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DATE: September 17, 2013

TO: Ms. Jeanine Townsend
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FROM: Kenneth A. Harris Jr.
Executive Officer
CENTRAL COAST REGIONAL WATER QUALITY CONTROL BOARD

SUBJECT: COMMENTS TO SWRCB/OCC FILE A-2209(a)-(e) – SEPTEMBER 24, 2013 BOARD MEETING

The Central Coast Regional Water Quality Control Board (Central Coast Water Board) appreciates the careful review by the State Water Resources Control Board (State Water Board) of the Central Coast Water Board's Order No. R3-2012-0011(Agricultural Order) and its associated Monitoring and Reporting Program.

The Central Coast Water Board supports most of the revisions made by State Water Board staff in the September 9, 2013 State Water Board Draft Order, and provides the following comments and recommendations for specific additional edits related to requirements for total nitrogen and nutrient management reporting, cooperative groundwater monitoring programs, individual surface water discharge monitoring, and compliance with water quality standards.

Total Nitrogen and Nutrient Management Reporting for Tier 2 and Tier 3 Farms that are High Risk for Loading Nitrate to Groundwater

The Central Coast Water Board recommends that the State Water Board retain specific nutrient budgeting and nutrient management reporting requirements that are critical to effectively implement the Agricultural Order and achieve its stated purpose of reducing pollutant loading, improving water quality and protecting sources of drinking water. These provisions are standard industry practices and were included in the Agricultural Order to ensure that the farms with highest risk with regard to nitrogen are using the best practicable treatment or control of the discharges consistent with Resolution 68-16.

- We strongly agree with the language in the State Water Board Draft Order to uphold the reporting of total nitrogen applied for the subset of Tier 2 and Tier 3 farms that are high risk for loading nitrate to groundwater.

- We agree with the State Water Board staff's proposed changes to the Draft Order which reinstate and clarify the option to report nitrogen applied by risk unit (Method 2). We further recommend that the proposed Method 2 include soil nitrogen content as part of the total nitrogen applied required to be reported as stated in the August 20 version of the Draft Order. The August 20 version of the Draft Order required Tier 2 and Tier 3 farms that are high risk for loading nitrate to groundwater to take a soil sample per each risk unit, to measure the total nitrogen present in the soil in lbs /acre prior to the first application of fertilizer to the first crop-in-rotation.

- We recommend that the requirements for Method 1(b) and Method 2(c) for annual reporting of nitrogen application should report the average load of nitrogen in irrigation water during the annual reporting period, reported as total nitrogen in lbs. of nitrogen in irrigation water, rather than average annual nitrogen concentration in irrigation water.

- We recommend that Footnote #1 on page 47 clarify that the reporting requirement is for the nitrogen content of fertilizer in lbs and not the total lbs of fertilizer. For example, if 100 lbs /acre of fertilizer is applied with 12 percent nitrogen, 12 lbs/acre of nitrogen is reported.

We continue to disagree with the removal of other reporting requirements related to nutrient management for a subset of Tier 3 farms. We specifically recommend that the State Water Board reinstate the following requirements in the Agricultural Order:

- The requirement for Tier 3 farms with high nitrate loading risk to report the typical crop nitrogen uptake and report the basis for the determination (e.g., developed by commodity or industry group, publicized agronomic literature, research trials, site specific analysis). (Condition 74 and Tier 3 MRP Section B.1.(a)). Reporting of this information is especially important in cases where growers are applying nitrogen in amounts greater than the standard recommended application rates.

- The requirement for Tier 3 farms to calculate and report the annual balance of nitrogen applied per crop compared to the typical crop nitrogen uptake (Condition 77 and Tier 3 MRP Section B.1.(b)).

In addition, to help define a long-term water quality solution, we also recommend that the State Water Board direct the Expert Panel to develop a method for determining basin specific nutrient load limits that will achieve surface water and groundwater quality objectives over the long-term according to a reasonable and defined schedule.

The Central Coast Water Board consulted with a group of experts that included private industry Certified Crop Advisors (CCAs), as well as University of California Cooperative Extension (UCCE) researchers, and also technical advisors and staff from the Central Valley Water Board to develop the nutrient management requirements for the Agricultural Order[1]. The experts consistently recommended that "documenting the reduction of nitrogen input to the production system and improved irrigation efficiency should be the focus of the Ag Order". Staff and the technical experts carefully evaluated and determined what should be the minimum reporting requirements that would 1) trigger behavioral changes and influence growers to improve irrigation and nutrient management practices, and 2) provide the Water Board and public with the most reasonable verification reporting of pollutant load reductions. The experts agreed that identifying how much nitrogen is needed and comparing that to the amount of nitrogen that is applied is a fundamental and critical necessity in influencing change and preventing nitrate impacts to groundwater. This documentation, in a manner that allows timely evaluation (in a Water Board database) is fundamental to effective program implementation.

Farm advisors and University crop specialists have been recommending nutrient management practices for decades. Nutrient budgeting should be a standard industry practice, and many growers report that they are already implementing these fundamental practices. The 2004 Agricultural Order required all growers to implement nutrient management practices. In 2006, 67% of growers reported that they knew their crop nutrient requirements, and a similar percentage reported that they used nutrient budgets and kept records of nitrogen applied[2]. At this time, the Central Coast Water Board has no information to verify the level of practice implementation or evaluate the extent to which implementation is actually leading to more efficient fertilizer application or pollutant load reduction. Some of the experts stated that growers are likely not implementing irrigation and nutrient management practices, or not implementing these practices effectively, despite reporting that they do. Thus, proper record-keeping and reporting of this information is critical.

With their experience, the experts agreed that tremendous improvements in nitrogen application should and could be made. The experts came up with 3 elements: documenting total nitrogen applied, determining nitrogen crop needs, and meeting specific nutrient balance ratios. Also, they agreed that the growers could meet specific nutrient balance ratios in 3 years if they were required to work with a Certified Crop Advisor to do so. The experts recommended that requiring the reporting of the key irrigation and nutrient management plan (INMP) elements, including the nutrient balance ratios, would minimize the burden of reporting and would likely cause fundamental on-the-ground improvements in nutrient budgeting.

Experts identified the following specific benefits and outcomes from the INMP requirements included in the Agricultural Order:

- implement a system of fertilizer record keeping that growers will utilize when making their fertilizer application decisions, which is critical for effective nutrient budgeting;
- identify an annual target of fertilizer application – that would be considered as a reasonable standard at this point in time; with the future planned step of fine-tuning targets once growers are familiar with crop needs, the amount of nitrogen removed by the crop, and after having an effective record keeping system in place;
- allow for growers to compare how much nitrogen is needed and better understand how much fertilizer is over applied;

[1] Admin Records #177, #178, #179, and #195.

[2] Admin Record #23

- document specific conditions where growers are applying more fertilizer than is necessary or applying reasonable amounts;
- advance towards a more sustainable fertilizer application state;

Published guidelines are available for the predominant crop types which are high risk for nitrate loading to groundwater with the most acreage on the Central Coast[3]. For example, Admin Record Reference #227 is a UC Publication titled "Nutrient Management in Cool-Season Vegetables". The publication discusses nitrate pollution, provides specific recommendations about irrigation and nutrient management practices, and provides crop nitrogen uptake values for broccoli, cauliflower, celery and lettuce. For example, the recommended crop uptake for broccoli is 180 lbs. to 220 lbs per acre. To prevent nitrate pollution to groundwater, the publication instructs growers to compare how much nitrogen they apply to these crop uptake values. This is how we intend for the nitrate balance ratio calculation to be used. There is also published literature identifying specific recommendations for management goals and management practices for cool-season vegetables on the Central Coast that outline the best economically achievable technologies or processes for limiting the movement of nutrients into groundwater and surface water[4]. The Agricultural Order was developed using these references and we expect growers to continue to improve their nutrient management practices through an iterative process that is informed by this information. In some cases, growers may not use published literature to determine crop needs and may base their fertilizer decisions on other information. The requirement for Tier 3 farms with high nitrate loading risk to report the typical crop need and report the basis for the determination, provides the opportunity for growers to describe how they make decisions about how much fertilizer to apply and allows the Central Coast Water Board to take that information into account.

The Central Coast Water Board needs this information to identify and prioritize higher risk farms for appropriate follow-up. In addition, the Central Coast Water Board needs this information to evaluate and verify the effectiveness of the Order and progress towards water quality improvement. We are focusing on these specific examples related to nitrogen because addressing nitrate contamination is the highest priority for the Agricultural Order. There are no compliance points in the State Water Board Draft Order related to nitrogen application or loading reduction. The reporting requirements described here are the only requirements that will allow the Central Coast Water Board to measure progress to reduce nitrate loading over time to better protect water quality.

Most growers indicate that they do not object to nutrient budgeting. The primary issue is the reporting of this information. Agricultural petitioners express concerns with such information being available to the public. However, Information regarding fertilizer applications may be protected by the Water Code, and will not be disclosed to the public if the discharger establishes that the information is a trade secret. Reporting requirements ensure good record-keeping, create accountability and compel the highest risk farms to evaluate and change their practices, as appropriate, to protect water quality. The requirement to report this information is not only basic and fundamental; it is also reasonable, especially given the severe water quality conditions and impacts to drinking water and public health.

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[3] Admin Record References #47, #132, #133, #134, #135, #136, #137, #226, and #227.

[4] Admin Record Reference #228

It is important to remember that these specific nutrient management reporting requirements are only required for a fraction of farms enrolled in the Agricultural Order. The requirements apply to the subset of Tier 2 and/or Tier 3 farms that are determined to be high nitrate loading risk to groundwater based on specific factors such as crop type, soil type, irrigation type, nitrate concentration, and proximity to impacted public drinking water wells. Thus, the requirements are targeted for farms where they are most important. This scaling of requirements was one of several deliberate decisions by the Central Coast Water Board to ease the reporting burden and take initial, fundamental steps towards water quality improvement.

In addition, these nutrient management requirements do not conflict with the Expert Panel process. Experts already agree that reporting of total nitrogen applied should be a fundamental reporting requirement. The requirements in the Draft Order provide flexibility in how to report the information and the Expert Panel process can inform the details. Reporting for the subset of Tier 2 and Tier 3 farms that are high risk for loading nitrate to groundwater is not due until October 2014 - so there is time for the Expert Panel to convene and provide input to the details of reporting.

Cooperative Groundwater Monitoring Programs

We agree that it is important for the State Water Board's Draft Order to define how cooperative groundwater monitoring programs sample domestic drinking water wells. We recommend that the Draft Order include the following provision:

"The cooperative program must sample all domestic drinking water wells on participant owned/leased/operated land unless an acceptable technical rationale is provided for sampling a representative subset in specific areas. Sufficient technical rationale must provide evidence that groundwater quality from the domestic drinking water well not sampled is represented by other wells sampled with reasonable certainty, based on factors such as close proximity, same aquifer, and similar well depth and screened interval. The proposed list of wells for sampling and any technical rationale for sampling a subset must be approved by the Executive Officer prior to implementation."

This statement is consistent with verbal and written comments from agricultural petitioners interested in implementing a cooperative groundwater monitoring program which stated that "the default is to sample every well".

Individual Surface Water Discharge Monitoring and Reporting Requirements

We agree with the changes to the Individual Surface Water Discharge Monitoring provisions and MRP language. However, we note that the Draft Order only recommends changes to the MRP date to initiate monitoring (Tier 3, MRP, Part 5, Section A.9.) from October 1, 2013 to December 1, 2013. For consistency and to retain the requirement to initiate monitoring by a date certain, the State Board's Draft Order should also include a consistent edit to Agricultural Order Provision 72.

Compliance with Water Quality Standards

The Central Coast Water Board supports the changes on pages 25 – 26 of the State Water Board Draft Order regarding compliance with Provisions 22, 23, and 82 and the addition of the term "cause or contribute" to Provision 22 and other provisions in the Agricultural Order.

The Central Coast Water Board opposes revisions proposed by petitioner Grower-Shippers and supported by some other agricultural petitioners regarding Provisions 22, 23, and 82. The State Water Board Draft Order would provide reasonable clarification that dischargers subject to the Agricultural Order are required to comply with Provisions 22, 23, and 82 through an iterative process and that the dischargers are not expected to be in immediate compliance with Provisions 22, 23, and 82. Dischargers would be subject to enforcement if they fail to effectively implement this iterative process. As we stated at the State Water Board's meeting of September 10, 2013, the State Water Board's proposed compliance language is consistent with California Water Code section 13269, the Central Coast Water Board's Water Quality Control Plan (Basin Plan), and the Policy for Implementation and Enforcement of the Nonpoint Source Pollution Control Program (NPS Policy) and provides these dischargers with flexibility not afforded most dischargers subject to the Porter-Cologne Water Quality Control Act (Porter-Cologne Act). Further edits as proposed by agricultural petitioners would not be consistent with section 13269 or the NPS Policy. In addition, it should be noted that the Agricultural Order is not subject to some of the same enforcement provisions that apply to NPDES permits, including mandatory minimum penalties and citizen suits.

The Central Coast Water Board supports the proposed "cause or contribute" language proposed to be included in Provision 22 and other provisions of the Agricultural Order. This language is consistent with most permits issued by regional water boards. In addition, it is consistent with the anti-degradation principals contained in the Porter-Cologne Act to assure that incremental discharges do not impair the beneficial uses of waters of the state. The language regarding the iterative process will protect dischargers from unreasonable enforcement.

The Central Coast Water Board opposes petitioner Grower-Shippers' request to remove Provision 23. That provision requires compliance with the Basin Plan as required by Water Code section 13269. It is not duplicative of Provision 22 as the Basin Plan includes other provisions that apply to agricultural discharges not covered by Provision 22.

In conclusion, the Central Coast Water Board sincerely appreciates the priority the State Water Board has given to the critically important water quality issues in the Central Coast region, and respectfully requests that you consider these additional recommendations.

Enclosures:

1. Admin Record Reference #227 - Pettygrove S., T. Hartz, B. Hanson, L. Jackson, R. Smith, T. Lockhart, and S. Grattan. (2003). Nutrient management in Cool-Season vegetables. UC California ANR Publication 8098. Farm Water Quality Plan Reference Sheet 9.9.

2. Admin Record Reference #228 - Pettygrove, G.S., T. Hartz, R. Smith, T. Lockhart, B. Hanson, L. Jackson, and S. Grattan. (2003). Nutrient Management Goals and

Management Practices for Cool-Season Vegetables. UCANR Publication 8097. Farm Water Quality Plan Fact Sheet 3.4.

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Reference:
Nutrient Management in Cool-Season Vegetables

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Farm Water Quality Planning
A Water Quality and Technical Assistance Program for California Agriculture
http://waterquality.ucanr.org

This Reference Sheet is part of the **Farm Water Quality Planning (FWQP)** series, developed for a short course that provides training for growers of irrigated crops who are interested in implementing water quality protection practices. The short course teaches the basic concepts of watersheds, nonpoint source pollution (NPS), self-assessment techniques, and evaluation techniques. Management goals and practices are presented for a variety of cropping systems.

UC PEER REVIEWED

Although many factors have contributed to the nutrient load in surface and ground waters, fertilizer use has been one of the significant influences. The Fertilizer Research and Education Program, an industry-funded program administered by the California Department of Food and Agriculture, has sponsored extensive research on efficient nutrient management practices in vegetable production. This Fact Sheet summarizes that research. For techniques to help improve nutrient use efficiency and minimize nutrient leaching, refer to FWQP Fact Sheet 3.4, *Management Goals and Recommended Practices for Nutrient Management in Cool-Season Vegetables* (UC ANR Publication 8097).

Fertilizer use is an integral part of conventional vegetable production. It has also become a serious environmental issue. The two nutrients having the greatest potential to harm water quality are nitrogen (N) and phosphorus (P). Nitrogen and phosphorus loading in surface water bodies contributes to an *eutrophic* environment. Eutrophication is the process by which a body of water becomes enriched in nutrients that stimulate the growth of aquatic plants (e.g., algae), which in turn lead to the depletion of dissolved oxygen in the water. Nitrate pollution of ground water is the more serious potential problem because of its effect on drinking water quality.

The federal Clean Water Act's Section 303 sets a drinking water standard for nitrogen but not phosphorus. Drinking water standards for nitrogen have been set at 10 parts per million (ppm) for nitrogen from nitrates (NO_3-N), also expressed as 45 ppm of nitrates (NO_3). In coastal areas of California where vegetable production is concentrated (Monterey, San Luis Obispo, Santa Barbara, and Ventura Counties), ground water frequently exceeds 10 ppm NO_3-N (Pettygrove et al. 1998). It is becoming harder for urban and rural water users in these areas to obtain drinking water that is in compliance with this standard. No specific standards have been set for phosphorus in fresh water. To prevent eutrophication, dissolved phosphates should not exceed 25 parts per billion (ppb) in lakes, 50 ppb in streams flowing into lakes, and 100 ppb in streams that do not flow into lakes.

NITROGEN IN COASTAL VEGETABLE PRODUCTION

Current nitrogen use patterns and consequences. Vegetable farming practice in California's coastal regions has characteristic features that result in the overuse of nitrogen . Double- or triple-cropping a field in a single year is the norm, with lettuce, broccoli, cauliflower, and celery dominating crop rotations. All of these are shallow-rooted crops with yields and quality levels that are sensitive to even short-term water stress or unavailability of N. Consequently, irrigation and N fertilizer are applied frequently and liberally to ensure maximum yield and quality.

Nitrogen application rates vary widely by grower, season of the year, soil type, and other factors. A range of "typical" N application rates for the major crops is given in Table 1. Application rates are generally far greater than the amount of N removed from the field in the harvested product.

Table 1. Typical nitrogen (N) application, crop uptake, and removal in cool-season vegetable production in aboveground biomass (roots contain approximately 10% as much N)

Crop	N application	Crop uptake	Removal in harvested portion
	lb N/acre		
Broccoli*	175–250	180–220	60–80
Cauliflower*	175–300	180–220	60–80
Celery†	250–350	200–240	120–150
Lettuce†	120–200	80–120	60–80

(*Hartz, personal communication) (†Hartz et al. 2000)

There are six possible fates for N that remains in the field:

- *Leached below the root zone.* Nitrate moves readily with water that percolates through the root zone. Most of the N leached below the root zone of the crop is in the NO_3 form. Over the long term, much of the applied N that is not removed in harvested product leaches out of the root zone and becomes a potential contaminant of ground water.
- *Soilborne erosion losses.* Nitrogen in soil aggregates can be moved by water or wind. Both ammonium (NH_4) and NO_3 will move with sediments. Erosion control practices such as cover cropping, contour farming, the use of benches, vegetative buffer strips, and vegetated waterways can significantly reduce soil erosion losses.
- *Denitrification.* Soil microbes can convert NO_3 into nitrogen gas, which is lost to the atmosphere. This denitrification occurs to some extent in all soils when oxygen levels are low: for example, after irrigation or rainfall has saturated soils. In heavy clay soils with poor drainage or in soils with restrictive layers that prevent drainage, N losses through denitrification may be 15 to 50% of applied fertilizer N. In typical vegetable fields, only a small percentage of applied N is lost through denitrification.
- *Immobilization in and mineralization from organic matter.* Applied N may be tied up (*immobilized*) in soil organic matter or in the biomass of soil microbes as they work to decompose crop residues. Large amounts of applied N can be immobilized temporarily into organic N by the soil microbes, for example, when low-N plant material is incorporated into the soil. Organic N is slowly and constantly being recycled back into plant-available N through a process called *mineralization.* The loss of soil organic matter reduces the capacity of the soil to retain applied N.
- *Residual soil nitrogen.* Nitrogen may remain in the root zone as residual soil N, available for uptake by subsequent crops. This residual soil N generally builds up over a cropping season, as long as in-season irrigation is controlled to minimize leaching loss. During a typical winter, however, rainfall is sufficient to leach most of the residual NO_3 from the top several feet of soil.
- *Ammonia volatilization.* When animal manure, urea, or ammonium-containing fertilizers are left on the surface of the soil, N can be lost to the air as gaseous

ammonia. This loss can be significant in alkaline (high pH), sandy soils. If manure or fertilizers are incorporated within a few hours after application, this loss is negligible.

Forms of fertilizer nitrogen. Fertilizer N may be applied in the urea, NH_4, or NO_3 forms. Urea is rapidly converted to NH_4 in the soil. Although NH_4 is readily taken up by plants, it accounts for only a small percentage of crop N uptake. A microbial process called *nitrification* rapidly converts NH_4 to NO_3 in warm, moist soils. The majority of N taken up by plants will typically be in the form of NO_3. Also, since NH_4 is bound to soil particles by its positive charge, it is not easily leached. For these reasons, growers focus their N management strategies on NO_3.

Nitrogen dynamics within a cropping season. Most cool-season vegetables grown on California's central coast are shallow rooted, with most of their roots in the top 12 to 18 inches of soil. Although some N uptake occurs below the top foot of soil, growers should target their management practices on maintaining adequate mineral N in the top foot of soil and minimizing the leaching of NO_3 below that zone.

Spring planting. With normal winter rainfall (12 inches or more in most coastal vegetable production areas), a field that has been fallow throughout the winter will usually have a low level of plant-available N prior to planting in the spring. At this time the soil is cool and microbial activity is low. The rate of mineralization of N from the residue of the previous crop is relatively slow. Winter rains are likely to leach the majority of any N fertilizer applied in the fall or residual soil NO_3 to beyond the root zone of shallow-rooted vegetable crops. Consequently, the need for fertilizer N for an early spring-planted crop may be relatively high. By contrast, during dry winters with little leaching or when spring planting follows the last significant rain by more than a month, mineralization may make NO_3 more abundant.

Summer planting. By contrast, N fertilizer requirements for summer-planted crops are frequently much lower. Substantial soil NO_3 may have accumulated in spring from soil N mineralization and fertilizers that were not taken up by the spring crop. Freshly incorporated vegetable crop residue releases N reasonably quickly. This is particularly significant following broccoli, cauliflower, and celery crops since the amount of N in their residues is much greater than in lettuce residues. Additionally, warm soil temperatures increase the N mineralization rate. Unless N fertilizer applications are adjusted to make use of these other sources of available N, high levels of soil residual NO_3 may be present in the fall when there is a greater risk that it will be leached by winter rain.

Crop growth stage and nitrogen requirements. The pattern of growth and N uptake is similar in all of the major cool-season vegetable crops, whether planted as seed or as transplants. In the initial growth stage (approximately one-half of the cropping period), both growth and N uptake are slow (Figure 1). During that period, net soil N mineralization may actually be greater than crop N uptake. The crop does not deplete the soil NO_3, and fertilizer requirements are minimal. Once rapid vegetative growth begins, N uptake accelerates, reaching approximately 3 to 5 lb N per acre per day, depending on the crop and environmental conditions. More than 75% of total crop N requirement and uptake occurs in the latter half of the cropping period. Of course, fertilizer need is greatest during this period.

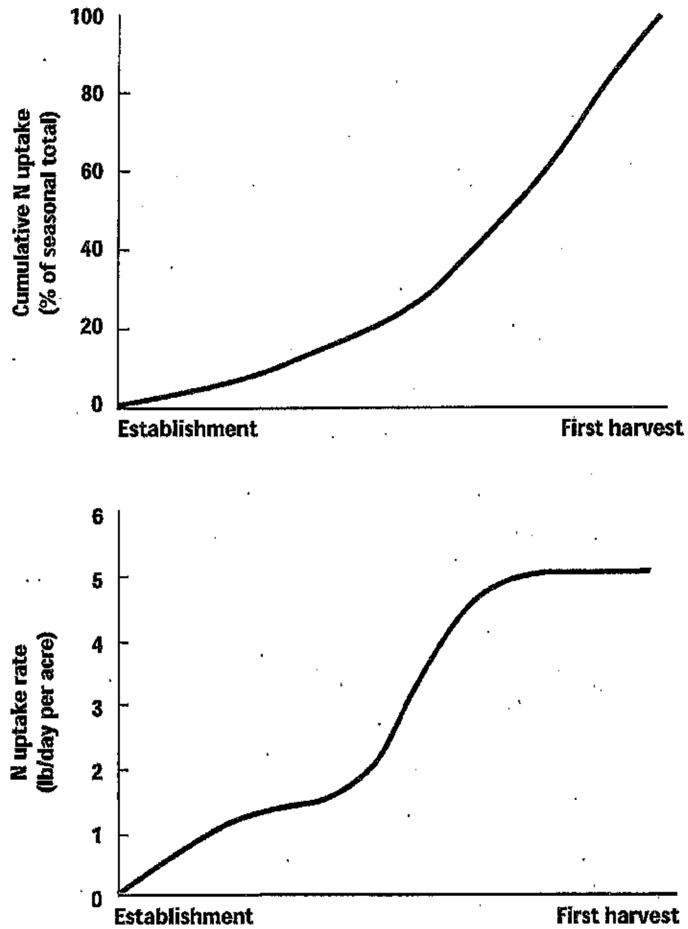

Figure 1. Seasonal N uptake pattern for cool-season vegetables in coastal production areas of California.

Soils with modest levels of NO_3-N can support the immediate needs of vegetable crops for maximum growth rate. (A *modest level* is generally more than 10 ppm [also written as mg/kg of dry soil; 1 ppm of NO_3-N = 2 lb/acre] in the top 6 to 8 inches of the root zone.) Soil NO_3-N can drop quickly, however, as a result of the combined action of crop uptake and leaching by rain or irrigation. A higher level of soil NO_3 may be needed to ensure sufficient N availability to meet short-term requirements. Under typical field conditions, a soil NO_3-N concentration of 20 or more ppm is sufficient to maintain maximum growth rates for several weeks or longer.

When crops are fertilized with N at a rate beyond their requirement, they continue to take up luxury amounts. At these excessive N rates, however, the crop uptake efficiency is lower, leading to a large increase in the amount of NO_3 left in the soil, potentially to be leached. In-season soil NO_3 testing provides a convenient way to determine short-term need for a sidedressed application of N. As a rule of thumb, whenever soil NO_3-N exceeds 20 ppm N, you can delay or reduce the rates of sidedress N applications. Frequent testing can ensure that adequate soil NO_3 levels are maintained and unnecessary fertilizer applications are avoided.

As a result of N inputs from fertilizer, crop residues, soil mineralization, and irrigation water, NO_3 pools can build up to high levels at the end of the growing season in fall and winter. This NO_3 can easily be leached by winter rains. Cereal cover crops have the capacity to capture and trap much of this N and make it available for subsequent crops. Cover crops should be included as much as possible in crop plans to reduce NO_3 leaching and provide other benefits to the soil.

Influence of Irrigation

Crop water requirements are modest in California's coastal production areas. If irrigation is applied in a timely and efficient manner, lettuce requires 6 to 10 inches (acre-inches per acre), broccoli and cauliflower 8 to 14 inches, and celery 12 to 18 inches of water. Cool-season vegetables require frequent irrigation, due to their shallow rooting and sensitivity to moisture stress.

Distribution uniformity (how evenly the irrigation water is applied across the field) and irrigation efficiency (the percentage of applied water that remains in the root zone, available for plant uptake) can vary drastically from field to field. The greater the distribution uniformity, the greater the potential maximum irrigation efficiency. Irrigation system performance is dependent upon system design and maintenance, proper or improper redesigns or retrofits, equipment age, pressure variability, and various management practices. The distribution uniformity of a sprinkler irrigation system can also be affected significantly by wind conditions.

Conventional sprinkler or furrow irrigation systems often have poor distribution uniformity or irrigation efficiency. Microirrigation (drip tape, drip emitters, microsprayers, and microsprinklers) has the potential for higher distribution uniformity than other irrigation methods, but such systems often are not designed and maintained to meet this potential. These conditions were noted in irrigation system evaluations in San Luis Obispo and Santa Barbara Counties (Pitts et al. 1996). Low distribution uniformity and low efficiencies often lead to overirrigation, with excessive amounts of water lost to deep percolation (drainage) below the crop root zone.

Excessive irrigations can have significant impact on soil NO_3-N levels. Even in a field with 20 ppm soil NO_3-N, an inch of water leaching from an irrigation may carry as much as 20 lb N per acre below the root zone.

Irrigation water can also be a source of NO_3. Many agricultural wells now contain 10 or more ppm NO_3-N. One foot of irrigation water at a concentration of 10 ppm would contain 27 lb NO_3-N per acre-foot of water. Once in soil solution, that NO_3 would be indistinguishable from residual soil NO_3, and equally available for crop uptake. Irrigation water should be tested for NO_3 content before it is applied. If you know how much irrigation water is being applied and the concentration of NO_3-N in that irrigation water, you can also determine the amount of NO_3-N that will be applied in that irrigation by using this equation:

$$\text{Pounds of N/acre} = 0.23 \times \text{ppm } NO_3\text{-N in irrigation water} \times \text{inches of water}$$

If the water analysis is expressed as NO_3 rather than NO_3-N, use a different conversion factor:

$$\text{Pounds of N/acre} = 0.051 \times \text{ppm } NO_3 \times \text{inches of water}$$

In summary, N requirements of cool season vegetables vary by crop, season, soil type, and cropping history. Efficient N fertilizer management is a necessity to minimize further NO_3 pollution of ground water, and requires a grower to take into account field-specific factors. Techniques that minimize unnecessary N application include soil and irrigation water monitoring for NO_3, cover cropping, and achievement of high application efficiency and distribution uniformity of irrigation water. Irrigation with minimal loss of nutrients and moisture from the root zone translates into reduced fertilizer and irrigation water costs.

PHOSPHORUS IN COASTAL VEGETABLE PRODUCTION

Phosphorus is present in soil in a number of chemical forms: a very small amount of soluble P (mostly PO_4-P) in the soil water, P adsorbed onto soil particles, chemical precipitates, and P as a constituent of organic matter. These different P sources establish an equilibrium in the soil; as plants remove soluble P, the other forms replenish the soluble P supply. Common laboratory soil test procedures provide an estimate of the amount of P in the soil that is available to plants. Unlike soil nitrate testing, which measures the actual amount of nitrate present, soil testing for P as carried out by most laboratories gives an index value or ranking of the relative P supply. Researchers over many years have calibrated these soil test procedures in greenhouse and field trials so that the results can be used to predict whether a vegetable crop is likely to respond to additional P fertilization.

It has been traditional practice to fertilize with P before and sometimes during each vegetable crop, regardless of soil test P level. Since the common coastal vegetable crops use a relatively small amount of P (and even less is removed from the field in harvested product), residual soil P levels have risen dramatically. Currently, it is not uncommon to find a soil that tests for P far in excess of the level required for optimum plant growth. While this generally does not present a significant agronomic problem, it does create a potential environmental hazard. The growth of algae in surface waters is often limited by the low concentration of P. Runoff from highly fertilized vegetable fields can carry with it a significant amount of P, stimulating algae growth in the receiving water body. Increased algae growth can be a nuisance for human recreational activities, but more importantly it can cause serious problems in aquatic ecosystems (low dissolved oxygen, high pH, etc.). The higher the soil test P level, the greater the P pollution hazard. Unlike surface water, leaching of P to ground water does not occur, due to the ease with which soil minerals immobilize P.

You can reduce the movement of P from your farm to the environment by following these guidelines:

1. *Fertilize only when soil testing suggests that plants are likely to respond to fertilization.* For soils with pH > 6.2, the most appropriate soil test is the Olsen (*bicarbonate*) procedure. Soils with Olsen P > 80 ppm contain sufficient available P for optimum vegetable crop production. Continued fertilization of these soils wastes money and increases the potential for P pollution. Soils testing in the range of 40 to 80 ppm may under some circumstances (low soil temperature, for example) respond to P applications, but only a small amount of P would be required. Small, at-planting "starter" applications would be sufficient. For summer-planted fields, no P fertilization should be necessary for soils that test > 40 ppm.
2. *Maximize the efficiency of P fertilizer applications.* Injected bands of P fertilizer are generally more available to plants than are broadcast applications. Where you use a broadcast application, immediately incorporate the fertilizer. Apply P fertilizer as close to the time of planting as possible, since P fertilizer becomes less available to plants the longer it is in contact with the soil. This timing will allow you to use a lower application rate and still achieve the same agronomic effect.
3. *Minimize the amount of tailwater leaving the farm during the irrigation season through the use of a tailwater return system and by following the recommendations of a mobile irrigation lab.* Even tailwater from fields with only moderate soil P levels can contain significant quantities of P. It may be impractical to eliminate runoff from winter storms, but during the winter the water temperature is low enough to minimize algae growth, regardless of P concentration.

4. *Institute erosion control practices.* Soil particles contain significant amounts of P in non-soluble forms; erosion moves those P-rich soil particles into waterways where they will continually release P in soluble form, available to support algae growth. Cover cropping is an excellent practice for erosion control. Additional erosion control practices are detailed in other publications in the Farm Water Quality Planning series.

For more information visit the UC Davis Vegetable Research and Information Center at http://www.vric.ucdavis.edu.

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Farm Water Quality Planning

A Water Quality and Technical Assistance Program for California Agriculture
http://waterquality.ucanr.org

This FACT SHEET is part of the **Farm Water Quality Planning (FWQP)** series, developed for a short course that provides training for growers of irrigated crops who are interested in implementing water quality protection practices. The short course teaches the basic concepts of watersheds, nonpoint source pollution (NPS), self-assessment techniques, and evaluation techniques. Management goals and practices are presented for a variety of cropping systems.

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Management Goals and Management Practices:

Nutrient Management Goals and Management Practices for Cool-Season Vegetables

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This Fact Sheet includes Management Goals and Management Practices for reduction of nutrient pollution in cool-season vegetables. For our purposes, we are defining a *Management Goal* (MG) as the best economically achievable technology or process for limiting the movement of nutrients, particularly nitrogen (N) and phosphorus (P), into ground or surface waters. Management Goals are general (for example, "Base the amount and timing of N fertilizer applied on crop needs").

As used here, a *Management Practice* (MP) is a specific practice to be used in accomplishing a Management Goal (for example, "Use plant tissue analysis to aid in fertilization decisions"). Growers and crop advisors have found these practices suitable for vegetable production in California's coastal region. Management Practices are not requirements and will not necessarily be feasible or necessary for pollution control in every situation. Rather, they are options for managing N and P fertilizers and water efficiently.

The development of a comprehensive farm plan for nutrient management on cool-season vegetable crops involves a series of ten Management Goals:

- MG 1. Evaluate current irrigation and fertilization practices and plan improvements in management.
- MG 2. Avoid fertilizer material spills during all phases of transport, storage, and application.
- MG 3. Base the amount and timing of N fertilizer applications on crop needs and production goals.
- MG 4. Place N fertilizer materials where maximum plant uptake will occur.
- MG 5. Minimize leaching losses of nitrate during non-crop periods.
- MG 6. Operate irrigation systems to minimize deep percolation and N losses.
- MG 7. Improve the uniformity of existing furrow irrigation.
- MG 8. Improve the uniformity of existing sprinkler irrigation.
- MG 9. Improve the uniformity of existing drip irrigation.
- MG 10. Evaluate and maintain nutrient management goals and recommended practices.

To implement the Management Practices, you may require specific technical information. Consult your local UCCE Farm Advisor or visit the UC Davis Vegetable Research and Information Center Web site for help with developing these practices.

MG 1. Evaluate current irrigation and fertilization practices and plan improvements in management

MP 1.1. Determine nitrate and salt contamination of ground water in existing wells; and assess the potential for transport of soluble contaminants such as nitrates and salts downward to the ground water and laterally to surface

MP 1.2. Develop and implement a system for keeping long-term records on each field for water and nutrient/soil amendment inputs, cultural operations, pest problems, land leveling or other improvements, and crop yield and quality. The Farm Water Quality Plan (ANR Pub 9002) gives one method for developing a long-term system.

MP 1.3. Review current cultural practices to develop improved nutrient and water management plans.

MG 2. Avoid fertilizer material spills during all phases of transport, storage, and application

MP 2.1. Have organized training sessions for field personnel.

MP 2.2. When transporting fertilizer, do not overfill trailers or tanks. Cover or cap loads properly and display appropriate placards on vehicles.

MP 2.3. When transferring fertilizer into on-farm storage or into a fertilizer applicator, take care not to allow materials to accumulate on the soil.

MP 2.4. Maintain all fertilizer storage facilities to meet government and industry standards and protect them from the weather.

MP 2.5. Clean up fertilizer spills promptly.

MP 2.6. Shut off fertilizer applicators during turns and use check valves on application equipment.

MP 2.7. Maintain proper calibration of fertilizer application equipment.

MP 2.8. Whenever injecting fertilizer into irrigation water, ensure that there is no backflow into wells or other water sources.

MP 2.9. Distribute rinse water from fertilizer application equipment evenly throughout the field.

MG 3. Base the amount and timing of N and P fertilizer applications on crop needs

MP 3.1. Determine crop nutrient requirements and establish a crop nutrient budget.

MP 3.2. Measure nitrate levels in the irrigation water and adjust N fertilizer rate accordingly.

MP 3.3. Before applying N and P early in the growth cycle, assess the amount of nitrate and phosphorous already present through the use of soil sampling and analysis. For soils with pH > 6.2, the most appropriate soil test is the Olsen (or *bicarbonate*) procedure. The Olsen procedure is acceptable for soils with a lower pH, but some laboratories may recommend a different method.

MP 3.4. Use soil nitrate quick tests or plant tissue sampling to guide your decisions on N fertilization in the middle and late periods of the crop growth cycle.

MP 3.5. Make multiple small applications of N fertilizer.\

MP 3.6. Make efficient P fertilizer applications.

MP 3.6.1. When appropriate, apply injected bands of P fertilizer into the soil. P fertilizer is generally more available to the plants if it is injected in bands than if it is applied as a broadcast application.

MP 3.6.2. Apply P fertilizer as close to the time of planting as possible. The longer P fertilizer is in contact with the soil, the less accessible it is to plants.

MP 3.6. When applying manure before you plant a crop, determine the nutrient content and release rate of the manure and the amount of nitrate already present in the soil. Apply manure at a rate consistent with the crop nutrient requirements.

MP 3.7. When possible, avoid water-running N fertilizer in the furrows. If fertilizer N must be water-run, make sure to maximize the uniformity of the irrigation, inject the fertilizer during the last half of the irrigation set, and manage the tailwater.

MP 3.8. Do not apply fertilizer N or surface broadcast P less than 24 hours in advance of a predicted large storm event.

MG 4. Place N fertilizer materials where maximum plant uptake will occur

MP 4.1. Incorporate N fertilizer into the crop bed by placing fertilizer on the seed row and watering it in, by knifing fertilizer into the bed, or by broadcasting fertilizer and then listing it up into the bed.

MG 5. Minimize leaching losses of nitrate during non-crop periods

MP 5.1. If conditions permit, grow a cover crop rather than leave fields fallow during the rainy season.

MP 5.2. Use only low-N fertilizers (such as $N:P_2O_5:K_2O$ equal to 1:3:3) during bed preparation in the fall. Higher N materials may be appropriate if a crop is to be planted soon.

MG 6. Operate irrigation systems to minimize deep percolation and N and P losses (These practices apply to all system types.)

MP 6.1. Monitor soil moisture between irrigations and use that information to guide your irrigation timing decisions.

MP 6.2. Crop need should determine irrigation amount.

MP 6.3. Know the irrigation system flow rates and the time required to apply the desired inches of water.

MP 6.4. Use the minimum leaching fraction that will prevent stand establishment problems or yield reductions from salinity.

MP 6.5. When fertigating with a drip or sprinkler system, run the fertilizer in the later part of the set so as not to leach nutrients beyond the root zone. Avoid fertigating with furrow systems.

MP 6.6. Follow state regulatory requirements and industry guidelines for backflow prevention when injecting fertilizer into irrigation water (CCR Title 3). Schedule regular maintenance of backflow prevention devices.

MP 6.7. If irrigation uniformity remains low after all practical improvements have been made, consider converting to an irrigation system with a greater potential to improve uniformity in a way that minimizes deep percolation.

MP 6.8. Minimize the amount of tailwater leaving the farm during the irrigation season. Even tailwater from fields with only moderate soil nutrient levels can contain significant quantities of N and P that can lead to algal blooms and associated problems.

MG 7. Improve existing furrow irrigation uniformity

MP 7.1. Convert to surge irrigation.

MP 7.2. Where furrow runs are more than 1000 feet long, consider cutting the furrow run length in half with a corresponding decrease in set time.

MP 7.3. Use high irrigation flow rates initially to get water down the furrow and then cut the flow rates back to finish the irrigation.

MP 7.4. Reduce variations in slope when preparing irrigation furrows.

MP 7.5. Use practices that increase irrigation uniformity between furrows (e.g., by using torpedoes in furrows that don't get wheel traffic or by alternating wheel rows with each tractor pass, you can ensure greater uniformity in water advance time in all furrows).

MP 7.6. Recirculate, rechannel, or reuse surface water runoff.

MP 7.7. Keep records on a field-by-field basis of advance and recession times.

MP 7.8. Utilize the services of a mobile irrigation lab.

MG 8. Improve existing sprinkler irrigation uniformity

MP 8.1. Monitor flows and pressure variations throughout the system to detect non-uniform application.

MP 8.2. Maintain the irrigation system by repairing leaks, replacing malfunctioning sprinklers, monitoring nozzle performance for wear, and maintaining adequate water pressure through the entire set.

MP 8.3. Operate sprinklers during the least windy periods, whenever possible. When sprinkler irrigating under windy conditions, reduce the spacing between laterals when possible to optimize application uniformity.

MP 8.4. Use offset lateral moves on successive irrigations to improve distribution uniformity.

MP 8.5. Use flow-control nozzles when the pressure variation throughout the system is excessive.

MP 8.6. Make set times as short as possible during stand establishment.

MP 8.7. For very large blocks, consider converting to linear-move sprinkler systems.

MP 8.8. Utilize the services of a mobile irrigation lab.

MG 9. Improve existing drip irrigation uniformity

MP 9.1. Monitor flows and pressure variations throughout the system to detect non-uniform application.

MP 9.2. Use lateral hose lengths that ensure uniformity.

MP 9.3. Use drip tape that has a small emitter discharge exponent to reduce flow variations that result from pressure differences.

MP 9.4. Check for the potential for emitter clogging by conducting water analysis and fertilizer/water compatibility tests.

MP 9.5. Use filtration, chemical treatments, and flushing as needed to prevent or correct clogging problems.

MP 9.6. Maintain appropriate water pressure throughout the system.

MP 9.7. Utilize the services of a mobile irrigation lab.

MG 10. Evaluate and maintain nutrient management goals and recommended practices

MP 10.1. Periodically evaluate management goals and recommended practices implemented for nutrient management. Correct deficiencies as needed.

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