Row Crops Best Management Practices to Protect Water Quality

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Row crops growers in California employ numerous practices to protect water quality, whether they are growing vegetables, herbs, onions, or melons. *Row Crops Best Management Practices to Protect Water Quality* 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: A well managed irrigation program that includes drip irrigation results in a uniform crop, minimal water runoff, and dry furrows for this romaine lettuce grown on 80-inch beds.

*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

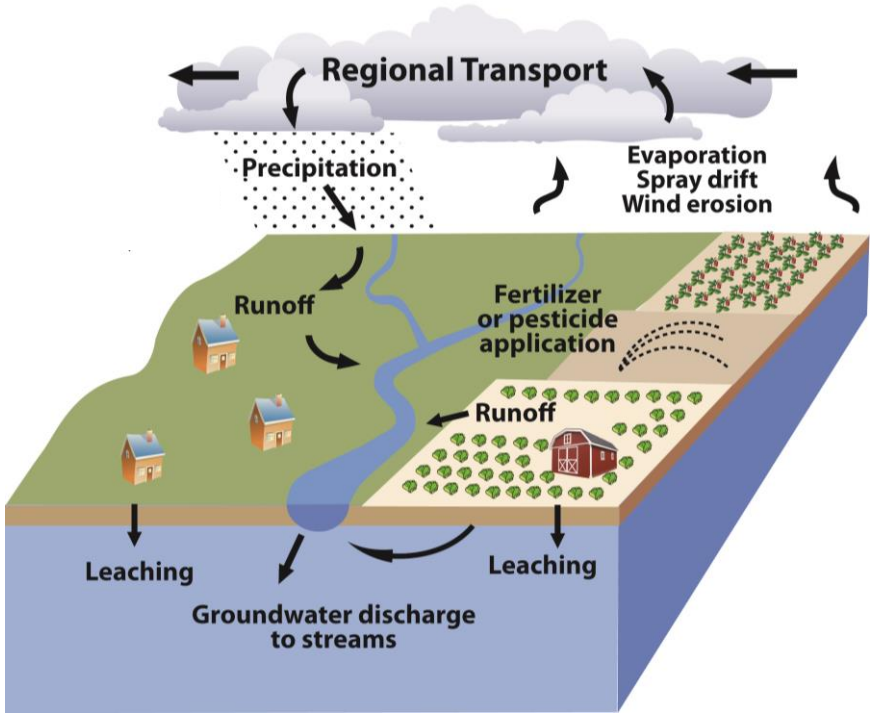


Figure adapted from: http://pubs.usgs.gov/fs/fs03500/fs03500.pdf

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).

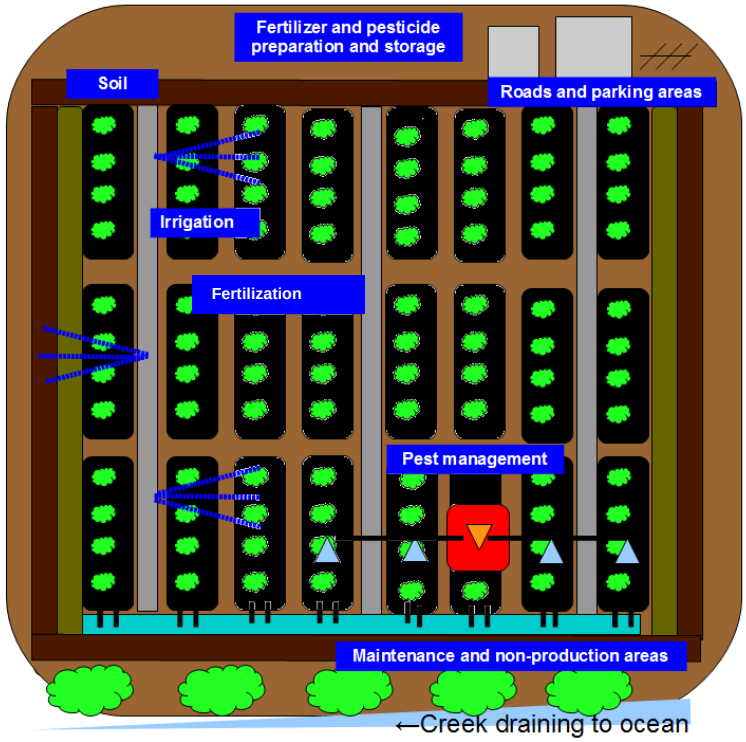
- High concentrations of nitrate in drinking water pose human health risks.
- Excess nitrogen and phosphorus in surface waters stimulate growth of aquatic plants and algae.
- Excess pesticides contaminate food and water sources for fish, wildlife, and humans.
- Excess sediment causes flooding and turbidity,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

Water Quality and Potential Agricultural Pollutants

Some row crops production practices may contribute to water quality impairments:

- Bare soil during tillage and formation of planting beds is susceptible to wind erosion.
- Irrigation during plant establishment may carry pollutants with water.
- Some crops are shallow-rooted, which limits nutrient and water uptake.
- During excess irrigation or storms, pollutants resulting from the improper amount, placement or timing of fertilizers, pesticides or irrigation, from improper calibration or maintenance of application equipment, or from improper storage of fertilizers and pesticides may enter the environment.

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



This sample farm diagram indicates the areas of an operation in which best management practices may be implemented.

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

*Refer to the Acronyms and Glossary (pp. 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: My operation is 100 acres of lettuce on land that was previously orchard.

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

- Nutrients from fertilizers (for example, banded application of standard fertilizer at planting or liquid formulations applied with drip irrigation after rosette stage).
- Pesticides in current use (for example, diazinon)
- Legacy pesticides adhered to sediment (for example, DDT derivatives)
- Sediment
- Salts
- Trash
- Fuel

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

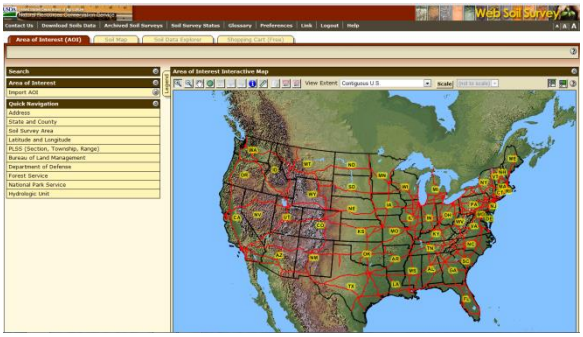
My property is adjacent to a creek that drains to a river.

3. What are my regulatory obligations?

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

Precise irrigation (p. 10) and nutrient management (p. 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 lettuce operation (see Additional Resources, p. 24).**

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. (see Additional Resources, p.24).

Vegetative buffers are intentionally-planted areas that intercept sediment from water runoff.

Vegetative buffers also filter excess nutrients and pesticides.

- ❑ 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).
- ❑ Develop a farm water quality plan (see Additional Resources, p. 24).
- ❑ Install vegetative buffers*, straw wattles or other means of reducing sediment movement from the production area.

* Check current crop-specific food safety guidelines prior to installation (see Additional Resources, p. 24).

Soil Management

Permanent hedgerows intercept runoff, minimize dust damage to crop and reduce wind erosion.

As permanent hedgerows, some California native shrubs and grasses can host more than three times as many beneficial insects compared to pest insects (Morandin *et al.*, 2011).

- ❑ Install permanent hedgerows (see Additional Resources, p. 24), windbreaks* or other means of reducing off-site sediment movement**.**
- ❑ After production, plant subsequent cash or cover crops**.**

* Check current crop-specific food safety guidelines prior to installation (see Additional Resources, p. 24).

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

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).

Local weather station data such as daily soil and air temperatures are available at no cost (see CIMIS in Acronyms and Glossary p. 22).

Irrigation uniformity evaluations may be conducted 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) (see Additional Resources, p. 24).

- 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

Celery can be transplanted into dry beds and then drip-irrigated for plant establishment. Drip tape can also be used to pre-irrigate prior to transplanting.

- Use drip irrigation as early as possible in the production cycle to precisely and uniformly apply water and minimize surface runoff.

- Inject a liquid emulsified formulation of polyacrylamide, a chemical polymer, to reduce sediment movement with surface runoff (see Additional Resources, p. 24).

Runoff from untreated sprinkler irrigation (left) compared to 5 ppm polyacrylamide treatment in lettuce fields. Suspended sediment and pyrethroid concentrations in treated runoff were reduced by more than 90% (Cahn, 2010).

Nutrients, pesticides and sediment can move with runoff generated from excess irrigation, overhead irrigation in windy conditions, or when backfill for irrigation trenches is not compacted.

Fertilizer Management

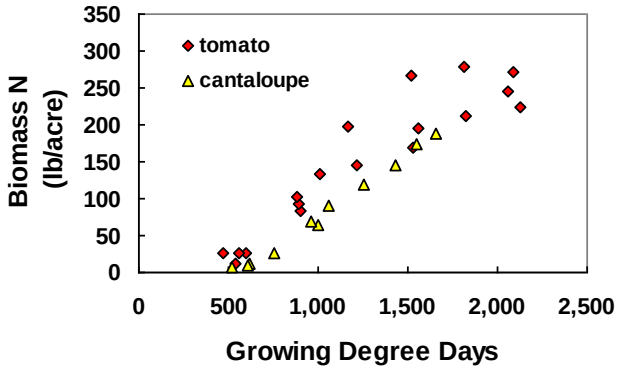
Pre-plant soil tests may show sufficient nutrients depending on the crop. For example, additional phosphorus is not needed for lettuce if pre-plant soil levels are above 50 ppm (Hartz, 2011).

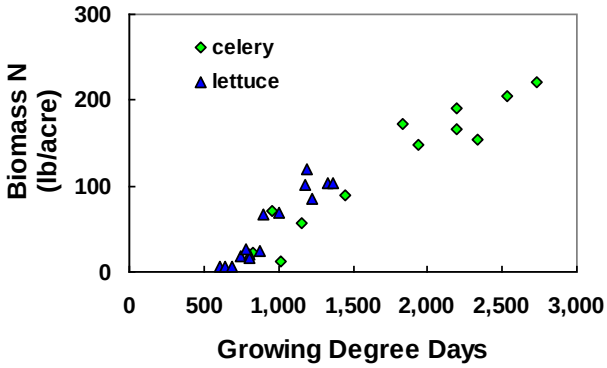
A nitrate quick test is a simple and fast way to determine parts per million (ppm) of nitrate from a soil or water sample.

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 at the end of the irrigation run.
- ❑ Inspect backflow prevention devices annually.

Fertilizer Management





Nitrogen present in four crops over time. Uptake is slow early in the season for most vegetable crops. Peak uptake is about 3-4 pounds of nitrogen/acre/day (cool conditions) and 4-6 pounds of nitrogen/acre/day (warm conditions) (Hartz, 2011).

Biomass N: amount of nitrogen in dried plant tissue.

Growing degree days: cumulative number of temperature degrees in which the average daily temperature exceeds a base temperature below which the crop does not grow.

- ❑ Time fertilizer application to maximize plant uptake. Consider how plant growth and development is affected by length of season, plant variety, weather at the production site, and the use of mulch.
- ❑ Maintain fertilizer use records.

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

Pest Management

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

Yellow sticky cards are used to detect the presence of many adult insect pests 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

The following materials are listed in order of usefulness in an IPM program, taking into account efficacy, information related to natural enemies and honey bees and environmental impact. Not all registered pesticides are listed. Always read label of product being used.

Common name (trade name)	Amount/acre (in 200 gallons water/acre)	Re-entry interval (hours)	Pre-harvest interval (days)
BACILLUS THURINGENSIS ssp.AIZAWA#	Label rates	4	0
MODE OF ACTION GROUP NUMBER[1]			
COMMENTS: This material is most effective against newly hatched larvae so proper treatment timing is essential.			
EMAMECTIN BENZOATE	3.2-4.8 oz	12	14
MODE OF ACTION GROUP NUMBER[1]: 6			
INDOXACARB	2.5-3.5 oz	12	3
MODE OF ACTION GROUP NUMBER[1]: 22			
COMMENTS: Do not apply more than 14 oz/acre/crop. Add a wetting agent to improve coverage. Minimum interval between sprays is 3 days.			

Snapshot of UC IPM guidelines for beet armyworm in cole crops. The website provides a list of treatments and application rates with options to compare water and air quality impacts: (http://ucipm.ucdavis.edu/PMG/r108301211.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 diazinon (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. Pyrethroid pesticides and chlorpyrifos can adhere to dust or sediment.

Fertilizer and Pesticide Preparation and Storage

Accurate measurements ensure the labeled rate is applied. Careful calculation of the required spray volume eliminates the need to dispose of excess.

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 feet downslope from water sources.
- ❑ Seal any open or torn bags containing granular or powder formulations.
- ❑ Enclose open containers of liquid formulations in a tray, sealed plastic bags, or other form of secondary containment.

Fertilizer and Pesticide Preparation and Storage

Clean any spills immediately in accordance with the product material safety data sheet (MSDS) and dispose of material in accordance with label instructions and as required by law.

- Provide cleanup materials for liquid and granular spills in a readily-accessible location.
- Dispose empty fertilizer and pesticide containers in covered trash bins.
- Contact your local Agricultural Commissioner's Office for a list of approved disposal sites for excess agricultural chemicals (see Additional Resources p. 24).

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

Non-production and Maintenance Areas

Straw wattles absorb runoff and sediment.

A vegetated ditch captures and slows runoff and sediment movement.

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

- ❑ Use permanent hedgerows (see Additional Resources, p. 24), 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 gravel, landscape, or vegetative buffers*.

- ❑ 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.

* Check current crop-specific food safety guidelines prior to installation.

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 feet 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.

Roads and Parking Areas

Vegetation along the road minimizes off-site movement of runoff and sediment.

- 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.

A waterbreak reduces flow down the full length of a 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. Mulched roadways also minimize dust damage to crops and reduces spread of spider mites.

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. Soil adhered to gravel or from bare roads may contain nutrients and pesticides.

Acronyms and Glossary

Basin Plan a "master planning document" and "regulatory tool" for each Regional Water Quality Control Board (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 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.

CIMIS (California Irrigation Management Information System) an integrated network of weather stations located throughout California that provides data such as daily soil and air temperatures to aid in irrigation scheduling. Find your nearest weather stations: http://wwwcimis.water.ca.gov/

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.

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.

Acronyms and Glossary

Pollutant a discharged contaminant (general term) or a 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)

SWRCB (**State Water Resources Control Board)** an agency created to preserve, enhance, restore, and allocate water resources. Creates state-wide policy and coordinates and supports the efforts of the nine RWQCBs (SWRCB, 2013).

TMDL (Total Maximum Daily Load) a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards (SWRCB, 2012d). TMDLs have been established for nitrogen, pesticides, salts, and trash.

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

Additional Resources

Example for lettuce operation (page 7)
Measures to minimize water quality impairments to surface and ground water for lettuce
http://www.ipm.ucdavis.edu/PMG/r441311611.html

Soil Management (pages 8-9)
Web soil survey for location-specific soil types, erosion potential, etc.
http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

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

UC Food safety
http://ucfoodsafety.ucdavis.edu/Preharvest/

Installation of hedgerows, including discussion of food safety concerns
http://ucfoodsafety.ucdavis.edu/files/26499.pdf

Irrigation Management (pages 10-11)
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 scheduling irrigations of coastal vegetables
http://vric.ucdavis.edu/pdf/county%20newsletter_NR/MontereyCropNotes_newsletter_2011_NovDec.pdf (p. 6-10).
Includes discussion of other soil moisture sensors.

Fertilizer Management (pages 12-13)
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 (pages 14-15)
UC Cooperative Extension weed susceptibility database
http://info.ucanr.org/weed_sept/

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

Fertilizer and Pesticide Preparation and Storage (pages 16-17)
County Agricultural Commissioner contact information
http://www.cdfa.ca.gov/exec/county/countymap/

Non-production and Maintenance Areas (pages 18-19)
See websites on UC Food safety and hedgerow installation above (Soil Management)

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SWRCB, 2012b. Basin Plan (Region 4).
http://www.waterboards.ca.gov/losangeles/water_issues/programs/basin_plan

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http://www.waterboards.ca.gov/publications_forms/publications/factsheets/docs/region_brds.pdf

SWRCB, 2012d. TMDL program.
http://www.waterboards.ca.gov/water_issues/programs/tmdl/docs/tmdl_factsheet.pdf

SWRCB, 2013. California Water Boards: Who We Are and What We Do.
http://www.waterboards.ca.gov/about_us/water_boards_structure/whoweare.shtml

	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			

Notes

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