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CALLEGUAS CREEK WATERSHED MANAGEMENT PLAN

Calleguas Creek Watershed Nitrogen Compounds and Related Effects TMDL Special Study:

Agricultural BMP Effectiveness Assessment

submitted to:

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

ON BEHALF OF:

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1 Introduction

The Calleguas Creek Watershed (CCW) Nitrogen and Related Effects TMDL (TMDL) contains requirements for a number of special studies. One of the requirements is to assess the effectiveness of various agricultural BMPs in reducing nitrogen loadings to the Calleguas Creek Watershed (CCW). The purpose of this report is to summarize the effectiveness of agricultural BMPs by using two existing studies: "*Modifying Agricultural Practices to Reduce Nutrient and Pesticide Loading, Calleguas Creek and Lower Santa Clara River Watersheds* (2007)" and *"Summary of Improvements: Use of Improved Technologies and Best Management Practices for the Control of Nursery Runoff into Ventura County and Los Angeles County Watershed"* that were conducted for other purposes, but can be used to meet the requirements of the TMDL Nonpoint Source Monitoring Workplan.

Management strategies for minimizing agricultural runoff and improving water quality can be divided into two categories, source control and runoff control. Source control refers to how farm inputs are managed, such as the water, fertilizer, and pesticides applied to improve crop yield and quality. Runoff control addresses the quality of excess water not used by the crop with the potential to move off the property or into the groundwater. Listed below are methods for both Source Control and Runoff Control:

Source Control

- Irrigation management
- Nutrient and fertilizer management
- Integrated Pest Management
- Erosion and runoff management
- Maintaining a clean facility and management of non-production areas
- Proper training of workers

Runoff Control

In Field:

- Cover crops, mulch
- Terracing, contours

Edge of Field:

- Vegetated ditches and buffers

Structural BMP:

- Grassed waterway
- Detention basin
- Recycling basin
- Constructed wetland

Two studies were completed in Ventura County to assess agricultural BMP effectiveness as mentioned above. The first study, *Modifying Agricultural Practices to Reduce Nutrient and Pesticide Loading, Calleguas Creek and Lower Santa Clara River Watersheds* (2007), was conducted by the United Water Conservation District (UWCD) in cooperation with the Ventura County Farm Bureau and FGL Environmental Laboratory. Study sites include citrus, avocado, sod, strawberry, and row crop operations. The second project, completed by the University of California Cooperative Extension, Ventura County (UCCE), was used to evaluate the effectiveness of agricultural BMPs in reducing nitrogen loadings from nurseries. Project results were reported in the final report entitled *Summary of Improvements: Use of Improved Technologies and Best Management Practices for the Control of Nursery Runoff into Ventura County and Los Angeles County Watersheds.*

2 Best Management Practice Evaluation – Case Studies

Both the UCCE and UWCD projects aim to assess agricultural BMP effectiveness, though they are heavily focused on runoff control management practices. Only the irrigation upgrades completed as part of the UCCE study may be considered a type of source control. However, a few UWCD study participants had in place source control in the form of real-time soil moisture sensors to assist in irrigation timing. Each study attempts to characterize agricultural runoff before and after a management practice improvement, and many of the BMP examples can be used in different types of farming operations. The summary of the relevant study results are presented for nitrate plus nitrite as the TMDL load allocation for agriculture is 9 mg/L (NO_3-N + NO_2-N).

2.1 UWCD PROJECT SUMMARY

The purpose of the project was to implement BMPs at established agricultural field sites within the Calleguas Creek and Santa Clara River watersheds, and conduct "in field" monitoring to demonstrate the efficiency of BMPs at reducing discharges of nutrients, pesticides, and herbicides to both surface waters and groundwater. Since this report is concerned with addressing the requirements of the Nitrogen TMDL Workplans, the following summary highlights project findings for nitrate and nitrite.

2.1.1 Study Locations

BMP evaluations were conducted at a total of sixty sites; forty-three of the sites are in the CCW and seventeen in the Ventura County portion of the Santa Clara River watershed. Crop types evaluated included avocado, strawberry, citrus, row crops and sod. The study area and site locations are shown in **Figure 1**. The following outlines the distribution of sites and crop types by subwatershed within the study area:

Calleguas Creek watershed (43 field sites)

- Lower Calleguas Creek, Mugu Lagoon drainage area – four strawberry, two sod;
- Calleguas Creek, lower main stem– two row crop, one avocado, one citrus;
- Revolon Slough drainage (greater Camarillo area to confluence with Calleguas Creek) – three strawberry, seven row crop;
- Upper Revolon Slough drainage, Beardsley Wash (West Las Posas Basin to Highway 101) – five citrus; three row crop, three avocado, one strawberry;
- Arroyo Las Posas (Somis to Moorpark) – four avocado, five citrus;
- Conejo Creek (confluence with Calleguas Creek through Santa Rosa Valley) – one citrus, one row crop.

Lower Santa Clara River watershed (17 field sites)

- Piru area, upstream of the confluence with Piru Creek – two row crop, and one citrus;
- Fillmore area – two row crop, two citrus, and two avocado;
- Santa Paula area – four citrus, two row crop, two avocado.

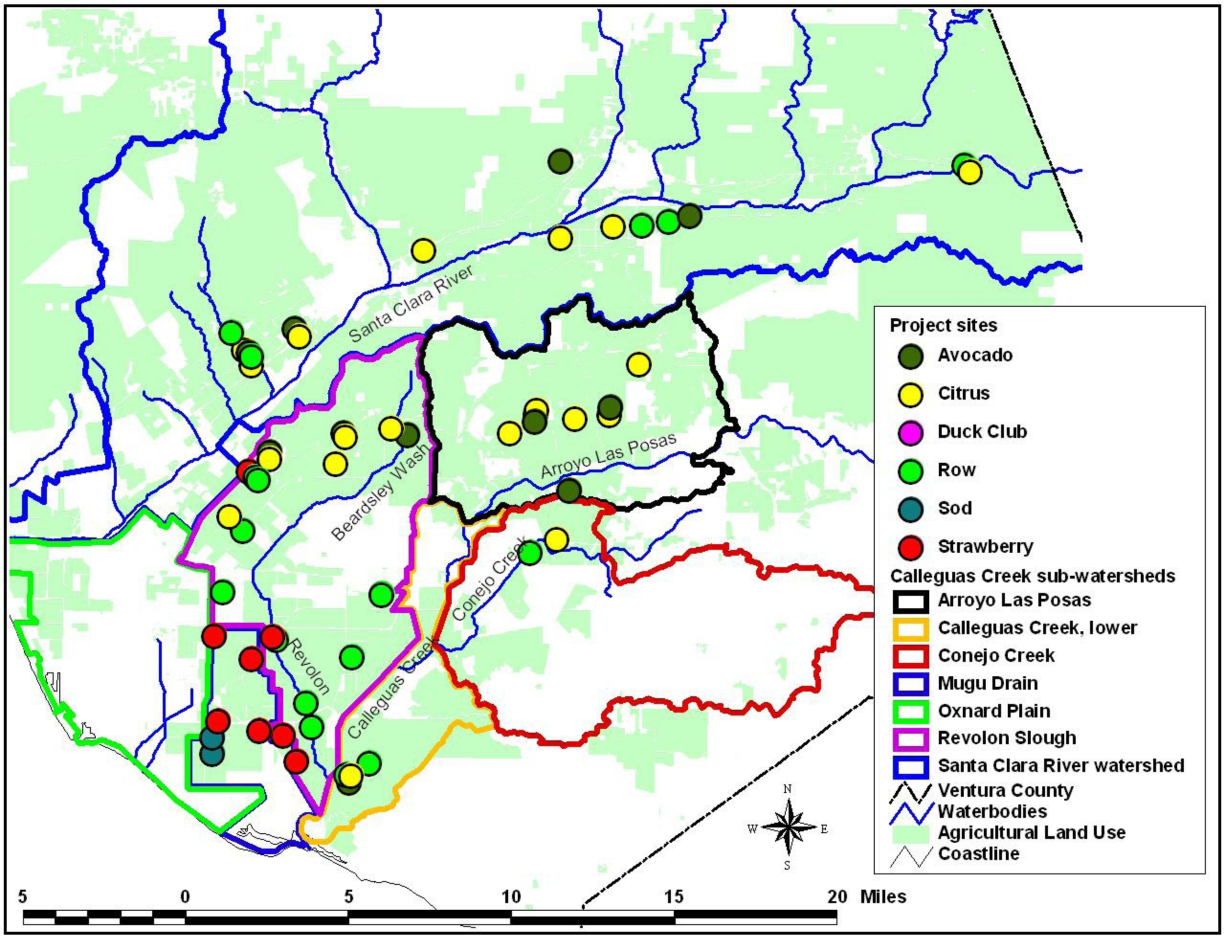

Figure 1. Study site locations and sub-watersheds; Ventura County, California

2.1.2 Methods

Several types of water-borne transport mechanisms were considered during monitoring activities: winter storm runoff, surface flow from irrigation (tailwater), discharge from tile drains installed beneath fields, and downward percolation of irrigation and rain water within and below plant root zones. Drainage patterns were identified at each field site, and sampling locations for nitrogen-based nutrients were established for tile drains, surface runoff, and shallow subsurface lysimeters. Samples collected from lysimeters represented soil moisture conditions at two depths, one foot below the land surface and six feet below the surface. Nutrients present in the one-foot zone are generally available for plant uptake. Nutrients present at a depth of six feet have passed through the active root zone and are no longer available for use by the crop. Monitoring results indicate that nitrogen concentrations were generally high in tested waters, with the sites of highest concentrations varying from runoff to percolating water, depending upon the nitrogen compound.

2.1.3 Results

Nitrate plus nitrite is generally lower in storm runoff and in tailwaters (with the exception of the limited data from sod), with concentrations less or equal to the TMDL numeric target (**Figure 2**). Percolating waters generally have higher concentrations of nitrate plus nitrite, with averages of up to 100 mg/L NO_3-N + NO_2-N in non-orchard crops. Tailwaters from sod sites had the highest concentrations of nitrate plus nitrite.

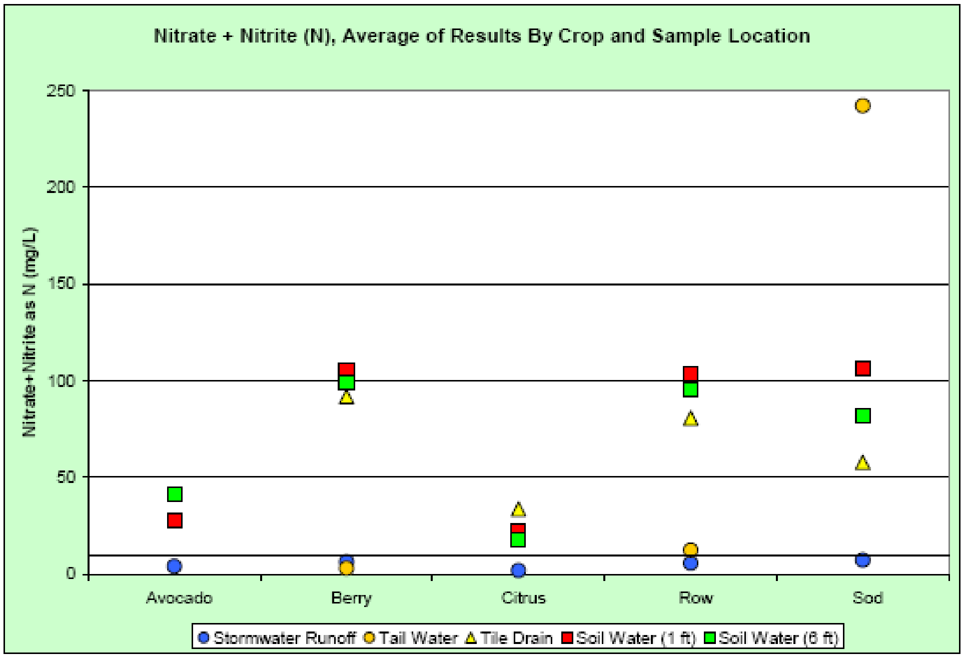

Figure 2. Results of sampling for varying crop types and sample locations, nitrate + nitrite as N. The symbols represent the average concentration for both surface waters and percolating waters. Non-detects are including in the average as zero concentrations. Crops with no tailwater symbol indicate that there was no tailwater observed at any study site with that crop. The line at 10 mg/L is the TMDL numeric target.

An additional method of analyzing percolating waters is to compare the shallow (1-foot) lysimeter results to those from the deeper (6-foot) lysimeters. When nutrient concentrations are higher in the deeper lysimeters, nutrients are being driven below the crops' root zone by a combination of deep percolation of irrigation waters and rainfall. This percolating water typically has nitrate plus nitrite concentrations well in excess of the TMDL numeric target (**Figure 3**). These high concentrations are detected locally in groundwater, particularly in areas such as the Oxnard Plain Forebay basin where the aquifer is unconfined and the agricultural waters percolate unimpeded down to the aquifers. Nitrate plus nitrite concentrations in paired lysimeter samples are exemplified in **Figure 4** and **Figure 5** with results from Avocados and Citrus sites, respectively. In particular, the majority of analyses of nitrate plus nitrite indicated higher concentrations at depth.

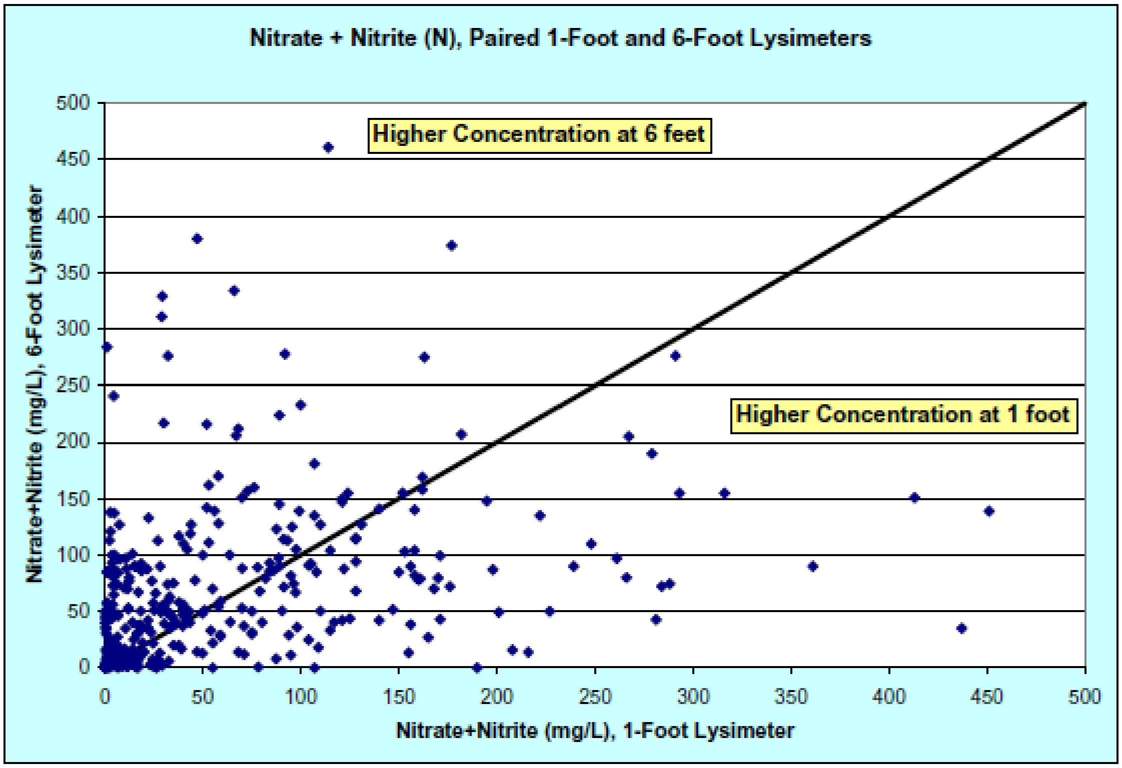

Figure 3. Comparison of nitrate + nitrate (N) analyses from paired lysimeters. Samples that plot above the diagonal line indicate that nitrate + nitrite are higher in the deeper lysimeter, where it is generally not available for plant uptake.

2.1.4 Assessment of BMPs

The UCWD study was developed with the intent of evaluating the following BMPs:

- Mulch
- Cover Crops
- Filter Strips
- Grassed Ditch
- Polyacrylamide Cakes
- Improvements to drainage structures

Additionally, though not the focus of the study, the source control practice of controlling irrigation by monitoring soil moisture with real time sensors was evaluated.

Many of the sites already had a number of BMPs in place (e.g., drip tape, microsprinklers, drainage structures, grading improvements, terracing, drainage pipes, culverts, drop structures, lined ditches, mulch or cover crops) and the baseline data set samples are not often from bare ground with no existing BMPs. BMPs for this study were implemented in addition to existing improvements.

Testing of the effectiveness of BMPs was designed to occur during a two-year period, with the second year reflecting fine-tuning of year-one BMPs. The lack of significant runoff in the dry winter of 2006-2007 limited the number of sites and BMPs that could be tested in this complete fashion. Some BMPs, particularly mulch and cover crops, were very effective in reducing or eliminating storm runoff. When runoff is eliminated, there is a 100 percent reduction in pesticide, herbicide, and nutrient transport.

The application of the existing nutrient BMP (real-time measurement of soil moisture) at two sites resulted in some of the lowest concentrations of nutrients in percolating waters (see **Figure 4** and **Figure 5**). It is clear that controlling irrigation so that fertilizer is not pushed beyond the root zone is a key factor in reducing nutrients in percolating waters. In addition, fine-tuning irrigation practices can also reduce movement of nutrients in tailwater – the best example being in strawberries, where overhead sprinkling of newly-set plants largely runs off the field.

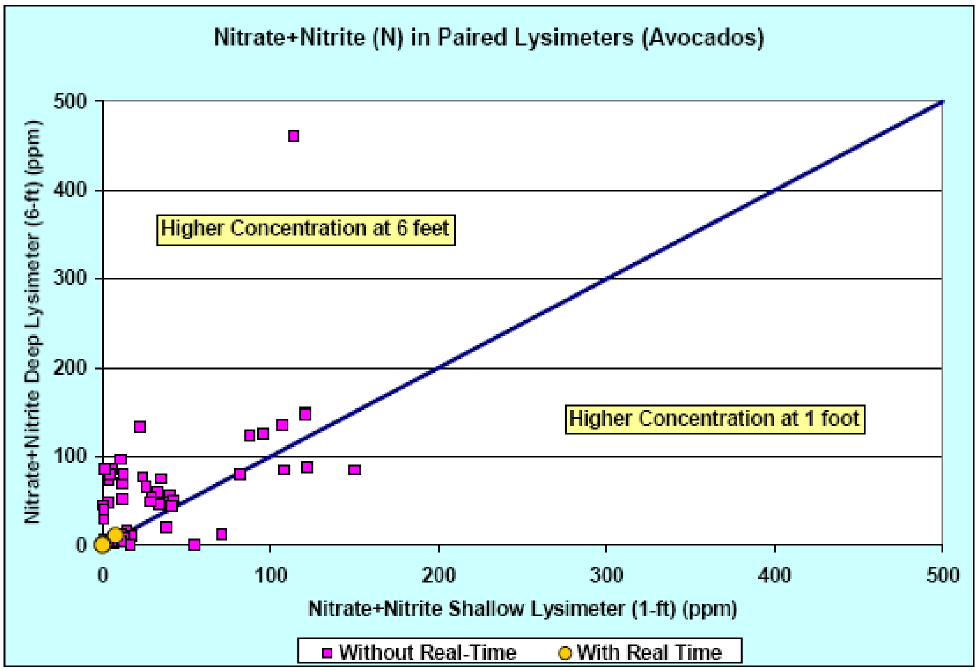

Figure 4. Comparison of nitrate + nitrite (N) analyses from paired lysimeters in avocados. Samples that plot above the diagonal line indicate that nitrate + nitrite are higher in the deeper lysimeter, where it is generally not available for plant uptake. The two circles represent samples from sites where the depth of the wetting front is measured in real time and the irrigation run time is adjusted accordingly.

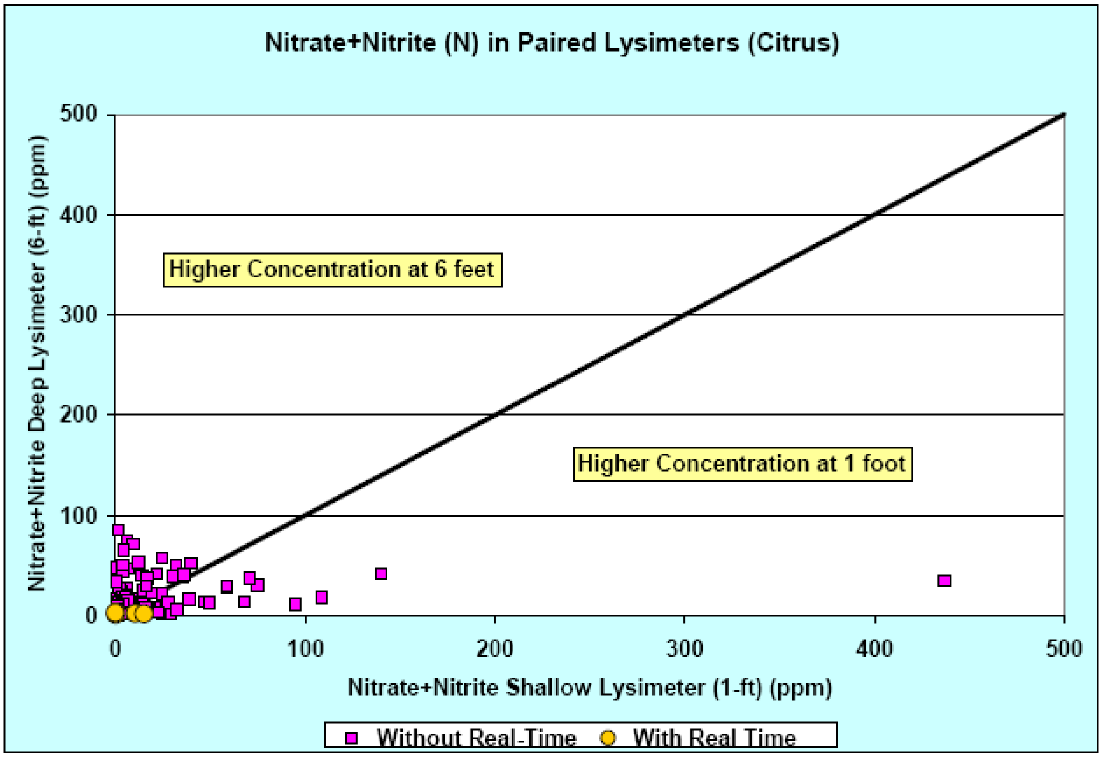

Figure 5. Comparison of nitrate + nitrite (N) analyses from paired lysimeters in citrus. Samples that plot above the diagonal line indicate that nitrate + nitrite are higher in the deeper lysimeter, where it is generally not available for plant uptake. The three circles represent samples from sites where the depth of the wetting front is measured in real time and the irrigation run time is adjusted accordingly.

The results of the study suggest six categories of runoff control BMPs (**Table 1**). However, it should be emphasized that for individual sites, results of BMP implementation vary widely. Thus, future implementation of BMPs should not be one-size-fits-all. Instead, the characteristics of the individual sites in this study should guide the potential effectiveness of BMPs. Ultimately, it is unlikely that the movement of agricultural nutrients can be entirely eliminated using the BMPs tested in this study. The reduction in runoff would likely be larger if multiple BMPs are used conjunctively with each other, enhancing the cumulative effects of the layered management practices.

Table 1. Applicability of various BMPs by crop type

Crop Type	Mulch	Cover Crop	Filter Strips	Grassed Ditches	PAM	Improved Drainage Structures
Avocado	yes, occurs naturally	not practical- roads only	yes	yes	*	dependant on site conditions
Citrus	yes	yes	yes	yes	*	dependant on site conditions
Row Crop	not practical- roads only	not practical- roads only	yes	yes	*	dependant on site conditions
Strawberry	not practical- roads only	not practical- roads only	maybe	yes	*	dependant on site conditions
Sod	not practical- roads only	not practical- roads only	yes	very practical	*	dependant on site conditions

* The possible watershed effects resultant from use of this product have not been studied in this project, and therefore recommendations are withheld at this time.

2.2 UCCE PROJECT SUMMARY

Nineteen nurseries in Ventura County collaborated with the University of California Cooperative Extension to carry out the goals of a Proposition 13 grant. Among the 19 nursery sites, 36 improvement projects were completed. The BMPs can be grouped into four categories: recycling systems, detention basins, irrigation upgrades and mulch. The following summary is taken from the final grant report and includes information comparing the effectiveness of four types of BMPs (two of which were implemented in the CCW) outlining their benefits and drawbacks, as appropriate to reduce nutrient concentration runoff.

2.2.1 Study Locations

A total of 36 improvement projects (BMPs) were installed at 17 wholesale production nursery sites, 14 in Ventura County and 3 in Los Angeles County. **Table 2** lists the nursery sites per watershed. The primary improvement projects for the indicated watersheds include installation of recycling basins, detention basins, irrigation upgrades and the application of mulch.

Table 2. Nursery Site identification per Watershed

Santa Clara Watershed	Calleguas Watershed	Ventura River Watershed	Los Angeles County Watershed
04V47	04V01	06V18	06L40
04V88	04V42		06L31
04V29	04V53		06L22
06V11	04V69		
04V43	04V75		
	06V64		
	06V95		
	06V86		

Three nurseries located within the Calleguas Creek Watershed where runoff occurred and nitrogen loading could be calculated are described in further detail below.

2.2.1.1 04V01– Project Improvement Type: Recycling Basin

This site involved three projects: the creation of a retention basin with water recycling, installation of low volume micro-sprinklers inside of a shadehouse, and a concrete mixing pad for soil and fertilizers. This nursery has also been a good example of the use of passive water conservation efforts like placing plants in drainage ditches and positioning succulents in drier areas of the nursery. Runoff from irrigation and storm events was quantified for one-half of the nursery, and water analyses were taken routinely.

This is a relatively small nursery with 8 acres in production out of a total of 12.3 acres. They grow bedding plants, among other types of plants. Approximately 5 acres are in outdoor container production, 2 acres are under shadehouse, and 1 acre is in greenhouse.

Being a small nursery, this cooperator is an example to other small growers of a recycling system and other management practices that can be achieved with limited funding.

2.2.1.2 04V53– Project Improvement Type: Recycling Basin

This project involved the entire facility, which was designed around the capture and reuse of irrigation water. The site was graded, channeled, piped, and laid out to facilitate the flow and capture of all tailwater resulting from the irrigation. The recycling facility includes a sediment basin, a collection reservoir, a fresh water reservoir, as well as a computerized blending and monitoring system. Stormwater runoff was also captured, to the degree allowed, and reused in the recycled water system. The recycling system is very sophisticated and has provided data on the quantity of recycled water since August 2005.

04V53 is a very large container nursery with substantial runoff, during both wet and dry seasons. They grow ornamental plant stock in containers on 170 acres out of a total area of 200 acres. They grow mainly outdoors, with 20% of the production in shadehouses. In addition to a large and very sophisticated recycling basin to capture and reuse the majority of their runoff, they also installed a grassed waterway and a constructed wetland to treat runoff before discharge in cases when they need to release runoff. The entire facility is graveled to slow runoff, decrease sediment carried by runoff, and limit erosion. They also use polyacrylamide (PAM) to decrease sediment carried by runoff.

2.2.1.3 06V64– Project Improvement Type: Irrigation Upgrade

This project involved the conversion of 6 acres of production area from hand watering to drip irrigation and impact sprinklers. The grower also tried using pulse irrigation on the section of the nursery where runoff was measured during the study.

06V64 is a relatively new (4-year-old) expansion site for the plant growers. They are growing a variety of container plants, ground cover plants and ornamentals on 10 acres, out of a total property size of 11 acres, on sloping terrain next to a creek. The operation is mainly open field but has some shadehouses and a greenhouse.

2.2.2 Assessment of BMPs

The following discusses the assessment of the effectiveness of each type of BMP.

2.2.2.1 Recycling systems

The most dramatic improvements in the reduction of runoff concentrations were seen for sites with recycling systems. Water flowing into these systems had the highest nutrient concentrations (**Figure 6**). For each of these sites there was no measurable runoff from irrigation events leaving the property once these projects were completed. These improvements are expected to continue to collect all irrigation runoff and considerable runoff from storm events. There is typically no off-site transport of nutrients in runoff from irrigation events, and off-site transport during storm events is expected to be largely mitigated. Mitigation during storm events will depend on the size of the basins relative to the size of the precipitation event. Because nutrients in the recycled water are reused by these sites, these systems also deliver the benefit of fertilizer cost savings to the grower.

2.2.2.2 Irrigation upgrades

Samples from sites with irrigation upgrade projects tended to meet TMDL targets (**Figure 6**). Because these improvements were completed only at the end of the project, concentration reductions achieved by these improvements could not be reasonably assessed. Decreases in runoff volumes attained by irrigation upgrade projects are expected to decrease export of nutrients during irrigation events. Two cooperators, however, produced no observable runoff from irrigation events prior to implementing these improvements.

2.2.2.3 Detention basins

Reductions in runoff nutrient concentrations were considerable for sites with detention basins. Nearly half of the samples collected by retention basins would not have met water the water quality objective for NO_3–N (**Figure 6**). For each of these sites, there was no measurable runoff from irrigation events once these projects were completed. These improvements are expected to continue to collect all irrigation runoff and considerable runoff from storm events. There is typically no off-site transport of nutrients in runoff from irrigation events, and off-site transport during storm events is expected to be largely mitigated. Mitigation during storm events will depend on the size of the basins relative to the size of the precipitation event. Leaching losses of some constituents, particularly NO_3–N, may be a consideration for unlined basins. However, nurseries 04V47 and 04V88 have hydroseeded their basins' banks and are considering planting the bottom of the basins in order to enhance nutrient and water uptake in these basins. This will decreases losses from leaching.

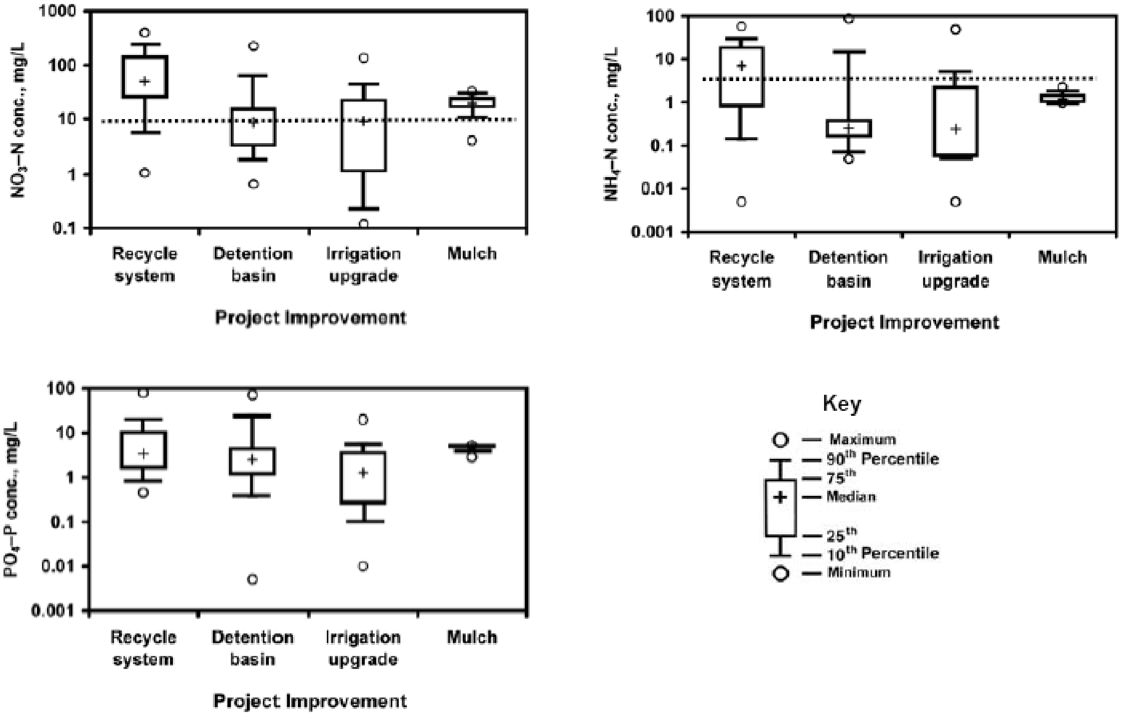

Figure 6. Nutrient concentrations in runoff water prior to project improvements for all studied watersheds. Recycle systems and detention basins capture all irrigation runoff and the beginning of storm runoff before it leaves the property, mitigating shown nutrient concentrations. Because irrigation upgrade and mulching improvements were completed only at the end of the project, their effectiveness in mitigating these concentrations could not be reasonably assessed. Note y-axes are log scale, and vary among plots. Horizontal dashed lines indicate water objectives of 10 mg/L NO3–N and 3.2 mg/L NH4–N. Median NO3–N concentrations for recycle system, detention basin, irrigation upgrade, and mulch project improvements were 50.5, 8.54, 9.12, and 19.7 mg/L, respectively. Median NH4–N concentrations for recycle system, detention basin, irrigation upgrade, and mulch project improvements were 7.05, 0.25, 0.24, and 1.18 mg/L, respectively. Median PO4–P concentrations for recycle system, detention basin, irrigation upgrade, and mulch project improvements were 3.37, 2.56, 1.27, and 4.9 mg/L, respectively. Number of observations (n) = 147.

2.2.2.4 Mulch

Samples from the site with a mulching project tended to meet the water quality objective for NH_4–N (**Figure 6)** though samples typically did not meet the water quality objective for NO_3–N (**Figure 6**). Because this improvement was completed only at the end of the project, concentration reductions achieved by this improvement could not be reasonably assessed. Decreases in runoff volumes attained by mulching are expected to decrease export of nutrients in runoff. Furthermore, mulch with a high carbon-to-nitrogen ratio may immobilize nitrogen in flowing runoff water. No storm produced observable runoff during the study period at this site.

2.2.3 UCCE Study Conclusions

The four BMPs evaluated through the study will all likely prove effective in reducing discharges of nitrogen from nurseries. Recycling systems and detention basins were found to reduce the amount of nitrogen discharged significantly by capturing and keeping most or all of the nursery runoff on site. Irrigation upgrades and mulch BMPs were installed at the end of the assessment period and the effectiveness of these improvements was not quantitatively assessed during the study. However, both BMPs are expected to reduce runoff volumes and thereby reduce nitrogen loading to receiving waters.

Additionally, survey data collected before and after educational activities and adoption of the Conditional Waiver showed statistically significant improvement in the number of BMPs implemented in every category.

3 BMP Effectiveness Assessment Summary

Both the UWCD and UCCE studies, although conducted to assess different BMPs, indicate that when BMPs are implemented there can be quantifiable decrease in nitrogen runoff. Where capturing runoff is feasible, this is the most effective way to eliminate nitrogen transport in surface runoff. However, there are costs for construction, loss of growing area, and maintenance that must be considered before installing a runoff capture basin. Non-construction improvements such as improving irrigation and mulching can also be effective BMPs, but as demonstrated in the UWCD study, multiple practices utilized in conjunction with one another is the best way to ensure agricultural runoff is minimized and is of best quality possible. Though, not the focus of these studies, source control is an important component of farm management and BMP implementation. Applying the proper amounts of fertilizer at the correct times can ensure that crops receive the nutrients they need and losses due to deep percolation or surface runoff are minimized. The proper irrigation system as well as management of irrigation, controls the movement of applied fertilizers and is therefore an important component of nutrient management. The results of both studies demonstrate that BMP implementation can lead to a reduction in nitrogen loading to the CCW.

4 References

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