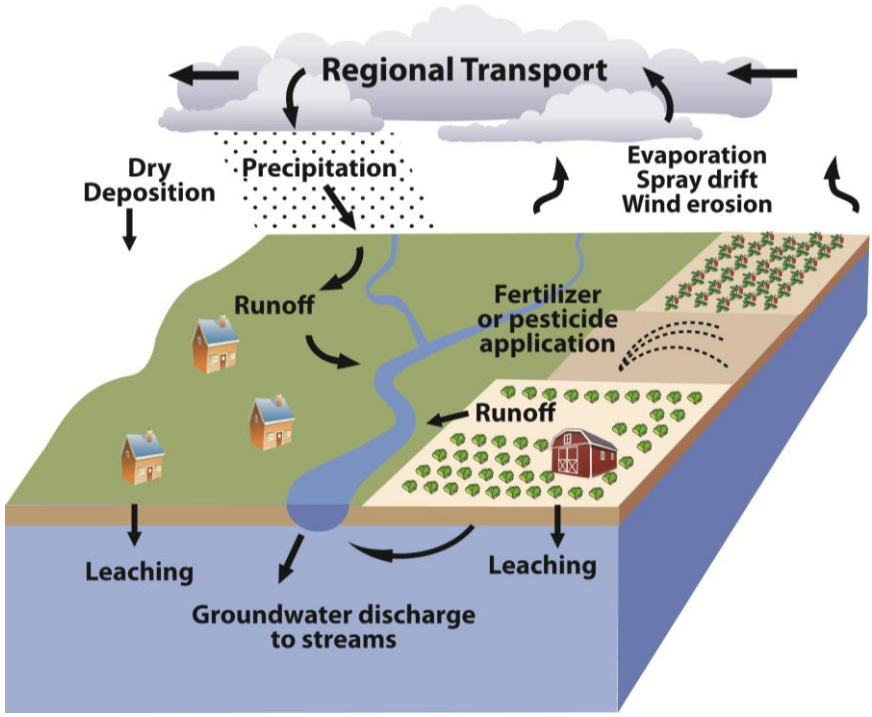


Figure adapted from: http://pubs.usgs.gov/fs/fs03500/fs03500.pdf

Runoff, leaching, drift, evaporation and wind erosion are some ways that pollutants move from agricultural areas in a watershed.

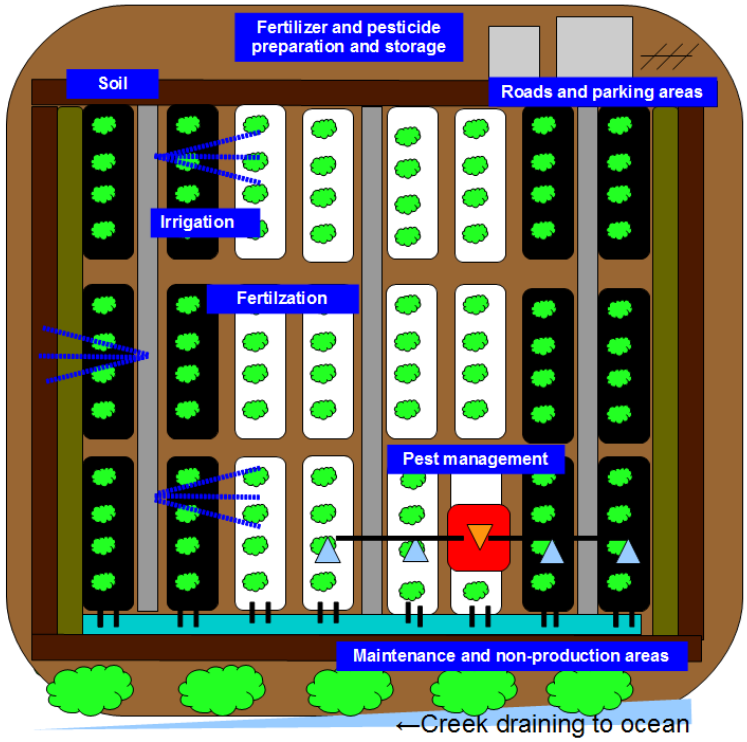
Over 9,000 miles of rivers and streams and over 500,000 acres of lakes and reservoirs in California are considered impaired by levels of nutrients, pesticides, sediment, trash, metals, salts and pathogens that exceed established thresholds (SWRCB, 2012a).

- ❑ High concentrations of nitrate in drinking water pose human health risks.
- ❑ Excess nitrogen and phosphorus in surface waters stimulate growth of aquatic plants and algae.
- ❑ Excess pesticides contaminate food and water sources for fish, wildlife, and humans.
- ❑ Excess sediment causes flooding and turbidity, degrading habitat and recreation.

Water Quality and Potential Agricultural Pollutants

Some strawberry production practices may contribute to water quality impairments:

- Bare soil during tillage and formation of planting beds is susceptible to wind erosion.
- Overhead irrigation over plastic mulch during plant establishment may carry pollutants with water.
- Nutrient and water uptake is limited by the shallow root system of the crop.
- Pollutants may enter the environment through improper amount, placement or timing of fertilizers, pesticides or irrigation; improper storage of fertilizers and pesticides; and improper equipment calibration and maintenance.



Implementation of best management practices adapted to local conditions can prevent or reduce pollutant discharges.

Which management practices will be most effective to protect water quality?

Answer three key questions to determine whether a management practice is right for your operation.

1. What materials in my operation have the potential to become pollutants?

- ❑ Nitrogen or other nutrients
- ❑ Pesticides in current use
- ❑ Legacy pesticides (materials no longer in use that persist in the environment) adhered to soil
- ❑ Salts
- ❑ Trash
- ❑ Fuel

2. Which water bodies are potentially at risk and where are they located relative to my operation?

Identify type (creek, river, lake, groundwater) and proximity.

3. What are my regulatory obligations?

- ❑ Identify which Regional Water Quality Control Board (RWQCB)* regulates your location(s).
- ❑ Review the appropriate RWQCB Basin plan(s)*.
- ❑ Familiarize yourself with the Total Maximum Daily Loads (TMDLs)* adopted in your area.
- ❑ Identify and join a Conditional Waiver discharger group*, if available.

*Refer to the Acronyms and Glossary (pages 22-23) for more information.

Which management practices will be most effective to protect water quality?

Use your answers to guide management practice decisions and implementation of new practices.

Example: Your operation is 50 acres of organic berries on land that was previously orchard.

1. What materials in my operation have the potential to become pollutants?

- ❑ Nutrients: Compost applied prior to creating planting beds and liquid fish fertilizer
- ❑ Legacy pesticides adhered to soil
- ❑ Sediment
- ❑ Salts
- ❑ Trash
- ❑ Fuel

2. Which water bodies are potentially at risk and where are they located relative to my operation?

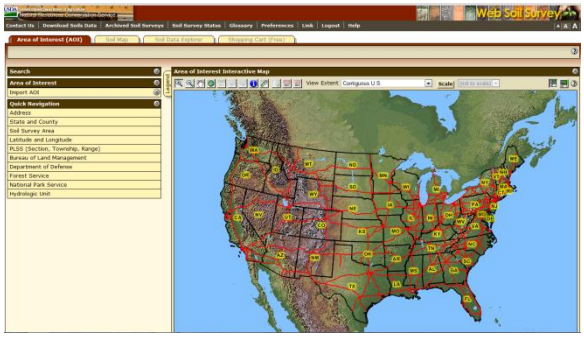
The property is adjacent to a creek that drains to a river.

3. What are my regulatory obligations?

The RWQCB has established nitrogen and legacy pesticide TMDLs for the river in your region.

Precise irrigation (page 10) and nutrient management (page 12) to prevent leaching and sediment movement **may be the most cost-effective management practices with the greatest impact on water quality for this example operation.**

Soil Management



The USDA-NRCS Web Soil Survey provides access to maps and detailed soil descriptions for any area of interest in the U.S.

Vegetative buffers are intentionally-planted areas that can filter any excess nutrients and pesticides and intercept sediment from water runoff.

This grassed buffer reduces movement of pests such as spider mites.

- ❑ Know your soil series and erosion hazard potential (see Additional Resources, p. 24).
- ❑ Develop a soil conservation plan in consultation with USDA-NRCS or other local agency (see Acronyms and Glossary, p. 23).
- ❑ Install vegetative buffers, straw wattles or other means of reducing sediment movement from the production area.

Soil Management

Permanent hedgerows intercept runoff. In addition, some California native shrubs and grasses can host more than 3 times as many beneficial insects compared to pest insects (Morandin *et al*., 2011).

Plastic windbreaks minimize wind erosion and dust damage to crop.

- ❑ Install permanent hedgerows, windbreaks or other means of reducing off-site sediment movement.
- ❑ After production, plant subsequent cash or cover crops.

Wind, irrigation and storm runoff may transport sediment, nutrients and pesticides from bare fields.

Potential pollutants with TMDLs:
Nitrogen, pesticides

Irrigation Management

The water available to plants may be estimated to about 5% accuracy using the feel and appearance of soil samples (see Additional Resources, p 24).

Tensiometers are an economical and fast way to determine when to water: irrigate when the tension falls below an established threshold, e.g., 15-20 cb for a sandy loam soil (see Additional Resources, p. 24).

Irrigation uniformity evaluations may be conducted at no cost to the grower through Resource Conservation Districts (see RCD in Acronyms and Glossary, p. 23).

- ❑ Use crop rooting depth, soil texture and an estimate of the available water content of your soil or a calculated crop coefficient (if available) to determine how much water to apply.

- ❑ Use soil moisture-sensing equipment installed at the level of the crop root zone or track evapotranspiration values (ETo) from local weather stations to determine when to water (soil water depletion).

- ❑ Annually test the distribution uniformity of your irrigation system by monitoring water delivery and pressure differences within a block.

- ❑ Perform regular maintenance on your irrigation system to maintain distribution uniformity and prevent runoff from leaks and clogged lines.

Irrigation Management

Reduce or even eliminate the use of overhead sprinklers to establish transplants: test a small area using one line of drip tape for each plant row and actively monitor salinity in the transplant root zone using a handheld probe.

Reserve overhead sprinklers to leach salts from the transplant root zone (in absence of rain) or for frost protection.

- Use drip irrigation as early as possible in the production cycle.
- Inject liquid emulsified formulations of polyacrylamide to reduce sediment movement with surface runoff.

Runoff from untreated sprinkler irrigation (left) compared to 5 ppm polyacrylamide treatment (right). Suspended sediment in treated runoff was reduced by more than 90% (Cahn, 2010).

Sediment, nutrients and pesticides move with irrigation and storm runoff during windy conditions, when spraying unpaved roads or when backfill for irrigation trenches is not compacted.

Potential pollutants with TMDLs:
Nitrogen, pesticides, salts

Fertilizer Management

Analysis of pre-plant soil samples may show plenty of residual nitrogen, especially if the previous crop was vegetables. Strawberry fields also tend to have highly available phosphorus and potassium.

A nitrate quick test is a simple and fast way to determine parts per million (ppm) of nitrate from a soil or water sample.

A backflow prevention device prevents contamination of the well or water source when injecting fertilizer or pesticides.

- ❑ Conduct soil tests to determine if pre-plant or early-season fertilizer is needed.
- ❑ Apply the minimum amount of fertilizer based on test results from soil or plant tissue.
- ❑ Consider nitrate present in irrigation water when calculating fertilizer application (see Additional Resources, p. 24).
- ❑ If fertigating, inject fertilizer toward the end of the irrigation run.
- ❑ Inspect backflow prevention devices annually.

Fertilizer Management

Seasonal nitrogen uptake for strawberry at Watsonville and Santa Maria, California (Bolda, 2012)[z]

Total uptake during early growth (planting-March)	Average daily uptake during active growth (April-August)	Total nitrogen uptake for the season[y]
20 lb/A	1 lb/day	180-220 lb/A

[z] Growing conditions in Oxnard and Irvine promote active growth and nutrient uptake earlier in the season compared to Watsonville and Santa Maria. There is likely *less* nutrient uptake overall in southern California, however, because the growing season is typically shorter than in northern California.

[y] Seasonal uptake for phosphorus (P_2O_5) and potassium (K_2O) in northern California is 90-110 lb/A and 270-330 lb/A, respectively.

- ❑ Time fertilizer application to maximize plant uptake. Consider how plant growth and development is affected by length of season, plant variety, transplant chill hours, weather at the production site, mulch (black vs. clear), and the use of tunnels.

- ❑ Maintain fertilizer use records.

Fertilizer applied prior to the active growth stage of the plant may be leached with irrigation or storm water.

Potential pollutants with TMDLs:
Nitrogen, salts, trash

Pest Management

Inspect transplants for signs of weakness, disease or insects before planting to prevent spread of pests and disease.

A beating tray is one method to check for both insect pests such as lygus and their natural enemies as part of a regular monitoring program.

- When selecting plant varieties, use available guides on variety disease resistance or tolerance (see Additional Resources, p. 24) as well as disease and vector history in your field to reduce pesticide use.

- Apply pesticides only when justified by pest population and crop damage thresholds.

- Choose pesticides that are most selective for the target species (see Additional Resources, p. 24).

- Use databases such as UC IPM WaterTox to evaluate the water quality risk of applying a specific pesticide (see Additional Resources, p. 24).

Pest Management

Common name (trade name)	Amount/acre (in 200 gallons water/acre)	Re-entry interval (hours)	Pre-harvest interval (days)

WATER QUALITY Compare treatments AIR QUALITY Calculate emissions

The following materials are listed in order of usefulness in an IPM program, taking into account efficacy.. Also consider the general properties of the fungicide as well as information relating to environmental impact. Not all registered pesticides are listed. Always read label of product being used:

PYRACLOSTROBIN /BOSCALID (Pristine)	18.5-23 oz	12	0

MODE OF ACTION GROUP NAME (NUMBER1): Quinone outside inhibitor (11) and Carboxamide (7)

COMMENTS: Pyraclostrobin is a strobilurin and boscalid is a carboxyanilde fungicide. Begin applications at bloom and alternate with cyprodinil/fludioxonil (Switch) or fenhexamid (Elevate).

FENHEXAMID (Elevate) 50 WDG	1.5 lb	12	0

MODE OF ACTION GROUP NAME (NUMBER1): Hyrdoxyanilide (17)

COMMENTS: A hydroxyanilide fungicide. Begin applications at early bloom before disease development begins;continue applications at 7- to 10-day intervals when conditions favor disease development but do not make more than 2 consecutive applications before alternating with a fungicide of a different chemistry for at least 2 applications. May be applied alone, or under light to moderate disease pressure can be tank-mixed at a rate of 1-1.5 lb/acre with a fungicide of a different chemistry (e.g. captan). For tank mixes, observe all directions for use on all labels and employ the most restrictive limits and precautions. Never exceed the maximum a.i. On any lable when tank mixing products that contain the same a.i. Do not exceed 6 lb/acre/season.

Partial list of treatments and application rates for botrytis fruit rot with options to compare water and air quality impacts, as viewed at the UC IPM guidelines: http://ucipm.ucdavis.edu/MPG/selectnewpest.strawberry.html

- ❑ Use the lowest effective application rate according to the product label and the most current recommendations from UC, local agencies, and industry.
- ❑ If using chlorpyrifos or other water-soluble organophosphate pesticides, consider applying a commercial enzyme product (e.g., Landgard™) to runoff capture ditches to hasten pesticide degradation.
- ❑ Maintain pesticide use records.

Pesticides may move with wind, storm or irrigation runoff or when applicator nozzles are not closed during turns.

Potential pollutants with TMDLs:
Pesticides, salts, trash

Fertilizer and Pesticide Preparation and Storage

Accurate measurements ensure the labeled rate is applied and may reduce or eliminate any excess requiring disposal.

Store fertilizers and pesticides atop an impermeable surface with secondary containment.

Pesticide storage must be labeled and should be kept locked.

- ❑ Accurately measure all fertilizers and pesticides and calibrate application equipment.
- ❑ Mix and load fertilizers and pesticides on an impermeable surface (e.g., concrete floor) or in an area with low potential for runoff.
- ❑ Store fertilizer and pesticide application equipment in a covered or enclosed location.
- ❑ Store fertilizers and pesticides in a structure that complies with local, state and federal guidelines and is located at least 100 ft. downslope from water sources.
- ❑ Seal any open or torn bags containing granular or powder formulations.

Fertilizer and Pesticide Preparation and Storage

Clean any spills immediately according to a pre-determined protocol and dispose of material as required by law.

- ❑ Provide cleanup materials for liquid and granular spills in a readily-accessible location.
- ❑ Enclose open containers of liquid formulations in a tray, sealed plastic bags, or other form of secondary containment.
- ❑ Use covered disposal containers for empty fertilizer and pesticide containers.
- ❑ Contact your local Agricultural Commissioner's Office for a list of approved disposal sites (see Additional Resources p. 24).

Improper disposal of empty bags in a full or uncovered dumpster may lead to off-site movement.

Potential pollutants with TMDLs:
Nitrogen, pesticides, salts, trash

Non-production and Maintenance Areas

Perimeter hedgerows minimize wind erosion from the production area.

Straw wattles absorb runoff and sediment.

Polyacrylamide in an anchored bag binds to sediment in a runoff capture area.

- ❑ Use permanent hedgerows, straw wattles or other runoff capture devices around property perimeter and especially adjacent to critical locations such as drainage areas, creeks or paved streets.
- ❑ Surround maintenance areas with landscape, vegetative buffers or gravel.
- ❑ Minimize use of fertilizers and pesticides in landscaped areas.
- ❑ Apply polyacrylamide to runoff capture ditches prior to storm events.
- ❑ Inspect culverts, roadside ditches, waterbreaks and outlets, cleaning them after major rain events.

Non-production and Maintenance Areas

Covered dumpsters and trash cans prevent off-site movement of trash.

Provide secondary containment for fuel tanks.

- ❑ Use tight-fitting lids on all dumpsters and trash cans and secure them upright.
- ❑ Store equipment and spare parts under tarps or other cover.
- ❑ Place fuel tanks at least 100 ft. downslope from water sources.
- ❑ Assess the potential for spills (fuel, vehicle fluids, cleaning products) and provide cleanup materials in a readily-accessible location.

Trash may move off-site via roadside ditches, especially during and after storms.

Potential pollutants with TMDLs:
Nitrogen, pesticides, salts, trash

Roads and Parking Areas

A vegetated ditch along the road captures and slows runoff and sediment.

A waterbreak reduces flow down the full length of a road.

- Grade roads to direct runoff to ditches, vegetated areas or a sediment trap. If crops are grown immediately adjacent to roads, direct runoff toward the center line of the road.

- On roads with gradients exceeding 8% slope, create and regularly maintain waterbreaks (waterbars).

Roads and Parking Areas

Mulched or seeded roads reduce sediment movement and may increase water infiltration.

A grid of rubber rings helps stabilize gravel in this parking area.

- ❑ Apply mulch to moderately-used, unpaved road surfaces and other bare soil traffic areas prior to winter rains or seed with annual or perennial grasses and mulch until grass is established.
- ❑ Use corrugated steel plates, shaker plates, or other devices to keep sediment and gravel on the property, especially in high-traffic areas such as entrances and exits.

Without stabilization measures, gravel can move with irrigation or storm runoff, carrying sediment and adsorbed nutrients and pesticides.

Potential pollutants with TMDLs:
Trash

Acronyms and Glossary

Basin Plan a "master planning document" and "regulatory tool" for each RWQCB that includes water quality objectives, implementation programs to achieve the objectives, time schedules for actions and determination of compliance (SWRCB, 2012b). Visit your RWQCB website (see RWQCB, below) to view its Basin Plan.

BMP best management practice, an on-farm procedure or method based on scientific research or testing and adapted to local site conditions that achieves the objectives of productivity, profitability and an additional goal such as minimization of pollutant movement off-site.

Conditional waiver or **Ag waiver** shortened name for a regulatory program requiring owners and operators of irrigated land used for commercial crop production to measure and control discharges from their property, instead of applying for a waste water discharge permit (full name: Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands).

Discharge group a membership-based collective of agricultural landowners and growers created to comply with the conditional waiver; e.g., VCAILG (Ventura County Agricultural Irrigated Lands Group).

Distribution uniformity (abbreviated DU) the degree to which irrigation water is evenly applied to a field, expressed as a percentage. Higher DU values indicate more uniform application of water; ideal system performance is greater than 80%. Irrigation evaluations to determine DU can be conducted by RCDs (see RCD below).

Evapotranspiration, reference (abbreviated ET_o for grass grown in standardized conditions) the loss of water to the atmosphere via evaporation from soil and plant surfaces and transpiration from plant tissues, expressed in inches or millimeters, and available from weather station data. Higher ET_o values indicate greater water loss. Cumulative ET_o may be used to schedule irrigations (http://wwwcimis.water.ca.gov/).

IPM integrated pest management, an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of control strategies .

Acronyms and Glossary

Leaching process in which soluble substances dissolved in water (such as nutrients from fertilizer), percolate from the upper soil horizon to lower soil layers and, in some cases, to groundwater.

Pollutant discharged contaminant for which a TMDL has been established by the RWQCB.

RCD Resource Conservation District, non-regulatory, locally-led, not-for-profit organization established under Division 9 of the California Public Resources Code to collaborate with landowners, government agencies and other willing partners to facilitate the conservation and restoration of natural resources. Find your RCD: http://carcd.org/rcd_directory0/aspx

Runoff Water movement along the soil or ground surface. Runoff that carries sediment and other pollutants may contaminate surface waters.

RWQCB Regional Water Quality Control Board, develops and enforces water quality objectives and implementation plans to protect state waters (SWRCB, 2012c). Find your RWQCB: http://www.waterboards.ca.gov/waterboards_map.shtml

Sediment trap a containment area where runoff is temporarily held, allowing sediment to settle before runoff is discharged. (http://www.cabmphandbooks.com/Documents/Construction/SE-3.pdf)

TMDL total maximum daily load, the qualitative amount of a pollutant a water body can tolerate on a daily basis within established water quality benchmarks (SWRCB, 2012d).

UC University of California, a public institution providing education, research and extension.

USDA-NRCS United States Department of Agriculture-Natural Resource Conservation Service, a federal agency with county-based service centers that provide conservation planning and assistance to private landowners. Find your service center: http://www.nrcs.usda.gov/

Waste Discharge Requirements Program program regulating point-source discharges that are exempt from California solid waste regulations and are not subject to the Federal Water Pollution Control Act. This program includes the Conditional Waiver of Waste Discharge Requirements (see Conditional waiver, above).

Additional Resources

Soil (page 8)
Web soil survey for location-specific soil types, erosion potential, etc.:
http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

Irrigation (page 10)
Estimating soil moisture by feel and appearance:
http://www.mt.nrcs.usda.gov/technical/ecs/agronomy/soilmoisture/index.html
(at the bottom of the page, a pdf can be downloaded and printed to take to the field).

Using tensiometers for strawberries (sandy and sandy loam soils):
http://cemerced.ucdavis.edu/files/40402.pdf
See also Integrated Pest Management for Strawberries (Strand, 2008) Table 6, p.22.

Fertilizer (page 12)
Using the nitrate present in soil and water in your fertilizer calculations:
http://www.valleywater.org/programs/agriculture.aspx (see additional resources on right side of page).

Pest management (page 14)
Characteristics of common strawberry cultivars, including susceptibility to pests and disorders:
http://ucipm.ucdavis.edu/PMG/r734900111.html

UC Cooperative Extension weed susceptibility database:
http://info.ucanr.org/weed_sept/

UC IPM WaterTox:
http://ucipm.ucdavis.edu/TOX/

Fertilizer and pesticide storage (page 16)
County Agricultural Commissioner contact information:
http://www.cdfa.ca.gov/exec/county/countymap/

UC Farm water quality planning
http://anrcatalog.ucdavis.edu/FarmWaterQualityPlanning/

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	BMP	Installation Date	Notes/Maintenance
Soil Management			
Irrigation Management			
Fertilizer Management			
Pest Management			
Fertilizer and Pesticide Preparation and Storage			
Maintenance and Non-production Areas			
Roads and Parking Areas			