

Modifying Agricultural Practices, Nutrients and Pesticides, Calleguas Creek and Santa Clara River

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In cooperation with:
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ABSTRACT

The purpose of the project was to implement Best Management Practices (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 pesticides and herbicides to both surface waters and groundwater. The waters and sediment of certain reaches of Calleguas Creek and the Santa Clara River are listed as impaired for certain nutrients and some chlorinated and organophosphate pesticides, many of which are no longer registered for use in Ventura County. Several types of water-borne transport mechanisms were considered: 1) winter storm runoff; 2) surface flow from irrigation (tailwater); 3) discharge from tile drains installed beneath fields; and 4) downward percolation of irrigation and rain water within and below plant root zones. Crop types evaluated at a total of sixty field sites included avocado, strawberry, citrus, row crops and sod. Participation by area land owners was voluntary. The BMPs that were implemented included mulch, cover crops, filter strips, grassed ditches, and Polyacrylamide cakes.

Monitoring at the sites allowed for a survey-scale documentation of pesticide and herbicide concentrations in soil water and stormwater runoff. Liquid phase detections were more common for chlorinated pesticides than for organophosphate pesticides and triazine herbicides. DDT and its derivatives along with chlordane were the most-frequently detected pesticides, at concentrations less than one part per billion. Organophosphate pesticides and triazine herbicides were not commonly detected in soil water. The pesticides and herbicides detected at field sites were found in much greater concentrations in the solid phase than in the liquid phase, as many of the organic compounds evaluated bond strongly to soil particles. Solid phase pesticide and herbicide detections commonly ranged to the 100s of parts per billion.

Up- and down-stream or side-by-side sampling during winter storms allowed assessments of BMP effectiveness. BMP installations were principally designed to reduce the amount of soil discharged from the agricultural fields during significant precipitation events. Measurements of total suspended solids were also used to assess BMP effectiveness, as many of the BMPs employed in this study do not significantly alter the chemistry of runoff water or entrained solids. Mulch and cover crops were the most effective at reducing runoff and transport of solids. At most mulch sites runoff was completely eliminated during moderate storms. The amount of sediment trapped upstream of a BMP and the absence of soil erosion may be the most reliable measure of the effectiveness of BMPs designed to reduce the transport of soils. For sites where suspended solids were measured upstream and downstream of a BMP, solids were reduced an average of nine percent.

Nitrate was measured at high and variable concentrations in shallow and deep soil waters, exceeding the primary drinking water standard by an order of magnitude in many samples of percolating water. Ammonia and organic nitrogen concentrations were commonly higher in tailwater and storm runoff than in soil water. Controlling irrigation so that fertilizer is not pushed beyond the root zone is a key factor in reducing nutrients in percolating waters. Study sites equipped with real-time measuring devices for soil moisture exhibited the lowest concentrations of nutrients in waters percolating below plant root zones.

1. INTRODUCTION

The majority of funding for this project came from the State Water Resources Control Board through a Proposition 13 Watershed Protection Grant Program. A portion of the funding came from local interests (United Water Conservation District, Ventura County Farm Bureau, and FGL Environmental Laboratory). The project was conducted by United Water Conservation District in cooperation with the Ventura County Farm Bureau and FGL Environmental Laboratory.

1.1 PROBLEM STATEMENT

Specific reaches of Calleguas Creek and the Santa Clara River (Ventura County, California) are listed by the EPA as impaired by nitrogen and a number of agricultural pesticides. Various Best Management Practices (BMPs) exist for controlling pesticide and herbicide loads associated with agricultural runoff, but have yet to be implemented on a scale that creates meaningful benefit to the watershed. The purpose of this project was to work with the local agricultural community to implement BMPs at established field sites and conduct “in field” monitoring to demonstrate the efficiency of BMPs at reducing discharges of pesticides, herbicides, and nutrients to both surface waters and groundwater. The goal is to influence the actions of a large segment of the agricultural community by providing documentation of measurable benefits contributed by specific BMPs. The following steps were taken to achieve these objectives: 1) monitoring was conducted to establish a baseline data set characterizing agricultural discharges at the onset of the project; 2) BMPs aimed at pesticides, herbicides, and nitrogen-based nutrients of concern were implemented in agricultural fields representing different crop types and geographic locations within the Calleguas Creek and lower Santa Clara River watersheds; 3) discharges were retested to measure the effectiveness of BMPs and offer evidence that pesticide and herbicide concentrations in farm discharges could be reduced; and 4) ongoing marketing of results through education and peer advising by farm organizations to reach a wide audience of growers and provide leadership for BMP implementation throughout the agricultural community.

Both the Calleguas Creek and Santa Clara River watersheds drain agricultural and urban areas, including many of the cities of Ventura County and the agricultural areas of the Santa Clara River valley, the Oxnard Plain, Las Posas basin, and Santa Rosa Valley. Calleguas Creek discharges to the ecologically sensitive Mugu Lagoon. The Santa Clara River is the second largest discharging river in southern California, contributing large volumes of water and sediment, together with entrained solids and dissolved constituents to lowland and beach areas. The watersheds continue to be the focus of considerable work relating to TMDL development. In 2006 the Los Angeles Regional Water Quality Control Board (Regional Board) passed a Conditional Waiver for Waste Discharge Requirements from Irrigated Agricultural Lands (Conditional Ag Waiver). Prior to the adoption of the Conditional Ag Waiver, the Regional Board helped establish an Agricultural Oversight Committee in Ventura County, consisting of grower representatives from the major local crops, local agricultural organizations, and water

district representatives. The principal purpose of the Agricultural Oversight Committee was to assist with TMDL implementation and to provide advice and expertise to the Regional Board as they developed the Conditional Ag Waiver. Following communications with members of the Agricultural Oversight Committee, a number of local growers embraced a proactive response in reducing agricultural discharges. Voluntary local support to reduce pesticide and herbicide discharges allowed this project to proceed. United Water conducted and managed the project, with technical assistance and laboratory analyses from FGL Environmental, a commercial water quality laboratory and agricultural consulting firm located in Santa Paula, California. The Ventura County Farm Bureau was also a cooperator in the project and assisted in the conception of the project and has promoted maximum exposure and buy-in from individual farmers in the local community.

The list of pesticides evaluated in this study was based on pesticide impairments on the various reaches of Calleguas Creek at the time the project was proposed. The list of analytes was expanded to include additional chlorinated and organophosphate pesticides, as well as triazine herbicides common to the EPA methods approved for the analysis of the chemicals listed as impaired. There often exists a lag time of several years between the time new constituents are introduced and they may be recognized to cause toxicity problems in aquatic environments. Additional years may pass before regulatory controls are enacted, and methods for chemical analysis are standardized and approved by regulatory agencies. The list of compounds evaluated in this study is by no means an inclusive list of active agricultural constituents currently being used by local growers. A number of the organophosphate pesticides, and two of the triazine herbicides, considered in this study remain registered for use, but use of most of the chlorinated pesticides has been banned since the late 1980s.

1.2 PROJECT DESCRIPTION

The project was designed to implement and test various agricultural management practices to determine their ability to reduce pesticide, herbicide, and nutrient (specifically nitrogen compounds) loading to local water bodies. To evaluate the effectiveness of BMPs, samples of soil water, subsurface “tile drain” discharge, and surface runoff were collected from agricultural fields where additional management practices had been implemented for consideration in this study. Management practices were implemented at the field sites and water samples were collected to determine their effectiveness in reducing the movement of legacy and contemporary pesticides and herbicides from the fields and orchards. The project was completed by performing the steps outlined below:

- Current pesticide and herbicide management practices were identified and documented;
- Field sites were selected from a list of properties offered as available by the property owner;

- Drainage patterns were identified at each field site, and sampling locations were established for tile drains, surface runoff, and placement of the lysimeters used to extract soil moisture from the shallow subsurface;
- Installed lysimeters (one pesticide/herbicide lysimeter and two nutrient lysimeters were installed at each site)
 - Pesticide/herbicide lysimeters were installed at an appropriate depth to sample soil water from just below the active root zone. The lysimeters are fabricated from a high-fired alumina ceramic, and are designed to hold a vacuum sufficient to draw as much as a liter of soil moisture into the device;
 - A pair of nutrient lysimeters were installed, one that sampled soil water one foot below the surface, and another that sampled water from six feet below the land surface;
- Collected baseline information – A baseline data set was collected to characterize pesticide, herbicide, and nitrogen concentrations at each field site prior to the implementation of BMPs. Samples were collected from lysimeters, tile drains, and drainage ditches or furrows during representative dry and wet field conditions. A minimum of six baseline samples were obtained from each field site;
- Sample analysis-
 - Samples were analyzed for specific pesticides and pesticide byproducts identified as impairing Calleguas Creek reaches 1 through 6 and reach 9 at the time this study was proposed (SWRCB, 2003). Impairments were listed of the following compounds: Chlordane, Chlorpyrifos, 4,4'-DDT, Diazinon, Dieldrin, Endosulfan, Malathion, and Toxaphene. The laboratory methods approved for the analysis of the listed pesticides include additional compounds, and all samples were analyzed for the broader suite of analytes. This suite included the chlorinated and organophosphate (OP) pesticides, and triazine herbicides listed below. With the exception of Toxaphene, all pesticides and herbicides were analyzed using EPA Method 8270. Toxaphene was analyzed using EPA Method 8081A. Liquid phase concentrations of the following pesticides and herbicides and their derivatives were determined for all samples, and solid phase analyses were completed for stormwater samples when sufficient weights of sediment were captured during sampling;
 - Chlorinated pesticides: Aldrin, alpha-BHC, beta-BHC, delta-BHC, gamma-BHC (Lindane), alpha-Chlordane, gamma-Chlordane, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, Dieldrin, Endrin, Endrin aldehyde, Endrin ketone, Endosulfan I, Endosulfan II, Endosulfan sulfate, Heptachlor, Heptachlor Epoxide, Methoxychlor, Toxaphene
 - OP pesticides: Azinphos Methyl, Chlorpyrifos, Demeton-O, Demeton-S, Diazinon, Dimethoate, EPN, Malathion, Mevinphos, Naled, Parathion Methyl, Parathion ethyl, Phorate, Sulfotepp, Thionazin, Disulfoton

- Triazine herbicides: Atrazine and Simazine
 - Nitrogen-based nutrients were analyzed in water samples collected from lysimeters, tile drains, tailwater, and stormwater runoff. Samples collected from lysimeters represented soil moisture conditions at two depths. Lysimeters were positioned to collect soil moisture from 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. Several methods were implemented to analyze the nitrogen species in water samples. Ammonia and Total Kjeldahl Nitrogen (TKN) were analyzed using methods SM 4500NH3H and SM 4500NH3G, respectively. Nitrate plus nitrite was analyzed using SM 4500NO3F.
- Data analysis – Data was evaluated with regard to crop type, geographic location, and chemical similarities between shallow soil water (lysimeters), deep soil water (tile drains and 6-foot lysimeters), tailwater (irrigation runoff), and samples of stormwater runoff (both liquid phase and solid phase chemical detections)
- Results were shared with local experts and growers – Throughout the project, results were shared and input was encouraged from representatives from the Los Angeles Regional Water Quality Control Board, University of California Cooperative Extension, Ventura County Farm Bureau, Ventura County Agricultural Commission, local growers and agricultural consultants, and the project’s Technical Advisory Committee (TAC). Project updates were presented to the agricultural community through discussion with the Ventura County Agricultural Oversight Committee and various presentations sponsored by the Association of Water Agencies of Ventura County and the Ventura County Farm Bureau;
- Modification of management practices – With the consultation of a crop advisor from FGL Environmental, and additional assistance from a specialist from Cachuma Resource Conservation District, participating growers selected improvements deemed appropriate for their field sites. Participation was voluntary and BMP installations were conducted at the grower’s expense. The types of BMPs installed and tested included:
 - Mulch
 - Cover crops
 - Wattles
 - Grassed filter strips
 - Grassed ditches
 - Polyacrylamide cakes
 - Improvements to drainage structures
- Collection of post-BMP samples – Water samples were collected from lysimeters, tile drains, and ditches or other surface water discharge points at all sites where BMPs had been implemented. A stormwater sampling regime provided protocol for collection of samples representative of site conditions

both upstream and downstream of the various BMPs. Results were compared to evaluate the effectiveness of the site modifications in reducing sediment transport or changing liquid phase or solid phase chemical concentrations;

- Expansion of recommended pesticide, herbicide, and nutrient management practices to additional growers – A key element of this project is the distribution of study results to the agricultural community. This process is ongoing with outreach occurring in tandem with submittal of this report.

1.3 COMPLEMENTARY PROJECT

United Water Conservation District was awarded an earlier Proposition 13 grant through the Nonpoint Source Pollution Control Program (referred to herein as the PRISM grant/project). The PRISM project was very similar in scope to this project, but was limited to the Calleguas Creek watershed and did not include an assessment of nitrogen compounds or solid phase analyses for stormwater samples. The PRISM project was designed to assess the efficiency of BMPs at reducing pesticide and herbicide discharges from 50 agricultural field sites in the Calleguas Creek watershed. This study was designed as an extension of the PRISM project, and shares 43 of the original 50 field sites. Additional lysimeters were installed at the 43 joint field sites to allow monitoring of nitrogen compounds. Samples collected at all PRISM field sites were integrated into the results for this study. This current project funds sample collection and analysis for pesticides, herbicides, and nutrients at 60 field sites; the 43 mutual field sites in the Calleguas Creek watershed, and an additional 17 field sites located in the lower Santa Clara River watershed.

2. METHODS

The development and approval of a Quality Assurance Project Plan (QAPP) was required prior to the commencement of other project activities. The QAPP presented guidelines for all technical and data quality aspects of the project including planning, implementation, and assessment. Procedural methods outlined in the QAPP were strictly adhered to in performance of the study. The QAPP is presented in Appendix A.

2.1 SELECTION OF FIELD SITES

Voluntary participation from individuals in the agricultural community was an integral component of this project. Participants were solicited through networking efforts with the Ventura County Farm Bureau, Ventura County Agricultural Oversight Committee, the Association of Water Agencies of Ventura County, and FGL Environmental. A specific number of sites and crop types were targeted for each watershed. The 43 sites in the Calleguas Creek watershed were selected from the 50 existing field sites of the PRISM study (Section 1.3 Complementary Project). The 17 sites located in the Ventura County portion of the Santa Clara River watershed were selected for the project based on the following characteristics: the property was offer as available by the owner or operator, field conditions were typical or representative for the particular crop being

assessed, the site was isolated from influences from surrounding properties (i.e. surface water influence or run-on from adjacent agricultural areas or other land uses, or drainages from other crops grown on the same parcel), a specific location was identified where surface runoff could be safely sampled during wet weather, and reliable accessibility during wet weather conditions. The study area and site locations are shown in Figure 1. Following is 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.

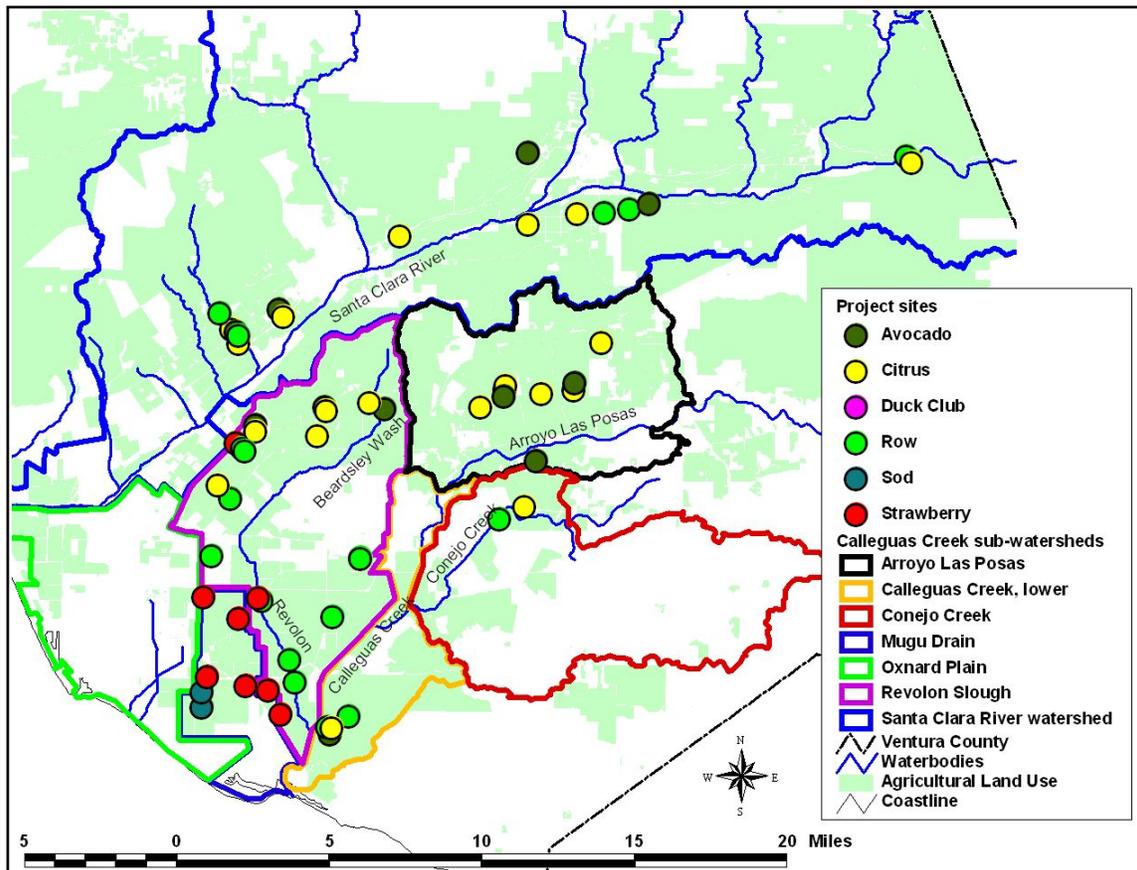


Figure 1. Study site locations and sub-watersheds; Ventura County, California

Property access agreements were obtained from all project participants. Site reconnaissance was performed at each site. Site reconnaissance forms were prepared and included the site name and driving instructions to the property, the location of surface water sample points, and the location of lysimeter installations. Site coordinates were identified and recorded using a GPS unit, and baseline conditions were documented with photographs. At sites with subsurface drains, the distribution of the collection lines was confirmed with the property owner to assure that tile drains did not extend to adjacent properties.

Of the original 60 field sites, four sites were withdrawn from the study before the project was completed. Two strawberry sites were sold and converted to sod. Property management changed at one row crop and the property was no longer accessible, and one citrus orchard was torn out and the property converted to a different land use.

2.2 INSTALLATION OF MONITORING EQUIPMENT

Sets of specialized lysimeters were installed at each field site in order to sample soil water from three different depths (Figure 2). Samples for pesticide and herbicide analyses were collected from depths ranging from approximately 12 to 28 inches below the land surface, and were intended to sample soil moisture within and below the active root zone of the crops being tested. Samples for nitrogen compounds were collected from one foot below the surface, and six feet below the surface. Care was taken to ensure that soil water samples were representative of field conditions. Lysimeters were positioned well within the crop boundaries to avoid edge effects related to crop irrigation or pesticide and herbicide applications. For installations in orchard crops (avocado and citrus), lysimeters were positioned below or within the drip-line of the tree canopy. Only one set of lysimeters was installed at each site, and no attempt was made to characterize variability within the growing areas of individual field sites.



Figure 2. Photo of installed lysimeters with protective PVC caps

2.2.1 Installation of lysimeters – Pesticide/herbicide samples

Specialized lysimeters were installed at each field site to sample soil water for pesticide and herbicide analyses from just below the active root zone of the crops being tested. The lysimeters were specifically designed for use where samples are collected to detect concentrations of organic and inorganic solutes or pesticides and herbicides with very low detection sensitivities. The lysimeters were fabricated from a high-fired alumina ceramic with low adsorption characteristics. All the fittings were composed of Teflon or stainless steel in order to prevent sampling compounds from bonding to the surfaces of the lysimeter apparatus. The lysimeters have a glazed inner reservoir with a volume of 560 mL, but under moist soil conditions can draw and hold volumes greater than a liter. The lysimeters are capsule-shaped, with an outside diameter of 4 inches, length of 18 inches, and ceramic pore spaces of approximately 2.5 microns. A photo of a lysimeter is

shown in Figure 3. Vacuum and discharge tubing is attached to the lysimeter within the PVC collar shown in the figure.

In order to install lysimeters, a 6-inch diameter hole was dug using a post-hole digger. Soil horizons were characterized and recorded. The depth of the lysimeter installation varied dependant on the type of crop being grown at each field site. The holes were dug deep enough so that when the lysimeters were installed, the top of the infiltration surface was positioned near the lower boundary of the active root zone of the mature crop. Approximate depths of active root zones for each crop are presented in Table 1. To become “air tight” and capable of holding a vacuum charge, the ceramic of the lysimeter had to be wetted prior to installation. To do this, the lysimeter was placed in a 5 gallon bucket filled with water, and a vacuum was pulled within the lysimeter using a pressure/vacuum air pump. Once the lysimeter was prepared, a slurry of silica flour mixed with water was prepared and poured into the hole. After placement of the lysimeter, additional slurry was added to completely cover the infiltration surface of the lysimeter and fill the annular space between the lysimeter and walls of the boring. The particles contained in the silica flour were smaller than 75 μm (sifted through a 200 mesh sieve). The slurry hardened to a hard cake similar to a low-density silica plaster. The hardened silica cake provided filtration of the soil water and maintained good communication between the soil and the lysimeter acting as a conduit to convey the vacuum within the lysimeter to the surrounding soil. The installation was sealed with a layer of bentonite placed above the infiltration surface of the lysimeter, preventing any short-circuiting of irrigation water or rain water from the surface. The lysimeter was then purged and charged with a vacuum of approximately 700 millibars. Prior to sample collection, the lysimeter was purged and reset one additional time. The lysimeter fittings and tubes were protected from surface activities by a capped section of 6 inch PVC pipe.



Figure 3. Lysimeter used to sample soil moisture for pesticide and herbicide analyses

Table 1. Maximum depth of active root zones for each crop type (approximate)

Crop	Max Depth of Active Root Zone
Avocado	12-18 inches
Citrus	18-24 inches
Sod	6-12 inches
Grains (Duck Club feed crops)	24-36 inches
Strawberry	6-12 inches
Row Crops	12-18 inches

2.2.2 Installation of lysimeters – Nutrient samples

The lysimeters used to sample soil moisture for the analyses of nitrogen compounds are constructed of a section of PVC pipe secured to a porous ceramic cup at the base, and a rubber seal and cap on the top (Figure 4 and Figure 5). The outside diameter is 1.9 inches, and two lengths of these small diameter lysimeters were used in this study. A one-foot lysimeter was installed at each site to sample soil moisture close to the surface, and a six-foot lysimeter was used to sample deeper soil moisture from below the root zone. Once the lysimeters were installed, they were charged with a 600 millibar vacuum. Infiltration occurred through the porous ceramic cup at the base of the lysimeter. The PVC pipe served as the body of the lysimeter and sample reservoir. A tube through the rubber cap at the top of the lysimeter serves as an access port for sample extraction and the introduction of vacuum.

In order to install the set of lysimeters, two holes were bored using a three-inch auger. One hole was bored to an approximate depth of one foot, and the other to a depth of approximately six feet. Prior to insertion of lysimeters, a small amount of silica slurry was prepared and poured into each hole (enough to ensure that the ceramic cup would be covered; approximately 200 to 400 mL). Immediately after the silica slurry was poured into a hole, the lysimeter was inserted and held in position until the slurry hardened to a hard cake similar to a low-density silica plaster. As discussed in Section 2.2.1 (Installation of Lysimeters – Pesticide/Herbicide Samples), the silica is used to maintain good communication between the soil and the lysimeter, and is necessary to convey a vacuum from within the lysimeter to the surrounding soil. After the silica was set, the remainder of the hole was backfilled with granular bentonite. The bentonite was then wetted to form a seal to prevent short-circuiting by irrigation or rain water. The lysimeters were charged with a 600 millibar vacuum. Prior to sampling, the lysimeters were purged and reset one additional time. Installed lysimeters were protected from surface activities by capped sections of three inch PVC pipe.



Figure 4. Lysimeter used to sample soil moisture for nitrogen compounds. The lysimeter is composed of a section of PVC pipe (either one foot or six feet in length) secured to a porous ceramic cup at the base, and a rubber cap on the top. The PVC pipe serves as the lysimeter body and reservoir.



Figure 5. View of the rubber cap with access port

2.3 SAMPLING PROTOCOL

Concentrations of pesticides, herbicides, and nitrogen compounds were monitored in discharges from agricultural field sites by sampling soil moisture from lysimeters, subsurface drainage systems (“tile drains”), stormwater surface runoff, and, where available, irrigation surface runoff (“tailwater”). Following is a description of the sampling procedures for each type of sample event.

2.3.1 Sample collection from lysimeters

Samples for Pesticide and Herbicide Analyses

The lysimeter used to sample soil moisture for pesticide and herbicide analyses is described in Section 2.2.1 (Installation of lysimeters – Pesticide/Herbicide Samples) and shown in Figure 3. There are two fittings at the top of each lysimeter; a pressure/vacuum port and a sample port. The sample port is connected to a stainless steel tube that extends to the bottom of the glazed inner reservoir of the lysimeter. When the ceramic of the lysimeter is wetted prior to installation, the lysimeter becomes air tight. Because the

ceramic needs to stay wet to hold a charge, lysimeters were charged with a vacuum after each sampling visit to field sites, resulting in water being drawn in from the surrounding substrate and remaining within the reservoir between sample events. One to five days prior to sampling, lysimeters were purged and recharged with a vacuum of approximately 700 millibars. To extract water from the lysimeter, air is pumped into the pressure/vacuum port of the lysimeter. This positive pressure displaces any water within the lysimeter body through the stainless steel tube connected to the sample port. A section of Teflon tubing is attached to the sample port, allowing the sample to be expelled directly into a 1-liter amber glass sample bottle. Sample quantities varied depending upon soil moisture conditions at each site in the days prior to sample collection. On many occasions, the amount of sample obtained from the lysimeter was substantially less than 1 liter. In the event that the collected sample volume was less than 850 mL, the lysimeter vacuum was reset and the partial sample was delivered to the laboratory for refrigerated storage. Composite samples were commonly needed for lysimeters that produced little water. Composite samples were completed within seven days, in compliance with the holding times for the analyses used in this study. All samples were clearly identified, a chain of custody was completed, and samples were deposited at FGL Environmental either by the end of the day, or if sampling occurred during off hours, samples were placed on ice and held until the laboratory was open for business.

Samples for Nutrient Analyses

The lysimeters used to sample soil moisture for the analyses of nitrogen compounds are described in Section 2.2.2 (Installation of Lysimeters – Nutrient Samples) and shown in Figure 4. One to five days prior to sampling, lysimeters were purged and recharged with a vacuum of approximately 600 millibars. To collect the soil water sample from the lysimeter, a small-diameter sample tube was inserted into a stopper fitted to a sample collection flask. The cap of the lysimeter was removed and the small-diameter sample tube was inserted to the bottom of the lysimeter where soil water has pooled. The stopper has a second port that allows the attachment of a vacuum line. A hand vacuum pump was then connected to the flask. The hand pump was used to create a vacuum in the flask, which in turn pulled water up from the lysimeter and into the collection flask. The sample was then transferred to a plastic half-pint bottle prepared with a sulfuric acid preservative. All samples were clearly identified, a chain of custody was completed, and samples were deposited at FGL Environmental either by the end of the day, or if sampling occurred during off hours, samples were placed on ice and held until the laboratory was open for business.

2.3.2 Sample collection from subsurface drainage systems

Of the 60 original field sites, 15 were equipped with tile drains for subsurface drainage. In some agricultural areas, subsurface networks of perforated pipe are installed in order to assist the subsurface drainage of soils. In areas with soils of low permeability, or areas where shallow groundwater exists, saturated soil conditions may negatively affect plant health. Perforated drainage pipes are often positioned from approximately five to fifteen feet below the land surface, at depths sufficient to avoid damage during the deep ripping of soils and provide gravity flow to collection or discharge points. Some drainage

systems discharge directly by gravity flow to ditches or channels, and other installations use sump pumps to lift water to surface discharge areas. These drainage systems are commonly called tile drains because they were traditionally constructed with short segments of tile or clay pipe, loosely-jointed and packed in gravel to allow the ingress of water.

Drainage areas for all tile drains were confirmed to be limited to the field being sampled (growers were interviewed, and maps of drainage systems were referenced). Tile drains were sampled concurrently with lysimeter samples, allowing a correlation between samples from shallow and deep soils. If the tile drains underlying grant sites were part of a larger collection system, sites were selected at the upstream portions of these systems. In this case, samples were collected from sediment cleanout sumps, where a single grower managed the cropping that overlays the drains. Other sites had smaller drainage systems that only serviced the property participating in this study. At several of these sites, drain samples were collected at the surface discharge pipe of sump pump lift stations. At other sites, drain water discharged directly to a surface water channel and samples were collected from the point of discharge.

Sample Collection for Pesticide and Herbicide Analyses

Samples for pesticide and herbicide analyses were collected in a 1-liter amber glass bottle. To collect the samples from the tile drains, the bottles were either held by hand or attached to a telescoping sample rod. Sample bottles were filled directly at pipe discharge points, or submerged below the water surface when sampling deep sumps.

Sample Collection for Analyses of Ammonia/TKN//Nitrate & Nitrite

The same procedures stated above were employed with one exception. Samples were collected in a clean sample container and transferred to the pint sample bottle containing sulfuric acid preservative.

All samples were clearly labeled, a chain of custody was completed, and samples were deposited at FGL Environmental either by the end of the day, or if sampling occurred during off hours, samples were placed on ice and held until the laboratory was open and able to receive the samples.

2.3.3 Sample collection from stormwater surface runoff

Stormwater runoff samples were collected by a team of trained employees of United Water Conservation District. When a significant rainfall event was forecasted and appeared imminent, a sample team of five to seven staff members would be equipped and mobilized to various areas within the watershed. Each person had previous knowledge of their assigned sites. In general, the sampler would remain at the first site until runoff occurred, grab the sample, and then move on to the next site. During the first few sample events, samplers arrived at their first site, and waited up to 5 hours before runoff began. As the study progressed, it became evident that depending upon antecedent conditions and the intensity of a storm, a minimum of one-half to one inch of rain was generally

required to reach runoff stage at many field sites. Wet antecedent conditions produced runoff earlier in the storm events, as did a higher intensity of precipitation.

Sample Collection for Pesticide and Herbicide Analyses

All samples were collected from predetermined locations at field sites. The pesticide and herbicide analyses were performed on both the liquid phase of stormwater samples, and the solid phase of stormwater samples. The solid phase was composed of the sediment commonly entrained in stormwater runoff. In an effort to capture adequate quantities of suspended solids to perform the laboratory analysis, 2 liters of sample were collected from each site.

Samples were collected in a 1-liter amber glass bottle. When possible, sample water was allowed to flow directly into the 1-liter bottles. The sample bottle was immersed in the centroid of the drainage flow, with the container opening facing upstream. Sample bottles were preferentially positioned near the top of the water column, but below the water surface. When the depth of flow in the channel was less than approximately four inches, an unused wide-mouthed half-pint glass jar was used to transfer sample water from the channel to the 1-liter amber sample bottles. Every effort was made to avoid disturbing sediment from the bed of the channel.

Sample Collection for Analyses of Ammonia/TKN//Nitrate & Nitrite

The same procedures stated above (Sample Collection for Pesticide and Herbicide Analyses) were employed with one exception. The sample was collected in a clean container (preferably the container that was used for concurrent sampling for pesticides and herbicides at the same site) and transferred to the half-pint sample vessel containing the sulfuric acid preservative.

Sample Collection for Analysis of Total Suspended Solids

The same procedures stated above (Sample Collection for Pesticide and Herbicide Analyses) were employed except samples for Total Suspended Solids (TSS) were collected in a 1-pint plastic bottle.

All sample containers were clearly identified, a chain of custody was completed, and samples were deposited at FGL Environmental either at the end of the sample event, or if sampling occurred during off hours, samples were placed on ice and held until the laboratory was open for business.

2.3.4 Sample collection from irrigation surface runoff

Attempts were made to collect at least one irrigation surface runoff (“tailwater”) sample from each field site. Samples were collected when runoff from irrigation was noticed at the sites during field visits. Although irrigation events were witnessed at all sites during the duration of the study, tailwater runoff was absent during many observed irrigation cycles. All orchards in the study were equipped with micro sprinklers, and most irrigation events observed at these sites did not result in surface runoff. Strawberry crops have drip tape installed beneath the plastic “mulch” used to cover the plant beds, and

generally did not have runoff from irrigation events. However, broadcast irrigation is commonly used when plants are young and roots are poorly established; this irrigation practice was observed to produce overland runoff. Irrigation practices at row crops were either from drip tape, broadcast sprinklers, or furrow irrigation. Most drip tape practices did not result in surface runoff. Surface runoff was common at sites that employed either broadcast sprinklers or furrow irrigation practices.

Sample Collection for Pesticide and Herbicide Analyses

When possible, samples were collected directly into a 1-liter amber glass bottle. The sample bottle was immersed in the centroid of the drainage flow, with the container opening facing upstream. Sample bottles were preferentially positioned near the top of the water column, but below the water surface. When the depth of flow in the channel was less than approximately four inches, a clean wide-mouthed half-pint glass jar was used to scoop the runoff from the channel and pour it into the 1-liter amber sample bottle. Every effort was made to avoid disturbing sediment from the bed of the channel.

Sample Collection for Analyses of Ammonia/TKN//Nitrate & Nitrite

The same procedures stated above (Sample Collection for Pesticide and Herbicide Analyses) were employed with one exception. The sample was collected in a clean container (preferably the container that was used for concurrent sampling for pesticides and herbicides at the same site) and transferred to the half-pint sample bottle containing the sulfuric acid preservative.

Sample Collection for Analysis of Total Suspended Solids

The same procedures stated above (Sample Collection for Pesticide and Herbicide Analyses) were employed except samples for TSS were collected in a 1-pint plastic bottle.

All samples were clearly identified, a chain of custody was completed, and samples were deposited at FGL Environmental either by the end of the day, or if sampling occurred during off hours, samples were placed on ice and held until the laboratory was open for business.

2.4 LABORATORY ANALYSES

Water samples were analyzed to determine pesticide and herbicide concentrations in soil water, subsurface drainage, and surface runoff associated with each field site. FGL Environmental performed all analyses for the project. FGL is certified by the Environmental Laboratory Accreditation Program (ELAP) and was approved by the State Water Quality Control Board (SWQCB) to conduct laboratory analyses for this project.

As discussed in Section 1.3 (Complementary Project), the PRISM grant was awarded prior to the grant for this current project. All data from monitoring activities at the 43 mutual sites, whether funded by the PRISM grant or the grant for this current project, is included in this report. This includes analytical results from a storm event that occurred at the beginning of the PRISM project, while this current project was still in the approval

stages. The storm event occurred on February 24th, 2004. Stormwater runoff samples were collected from 34 of the 43 mutual field sites. Samples collected during this early storm were analyzed using different methods than all following sample events. Methods for analyses were changed after this first sample event in order to achieve lower quantitation limits for detections.

Samples collected during the February 24th, 2004 event were analyzed using EPA methods 8081A and 8141A. EPA method 8081A was implemented to assess chlorinated constituents using a gas chromatograph with dual Electron Capture Detectors (ECDs); OP constituents and triazine herbicides were assessed by EPA method 8141A using a gas chromatograph with a nitrogen-phosphorous detector. Detections were confirmed on a second column with a different phase. With method 8081A the laboratory was capable of quantifying detections of most chlorinated organic compounds at 0.05 µg/L (50 parts per trillion, as 1 µg/L equals one part per billion). Methoxychlor and Toxaphene had higher Practical Quantitation Limits (PQLs) of 0.1 µg/L and 2 µg/L, respectively. The PQL is the lowest concentration at which the laboratory can reliably determine chemical concentration. The PQL for the OP compounds and triazine herbicides analysed by Method 8141A was determined to be 2 µg/L. All samples were extracted using EPA method 3520, a continuous liquid-liquid extraction technique. Under optimum conditions, the initial sample volume was one liter and final sample extract volume was 5 mL. Less initial volume resulted in proportionally higher reporting limits.

In early 2004 discussions between the Regional Board and agricultural representatives were taking place as the Regional Board was formulating early drafts of the Conditional Ag Waiver. It became evident that the detection levels obtainable using EPA methods 8081A and 8141A were substantially higher than water quality objectives for some of the pesticides and herbicides being assessed. In order to achieve lower detection limits analytical methods were switched to EPA method 8270 for all compounds except Toxaphene, which continued to be analyzed with EPA method 8081A (but with improved detection limits). EPA method 8270, and method 8081A for Toxaphene, were approved for use and integrated into the QAPP for this project. EPA method 8270 analyzed organic compounds by gas chromatography/mass spectrometry (GC/MS) and was used to analyze both the liquid and solid phases of stormwater samples. Method 8081A was used to analyze for Toxaphene both in solution and as bonded to sediments. The PQLs for both methods are presented in Table 2.

Table 2. List of study analytes, analytical methods, and method PQLs

Chlorinated Pesticides	EPA method	PQL
Liquid Phase		
Aldrin, alpha-BHC, beta-BHC, delta-BHC, gamma-BHC, alpha-Chlordane, gamma-Chlordane, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, Dieldrin, Endrin, Endrin aldehyde, Endrin ketone, Endosulfan I, Endosulfan II, Endosulfan sulfate, Heptachlor, Heptachlor epoxide, and Methoxychlor	8270	0.010 µg/L
Toxaphene	8081A	0.4 µg/L
Solid Phase		
Aldrin, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT	8270	5 µg/kg
alpha-BHC, beta-BHC, delta-BHC, gamma-BHC, alpha-Chlordane, gamma-Chlordane, Dieldrin, Endrin, Endrin aldehyde, Endrin ketone, Endosulfan I, Endosulfan II, Endosulfan sulfate, Heptachlor, Heptachlor epoxide, and Methoxychlor	8270	3 µg/kg
Toxaphene	8081A	200 µg/kg
Organophosphate Pesticides (including Triazine Herbicides)		
Liquid Phase		
Atrazine, Azinphos Methyl, Chlorpyrifos, Diazinon, EPN, Mevinphos, Parathion Methyl, Phorate, Simazine, Sulfotepp, and Thionazin	8270	0.050 µg/L
Demeton-O, Demeton-S, Dimethoate, Malathion, Naled, Parathion ethyl, and Disulfoton	8270	0.100 µg/L
Solid Phase		
Atrazine, Chlorpyrifos, Demeton-O, Demeton-S, Diazinon, EPN, Parathion Methyl, Parathion ethyl, Phorate, Simazine, Sulfatepp, and Thionazin	8270	5 µg/kg
Azinphos Methyl, Dimethoate, Malathion, Mevinphos, Naled, and Disulfoton	8270	100 µg/kg

2.5 WATER QUALITY SAMPLING

A baseline data set was compiled by measuring conditions present at field sites at the onset of the project, prior to implementation of BMPs. A minimum of six samples were collected and analyzed from each field site. Runoff samples were collected during three storms. The first storm event occurred on February 25th 2004, and collection and analyses of samples was funded by the PRISM grant. The PRISM grant did not include an assessment of pesticides and herbicides in the solid phase or nitrogen compounds. Results for this event only included analyses of pesticides and herbicides in the liquid phase for samples collected from 34 of the 43 mutual field sites. Two additional storm events were monitored at all other field sites on December 28th 2004 and February 21st, 2005. Analyses for these events included pesticide and herbicide concentrations in the liquid and solid phases of the stormwater samples, as well as an analysis of the nitrogen compounds; ammonia, TKN, and nitrate plus nitrite. Lysimeters at the field sites were

sampled a total of four times each before the implementation of BMPs. Soil moisture samples collected from lysimeters placed at 1 and 6 foot depths were analyzed for the nitrogen compounds, and soluble pesticides and herbicides were analyzed in soil moisture samples collected from just below the root zone. Where available tile drains were sampled concurrently with lysimeters and samples were also analyzed for the nitrogen compounds and soluble pesticides and herbicides.

2.6 SELECTION OF BMPS

The original proposal for this project presented plans to test a wide range of BMPs related to agricultural inputs and outputs. Input practices, or “front end” practices, include management strategies that would result in changes to pesticide and herbicide applications. Output practices, or “back-end” practices, pertain to management strategies that address transport of substances off of the agricultural field. During review of the QAPP, William Ray, the Project Representative of the SWRCB requested that all pesticide and herbicide application practices remain constant and only “back-end” practices be modified. Therefore, the only type of management practices that were tested in this study were BMPs that addressed soil erosion, and soil or water retention. The BMPs that were installed and assessed included mulch, cover crops, filter strips, grassed ditches and polyacrylamide cakes.

As mentioned previously, project sites were selected from a number of properties offered as available by the land owner. Key selection criteria included the surface water drainage patterns on the sites, the ability to safely sample stormwater runoff, and a preference for sites with subsurface drainage systems. It is noteworthy that many of the sites selected for inclusion in the study already had a number of BMPs in place. Existing BMPs commonly included precision irrigation equipment such as drip tape or micro sprinklers, with the systems designed to emit water at appropriate rates. Drainage structures to channel water and curtail soil erosion are also common, and include features such as grading improvements, terracing, drainage pipes, culverts, drop structures, and lined ditches. Orchard sites often have some amount of mulch or cover crop, be it leaf litter, weeds, grasses, branch cuttings, or imported woody mulch. BMPs for this study were implemented in addition to existing improvements, and the baseline data set samples were not often from bare ground with no existing BMPS.

A crop advisor from FGL Environmental and UWCD staff met with each participating grower to review baseline data and site characteristics and discuss appropriate BMPs for each site. With guidance from the crop advisor and UWCD staff, each grower chose a BMP appropriate for their field site and agricultural operation. This project relied on voluntary participation from individual growers and each grower was responsible for funding, implementing, and maintaining BMPs in their field sites. The BMP selection meetings were held in fall of 2005, and BMPs were in place at 36 sites for stormwater sampling in winter of 2006. Additional BMP implementations occurred throughout the year, and BMPs were in place at 46 of the original 60 field sites by winter of 2007. In winter 2007 certain sites were not sampled for the following reasons: four field sites had been withdrawn from the study, two row crops were leased to new operators and

although baseline conditions continued to be monitored, no BMPs were implemented, baseline results at three avocado field sites showed additional BMP installations were not required, and growers at the remaining five sites did not follow through with their commitment to install selected BMPs.

2.6.1 Mulch

Mulch was implemented at five citrus sites, one of which was implemented in conjunction with wattles (Figure 6), and one application was to a dirt roadway adjacent to an avocado grove. In general, mulch was obtained from greenwaste programs. Typically, implementation required hiring a hauling company to deliver the mulch to the site and using a spreader to distribute mulch throughout the field. In one case, an older lemon crop had been removed from an adjacent area, and the material was shredded and spread throughout the ranch (Figure 7). Citrus sites often have some mulch present as a ground cover due to the common practice of leaving tree cuttings on site. Sometimes the cuttings are mechanically shredded and other times they are simply left where they fall and worn down as equipment passes through the rows. Mature avocado sites commonly have abundant natural mulch from the large amounts of leaf material that accumulates on the ground below the tree canopies. Younger orchards often have leaf accumulation beneath the trees, but more bare ground often exists in young orchards as the tree canopy offers less aerial coverage.



Figure 6. Greenwaste mulch used in conjunction with a wattle filter strip



Figure 7. Mulch at a citrus site. The mulch was composed of shredded material from an old citrus orchard that was being removed and replaced.

2.6.2 Cover Crops

Three cover crops were implemented and assessed as part of this project. In addition, several cover crops were already present at field sites when the study began, and were included in the baseline water quality assessment. In the case that the cover crop was an established baseline BMP, other management practices were implemented to work in conjunction with the existing cover crop. All existing cover crops were located in citrus fields. In general, cover crops were composed of cereal grain grasses (such as barley or rye, as shown in Figure 8), or fescue. Often growers allow the cover crop to go to seed and then mow it and leave cuttings in place to provide seed for the following year (Figure 9). In some cases cover crops were simply weeds that had not been sprayed or removed (Figure 10).



Figure 8. Barley cover crop in a citrus orchard



Figure 9. Cover crop that has been mowed and left on site to reseed for the next year's crop



Figure 10. Cover crop composed of mowed weeds implemented in conjunction with a wattle at the end of the row

2.6.3 Filter Strips

The main purpose of filter strips is to remove entrained sediment from surface flows. With this practice sediments are removed by a filtering process during lower flow regimes as water passes through the filter strip. Under higher flow regimes, filter strips serve to slow surface flows, allowing sediment to settle out from the water column in areas near the filter strip. The type of filter strips assessed in this study included vegetative filter strips and wattles, which consist of straw rolls or tubular bundles of straw wrapped in netting. Filter strips were installed at 30 of the project field sites.

At nine field sites, strips of sod (fescue variety) were placed in the terminus drainage ditch of the field, perpendicular to the flow of drainage (Figure 11). The earth below the sod was scraped away so that the sod was installed flush with the drainage surface. When possible, nearby irrigation lines were extended to allow for water to reach the sod (Figure 12). The sod was anchored in place using bent rebar (in a configuration similar to an unused staple). The strips of sod were positioned at the end of rows where they would not be subjected to compression from tractor tires. It was important to mark the installations with stakes requesting that they were not disturbed (preferentially in both English and Spanish, as some earlier installations were removed by weeding crews). This type of grassed filter strip was installed at three strawberry sites, three row crops, two sod sites, and one avocado orchard.

Wattles were used in a variety of ways at twenty-three field sites; four were installed in strawberry fields, three in row crops, five in avocado orchards, eleven in citrus orchards, and two in sod fields. Some of these applications were in addition to other BMPs. A few sites installed wattles for the first year of post-BMP monitoring, and switched to other management practices for the second year of post-BMP monitoring. In strawberry and row crops, wattles were generally positioned in the terminus drainage ditch,

perpendicular to flow in the drainage (Figure 13). Because space was not as limited in orchard settings, applications varied from strips across drainage channels, to a series of strips positioned radially around a drainage structure (Figure 14).



Figure 11. Grassed filter strip composed of a series of strips of sod place in a drainage ditch perpendicular to the flow of discharge



Figure 12. Grassed filter strip installation. Where available, irrigation lines were extended to provide water to the grass



Figure 13. Wattle filter strip placed in a ditch at a strawberry site



Figure 14. Wattles placed radially around a drainage structure

2.6.4 Grassed Ditch

Grass was planted in drainage ditches at three field sites used for the production of alternating crops of strawberries and row crops (Figure 15). This BMP was chosen as a second iteration after a year of using wattle filter strips. The grower valued the rapid drainage of surface water, and was displeased with areas of back-ponding the extended into some furrows. The grass seed was planted in the fall of 2006, and the only post-BMP sampling occurred in the winter of 2007. It should be noted that 2007 was a very dry year, and irrigation of established strawberry crops does not produce runoff. The ditches where the grass was planted were relatively dry and some grassed ditches did not have robust growth present.



Figure 15. Grassed drainage ditch at a strawberry field site

2.6.5 Polyacrylamide Cakes

Polyacrylamide (PAM) is a synthetic water-soluble polymer made from monomers of acrylamide. The three most common forms of PAM are dry granules, solid blocks (cakes), and emulsified liquids. PAM acts to bind suspended sediment particles together so that the larger, heavier aggregates of soil particles settle out of the water column. PAM was not one of the BMPs originally proposed for use in this project.

A participating grower in the project chose to implement PAM cakes in a collector ditch to test if they could reduce suspended sediment from surface water prior to discharge from his property. The PAM cakes were suspended in a canvas bag in the collector ditch (Figure 16). The polyacrylamide cakes were placed in the ditch the day before the storm was expected and removed after the storm had passed.



Figure 16. Polyacrylamide cakes where placed in a canvas bag and anchored in a drainage ditch

2.6.6 Improvements to Drainage Structures

Improvements were made to drainage structures at seven of the project field sites. Sandbags were installed to stabilize drainage structures at three field sites, and served to reinforce earthen banks in areas of water flow and ponding (Figure 17). A new drainage structure was built at a citrus site where drainage from an orchard had previously traveled over a dirt road, causing significant erosion problems (Figure 18). At three sites used for growing strawberries and row crops, a grower placed sandbags within and around drainage ditches to preserve the grade of the ditches and prevent downward cutting by erosion. For the first year of monitoring, he had implemented wattles in the ditches, but felt that the wattles slowed the drainage too much, and resulted in ponding within the furrows. In general, strawberry production practices prioritized moving water out of the fields as quickly as possible. Efficient drainage is a priority for all growers in areas with little slope. For the second year of monitoring the drainage was reinforced throughout the field as shown in Figure 19, and grass was planted in the main collector ditches outside of the planted areas.



Figure 17. Sandbags used to stabilize a drainage structure



Figure 18. New drainage structure built where runoff had previously traveled over a dirt road



Figure 19. Sandbags used to reinforce sensitive areas in a drainage ditch, preventing downward cutting and changes to site grading

2.7 POST-BMP WATER QUALITY SAMPLING

Originally, the project plan was to assess BMPs by comparing post-BMP sample results to the baseline data set. As the project evolved, it became evident that the variability associated with parameters that effect liquid and solid phase chemical transport during storm events (precipitation intensities, antecedent soil moisture, changing physical conditions at the field sites, etc.) did not allow for a reliable comparison between grab samples from sequential storms. Rather than comparing baseline results to post-BMP results, additional sampling procedures were adopted to allow for collection of comparable samples that were representative of site conditions both upstream and downstream of the BMP. In the interim, post-BMP samples continued to be collected and analyzed for the pesticides, herbicides, and nutrients as outlined in the original project plan.

As discussed in Section 2.6 (Selection of BMPs), only back-end BMPs were implemented for testing in this study. Back-end BMPs were designed to retain soil at the field sites and in general, did not impact soil water collected in lysimeters or subsurface drainage collected from tile drains. Therefore, data from stormwater runoff samples provided the only quantitative indicators of the efficiency of the various management practices being tested.

Results from early stormwater sampling events revealed that the highest concentration of pesticides and herbicides are moving off agriculture fields in the solid phase, and liquid phase concentrations are much lower. The respective volumes of solids and water associated with these concentrations were not determined. This observation correlates with the fact that most of the constituents assessed in this study have a tendency to sorb to soil particles and organic matter. In an attempt to obtain a better characterization of the effectiveness of newly-implemented management practices, measurement of Total Suspended Solids (TSS) were employed to assess the efficiency of BMPs at reducing sediment in stormwater discharge from field sites. TSS measured in surface water samples collected from above BMP installations was compared to TSS in water samples collected from areas below the BMP (and sampled immediately before the upstream sample). In situations where the above/below method would not work (for instance the application of mulch to 3 rows in an orchard), a side-by-side approach was used. A sample collected from a ditch below a BMP was compared to a sample collected from a “like” area without a BMP (in the same example, from another row that did not have mulch applied). In some cases, neither the above/below or side-by-side methods were applicable (for instance mulch applied to the entire orchard). In this situation, samples were collected from below the BMP and compared to baseline results if a comparison was feasible.

2.7.1 First year of BMP assessment

In the winter of 2005-2006, BMPs were monitored at field sites during 2 storm events (February 27th 2006, and March 28th 2006). Where possible, samples were collected as discussed above using the above/below or side-by-side method. In addition to the measurement of TSS, all samples collected during the February event were analyzed for the full pesticide and herbicide suites. The hypothesis was that the concentrations of pesticides and herbicides in both the liquid and solid phases would remain similar above and below BMPs, but that the TSS, a measure of the entrained sediment, would be lower below the BMP than above the BMP. The pesticide and herbicide analyses are relatively expensive and the results were not available by the time the second storm occurred. For the March sample event, TSS was analyzed for all samples (above/below and side-by-side BMPs) but the pesticide and herbicide suites were analyzed for samples collected below the BMPs only.

2.7.2 Second year of BMP assessment

Unfortunately, the last year that the study was conducted (2006-2007) was very dry for Ventura County, and did not allow many opportunities for stormwater sampling. As of May 2007, the rain year was one of the driest on record for Ventura County since precipitation data collection officially began in the 1890s. The sample team mobilized for sampling on February 22nd, 2007, but a single band of precipitation moved quickly across the study area and the rest of the storm dissipated as it moved onshore. Runoff was not observed at any of the sites during the February storm. Another rainfall event occurred on April 20th, 2007. This storm was also relatively short in duration, but produced approximately an inch of rain on the Oxnard plain, and about a third of an inch

further inland in the Arroyo Las Posas area. All sites with implemented BMPs (46 total sites) were monitored throughout the storm and runoff was sufficient for sampling at 12 field sites. TSS samples were collected at sites with adequate runoff (for above/below and side-by-side BMP comparisons) and the pesticide, herbicide, and nitrogen suites were analyzed from samples collected below the BMPs.

Qualitative assessments were made by visual observations of conditions at the field sites before storm events, during storm runoff, and after storm events. A number of photographs were taken to provide documentation of BMP installations before, during and after winter storms. Lysimeters (and tile drains where available) installed at field sites were sampled a minimum of six times during the post-BMP period.

3. RESULTS

3.1 PESTICIDE AND HERBICIDE DETECTION SUMMARIES

This section presents analytical results obtained during the sampling of field sites over the duration of the study. Toxicity criteria for some chemicals analyzed as part of this study are reported at very low concentrations (see Section 4.4 Toxicity Discussion). Laboratory methods and sample volumes were selected to consistently produce the lowest detection levels attainable by the local commercial laboratory that served as a partner in this study. These methods are described in the project QAPP and summarized in the Methods section of this report. The anticipated Practical Quantitation Limit (PQL) and Method Detection Limit (MDL) of all analytes were published in the QAPP. The PQL is defined as the lowest concentration that can be determined from a single analysis, with a defined level of confidence. The MDL concentration is less than the PQL. The MDL is the minimum concentration of an analyte that can be reported with 99 percent confidence that the concentration is greater than zero. For chemical detections reported between the PQL and the MDL there is less certainty associated with the reported concentration, but there is high confidence that the chemical was detected at some concentration greater than the MDL.

A summary of the actual PQLs and MDLs reported for all liquid phase sample analyses are shown in Table 3.

Table 2 (in Section 2.4 Laboratory Analyses) displays the suite of chlorinated pesticides evaluated as part of this study. In the first season of sampling the companion PRISM study used EPA method 8081A for chlorinated pesticide analyses. Sample analysis was switched to EPA method 8270, resulting in lower laboratory PQLs and method detection levels. The reported PQLs for most chlorinated compounds dropped from 0.050 µg/L under method 8081A to 0.010 µg/L using method 8270. Corresponding MDLs were reported as low as 0.001 µg/L (1 ng/L, or one part per trillion). With the exception of Toxaphene, the average MDLs for all chlorinated compounds are 0.010 µg/L or less. The PQLs and MDLs reported for Toxaphene are considerably higher, averaging 0.522 µg/L and 0.316 µg/L, respectively.

A summary of the values and counts of chlorinated pesticide detections below the method PQL is shown in Table 4. This table is based on detections reported at concentrations below the PQL but above the MDL. The table also shows the number of detections for each compound at a concentration greater than the PQL. This table shows that some compounds were detected only at very low concentration (below the PQL), while others recorded many detections above the PQL, where the actual concentration is reported with greater certainty. In the tables and figures of this chapter reporting chemical detections by crop and sample type, all detections are shown without differentiating between those above and below the PQL.

In addition to the liquid phase analysis of stormwater samples, the chemistry of solids entrained in stormwater runoff was evaluated when possible. Despite the collection of two liters of water for stormwater samples, a number of samples had very limited weights of suspended sediment. Sediment weights of approximately ten grams were required for chemical analysis. If less sediment was available from the stormwater sample, dilution factors affected the PQL and MDL of the analysis. If less than approximately one gram of sediment was available, sample analysis was considered impractical.

Table 3. Practical quantitation and method detection limits, all liquid phase chlorinated pesticide results

	Units	PQL			MDL			Count
		Maximum	Minimum	Average	Maximum	Minimum	Average	
4,4 - DDD	ug/L	0.050	0.010	0.013	0.011	0.002	0.002	965
4,4 - DDE	ug/L	0.050	0.010	0.013	0.010	0.002	0.002	965
4,4 - DDT	ug/L	0.100	0.010	0.013	0.015	0.003	0.003	958
Aldrin	ug/L	0.050	0.010	0.013	0.014	0.004	0.004	870
Alpha BHC	ug/L	0.050	0.010	0.013	0.008	0.002	0.002	898
alpha-Chlordane	ug/L	0.050	0.005	0.013	0.009	0.002	0.002	964
Beta BHC	ug/L	0.050	0.010	0.012	0.011	0.002	0.002	932
Chlordane	ug/L	0.050	0.010	0.044	0.005	0.005	0.005	48
Delta BHC	ug/L	0.050	0.010	0.013	0.015	0.003	0.006	771
Dieldrin	ug/L	0.050	0.005	0.013	0.038	0.005	0.010	886
Endosulfan I	ug/L	0.050	0.010	0.013	0.024	0.004	0.007	946
Endosulfan II	ug/L	0.050	0.010	0.013	0.024	0.004	0.005	935
Endosulfan Sulfate	ug/L	0.100	0.010	0.013	0.015	0.006	0.007	856
Endrin	ug/L	0.050	0.010	0.013	0.011	0.003	0.003	967
Endrin Aldehyde	ug/L	0.050	0.010	0.013	0.034	0.003	0.009	803
Endrin Ketone	ug/L	0.050	0.010	0.013	0.014	0.002	0.003	781
Gamma BHC (Lindane)	ug/L	0.050	0.010	0.013	0.010	0.003	0.003	640
gamma-Chlordane	ug/L	0.050	0.010	0.013	0.006	0.001	0.002	967
Heptachlor	ug/L	0.050	0.005	0.013	0.024	0.004	0.006	971
Heptachlor Epoxide	ug/L	0.050	0.010	0.013	0.010	0.002	0.003	930
Methoxychlor	ug/L	0.400	0.005	0.021	0.017	0.002	0.002	968
Toxaphene	ug/L	5.000	0.400	0.522	0.970	0.200	0.316	966

Table 4. Liquid phase chlorinated pesticide detection summary for values below the PQL

	Units	Detects below PQL				Detects above PQL	
		Minimum	Maximum	Average	Count	Count	
4,4 - DDD	ug/L	0.004	0.038	0.018	5	24	
4,4 - DDE	ug/L	0.003	0.049	0.014	42	131	
4,4 - DDT	ug/L	0.003	0.045	0.013	41	148	
Aldrin	ug/L	0.009	0.009	0.009	1	2	
Alpha BHC	ug/L	0.005	0.007	0.006	2		
alpha-Chlordane	ug/L	0.002	0.015	0.007	14	22	
Beta BHC	ug/L	0.004	0.008	0.006	4		
Delta BHC	ug/L	0.004	0.005	0.004	3	1	
Dieldrin	ug/L	0.005	0.028	0.013	4	2	
Endosulfan I	ug/L	0.004	0.005	0.005	2		
Endrin	ug/L	0.007	0.009	0.008	6	4	
Endrin Ketone	ug/L	0.008	0.008	0.008	1	3	
Gamma BHC (Lindane)	ug/L	0.005	0.009	0.007	4		
gamma-Chlordane	ug/L	0.002	0.010	0.006	24	14	
Heptachlor	ug/L	0.004	0.011	0.007	10	1	
Heptachlor Epoxide	ug/L	0.004	0.008	0.006	4	1	
Methoxychlor	ug/L	0.007	0.022	0.012	8	7	
Toxaphene	ug/L	0.600	0.600	0.600	1	24	
Endrin Aldehyde						1	

A summary of chlorinated solid phase PQLs and MDLs for stormwater analyses are shown in Table 5. PQLs range from approximately one to 300 µg/kg for many of the chlorinated compounds, with PQLs as high as 500 µg/kg reported for DDT and its

derivatives. This high variability in the PQL is largely related to limited sediment quantities entrained in a number of stormwater samples. With the notable exception of Toxaphene, the average MDL reported for most compounds is less than 6 µg/kg. MDLs for solid-phase analyses are commonly three orders of magnitude greater than for the corresponding liquid-phase analysis.

Table 6 displays a summary of reported solid-phase detections at concentrations below the PQL. As with the liquid-phase detections, there are a number of compounds for which all detections were recorded below the PQL. Detections for Toxaphene and gamma-Chlordane were reported below the PQL more often than above the PQL. DDD and alpha-Chlordane detections were reported below the PQL nearly as often as above the PQL.

Table 5. Practical quantitation and method detection limits, all solid phase chlorinated pesticide results

	Units	PQL			MDL			Count
		Maximum	Minimum	Average	Maximum	Minimum	Average	
4,4 - DDD	ug/kg	500	1.20	35.86	25	0.11	2.63	209
4,4 - DDE	ug/kg	500	1.20	41.16	15	0.07	1.56	209
4,4 - DDT	ug/kg	500	1.20	36.59	37	0.16	3.82	209
Aldrin	ug/kg	300	1.20	30.05	15	0.07	1.55	210
Alpha BHC	ug/kg	300	0.69	21.53	14	0.06	1.50	209
alpha-Chlordane	ug/kg	300	0.69	21.39	32	0.14	3.31	209
Beta BHC	ug/kg	300	0.69	21.53	18	0.08	1.88	209
Delta BHC	ug/kg	300	0.69	20.77	20	0.09	2.05	143
Dieldrin	ug/kg	300	0.69	21.59	57	0.25	5.90	188
Endosulfan I	ug/kg	300	1.30	23.95	37	0.31	5.19	209
Endosulfan II	ug/kg	300	0.69	21.76	110	0.51	11.81	169
Endosulfan Sulfate	ug/kg	300	0.69	22.01	18	0.08	2.01	185
Endrin	ug/kg	300	0.69	21.99	110	0.51	11.81	188
Endrin Aldehyde	ug/kg	300	0.69	22.79	40	0.18	4.74	196
Endrin Ketone	ug/kg	300	0.69	21.41	43	0.19	4.47	208
Gamma BHC (Lindane)	ug/kg	300	0.69	21.65	16	0.07	1.69	209
gamma-Chlordane	ug/kg	300	0.69	21.41	22	0.10	2.31	208
Heptachlor	ug/kg	300	0.69	21.53	9.8	0.04	1.02	209
Heptachlor Epoxide	ug/kg	300	0.69	21.65	30	0.13	3.12	209
Methoxychlor	ug/kg	300	0.69	23.50	31	0.14	3.22	209
Toxaphene	ug/kg	310000	46.00	9910.80	820	12.00	252.12	208

Table 6. Solid phase chlorinated pesticide detection summary for values below the PQL

	Units	Detects below PQL				Detects above PQL	
		Minimum	Maximum	Average	Count	Count	
4,4 - DDD	ug/kg	2.02	16.3	11.00	6	8	
4,4 - DDE	ug/kg	2.8	272	32.81	30	91	
4,4 - DDT	ug/kg	2.1	96	27.57	25	70	
alpha-Chlordane	ug/kg	1.21	17.3	6.62	14	20	
Endosulfan I	ug/kg	25.8	25.8	25.80	1		
Endosulfan Sulfate	ug/kg	3.1	3.1	3.10	1		
gamma-Chlordane	ug/kg	0.91	23	6.91	25	21	
Methoxychlor	ug/kg	9.4	9.4	9.40	1		
Toxaphene	ug/kg	61	1101	299.33	18	7	
Dieldrin	ug/kg					1	
Heptachlor Epoxide	ug/kg					1	

The ranges of PQLs and MDLs for liquid phase organophosphate and triazine herbicide analyses are summarized in Table 7. As with the chlorinated compounds, the high values reported for the maximum PQLs for these compounds are from the earliest samples collected for the PRISM study. The switch from EPA method 8141A to method 8270 resulted in much lower detections for the OP and triazine compounds. Following the switch to method 8270, PQLs for the organophosphates and triazines were reported at either 0.050 or 0.100 µg/L for these compounds. The range of MDLs for liquid phase organophosphate pesticides and triazine herbicides are also shown in Table 7. The average MDL was 0.040 µg/l or less for most of these compounds. Comparison of Table

3 and Table 7 shows that the detection levels provided by method 8270 are lower for most chlorinated pesticides than they are for the organophosphates and triazines.

Table 8 displays the range of organophosphate and triazine chemical detections reported below the Practical Quantitation Limit. A number of the compounds listed in Table 7 were never detected, and others such as Mevinphos were never detected above the PQL. Chlorpyrifos was the OP pesticide detected most frequently in this study, and 25 of 92 detections were below the PQL. For the triazine herbicide Simazine, 28 of 46 detections were reported below the PQL.

Table 7. Practical quantitation and method detection limits, all liquid phase organophosphate pesticide and triazine herbicide results

	Units	PQL			MDL			Count
		Maximum	Minimum	Average	Maximum	Minimum	Average	
Atrazine	ug/L	0.250	0.050	0.055	0.056	0.014	0.015	909
Azinphos Methyl	ug/L	2.000	0.050	0.181	0.022	0.006	0.006	662
Chlorpyrifos	ug/L	2.000	0.050	0.145	0.084	0.021	0.023	929
Demeton-O	ug/L	0.500	0.100	0.109	0.270	0.067	0.073	713
Demeton-o,s	ug/L	2.000	2.000	2.000				43
Demeton-S	ug/L	0.500	0.100	0.109	0.150	0.037	0.040	760
Diazinon	ug/L	2.000	0.050	0.148	0.110	0.028	0.031	889
Dimethoate	ug/L	2.000	0.100	0.201	0.056	0.014	0.015	887
Disulfoton	ug/L	2.000	0.100	0.205	0.140	0.035	0.038	856
EPN	ug/L	2.000	0.050	0.144	0.025	0.006	0.007	935
Malathion	ug/L	2.000	0.100	0.199	0.026	0.007	0.007	908
Mevinphos	ug/L	2.000	0.050	0.145	0.035	0.009	0.010	922
Naled	ug/L	2.000	0.100	0.201	0.140	0.034	0.037	883
Parathion	ug/L	2.000	0.010	0.174	0.084	0.021	0.023	966
Parathion Methyl	ug/L	2.000	0.050	0.141	0.190	0.047	0.051	966
Phorate	ug/L	2.000	0.050	0.155	0.080	0.020	0.022	839
Ronnel	ug/L	2.000	0.050	0.141	0.068	0.017	0.019	966
Simazine	ug/L	0.500	0.050	0.055	0.100	0.026	0.028	915
Sulfotepp	ug/L	2.000	0.050	0.144	0.038	0.010	0.010	930
Thionazin	ug/L	2.000	0.050	0.144	0.072	0.018	0.020	940

Table 8. Liquid phase organophosphate pesticide and triazine herbicide detection summary, values below PQL

	Units	Detects below PQL				Detects above PQL	
		Minimum	Maximum	Average	Count	Count	
Atrazine	ug/L	0.017	0.079	0.040	4	4	
Chlorpyrifos	ug/L	0.021	0.068	0.034	25	92	
Diazinon	ug/L	0.041	1.100	0.402	3	2	
Dimethoate	ug/L	0.610	0.610	0.610	1	9	
EPN	ug/L	0.030	0.030	0.030	1	7	
Malathion	ug/L	0.025	1.170	0.449	3	5	
Mevinphos	ug/L	0.012	0.043	0.030	4		
Parathion	ug/L	0.028	0.028	0.028	1	1	
Ronnel	ug/L	0.036	0.036	0.036	1	2	
Simazine	ug/L	0.027	0.068	0.039	28	46	
Azinphos Methyl	ug/L					6	
Demeton-O	ug/L					1	
Parathion Methyl	ug/L					3	

The graphical displays of sample results appearing later in this section are based on reported detections above the MDL for individual samples. In the reporting range between the PQL and the MDL there is less confidence in the actual concentration reported for each analyte. However, there is a high degree of confidence that the presence of the chemical was detected. Chemical concentrations reported between the PQL and MDL are not differentiated from other detections (above the PQL) in the plots and tables within this section.

A summary of PQLs and MDLs for solid phase evaluations of organophosphate pesticides and triazine herbicides in stormwater samples is shown in Table 9. As with the chlorinated compounds, reported Practical Quantitation Limits are much higher in the solid phase than in the liquid phase, and range from 1.20 to 500 µg/kg for many compounds. This range of PQLs is largely related to limited sediment weights present in some of the stormwater samples. The compounds Azinphos Methyl, Dimethoate, Disulfoton, Mevinphos and Naled reported PQLs and MDLs higher than the other compounds. The elevated PQLs and reduced count of sample results for these compounds suggest that the laboratory had difficulty with the analyses for these particular compounds.

Solid phase detections of organophosphate pesticides and triazine herbicides below the PQL are summarized in Table 10. Chlorpyrifos is the only OP compound frequently reported at concentrations less than the PQL. Simazine was detected in 23 percent of the sediment samples from stormwater, but only two detections are reported below the method PQL.

Table 9. Practical quantitation and method detection limits, all solid phase organophosphate pesticide and triazine herbicide results

	Units	PQL			MDL			Count
		Maximum	Minimum	Average	Maximum	Minimum	Average	
Atrazine	ug/kg	300	0.69	21.53	17	0.08	1.77	209
Azinphos Methyl	ug/kg	5200	23.00	537.17	5200	23.00	537.17	92
Chlorpyrifos	ug/kg	500	1.20	36.28	62	0.28	6.45	209
Demeton-O	ug/kg	500	1.20	35.49	52	0.23	5.37	169
Demeton-S	ug/kg	500	1.20	35.06	18	0.08	1.88	162
Diazinon	ug/kg	500	1.20	37.43	62	0.28	6.57	209
Dimethoate	ug/kg	5200	23.00	548.96	5200	23.00	548.96	89
Disulfoton	ug/kg	5200	23.00	604.67	5200	23.00	604.67	92
EPN	ug/kg	500	1.20	35.86	120	0.55	12.85	209
Malathion	ug/kg	500	1.20	37.32	93	0.41	10.89	209
Mevinphos	ug/kg	5200	23.00	537.17	5200	23.00	537.17	92
Naled	ug/kg	5200	23.00	537.17	5200	23.00	537.17	92
Parathion	ug/kg	500	0.50	33.79	130	1.10	14.30	209
Parathion Methyl	ug/kg	500	1.20	36.25	190	0.83	19.88	206
Phorate	ug/kg	500	1.20	35.99	49	0.22	5.06	208
Ronnel	ug/kg	500	1.20	35.86	19	0.09	1.99	209
Simazine	ug/kg	500	1.20	35.86	32	0.14	3.29	209
Sulfotepp	ug/kg	500	1.20	35.86	72	0.32	7.52	209
Thionazin	ug/kg	500	1.20	36.06	88	0.39	9.30	209

Table 10. Solid phase chlorinated pesticide detection summary for values below the PQL

Detects below PQL						Detects above PQL
	Units	Minimum	Maximum	Average	Count	Count
Atrazine	ug/kg	3.70	3.70	3.70	1	4
Chlorpyrifos	ug/kg	3.90	53.00	17.91	22	92
Diazinon	ug/kg	9.30	9.60	9.45	2	2
Simazine	ug/kg	4.20	8.20	6.20	2	46
Sulfotepp	ug/kg	46.00	46.00	46.00	1	
Azinphos Methyl	ug/kg					6
Demeton-O	ug/kg					1
Dimethoate	ug/kg					9
EPN	ug/kg					7
Malathion	ug/kg					5
Parathion	ug/kg					1
Parathion Methyl	ug/kg					3
Ronnel	ug/kg					2

3.1.1 Lysimeter Samples

Detection summaries for lysimeter samples are detailed in this section. The following plots display chemical results for all lysimeter samples from this study, and tables are used to summarize detections by crop classification. The number of samples noted in the detection summaries are based on the total number of samples collected for which analytical results were returned from the laboratory. In the rare event that lab analysis was not successful, the sample was not counted in this total. If a sample was not obtained during a field visit due to dry soil conditions or other difficulties, these unproductive attempts at sample collection are not considered in the following summaries. Figures and tables are grouped by two classes of chemicals, the chlorinated pesticides and organophosphate pesticides analyzed initially by EPA methods 8081A and 8141A, and later by EPA method 8270. The triazine herbicides Simazine and Atrazine are grouped with the organophosphate pesticides.

All lysimeter detections of chlorinated pesticides are summarized in Figure 20. Chemicals are sorted by the number of detections. The range of detected values, along with the average concentration, are plotted on the y-axis in log scale. The minimum concentrations shown reflect the sensitivity of the analytical methods employed at the laboratory, and does not suggest that lower concentrations of these chemicals are not present in the field. The standard deviation is shown only in excess of the average, as the log scale often does not allow a plot of the standard deviation below the mean. Standard deviation is plotted as a horizontal tick. This plotting convention is used for all graphs in this section.

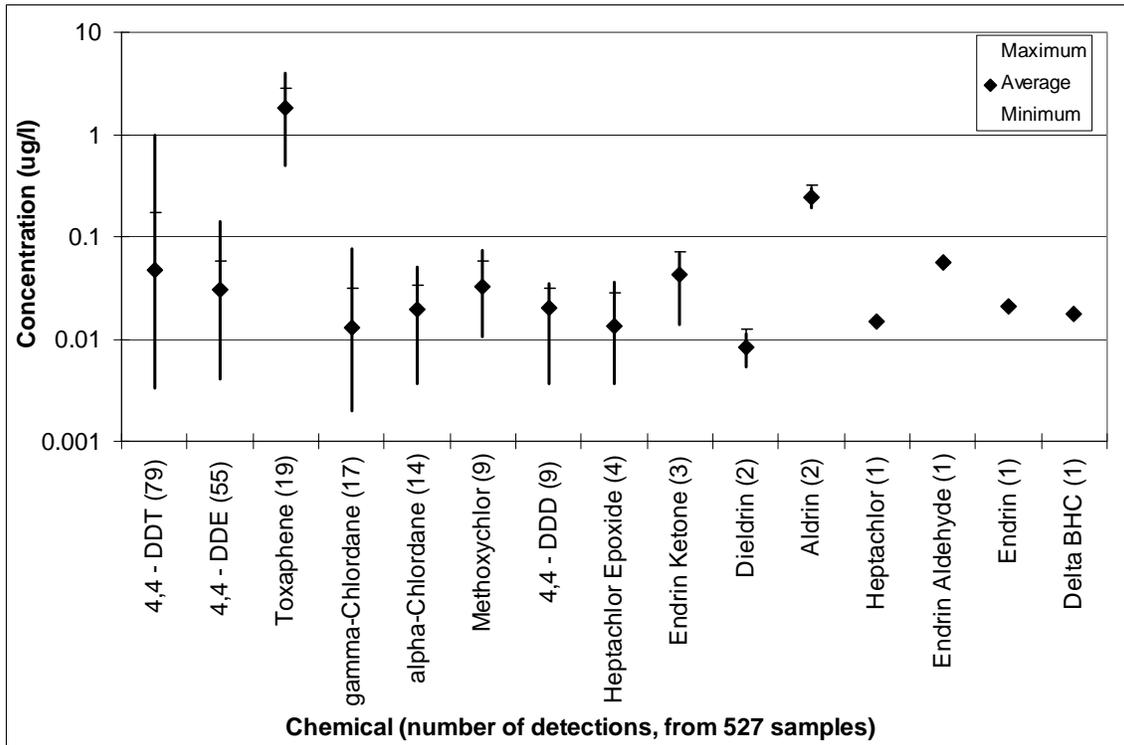


Figure 20. Liquid phase chlorinated pesticide detections, lysimeter samples

DDT and DDE were the chlorinated pesticides detected most-frequently in soil moisture collected from lysimeters at field sites (Figure 20). With the exception of Toxaphene and the rare detections of several other compounds, DDT and DDE also recorded the greatest maximum and average concentrations in soil moisture of the shallow subsurface. Toxaphene was detected in 19 of the 390 lysimeter samples. The laboratory detection level for Toxaphene is higher than that of the other chlorinated pesticides. The higher concentrations recorded for Toxaphene suggest that it would be detected in additional samples (at lower concentrations) if detection levels were similar to that of the other compounds. Gamma-chlordane and alpha-Chlordane were recorded in approximately three percent of the samples, at concentrations less than 0.1 parts per billion. Ten other chlorinated compounds were detected in fewer than two percent of the 527 lysimeter samples. The range of detections for these chemicals are shown in Table 11.

DDT and DDE were the chlorinated pesticides most-frequently detected in lysimeters at field sites for each crop. The highest DDT concentrations were recorded at berry and row crop sites, with maximum-recorded values of 0.338 $\mu\text{g/L}$ and 0.332 $\mu\text{g/L}$, respectively. Average DDT concentrations were recorded at less than 0.065 $\mu\text{g/L}$ for all crops types except berries, where the average value of detections was 0.173 $\mu\text{g/L}$. This average value is for detections only; berries recorded only three detections for DDT in 62 lysimeter samples. Berries were the one crop for which DDE was detected more often than DDT. Toxaphene was recorded in seven percent of the lysimeter samples from row crops, and at higher concentrations than all other chlorinated compounds. As shown in Figure 20,

Table 11. Chlorinated pesticide detections by crop, lysimeter samples**Avocado (98 samples)**

	Units	Minimum	Maximum	Average	Std. Deviation	Number of Detections
4,4 - DDT	ug/L	0.003	1.000	0.062	0.210	22
4,4 - DDE	ug/L	0.007	0.111	0.023	0.030	11
alpha-Chlordane	ug/L	0.004	0.049	0.020	0.015	6
gamma-Chlordane	ug/L	0.002	0.042	0.012	0.017	5
Heptachlor Epoxide	ug/L	0.004	0.036	0.013	0.015	4
4,4 - DDD	ug/L	0.018	0.031	0.024	0.007	3
Endrin Ketone	ug/L	0.069	0.069	0.069		1
Methoxychlor	ug/L	0.074	0.074	0.074		1

Berry (62 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of Detections
4,4 - DDE	ug/L	0.005	0.071	0.033	0.023	9
4,4 - DDT	ug/L	0.026	0.338	0.173	0.157	3
alpha-Chlordane	ug/L	0.015	0.051	0.030	0.019	3
Toxaphene	ug/L	1.050	2.600	2.083	0.895	3
4,4 - DDD	ug/L	0.010	0.032	0.021	0.015	2
gamma-Chlordane	ug/L	0.005	0.076	0.040	0.051	2
Methoxychlor	ug/L	0.044	0.067	0.055	0.016	2
Delta BHC	ug/L	0.017	0.017	0.017		1
Dieldrin	ug/L	0.011	0.011	0.011		1
Endrin Ketone	ug/L	0.014	0.014	0.014		1
Heptachlor	ug/L	0.015	0.015	0.015		1

Citrus (164 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of Detections
4,4 - DDT	ug/L	0.004	0.072	0.023	0.019	25
4,4 - DDE	ug/L	0.004	0.100	0.032	0.026	22
alpha-Chlordane	ug/L	0.008	0.023	0.014	0.007	4
4,4 - DDD	ug/L	0.004	0.034	0.015	0.017	3
gamma-Chlordane	ug/L	0.004	0.011	0.008	0.005	2
Toxaphene	ug/L	0.800	0.887	0.844	0.062	2
Dieldrin	ug/L	0.005	0.005	0.005		1
Endrin Aldehyde	ug/L	0.056	0.056	0.056		1

Duck Ponds (3 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of Detections
4,4 - DDT	ug/L	0.009	0.009	0.009		1

Row Crops (181 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of Detections
4,4 - DDT	ug/L	0.003	0.332	0.046	0.071	26
4,4 - DDE	ug/L	0.004	0.139	0.030	0.035	13
Toxaphene	ug/L	0.500	4.000	1.945	1.119	13
gamma-Chlordane	ug/L	0.002	0.012	0.008	0.004	7
Methoxychlor	ug/L	0.011	0.042	0.018	0.012	6
Aldrin	ug/L	0.189	0.301	0.245	0.079	2
4,4 - DDD	ug/L	0.019	0.019	0.019		1
alpha-Chlordane	ug/L	0.009	0.009	0.009		1
Endrin	ug/L	0.021	0.021	0.021		1
Endrin Ketone	ug/L	0.047	0.047	0.047		1

Sod (19 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of Detections
4,4 - DDT	ug/L	0.017	0.024	0.020	0.005	2
gamma-Chlordane	ug/L	0.007	0.007	0.007		1
Toxaphene	ug/L	1.400	1.400	1.400		1

the most common chlorinated pesticide detections were for DDT, DDE, Chlordane, Toxaphene, and DDD. Detections of other chlorinated pesticides were recorded infrequently and generally at low concentrations at various field sites.

Lysimeter detections for the organophosphate pesticides and triazine herbicides evaluated as part of this study are shown in Figure 21. Simazine and Chlorpyrifos were detected most-frequently, and at greater concentrations than the other compounds with the exception of Dimethoate. Dimethoate was the only organophosphate pesticide detected at concentrations greater than 1.010 µg/L, and was detected in six of 524 samples. Simazine was detected in less than nine percent of the samples, and Chlorpyrifos in four percent of all lysimeter samples. All remaining OP and triazine compounds were detected in one percent or less of the samples.

The distribution of lysimeter organophosphate pesticide and triazine herbicide detections, grouped by crop type, are shown in Table 12. Simazine was detected most-frequently in the avocado and citrus orchards, and rarely in the row crops. Recorded concentrations were greatest in the soil moisture of the avocado groves, averaging 0.157 µg/L, with detections in eighteen percent of the samples collected. For citrus, detections were observed in sixteen percent of the samples, with an average concentration of 0.102 µg/L. Chlorpyrifos was detected in six percent of the row crop and five percent of the berry lysimeter samples, at concentrations averaging 0.107 and 0.050 µg/L, respectively. Other

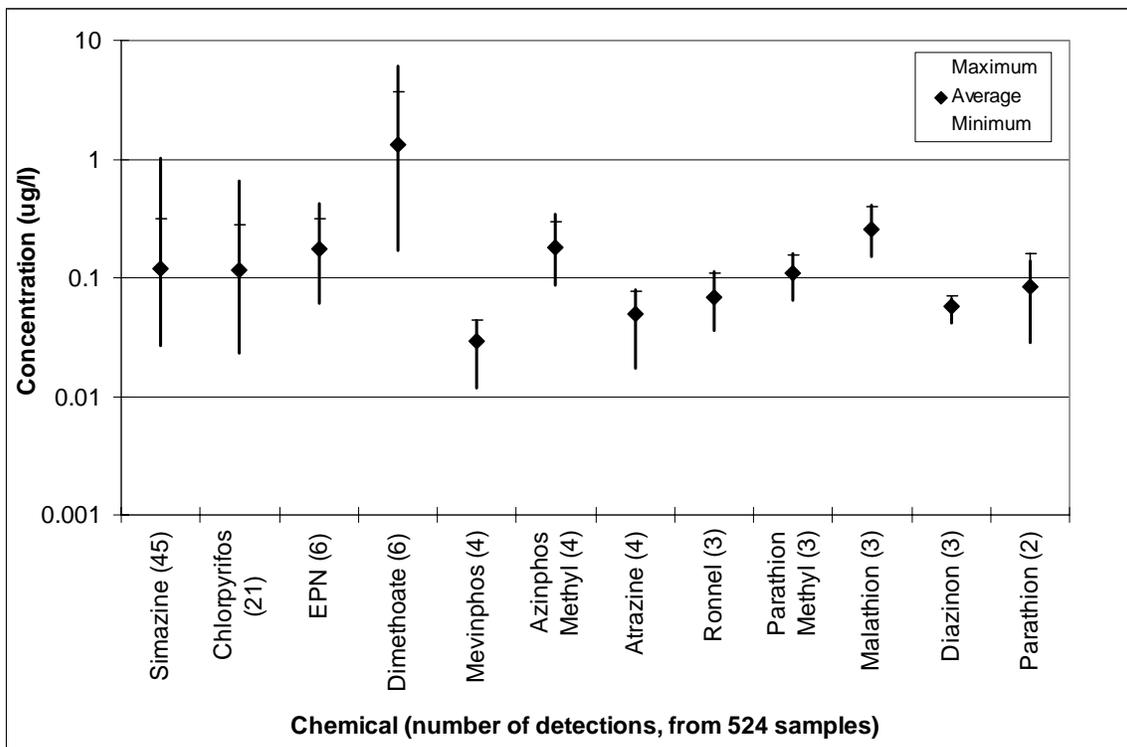


Figure 21. Organophosphate pesticide and triazine herbicide detections, lysimeter samples

OP pesticides (and the triazine herbicide, Atrazine) were detected infrequently and generally in low concentrations in lysimeters at the various field sites.

Table 12. Organophosphate pesticide detections by crop, lysimeter samples

Avocado (97 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of Detections
Simazine	ug/L	0.030	0.808	0.157	0.207	17
EPN	ug/L	0.063	0.418	0.237	0.178	3
Atrazine	ug/L	0.063	0.079	0.071	0.011	2
Azinphos Methyl	ug/L	0.195	0.343	0.269	0.105	2
Chlorpyrifos	ug/L	0.098	0.125	0.112	0.019	2
Diazinon	ug/L	0.064	0.066	0.065	0.001	2
Dimethoate	ug/L	0.172	0.301	0.237	0.091	2
Malathion	ug/L	0.151	0.215	0.183	0.045	2
Mevinphos	ug/L	0.024	0.043	0.034	0.013	2
Parathion	ug/L	0.028	0.139	0.084	0.078	2
Parathion Methyl	ug/L	0.097	0.162	0.130	0.046	2
Ronnel	ug/L	0.058	0.112	0.085	0.038	2

Berry (62 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of Detections
Chlorpyrifos	ug/L	0.037	0.075	0.050	0.022	3
Azinphos Methyl	ug/L	0.102	0.102	0.102		1
Dimethoate	ug/L	0.168	0.168	0.168		1
EPN	ug/L	0.134	0.134	0.134		1
Ronnel	ug/L	0.036	0.036	0.036		1

Citrus (161 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of Detections
Simazine	ug/L	0.027	1.010	0.102	0.191	26
Chlorpyrifos	ug/L	0.026	0.660	0.171	0.274	5
Atrazine	ug/L	0.017	0.017	0.017		1
EPN	ug/L	0.060	0.060	0.060		1
Mevinphos	ug/L	0.012	0.012	0.012		1

Duck Ponds (3 samples)

NO DETECTIONS

Row Crops (182 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of Detections
Chlorpyrifos	ug/L	0.023	0.440	0.107	0.136	11
Dimethoate	ug/L	0.188	6.120	2.403	3.239	3
Simazine	ug/L	0.027	0.044	0.036	0.012	2
Atrazine	ug/L	0.037	0.037	0.037		1
Azinphos Methyl	ug/L	0.085	0.085	0.085		1
Diazinon	ug/L	0.041	0.041	0.041		1
EPN	ug/L	0.149	0.149	0.149		1
Malathion	ug/L	0.411	0.411	0.411		1
Mevinphos	ug/L	0.039	0.039	0.039		1
Parathion Methyl	ug/L	0.064	0.064	0.064		1

Sod (19 samples)

NO DETECTIONS

3.1.2 Tile Drain Samples

In some agricultural areas, subsurface networks of perforated pipe are installed in order to assist the subsurface drainage of soils. In areas with soils of low permeability, or areas where shallow groundwater exists, saturated soil conditions may negatively affect plant health. Perforated drainage pipes are often positioned from approximately five to fifteen feet below the land surface, at depths sufficient to avoid damage during the deep ripping of soils and provide gravity flow to a collection or discharge point. Some drainage systems discharge directly by gravity flow to ditches or channels, and other installations use sump pumps to lift water to surface discharge areas. These drainage systems are commonly called tile drains because they were traditionally constructed with short segments of tile or clay pipe, loosely-jointed and packed in gravel to allow the ingress of water.

A summary of chlorinated pesticide detections from subsurface tile drains is shown in Figure 22. DDT and DDE were the most common detections, recorded in twelve and seven percent of the samples, respectively. DDT and DDE were however recorded at lower concentrations in tile drains than they were in lysimeters. Six other chlorinated compounds were detected in less than two percent of the tile drain samples, in concentrations similar to those recorded in lysimeters.

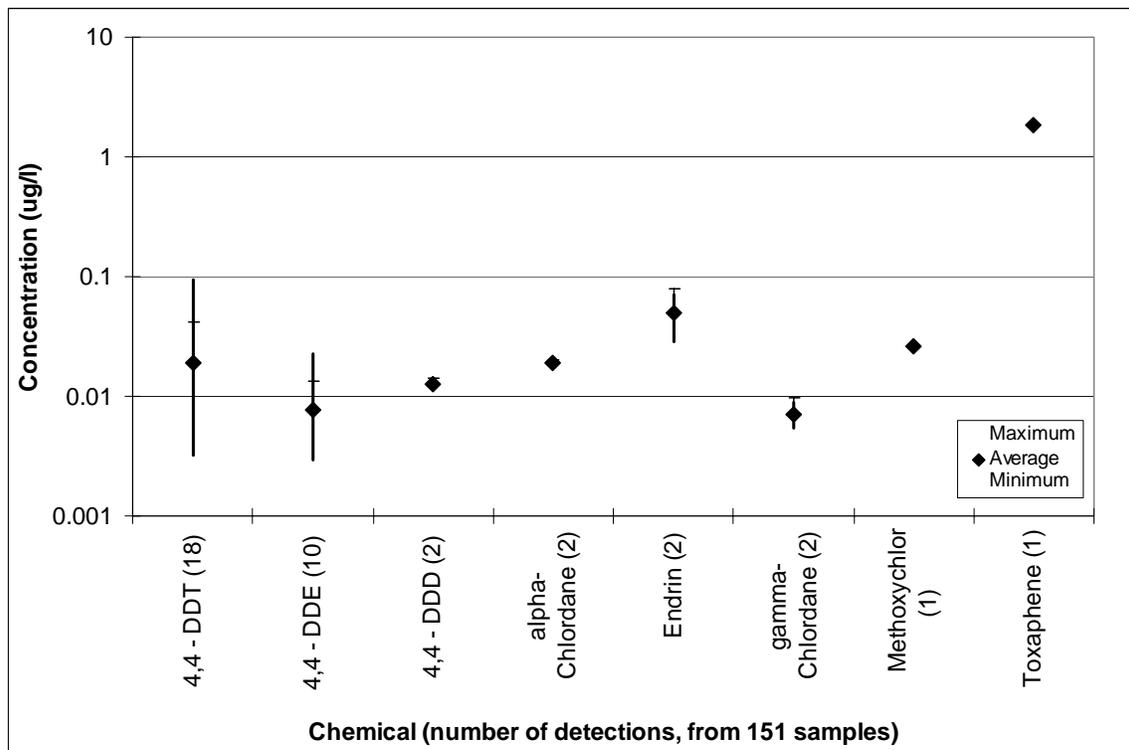


Figure 22. Chlorinated pesticide detections, tile drain samples

A numerical summary of chlorinated pesticide detections from tile drain samples is shown in Table 13. The majority of samples and detections are from berries and row crops. DDT was the most common detection at berry sites, averaging 0.019 µg/L and detected in twenty percent of the samples. DDE and DDT were the most commonly detected compounds in row crops, averaging 0.008 and 0.027 µg/L, respectively. Few tile drain samples were collected from citrus sites, and tile drains were not present at any of the avocado sites. Tree crops are not commonly planted in areas with subsurface drainage problems, or very heavy soils.

Detections of liquid phase organophosphate pesticides and triazine herbicides in tile drains are shown in Figure 23. From 151 samples, there were only three detections. The three detected compounds (Simazine, EPN and Azinphos methyl) were detected at similar or higher concentrations in lysimeters at various field sites. Table 14 shows that the three detections occurred at berry sites. Simazine, however, was not detected in lysimeters at any berry sites.

Table 13. Chlorinated pesticide detections by crop, tile drain samples

Avocado (0 samples)

NO SAMPLES

Berry (56 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of Detections
4,4 - DDT	ug/L	0.003	0.094	0.019	0.028	11
4,4 - DDE	ug/L	0.006	0.010	0.008	0.002	4
Endrin	ug/L	0.028	0.071	0.050	0.030	2
Methoxychlor	ug/L	0.026	0.026	0.026		1
alpha-Chlordane	ug/L	0.020	0.020	0.020		1

Citrus (12 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of Detections
4,4 - DDT	ug/L	0.009	0.010	0.009	0.001	2
gamma-Chlordane	ug/L	0.009	0.009	0.009		1

Duck Ponds (1 sample)

NO DETECTIONS

Row Crops (63 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of Detections
4,4 - DDE	ug/L	0.003	0.023	0.008	0.007	6
4,4 - DDT	ug/L	0.018	0.042	0.027	0.010	4
4,4 - DDD	ug/L	0.011	0.014	0.012	0.002	2
Toxaphene	ug/L	1.860	1.860	1.860		1
gamma-Chlordane	ug/L	0.005	0.005	0.005		1
alpha-Chlordane	ug/L	0.018	0.018	0.018		1

Sod (18 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of Detections
4,4 - DDT	ug/L	0.008	0.008	0.008		1

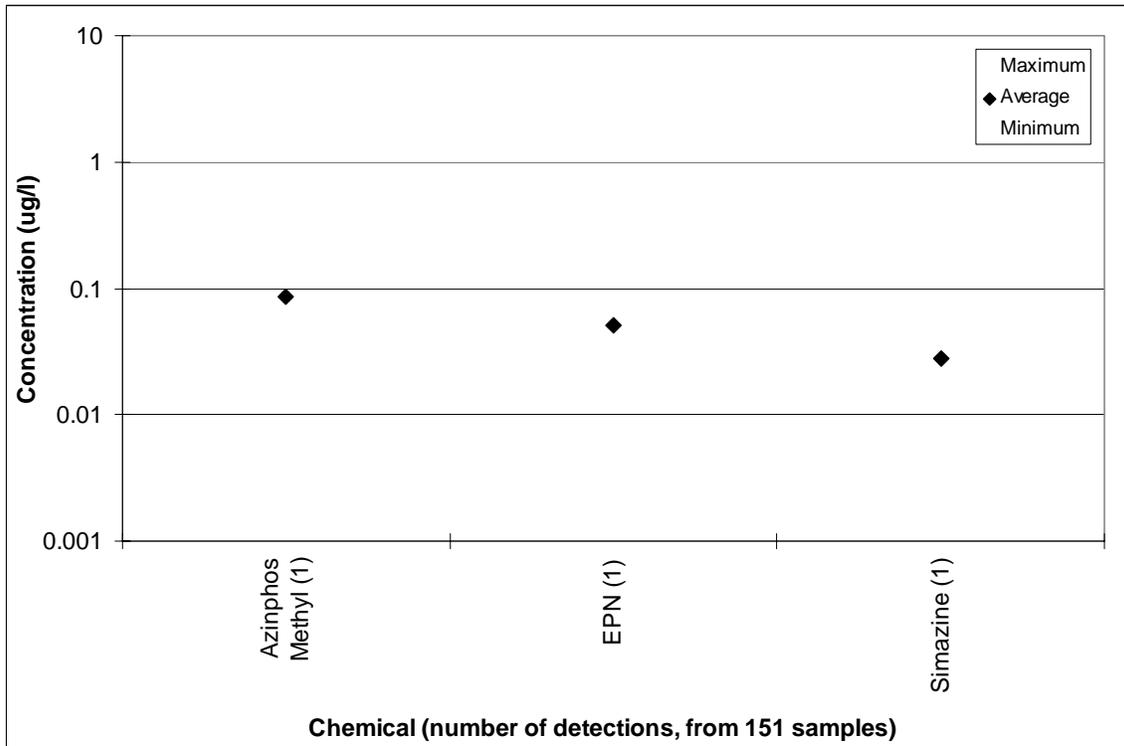


Figure 23. Organophosphate pesticide and triazine herbicide detections, tile drain samples

Table 14. Organophosphate pesticide and triazine herbicide detections by crop, tile drain samples

Avocado (0 samples)

NO SAMPLES

Berry (56 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of Detections
Simazine	ug/L	0.028	0.028	0.028		1
EPN	ug/L	0.051	0.051	0.051		1
Azinphos Methyl	ug/L	0.086	0.086	0.086		1

Citrus (11 samples)

NO DETECTIONS

Duck Ponds (1 sample)

NO DETECTIONS

Row Crops (64 samples)

NO DETECTIONS

Sod (18 samples)

NO DETECTIONS

3.1.3 Tailwater Samples

Tailwaters are defined as surface water flowing off of agricultural areas during irrigation events. This generally occurs when irrigation water is applied at a rate exceeding the infiltration capacity of the soil. This can happen early in an irrigation event if water is applied too rapidly, where emitters apply more water than soils can infiltrate. Tailwaters may also flow from a field with a properly-designed irrigation system if the irrigation event continues too long and near-surface soils become saturated. Tailwaters are also more common in fields with poor uniformity in the distribution of irrigation water, as irrigation often continues until all areas of the field receive enough water. One notable source of tailwater in the study area is the common practice of broadcast irrigation following the planting of young strawberry plants. Plastic mulch covering the beds results in significant runoff, while some water reaches the young plants through the holes cut in the plastic around each plant. This practice is used until plant roots grow to such a size that they can be irrigated with drip tape buried between rows of plants.

Six chlorinated pesticides were detected in a total of 31 tailwater samples, and the ranges of detections are shown in Figure 24. DDT and DDE were detected in approximately two-thirds of all tailwater samples. Detections were less frequent for DDD, chlordane and Toxaphene. Toxaphene was detected in only two samples, but at concentrations greater than the other chlorinated pesticides.

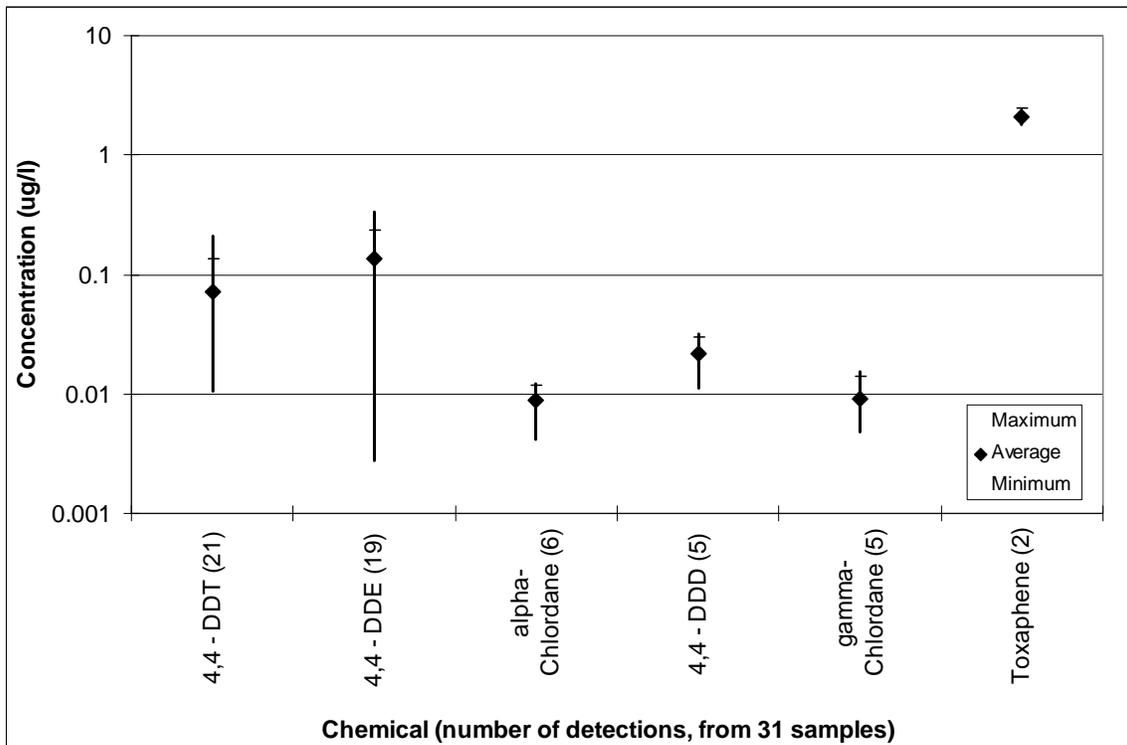


Figure 24. Chlorinated pesticide detections, tailwater samples

Table 15 displays detection summaries for chlorinated pesticides in tailwater samples. There was a limited number of samples collected for each crop type, as tailwaters were infrequently observed by field staff. On a percentage basis, detections of DDT and DDE are common. DDT and DDE were detected in six of seven samples at berry sites, and DDT was detected in thirteen of eighteen samples from row crops. The greatest range of chlorinated compounds was seen in row crops and berries, but detections were limited to the DDT family, chlordane and Toxaphene.

Few detections of liquid phase organophosphate pesticides and triazine herbicides were observed in tailwater samples (Figure 25). The five detections were all recorded at row crop sites. Chlorpyrifos was detected more frequently than Simazine and Dimethoate, but at lower concentrations. Numerical detection summaries are shown in Table 16.

Table 15. Chlorinated pesticide detections by crop, tailwater samples

Avocado (1 sample)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of Detections
4,4 - DDT	ug/L	0.020	0.020	0.020		1
4,4 - DDD	ug/L	0.020	0.020	0.020		1

Berry (7 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of Detections
4,4 - DDT	ug/L	0.021	0.210	0.114	0.075	6
4,4 - DDE	ug/L	0.043	0.334	0.169	0.112	6
alpha-Chlordane	ug/L	0.010	0.011	0.010	0.001	3
Toxaphene	ug/L	2.360	2.360	2.360		1
gamma-Chlordane	ug/L	0.013	0.013	0.013		1

Citrus (2 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of Detections
4,4 - DDT	ug/L	0.016	0.016	0.016		1
4,4 - DDD	ug/L	0.018	0.018	0.018		1

Duck Ponds (0 samples)

NO RESULTS

Row Crops (18 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of Detections
4,4 - DDT	ug/L	0.010	0.163	0.059	0.053	13
4,4 - DDE	ug/L	0.003	0.315	0.124	0.098	12
gamma-Chlordane	ug/L	0.005	0.015	0.008	0.005	4
alpha-Chlordane	ug/L	0.004	0.012	0.007	0.004	3
4,4 - DDD	ug/L	0.011	0.031	0.024	0.011	3
Toxaphene	ug/L	1.820	1.820	1.820		1

Sod (3 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of Detections
4,4 - DDE	ug/L	0.049	0.049	0.049		1

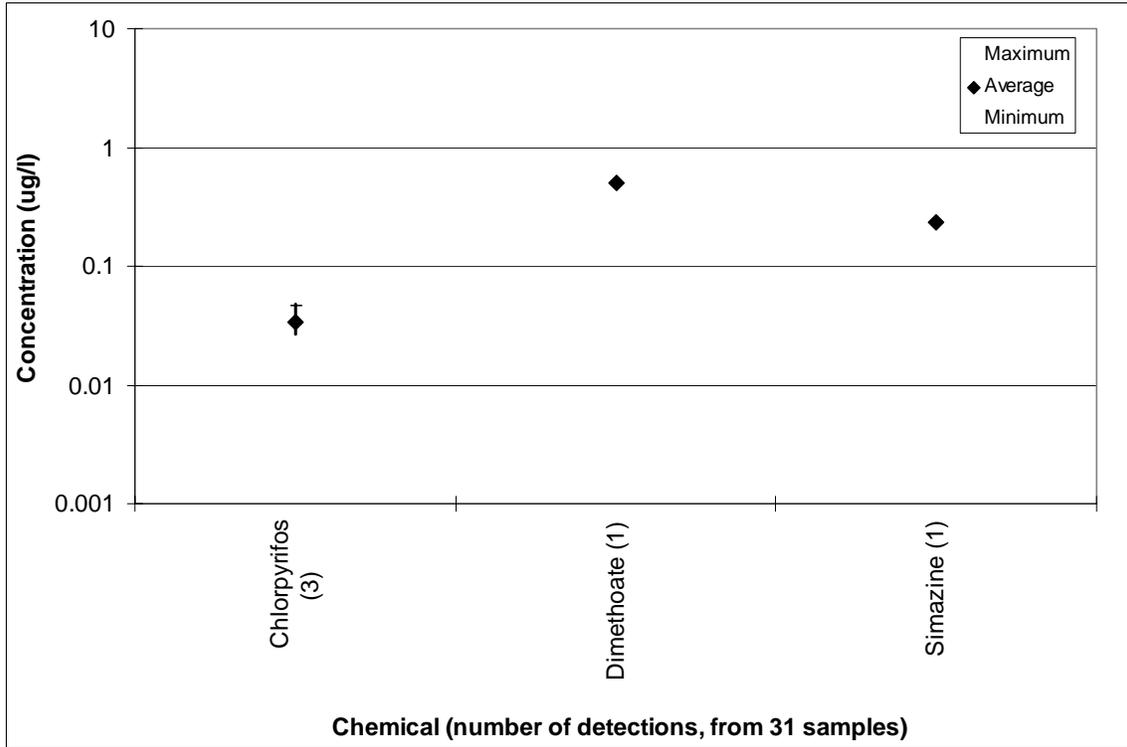


Figure 25. Organophosphate pesticide and triazine herbicide detections, tailwater samples

Table 16. Organophosphate pesticide and triazine herbicide detections by crop, tailwater samples

Avocado (1 sample)

NO DETECTIONS

Berry (7 samples)

NO DETECTIONS

Citrus (2 samples)

NO DETECTIONS

Duck Ponds (0 samples)

NO RESULTS

Row Crops (18 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of Detections
Chlorpyrifos	ug/L	0.027	0.048	0.034	0.012	3
Simazine	ug/L	0.234	0.234	0.234		1
Dimethoate	ug/L	0.506	0.506	0.506		1

Sod (3 samples)

NO DETECTIONS

3.1.4 Stormwater Runoff – Liquid Phase

Stormwater runoff samples were collected from downstream areas of agricultural sites during significant precipitation events. The conditions under which samples were collected were highly variable. Grab samples were collected when personnel arrived at the field site and runoff was available for collection. As a result, the data set for surface runoff samples is from a wide range of site conditions, ranging from a trickle for some samples to significant flows at others. Flow conditions for individual samples were not well-documented, so the available data represents a survey-level data set for each crop classification. While these samples of stormwater runoff are likely to reasonably represent the range of site conditions at project sites, this data set is not well-suited as a documentation of “typical” site conditions during winter precipitation events.

The following plots and tables are based on all surface water runoff samples, both the samples from the baseline periods and samples collected after BMP installations. BMP evaluations are considered in Section 4.6 (Assessment of Best Management Practices). A limited number of samples were collected both upstream and downstream of BMP installations and that limited data set suggests little chemical change below the BMPs installed by area growers. Sites not yielding runoff during storm events, or at least when staff was at the site to perform sampling, are not considered in this section.

The detections of liquid phase chlorinated pesticides dissolved in 260 stormwater runoff samples collected for this study and the companion PRISM study are summarized in Figure 26. As observed in the lysimeter and tailwater samples, compounds of the DDT family and chlordane are detected with the greatest frequency. Figure 26 also shows that the compounds detected most often are generally detected in the highest concentrations. The exception is Toxaphene, which was detected in only three samples, but at concentrations higher than all other chlorinated pesticides. Eleven compounds were detected in five or fewer of the 260 samples, representing a detection frequency of less than two percent. With the exception of Toxaphene, Methoxychlor and Dieldrin, these compounds were detected at concentrations less than 0.010 µg/L.

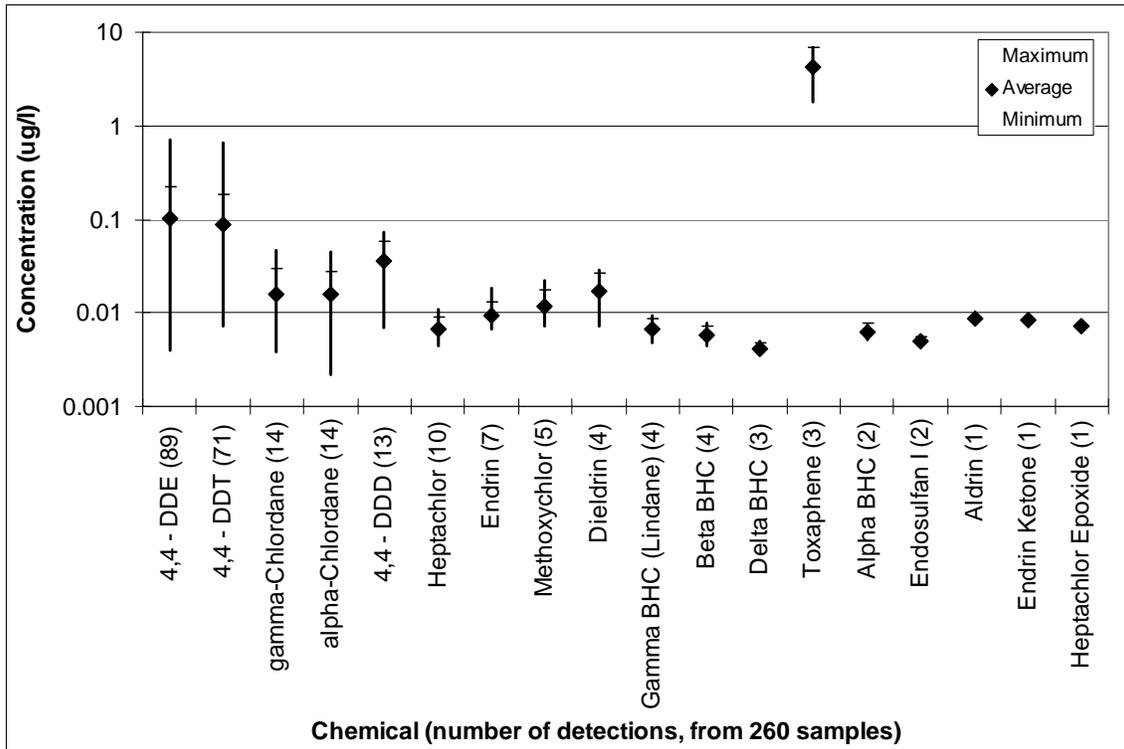


Figure 26. Liquid phase chlorinated pesticide detections, stormwater runoff

Table 17 presents a crop-by-crop numerical summary of liquid phase chlorinated pesticide detections in stormwater samples. These data are for chemical concentrations dissolved in the water column, and do not include the analysis of sediment entrained in the stormwater runoff. DDE and DDT were the first and second most-common chemical detected in each crop, the range of DDE concentrations was the greatest of all compounds except Toxaphene (which was present at higher concentrations and greater variability). DDE was commonly detected at berry, sod and row crop sites, with detection frequencies ranging from 58 to 70 percent. Average and maximum DDE and DDT concentrations were highest at the row crop and berry sites.

Many of the chemical detections listed in Table 17 record three or fewer detections at concentrations less than 0.010 $\mu\text{g/L}$. These reported detections were present in one percent or less of the stormwater samples, and are below the PQLs for the analytical methods employed in this study (Table 3). The laboratory states a 99 percent confidence level that these compounds were present, but the reader is reminded that these results fall below the quantitative limit of the EPA method 8270, and are very near the qualitative limit of this method.

Table 17. Liquid phase chlorinated pesticide detections by crop, stormwater runoff**Avocado (49 samples)**

	Units	Minimum	Maximum	Average	Std. Deviation	Number of detections
4,4 - DDE	ug/L	0.005	0.026	0.012	0.009	5
4,4 - DDT	ug/L	0.010	0.031	0.020	0.009	4
Methoxychlor	ug/L	0.008	0.013	0.011	0.003	2
Heptachlor	ug/L	0.004	0.005	0.005	0.000	2
Gamma BHC (Lindane)	ug/L	0.006	0.006	0.006		1
Endrin	ug/L	0.009	0.009	0.009		1
Delta BHC	ug/L	0.005	0.005	0.005		1
alpha-Chlordane	ug/L	0.016	0.016	0.016		1
4,4 - DDD	ug/L	0.017	0.017	0.017		1

Berry (32 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of detections
4,4 - DDE	ug/L	0.038	0.702	0.144	0.155	19
4,4 - DDT	ug/L	0.045	0.663	0.148	0.156	15
gamma-Chlordane	ug/L	0.047	0.047	0.047		1
Endrin	ug/L	0.008	0.008	0.008		1
Dieldrin	ug/L	0.028	0.028	0.028		1
alpha-Chlordane	ug/L	0.045	0.045	0.045		1
4,4 - DDD	ug/L	0.042	0.042	0.042		1

Citrus (95 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of detections
4,4 - DDE	ug/L	0.004	0.059	0.026	0.015	16
4,4 - DDT	ug/L	0.007	0.058	0.028	0.015	15
Heptachlor	ug/L	0.005	0.011	0.008	0.002	6
gamma-Chlordane	ug/L	0.004	0.009	0.005	0.002	5
Endrin	ug/L	0.007	0.009	0.008	0.001	3
alpha-Chlordane	ug/L	0.002	0.008	0.005	0.003	3
Methoxychlor	ug/L	0.007	0.022	0.015	0.010	2
Alpha BHC	ug/L	0.005	0.007	0.006	0.002	2
Gamma BHC (Lindane)	ug/L	0.007	0.007	0.007		1
Delta BHC	ug/L	0.004	0.004	0.004		1
Beta BHC	ug/L	0.004	0.004	0.004		1
4,4 - DDD	ug/L	0.018	0.018	0.018		1

Duck Ponds (2 samples)

NO DETECTIONS

Row Crops (72 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of detections
4,4 - DDE	ug/L	0.005	0.517	0.124	0.119	42
4,4 - DDT	ug/L	0.016	0.331	0.096	0.078	32
4,4 - DDD	ug/L	0.007	0.073	0.039	0.025	10
alpha-Chlordane	ug/L	0.005	0.033	0.016	0.009	9
gamma-Chlordane	ug/L	0.004	0.038	0.018	0.013	8
Dieldrin	ug/L	0.007	0.022	0.013	0.008	3
Beta BHC	ug/L	0.005	0.008	0.006	0.002	3
Toxaphene	ug/L	1.800	6.900	4.300	2.551	3
Endrin	ug/L	0.008	0.018	0.013	0.007	2
Heptachlor	ug/L	0.006	0.006	0.006	0.000	2
Endosulfan I	ug/L	0.004	0.005	0.005	0.001	2
Endrin Ketone	ug/L	0.008	0.008	0.008		1
Delta BHC	ug/L	0.004	0.004	0.004		1
Gamma BHC (Lindane)	ug/L	0.009	0.009	0.009		1
Aldrin	ug/L	0.009	0.009	0.009		1
Heptachlor Epoxide	ug/L	0.007	0.007	0.007		1
Methoxychlor	ug/L	0.009	0.009	0.009		1

Sod (10 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of detections
4,4 - DDE	ug/L	0.012	0.202	0.071	0.068	7
4,4 - DDT	ug/L	0.035	0.115	0.068	0.029	5
Gamma BHC (Lindane)	ug/L	0.005	0.005	0.005		1

Detections of organophosphate pesticides and triazine herbicides in stormwater samples are shown in Figure 27. These results are for the liquid phase only, and not the sediment fractions commonly present in stormwater samples. Chlorpyrifos was by far the most-commonly detected of the OP pesticide group, and was detected in 36 percent of the samples. Simazine was detected in ten percent of the samples, in concentrations slightly less than Chlorpyrifos. Dimethoate was only detected in one percent of the samples, but recorded both the highest average concentration and the highest single detection among the OP pesticides or triazine herbicides. Several other compounds, including Malathion, Atrazine and Diazinon, recorded five or less detections among the 260 stormwater samples.

Table 18 details liquid phase detections of organophosphate pesticides and triazine herbicides in stormwater runoff, with classification by crop type. Chlorpyrifos was detected most-frequently, and in similar concentrations, at the berry and citrus sites. It was detected in 55 percent of the citrus samples and 53 percent of the berry samples. Average Chlorpyrifos detections for stormwater samples at the citrus sites were 0.750 $\mu\text{g/L}$, and the maximum-recorded concentration at citrus sites was 2.600 $\mu\text{g/L}$. The average Chlorpyrifos concentration for detections at berry sites was 0.854 $\mu\text{g/l}$. Chlorpyrifos was recorded less-frequently at row crop and avocado sites, and was not detected at the sod or duck pond sites. Simazine was detected in eighteen percent of the citrus samples and twelve percent of the avocado stormwater samples. Simazine

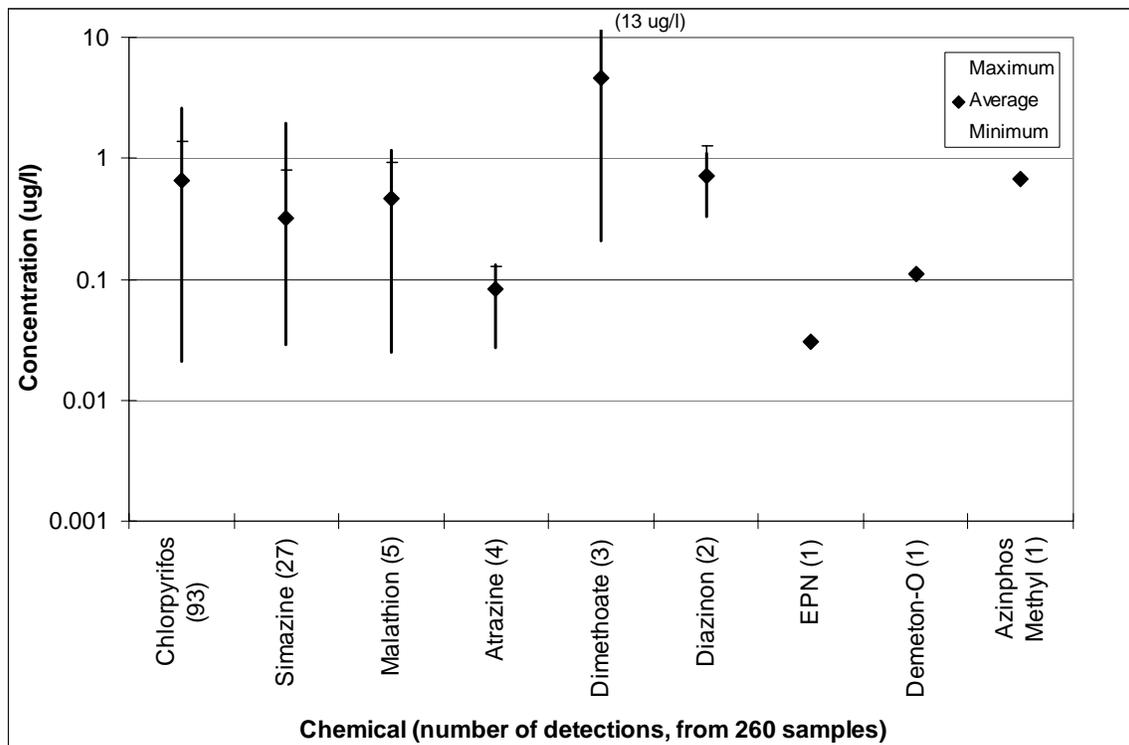


Figure 27. Liquid phase organophosphate pesticide and triazine herbicide detections, stormwater runoff

detections were uncommon at the berry and row crop sites. Chlorpyrifos, Simazine and Atrazine were the only constituents in this group detected at avocado sites.

Table 18. Organophosphate pesticide and triazine herbicide liquid phase detections by crop, stormwater samples

Avocado (49 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of detections
Simazine	ug/L	0.029	1.940	0.486	0.730	6
Chlorpyrifos	ug/L	0.027	0.479	0.222	0.175	5
Atrazine	ug/L	0.027	0.027	0.027		1

Berry (32 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of detections
Chlorpyrifos	ug/L	0.068	2.380	0.854	0.817	17
Simazine	ug/L	0.139	0.139	0.139		1
Malathion	ug/L	0.143	0.143	0.143		1
Atrazine	ug/L	0.082	0.082	0.082		1

Citrus (95 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of detections
Chlorpyrifos	ug/L	0.021	2.600	0.750	0.716	52
Simazine	ug/L	0.030	1.560	0.289	0.427	17
Atrazine	ug/L	0.090	0.133	0.112	0.030	2
Malathion	ug/L	0.025	0.025	0.025		1
EPN	ug/L	0.030	0.030	0.030		1

Duck Ponds (2 samples)

NO DETECTIONS

Row Crops (74 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of detections
Chlorpyrifos	ug/L	0.023	2.510	0.338	0.579	19
Simazine	ug/L	0.040	0.385	0.203	0.173	3
Malathion	ug/L	0.478	1.170	0.725	0.386	3
Dimethoate	ug/L	0.210	13.000	4.607	7.272	3
Diazinon	ug/L	0.330	1.100	0.715	0.544	2
Demeton-O	ug/L	0.111	0.111	0.111		1
Azinphos Methyl	ug/L	0.671	0.671	0.671		1

Sod (10 samples)

NO DETECTIONS

3.1.5 Stormwater Runoff – Solid Phase

The chemical analysis of sediments entrained in stormwater runoff was also a component of this study, allowing a comparison of solid- and liquid- phase chemical concentrations. As detailed previously, the volume or discharge rate of stormwater runoff and entrained sediment were not measured or estimated at project sites for individual storm events. The collection of grab samples allows for a survey of stormwater characteristics at the various

project sites. Figure 28 displays the range of detections for solid phase chlorinated pesticides recorded in stormwater runoff from project sites in the Calleguas Creek and Santa Clara River watersheds. The units for the analysis of solids are $\mu\text{g}/\text{kg}$, or parts per billion. These units are directly comparable to the units $\mu\text{g}/\text{L}$ used to present liquid phase chemical detections in this study. The vertical scale in Figure 28 has increased by three orders of magnitude from the liquid phase plots to accommodate the higher concentrations observed in the solid phase. Many of these chlorinated compounds are known to bond strongly to soil particles, so the higher concentrations measured in eroded soil was not unexpected.

Figure 28 shows that the chlorinated pesticides commonly detected in the liquid phase are also those detected most frequently in the solid phase. DDE was detected in the sediment of more than 58 percent of the stormwater samples, with an average concentration of 104 $\mu\text{g}/\text{kg}$. DDT was detected in 45 percent of the samples and at slightly lower concentrations. Toxaphene was detected in 25 of the 209 sediment samples, and at concentrations greater than the other chlorinated compounds. DDD and Chlordane were the only other compounds with a significant frequency of detection. Five additional compounds were detected only one time in the 209 samples obtained from the various field sites.

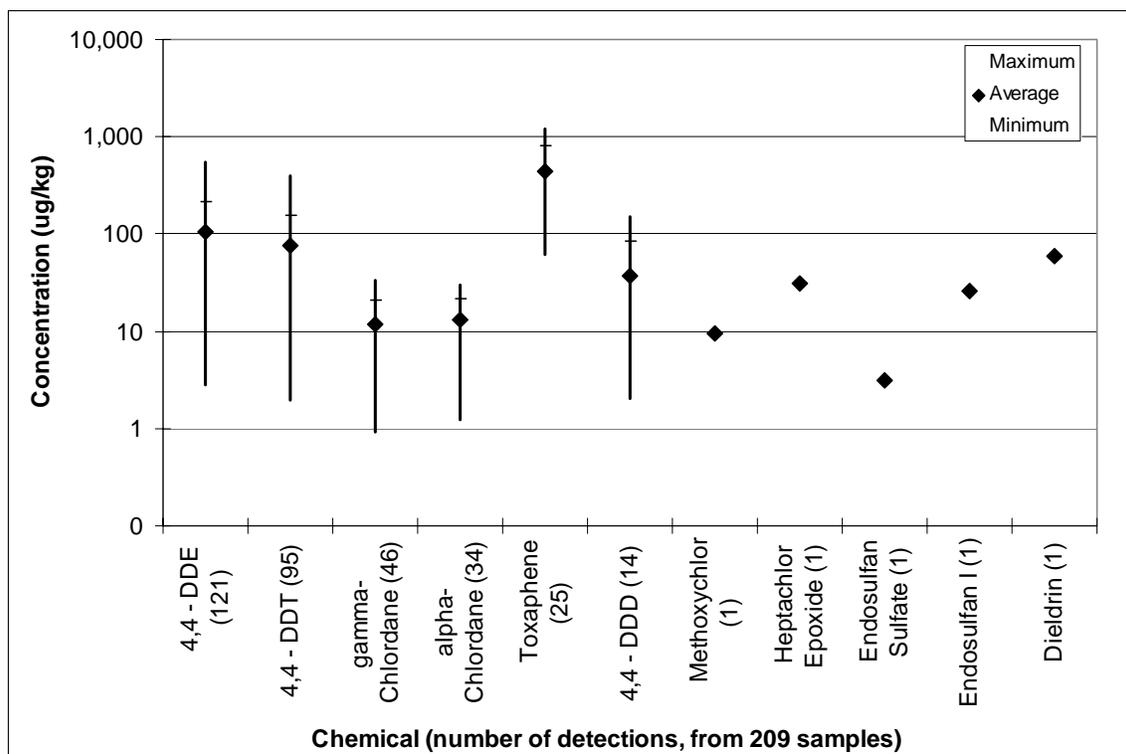


Figure 28. Chlorinated pesticide detections, solid phase, stormwater samples

Detections of solid phase chlorinated compounds, classified by crop type, are shown in Table 19. DDE was the chlorinated pesticide most commonly detected for each crop classification, and was detected in a high percentage of the samples from sod, berry and row crop sites. Average DDE concentrations ranged from 123 to 163 $\mu\text{g}/\text{kg}$ among these crop types. DDT ranked second for detection frequency for all crops except avocado, for which gamma- and alpha-Chlordane was detected more frequently than DDT. Toxaphene was recorded most-frequently and in highest concentrations at berry sites. The reader is reminded that the concentrations listed in Table 19 are just concentrations measured in entrained sediment. These data do not address the volumes of sediment entrained in stormwater samples, which would be required for any comparative assessment of solid phase pesticide and herbicide loading from various crop types in these watersheds.

A detection summary of all solid phase organophosphate pesticides and triazine herbicides observed in stormwater runoff is shown in Figure 28. Chlorpyrifos was detected in 43 percent of the stormwater samples. A wide range of concentrations were detected, and the average concentration for the 90 detections was 191 $\mu\text{g}/\text{kg}$. Simazine was detected in 6 of 209 samples, at concentrations that averaged 100 $\mu\text{g}/\text{kg}$. Several other constituents in the group recorded infrequent solid phase detections at relatively low concentrations.

Solid phase detections of organophosphate pesticides and triazine herbicides in stormwater runoff are summarized by crop type in Table 20. Chlorpyrifos is the compound detected most frequently for each crop type, and was observed in nearly seventy percent of the samples from berry and citrus sites. Detected concentrations averaged 218 $\mu\text{g}/\text{kg}$ at citrus sites and 167 $\mu\text{g}/\text{kg}$ for berries. Chlorpyrifos was detected in eighteen percent of the stormwater sediment samples from avocado and row crops. Simazine was detected most frequently at the citrus sites, but was reported in only five percent of the samples.

Table 19. Chlorinated pesticide solid phase detections by crop, stormwater samples

Avocado (40 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of detections
4,4 - DDE	ug/kg	2.80	72.70	33.03	23.53	13
gamma-Chlordane	ug/kg	1.58	33.70	14.04	12.06	7
alpha-Chlordane	ug/kg	1.86	19.90	9.88	6.14	6
4,4 - DDT	ug/kg	2.10	56.50	26.22	21.61	5
Heptachlor Epoxide	ug/kg	31.50	31.50	31.50		1
Methoxychlor	ug/kg	9.40	9.40	9.40		1

Berry (26 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of detections
4,4 - DDE	ug/kg	11.00	556.00	162.60	146.58	21
4,4 - DDT	ug/kg	2.89	361.00	109.84	88.23	19
Toxaphene	ug/kg	61.00	1190.00	685.89	492.11	9
gamma-Chlordane	ug/kg	12.00	33.10	21.66	6.67	7
alpha-Chlordane	ug/kg	15.30	29.90	23.62	7.14	5
4,4 - DDD	ug/kg	11.90	150.00	61.45	60.73	4

Citrus (75 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of detections
4,4 - DDE	ug/kg	6.70	215.00	61.70	58.20	35
4,4 - DDT	ug/kg	6.60	204.00	50.58	53.60	22
gamma-Chlordane	ug/kg	5.30	19.70	10.26	5.85	5
alpha-Chlordane	ug/kg	9.70	17.60	15.25	3.75	4
Toxaphene	ug/kg	64.00	523.00	352.00	200.19	4
4,4 - DDD	ug/kg	14.90	14.90	14.90		1

Duck Ponds (0 samples)

NO RESULTS

Row Crops (60 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of detections
4,4 - DDE	ug/kg	5.80	522.00	122.98	127.29	44
4,4 - DDT	ug/kg	1.99	395.00	69.69	82.71	44
gamma-Chlordane	ug/kg	0.91	29.10	8.76	7.99	24
alpha-Chlordane	ug/kg	1.21	30.10	10.65	9.47	16
Toxaphene	ug/kg	61.00	633.00	277.40	174.29	10
4,4 - DDD	ug/kg	2.02	44.60	16.94	14.26	7
Endosulfan I	ug/kg	25.80	25.80	25.80		1

Sod (8 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of detections
CONSTITUNT						
4,4 - DDE	ug/kg	29.50	392.00	140.99	125.88	8
4,4 - DDT	ug/kg	21.60	270.00	163.12	118.36	5
alpha-Chlordane	ug/kg	4.60	22.50	10.77	10.17	3
gamma-Chlordane	ug/kg	3.80	19.70	10.04	8.48	3
4,4 - DDD	ug/kg	16.30	133.00	74.65	82.52	2
Toxaphene	ug/kg	202.00	399.00	300.50	139.30	2
Dieldrin	ug/kg	58.50	58.50	58.50		1
Endosulfan Sulfate	ug/kg	3.10	3.10	3.10		1

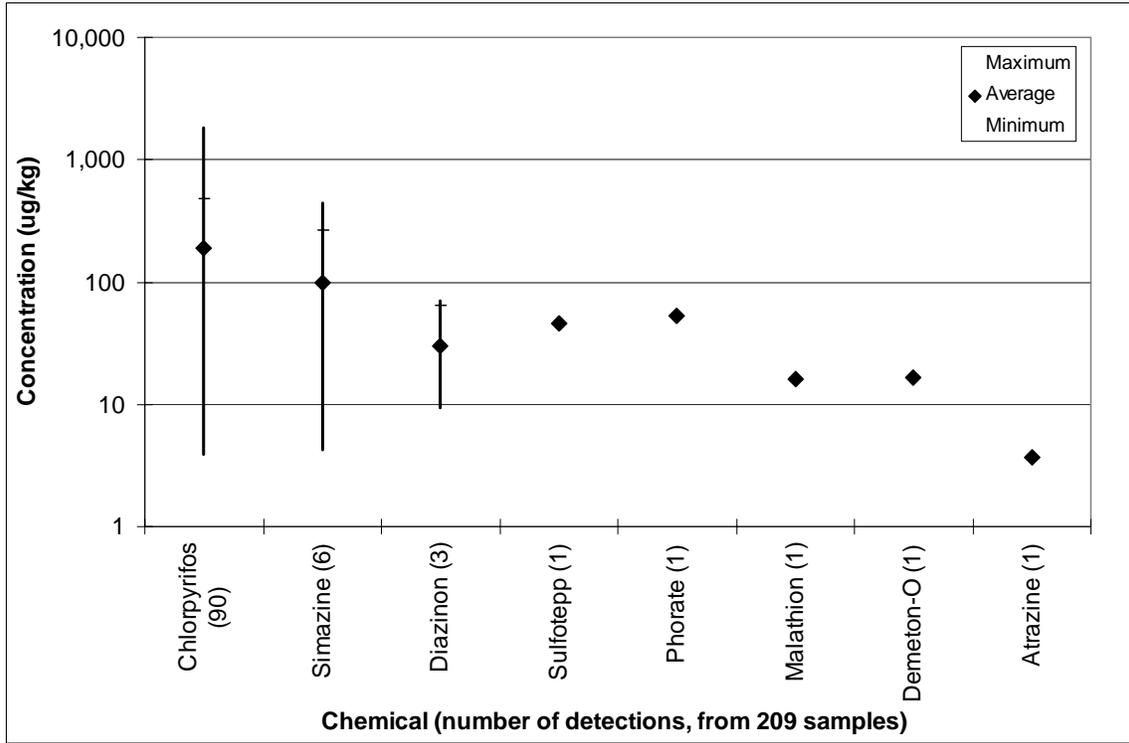


Figure 29. Organophosphate pesticide and triazine herbicide detections, solid phase, stormwater samples

Table 20. Organophosphate pesticide and triazine herbicide solid phase detections by crop, stormwater samples

Avocado (40 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of detections
Chlorpyrifos	ug/kg	6.00	137.00	53.66	47.07	7
Diazinon	ug/kg	70.00	70.00	70.00		1
Phorate	ug/kg	53.40	53.40	53.40		1
Simazine	ug/kg	442.00	442.00	442.00		1
Sulfotepp	ug/kg	46.00	46.00	46.00		1

Berry (26 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of detections
Chlorpyrifos	ug/kg	3.90	1120.00	166.69	269.49	18

Citrus (75 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of detections
Chlorpyrifos	ug/kg	7.30	1110.00	217.95	259.29	51
Simazine	ug/kg	8.20	67.70	37.95	25.80	4
Atrazine	ug/kg	3.70	3.70	3.70		1

Duck Ponds (0 samples)

NO RESULTS

Row Crops (60 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of detections
Chlorpyrifos	ug/kg	5.00	1830.00	238.75	532.81	11
Diazinon	ug/kg	9.30	9.60	9.45	0.21	2
Simazine	ug/kg	4.20	4.20	4.20		1

Sod (8 samples)

	Units	Minimum	Maximum	Average	Std. Deviation	Number of detections
Chlorpyrifos	ug/kg	4.50	17.40	11.97	6.69	3
Demeton-O	ug/kg	16.60	16.60	16.60		1
Malathion	ug/kg	16.20	16.20	16.20		1

3.2 REDUCTION OF PESTICIDES AND HERBICIDES USING BMPS

As discussed in Section 2.6 (Selection of BMPs), the BMPs installed as part of this project primarily focused on managing stormwater runoff. Sampling was conducted either above and below the BMP, or by side-by-side sampling of agriculture areas with and without BMP installations (see Section 2.7 Post-BMP Water Quality Sampling). Perhaps the greatest effectiveness of project BMPs was at sites where runoff was completely eliminated during certain storm events. This occurred more than once at five out of six sites where mulch was installed (see Table 26 in Section 4.6.2 Qualitative Assessment), and three sites where cover crops were installed (Table 27 in Section 4.6.2 Qualitative Assessment).

At BMP sites where storm runoff was observed, measurements of pesticide and herbicide concentrations and total suspended solids were used to determine the effectiveness of a BMP. Section 2.7 (Post-BMP Water Quality Sampling) discusses the sampling protocols for stormwater monitoring. There was limited sampling of pesticide and herbicide concentrations both upstream and downstream of BMPs because most BMPs were focused on reducing suspended solids in the storm runoff. For liquid-phase samples collected from above and below BMPs, DDT concentrations were somewhat lower in the samples taken below the BMPs than in the samples taken above the BMPs (Figure 30).

Pesticide and herbicide concentrations in suspended solids were analyzed from pairs of samples of storm runoff upstream and downstream from several types of BMPs. DDE, DDT, and Chlorpyrifos analytical results from these pairs of samples are shown in Figure 31. There is no apparent trend in these analyses – upstream samples may be higher or lower in pesticides and herbicide concentration than downstream samples. Potential causes of these variations are discussed in Section 4.6 (Assessment of Best Management Practices).

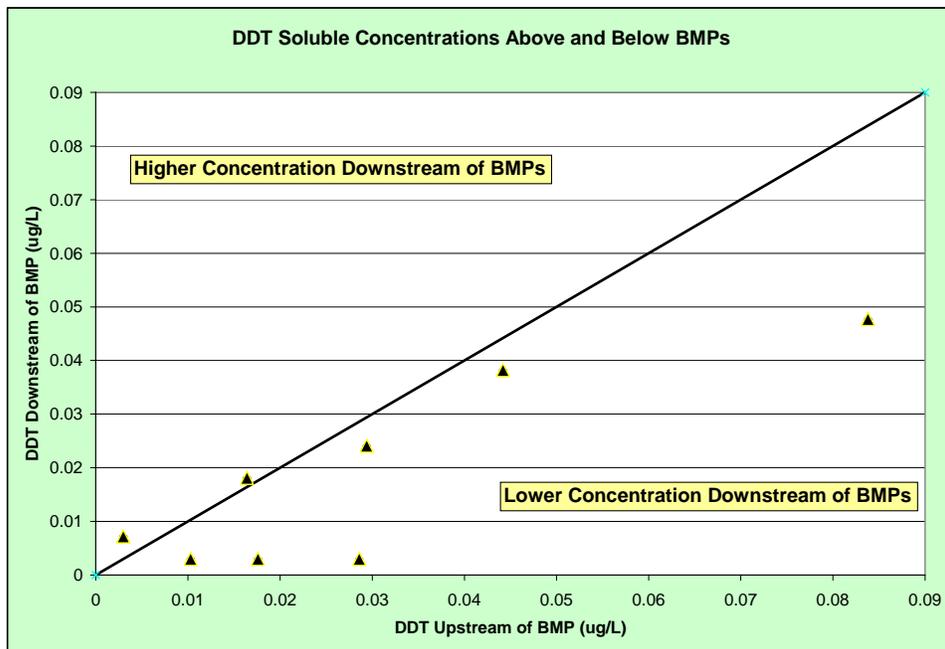


Figure 30. Concentrations of soluble DDT above and below BMPs. Each data point represents a pair of samples – one from above and one from below a BMP that were sampled from a single storm event. A data point to the right of the solid line indicates lower concentrations downstream of the BMP.

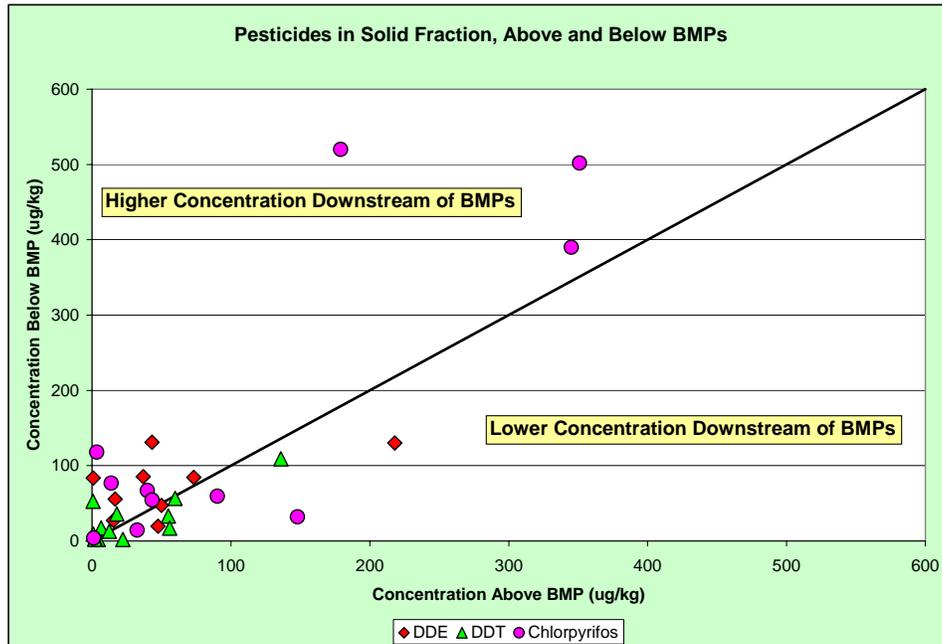


Figure 31. Pesticide concentrations in suspended solids sampled above and below BMPs. Each data point represents a pair of samples – one from above and one from below a BMP that were sampled from a single storm event. Points above the diagonal line represent samples where pesticide concentrations were higher in samples below the BMP and points below the line represent samples where pesticide concentrations were lower in samples below the BMP.

Of primary importance in the study was the potential reduction in solids using the various BMPs, especially because baseline analyses indicated that the highest concentrations of pesticides and herbicides in storm runoff were carried in suspended sediment. Figure 32 indicates the effectiveness of the various BMPs in reducing suspending solids in the runoff water. A majority of paired samples (one sample upstream and one sample downstream of the BMP) indicate reduction in suspended solids downstream of the BMPs.

The paired samples indicate a range of upstream/downstream changes in suspended solids from a downstream reduction of 100 percent to a downstream increase of 500 percent. Potential causes of these increases are discussed in the Section 4.6 (Assessment of Best Management Practices). The median decrease in solids downstream of BMPs was 9 percent.

Figure 33 displays the changes in concentrations of total suspended solids across the breadth of BMPs and crops for which the BMPs were implemented. The lack of significant storm runoff in the dry winter of 2006-2007 prevented expanded testing of BMPs that were implemented during the summer and fall of 2006.

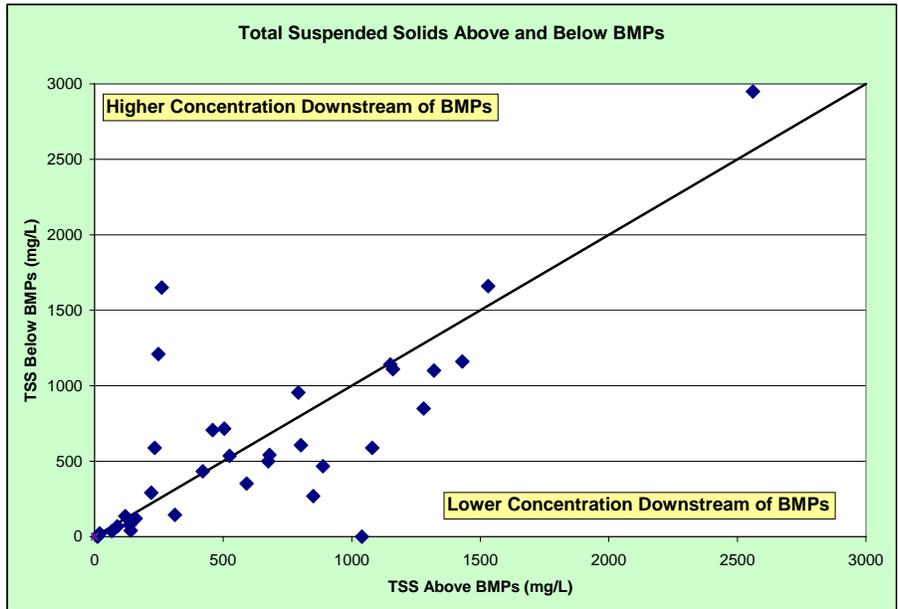


Figure 32. Effectiveness of BMPs in reducing suspended solids from storm runoff. Each data point represents a pair of samples – one from above and one from below a BMP that were sampled from a single storm event. A data point to the right of the solid line indicates lower suspended solids downstream of the BMP. The majority of the sample pairs indicate that suspended solids were reduced downstream of the BMPs.

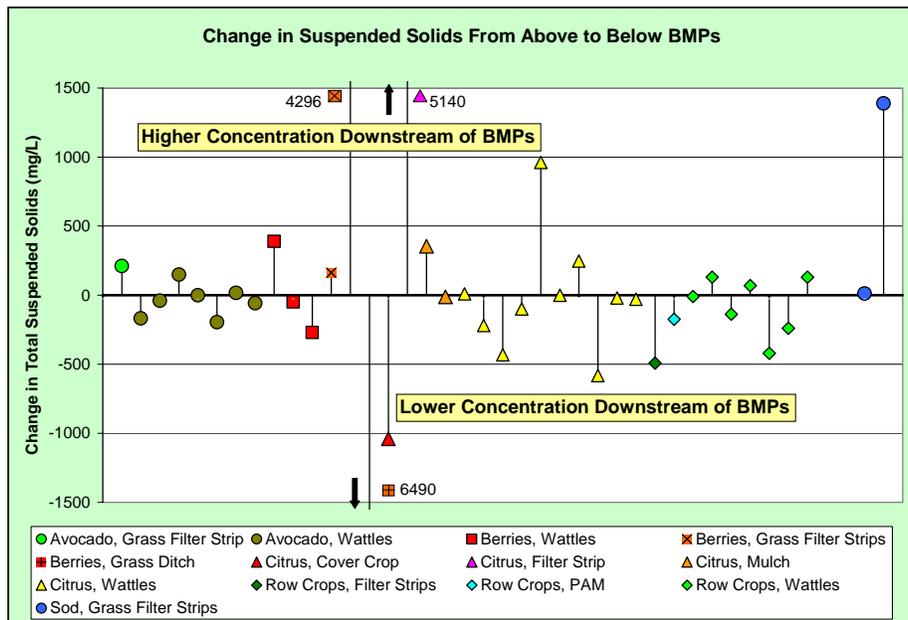


Figure 33. Change in suspended solids downstream of BMPs. Chart indicates changes in concentration of suspended solids by crop and BMP – each point represents a sample for a particular storm event.

3.3 NUTRIENT RESULTS

Nutrient concentrations were generally high in tested waters, with the sites of highest concentrations varying from runoff to percolating water, depending upon the nitrogen compound. 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 maximum contaminant level (MCL) for drinking water (Figure 34). Percolating waters generally have higher concentrations of nitrate plus nitrite, with averages of up to ten times the MCL in non-orchard crops. Tailwaters from sod sites had the highest concentrations of nitrate plus nitrite.

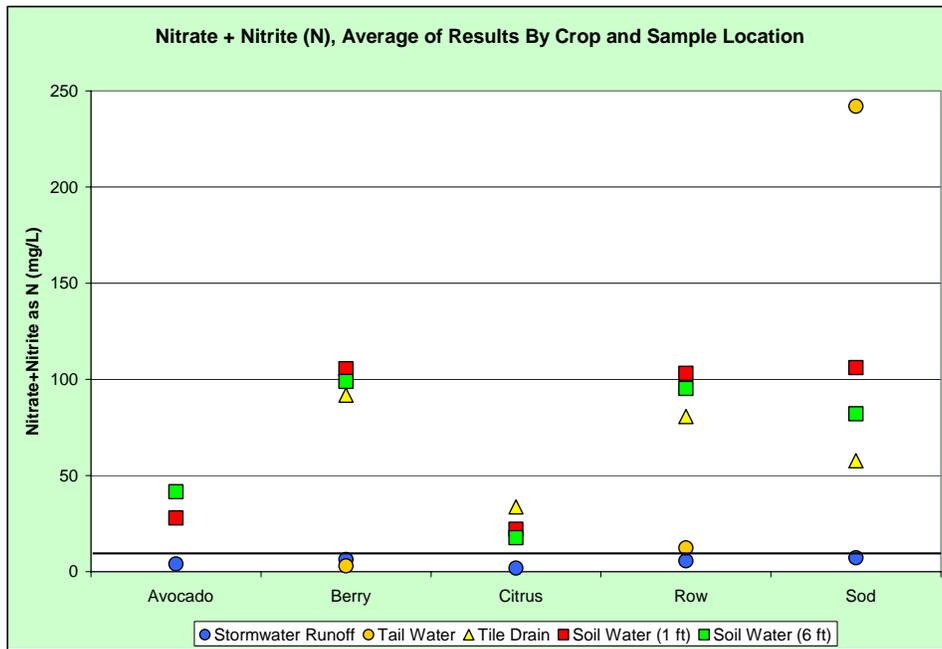


Figure 34. Results of sampling for varying crop types and sample locations, nitrate + nitrite as N. The symbols represent the average concentration for both surface waters and percolating waters. Non-detects are including in the average as zero concentrations. Crops with no tailwater symbol indicate that there was no tailwater observed at any study site with that crop. The line at 10 mg/L is the drinking water Maximum Contaminant Level (MCL).

The concentrations of ammonia detected vary widely among crop type and sampling site (Figure 35). Notable was the high concentration of ammonia in two tailwater samples at sod study sites. In a reversal of the nitrate plus nitrite sampling, concentrations of Total Kjeldahl Nitrogen were highest in storm water runoff (Figure 36).

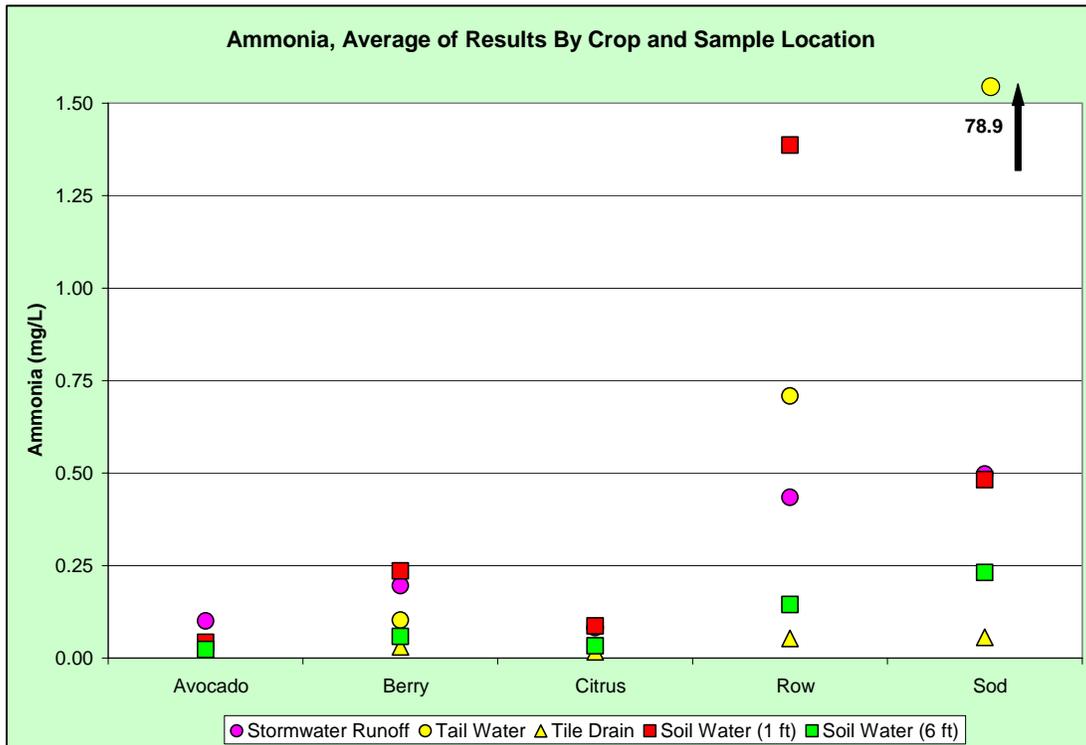


Figure 35. Results of sampling for varying crop types and sample locations, ammonia. The symbols represent the average concentration for both surface waters and percolating waters. Non-detects are including in the average as zero concentrations. Crops with no tailwater symbol indicate that there was no tailwater observed at any study site with that crop.

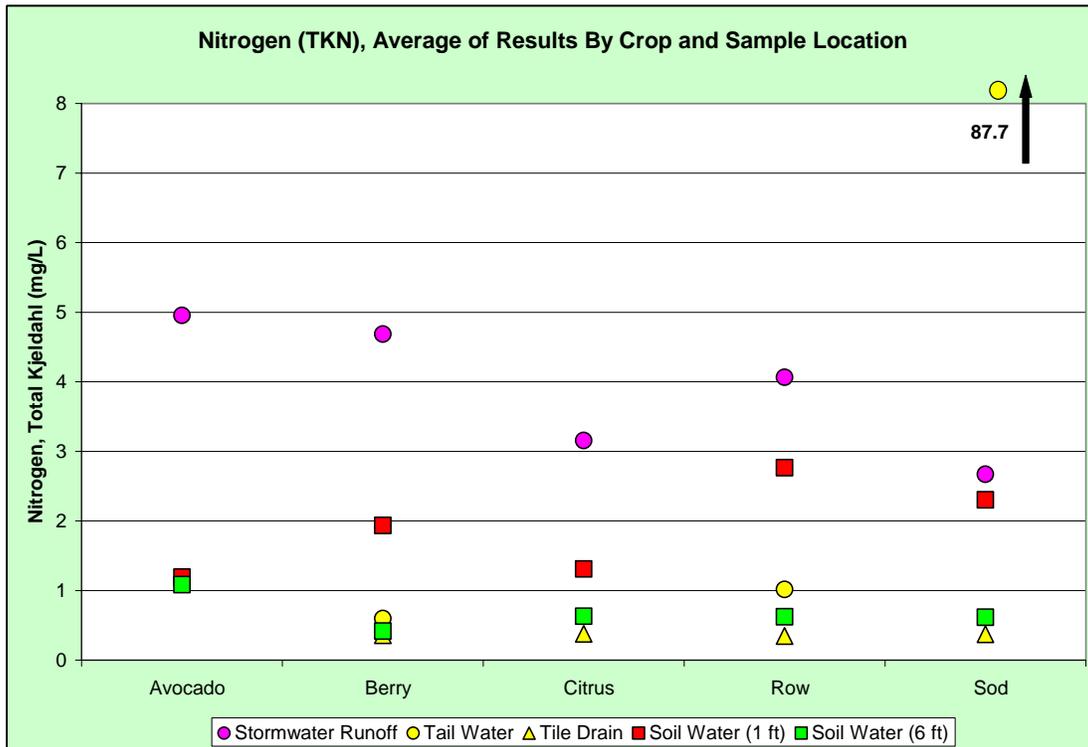


Figure 36. Results of sampling for varying crop types and sample locations, Total Kjeldahl Nitrogen. The symbols represent the average concentration for both surface waters and percolating waters. Non-detects are including in the average as zero concentrations. Crops with no tailwater symbol indicate that there was no tailwater observed at any study site with that crop.

An additional method of analyzing percolating waters is to compare the shallow (1-foot) lysimeter results to those from the deeper (6-foot) lysimeters (Figure 37 to Figure 39). 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. The consequences of higher concentrations of nutrients at depth beneath the crops are discussed in Section 4.6.1 (Quantitative Assessment). In particular, the majority of analyses of nitrate plus nitrite indicated higher concentrations at depth.

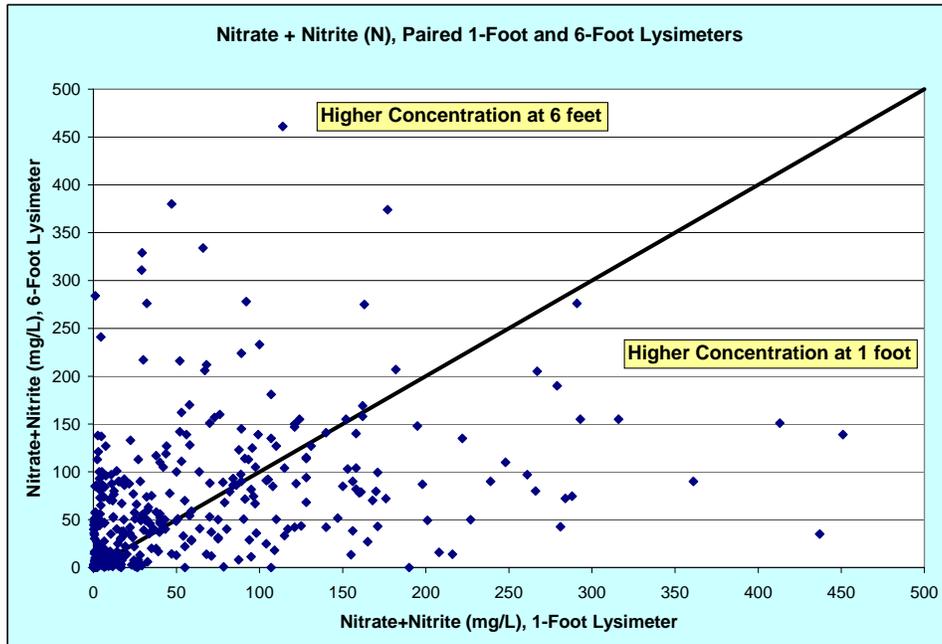


Figure 37. Comparison of nitrate + nitrite (N) analyses from paired lysimeters. Samples that plot above the diagonal line indicate that nitrate + nitrite are higher in the deeper lysimeter, where it is generally not available for plant uptake. The drinking water maximum contaminant level (MCL) is 10 mg/L.

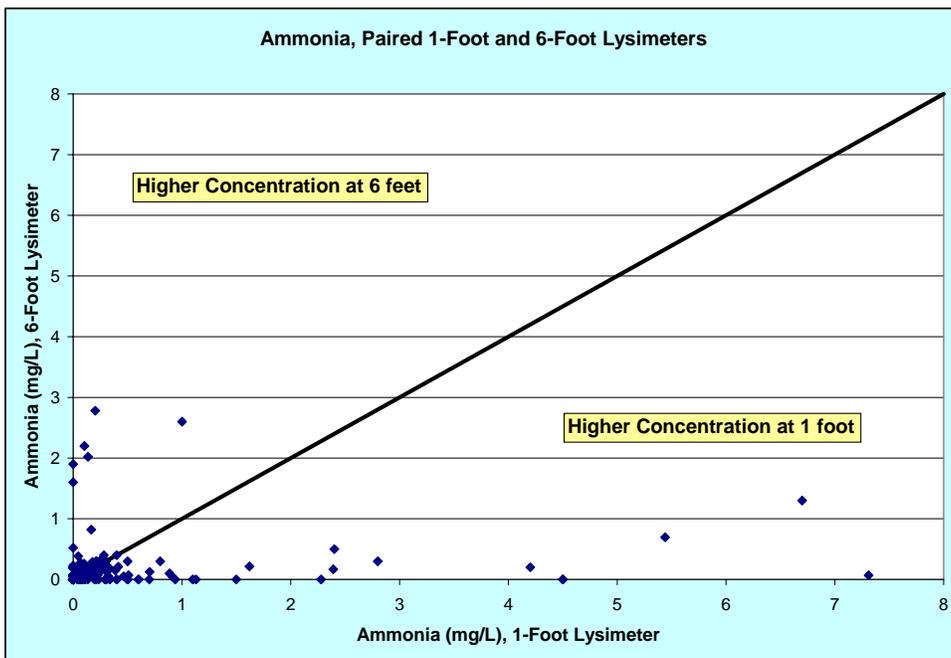


Figure 38. Comparison of ammonia analyses from paired lysimeters. Samples that plot above the diagonal line indicate that ammonia is higher in the deeper lysimeter.

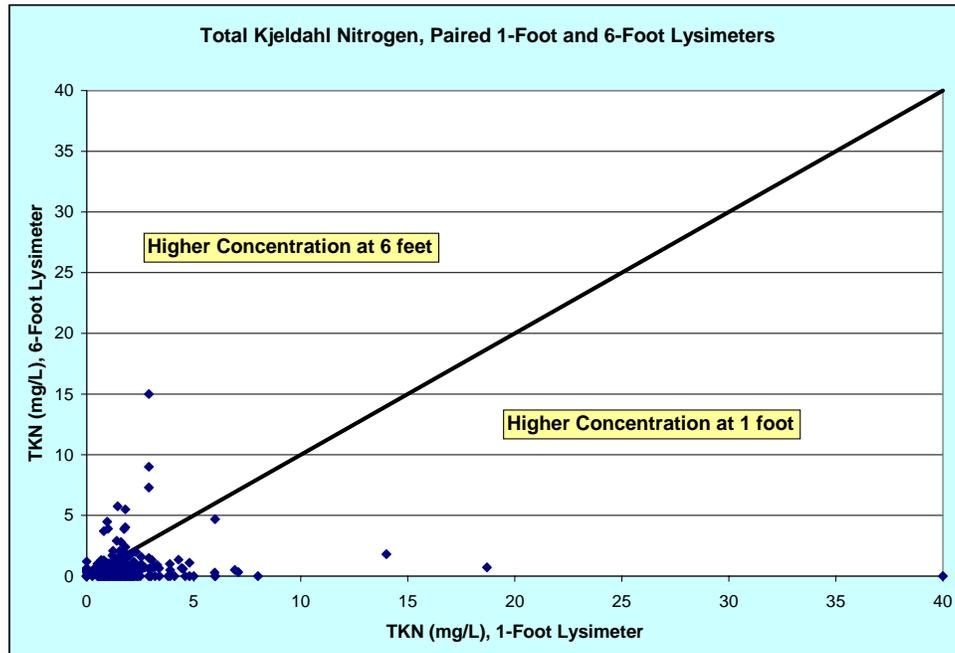


Figure 39. Comparison of Total Kjeldahl Nitrogen (TKN) analyses from paired lysimeters. Samples that plot above the diagonal line indicate that TKN is higher in the deeper lysimeter.

The concentrations of nitrate plus nitrite are also plotted separately for the various types of crops in the study (Figure 40 to Figure 44). The crop types with the highest concentrations of nitrate plus nitrite at individual sites were row crops and berries, although the overall average concentration for sod was equal. Notably, at sites where the depth of the wetting front was measured in real time and the irrigation run time was adjusted accordingly, nitrate plus nitrite concentrations were among the lowest analyzed (Figure 40 and Figure 41).

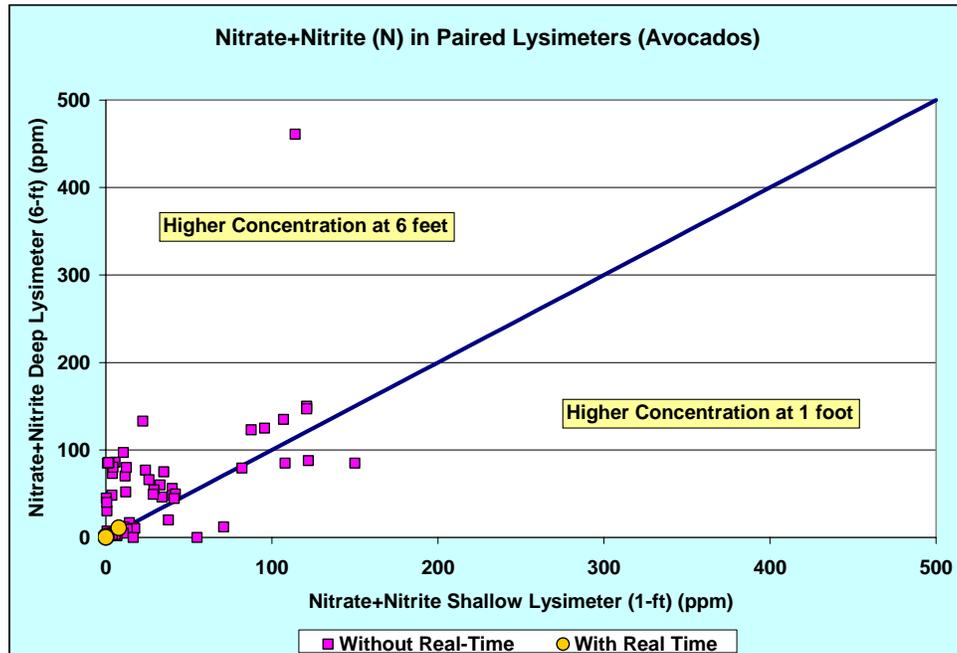


Figure 40. Comparison of nitrate + nitrite (N) analyses from paired lysimeters in avocados. Samples that plot above the diagonal line indicate that nitrate + nitrite are higher in the deeper lysimeter, where it is generally not available for plant uptake. The drinking water maximum contaminant level (MCL) is 10 mg/L. 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.

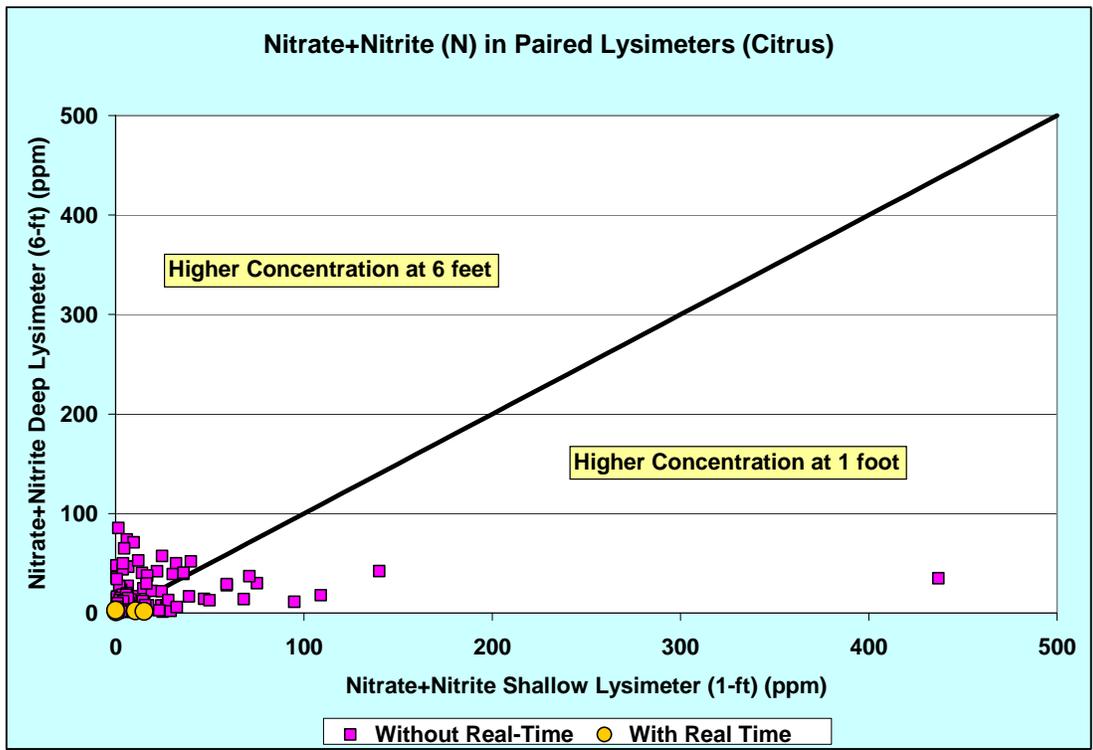


Figure 41. Comparison of nitrate + nitrite (N) analyses from paired lysimeters in citrus. Samples that plot above the diagonal line indicate that nitrate + nitrite are higher in the deeper lysimeter, where it is generally not available for plant uptake. The drinking water maximum contaminant level (MCL) is 10 mg/L. 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.

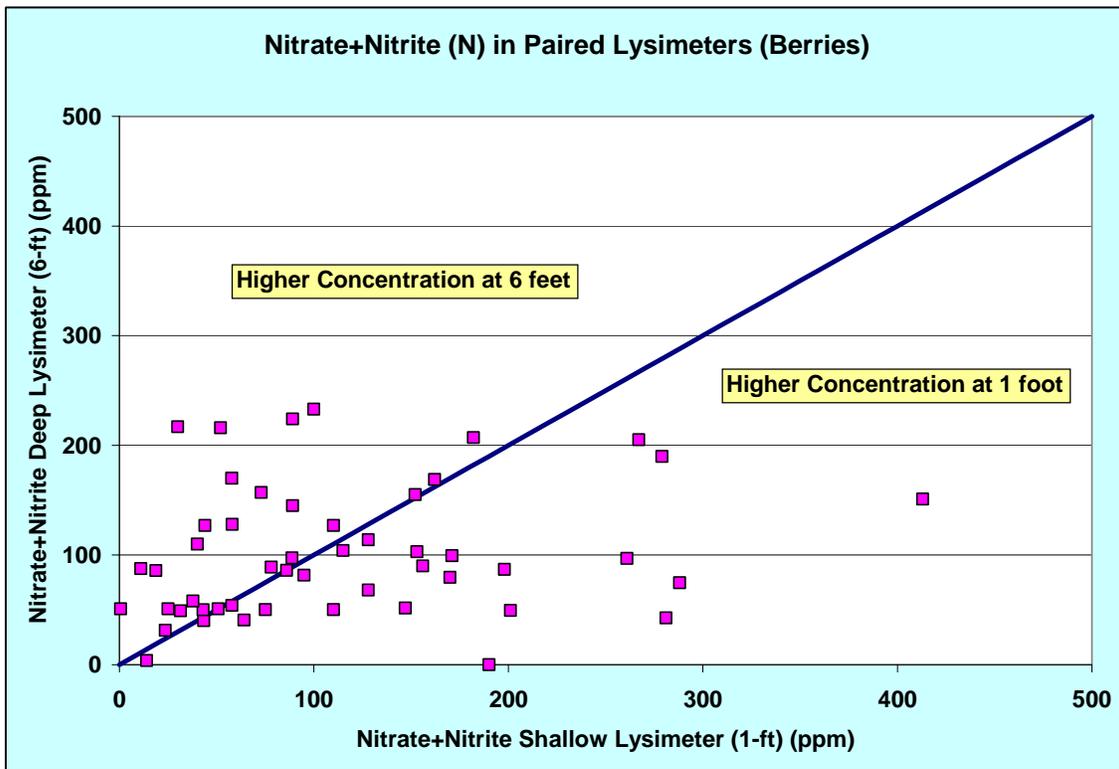


Figure 42. Comparison of nitrate + nitrite (N) analyses from paired lysimeters in berries. Samples that plot above the diagonal line indicate that nitrate + nitrite are higher in the deeper lysimeter, where it is generally not available for plant uptake. The drinking water maximum contaminant level (MCL) is 10 mg/L.

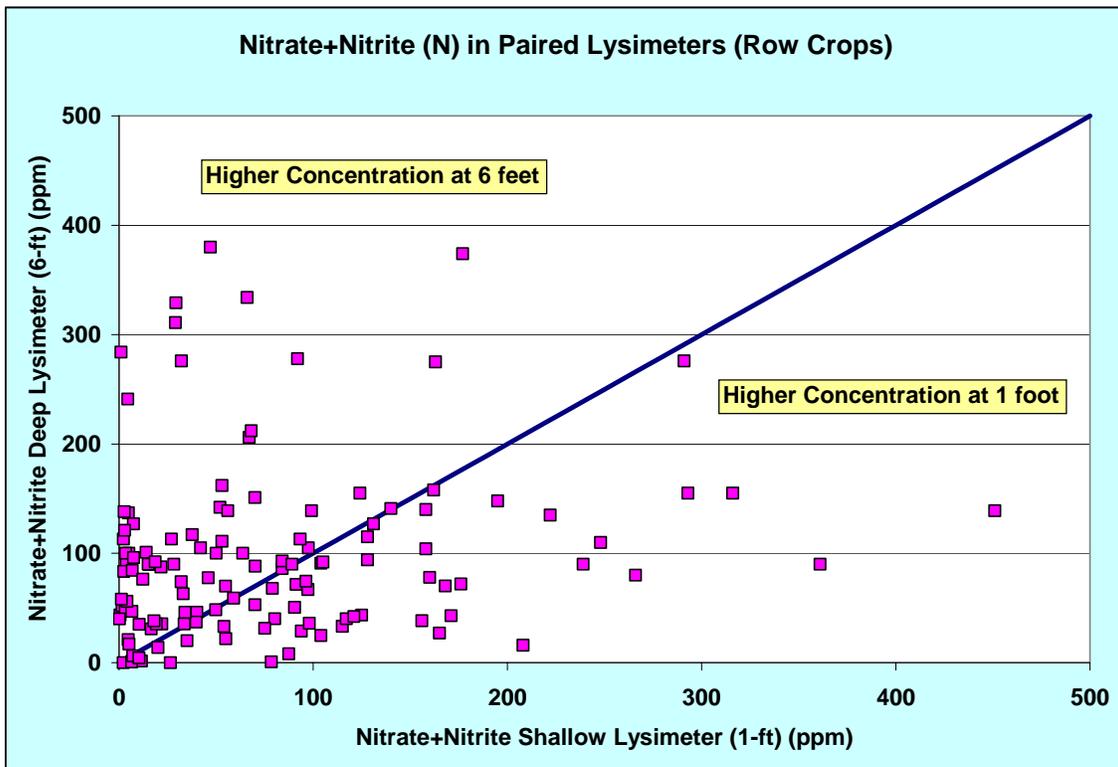


Figure 43. Comparison of nitrate + nitrite (N) analyses from paired lysimeters in row crops. Samples that plot above the diagonal line indicate that nitrate + nitrite are higher in the deeper lysimeter, where it is generally not available for plant uptake. The drinking water maximum contaminant level (MCL) is 10 mg/L.

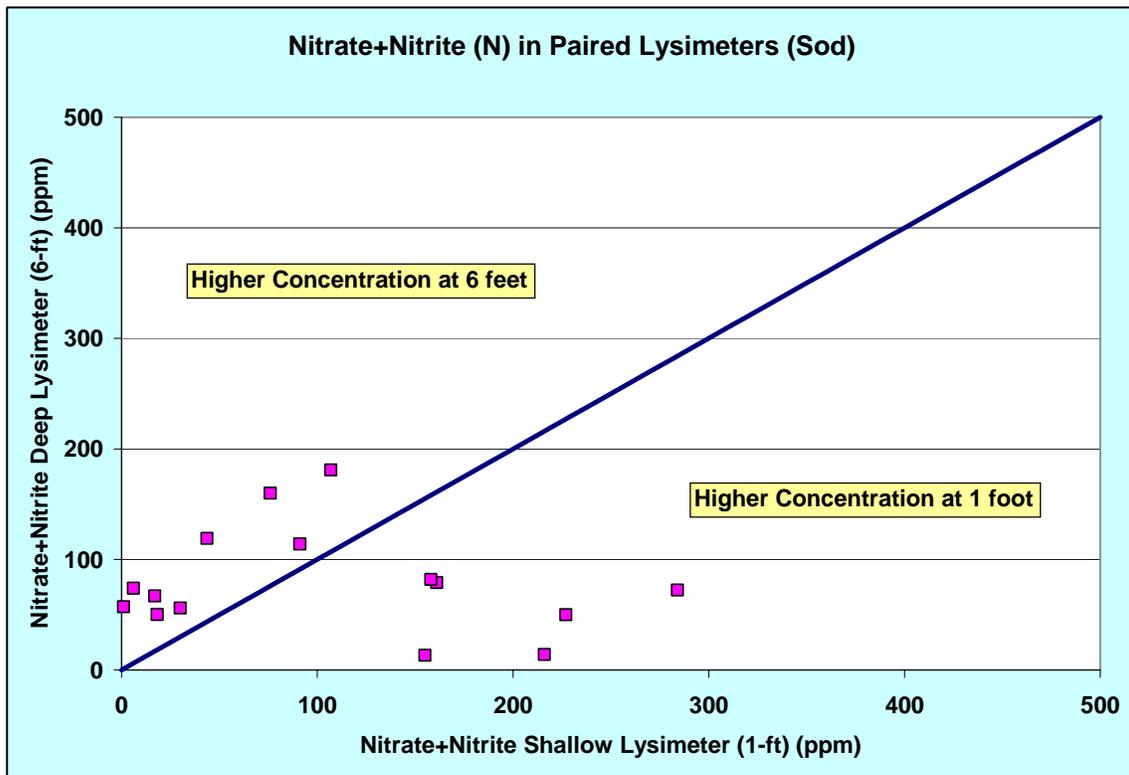


Figure 44. Comparison of nitrate + nitrite (N) analyses from paired lysimeters in sod. Samples that plot above the diagonal line indicate that nitrate + nitrite are higher in the deeper lysimeter, where it is generally not available for plant uptake. The drinking water maximum contaminant level (MCL) is 10 mg/L.

4. DISCUSSION

4.1 CHARACTERIZATION OF LOCAL PESTICIDE AND HERBICIDE PRACTICES

Throughout this report, all of the chemical compounds being analyzed have been generically referred to as pesticides and herbicides. Technically, the constituents discussed are active ingredients or markers of active ingredients used in formulated pesticide and herbicide products. These markers are either breakdown products of the active ingredient or isomers used in the manufacturing of the active ingredient. For instance, Endosulfan is a mixture of the isomers Endosulfan I and Endosulfan II; and Endosulfan sulfate is a breakdown byproduct of Endosulfan. Also, commercial BHC (Benzene HexaChloride) is a mixture of alpha-BHC, beta-BHC, and gamma-BHC; these isomers are markers of Lindane. The Demeton product is a mixture of the isomers Demeton-O and Demeton-S. Alpha Chlordane, gamma Chlordane, and Heptachlor are all major components of technical Chlordane. DDD and DDE are the well-known daughter products of the infamous chlorinated pesticide DDT.

A description of approved local uses for the pesticides and herbicides analyzed in this study are presented in Table 21 and Table 22 and discussed throughout the remainder of this section. The information regarding pesticides and herbicide use in the subsequent tables and discussion is paraphrased from a 2007 written communication requested of and provided by Susan Johnson, Chief Deputy Agricultural Commissioner for Ventura County.

Table 21 Description of local pesticide uses in Ventura County

	Currently Registered	Type *	Latest Cancellation	Dates of Use	Target Pest	Applied to	Historic Use in Ventura County
Chlorinated Pesticides							
Aldrin	no	I,A	1989	1959-1989	subterranean termites	structures	structural use
Dieldrin	no	I,A	1985	1958-1985	subterranean termites	structures	structural use
DDT	no	I	1989	1952-1989	most insects	most crops	used on lima beans, citrus, and walnuts
Endrin	no	I,R	1989	1970s**-1989	insects, rodents, birds	wheat, cotton, barley, rye	possible rodenticide
Endosulfan	yes	I		1972-present	insects	many	no significant use since 2000
Heptachlor	no	I,F	1987	1965-1988	subterranean termites	structures, seeds	possible seed treatment
Lindane	no	I	1989	1954-1989	lice, ticks, homopterans	people, animals, seeds	most recent use in lice shampoo
Methoxychlor	no	I	2001	1978-2001	animal pests, homopterans, lepidopterans		possible use on greenhouse flowers
Toxaphene	no	I	1983	1954-1983	weevils, worms	grapes, cotton	unlikely to have been used
Organophosphate Pesticides							
Azinphos Methyl	yes	I		Not avail.	codling moth, fruit fly	apples, pears, almonds, pistachios, walnuts	none in Ventura County
Chlorpyrifos	yes	I		1960s**-present	ants, aphids, scale	lemons and other citrus, strawberries	once a year in citrus, occasional use in strawberries
Demeton	no	I	1988	1976-1988	mites, leafhoppers, aphids, leafminers	cabbage, lettuce, greens	none known
Diazinon	yes	I		1950s+-present	worms, ants	lawn and garden, vegetable crops	row crops, residential, citrus for ants
Dimethoate	yes	I		1970s-present	aphids, leafhoppers, scale	celery, cabbage, beans, lettuce, flowers, mustard, and turnips	
EPN	no	I	1988	1973-1988	cotton bollworm. Leafworm. Aphids, mites	cotton	
Mevinphos	no	I	1994	1974-1994	aphids, leafhoppers, scale	wide variety of field and vegetable crops	
Naled	yes	I	Most uses 1995	1968-1995	only current use in Med-fly traps		use in Med-fly traps
Parathion Methyl	no	I,A	1987	1958-1987	aphids, leafhoppers, mites, worms	cotton, dormant spray in fruit trees, citrus	
Parathion ethyl	no	I,A	1989	1959-1989	aphids, worms, leafhoppers, scale	cotton, dormant spray in fruit trees, lettuce, cabbage	
Phorate	yes	I		1970-present	aphids, mites, leafhoppers, scale	cotton, potatoes	
Sulfotepp	no	I	2003	1975-2003	insecticide	wine grapes, nursery stock, cut flowers	
Disulfoton	no	I	1994	1973-1994	aphids, mites, leafhoppers, scale	cotton, wheat, Christmas trees, vegetable crops	preplant peppers, vegetable crops

*Key for "Type" category; A=Acaricide, F=Fungicide, H=Herbicide, I=Insecticide, R=Rodenticide

**Estimated date

Source: written communication, Susan Johnson, 2007

Table 22 Description of local herbicide uses in Ventura County

	Currently Registered	Type *	Latest Cancellation	Dates of Use	Target Pest	Applied to	Historic Use in Ventura County
Triazine Herbicides							
Atrazine	yes	H		1959** -present	Pre-emergent herbicide	Weed control, landscaping	Only on industrial sites
Simazine	yes	H		1958- present	Pre-emergent herbicide	Weed control, citrus and avocados	Limited due to groundwater contamination

*Key for “Type” category; A=Acaricide, F=Fungicide, H=Herbicide, I=Insecticide, R=Rodenticide

**Estimated date

Source: written communication, Susan Johnson, 2007

4.1.1 Usage of Chlorinated Pesticides in Ventura County

Of the chlorinated pesticides analyzed in this study, Endosulfan is the only product that is currently registered for use in California. There are 24 registered products that have Endosulfan as an active ingredient. Registered crops include strawberries, lemons, oranges, tomatoes, collard greens, broccoli, and fruiting peppers. According to the Ventura County Agricultural Commissioner’s office, there has been no reported usage of the product in Ventura County since 2003. Beginning in the mid 1990s, labels on Endosulfan products required the implementation of buffer zones between uses on crops and waterways. Following this requirement, usage of the product in Ventura County diminished. Reported uses of the product were as a foliar spray by either ground or air applications.

Aldrin, Dieldrin, and Heptachlor were used primarily as preventative and prescriptive treatments for subterranean termites in structures. Their use was common throughout the state until the mid eighties. Endrin was used primarily as a rodenticide and avicide in both agricultural and non-agricultural settings. According to the Agricultural Commissioner’s office, no information is available on the historical prevalence of use of the Endrin in Ventura County.

The agricultural use of Lindane was as a seed treatment. It was also used in non-agricultural settings as a drench or dip to control animal pests and as a shampoo to control head lice among humans. DDT was in common use throughout most of the 1950s and 1960s. Its initial use was on walnuts in the Simi Valley area, apricots in the Moorpark area and citrus in the Santa Clara River valley. It was also used on lima beans in the Oxnard Plain. At the time of reported usage, pesticides were commonly sprayed on schedule as a preventative treatment. Applications were made by ground or by air.

The most common use for Toxaphene was in cotton and table grapes. These crops were not grown in Ventura County and according to the Agricultural Commissioner’s office, local usage of Toxaphene was limited. Usage of Methoxychlor was common in both agricultural and residential settings. It was used to control a variety of common pests.

Methoxychlor was applied in agricultural settings as a prescriptive treatment for aphids, scale, leafhoppers and worms.

(This section paraphrased from written communication from Susan Johnson, 2007)

4.1.2 Usage of Organophosphate Pesticides in Ventura County

Disulfoton is a broad spectrum organophosphate insecticide and acaricide used in a wide variety of pesticide products. The majority of use in agriculture is with wheat and cotton. It is also commonly used as a preventative treatment prior to planting in some vegetable crops and in lawn and garden situations on ornamentals. The primary use in Ventura County is as a pre-plant treatment in bell peppers used conjunctively with a fumigant such as 1,3 Dichloropropene or Methyl Bromide. It is also used as a pre-plant application in cabbage, broccoli, cauliflower, and leaf lettuce. Disulfoton is commonly formulated as a granular material and applied to the soil. There are also liquid formulations that can be used as a foliar spray by ground or by air. Most applications in Ventura County are spray applications done by ground.

Dimethoate is an insecticide used to kill mites and insects systemically and on contact. It is typically used against a wide variety of insects, including aphids, thrips, planthoppers and whiteflies on alfalfa, apples, corn, cotton, grapefruit, grapes, lemons, melons, oranges, pears, pecans, safflower, sorghum, soybeans, tangerines, tobacco, tomatoes, watermelons, wheat and other vegetables. It is also used on nursery ornamentals and lawn and garden applications. It may also be used as a residual wall spray in farm buildings for house flies, and has been administered to livestock for the control of botflies. The predominant use of Dimethoate in Ventura County has been on cauliflower, green beans, head lettuce, leaf lettuce, collards, celery, cabbage, mustard, kale, turnips, and cut flowers. Dimethoate is available in aerosol spray, dust, emulsifiable concentrate, and as Ultra Low Volume (ULV) concentrate formulations. Applications are commonly made by ground with a low pressure sprayer.

Diazinon is a pesticide commonly used in Ventura County on root vegetables, cole crops, spinach, lettuce, raspberries, green onions, strawberries, sweet corn, and cut flowers. The most usage is reported with green onions, raspberries, sweet corn and cut flowers. It is most commonly applied by ground with a low pressure ground rig in all crops except sweet corn. It is applied by air in sweet corn to control corn earworm, as both a preventative and prescriptive application on a weekly basis after tasseling has occurred. Diazinon is formulated as an emulsifiable concentrate, wettable powder, granular material and as a bait. Its use is prescriptive to control a wide variety of pests including worms, aphids, scale, thrips, leafhoppers and planthoppers. Diazinon is also a common active ingredient in lawn and garden sprays and is most commonly applied in a granular form to control ants, but may also be used in a ready-to-use formula for a wide variety of garden pests. It was a very common product used in structural pest control inside dwellings, but has been replaced by synthetic pyrethroids in the last five years.

Malathion is a pesticide that is used to kill insects on agricultural crops, stored products, golf courses, residential and industrial gardens, and at outdoor sites where trees and

shrubs are grown; it is also used to kill mosquitoes and Mediterranean fruit flies (Medflies) in large outdoor areas. Additionally, Malathion is used to kill fleas on pets and to treat head lice on humans. It is usually sprayed on crops or sprayed from an airplane over wide land areas, especially in the states of California and Florida. Malathion comes in two forms: a pure form of a colorless liquid and a technical-grade solution (brownish-yellow liquid), which contains Malathion (greater than 90 percent) and impurities in a solvent. Malathion has been manufactured in the United States since 1950 and has been used to kill insects on many types of crops since that time. Its use is common in the San Joaquin Valley to control the beet leafhopper on rangeland and other non-irrigated lands to control the spread of lettuce mosaic virus. Crops treated with Malathion in Ventura County include root vegetables, cole crops, mustard, parsley, strawberry, avocado, lemon, green beans, tomatoes, watercress, peppers, and nursery stock. The most usage is in nursery stock, celery and watercress. The product is formulated as an aqueous solution, an emulsifiable concentrate, a wettable powder, flowable powder and in ready to use formulations for lawns and gardens. It has also been used in flea and tick products including collars and is a frequent ingredient in home use products to control common lawn and garden insects and mites.

Chlorpyrifos is the active ingredient in Lorsban and Dursban. Lorsban is an agricultural product and Dursban is a non-agricultural product. Use of Lorsban is most common in Ventura County on Lemons. It is commonly applied in the fall between September and November with a high pressure speed sprayer. It can also be applied in granular form to orchard floors in lemons and oranges to control ants. Dursban was once one of the most commonly used pesticides in structural pest control. It was used primarily to control subterranean termites, ants, and cockroaches. It was also used in institutional settings, in lawn and garden products and to control fleas and ticks on pets. With the advent of the Food Quality Protection Act in 1997 at the federal level the material came under scrutiny because of the concept of the “risk cup”. Under this procedure the lifetime risk from a particular material was assessed based on how widespread the use of the material was and how diverse the setting in which it was used. Since Chlorpyrifos was used in a wide variety of settings, the possible lifetime exposure from all uses exceeded the acceptable amount in the “risk cup”. In late 1990s most of the residential and lawn and garden uses were removed from the labels and the agricultural uses were retained. Dursban is no longer available for structural, or lawn and garden uses.

(This section paraphrased from written communication from Susan Johnson, 2007)

4.1.3 Usage of Triazine Herbicides in Ventura County

Simazine is an herbicide used to prevent the growth of weeds in established orchards. It is applied to the ground prior to the emergence of the target weed and then water is applied to move the active ingredient to the root zone of the weeds. It is used in oranges, lemons, avocados and occasionally in nursery stock in Ventura County. Simazine is listed in Section 6800(a) of the California Code of Regulations as a Ground Water Protection Chemical. Pesticides and herbicides listed in 6800(a) have been found to contaminate groundwater in many parts of the state. The use of these materials was restricted in areas where they had been found in groundwater in the late 1980s and

subsequently use of the material decreased. In 2005, the Ground Water Protection Regulations (CCR Section 6800(a)(b) et al) were revised to further restrict the use of the materials listed therein in areas where the depth to groundwater was less than 70 feet or where soil profiles were deemed likely to allow groundwater contamination. Use of Simazine in Ventura County has decreased significantly as a result of these regulations. Under the old regulations there were only six sections in the county where Simazine use was restricted. Under the new regulations there are 64 sections (Groundwater Protection Areas, shown in Figure 45) where the use of Simazine and other groundwater contaminants are restricted. Use of the material is still fairly common in sections where the use is not considered a threat to groundwater. Simazine is also an ingredient in some lawn and garden products, and is used prior to setting out transplants.

Atrazine is a similar chemical to Simazine and is subject to the same restrictions. Atrazine is not used in orchards in Ventura County because it is not registered for citrus, avocados or nursery stock. It is used on bare ground and then water is applied to move the chemical to the correct soil depth for weed control. It can only be used in areas not vulnerable to groundwater contamination. Atrazine is commonly used in areas where almonds and other nut crops are grown, such as the San Joaquin Valley.

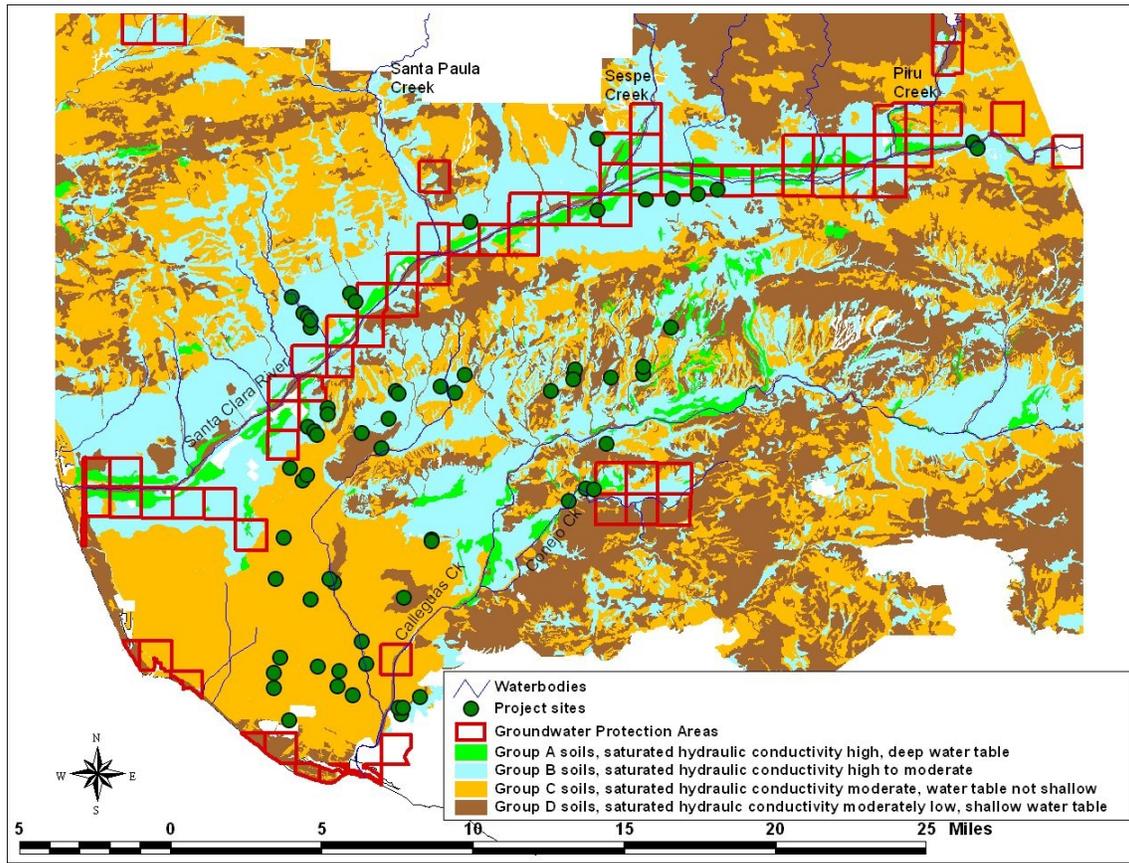


Figure 45 Groundwater Protection Areas (GWPA) and hydrologic soil classifications

4.2 SOIL CONSIDERATIONS

Certain soil characteristics are known to affect the mobility of pesticides in the shallow subsurface. Among the significant soil characteristics affecting the transport of chemicals are: water-holding and water retention properties, potential for surface compaction, the presence of soil components that may bind with and retard chemical movement, and the presence of microbes that can degrade pesticide residues (CDPR, 2006). While not proposed in the original scope of this project, it is reasonable to consider how the physical properties of various soils might influence or facilitate the migration of nitrogen or organic compounds in the shallow subsurface.

Detailed mapping of soils existing in the project area has previously been conducted by the U.S. Department of Agriculture, Natural Resources Conservation Service. Mapping of soils in the Ventura area (CA674) is available in digital format, as is an extensive database detailing soil descriptions and the physical properties of Ventura County soils. This Soil Survey Geographic (SSURGO) data set includes details on the 141 soil types mapped in the greater Ventura area, many of which are found within the study area of this project (NRCS, 2007).

One of the general soil classifications included in the SSURGO database is the Hydrologic Soil Group, which ranks near-surface soils by their saturated hydraulic conductivity and depth to internal free water (perched water or the local water table). This soil classification was selected as a simple way to rank soil permeability at project sites. The distribution of soils within this four-tier classification schedule is displayed in Figure 45. Among the lysimeter sites of the PRISM and Consolidated projects addressed by this report, only two sites were located in Group A soils, described as having very high near-surface hydraulic conductivity and very deep internal free water. Thirty-two sites were located in Group B soils, soils having moderately-high conductivity and deep or very deep free water. Twenty-three sites, many located on the Oxnard Plain, are classified as Group C soils; these soils have moderate saturated hydraulic conductivity and a free water depth that is not shallow. Eight sites are in Group D soils, where soil permeability is moderately low, and saturated conditions are shallow or very shallow (continuous or transitory). Inspection of Figure 45 shows that many reaches of the active river and creek channels in Ventura County are classified as Group D soils, not due to their permeability but due to their permanent or transitory saturated conditions.

Nitrogen results from all six-foot lysimeters at project sites were queried by Hydrologic Soil Group. Various crop types were located within each group with the exception of Group A, where both locations are citrus sites. With the exception of zero ammonia detections among the Group A citrus sites, the frequency of detections and the average concentration among the various nitrogen species did not vary significantly between the soil groups. The lysimeters within the Group C soils did record the highest average nitrate plus nitrite concentrations, but this group contains the greatest percentage of row crops and berries. Sampling conducted as part of this study has shown that soil water

beneath berries and row crops often have higher nitrogen concentrations than with orchard crops. This analysis suggests that cultural practices associated with the cultivation of various crop types may have a greater influence on nitrogen concentrations in deep soil water than does the Hydrologic Soil Group.

Detections of selected organic compounds were also evaluated based on Hydrologic Soil Group classifications. DDT, DDE and Chlorpyrifos were the pesticides most-commonly detected in lysimeters during this study. The frequency of detections and range of values for these compounds were similar between the Group B and C soils. DDT was detected most frequently and at similar concentration among the Group D and Group A soils, but the small sample populations of these two groups and the lack of historical application records for DDT in the study area leaves no confidence that this observation is meaningful. Detections of Simazine were also queried by soil group, as this herbicide was detected in nearly nine percent of the lysimeter samples, and this chemical is considered a threat to groundwater quality in certain environments (CDPR, 2006). Simazine was detected in twelve percent of the samples from the Group B soils, but not detected among the highly-permeable Group A soils. The frequency of Simazine detections was three percent of the samples among the Group C soils, but the highest average chemical concentrations in soil water were recorded at these sites. As with the nitrogen results discussed above, a thorough knowledge of chemical applications is likely required before meaningful observations can be made regarding the influence of soil properties on the subsurface transport of specific agricultural chemicals. The survey-scale data set afforded by this project is not likely to adequately address the significance of soil properties in the retention or movement of agricultural chemicals.

It is known that area growers often apply soil amendments and physically manipulate soils to improve soil drainage properties. Drainage problems are also addressed by land grading and the installation of subsurface drainage systems (tile drains). The organic content of soils may also be manipulated in various ways by area growers. As the manipulation of cultivated soils is known to be a common practice, the physical properties of cultivated soils may differ from the properties reported in available data sets such as SSURGO. The preliminary soil assessments presented here appear to be too simplistic to adequately address soil-related influences on subsurface migration of agricultural chemicals.

4.3 AGRICULTURAL CHEMICALS IN PRODUCTION WELLS

Results from this study show that among the suite of agricultural pesticides and herbicides evaluated, liquid phase detections in near-surface soil moisture and in deeper soil water collected from subsurface drainage systems are generally infrequent and of low concentration. The suite of chemicals evaluated in this project was largely based on existing listings of impairments in surface waters within the study area, and it is recognized that a number of active agricultural chemicals were not assessed in this study. Other sampling programs exist that conduct and summarize the sampling of public and private drinking water wells. Recent data sets from two such efforts are briefly detailed below.

The Pesticide Contamination Prevention Act of 1985 strengthened the California Department of Pesticide Regulation's (CDPR's) regulatory authority with respect to groundwater contamination issues and established a mechanism for the collection and reporting of pesticide and herbicide detections in drinking water wells located throughout the state. For the reporting period from July 2005 through June 2006, a total of 65 public or private drinking water wells in Ventura County were sampled by CDPR for as many as 58 distinct chemical compounds. The distribution of the wells sampled in this program is not readily apparent, but the number of samples for individual compounds is published in tabular form in the annual report. For example, Atrazine and Simazine were assessed in samples collected from 28 wells, Diazinon was assessed in samples from 18 wells, Toxaphene in samples from 11 wells, and Methyl Bromide (bromomethane) in samples collected from 42 wells. Among these samples, there were zero pesticide detections reported (CDPR, 2006). Method detection levels for the various compounds analyzed are likely variable. Analytical method detection levels may be available from the DPR, but they do not appear to be published in the 2006 document. Reported detections of pesticides in other counties show detections as low as 0.01 µg/L, which is similar to many of the PQLs for analyses conducted as part of this (Consolidated) study.

Another data set containing pesticide analyses for drinking water wells in Ventura County is available from the California Department of Health Services (CA DHS), Drinking Water Program. This database is an archive of sample results collected by individual wholesale and retail drinking water providers, who are required by CA DHS to periodically sample wells for organic compounds. Monitoring assessments of Ventura County wells between 2002 and 2006 resulted in more than 6,900 chemical records in the agricultural compounds classification. Of these records, there were a total of ten detections reported. One detection was reported for both Dibromochloropropane and 1,2-Dichloropropane, at concentrations below the drinking water standard. The herbicide Diuron was detected in three samples, with concentrations ranging from 0.1 to 1.4 µg/L. Special circumstances related to these three Diuron detections suggest the detections are not related to local agricultural practices. A maximum contaminant level for Diuron is not listed in the CA DHS database. The remaining five reported detections were for Bromomethane and Chloromethane, at concentrations ranging from 0.7 to 3.2 µg/L. It is uncertain if these detections are related to the use of agricultural chemicals. It is considered likely that these results record the presence of disinfection by-products related to prior well disinfection activities.

Existing groundwater sampling programs show that detections of pesticides and herbicides in Ventura County drinking water wells are very rare. This finding is good news and does not suggest widespread groundwater contamination issues in Ventura County with respect to organic agricultural chemicals. However, it should be noted that the sampling of existing drinking water wells may not provide a thorough assessment of groundwater conditions in areas for which the predominant land use is agricultural. While the distribution of the wells sampled by CDPR remains uncertain, a number of the public supply wells represented in the CA DHS database are located in urban areas, and

may have long well screens that can serve to dilute the concentrations of near-surface contaminants in water produced by the well. While the data set accurately reports the water quality of well water entering these public water systems, the wells are not located and designed in such a way that they would show the “worst case” conditions for groundwater contamination related to agriculture.

4.4 TOXICITY DISCUSSION

The type of sampling conducted during this study differs from the type of sampling typically conducted within a watershed in order to assess attainment of water quality objectives in waterbodies. The analytical results from stormwater runoff presented here are from samples collected directly from active agricultural areas, as opposed to the waterbody (stream or lake) sampling typically conducted to assess the health of a watershed. Flow in a stream channel is often comprised of water from numerous origins, including urban runoff, groundwater discharge, runoff from agricultural areas, and other sources. Sample results presented here are grab samples collected during storm events, and it is not known where recorded concentrations fall in the range of concentrations likely present throughout a storm event. In short, this is a survey-level data set for the water quality of surface runoff and soil water in agricultural areas. Temporal water quality changes in area waterbodies are influenced by a number of complex and dynamic processes not addressed in this study.

While the application of waterbody water quality standards to the datasets generated by this study may not be appropriate, it is of interest to at least compare project results to existing standards. Table 23 and Table 24 summarize toxicity targets or concentrations from TMDL work within the Calleguas Creek watershed and from the California Toxics Rule (LARWQCB, 2005a; LARWQCB, 2005b; and EPA, 2000). Water and sediment targets have been developed for a number of the chlorinated pesticides evaluated in this study. There are few existing standards for organophosphate pesticides, and local standards have not yet been developed for the herbicides Simazine and Atrazine.

In the Calleguas Creek watershed, the freshwater water quality target for 4,4' DDT is 0.001 µg/l. The lowest method detection limit achieved in this study was 0.003 µg/l, so in this case any detection was recorded in excess of the water quality target. Among the chlorinated pesticide evaluated in this study, Toxaphene was recorded at the highest concentrations, but the water quality target for this compound is set very low at 0.000020 µg/L. In this example, all detections are at least four orders of magnitude greater than the water quality target.

Table 23 Calleguas Creek watershed toxicity criteria for chlorinated pesticides

Chlorinated Pesticides	Actively Registered	TMDL Numeric Targets (Tentative) ¹				CA Toxics Rule					
		Water Quality Targets		Sediment Targets		Fresh Water		Marine		Human Health for consumption of	
		Freshwater (µg/L)	Marine (µg/L)	Freshwater (µg/dry kg)	Marine (µg/dry kg)	CMC (µg/L)	CCC (µg/L)	CMC (µg/L)	CCC (µg/L)	Water and Organisms (µg/L)	Organisms only (µg/L)
Aldrin		3.0 ²	1.3 ²	NA	NA	3	NA	1.3	NA	0.00013	0.00014
alpha-BHC		NA	NA	NA	NA	NA	NA	NA	NA	0.0039	0.013
beta-BHC		NA	NA	NA	NA	NA	NA	NA	NA	0.014	0.046
delta-BHC		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
gamma-BHC(Lindane)		0.95 ²	0.16 ²	0.94	NA	0.95	NA	0.16	NA	0.019	0.063
alpha-Chlordane		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
gamma-Chlordane		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chlordane		0.0043	0.0040	4.5	0.5	2.4	0.0043	0.09	0.004	0.00057	0.00059
4,4'-DDD		NA	NA	3.5	2.0	NA	NA	NA	NA	0.00083	0.00084
4,4'-DDE		NA	NA	1.4	2.2	NA	NA	NA	NA	0.00059	0.00059
4,4'-DDT		0.001	0.001	NA	1.0	1.1	0.001	0.13	0.001	0.00059	0.00059
Dieldrin		0.056	0.0019	2.9	0.02	0.24	0.056	0.71	0.0019	0.00014	0.00014
Endrin		0.036	0.0023	2.7	NA	0.086	0.036	0.086	0.036	0.76	0.81
Endrin aldehyde		NA	NA	NA	NA	NA	NA	NA	NA	0.76	0.81
Endrin ketone		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Endosulfan I	X	0.056	0.0087	NA	NA	0.22	0.056	0.034	0.0087	110	240
Endosulfan II	X	0.056	0.0087	NA	NA	0.22	0.056	0.034	0.0087	110	240
Endosulfan sulfate	X	NA	NA	NA	NA	NA	NA	NA	NA	110	240
Heptachlor		0.0038	0.0036	NA	NA	0.52	0.0038	0.52	0.0038	0.00021	0.00021
Heptachlor epoxide		0.0038	0.0036	0.6	NA	0.52	0.0038	0.52	0.0038	0.0001	0.00011
Methoxychlor		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Toxaphene		0.00020	0.00020	NA	NA	0.73	0.0002	0.73	0.0002	0.00073	0.00075

NA = No Applicable Standards

Criterion Maximum Concentration (CMC) = Acute Criteria

Criterion Continuous Concentration (CCC) = Chronic Criteria

¹ - Derived from the California Toxics Rule, Chronic Criteria (CCC) were applied unless otherwise noted.

² - No Chronic Criteria (CCC) exists; Number is based on Acute Criteria (CMC)

Source: LARWQCB, 2005a and EPA, 2000

Table 24 Calleguas Creek watershed toxicity criteria for organophosphate pesticides

Organophosphate Pesticides	Actively Registered	TMDL Numeric Targets (Tentative)			
		Freshwater		Saltwater Mugu Lagoon / SCR Estuary	
		Chronic (4 day average) (µg/L)	Acute (1 hour average) (µg/L)	Chronic (4 day average) (µg/L)	Acute (1 hour average) (µg/L)
Chlorpyrifos	X	0.014	0.025	0.009	0.02
Diazinon	X	0.10	0.10	0.40	0.82

Santa Clara River (SCR)
Source: LARWQCB, 2005b

4.5 COMPARISON OF RESULTS BY SAMPLE TYPE

Sample results from lysimeters and tile drains were not expected to vary significantly over the course of this study. Pesticide and herbicide applications were not monitored or manipulated throughout the sampling period, and it is assumed that growers did not substantially alter their pesticide or herbicide application practices over the course of the study. Sample collection from lysimeters and tile drains were infrequent at individual field sites, and the timing of sampling was not coordinated with chemical applications. Likewise, sample collection was not coordinated to correspond with irrigation events. Collection of lysimeter samples was often possible upon visits to field sites. However, lysimeter samples were not obtainable in very dry soil conditions, observed most often at avocado or citrus sites. In this case sample collection was delayed until the orchard received water either by irrigation or precipitation. Also, many of the BMP installations focused on sediment control near the downstream margins of agricultural areas, and BMPs of this nature would not influence the chemistry of soil moisture in the areas of active cropping where the lysimeters were installed.

The sample collection strategies employed in this study produced a data set that documents a range of chlorinated and organophosphate pesticide and triazine herbicide detections observed in soil water and surface runoff from agricultural areas of the Calleguas Creek and Santa Clara River watersheds. Sample collection from a representative number of sites for the major crop types in the area was prioritized in the proposal for this study, as opposed to a sampling strategy centering on intensive documentation of conditions at a limited number of individual sites. The resulting data set affords a survey-scale documentation of chemical movement by various means, but no quantification of chemical flux in surface water or soil water. Quantitative documentation of stormwater runoff and chemistry has been studied previously at several agricultural properties in the Calleguas Creek watershed (Suffet and Augustenborg, 2003).

Aside from Endosulfan, none of the chlorinated pesticides evaluated as part of this study were in use during the study period, and most have not been registered for local use since the late 1980s (Table 21). BMPs limiting the discharge of surface water and entrained sediment are the primary way the migration of these legacy pesticides can be mitigated. BMPs and appropriate application practices can be used to reduce the offsite migration of organophosphate pesticides, triazine herbicides, and other contemporary pesticides. Approximately half of the organophosphate pesticides detected in various samples are no longer registered for use in Ventura County (Table 21). The OP pesticide Chlorpyrifos and the triazine herbicide Simazine were consistently detected more frequently than the other OP and triazine constituents analyzed as part of this study, and these compounds are currently registered for agricultural uses in Ventura County.

The following discussions relating to pesticide and herbicide detections are based on the figures and tables shown in the Results section of this report. The graphics and tables include data from all samples of each type (lysimeter, tile drains, tailwater, and both liquid phase and solid phase evaluations of stormwater runoff). The upstream and downstream samples used for BMP assessments are included in these figures and tables, as are a limited number of duplicate samples collected for quality control purposes.

For the sample results from lysimeter installations in all crop settings, detections were recorded for fifteen different chlorinated pesticides or pesticide derivatives. Ten of these compounds were recorded in fewer than two percent of the 527 lysimeter samples (Figure 20). DDT and DDE were recorded most frequently, with DDT detected in fifteen percent of all samples. Toxaphene was recorded in nineteen samples, less than four percent of the lysimeter samples, but at concentrations greater than the other chlorinated pesticides. As indicated in Table 3, the laboratory detection levels for Toxaphene were significantly higher than for the other chlorinated compounds. It is likely that Toxaphene would be observed more frequently if detection levels were similar to the other chlorinated chemicals. Detections of gamma-Chlordane, alpha-Chlordane, and DDD were recorded in three percent or less of the lysimeter samples.

Tile drain samples were collected at fifteen of the field sites, and the list and ranking of pesticide detections is similar to those commonly observed in lysimeters. This is not a direct comparison, as drain samples were collected at a subset of the lysimeter sites. Most of the sites with tile drains were located on the coastal plain and associated with row crops, berries, or sod production. Seven chlorinated compounds detected in lysimeters were not observed in the samples of tile drain discharge. Generally, observed concentrations of chlorinated compounds were lower in the tile drains than in the lysimeters (Figure 20 and Figure 22).

Among the lysimeter samples, there were fewer liquid phase organophosphate pesticides and triazine herbicides detected than chlorinated pesticides. The triazine herbicide Simazine was observed at the greatest frequency, and was detected in 45 of 524 lysimeter samples. The OP pesticide Chlorpyrifos was detected in twenty-one samples (Figure 21).

Ten other compounds were detected in one percent or fewer of the lysimeter samples. Analytical detection levels were slightly higher for the organophosphate compounds and triazine herbicides than the chlorinated pesticides, and this analytical discrepancy prohibits a direct comparison of the frequency of detections for these two classes of compounds.

Detections of organophosphate pesticides or triazine herbicides were very rare in tile drain samples. A total of three detections were recorded from the 151 samples collected. The rarity of detections in the deep soils drained by subsurface drains suggests that these compounds do not readily persist or migrate in the deeper soil horizons. The number of OP compounds and triazine herbicides detected in tile drains, and the concentrations of the detections, are significantly reduced from the range of compounds and concentrations observed in the lysimeter samples. This observed reduction between the lysimeters and the deeper tile drains is much greater than the reductions observed for chlorinated pesticides.

Among the limited data set for tailwater samples, detections of liquid phase DDT and DDE were recorded in roughly two-thirds of the samples. Chlordane, DDD and Toxaphene were also detected (Figure 24). Tailwaters were observed most-frequently when broadcast irrigation was in use. Soil disturbance related to the water drop impacts may contribute to the high percentage of detections. On a percentage basis, liquid phase DDT and DDE were detected more frequently in tailwater samples from berries and row crops than they were in samples of stormwater runoff. Detections of organophosphate and triazine compounds were less common, with Chlorpyrifos detected in three of 27 samples.

A wide range of liquid phase chlorinated pesticides were detected in samples of stormwater runoff from field sites, both before and after the installation of BMPs. DDE and DDT were detected most-frequently and with average concentrations near 0.100 µg/L. Liquid phase DDE was detected in one-third of the stormwater samples. Five percent of the samples had detectable concentrations of gamma-Chlordane and alpha-Chlordane, and twelve other compounds were detected infrequently and generally in low concentration. Toxaphene was detected in three of 260 samples, but at concentrations higher than any other chlorinated compound. A summary of sample results is plotted in Figure 26, and a basic trend of declining concentration with decreased frequency of detections is shown. The BMPs employed in this study were not expected to significantly reduce liquid phase pesticide or herbicide concentrations. Mulch was observed to significantly reduce stormwater runoff at some sites, which reduces the volume of water and dissolved chemicals leaving the site.

Concentrations of solid phase chlorinated pesticides were determined from sediment entrained in the stormwater samples. Under low flow conditions or when BMPs were effectively reducing the quantity of sediment moving with stormwater runoff, limited weights of solid material was available for chemical analysis. Limited sediment weights

increased the detection limits for laboratory analyses, which likely influences the frequency of detections for the various compounds. Regardless, the observed solid phase concentrations are commonly 100 times that of the liquid phase stormwater detections (Figure 28 and Figure 29). Also, the list of frequently-detected compounds is similar for the solid phase and liquid phase stormwater results. Common to the liquid phase results, DDE, DDT, alpha-Chlordane and gamma-Chlordane recorded the most solid phase detections. Toxaphene was detected more frequently in the solid phase than in solution. Solid phase detections were recorded as high as 1190 µg/kg, with an average detected concentration of 438 µg/kg. DDE was the most common solid phase detection, and was detected in 121 of 209 samples, with an average concentration of 104 µg/kg. BMP installations were generally not expected to reduce solid phase pesticide concentrations, but they were intended to reduce erosion and sediment transport away from agricultural properties.

The range of liquid phase organophosphates and triazines detected in stormwater runoff was less than that of the chlorinated compounds. Nine different compounds were detected, with only Chlorpyrifos and Simazine reported in more than two percent of the samples. Among the 260 stormwater samples, Chlorpyrifos was detected in 93 samples and Simazine in twenty-seven. Chlorpyrifos was also commonly observed in the solid phase in stormwater samples, while solid phase Simazine detections were rare (Figure 29). Solid phase detections of Chlorpyrifos exceeded 1000 µg/kg in two stormwater samples, and the average concentration among 90 detections was 191 µg/kg. The highest Chlorpyrifos concentrations were observed in December 2004, prior to BMP installations at the project field sites.

Chlorpyrifos was detected in 43 percent of the solid phase stormwater samples, and Simazine was detected in only 6 of 209 sediment analyses. For the liquid phase evaluation of stormwater runoff, Simazine was detected 27 times and Chlorpyrifos 93 times. Unlike the chlorinated pesticides, where the prevalence and relative concentrations of the commonly-detected compounds are fairly uniform between the various types of samples and the liquid and solid phase, Simazine detections are skewed towards the liquid phase. Among the lysimeter samples, Simazine is detected more than twice as often as Chlorpyrifos. In the tile drains where OP pesticide and triazine herbicide detections are rare, Simazine was detected once and Chlorpyrifos was not detected. Simazine is known to be one of the more-soluble compounds and the monitoring data from this study agrees with this.

4.6 ASSESSMENT OF BEST MANAGEMENT PRACTICES

4.6.1 Quantitative Assessment

Pesticides and Herbicides

Although the lack of significant runoff in the dry winter of 2006-2007 limited the number of sites and BMPs that could be tested overall, winter 2005-2006 sampling is indicative that the BMPs implemented in this study can reduce the transport of pesticides and

herbicides off agricultural fields. Some BMPs, particularly mulching and cover crops, were very effective in reducing or eliminating storm runoff. When runoff is eliminated, there is a 100 percent reduction in pesticide and herbicide transport. Although runoff was eliminated from some of the mulched and cover cropped areas within orchards, it is not realistic that all runoff can be eliminated using these BMPs. If storms are intense enough, there will likely be runoff even from these areas (although the winter of 2005-2006 was very wet with several intense storms). Mulching and cover crops cannot be implemented effectively in farmed areas where soils are plowed regularly, as in strawberry and row crops.

Table 25 indicates the effectiveness of the various BMPs in reducing the transport of pesticides and herbicides, as evaluated in this study. Sequencing of various BMPs may add to their effectiveness – the lack of runoff in 2006-2007 precluded such an analysis. Some of the BMPs, such as wattles, were highly variable in their effectiveness. For instance, wattles are more effective when they are used in a flatter area where water can pond behind the wattles and less effective in steeper areas where it is difficult to trap sediments. In these steeper areas, it is important to minimize runoff with mulch or cover crops so that erosion is reduced – once scouring and sediment transport has occurred, it is difficult to trap these sediments.

Table 25. Effectiveness of various BMPs in reducing pesticide and herbicide transport.

<i>BMP</i>	<i>Pesticide/Herbicide Reduction</i>	<i>Effectiveness</i>	<i>Applicability</i>
<i>Mulch</i>	Up to 100 %	Good	Orchards
<i>Cover Crop</i>	Up to 100%	Good	Primarily Orchards
<i>Grassed Ditch</i>	Up to 90%	Good	All Crops
<i>Wattles</i>	From 70% to Increased	Variable	All Crops
<i>Grass Filter Strip</i>	Minor to Increased	Poor	All Crops
<i>PAM</i>	Up to 25%	Insufficient Data	All Crops

A hypothesis of this study was that pesticide and herbicide concentrations in the soluble portion of a runoff sample would not vary as the runoff flowed through the area with a BMP primarily designed to prevent soil erosion. An exception to this was when a BMP completely eliminates runoff. However, at some sites there were reductions in soluble pesticide and herbicide concentrations (e.g., Figure 30) above and below BMPs. The limited data set and lack of potential mechanism to explain this occurrence preclude any conclusions that the implemented BMPs can routinely reduce soluble pesticides and herbicides in runoff.

Another hypothesis of this study was that concentrations of pesticides and herbicides within the suspended solids carried by runoff would not vary much upstream and downstream of BMPs; the BMPs would reduce the amount of suspended solids, but not pesticide and herbicide concentrations within these solids. However, the concentrations varied widely in upstream and downstream samples (see Figure 31 and Figure 32). Potential causes of this variation include:

- 1) **Settling/scouring of upstream sediments** – The BMPs that act as sediment traps (e.g., wattles, filter strips) change the dynamics of the runoff flow. Settling of sediment upstream of the BMPs was observed, as was re-introduction of the settled sediments into the runoff by local scouring. These processes likely vary the concentrations of pesticides and herbicides upstream and downstream of BMPs, especially since sampling represented just one point in time. It is likely that the long-term average concentration of a constituent above and below a BMP will vary less over a period of time.
- 2) **Pesticides preferentially attached to sediments of certain grain sizes** – As sediment settles upstream of a BMP, it is more likely that finer-grained sediment (i.e., clay) will flow past the BMP and larger-grained sediment (i.e., silt and fine sand) will settle out as flow velocity decreases. If the pesticides preferentially attach to clays (which is quite likely), then pesticide concentrations would increase as clays become a larger proportion of suspended solids. Overall pesticide transportation is reduced because of the trapped sediment, even if pesticide concentration increases.
- 3) **Non-representative sampling** – A grab sample above and below a BMP may not completely represent the runoff flow. For instance concentrations may vary with time (see preceding) or depth in the runoff flow. Although care was taken to use identical sampling techniques upstream and downstream of a BMP, the flow regime and cross-section of the flow was commonly somewhat different above and below a BMP.

Suspended solids generally decrease downstream of BMPs. However, there is an increase in suspended solids in a subset of the samples. The first and third potential causes of changes in pesticide and herbicide concentrations discussed above (settling/scouring, non-representative sampling) may also be reasons for variations in suspended solids upstream and downstream of BMPs.

Nutrients

The primary transport of nutrients is in water that has percolated beneath the root zone. This percolating water typically has nitrate plus nitrite concentrations well in excess of the primary drinking water standard. 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. BMPs to reduce the concentration of percolating nutrients involve the proper application of fertilizers and techniques to prevent over-watering of crops, which pushes nutrients through the crops' root zone before the plants can utilize the nutrients. Application and irrigation practices were beyond the scope of this study; however, the existing practices at two sites where irrigation was controlled by real-time soil moisture measurements allowed an evaluation of that BMP. The effectiveness of irrigating using these real-time data is illustrated in Figure 40 and Figure 41, where nutrient concentrations are among the lowest in the study both at shallow and deep lysimeter depths.

Other BMPs that will help minimize the movement of nutrients from agricultural fields include:

Fertilizer Application – knowledge of crop nutrient demands, plant tissue analyses to control type and amount of fertilizer, correct timing of fertigation within an irrigation cycle (front-loading fertigation is more likely to push nutrients past the root zone), minimizing fertilizer applications prior to leaching;

Irrigation Practices – Knowledge of water demand, appropriate irrigation frequency and duration, real-time monitoring of soil moisture conditions during irrigation, uniformity of irrigation distribution, appropriate emitter size for soil infiltration rate, modification of irrigation practices when berries are young (substitute shallow drip tape for current overhead watering where most of the irrigation water runs off as tailwater).

4.6.2 Qualitative Assessment

Mulch

Mulch was implemented at five citrus sites, and on a dirt roadway beside an avocado site. The citrus sites were located throughout the study area with one each in the Beardsley wash area, Arroyo Las Posas, and the lower Calleguas Creek area. Two sites were located near Santa Paula, and the avocado site where mulch was placed on the roadway was located in the Fillmore area. All sites except the citrus in the lower Calleguas Creek area were implemented in fall 2005, and were monitored during four storm events. The site in lower Calleguas Creek was implemented in the fall of 2006 and was monitored during two relatively mild storm events that occurred in winter of 2007.

The sample set for assessing mulch as a BMP is relatively small with only six sites, one of which was not implemented and available for sampling before the winter of 2007. All study sites were monitored on two occasions in 2006 (February 27th, and March 28th). Although rain was sufficient to cause runoff at most other project sites monitored during the February 2006 storm, no runoff was observed at the mulched sites in the Beardsley wash area, and at one of the Santa Paula sites. During the March 2006 event, no runoff

was observed at the Santa Paula mulch site and where the roadway was mulched near Fillmore. As discussed in Section 2.7.2 (Second Year of BMP Assessment), the 2007 storm events were relatively mild, with dry antecedent conditions. All project sites were monitored during the February 22nd, 2007 event and runoff was not observed to occur at any site. Sites were monitored again on April 20th, 2007 and runoff was only witnessed at 12 of the 46 sites monitored. One of the sites where runoff was observed and sampled was a site with mulch, located near Santa Paula. A table summarizing the presence or absence of runoff during monitored storm events is presented below (Table 26).

Based on observations, mulch was the most successful of the suite of BMPs assessed at retaining water and soil on the agricultural field sites. The capacity of mulch to absorb water was highest when freshly implemented, and diminished with time, indicating a need for replenishment at timely intervals. A photo comparison is presented in Figure 46. The two images on the left were taken at the end of a row of citrus trees where mulch was applied. The images on the right were taken three rows away where no mulch had been recently applied. While no runoff was visible on the mulched side, runoff was actively flowing from the unmulched rows, and observed to be flowing throughout the length of the row. At mulched sites where runoff was observed, it was noted to be less intense than pre-BMP observations. Water flowing from mulched areas was relatively clear, with a lower sediment content than runoff observed during pre-BMP storm events at the same sites.

Table 26. Summary of presence or absence of runoff during post-BMP monitored events at mulched sites

Location of Mulched Site	Storm Event			
	2/27/2006	3/28/2006	2/22/2007*	4/20/2007
Beardsley wash	no runoff	sampled	no runoff	no runoff
Arroyo Las Posas	sampled	sampled	no runoff	no runoff
lower Calleguas Creek			no runoff	no runoff
Santa Paula 1	no runoff	no runoff	no runoff	no runoff
Santa Paula 2	sampled	sampled	no runoff	sampled
Fillmore roadway	trickle	no runoff	no runoff	no runoff

*Runoff was not observed at any of the project field sites during this storm event



Figure 46. Photo comparison of mulch vs. no mulch. Images on the left show a mulched row in a citrus orchard. Images on right were taken three rows away from a row that did not have mulch applied. Runoff is not evident from the row with mulch. Runoff is abundant in the row without mulch.

Cover Crops

Cover crops were implemented at three of the project field sites; two citrus sites and at a strawberry site during its fallow season. Existing cover crops were present at four project sites, all of which were citrus sites. The documented benefits of cover crops include their ability to mechanically filter sediment from discharges, slow the velocity of discharges allowing for more infiltration, directly metabolize nutrients and in some cases, pesticides, reducing contamination in both surface runoff and infiltration to groundwater (Karthikeyan et al., 2004). In addition, the use of a cover crop on a fallow field provides supplemental organic material that enhances the organic structure of the soil when it is turned during pre-planting soil preparation for the following crop.

The cover crops implemented in the citrus orchards were located in the Santa Paula and Fillmore areas. Both fields exhibited a notable decrease in runoff during monitored events (Table 27). The cover crop planted at a strawberry field during its fallow period was located in the lower Oxnard plain.

Table 27. Summary of presence or absence of runoff during post-BMP monitored events at cover cropped sites

Location of Cover Cropped Site	Storm Event			
	2/27/2006	3/28/2006	2/22/2007*	4/20/2007
Santa Paula (citrus)	no runoff	sampled	no runoff	sampled
Fillmore (citrus)	no runoff	no runoff	no runoff	no runoff
Oxnard Plain (fallow strawberry site)	sampled	sampled	no runoff	no runoff

*Runoff was not observed at any of the project field sites during this storm event

The site located in the Fillmore area had the beginning growth of the cover crop during the winter of 2005. Substantial flooding occurred at the site. A conversation occurred with the grower during a field visit, and he said that he had noticed less visible erosion on the side of the orchard where the cover crop was present than on the portion that had no cover crop. He attributed this directly to the presence of the cover crop.

As for the fallow strawberry field, it is an accepted fact that grass on a fallow field reduces removal of soil from both wind erosion and water erosion. Results from this analysis of the grassed cover crop on the fallow field are not conclusive, and did not provide support for any improvement attributable to the cover crop. A number of baseline samples were collected, but many of them were obtained while strawberries or vegetable crops were planted in the field. Only one baseline sample was collected from the site during a transitional period when the surface of the field was barren soil. Results from the transitional baseline sample are compared with results from samples collected after the grass cover crop was planted at the field site in Table 28. Concentrations of DDE were nominally higher in the post-BMP samples than in the baseline sample. Concentrations of DDT, alpha-Chlordane, and gamma-Chlordane were all lower in the post-BMP samples than in the baseline sample. This individual assessment is presented because the above and below BMP or side-by-side sample method could not be applied at this site.

Table 28. Comparison of post-BMP results to baseline results for a cover cropped fallow site

Constituent	Baseline	Post-BMP	
	Feb 05	Feb 06	March 06
DDE	232 µg/kg	270 µg/kg	288 µg/kg
DDT	171 µg/kg	27.5 µg/kg	83.7 µg/kg
alpha-Chlordane	29.9 µg/kg	29.4 µg/kg	<22 µg/kg
gamma-Chlordane	33.1 µg/kg	23 µg/kg	24.8 µg/kg

Visual observations at this site and others over the duration of the study confirmed that roughly-tilled soils have a fairly large capacity for infiltration. Figure 47 shows a freshly-tilled field in the background of the photo and an area of compacted earth in the

foreground. Water is pooling and running off of the compressed surface and has completely infiltrated in the roughly tilled surface. This observation was made during a moderate storm event. Multiple additional observations at various field sites confirmed that dirt access roads and equipment staging areas often produce runoff before cultivated areas.



Figure 47. The field in the background has been freshly tilled and shows no sign of runoff. The area in the foreground is a saturated compacted dirt surface with pooling and runoff occurring.

Existing Cover Crops at Project Sites

Cover crops were in place at several of the citrus sites during baseline conditions. Although all of the existing cover crops at field sites appeared to have some impact in reducing runoff and erosion, some were not implemented in a way that provided for optimal filtering or slowing of surface flows between the tree rows where water typically drains from the fields. In most cases cover crops were isolated to the center area between tree rows (Figure 48). An herbicide, generally Roundup, was applied at the borders between the trees and the cover crop leaving the area below the trees bare (this was done to keep cover crops away from the base of the tree canopy, as well as to limit the width of the cover crop to allow mowing in a single pass). In most orchards there is a shallow depression or swale that runs along each side of the tree rows. Runoff flows down through this line of depression until it reaches the bottom of the orchard and enters a ditch or other drainage structure. From a water quality perspective, the cover crop would be most beneficial if it were present in the area where discharges flow, providing filtration and slowing the movement of water, and allowing for the maximum amount of infiltration to occur.



Figure 48. Narrow cover crops may not be sufficient to filter and slow discharges from fields. In the photo above, runoff occurs along the rows of trees just below the tree line and is not subject to filtration by the cover crop.

Filter Strips-Wattles

Wattles were the most widely implemented BMP of this project. They were installed at 23 field sites. Implementations varied from the placement of one cut strip across a ditch, to a series of wattles placed radially around a drainage structure. The quantitative analysis of wattle effectiveness using TSS results was nonconclusive. A portion of the implementations had improved water quality below the wattle. An equal portion of implementations resulted in degraded water quality below the wattle, and a few implementations had similar chemistry and TSS above and below the wattles. A qualitative analysis based on visual observations agrees with and provides a possible explanation for this discrepancy. Wattles appear to be efficient in filtering water during low flow regimes. During low flows sediment and debris build up behind the wattles, showing the ability for wattles to filter these substances out of surface water. However, during higher flow regimes, discharges can overtop and scour around the wattles. Material that has built up behind the wattle can be scoured from the area and re-entrained in the discharge, resulting in higher suspended solids below the BMP than above (Figure 49). In addition, higher flows can also erode the material from below the wattle, forming tunnels where water velocity may increase and result in further erosion (Figure 50).



Figure 49. Higher flows can erode around and under wattles, contributing material to the downflow side of the BMP.

Wattles appear to be effective in certain applications. They appear to be beneficial when implemented in areas where high runoff discharge rates are not expected. An example of an appropriate installation would be placement of wattles at the end of rows throughout an orchard to filter water in stages, rather than only placing wattles at the bottom drainage structure for an entire block. Wattles also appeared to work well when implemented in conjunction with other management practices. At sites where growers and ranch managers were creative with the implementations of wattles, more success was observed. At these sites, the growers were satisfied with the results they observed, and extended applications of wattles to other non-monitored areas within their fields.

In order to remain effective, wattle implementations require regular maintenance. The wattles used in this study lasted throughout one season, but many needed to be replaced before the second year. Areas that have been eroded need to be filled-in between runoff events. The netting can become torn, and the shape of the wattles flattened over time as the straw fill compacts. This type of BMP may not be appropriate for implementation in strawberry fields where quick drainage from furrows is often preferred by ranch managers.



Figure 50. The area beneath this wattle has been eroded allowing water to flow uninhibited beneath the filter strip.

Grassed Filter Strips

Grassed filter strips were installed or grown in ditches at row crops, strawberries, and in one avocado orchard. Only one installation of grassed filter strips was available for sampling in 2006, and laboratory analysis for TSS upstream of the BMP failed. Additional implementations were installed during the fall of 2006 and several were sampled on April 20th, 2007. As with the wattle filter strips, the analytical results do not conclusively provide evidence of improved water quality below the grassed filter strips. In other studies, vegetated filter strips have been shown to retard, retain, and metabolize pollutants (Locke et al., 2006). Although filter strips less than 1 meter wide have been documented to trap a significant amount of sediment (Van Dijk et al., 1996; Blanc-Canqui et al., 2004), quantitative results from this study do not provide support for any improvements contributed by these implementations. Despite the lack of supportive data produced by this project, enough evidence has been provided through other studies to suggest that grassed filter strips have the potential to be successfully implemented in agricultural settings to improve water quality.

The types of grassed filter strips tested in this study were implemented at a very small scale. A series of three to five strips of sod, approximately 1 foot by 5 feet each, were placed in ditches perpendicular to the flow of discharge (Figure 51). This type of installation may be more successful if implemented on a larger scale. The filtering

capacity could be enhanced by increasing the width of each filter strip. Seeds could be planted, or multiple pieces of sod could be placed together, to match the width of the rows. These strips could be placed at the end of rows (every fifth, tenth, or perhaps twentieth row) throughout a crop or orchard field. In many row crops a patch of grass or beneficial flowers were planted at the end of each row (Figure 52). If these plantings were extended into the ditch at every fifth, tenth, or twentieth row and provided water during irrigation events, the effect would be similar to the grass filter strips.

Qualitatively, the grassed filter strips appeared to work similarly to the wattles during lower flow regimes, but lack the ability to pond water above the installation. In low flow settings, sediment and debris were observed behind the grassed filter strips. The grassed filter strips do not provide as much of a barrier as the wattles, and consequently did not suffer from the same erosional problems. Installations that were not irrigated were prone to drying out and stunted growth during the very dry winter of 2007. This problem was not observed during the winter of 2006. As with the wattles, this type of BMP may not be appropriate for implementation in strawberry fields where rapid surface drainage is a priority of ranch managers.



Figure 51. Grassed filter strips – A series of three strips of sod placed in a ditch perpendicular to the flow of discharge



Figure 52. Current practices in fields could be extended into ditches to provide filter strips

Grassed Ditches

Grass was planted in ditches at three field sites. The ditches were not planted until the fall of 2006 and were only monitored during the winter of 2007. The qualitative results indicate that implemented grassed ditches were successful at reducing sediment in discharges. It should be noted that 2007 was a very dry year, and irrigation of strawberry crops does not produce runoff. The ditches where the grass was planted were relatively dry and the grassed ditches that were sampled did not have robust growth present. Following implementations could be improved by supplying alternate methods of irrigation during the establishment phase (for instance, by water truck).

Grassed waterways have been shown to reduce runoff and sediment delivery by up to 97 percent (Fiener and Auerswald, 2003a), and to reduce soil mineral nitrogen content by up to 84 percent (Fiener and Auerswald, 2003b). Another study found that grassed waterways can reduce agricultural pollutants in runoff water by up to 56 percent (Briggs et al., 1999), and that greater retention and absorption of pesticides occurs in vegetated compared to non-vegetated waterways (Moore et al., 2002). This BMP was not widely tested in this study. Results from this test combined with available data provided by other studies certainly suggest that this BMP has great potential for improving water quality in agricultural runoff. Some concerns have been raised related to providing

habitat for unwanted vectors. In order to provide filtration and hold sediments in place, grassed waterways do not have to be allowed to grow uninhibited. Once established, the grass can be mowed or weed whacked with the same effort that was previously used to maintain the ditches without vegetation (Figure 53).



Figure 53. Established grassed waterways can be maintained at reasonable heights by use of a mower or weed whacker

Polyacrylamide Cakes

As discussed in Section 2.6.4 (Grassed Ditch), a participating grower in the project chose to implement PAM cakes in a drainage ditch as a BMP for his field site. The PAM cakes were suspended in a canvas bag in a drainage ditch. The polyacrylamide cakes were placed in the ditch the day before the storm was expected and removed after the storm had passed. PAM has been documented to be highly effective in reducing soil erosion off of fields and increasing infiltration of water in irrigated furrows. The highest rates of success have been recorded for direct injections of liquid PAM into irrigation water. PAM has been shown to significantly reduce soil erosion by 90-95 percent when applied to irrigation water. Increases in water infiltration rates vary from 20-60 percent from trial and experiments (Nishihara and Shock, 2001). Qualitative observations of effectiveness were not possible, and other than the ease of use and inexpensive application, no qualitative assessment is supplied.

This project tested the BMP that was implemented by the grower, and does not include any discussion related to consequences to downstream water quality or sediment issues resulting from introduction of the product to the watershed system.

Improvements to Drainage Structures

Improvements to drainage structures were not quantitatively assessed. The improvements that were implemented were observed and photographed throughout the duration of the study. Clearly, the construction of a new drainage structure at the site where runoff had previously eroded a rut across the road was a successful implementation that resulted in a decrease in sediment erosion. The reinforcement of drainage channels with sandbags in crop fields also appeared to decrease erosion of sediment. This implementation required considerable work on the part of the grower for installation and maintenance of the sandbags themselves, but in wetter seasons would have likely resulted in an equitable decrease of work required to maintain the furrows and ditches following storm events.

4.7 RECOMMENDED BMPS FOR EACH CROP TYPE

BMPs are not a “one size fits all” application, and it is important to consider the physical conditions at each individual site in the selection process. The applicability of implementing various BMPs in each crop type assessed in this study is presented in Table 29. Mulch has been found to be very effective in orchard settings and on dirt roads. In general, mature avocados have naturally occurring mulch from an abundant amount of leaf litter. In groves with young trees it may be appropriate for a grower to place mulch or a cover crop in the orchard until the canopy cover is mature enough to provide adequate leaf litter. Of the citrus sites studied in this project, either mulch or cover crops would have been universally applicable. Some growers may not be comfortable planting vegetation within orchard rows, and in this case a good practice may be to plant a 15-foot wide strip of grass along the lower end of each block where it would intercept and filter runoff before it leaves the property. Cover crops and mulch are not appropriate for use in tilled fields, but could be used in surrounding areas that are not regularly manipulated, such as in roadways and equipment staging areas.

Filter strips appear to be applicable in most settings. The possible exception is that their use within strawberry fields may slow drainage enough to negatively impact production by retaining excessive moisture within the beds, and making harvesting difficult. The most applicable BMPs for strawberry crops appears to be reinforcing drainage channels to prevent erosion, improving drainage structures to provide for some ponding to occur (allowing for sediment to settle out of the water column) before runoff leaves the property, and planting grass in collector ditches.

Visual observations made throughout this project indicate that BMPs will be most efficient at improving the quality of water leaving agricultural fields when used conjunctively with each other. When establishing a plan to implement BMPs at a field site the first consideration should be to check the grading, drainage channels and structures to identify areas that could be improved upon. The next step may be to determine if vegetation could be planted within drainage areas (either as cover crops, filter strips, or grassed ditches). Check for applicability of mulch to unmanipulated areas

(areas that are not regularly tilled). When multiple BMPs are used at a field site, each BMP can be implemented in the most efficient environment, enhancing the cumulative effects of the layered management practices. A management plan that integrates multiple BMPs will also be better suited for responding to a wider range of flow events. Filter strips are most effective in low to moderate flows and have a tendency to be overwhelmed in more intense events. Inclusion of the more substantial BMPs such as improvements to drainage structures, mulch, cover crops or grassed ditches will provide protection during larger flow events.

Table 29 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.

4.8 EDUCATIONAL COMPONENT/OUTREACH

Outreach has occurred in tandem with all other activities in this project. Multiple meetings and workshops have been held in cooperation with the Ventura County Farm Bureau and the Association of Water Agencies of Ventura County. The first workshop was held on April 22nd, 2004. Additional meetings were held on December 14th, 2004, October 25th, 2005, and November 27th, 2006. At each meeting project updates were discussed and interim results from the study were presented. The meetings were attended by members of the RWQCB, the Ventura County Farm Bureau, and the general agricultural community.

The workshops were very well attended by the agricultural community, with between 200 and 300 attendees at each meeting. There will also be continuing workshops of the same type hosted by the Farm Bureau dealing with the Irrigated Lands Conditional Waiver. United Water participants in this study have been invited to further discuss the PRISM and Consolidated findings at those future meetings. United Water Conservation District is also scheduled to present findings from this project at the 2007 National Conference on Agriculture and the Environment.

5. CONCLUSIONS

The study consisted of determining current concentrations of a range of pesticides (chlorinated and organophosphate), triazine herbicides, and nutrients being transported by water in agricultural fields in the Calleguas Creek and Santa Clara River watersheds of Ventura County, determining which pesticides, herbicides, nutrients, and practices could be targeted for reducing movement of these constituents, implementing a set of Best Management Practices (BMPs) to reduce movement of these constituents, and testing the effectiveness of these BMPs. Several types of water-borne transport mechanisms were considered: 1) winter storm runoff; 2) surface flow from irrigation (tailwater); 3) discharge from tile drains installed beneath fields; and 4) downward percolation of irrigation and rain water within and below plant root zones.

KEY FINDINGS

Winter storm runoff transports pesticides and herbicides both dissolved in the water column (liquid phase) and attached to soil and plant particles (solid phase). Nutrients are transported in a variety of mechanisms – nitrate and nitrite are largely transported in water percolating beneath a crop's root zone, ammonia is transported in storm runoff and irrigation tailwaters, and organic nitrogen is transported in both storm runoff and percolating waters.

Over 250 liquid-phase samples were collected during six storms over four winter seasons. Compounds of the DDT family (DDT, DDE, DDD), Chlorpyrifos, Chlordane, and Simazine were the most-frequently detected pesticides and herbicides, as well as having the highest concentrations of those pesticides and herbicides analyzed in the liquid phase (these concentrations were near or below one part per billion). The same constituents are the most frequently-detected and have the highest concentrations in the solid phase, with the exception that Toxaphene replaces Simazine on this list. However, pesticide and herbicide concentrations are higher in the solid phase, ranging into the 100s of parts per billion.

Nutrients were detected at relatively high concentrations, particularly in percolating waters. Nitrate plus nitrite exceeded the primary drinking water standard by an order of magnitude in many samples of percolating water. Ammonia and organic nitrogen were commonly higher in tailwater and storm runoff.

There were considerably fewer tail-water samples (31), largely because most irrigation within Calleguas Creek is done fairly efficiently and there is little excess irrigation water flowing off of fields. One of the exceptions to this is when overhead irrigation is used on just-planted strawberries that are surrounded by plastic sheeting and much of the applied water runs off the plastic. The DDT family and chlordane were the most-frequently detected pesticides or herbicides at concentrations less than one part per billion. In

addition, ammonia and nitrate plus nitrite were detected at higher concentrations in tailwater from sod fields.

Lysimeters (soil-moisture samplers) were used to collect percolating waters both within and below plants' root zones. Over 520 lysimeter samples were collected over a period of three and one-half years. The same suite of pesticides and herbicides was detected most-often and in the highest concentrations – the DDT family, Toxaphene, Simazine, Chlordane, and Chlorpyrifos. Concentrations of these pesticides and herbicides were less than one part per billion, except Toxaphene which was detected at several parts per billion. Because tile-drain waters also percolated through the soil to beneath the root zone, results were similar to those for lysimeters, although the DDT family dominated the detections. More than 900 nutrient samples were collected from shallow and deep soils in the study area. Nitrate plus nitrite (and locally ammonia) was found in the lysimeters at levels well above drinking water standards. These high detections are corroborated by the presence of high nitrates in some areas of unconfined aquifers, where the percolating agricultural water can reach the aquifer.

Using the base-line results discussed above, a series of BMPs were formulated to reduce pesticide and herbicide concentrations in the agricultural waters. At the request of the Project Representative of the SWRCB, all pesticide and herbicide application practices remained constant and only “back-end” (after-application) practices were targeted for reduction. Because the highest concentrations of pesticides and herbicides were in storm-water runoff (particularly in the soils carried by the runoff), the focus was on BMPs that addressed soil erosion, and soil or water retention. The BMPs that were assessed included mulch, cover crops, grass ditches, filter strips, and polyacrylamide cakes.

BMPs for nutrient reduction include application and irrigation practices – beyond the scope of this study. However, the existing practices at two sites where irrigation was controlled by real-time soil moisture measurements allowed an evaluation of that BMP.

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. However, winter 2005-2006 sampling was indicative that the BMPs implemented in this study can be effective in reducing the transport of pesticides and herbicides off agricultural fields. 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 effectiveness of the BMPs was measured primarily by analyzing chemical concentrations and suspended solids upstream and downstream from a BMP. In the liquid phase of the runoff water, concentrations were somewhat lowered downstream of the BMPs. Lacking a mechanism for how this occurred, the importance of these results is not clear. In the solid phase, pesticide and herbicide concentrations both increased and decreased downstream of the BMPs. These findings could result from a combination of settling and/or scouring of upstream sediments created by the BMP, pesticides preferentially attached to sediments of certain grain sizes (larger grain sizes settle upstream of the BMPs), or samples being taken from slightly different flow regimes or positions in the flow upstream and downstream of the BMP.

The amount of sediment trapped upstream of a BMP may be the most reliable measure of the effectiveness of BMPs designed to reduce transport of soils. For the BMP sites where suspended solids were measured upstream and downstream of a BMP, solids were reduced an average of about 9 percent. This analysis did not include the sites where mulching and cover crops reduced runoff and solids by 100 percent.

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. 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 berries, where overhead sprinkling of newly-set plants largely runs off the field.

It is unlikely that the movement of agricultural pesticides and herbicides can be entirely eliminated using the BMPs tested in this study. The reduction in pesticides and herbicides would likely be larger if multiple layers of BMPs are implemented; this portion of the study was marginalized by the lack of rain and runoff in the final year of the study. It is noteworthy that the largest detections of pesticides and herbicides were for legacy pesticides (those no longer used); although their rate of degradation is relatively slow, they will eventually largely disappear at these detection levels.

RECOMMENDATIONS

Transport of pesticides, herbicides, and nutrients from agricultural fields will likely be detected in some manner during monitoring activities associated with the Irrigated Lands Conditional Waiver – results of pre-existing in-stream monitoring have already led to pesticide, nutrient, and toxicity impairment listings along several reaches of Calleguas Creek and the Santa Clara River. It is very important to regulators and to the agricultural community that three activities related to the Waiver are correctly designed:

Surface water monitoring must be designed such that agricultural contributions are clearly delineated from urban or other activities;

If detections of pesticides, herbicides, and/or nutrients require corrective actions, then these corrective actions should be effective (e.g., required BMPs); Monitoring of groundwater should properly reflect the hydrogeology of the area so that agricultural contributions of pesticides, herbicides, and nutrients are accurately measured and the effects of any corrective actions are fairly evaluated.

Surface Water Monitoring – This has been largely accomplished for the monitoring of agricultural runoff that reaches stream bodies; researchers in this study have aided Farm Bureau consultants in choosing monitoring sites reflective of agricultural activities.

Corrective Actions – The results of this study and the companion PRISM study suggest the most effective BMPs. 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. For instance, wattles may be useful in areas where storm flow can be slowed sufficiently to deposit suspended sediments, but may be less useful in steeper terrain.

Groundwater Monitoring – Monitoring of the contribution to groundwater from percolating agricultural waters must be tailored to the groundwater conditions in the area. For instance, monitoring of production wells on the Oxnard Plain where there is a thick clay layer separating surface activities from the main aquifer would not be reflective of overlying agricultural activities. Appendix A of this report suggests site-specific groundwater monitoring techniques.

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APPENDIX A – RECOMMENDED GROUNDWATER TESTING FOR IRRIGATED LANDS CONDITIONAL WAIVER

As part of this study, the Los Angeles Regional Water Quality Control Board requested that the issue of future monitoring of groundwater be addressed for the Irrigated Lands Conditional Waiver. During the comment period before the Conditional Waiver was adopted, United Water Conservation District noted that groundwater monitoring for the waiver could not be a one-size-fits-all approach because of the varied hydrogeologic settings of the groundwater basins of Ventura County. Therefore, groundwater monitoring must be tailored to each setting so that future testing intercepts groundwater that is moving from irrigated lands to aquifers and/or surface waters. It is important to correctly monitor this groundwater for two reasons: 1) to determine if water percolating from irrigated lands meets appropriate water quality standards, and 2) to correctly monitor the results of corrective actions taken to mitigate any problems that may be identified.

Two different types of monitoring strategies are reviewed in this appendix: 1) a regional monitoring network that samples groundwater downgradient of agricultural fields in a similar forensic strategy to current surface water monitoring; and 2) a site-specific rotating monitoring program that samples percolating waters directly beneath agricultural fields. The philosophy behind these techniques differs substantially. The regional monitoring is designed to detect overall groundwater impacts in specific areas of the groundwater basins, but does not identify the specific practices (likely these are irrigation and fertilizer practices) which caused the groundwater impact. The site-specific monitoring is more proactive, identifying specific practices that cause impacts and allowing rapid measurement of improvements in water quality when best management practices (BMPs) are implemented. Following the discussion of each type of monitoring, advantages and disadvantages of each monitoring type are discussed and recommendations are made on which to implement.

REGIONAL MONITORING NETWORK

The regional monitoring strategy is designed in a similar manner to the surface water monitoring portion of the Irrigated Lands Conditional Waiver. It attempts to monitor groundwater downgradient from agriculture fields where water may be percolating from the fields to groundwater. The difference from surface water monitoring is that travel paths to groundwater are more circuitous and travel times are much larger (years for groundwater instead of hours or days). In this regional monitoring strategy, four different types of groundwater settings need to be considered for monitoring. They fall into two general categories – unconfined aquifers where irrigation water or rainfall applied at the

surface will percolate down to the aquifer, and confined aquifers where low-permeability sediments between the ground surface and an aquifer prevent significant downward percolation of surface waters. In confined aquifers, water samples from wells that produce from the confined aquifer are not indicative of overlying land uses – percolating water from these overlying uses cannot reach the confined aquifers. Instead, the confined aquifers are recharged from other areas that may be miles away. Thus, sampling from irrigation or drinking water wells that are completed in confined aquifers is not a scientifically-valid option for the Conditional Waiver. The four settings include:

- 1) **Unconfined Aquifers** – Unconfined aquifers where water percolating from overlying irrigated lands directly recharges the aquifers (e.g., all areas identified in Figure A54 that are not confined);
- 2) **Confined Aquifers with a Perched Zone** – Confined aquifers that underlie a perched zone of shallow groundwater where water percolating from overlying irrigated lands recharges the perched zone. Significant areas of the Oxnard Plain have such a perched zone, where water that percolates into the perched zone typically either flows into or is pumped into ditches to prevent land flooding. The ditches discharge to surface waters.
- 3) **Confined Aquifers with Tile Drains** – Percolating groundwater is rapidly intercepted by tile drains that discharge to surface waters. Little or no percolation reaches the confined aquifers. Tile drains are present in both the Oxnard Plain and Pleasant Valley areas.
- 4) **Confined Aquifers, No Perched Zone or Tile Drains** – This category includes all areas with a confined aquifer that does not have a perched zone or tile drains. Water percolating from overlying irrigated lands is significantly retarded from deep percolation by confining low-permeability sediments separating the ground surface from the confined aquifers. In most cases, this percolating water will find a natural lateral discharge point to nearby surface waters. Any deep percolation to the confined aquifers occurs very slowly, with lead times of years to decades or more between initial percolation at the surface and recharge to the aquifers. This is the setting for much of the Las Posas groundwater basin.

Because each setting requires a different approach, they are discussed in turn.

GROUNDWATER MONITORING – UNCONFINED AQUIFERS

In unconfined aquifers, direct monitoring of groundwater in the aquifers is possible from existing wells. However, most irrigation and drinking water wells penetrate a large portion of the aquifer to maximize production. The groundwater that enters these wells thus represents a mix of shallower groundwater that has recently percolated from the ground surface and deeper groundwater that may have percolated decades to centuries ago. Wells drilled to specifically monitor groundwater are usually completed in a discrete zone; a single site typically contains a cluster of wells completed at varying depths. To monitor water percolating to aquifers from irrigated lands, wells completed at

shallow aquifer depths would be necessary. In many areas of the Santa Clara River and Calleguas Creek watershed, such monitoring wells already exist.

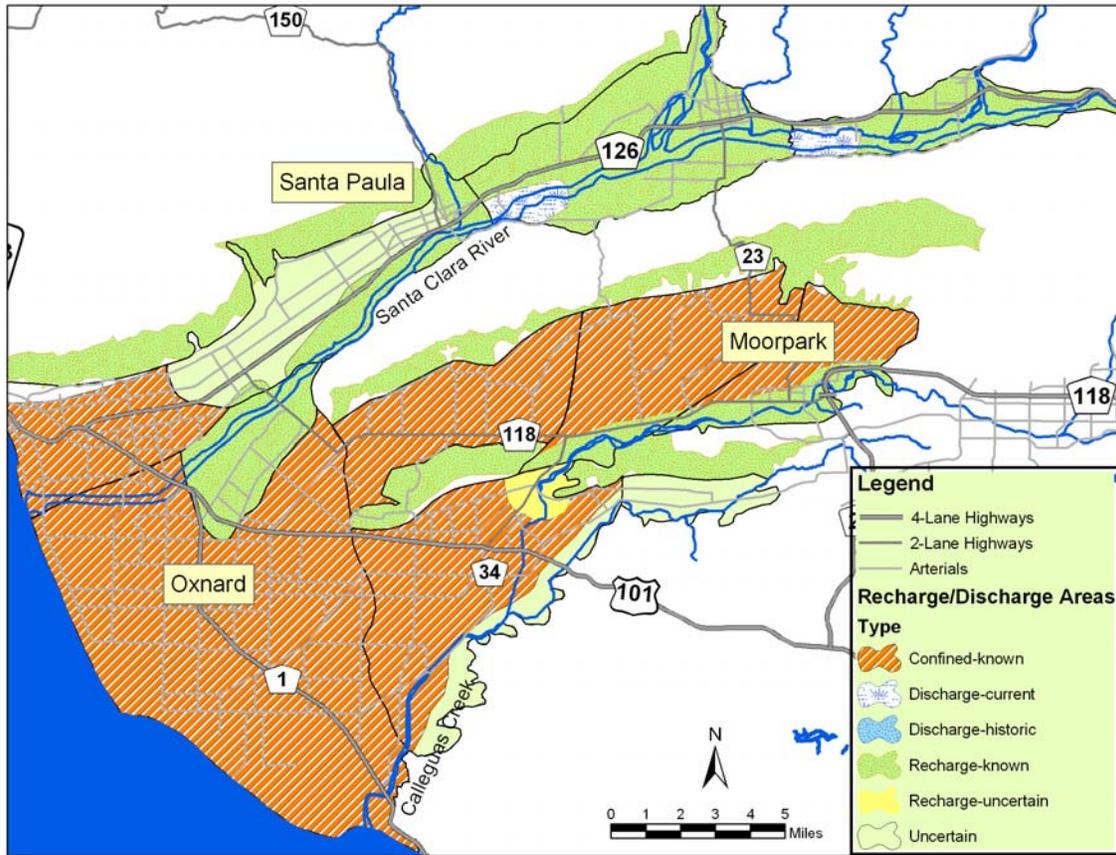


Figure A54. Hydrogeologic connection between aquifers and their overlying lands in the Santa Clara River and Calleguas Creek watersheds of Ventura County.

GROUNDWATER MONITORING – CONFINED AQUIFERS WITH A PERCHED ZONE

Percolating groundwater from irrigated lands overlying a shallow perched zone largely recharges the perched zone. The perched zone of the Oxnard Plain collects recharge from all overlying uses – including leaking underground fuel tanks. There are a number of shallow monitoring wells in the perched zone that could be appropriate monitoring sites for the Conditional Waiver. A few of these wells were installed for long-term monitoring by government agencies, but the majority were drilled for temporary use in response to a specific contaminant clean-up operation. As in monitoring streamflow, a monitoring site would need to be chosen that reflects irrigation returns to the exclusion of discharges from other overlying land uses. Thus, any monitoring well should be downgradient of or within irrigated lands. As with stream monitoring, a monitoring site

should reflect percolation from a number of upgradient lands rather than from a single irrigator.

The perched zone also discharges into a number of ditch systems that either flow into or are pumped into surface waters. Although taking samples from these ditches would be the easiest and least expensive method of groundwater sampling, the ditches commonly carry a mix of discharged perched water and runoff from nearby fields and streets. Thus, care would be required to identify specific ditches that carry only perched zone water if sampling from ditches was used to supplement sampling from perched zone monitoring wells.

GROUNDWATER MONITORING – CONFINED AQUIFERS WITH TILE DRAINS

Areas with tile drains are perhaps the easiest setting in which to monitor groundwater percolating from irrigated lands (as was done in the PRISM and Consolidated studies). There are both large and small tile drain systems; the largest systems drain so many properties that they can be considered the equivalent of a tributary in surface water monitoring. As with stream monitoring, a tile drain monitoring site should reflect contributions from a number of upgradient lands rather from a single irrigator.

GROUNDWATER MONITORING – CONFINED AQUIFERS, NO PERCHED ZONE OR TILE DRAINS

Water that percolates from irrigated lands that overlie a confined aquifer must find an exit path. Lacking tile drains or a perched zone to intercept this percolating water, a small portion of this water moves downward whereas the majority of the water finds a lateral path to surface waters. The small portion that percolates downward moves very slowly. Because of this slow movement, it is likely that sampling from wells beneath irrigated fields (assuming any water could be extracted from wells drilled into these low-permeability sediments) would extract older water that is unrelated to current land uses. Instead, sampling of laterally-moving groundwater would be the most representative method of determining the quality of these percolating waters.

However, sampling of this groundwater is problematic. Four potential methods of sampling are discussed:

- 1) **Sampling from shallow monitoring well** – A shallow monitoring well might intercept percolating waters, although the well yields might not be sufficient for analyses (this is a common problem with monitoring wells drilled into low-permeability sediments in such settings as landfills). It is not clear where such a monitoring well should be located relative to irrigated lands – if the well is in a grower's field, it would be only be indicative of water quality directly beneath that single field, but if the well is drilled downslope of several irrigated parcels,

- there is no assurance that water extracted from that well actually came from the irrigated parcels.
- 2) **Sampling from soil-moisture lysimeters in irrigated fields** – This method was used in the PRISM and Consolidated studies of agricultural pesticides and nutrients. Logistics are difficult, because the lysimeters in non-orchard areas must be removed and re-installed several times a year as crops are harvested and replanted. As with the previous method, the monitoring results reflect a small portion of a single grower’s field. To be representative of irrigated lands, there would need to be lysimeters in hundreds of fields. This type of sampling would be equivalent to surface water sampling for end-of-field runoff for every irrigated field, which is not consistent with the concept of group sampling that has been put in place for Ventura County. This amount of sampling would also be extremely expensive.
 - 3) **Sampling of areas where groundwater discharges into surface waters** – In theory, laterally-moving groundwater originating from irrigated lands could be intercepted and sampled where the groundwater seeps into surface waters. It is not clear where that occurs, because most secondary tributaries are dry for much of the year in areas such as the Las Posas groundwater basin near Moorpark. If such areas could be identified in streams where flow is more continuous during the year, then there would need to be an assurance that the seeping water sampled indeed originated from irrigated lands.
 - 4) **Sample groundwater indirectly** – In this approach, groundwater quality is tested through the surface water sampling program. Groundwater seeping into streams contributes to the water quality of that stream. With the Conditional Waiver surface water sampling program in place, this groundwater would be part of a melded sample taken in the stream. If the quality of the seeping groundwater is sufficiently poor to degrade the surface water at a sampling site, the cause of this degradation would have to be investigated as part of a corrective action plan. Presumably, this plan would include additional monitoring that could then include installing lysimeters in adjacent fields to pinpoint the source of the problem. Thus, detailed sampling of percolating waters would only occur when a problem is indicated in the surface water sampling.

We have reason to believe that such a scenario might occur. Prior to obtaining the PRISM and Consolidated grants, United Water conducted some forensic sampling of streams to try and identify a source of high nitrates in groundwater and nearby surface waters. The sampling continued upstream with no obvious source of high-nitrate discharge into the stream. Given the results of the Consolidated study that indicated that percolating groundwater beneath many irrigated fields carried a high nitrate load, it is possible that the high nitrate in the stream that United Water sampled originated from groundwater that seeped laterally into the stream.

SITE-SPECIFIC MONITORING

Unlike regional monitoring, this strategy involves sampling directly within agricultural fields so that specific farm practices can be linked to water quality. Also, unlike the regional monitoring where any water quality problems identified from that sampling require a forensic study to determine the source of the problem, site-specific monitoring allows direct linkage of farm practices and water quality. Perhaps the most effective aspect of site-specific monitoring is if water quality issues are identified, BMPs can be implemented and evaluated for effectiveness in a relatively short amount of time.

Site-specific monitoring would be implemented by installing soil-moisture lysimeters directly in a number of irrigated fields and orchards and taking periodic samples from percolating waters. The lysimeters should be installed so that the ceramic sampling tips are below the root zone of the crop, ensuring that the crop no longer has access to the compounds (e.g., nutrients) in the water. The focus of the sampling should be for nutrients because lysimeter sampling funded by the PRISM and Consolidated grants indicated that nutrients are relatively high in the percolating waters and pesticides are low or absent. In addition, current groundwater sampling of drinking water wells in Ventura County indicates that pesticides are extremely rare or absent, whereas nutrients are present in many of these wells.

It is not practical to concurrently install lysimeters in every irrigated field in Ventura County. In row crops, lysimeters must be removed and reinstalled during crop harvest and re-planting – a logistical challenge that took a substantial amount of the total time involved in sampling for the PRISM and Consolidated grants. The following recommended schedule takes this factor into consideration.

Number of Lysimeter Sites – No more than 50 sites, distributed across different crops and watersheds, should be monitored at any time by the Ventura County Agricultural Irrigated Lands Group (VCAILG). As sampling is completed at any site, a new site should be selected and lysimeters installed. The VCAILG should first identify volunteers for the initial program, filling in additional sites with a random selection procedure. A portion of the irrigators who are not part of the VCAILG should be selected at random by the Regional Board as an addition to the 50 sites identified by the VCAILG.

Installation of Lysimeters – At least two lysimeters are recommended to be installed at each site. The lysimeters should be installed within the active crop growing area so that samples represent typical conditions beneath the crop. Installation should follow procedures in the QAPP for the Consolidated grant to United Water Conservation District. It is recommended that lysimeter installation and water quality sampling be conducted by qualified personnel selected by the VCAILG (for the Group sites) or by individual irrigators. Lysimeters may have to be

removed and re-installed during crop harvest and re-planting. The lysimeters should remain at the selected sites throughout the monitoring period.

Constituents to Analyze – It is recommended that a suite of nutrients, similar to those sampled in the Consolidated grant to United Water Conservation District, should be analyzed. For any follow-up sampling required (see below), only those constituents identified as a water quality issue in initial sampling should be analyzed.

Monitoring Period and Frequency – Three samples should be drawn over a six-month period for initial evaluation. If nutrients analyzed in these samples are higher-quality than a baseline concentration, the lysimeters should be removed and re-installed at the next site selected. If water quality issues are identified in the initial sampling, it is recommended that appropriate BMPs be implemented on that property. Following implementation of appropriate BMPs, three additional samples should be drawn over a period of one year. The three samples could be drawn over a longer period of time if the Regional Board determines that there is a longer lag time between implementation of BMPs and improvement of water quality at the depth of the lysimeters. If the post-BMP samples are higher-quality than the predetermined baseline concentration, lysimeters should be removed and re-installed at the next site. If sampling indicates that the water quality issue has not been solved, then additional BMPs should be implemented and an additional three samples in one year should be repeated. If all industry-standard BMPs that are appropriate to the water quality issue at that site have been implemented, then additional sampling should not be required.

Transition to Long-Term Sampling – It is expected that as water quality issues are identified and addressed with BMPs, educational programs of the Conditional Waiver will lead to wide-spread implementation of these BMPs and a reduction in water quality issues identified from lysimeter sampling. If continuing rotation and sampling of new sites results in at least 80% of the new sites requiring no additional sampling beyond the initial three samples, then it is recommended that the groundwater monitoring transition to long-term sampling. Long-term sampling would be focused on continued success of implemented BMPs and could consist of random sampling of 20 sites per year in Ventura County, whether or not these sites had been previously sampled. Random sampling could consist of three samples over a six-month period.

EVALUATION AND RECOMMENDATIONS

EVALUATION OF MONITORING METHODS

Each of the two methods of monitoring groundwater for the Irrigated Lands Conditional Waiver discussed here has advantages and disadvantages. The regional monitoring method is more similar to the surface water monitoring where the sampled water is a collection of waters percolating from a number of irrigated lands. However, the regional method does not identify the source(s) of any water quality issue and it would take additional studies to identify these source(s) and work on implementing BMPs to mitigate the issues. For instance, nitrates are above drinking water standards in the majority of sites tested in the Consolidated grant to United Water Conservation District, so it could be expected that regional monitoring would find nitrate issues in many sampled areas. BMPs would have to be implemented across a wide area to mitigate the nitrate concentrations, and it would likely be years before water percolating from fields with newly-implemented BMPs would reach the sample points (this delay time is a key difference between surface water and groundwater sampling).

In contrast, site-specific sampling identifies problems where they occur and offers rapid solutions to the problems. Significantly, site-specific sampling allows immediate testing of the efficacy of newly-implemented BMPs. The disadvantage of site-specific sampling is that it is more labor-intensive, at least over the first few years of the program prior to the transition to long-term monitoring, and thus is likely to be more expensive. It also requires more bookkeeping (which lands have been tested, which are the next in line for random testing) and is more intrusive on private lands.

RECOMMENDATIONS

The recommended approach to monitoring groundwater for the Conditional Waiver is to implement a site-specific monitoring program. Although the monitoring is likely to be more expensive in the beginning and requires access to private lands, it is much more solution-oriented and will likely achieve water quality improvements faster and more effectively. It is also more of a partnership with agriculture in finding solutions, a strategy that works best with growers. In the long term, site-specific monitoring may be less expensive, also, because the forensic studies required to identify problems found in a regional monitoring strategy could be time-consuming and expensive.

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1.0 Project Management Elements

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1.2 Project Organization

The roles and responsibilities of individuals associated with this project are outlined below.

State Water Resource Control Board

Elizabeth Erickson
Grant Manager (RWQCB)

Janie Mitsuhashi
Program Analyst (SWRCB)

Jau Ren Chen
QA Officer (RWQCB)

Appendix B

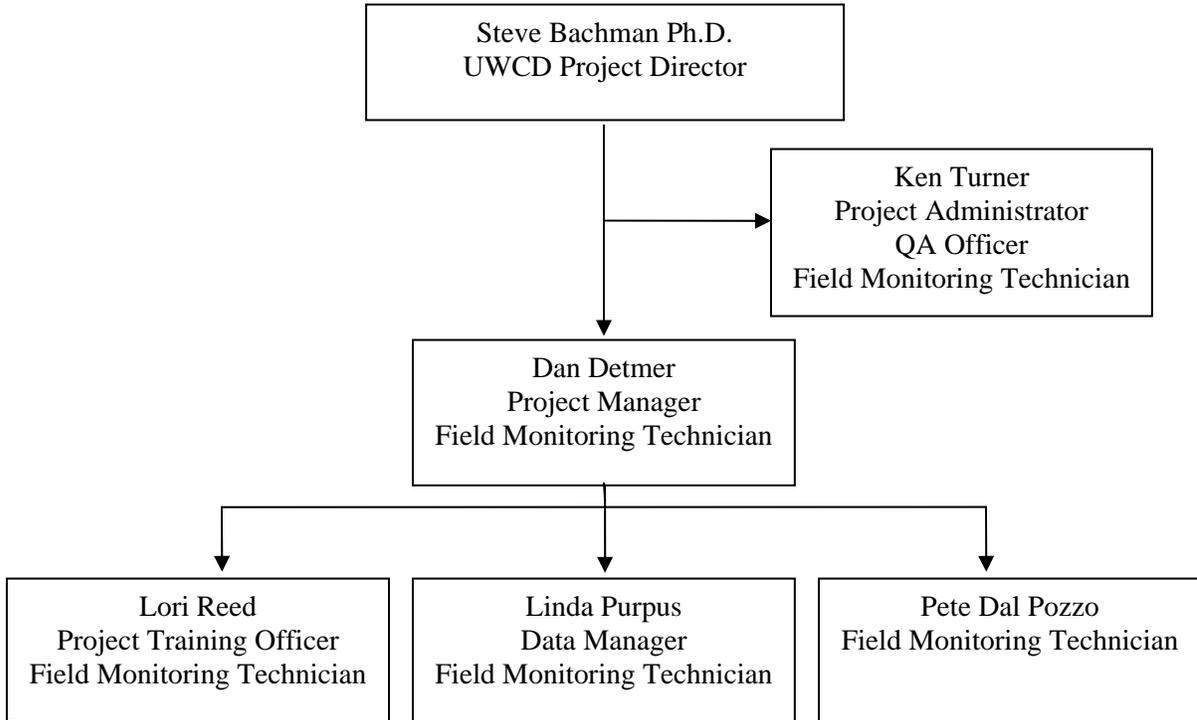
QAPP Grant Agreement 04-073-554-1

Ventura County Farm Bureau
Rex Laird
Project Cooperator

United Water Conservation District

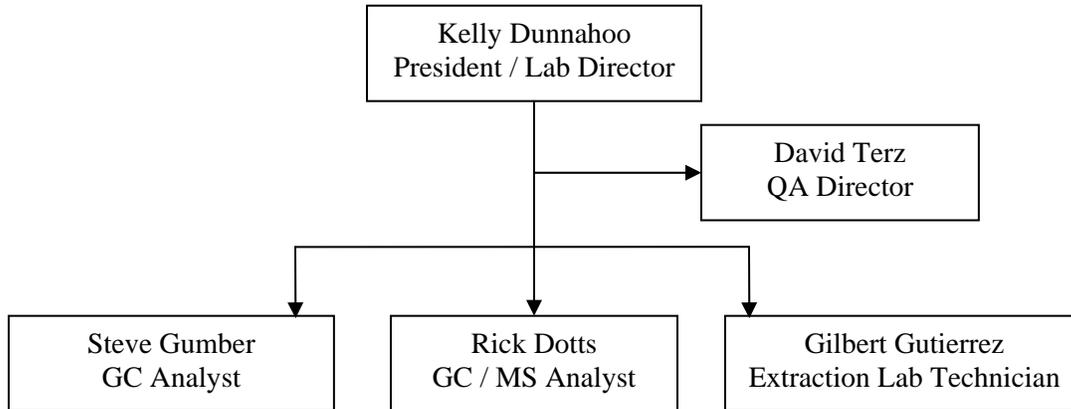
Field monitoring will be a substantial component of this project, and must be performed by trained personnel; therefore all United Water staff associated with the project will also serve as Field Monitoring Technicians. It is possible that additional trained assistants will be used for some monitoring procedures (i.e. drainage sampling).

The Data Manager is responsible for maintaining and distributing the QAPP.



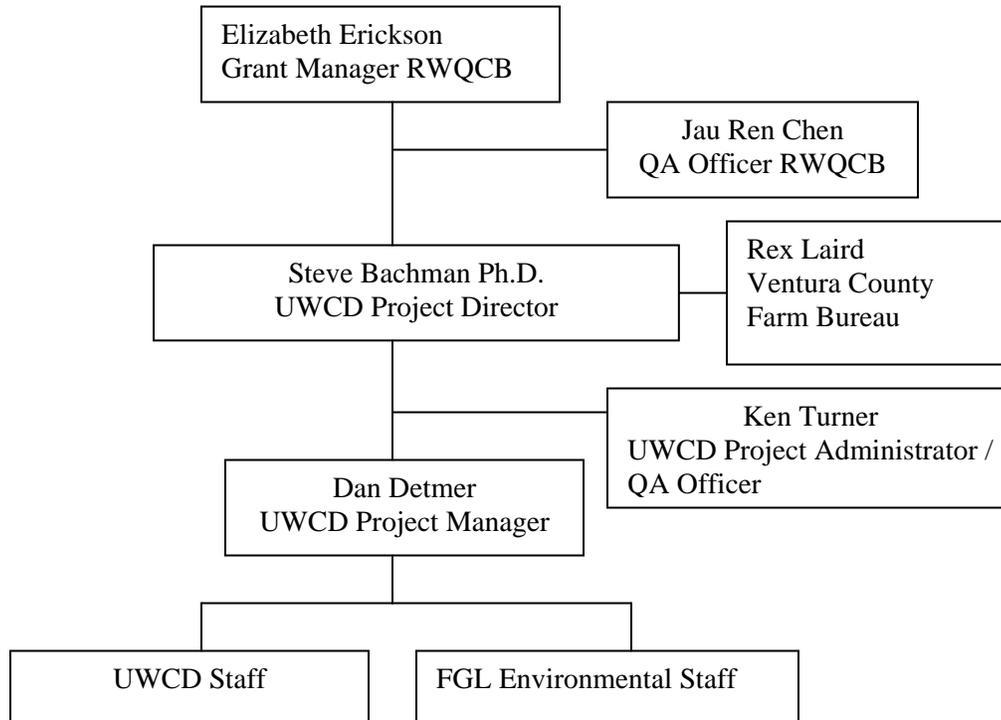
FGL Environmental

FGL Environmental will be the contract laboratory for all analyses. FGL will analyze submitted samples in accordance with all method and quality assurance requirements found in this QAPP. FGL will act as a technical resource to UWCD staff and management.



Interrelationship of Participants

The following organizational chart indicates lines of communication between project participants.



1.3 Problem Definition/Background

The waters of Calleguas Creek and the lower Santa Clara River (Ventura County) are impaired by a number of nutrients and agricultural pesticides. These pollutants exist in surface water runoff, and include legacy pesticides such as DDT and its natural degradation byproducts. In addition, some of the pollutants percolate downward through the soil and are a potential threat to the Municipal Potable Water Supply.

Both the Calleguas Creek and Santa Clara River watersheds drain agricultural and urban areas, including many of the cities of Ventura County and the agricultural areas of the Santa Clara River valley, the Oxnard Plain, Las Posas basin, and Santa Rosa Valley. Calleguas Creek discharges to the ecologically sensitive Mugu Lagoon. The

Santa Clara River is the second largest discharging river in southern California, contributing large volumes of water, sediment, together with entrained sorbed and dissolved constituents to lowland and beach areas.

Recently, cooperative efforts within both watersheds have developed TMDLs for nutrients. These TMDLs include Implementation Plans with specific goals and recommendations for reduction of agricultural pollutant loading to surface water in Calleguas Creek and the lower Santa Clara River. Various Agricultural Best Management Practices exist to lessen the impact of agricultural practices on the quality of adjacent water bodies, but they are rarely implemented on a scale that creates meaningful benefit to the watershed. The purpose of this project is to do just that – to change the habits of a large segment of the agricultural community by demonstrating that modifying management practices can significantly reduce the discharge of nutrients and pesticides into surface waters, thus reducing impairments in Calleguas Creek and the Santa Clara River. This will be accomplished by documenting current nutrient and pesticide management practices in important crops in the watershed, determining baseline conditions in the field, then changing management practices while field testing the impact. Results will be evaluated and successful management practices will then be expanded to the larger growing community. The project is designed to yield four important results:

- Identify BMPs and demonstrate the ability for changes in pesticide and nutrient management practices to reduce corresponding pollutant loading to waterbodies;
- Support associated TMDL implementations for the lower Santa Clara River and for Calleguas Creek with a proven mitigation for nutrient load management;
- Support future TMDL development for pesticide load management with proven mitigation BMPs; and
- Provide proven local management solutions for future permitting requirements.

1.4 Project Description

Following is an outlined summary of work to be performed.

1. Establish baseline conditions by conducting water quality monitoring and analyses for pesticides and fertilizer.
 - Determine current pesticide and nutrient management practices used by growers by surveying the Agricultural Oversight Committee crop representatives, Ventura County Farm Bureau, crop representatives, and the University of California Cooperative Extension (UCCE). Expand the survey to at least six (6) growers of each major crop type (avocado, citrus and row crop);
 - Determine field sites for each major crop that together represent a range of existing management and nutrient/pesticide application strategies. A map showing the study area and potential site structure is presented in Figure 1;

- Obtain written agreements from landowners for property access;
 - Link individual study parcels with their overland and subsurface drainage systems so that soil water samples, overland runoff, and drain discharges are correlated;
 - Install lysimeters at sixty (60) sites in nests of three (<1-foot, intermediate, 6-foot depth), with the intermediate lysimeter being a special porcelain/Teflon soil moisture sampler uniquely designed to collect samples that require analyses in the parts per trillion (ppt) range. Forty-three (43) of these sites will be those used in Grantee’s PRISM work. In those forty-three (43) sites, the existing PRISM pesticide lysimeters will be supplemented by two (2) regular lysimeters for nutrient sampling. In seventeen (17) new sites in the Santa Clara River watershed, both regular and pesticide lysimeters will be installed;
 - Conduct water quality sampling according to the approved QAPP and Monitoring Plan to collect baseline samples from lysimeter, drain, and overland runoff stations at all sixty (60) sites during representative dry and wet baseline conditions four (4) times per year, unless water is absent at any site(s) due to seasonal constraints;
 - Analyze samples for soluble nutrient constituents (ammonia, TKN, nitrate and nitrite) in water samples and pesticides (chlorinated and organophosphate pesticides listed in Tables 7-10) in both sediment and water fractions;
 - Enter Global Positioning System (GPS) location data into project Geographic Information System and water quality analysis data into database;
 - Analyze data with regard to time of sampling, location of sampling, correlation between site data and drain/ditch data, crop type, and correlation with management practices;
 - Share results with local experts and growers, both through the Agricultural Oversight Committee and other local contacts and to the wider agricultural community through a continuing seminar series;
2. Modify management practices to reduce nutrient and pesticide loading and transport of legacy pesticides in waterways.
- Determine the two (2) most effective BMP alternatives that are appropriate for each sampling site in coordination with the Grant Manager;
 - Assist and advise property owners with the first-round of BMP implementation at individual sampling sites. The cost of implementing the BMPs will be assumed by individual property owners. The target for success is to have BMPs implemented for at least thirty (30) project sites;
 - Note: Whenever possible the amount of chemicals applied will remain constant during each monitoring period and BMPs will not be implemented in combination. If it becomes necessary to use more than one BMP at a monitoring site, the management practices will either be implemented in steps or a BMP matrix will be established that will allow for one BMP to be matched to another in a systematic fashion as follows:
 - BMP1+BMP2 = Impact A
 - BMP1+BMP3 = Impact B
 - BMP2+BMP3 = Impact C
 Rearrange:
 - Impact A-BMP1 = BMP2
 - Impact B-BMP1 = BMP3
 Replace in third equation:
 - Impact C = Impact A-BMP1 + Impact B-BMP1
 Solve for BMP1:
 - BMP1 = $\frac{\text{Impact C} - (\text{Impact A} + \text{Impact B})}{2}$

Replace BMP1 with value and solve first two equations for BMP2 and BPM3.

- Collect water quality samples according to the approved QAPP and Monitoring Plan following the initial implementation of BMPs from lysimeter, drain, and overland runoff stations at all BMP sites during dry and wet conditions three (3) times per year for two (2) years, unless water is absent at any site(s) due to seasonal constraints;
 - Analyze samples for soluble nutrient constituents in water samples and pesticides in both sediment and water fractions to determine which sites require additional or modified BMPs;
 - Assist and advise with the implementation of a second-round of BMPs at a minimum of ten (10) sites where additional or modified BMPs are likely to be beneficial after reviewing water quality sampling results, depending upon seasonal constraints;
 - Collect water quality samples according to the approved QAPP and Monitoring Plan following the second-round implementation of BMPs from lysimeter, drain, and overland runoff stations at each second-round BMP site during dry and wet conditions three (3) times per year, unless water is absent at any site(s) due to seasonal constraints;
 - Analyze samples for soluble nutrient constituents in water samples and pesticides in both sediment and water fractions to determine which sites require additional or modified BMPs by evaluating monitoring results;
 - Conduct additional iterations of BMP implementation and retesting at sites that require additional BMPs, unless water is absent at any site(s) due to seasonal constraints, until it is determined that further, marginal improvements to pollutant reduction will be small and/or that more valuable testing and assessment can be gained from attention to other sites. The number of iterations will be determined by the remaining time on the grant and in consultation with the Grant Manager;
 - Assess success of BMPs following each sample collection by comparing monitoring results to baseline monitoring at all sites. Determine percent of load reduction for contaminants detected in baseline monitoring;
 - Determine the effectiveness of individual BMPs in preventing or reducing pollution using all water quality data collected and analyzed.
3. Provide outreach to growers within the watershed study area;
- Develop a written synopsis of the results of the implementation of the BMPs;
 - Distribute synopsis to all members of Ventura County Farm Bureau and Ventura County Agricultural Association, agricultural customers of local water quality laboratories, and UCCE, Ventura County Resource Conservation District, Strawberry Growers Association, CalAvo, Ventura County Agricultural Commissioner, Agricultural Oversight Committee, and Hansen Trust for distribution;
 - Include synopsis in UWCD and Calleguas Municipal Water District newsletters, and send to editorial boards of newspapers circulated in Ventura County;
 - Provide project summary materials that growers can use in their own presentations at agricultural seminars and conferences;
 - Plan and implement a series of three (3) workshops on the ongoing results of the study;
 - Publicize workshops using Association of Water Agencies of Ventura County and Ventura County Farm Bureau's mailing list;

- Determine additional interested parties to add to mailing list, particularly from distribution and attendance lists from Calleguas Creek and Santa Clara River watershed planning committees and general meetings;
 - Develop and distribute a survey at each workshop to receive feedback on the effectiveness of the workshop and to determine additional material to include in future workshops.
 - Hold quarterly meetings in coordination with the Agricultural Oversight Committee to inform growers of ongoing results and to receive feedback.
4. Prepare a draft project report that includes the results of the work listed above.

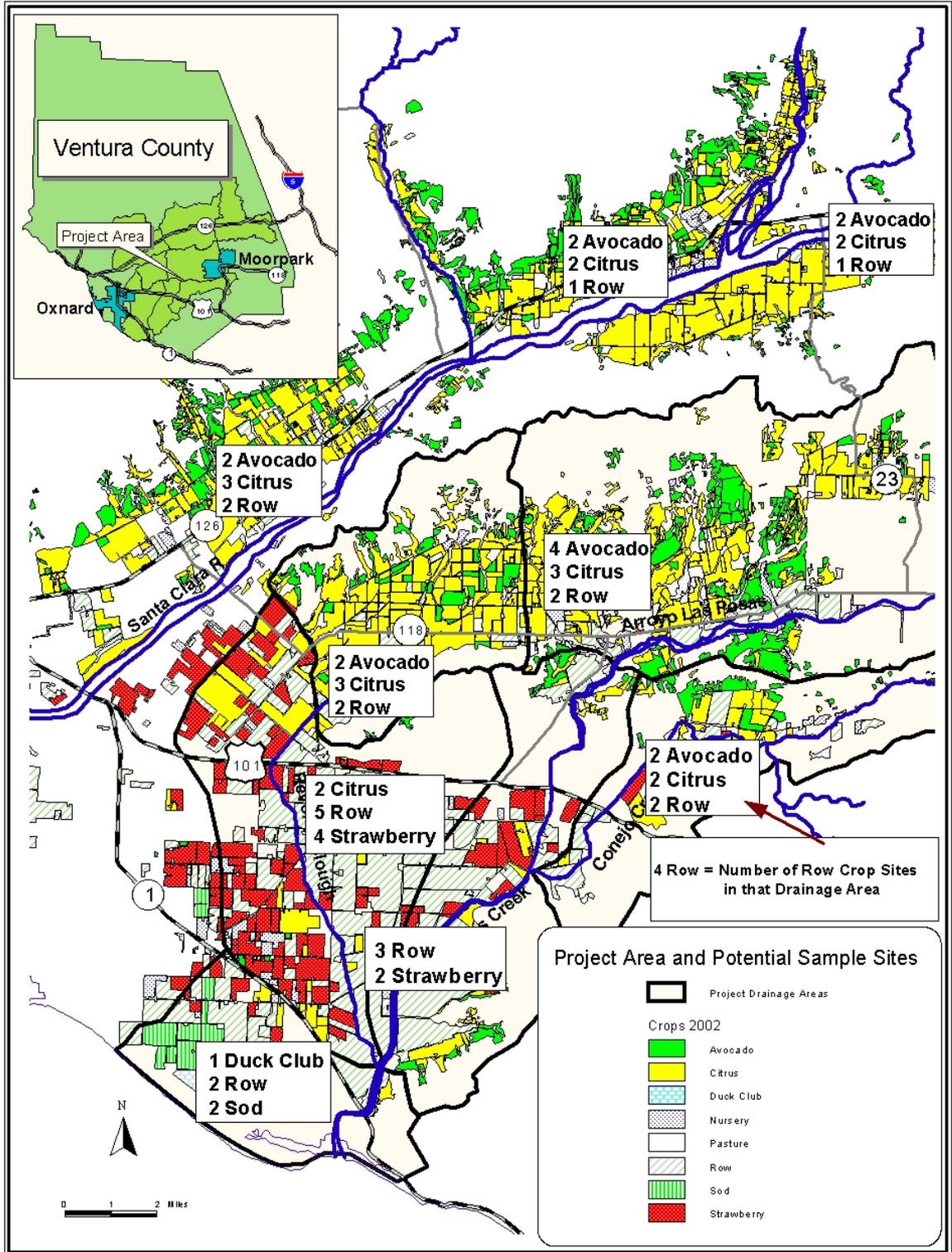


Figure 55 Map of study area and projected sample sites

1.5 Project Timetable

An approved project timetable is presented below in Table 1.

Table 30 Project Timetable

Task	DESCRIPTION	DUE DATE
--	Project Administration	October 10, 2004 and quarterly thereafter
	EXHIBIT A – SCOPE OF WORK	
1.0	CONTRACTS AND PERMITS	--
1.1	Contracts documentation	Before each award
1.2	Copy of final CEQA/NEPA documentation	August 15, 2004
1.3	Signed cover sheets for all permits	August 15, 2004
2.0	QUALITY ASSURANCE PROJECT PLAN AND MONITORING PLAN	--
2.1	Monitoring Plan	October 15, 2004
2.2	Quality Assurance Project Plan	October 15, 2004
3.0	WORK TO BE PERFORMED	--
3.1	Establishment of Baseline Conditions	--
	3.1.11 Reports or Documentation from 3.1.1 through 3.1.10	November 15, 2005
3.2	Modification of Management Practices	
	3.2.11 Reports or Documentation from 3.2.1 through 3.2.10	January 31, 2007
3.3	Outreach	--
	3.3.7 Reports or Documentation from 3.3.1 through 3.1.6	January 31, 2007
3.4	Draft and Final Project Report	--
	3.4.2 Draft Project Report	January 31, 2007
	3.4.3 Final Project Report	March 31, 2007
	EXHIBIT B – BUDGET AND REPORTING PROVISIONS	
6.1	Progress Reports by the tenth (10 th) of the month following the end of the calendar quarter (March, June, September, and December)	October 10, 2004 and quarterly thereafter
6.2	Expenditure/Invoice Projections	October 10, 2004 and every 6 months thereafter
6.3	Grant Summary Form	October 10, 2004
6.4	Natural Resource Projects Inventory project survey form	March 31, 2007
6.5	Project Assessment and Evaluation Plan	October 15, 2004
	EXHIBIT D – GRANT PROGRAM TERMS AND	

Task	DESCRIPTION	DUE DATE
	CONDITIONS	
7.	Adjoining Landowner Notification	December 15, 2004
8.	Written Landowner Access Agreements	December 15, 2004

1.6 Quality Objectives and Criteria

Primary data quality objectives are presented in Table 2. All sites will be selected based on their potential to be representative of the particular crop being analyzed. Ideal sites will exhibit some form of isolation from surrounding influences (i.e. drainages from other crops, and off-site drift of pesticide applications from adjacent crops). The study is designed to allow for comparability between different crops (avocado, citrus, row crops, strawberries, sod, and duck club grain fields), but also between subcategories of characterizations within each crop. Examples include a comparison of data obtained from an avocado grove on flat terrain to data obtained from an avocado grove located on a hillslope, as well as identification of differences between data from various vegetable row crops. To provide for direct comparability between all sites, protocols will be identical for all phases of the study, including installation, sampling, analysis, and data management.

Due to the quantitative nature of this project, there is limited opportunity for bias to become a factor. Procedures are standardized and performed uniformly from site to site. The only qualitative component is soil characterization, and it is intended that this task will be performed by the same person throughout the study. Because participation in the study is voluntary, it is possible that growers that are more astute regarding pesticide and nutrient application would be more likely to participate in the study. Likewise, growers that are aware of pollution concerns on their property may not be as willing to participate in the study. Indeed, many of the participants in the study were approached because of their affiliation with the Association of Water Agencies of Ventura County (AWA) the Ventura County Farm Bureau. It is likely that growers affiliated with these types of organizations are interested in the social, economic, and regulatory consequences of pesticide and fertilizer applications. For these reasons, it is possible that the field sites included in this study may be biased and may have a tendency to represent growers that are better stewards of their property with regard to pesticide and nutrient application. If this is the case, BMPs that are effective at these field sites are likely to have a greater impact on farms with poorer existing management practices when BMPs become more widely implemented in the watersheds.

A challenging component of this study will be obtaining sufficient sample volumes from pesticide lysimeters. Certain field conditions limit lysimeter samples to less than the required 1 liter. In order to obtain sufficient sample volume for analysis, composite samples (from consecutive, separate lysimeter extractions) will be acquired when necessary. All composite samples will be obtained over a series of no more than 5 successive days, and will be preserved on ice until deposited at FGL Environmental. Sediment volumes in sediment fraction samples may also be limited. The pesticide analysis for solids requires a minimum of 20 grams (wet mass). When possible, additional sample will be obtained to meet the minimum requirement. In field sites where erosion rates are low, it will not be feasible to obtain sediment fraction samples.

This condition is expected to occur more frequently as management practices are implemented.

Field homogeneity and sample handling protocols will be evaluated using field duplicates, which will be collected to represent 5% of total samples collected per year. Duplicate samples will be collected in the same manner and as close in time as possible to the original sample. The success of a duplicate will be measured by the relative percent difference (RPD) between the environmental sample result and the duplicate result. The RPD will be calculated using the following equation:

$$\% RPD = \left(\frac{|ES - D|}{((ES + D)/2)} \right) * 100$$

Where:

ES = environmental sample result

D = duplicate sample result

For the purposes of this study, the acceptable QA/QC limit for duplicates will be defined by having less than 20% RPD (VCSQMP 2003).

In addition, field blanks will be employed upon initiation of sampling. Field blanks (deionized water) will be taken to the field, transferred to the appropriate container, and handled in the same manner as the corresponding sample. A field blank will be considered acceptable if it is non-detect for all pesticide and nutrient analytes. If field blank performance is acceptable, further collection and analysis of field blanks will only be performed at the discretion of the UWCD Project Director. Laboratory data quality objectives are presented in Section 2.5 (Quality Control).

Table 31 Data Quality Objectives

Analysis	Detection Limit	Sensitivity*	Precision	Accuracy	Completeness
EPA Method 8270 Liquid Matrix Chlorinated Pesticides	See PQL Table 7	See MDL Table 7	See Table 7	See Table 7	80%
EPA Method 8270 Liquid Matrix Organophosphate Pesticides	See PQL Table 8	See MDL Table 8	See Table 8	See Table 8	80%
EPA Method 8081A Liquid Matrix Toxaphene	0.4 µg/L	0.29 µg/L	±30%	50-150%	80%
EPA Method 8270 Solid Matrix Chlorinated Pesticides	See PQL Table 9	see MDL Table 9	See Table 9	See Table 9	80%
EPA Method 8270 Solid Matrix Organophosphate Pesticides	See PQL Table 10	see MDL Table 10	See Table 10	See Table 10	80%
EPA Method 8081A Solid Matrix Toxaphene	200 µg/kg	52 ug/kg.	±30%	50-150%	80%
SM 4500NH3H Ammonia	0.2mg/L	0.042 mg/L	± 28%	71-114%	80%
SM 4500NH3G TKN	0.5mg/L	0.19mg/L	± 26%	72-137%	80%
SM 4500NO3F Nitrate & Nitrite	0.1mg/L	0.014mg/L	± 4.7%	92-113%	80%

*Sensitivity varies by analyte and is measured by the Method Detection Limit (MDL) which is the minimum concentration of an analyte that can be measured and reported with 99% confidence that the analyte concentration is greater than zero. This measurement is dependent on equipment and sample volume and is subject to change.

1.7 Special Training/Certification

United Water Conservation District

In order to maintain a high level of quality control, all field personnel will complete a regimented training session prior to performing any monitoring tasks. Monitoring tasks include set-up and installation of equipment, sample collection, sample transport, field documentation including completion of chain of custody documentation and field logs, and maintenance of all monitoring equipment. Trained field technicians will be required to demonstrate proficiency in all monitoring activities prior to performing the tasks independently.

All United Water field personnel attend a safety training orientation upon being hired, and documentation of the orientation is maintained in personnel files. In the event that non-staff assistants (not volunteers) are used for the monitoring program, they will

receive training in monitoring techniques as well as field safety procedures, and documentation of training will be maintained by the Project QA Officer. While the overall responsibility for safety belongs to United Water Conservation District, each individual has a personal responsibility to execute assigned tasks safely, and promptly report all hazardous conditions to supervisory personnel. United Water maintains a Safety and Training Manual that is located in the reception office at its Santa Paula location. In addition, Material Safety Data Sheets (MSDS) are located in the library at the same location.

Special consideration will be given to safety protocol for wet weather drainage sampling. This type of sampling will occur following the peak of storms, which can be at any time of the day or night, and during extreme conditions. The drainage sampling sites will be selected in advance with emphasis placed on safe accessibility. Once the location of sampling sites is established, sites will be assessed to determine which sites have cellular access, and a back-up protocol plan will be established for sites where access is not available. Site-specific safety protocol will be established where necessary.

FGL Environmental

FGL Environmental is a NELAC certified laboratory and handling and analysis of samples, as well as safety protocols, will meet minimum NELAC criteria.

1.8 Documents and Records

United Water Conservation District Quality Assurance Project Plan (QAPP)

The current version of this document will be maintained in a CONSOLIDATED-DATA folder located on the common server of United Water Conservation District's computer network. A hard copy of the original will be kept in United's Groundwater Department's library. Each new revision will include a notation that identifies appended material (Appendix A). All previous versions will be archived in the CONSOLIDATED-DATA/Library folder. All changes must be approved by the UWCD Project Director, or the Project Manager. The Project Data Manager will be responsible for incorporating changes and distributing the latest version. Upon approval, each new revision will be provided to all persons on the distribution list. Paper copies of any revised QAPPs will be promptly distributed to field monitoring technicians.

Sampling Documentation Protocol

- Site Conditions
 - Sample site locations will be surveyed and Site Reconnaissance Forms (Appendix B) will be completed outlining site specific information regarding geography; locations of lysimeters, tile drains, and surface drainages, safety considerations, and accessibility (including special access instructions as required).
 - Notes recorded in permanent field books are the only record of site conditions. The sampler(s) will take care to document all pertinent site conditions and events, including staff present, soil characteristics, observations of pesticide application activity if present, condition of equipment, quantity of sample, and any deviations from standard operating procedures or normal environmental conditions. Field notes will be neat, accurate and thorough. Upon completion of the study, field notebooks will be kept in United Groundwater Department's library.

- Chain-of-Custody – A carbon duplicate Chain-of-Custody (COC) form will be supplied by FGL along with sample containers. This form will be filled out at the time of sample collection and will accompany the sample through every processing step, documenting possession of the sample(s) from one responsible party to the next. It includes information such as sample number, location where sample was taken, type of preservative if applicable, type and size of container for each sample, dates and times of collection, name of person collecting the sample, and required analysis. If the sample changes possession, the person relinquishing the sample and the person receiving it must sign and date/time the COC form. Typically, the sample only changes possession when the sampler delivers the sample to the lab. When submitting a sample to the lab for analysis, the Field Monitoring Technician leaves the original COC form with the sample and retains the carbon duplicate. The duplicate will then be filed in United’s Groundwater Department’s library. FGL will return the original COC form with the analysis results. The COC form will be filed by date, and the analysis results will be filed by sample location.

Administrative Documentation

- Quarterly Progress Reports – A quarterly progress report will be submitted to the SWRCB’s Grant Manager by the 10th of the month following the end of the calendar quarter (March, June, September, and December). The progress reports shall describe activities undertaken and accomplishments of each task during the quarter, and any problems encountered during the performance of the study. The description of the activities and accomplishments of each task shall be in sufficient detail to provide a basis for payment of invoices and shall be translated into percent of task work completed for the purpose of calculating invoice amounts.
- Disclosure Requirement – The following disclosure statement will be included in any document, written report, contract, or brochure prepared related to this project:
“Funding for this project has been provided in full or in part through an Agreement with the State Water Resources Control Board (SWRCB) pursuant to the Costa-Machado Water Act of 2000 (Proposition 13) and any amendments thereto for the implementation of California’s Nonpoint Source Pollution Control Program. The contents of this document do not necessarily reflect the views and policies of the SWRCB, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.”
- The UWCD Project Director shall submit a 1 page summary form to the Grant Manager by October 10, 2004.
- At the completion of this project and prior to final payment, the UWCD Project Director shall complete and submit a survey form provided by the SWRCB’s Grant Manager.
- Subcontract Documentation – Documentation outlining steps taken in soliciting and awarding subcontracts shall be submitted to the SWRCB’s Grant Manager for review prior to subcontract award. The SWRCB’s Grant Manager will be furnished a copy of the awarded subcontract. All subcontractor activities and expenditures shall be documented in the progress reports.
- Expenditure/Invoice Projections – Every 6 months during the term of the project, the Project Administrator shall develop and submit expenditure/invoice projections to the assigned SWRCB Program Analyst to enable funding to be available for payment of invoices.
- A record of all project documentation will be scanned and kept electronically for a period no less than 36 years from project completion.

Electronic Records Management and Storage

Where computers or automated equipment are used for the capture, processing, manipulation, recording, reporting, storage or retrieval of project data, United Water Conservation District ensures that:

- Computer software is documented and adequate for use;
- Records that are stored or generated by computers or personal computers (PC's) have hard copy or write-protected backup copies;
- Records, which are stored only on electronic media, are supported by the hardware and software necessary for their retrieval;
- Maintenance of security of data includes the prevention of unauthorized access to, and the unauthorized amendment of, computer records;
- Procedures are established for protecting existing data through backing up the appropriate electronic data storage areas.

FGL Environmental

FGL maintains a record system to comply with all relevant regulations. The system can produce unequivocal, accurate records that document all laboratory activities. FGL retains on record all original observations, calculations and derived data, calibration records and a copy of the test report. This is primarily referenced from section 5.12 of "Quality Systems," developed at the National Environmental Laboratory Accreditation Conference (U.S. EPA 2001).

Record Keeping System and Design

The record keeping system allows historical reconstruction of all laboratory activities that produced the resultant sample analytical data. This includes interlaboratory transfers of samples and/or extracts.

- The records include the identity of personnel involved in sampling, preparation, calibration or testing.
- The records include all information relating to the laboratory facilities equipment, analytical test methods, and related laboratory activities, such as sample receipt, sample preparation, or data verification.
- The record keeping system facilitates the retrieval of all working files and archived records for inspection and verification purposes.
- All generated data except those that are generated by automated data collection systems, are recorded directly, promptly and legibly in permanent ink.
- Entries in records are not obliterated by methods such as erasures, overwritten files or markings. All corrections to record-keeping errors shall be made by one line marked through the error. The individual making the correction shall sign (or initial) and date the correction. These criteria also apply to electronically maintained records.

Hardcopy Records Management and Storage

- All records (including those pertaining to calibration and test equipment), certificates and reports are safely stored, held secure and in confidence to the client.
- All client records are held in strict confidence and will not be provided to any other party without consent of the client.
- All records are retained for a minimum of five years. The laboratory maintains all information necessary for the historical reconstruction of data. Records, which are stored only on electronic media, are supported by the hardware and software necessary for their retrieval.
- The laboratory has established a record management system for control of laboratory notebooks. Information, which is part of a routine analysis, is considered to be a

record (such as run schedules). Controlled logbooks are typically used for quality assurance documentation such as daily balance, temperature, conductivity checks and instrument maintenance and personal analyst logbooks.

- Access to archived information is documented with an access log.

Electronic Records Management and Storage

Where computers or automated equipment are used for the capture, processing, manipulation, recording, reporting, storage or retrieval of test data, the laboratory ensures that:

- Computer software is documented and adequate for use;
- Computer and automated equipment are maintained to ensure proper functioning and provided with the environmental and operating conditions necessary to maintain the integrity of calibration and test data;
- Records that are stored or generated by computers or personal computers (PC's) have hard copy or write-protected backup copies;
- Records, which are stored only on electronic media, are supported by the hardware and software necessary for their retrieval;
- Procedures are established for protecting the integrity of data; these procedures include data entry or capture, data storage, data transmission and data processing, maintenance of security of data includes the prevention of unauthorized access to, and the unauthorized amendment of, computer records;
- Procedures are established for protecting existing data through backing up the appropriate electronic data storage areas and protecting against electronic or magnetic sources.

2.0 Data Generation and Acquisition

2.1 Sampling Process Design

Applied chemicals are likely to reach surface and ground waters by two primary processes: 1) nutrients and pesticides enter the soil and are driven to subsurface drains or groundwater by a combination of deep percolation of irrigation water and rainfall; and 2) nutrients and pesticides are transported by overland runoff directly into surface waters.

To determine contributions through the soil, downward-percolating waters will be sampled using a set of three soil moisture lysimeters positioned at various depths. Two types of lysimeters will be utilized; a small diameter lysimeter will be used to obtain samples for nutrient analyses, and a larger lysimeter uniquely designed to collect samples that require analyses in the ppt range will be used to obtain samples for pesticide analyses. Each site will be equipped with two nutrient lysimeters and one pesticide lysimeter. The pesticide lysimeter will be positioned near the base of the active root zone (Table 3). The nutrient lysimeters will be installed at two depths; one will be shallow (less than 1-foot) to assess nutrient concentrations in the upper soil layer, and the other will be installed at approximately 6-feet below ground surface to allow for an assessment of nutrients that have bypassed the root uptake zone.

The direct contribution of nutrients and pesticides to surface waters will be measured in return flows collected from subsurface drainage systems (tile drains), and in overland runoff. Groundwater pumping (and therefore irrigation) is regulated in much of the study area, promoting the efficient use of water. Thus, overland runoff into ditches is usually present only during significant rainfall events. Overland runoff resulting from rainfall events will be collected from furrows or rills within the growing areas or sampled in

adjacent downstream ditches. To detect nutrient and pesticide contributions from water percolating and migrating through soil, return flows will be collected primarily from the subsurface drains in the study area. With the assistance of growers, drain sample collection points will be carefully selected to ensure correlation with crop blocks and lysimeter locations.

Each field site will initially be sampled a minimum of 4 times over a 6 to 9 month period to establish baseline data for dry and wet conditions. Sampling will occur periodically during the irrigation season as well as following significant rainfall events. These varied sampling dates will represent a range of discharge situations over varying seasons. At times, sample sites will be inaccessible due to circumstances such as recent application of pesticide, poor wet-weather access, or during crop transition. It will be up to the Project Manager's discretion to determine if the sample will be skipped for that sampling event, or if it is appropriate to obtain a sample on a different date.

Following the implementation of best management practices, each field site will be sampled a minimum of 3 times per year for 2 years, unless water is absent at any site due to seasonal constraints. This sampling will mimic the baseline sampling frequency at sample sites. Sampling will be repeated as management practices are modified and implemented.

Samples will be analyzed for nutrients and pesticides as presented in Table 4. Nutrient analyses will include nitrate, nitrite, TKN, and ammonia. Pesticides analyses will include both chlorinated and organophosphate pesticides. A complete list of pesticide analytes is presented in Table 7.

Table 32 Typical range of maximum depth of active root zones, by crop

Crop	Max Depth of Active Root Zone
Avocado	12-18 inches
Citrus	18-24 inches
Sod	6-12 inches
Grains (Duck Club feed crops)	24-36 inches
Strawberry	6-12 inches
Row Crops	12-18 inches

Table 33 Analysis performed on each sample type

Sample		TYPE OF ANALYSIS	
		Nutrients	Pesticides
Lysimeters			
1	1' depth	X	
2	At the base of the root zone		X
3	6' depth	X	
Tile drains		X	X
Surface runoff		X	X



Figure 56 Model 1923 Lysimeter

2.2 Sampling Methods

Lysimeter Installation (Model 1923 - Pesticide)

Description: The 1923 lysimeter is the larger of the two, and used to collect soil water samples for pesticide analyses. The outside diameter is 4 inches, and the length is 18 inches (Figure 2). The lower portion of the lysimeter contains a glazed reservoir. The area above the reservoir is the infiltration surface. The lysimeter will be installed so that the infiltration surface will be located within the base of the active root zone. At the top of the lysimeter there are two Teflon fittings; a sample recovery port with metal tube extending to the bottom of the lysimeter, and a pressure-vacuum port.

Preparation: Tubing will be attached to the Teflon fittings, providing access for sample collection, and covered with a protective PVC casing adaptor (collar). In order to “wet” the lysimeter, it will be placed in a 5-gallon bucket filled with deionized water and charged with a vacuum until the lysimeter fills with water. The lysimeter will be purged at least once and refilled prior to installation.

Installation: A hole will be dug using a 6-inch diameter “clam shell” post hole digger. The wetted lysimeter will be centered in the hole, and a silica slurry (silica flour mixed with deionized water) will be poured to fill the outside spaces surrounding the lysimeter to a level covering the lower 1 inch of the PVC collar. The silica flour is used to ensure good communication between the soil and the lysimeter. A 6-inch PVC vault will then

be positioned in the hole so that the lower end is level with the top of the lysimeter and the upper end is approximately 5-inches above the surface. The vault will be filled with approximately 2 inches of bentonite pellets. Bentonite pellets will also be placed in any cracks around the outside of the vault. The Bentonite is then wetted to form a seal that will prevent short-circuiting of irrigation or rain water along the sides of the vault. The lysimeter will be purged and charged with a 600 millibar vacuum. The lysimeter and tubing will be protected and covered with a removable PVC end-cap.

Clean-up: All soil will be cleaned from the post-hole digger and all other equipment that could potentially transfer contaminants (pesticides, nutrients) from one site to another.



Figure 57 Model 1900 Lysimeter



Figure 58 Model 1900 Lysimeter - View of stopper with access port

Lysimeter Installation (Model 1900 - Nutrient)

Description: The 1900 lysimeter is the smaller of the two, and used to collect soil water samples for nutrient analyses (Figure 3). The outside diameter is 1.9 inches, and two lengths will be implemented; 1-foot and 6-foot. Infiltration occurs through a porous ceramic cup at the base of the lysimeter. There is one tube in a cap at the top of the lysimeter that is used as an access port for sample extraction (Figure 4). The lower cup and top cap are secured to a section of PVC pipe which serves as the body of the lysimeter and sample reservoir.

Preparation: Tubing will be attached to the access port. The ceramic cup will be wetted by placing the lysimeter in a 5-gallon bucket filled with deionized water and charging it with a vacuum until water infiltrates through ceramic cup into the reservoir. The lysimeter will be purged at least once and refilled prior to installation.

Installation: Two nutrient lysimeters will be installed at each field site, one shallow (less than 1-foot) and the other deeper (6-foot). The holes will be cored with a 3-inch auger. Silica slurry will be poured into the hole. Immediately after the silica slurry has been poured, the lysimeter will be inserted into the hole and held in place until the slurry sets. The remainder of the hole will be backfilled to the surface with alternating layers of Bentonite pellets and native soil. The Bentonite is then wetted to form a seal that will prevent short-circuiting of irrigation or rain water. A 4-inch PVC vault will be positioned over the hole so that the lower end is approximately 5-inches below the surface and the upper end is approximately 5-inches above the surface. The lysimeter will be purged and charged with a 600 millibar vacuum. The lysimeter and tubing will be protected and covered with a removable PVC end-cap.

Clean-up: All soil will be cleaned from the auger and any other equipment that could potentially transfer contaminants from one site to another.

Preparation of Sample Containers

Sample containers will be supplied by FGL Environmental. FGL purchases the containers pre-cleaned, and they will include preservative as appropriate (Table 5). Prior to sample collection, the Field Monitoring Technician will attach a completed label sticker to the bottle. Labels will include site identification, date, time, and name of Field Monitoring Technician. Site identification will be predetermined following selection of field site sampling locations. The format for site identification will be as follows: township number (north); range number, (west); section number; LS for lysimeter sample, DR for subsurface drainage sample, or SR for surface runoff; followed by site identification number 01-99. Location identification number 02N21W11LS01 would represent Township 02 north; Range 21 west; section 11; lysimeter sample site 1. All sample locations are referenced to the San Bernardino base line and meridian.

Table 34 Reference for sample container, sample volume, preservative, and holding time

Analysis	Size of Container	Sample Volume Required	Preservative	Holding Time
Pesticides	1-Liter, Amber Glass	1-Liter	4° C	Samples extracted within 7 days and extracts analyzed within 40 days
Ammonia, TKN, Nitrite & Nitrate	Pint, Plastic	235 mL (minimum 75mL)	H ₂ SO ₄ & 4° C	28 days

Generic Sample Protocol

As a general protocol, sample bottles will not be rinsed prior to sample collection. The following reasons support this decision: 1) The soil lysimeters yield a limited volume of sample, all of which is necessary for the analysis in order to avoid excessive dilution at

the laboratory and thus, reduced analytical accuracy; 2) Sample bottles for ammonia and TKN contain preservation and therefore cannot be rinsed; and 3) It is anticipated that stormwater runoff will contain significant amounts of suspended sediment, and rinsing bottles with turbid water may increase the amount of sediment in the resultant sample (it is likely that suspended sediment introduced during the rinsing practice would be left behind in the sample container, and therefore added to the sample). Sample bottles received from the lab are pre-cleaned, and the lack of rinsing is not expected to have any adverse effect.

The Field Monitoring Technician will employ sampling techniques to prevent contamination, such as sanitary handling of the container and lid; keeping containers sealed until ready for use; and sealing containers immediately after they are filled. Once samples are obtained they will be placed on ice or blue ice in an ice chest, chain-of-custody forms will be filled out, and both will be delivered to FGL Environmental by the end of the day.

Lysimeter Sampling (Model 1923 - Pesticide)

To collect a sample, the lysimeter must first be primed with a vacuum. In order to prime the lysimeter, the sample recovery tube is pinched closed using a clamping ring and the vacuum port of a hand pump is connected to the pressure-vacuum access tube. The pump is then used to create a vacuum of approximately 600 millibars inside the lysimeter, which is indicated on the pump pressure gauge. The vacuum within the lysimeter causes soil moisture to move from the soil, through the porous infiltration surface, and into the lysimeter. The rate at which the soil water will collect within the lysimeter depends on soil moisture content, the capillary conductivity of the soil, and the amount of vacuum within the lysimeter. In moist soils with good conductivity, substantial volumes of soil water can be extracted within a few hours. Under more difficult conditions, several days may be required to collect an adequate volume for sampling and analysis. The appropriate delay between the time vacuum is applied and the time adequate sample volumes can be collected will be established by experience at each lysimeter site. Whenever possible, samples will be collected within 24 hours of the optimum time for filling of the sample reservoir within each lysimeter.

To recover a soil water sample, the clamping ring is removed from the pressure-vacuum access tube and this tube is attached to the pressure port of the hand pump. The sample recovery tube is then unclamped and placed in the sample container. A few strokes applied to the hand pump will develop enough pressure within the lysimeter to force the collected soil water out of the lysimeter and into the sample container. Pressure will be applied until no water remains in the lysimeter. Tube ends are resealed immediately following sample extraction. Vacuum is reset if sample recovery is low, in preparation for a composite sample.

Lysimeter Sampling (Model 1900 - Nutrient)

To collect a sample, the lysimeter must be primed with a vacuum that exceeds soil tension. To do so, the tube fitting on the end of the vacuum port of the pump is inserted into the neoprene tube of the stopper assembly. The vacuum hand pump is then stroked until a vacuum of 600 millibars is created within the lysimeter. The neoprene tube is then folded, resealed, and disengaged. As with the Model 1923, the vacuum will draw soil water into the reservoir of the lysimeter over a sufficient period of time.

To remove soil water sample from the lysimeter, a small-diameter sample tube is inserted into a two-hole stopper atop a flask (the flask will be used to collect the sample). The clamping ring on the lysimeter is opened and the small-diameter plastic tube is inserted through the end of the neoprene tube on the lysimeter stopper assembly and pushed down until it reaches the bottom of the lysimeter reservoir. A vacuum hand pump is then connected to the other hole of the flask stopper. Stroking the hand pump creates a vacuum in the flask which in turn draws the sample up from the lysimeter and into the collection flask. The sample can then be transferred to the appropriate sample container.

Lysimeter Maintenance

There are no maintenance requirements for the lysimeters other than protecting the access tubes from damage. Tube ends will be covered or plugged to prevent debris from entering the tubes and contaminating the samples. If excessive soil drying occurs and soil tension exceeds 2 bars, the infiltration surface of the lysimeter may need to be rewetted before obtaining a new sample. This is accomplished by inserting deionized water into the lysimeter (1500 mL for Model 1923, and 250 mL for Model 1900). After waiting approximately 1 hour, the water can be extracted from the sample reservoir. A vacuum is applied after the infiltration surface has been rewetted. If no sample is obtained after performing this rewetting procedure, the soil tension is likely in excess of 850 millibars and sample collection is not feasible under such dry soil conditions.

Drain/Surface Sampling

Under optimum conditions (sufficient flows) subsurface discharge from tile drains will be sampled at the same time that samples are obtained from lysimeters, allowing for a correlation between the two. If tile drain discharge is not sufficient to sample, then samples will be taken following irrigation or storm events. Surface drainage will be sampled at all sites following storm events. When possible, surface runoff resulting from irrigation (during the dry season) will be sampled. It is intended that dry weather samples will be obtained from at least 20 sites during two dry seasons (20 samples per season, total of 40 samples).

Pesticide: When possible, sample bottles will be immersed directly in the centroid of the drainage flow, with the container opening facing upstream. Sample bottles will be positioned near the top of the water column, but below the water surface. If the depth of flow in the overland channel is less than approximately four inches, sample bottles will be filled at the surface to avoid the collection of excessive sediment from the bed of the channel. When flows are sufficient, sample bottles will be completely filled, eliminating any air space. Sample containers will be held upstream of any flow disturbance surrounding the feet and legs of the sampler.

Ammonia/TKN//Nitrate & Nitrite: The same procedures stated above will be employed with one exception. The sample will be collected in a clean container (preferably the container that will be used for concurrent sampling for pesticides at the same site) and transferred to the pint sample vessel containing the sulfuric acid preservative.

At some locations, runoff from tile drains discharge directly to concrete channels. If channel conditions are unsafe and do not allow for the direct filling of sample bottles, an extension and intermediate glass collection flask may be used to collect samples. The extension allows for the glass flask to be extended into the channel while the sampler remains on the bank. The sample is promptly transferred from the collection vessel to

sample bottle. The collection vessel is cleaned before and after use with a bleach and Simple Green solution and rinsed with deionized water.

Required Equipment (Lysimeter Installation and Sample Collection)

3-inch Soil Auger

6-inch “Clam Shell” Post Hole Digger

Large Volume “Ultra” Lysimeter (Model 1923)

Lysimeter (Model 1900)

Teflon Tubing, ¼” x 0.020” wall

Polyethylene Tubing, ¼” x 0.020” wall

Neoprene Tubing, 3/16” ID x 1/8” wall

Pressure-Vacuum Hand Pump with Gauge

5-Gallon Bucket for Silica Slurry Mixture

5-Gallon Buckets for Deionized water

5-Gallon Buckets for Wash Water

Clamping Rings

Silica Flour, 80 mesh

Granular Bentonite, soil seal

Trowel

Aluminum Yard Stick

Sterile Amber Glass Sample Containers (1-Liter) with Teflon Lined Lids

Sterile Plastic Containers with Preservative (Pint)

Sterile Plastic Containers (1/2 Pint)

Flask

Ice Chest filled with Ice or Blue Ice

Aluminum Extension and Collection Flask

2.3 Sample Handling and Custody

As detailed above in Section 1.8 (Sampling Documentation Protocol) a carbon duplicate Chain-of-Custody form will be supplied by FGL along with the sample containers. This form will be filled out at the time of sample collection and will accompany the sample through each processing step, documenting possession and processing of the sample from one responsible party to the next. The samples will be labeled following protocol outlined in Section 2.2 (Preparation of Sample Containers), and samples will be obtained and transported to FGL Environmental employing protocols specified in Section 2.2 (Sampling Methods).

Laboratory Sample Receipt Protocols

- Upon receipt, the condition of the sample, including any abnormalities or departures from standard condition as prescribed in the relevant test method, are recorded.
 - All samples, which require thermal preservation, are considered acceptable if the arrival temperature is either within $\pm 2^{\circ}\text{C}$ of the required temperature or the method specified range. For samples with a specified temperature of 4°C , samples with a temperature ranging from just above the freezing temperature of water to 6°C shall be acceptable. Samples that are hand delivered to the laboratory shortly after collection may not meet this criterion. In these cases, the samples will be considered acceptable if there is evidence that the chilling process has begun, such as arrival in a cooler and on ice.
 - FGL has documented procedures for checking chemical preservation such as pH at the time of sample receipt.
- The results are all checked and recorded.

- Where there is any doubt as to the item's suitability for testing, where the sample does not conform to the description provided, or where the test required is not fully specified, FGL will consult the client for further instruction before proceeding. If the sample does not meet the sample receipt acceptance criteria FGL will either:
 - Retain correspondence and/or records of conversations concerning the final disposition of rejected samples; or
 - Fully document any decision to proceed with the analysis of samples not meeting acceptance criteria.
 - The condition of these samples will be noted on the chain of custody or sample discrepancy form;
 - The analysis data will be appropriately "qualified" on the final report.
 - FGL utilizes a Laboratory Information Management System (LIMS) electronic database to document receipt of all sample containers.
 - At a minimum, the following is recorded in the LIMS:
 - Client name and address;
 - Project name;
 - Sample description;
 - Sample date and time;
 - Name of sampler and employer;
 - Date and time of laboratory receipt;
 - Name of person who received the sample;
 - Unique laboratory ID code;
 - Analytical test methods requested;
 - Container types and preservation;
 - Initials of person making the entries.
 - All documentation, such as a fax transmittal form, that is transmitted by FGL or by the sample transmitter will be retained;
 - A complete chain of custody record is retained.
-

Storage Conditions

The laboratory maintains documented procedures and appropriate facilities to avoid deterioration, contamination, or damage to the sample during storage, handling, preparation, and testing; any relevant instructions provided with the sample will be followed. Where items have to be stored under specific environmental conditions, these conditions will be maintained, monitored and recorded where necessary.

- Samples are stored according to the conditions specified by preservation protocols:
 - Samples, which require thermal preservation, shall be stored under refrigeration, which is $\pm 2^{\circ}\text{C}$ of the specified preservation temperature unless method specific criteria exist. For samples with a specified storage temperature of 4°C , storage at a temperature above the freezing point of water to 6°C shall be acceptable;
 - Samples, sample fractions, extracts, leachates and other sample preparation products are stored away from all standards, reagents, food and other potentially contaminating sources. Samples shall be stored in such a manner to prevent cross contamination.

Sample Disposal

All analyzed samples or spent chemicals including used reagents, buffers, or standards will be collected in a plastic bottle and clearly marked "waste" or "poison". This waste material will be disposed of by FGL according to appropriate state and local regulations.

2.4 Analytical Methods

Pesticide samples will be analyzed using EPA method 8270 which analyzes organic compounds by gas chromatography/mass spectrometry (GC/MS), with the exception of toxaphene, which will be analyzed using EPA method 8081A. Liquid pesticide samples will be extracted using EPA method 3520, continuous liquid-liquid extraction. The initial sample volume is 1000mL and final sample extract volume is 1mL. Less initial volume will result in proportionally higher reporting limits or Practical Quantitation Limit (PQL). Sonication will be used to extract pesticide constituents from soil fractions (entrained suspended sediment in surface runoff samples) using EPA method 3550. Two basic methods will be implemented to analyze nutrients. Ammonia and TKN will be analyzed using SM 4500NH3H and SM 4500NH3G respectively. Total nitrate and nitrite will be analyzed using SM 4500NO3F. Standard Operating Procedures (SOPs) are presented in Table 6, and quality control criteria are detailed in Tables 7-11.

Table 35 Sample SOP Identification

Test Method	Constituent(s)	SOP ID	Date	Rev #	Modifications	Instrumentation
EPA 3520	Pesticide (liquid extraction)	S2ORG352.005	09/09/04	4	None known	Liquid-Liquid Extraction Glassware
EPA 3550	Pesticide (solid extraction)	S2ORG355.009	09/09/04	9	None known	Sonic Horn (550 Sonic Dismembrator, Fisher Scientific)
EPA 8081A	Toxaphene	S2ORG608.006	08/29/03	6	None known	HP 5890A Gas Chromatography /Electron Capture Detector
EPA 8270	Pesticides (excluding Toxaphene)	S2ORG82P.001	09/09/04	1	1. Injection volume is 5uL 2. Spike and surrogate levels lower	Saturn 2200 Ion Trap
SM 4500NO ₃ F	Total Nitrate & Nitrite	S2WCI087.003	03/09/03	3	None known	Technicon Flow Injection Analyzer
SM 4500NH ₃ (G &H)	TKN & Ammonia	S2WCI012.006	12/01/03	6	Uses a reduced amount of sample and reagents	FIA Star 5000 Flow Injection Analyzer

Non-Conformance and Corrective Action

- FGL has implemented non-conformance procedures to be followed when departures from documented policies, procedures and quality control have occurred. This requires the use of a non-conformance report (or similar form such as the report/invoice amendment cover letter), which may require corrective action. This procedure is outlined in the Non-conformance/Corrective Action Program and includes but is not limited to the following:
 - Assign a unique non-conformance tracking number to track the non-conformance and, if necessary, the corrective action to final closure;
 - Identifying the department in which the non-conformance occurred;
 - Identifying the type of non-conformance which occurred, such as calibration failure, standard expiration or reporting;
 - Record the pertinent details of the non-conformance, such as analytical method, batch ID, failure and probable cause;
 - Quality assurance review to track the non-conformance and determine whether a corrective action will be required.
- If a corrective action is deemed necessary the following procedures are performed:
 - Identify the individual(s) responsible for performing the corrective action;
 - Identify the remedial actions (short term) taken to prevent a similar non-conformance from occurring;
 - Identify the corrective actions (long term) taken to prevent a similar non-conformance from occurring;
 - Quality assurance review to verify the corrective actions taken are adequate;
 - Quality assurance closure of the corrective action upon approval.

2.5 Quality Control

- Analytical:
 - Batch Size: ten samples (including Preparation QC);
 - ICAL: Calibration Curve standards are from a primary source vendor containing target analytes and surrogates at a minimum of five levels. Performed prior to the analysis of samples, after instrument maintenance and whenever the Continuing Calibration Verification (CCV) indicates a new ICAL is necessary. A criterion is 20% RSD for average response factor calculations or a correlation factor of 0.99 for linear or quadratic calibrations;
 - CCV/CCB: Continuing Calibration Verifications /Continuing Calibration Blank are analyzed every ten samples (counting preparation QC), and at the end of the analytical sequence. The CCV is prepared at a midlevel concentration from a different manufacturer or if the same manufacturer is used, it must be a different lot number;
 - QC Limits for CCV/CCB: see Tables 7-11.
- Preparation:
 - Batch Size: twenty samples;
 - Method Blank: Laboratory DI, one per prep batch;
 - LCS: Laboratory Control Spike, measure of accuracy and support MS/MSD failures. Frequency is one per prep batch; use matrix spike solution containing all target analytes at a midlevel concentration;
 - MS: Matrix Spike, measure accuracy of target analytes in sample matrix. Frequency is one per prep batch; use matrix spike solution as described for LCS;
 - MSD: Matrix Spike Duplicate, measure precision of target analytes in sample matrix. Frequency is one per prep batch; use matrix spike solution as described for LCS;
 - Surrogates: added at same level to all samples and prep QC;
 - MDL: performed as part of the initial demonstration of method and whenever a major change in the method or instrumentation occurs;
 - QC Limits: For LCS/MS/MSD, the limits are initially set to 70-130%; as soon as enough points are gathered, new limits are generated by calculating the average recovery, r , and standard deviation, s . Limits are updated as $r \pm 3s$. For the surrogates, limits are initially set to 70-130%, and then control charts are determined using only data from actual samples;
- Calculations: (SW 846 Method 8000)
 - Recovery: $\% R = \frac{C_s - C_u}{C_n} \times 100$

Where:

C_s = Concentration of the spiked sample aliquot

C_u = Concentration of the unspiked sample aliquot (use 0 for LCS)

C_n = Nominal (theoretical) concentration increase that results from spiking the sample, or the nominal concentration from the spiked aliquot (for LCS)
 - Precision: $\% RPD = \left(\frac{|C_1 - C_2|}{((C_1 + C_2) / 2)} \right) \times 100$

Where:

C_1 = Result of first sample aliquot

C_2 = Result of second sample aliquot
- For GC analysis, confirmations are made on a second column of a different phase.

- Holding Times and Preservations (Table 5)

Table 36 Liquid Matrix-Chlorinated Pesticide Analyses; Quality control limits for continuing calibration verifications/continuing calibration blanks

LIQUID MATRIX Chlorinated Pesticides	Method	PQL	MDL	Initial Sample Volume	Final Sample Volume	Data Quality Objectives					
						CCV	CCB	Method Blank	LCS %	MS/BS %	MAV %
Aldrin	EPA 8270	10 ng/L	3.6 ng/L	1000mL	1mL	± 30%	n/a	<10 ng/L	20-166%	20-166%	30%
alpha-BHC	EPA 8270	10 ng/L	2.0 ng/L	1000mL	1mL	± 30%	n/a	<10 ng/L	24-149%	24-149%	30%
beta-BHC	EPA 8270	10 ng/L	2.1 ng/L	1000mL	1mL	± 30%	n/a	<10 ng/L	20-110%	20-110%	30%
delta-BHC	EPA 8270	10 ng/L	6.0 ng/L	1000mL	1mL	± 30%	n/a	<10 ng/L	50-150%	50-150%	30%
gamma-BHC(Lindane)	EPA 8270	10 ng/L	2.9 ng/L	1000mL	1mL	± 30%	n/a	<10 ng/L	50-150%	50-150%	30%
alpha-Chlordane	EPA 8270	10 ng/L	2.2 ng/L	1000mL	1mL	± 30%	n/a	<10 ng/L	50-150%	50-150%	30%
gamma-Chlordane	EPA 8270	10 ng/L	1.4 ng/L	1000mL	1mL	± 30%	n/a	<10 ng/L	50-150%	50-150%	30%
4,4'-DDD	EPA 8270	10 ng/L	1.9 ng/L	1000mL	1mL	± 30%	n/a	<10 ng/L	20-145%	20-145%	30%
4,4'-DDE	EPA 8270	10 ng/L	1.7 ng/L	1000mL	1mL	± 30%	n/a	<10 ng/L	20-136%	20-136%	30%
4,4'-DDT	EPA 8270	10 ng/L	3.1 ng/L	1000mL	1mL	± 30%	n/a	<10 ng/L	20-203%	20-203%	30%
Dieldrin	EPA 8270	10 ng/L	9.5 ng/L	1000mL	1mL	± 30%	n/a	<10 ng/L	29-136%	29-136%	30%
Endrin	EPA 8270	10 ng/L	2.6 ng/L	1000mL	1mL	± 30%	n/a	<10 ng/L	50-150%	50-150%	30%
Endrin aldehyde	EPA 8270	10 ng/L	8.4 ng/L	1000mL	1mL	± 30%	n/a	<10 ng/L	20-209%	20-209%	30%
Endrin ketone	EPA 8270	10 ng/L	2.2 ng/L	1000mL	1mL	± 30%	n/a	<10 ng/L	50-150%	50-150%	30%
Endosulfan I	EPA 8270	10 ng/L	6.1 ng/L	1000mL	1mL	± 30%	n/a	<10 ng/L	50-150%	50-150%	30%
Endosulfan II	EPA 8270	10 ng/L	4.4 ng/L	1000mL	1mL	± 30%	n/a	<10 ng/L	50-150%	50-150%	30%
Endosulfan sulfate	EPA 8270	10 ng/L	6.1 ng/L	1000mL	1mL	± 30%	n/a	<10 ng/L	20-107%	20-107%	30%
Heptachlor	EPA 8270	10 ng/L	6.0 ng/L	1000mL	1mL	± 30%	n/a	<10 ng/L	20-192%	20-192%	30%
Heptachlor epoxide	EPA 8270	10 ng/L	2.4 ng/L	1000mL	1mL	± 30%	n/a	<10 ng/L	26-155%	26-155%	30%
Methoxychlor	EPA 8270	10 ng/L	1.9 ng/L	1000mL	1mL	± 30%	n/a	<10 ng/L	50-150%	50-150%	30%
Toxaphene	EPA 8081	0.4 µg/L	0.29 µg/L	1000mL	1mL	± 30%	n/a	<0.4 µg/L	50-150%	50-150%	30%

Table 37 Liquid Matrix-OP Pesticide Analyses; Quality control limits for continuing calibration verifications/continuing calibration blanks

LIQUID MATRIX Organophosphorus Pesticides	Method	PQL	MDL	Initial Sample Volume	Final Sample Volume	Data Quality Objectives					
						CCV	CCB	Method Blank	LCS %	MS/BS %	MAV %
Atrazine	EPA 8270	50 ng/L	14 ng/L	1000mL	1mL	± 30%	n/a	<50 ng/L	32-117%	33-117%	30%
Azinphos Methyl	EPA 8270	50 ng/L	5.5 ng/L	1000mL	1mL	± 30%	n/a	<100 ng/L	35-443%	82-383%	30%
Chlorpyrifos	EPA 8270	50 ng/L	21 ng/L	1000mL	1mL	± 30%	n/a	<50 ng/L	40-159%	40-155%	30%
Demeton-O	EPA 8270	100 ng/L	67 ng/L	1000mL	1mL	± 30%	n/a	<50 ng/L	10-107%	10-51%	30%
Demeton-S	EPA 8270	100 ng/L	37 ng/L	1000mL	1mL	± 30%	n/a	<100 ng/L	10-196%	10-116%	30%
Diazinon	EPA 8270	50 ng/L	28 ng/L	1000mL	1mL	± 30%	n/a	<50 ng/L	33-152%	37-148%	30%
Dimethoate	EPA 8270	100 ng/L	14 ng/L	1000mL	1mL	± 30%	n/a	<100 ng/L	59-141%	51-145%	30%
EPN	EPA 8270	50 ng/L	6.2 ng/L	1000mL	1mL	± 30%	n/a	<50 ng/L	8-233%	19-222%	30%
Malathion	EPA 8270	100 ng/L	6.6 ng/L	1000mL	1mL	± 30%	n/a	<100 ng/L	10-355%	10-366%	30%
Mevinphos	EPA 8270	50 ng/L	8.8 ng/L	1000mL	1mL	± 30%	n/a	<50 ng/L	57-385%	5-478%	30%
Naled	EPA 8270	100 ng/L	34 ng/L	1000mL	1mL	± 30%	n/a	<100 µg/L	30-285%	10-358%	30%
Parathion Methyl	EPA 8270	50 ng/L	47 ng/L	1000mL	1mL	± 30%	n/a	<50 ng/L	10-343%	10-319%	30%
Parathion ethyl	EPA 8270	100 ng/L	21 ng/L	1000mL	1mL	± 30%	n/a	<100 ng/L	10-258%	10-215%	30%
Phorate	EPA 8270	50 ng/L	20 ng/L	1000mL	1mL	± 30%	n/a	<50 ng/L	10-139%	10-126%	30%
Simazine	EPA 8270	50 ng/L	26 ng/L	1000mL	1mL	± 30%	n/a	<50 ng/L	10-245%	10-242%	30%
Sulfotepp	EPA 8270	50 ng/L	9.5 ng/L	1000mL	1mL	± 30%	n/a	<50 ng/L	23-179%	11-177%	30%
Thionazin	EPA 8270	50 ng/L	18 ng/L	1000mL	1mL	± 30%	n/a	<50 ng/L	10-226%	10-210%	30%
Disulfoton	EPA 8270	100 ng/L	35 ng/L	1000mL	1mL	± 30%	n/a	<100 ng/L	10-100%	10-89%	30%

Table 38 Solid Matrix -Chlorinated Pesticide Analyses; Quality control limits for continuing calibration verifications/continuing calibration blanks

SOLID MATRIX Chlorinated Pesticides	Method	PQL	MDL	Initial Sample Volume	Final Sample Volume	Data Quality Objectives					
						CCV	CCB	Method Blank	LCS %	MS/BS %	MAV %
Aldrin	EPA 8270	5 µg/kg	0.29 ug/kg.	20 g	1mL	± 30%	n/a	<5 µg/kg	12-63%	12-63	30%
alpha-BHC	EPA 8270	3 µg/kg	0.28 ug/kg.	20 g	1mL	± 30%	n/a	<3 µg/kg	17-115%	17-115	30%
beta-BHC	EPA 8270	3 µg/kg	0.35 ug/kg.	20 g	1mL	± 30%	n/a	<3 µg/kg	19-120	19-120	30%
delta-BHC	EPA 8270	3 µg/kg	0.38 ug/kg.	20 g	1mL	± 30%	n/a	<3 µg/kg	12-117	12-117	30%
gamma-BHC(Lindane)	EPA 8270	3 µg/kg	0.31 ug/kg.	20 g	1mL	± 30%	n/a	<3 µg/kg	12-120	12-120	30%
alpha-Chlordane	EPA 8270	3 µg/kg	0.62 ug/kg.	20 g	1mL	± 30%	n/a	<3 µg/kg	46-123	46-123	30%
gamma-Chlordane	EPA 8270	3 µg/kg	0.43 ug/kg.	20 g	1mL	± 30%	n/a	<3 µg/kg	43-140	43-140	30%
4,4'-DDD	EPA 8270	5 µg/kg	0.49 ug/kg.	20 g	1mL	± 30%	n/a	<5 µg/kg	13-144	13-144	30%
4,4'-DDE	EPA 8270	5 µg/kg	0.29 ug/kg.	20 g	1mL	± 30%	n/a	<5 µg/kg	41-131	41-131	30%
4,4'-DDT	EPA 8270	5 µg/kg	0.71ug /kg.	20 g	1mL	± 30%	n/a	<5 µg/kg	12-160	12-160	30%
Dieldrin	EPA 8270	3 µg/kg	1.1 ug/kg.	20 g	1mL	± 30%	n/a	<3 µg/kg	12-155	12-155	30%
Endrin	EPA 8270	3 µg/kg	2.2 ug/kg.	20 g	1mL	± 30%	n/a	<3 µg/kg	21-185	21-185	30%
Endrin aldehyde	EPA 8270	3 µg/kg	0.78 ug/kg.	20 g	1mL	± 30%	n/a	<3 µg/kg	12-70	12-70	30%
Endrin ketone	EPA 8270	3 µg/kg	0.83 ug/kg.	20 g	1mL	± 30%	n/a	<3 µg/kg	12-134	12-134	30%
Endosulfan I	EPA 8270	3 µg/kg	0.72 ug/kg.	20 g	1mL	± 30%	n/a	<3 µg/kg	13-175	13-175	30%
Endosulfan II	EPA 8270	3 µg/kg	2.2 ug/kg.	20 g	1mL	± 30%	n/a	<3 µg/kg	12-168	12-168	30%
Endosulfan sulfate	EPA 8270	3 µg/kg	0.35 ug/kg.	20 g	1mL	± 30%	n/a	<3 µg/kg	12-157	12-157	30%
Heptachlor	EPA 8270	3 µg/kg	0.19 ug/kg.	20 g	1mL	± 30%	n/a	<3 µg/kg	14-156	14-156	30%
Heptachlor epoxide	EPA 8270	3 µg/kg	0.57 ug/kg.	20 g	1mL	± 30%	n/a	<3 µg/kg	51-145	51-145	30%
Methoxychlor	EPA 8270	3 µg/kg	0.60 ug/kg.	20 g	1mL	± 30%	n/a	<3 µg/kg	12-188	12-188	30%
Toxaphene	EPA 8081	200 µg/kg	52 ug/kg.	20 g	1mL	± 30%	n/a	<200 µg/kg	50-150	50-150	30%

Table 39 Solid Matrix - OP Pesticide Analyses; Quality control limits for continuing calibration verifications/continuing calibration blanks

SOLID MATRIX Organophosphorus Pesticides	Method	PQL	MDL	Initial Sample Volume	Final Sample Volume	Data Quality Objectives					
						CCV	CCB	Method Blank	LCS %	MS/BS %	MAV %
Atrazine	EPA 8270	5 µg/kg	0.33 ug/kg.	20g	1mL	± 30%	n/a	<5 µg/kg	45-115	45-115	30%
Azinphos Methyl	EPA 8270	100 µg/kg	---	20g	1mL	± 30%	n/a	<100 µg/kg	50-150	50-150	30%
Chlorpyrifos	EPA 8270	5 µg/kg	1.2 ug/kg.	20g	1mL	± 30%	n/a	<5 µg/kg	43-136	43-136	30%
Demeton-O	EPA 8270	5 µg/kg	1.0 ug/kg.	20g	1mL	± 30%	n/a	<5 µg/kg	10-140	10-140	30%
Demeton-S	EPA 8270	5 µg/kg	0.35 ug/kg.	20g	1mL	± 30%	n/a	<5 µg/kg	10-116	10-116	30%
Diazinon	EPA 8270	5 µg/kg	1.2 ug/kg.	20g	1mL	± 30%	n/a	<5 µg/kg	47-127	47-127	30%
Dimethoate	EPA 8270	100 µg/kg	---	20g	1mL	± 30%	n/a	<100 µg/kg	50-150	50-150	30%
EPN	EPA 8270	5 µg/kg	2.4 ug/kg.	20g	1mL	± 30%	n/a	<5 µg/kg	51-173	51-173	30%
Malathion	EPA 8270	100 µg/kg	1.8 ug/kg.	20g	1mL	± 30%	n/a	<100 µg/kg	47-158	47-158	30%
Mevinphos	EPA 8270	100 µg/kg	---	20g	1mL	± 30%	n/a	<100 µg/kg	50-150	50-150	30%
Naled	EPA 8270	100 µg/kg	---	20g	1mL	± 30%	n/a	<100 µg/kg	50-150	50-150	30%
Parathion Methyl	EPA 8270	5 µg/kg	3.6 ug/kg.	20g	1mL	± 30%	n/a	<5 µg/kg	61-183	61-183	30%
Parathion ethyl	EPA 8270	5 µg/kg	2.5 ug/kg.	20g	1mL	± 30%	n/a	<5 µg/kg	71-153	71-153	30%
Phorate	EPA 8270	5 µg/kg	0.94 ug/kg.	20g	1mL	± 30%	n/a	<5 µg/kg	10-145	10-145	30%
Simazine	EPA 8270	5 µg/kg	0.61 ug/kg.	20g	1mL	± 30%	n/a	<5 µg/kg	34-141	34-141	30%
Sulfotepp	EPA 8270	5 µg/kg	1.4 ug/kg.	20g	1mL	± 30%	n/a	<5 µg/kg	52-149	52-149	30%
Thionazin	EPA 8270	5 µg/kg	1.7 ug/kg.	20g	1mL	± 30%	n/a	<5 µg/kg	54-157	54-157	30%
Disulfoton	EPA 8270	100 µg/kg	---	20g	1mL	± 30%	n/a	<100 µg/kg	50-150	50-150	30%

Table 40 Nutrient Analyses / Quality control limits for continuing calibration verifications/continuing calibration blanks

Nutrients	Method	PQL	MDL	Initial Sample Volume	Final Sample Volume	Data Quality Objectives					
						CCV	CCB	Method Blank	LCS %	MS/BS %	MAV %
Ammonia	SM 4500NH3H	0.2 mg/L	0.042 mg/L	25mL	25mL	±10%	0.2mL	<0.2 mg/L	71-114%	61-119%	28%
TKN	SM 4500NH3G	0.5 mg/L	0.19 mg/L	25mL	25mL	±10%	0.2mL	<0.5 mg/L	72-137%	38-138%	26%
Nitrate & Nitrite	SM 4500NO3F	0.1 mg/L	0.014 mg/L	5mL	5mL	±10%	0.3mL	n/a	n/a	92-112%	4.7%

DEFINITIONS:

PQL – Practical Quantitation Limit – Limit of detection; or lowest concentration level that can be determined by a single analysis and with a defined level of confidence to be statistically different from a blank.

MDL - Method Detection Limit – The minimum concentration of an analyte that can be measured and reported with 99% confidence that the analyte concentration is greater than zero. This measurement is dependent on equipment and is subject to change.

CCV – Continuing Calibration Verification – Midpoint standard used to verify calibration whenever samples are analyzed. Results reported as percent recovery.

CCB – Continuing Calibration Blank - Volume of solvent analyzed to determine background instrument contamination.

Method Blank – An aliquot of reagent that is treated exactly as a sample including all sample preparation steps.

LCS – Laboratory Control Sample – A sample matrix free from the analytes of interest, spiked with verified known amounts of analytes.

MS/BS – Matrix Spike/Blank Spike – a measure of matrix effects within the sample.

MAV – Maximum acceptable value for reproducibility.

t.b.d. – To be determined. FGL is performing tests to establish these criteria.

2.6 Instrument/Equipment Testing, Inspection, and Maintenance

- All equipment is routinely maintained, inspected and cleaned. Specific routine maintenance procedures are documented in each analytical Standard Operating Procedure (SOP).
- Any item of equipment which has been subjected to overloading or mishandling, or which gives suspect results, or has been shown by verification or otherwise to be defective, will be clearly identified and taken out of service until it has been repaired and shown by calibration, verification or test to perform satisfactorily. The laboratory will review the effect of this defect on previous analyses.
- Records will be maintained for all routine and non-routine maintenance performed. These procedures are outlined in the instrument maintenance SOP. Records of the maintenance will include:
 - The manufacturer's name, model number, serial number and instrument identification;
 - The date the maintenance was performed and the analyst or service technician who performed the maintenance;
 - The symptoms of problems occurring on the instrument;
 - The cause of the problems occurring on the instrument;
 - The repair/maintenance performed to correct the problem;
 - Periodic maintenance includes verification of sufficient gas pressure and column maintenance prior to the analysis of the initial calibration.
- For reference equipment such as thermometers and weights, FGL maintains a program of calibrating the thermometers and weights on a yearly basis using NIST traceable thermometers and weights.

2.7 Instrument/Equipment Calibration and Frequency

Information regarding instrument and equipment calibration is presented in Section 2.5 (Quality Control).

2.8 Inspection and Acceptance of Supplies and Consumables

In general, each FGL lab employee orders the necessary supplies and standards necessary to complete the analysis for which he/she is responsible.

- Standards/Reagents:
 - All standards and reagents are purchased from recognized vendors;
 - All standards and reagents are recorded in FGL Environmental's LIMS system. The information stored includes: manufacturer, catalog number, lot number, constituents, and concentrations.
 - Standards have a Certificate of Analysis;
 - Solvents used for extraction are checked for contamination prior to use. FGL's vendor reserves a specific lot of the extraction solvent for FGL Environmental's use only.
- Sample bottles:
 - Purchased from a recognized vendor;
 - Purchased pre-cleaned;
- Laboratory deionized water (DI):
 - Laboratory DI is prepared onsite using granulated activated carbon to remove organics, followed by a reverse osmosis system (RO) to achieve an approximate conductivity of 15-20 umhos/cm. Finally the water is passed through a finishing bed of activated resin so as to achieve a conductivity of <1 umhos/cm;
 - Undergoes daily EC checks and monthly bacti, ammonia and Total Organic Carbon (TOC) checks.

2.9 Non-Direct Measurements

This section does not apply to the project. All data will be generated via sampling and analyses.

2.10 Data Management***United Water Conservation District***

Data will be analyzed with regard to time of sampling, location of sampling, correlation between lysimeter and subsurface drain data, crop type, and correlation with changes to pesticide management practices. The results will be entered into a water quality database (Microsoft Access) maintained by United Water for samples related to this project, and queried for use in spreadsheet and GIS programs. This task will be performed primarily by United Water staff.

FGL Environmental***Sample Handling Records***

A record of all procedures to which a sample is subjected while in the possession of the laboratory are maintained. These include records pertaining to:

- Sample preservation including appropriateness of sample container and compliance with holding time requirement;
- Sample identification, receipt, acceptance or rejection and log-in;
- Sample storage and tracking including shipping receipts, transmittal forms;
- Sample preparation including cleanup and separation protocols, ID codes, volumes, weights;
- Sample analysis including all original raw data, whether hard copy or electronic, for calibrations, samples and quality control measures, including analysts work sheets and data output records (chromatograms, strip charts, and other instrument response readout records); these records will include the following:
 - Laboratory sample ID code;
 - Date of analysis;
 - Instrumentation identification and instrument operating conditions/parameters (or reference to such data);
 - Analysis type;
 - All manual calculations;
 - Analyst's or operator's initials;
 - Reviewer's initials.
- Standard origin, receipt, preparation, and use;
- Equipment receipt, use, specification, operating conditions and preventative maintenance;
- Calibration criteria, frequency and acceptance criteria;
- Data and statistical calculations, review, confirmation, interpretation, assessment and reporting conventions;
- Method performance criteria including expected quality control requirements;
- Quality control protocols and assessment;
- Electronic data security, software documentation and verification, software and hardware audits, backups, and records of any changes to automated data entries.

Laboratory Support Activities

In addition to documenting all the above-mentioned activities, the following shall be retained:

- Copies of final reports;
- Archived standard operating procedures;
- Correspondence relating to laboratory activities for a specific project;
- All corrective action reports, audits and audit responses;

- Proficiency test results and raw data;
- Personnel qualifications, experience and training records;
- Initial and continuing demonstration of proficiency for each analyst; and
- A log of names, initials and signatures for all individuals who are responsible for signing or initialing any laboratory record.

3.0 Assessment and Oversight

3.1 Assessment and Response Actions

Throughout the course of this study, all members of the project team will be responsible for conducting assessments and reporting any conditions that require attention to the Project Manager or Project Director. An assessment meeting will be held monthly, and attended by all United Staff associated with the project. The purpose of the meeting will be to review all field and data activities, discuss current analytical results, evaluate if the project objectives are being met, and if required, initiate any modifications to protocol. All modifications resulting from this meeting must be approved by the Project Director, be incorporated into the QAPP (if applicable), and documented in the quarterly/monthly progress report to SWRCB's Project Representative.

3.2 Reports to Management

No formal QA status reports are required. The project team has an open communication policy and all team members will be responsible for promptly notifying the Project Director or Project Manager of any QA issues that arise. Any significant QA issues will be documented in the Quarterly Report. If modifications are required, the QAPP will be revised by the Data Manager and sent to all appropriate parties for approval.

4.0 Data Validation and Usability

4.1 Data Review, Verification and Validation / Verification and Validation Methods

Data Verification will occur on several different levels. As part of the standard field protocols, all out of the ordinary environmental conditions, and sampling experiences will be noted in field log books and reported to the Project Director or the Project Manager. Upon receipt of sample analyses from FGL Environmental, the Project Data Manager will ensure that sample information is complete including sample matrixes, blanks, duplicates, and extraction and holding times. Data will be entered into UWCD's relational data base, and once again checked for completeness and correctness. The Data Manager will flag values that correlate to anomalies referenced in field log books. The Project Manager will then validate the data by critically examining the sample analyses and notes from field log books. If extreme values can be identified and substantiated as errors, a second sample will be taken as soon as possible, if feasible, to replace the original sample, and corrective action will be taken to prevent future errors. The policy of this study will be to include all values (outliers and spurious results) other than those that can be identified and substantiated as errors. Outliers and spurious results will be qualified when possible. Challenges associated with data quality will be addressed in quarterly progress reports. Any procedural revisions will be appended to this QAPP and documented in the following quarterly progress report.

4.2 Reconciliation with Data Quality Objectives (DQOs)

If data does not meet the project's specifications, the following actions will be taken. First, the Project Manager (with input from the United Water staff project team) will review the errors and determine if the problem is attributed to equipment failure, calibration/maintenance techniques, lab reporting error, or monitoring/sampling techniques. Corrective action will be suggested. If the problems cannot be corrected by training, revision of techniques, or replacement of supplies/equipment, then the Project Manager will review the DQOs and determine if the specific DQOs are feasible. If the specific DQOs are not achievable, the Project Manager will determine whether the specific DQO can be relaxed, or if the parameter should be eliminated from the monitoring program. Any revisions in the DQOs will be appended to this QAPP and documented in the following quarterly progress report.

4.3 Reconciliation with User Requirements

The primary "product" of this study will be a recommendation of specific management practices that are found to reduce pesticide and nutrient loading to surface waters and soil waters by a quantified percentage. The management practices will be recommended based on crop and field characteristics. The percentage reduction will be established from random sampling events, i.e. during a given sampling period, all field sites are in various stages of pesticide/nutrient application and irrigation schedules. The retrieved data is intended to represent the common range of conditions for crop and field characteristics.

References

U.S. Environmental Protection Agency. 2001. *Quality Systems*. National Environmental Laboratory Accreditation Conference, Revision 15.

Ventura Countywide Stormwater Quality Management Program (VCSQMP). 2003. *Ventura Countywide Stormwater Monitoring Program 2002/03 Monitoring Report July 2003*.

Appendix

Appendix A – Description of Changes Incorporated in Each Document Revision

Revision	Date
Original	09/16/04
Revision 1	06/03/05

Revision 1

- Updated e-mail addresses for Jau Ren Chen, and Elizabeth Erickson
- Changed Program Analyst from Monica Torres to Janie Mitsuhashi
- Deleted all references to total nitrogen
- Updated Table 2 (Data Quality Objectives) to include data for solid matrices, and newly derived MDLs
 - Note: The QA Officer (Jau Ren Chen) had requested that precision and accuracy values for ammonia, TKN, and Nitrate and Nitrite be changed to 25% and 80-120% respectively. The values given represent limits derived from FGL control charts and were not changed.
- Updated Table 5 (Reference for sample container, sample volume, preservative, and holding time); changed volume of sample required for Ammonia, TKN, Nitrite & Nitrate analyses to 235 mL
 - Ammonia and TKN were listed separately from Nitrite & Nitrate and had sample volume requirements of 50mL and 5ml respectively. Only one sample is obtained for all analyses, therefore the analyses were combined in the table. The volume was increased to reflect the total 1/2 pint (~235 mL) volume of sample collected during optimum conditions, as well as the minimum volume of sample required for the combined analyses (75mL).
- Section 2.2, Sampling Procedures, Drain/Surface Sampling; Nitrate and nitrite sampling procedures were incorrectly described as being the same as procedures for pesticide sampling. Nitrate and nitrite were removed from the pesticide section and included with the sampling procedures for ammonia and TKN.
- Tables 7-10 were updated to reflect current values and limits derived from FGL control charts
- Deleted ronnel from Tables 8 and 10

Appendix B – Site Reconnaissance Form

SITE RECONNAISSANCE FORM

Site ID	<input type="text"/>	Date & Time	<input type="text"/>
Surveyed By	<input type="text"/>	Cell Phone Coverage	<input type="text"/> Yes <input type="text"/> No
Crop	<input type="text"/>	Hydrologic Unit	<input type="text"/>
Watershed	<input type="text"/>	7.5" TOPO Map	<input type="text"/>
Latitude (dd)	<input type="text"/>	Datum	<input type="text"/>
Longitude (dd)	<input type="text"/>	GPS Unit	<input type="text"/>
Station Elevation	<input type="text"/>	Site Access Permission (name, phone #, notes)	<input style="width: 100%; height: 100%;" type="text"/>
Major Hwy or Streets	<input type="text"/>		
Gates/Keys	<input type="text"/>		
4X4 Req'd	<input type="text"/> Yes <input type="text"/> No		
Directions to Site <input style="width: 100%; height: 100%;" type="text"/>			
Known Precautions that May Affect Access <input style="width: 100%; height: 100%;" type="text"/>			
Map of Site w/ Location of Lysimeter, Tile Drains, and Surface Drainage <input style="width: 100%; height: 100%;" type="text"/>			
Lysimeter Installation			
Installed By	<input type="text"/>	Date & Time	<input type="text"/>
Soil Characterization	<input style="width: 100%; height: 100%;" type="text"/>		
Notes: <input style="width: 100%; height: 100%;" type="text"/>			

Supplemental Appendix

Includes the following SOPs

- S2ORG352.005
- S2ORG355.009
- S2ORG608.006
- S2ORG82P.001
- S2WCI087.003
- S2WCI012.006