Department of Pesticide Regulation
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Study 241: Protocol to Demonstrate the Effectiveness of Chemigation of Pre-emergence Herbicides through Low-Volume Micro-Sprinkler Irrigation Systems on a Sandy Soil

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I. Introduction

In May 2004, the California Department of Pesticide Regulation (DPR) revised regulations for the protection of ground water from pesticide contamination. The regulations allow continued use of ground water contaminants in vulnerable areas but use requires a permit, which must be conditioned with a management practice that mitigates movement to ground water. Two pathways of pesticide movement to ground water have been determined (Troiano et al., 2000). In coarse, permeable soils, residues leach with water during normal percolation processes (Troiano et al., 1993). In contrast, for less permeable soils with a hardpan layer residues are moved offsite in runoff water to sensitive sites that provide a path to ground water (Braun and Hawkins, 1991).

Chemigation has been identified as a mitigation measure in runoff ground water protection areas (GWPAs) as listed in the Title 3, California Code of Regulations section 6487.4 and may be a mitigation measure for pre-emergence herbicide applications in GWPAs. In less permeable soils, chemigation provides a procedure to incorporate herbicides into soil after application. This mitigates movement in runoff GWPAs because lack of complete incorporation into soil has been determined as the source for runoff of residues due to winter rainfall (Braun and Hawkins, 1991, Troiano and Garretson, 1998). In coarse soil, pressurized irrigation systems allow for better management of the amount of irrigation water applied, which reduces the threat of ground water contamination from over watering during irrigation (Troiano et al., 1993). Furthermore, low volume irrigation systems such as micro-sprinklers provide for greater uniformity of water applications, thereby decreasing the potential for over watering and the production of excessive percolating water (Freeman et al., 1976).

The application of herbicides through low-volume systems, such as micro sprinklers, is not a novel procedure as evidenced by a number of studies on the soil movement and efficacy of herbicides applied through low-volume irrigation systems (Del Amor et al., 1981; Gerstl and Albasel, 1984; Gerstl and Yaron, 1983; Ogg, 1986). In a previous cooperative study conducted in citrus in Tulare County, the distribution of diuron and simazine were measured in soil after chemigation with the purpose of providing data on efficacy and leaching of pre-emergence herbicides applied through micro-sprinkler (Basinal et al., 2005). In that study, soil cores taken 120 days after application indicated that most of the herbicide residues were maintained within the first 30 cm of soil with very low levels detected between 30 and 45 cm. Efficacy data indicated that the control between the grower standard practice of broadcast spraying and the

chemigation method were similar with both methods providing 100% control 51 days after application. At 73 days after application, the grower standard practice had 85% to 95% control while the chemigation method had 80% to 90% control. More importantly, one of the participating growers also concluded that the control in the chemigation method was as good as his standard method of broadcast application.

In an effort to extend efficacy, many growers split the application of pre-emergence herbicides into two reduced rate applications that occur three to five months apart. In a survey of citrus growers, approximately 33% applied pre-emergence herbicides in a split application in fall and spring (Prather et al., 1999). This study will determine how simazine behaves after single and split chemigation applications on sandy loam soil under an efficient irrigation regime.

II. Study Objective

The objectives of this study are:

1. Determine how simazine behaves after chemigation and under an efficient irrigation regime.
2. Measure movement and efficacy of simazine chemigation on a sandy soil.
3. Evaluate the suitability of chemigation as a mitigation measure in leaching GWPAs.
4. Compare the efficacy of chemigation of pre-emergence herbicide between a single application and split-applications.
5. Compare between treatments, the extent of pesticide movement of residues into the soil profile after incorporation and subsequent irrigation.

III. Personnel

Study personnel from the Environmental Monitoring Branch of DPR include:

- Project Leader: Alfredo DaSilva
- Field Coordinator: Cindy Garretson
- Senior Scientist: John Troiano
- Laboratory Liaisons: Carissa Ganapathy for analyses conducted by Center for Analytical Chemistry, California Department of Food and Agriculture (CDFA); Cindy Garretson for analyses conducted by Fresno Staff
- Cooperating grower: Mike Reimer
- Cooperating investigators: Center for Irrigation Technology, California State University, Fresno: William Green; Syngenta: Louis Hearn
- Agency/Public Contact: Mark Pepple

Questions concerning this study should be directed to Mark Pepple at (916) 324-4086, or e-mail <mpepple@cdpr.ca.gov>, or fax (916) 324-4088.

IV. Study Plan

Study Site Description

This study will be conducted in a 6-year-old, 4-acre Mayfire nectarine orchard in Dinuba, Tulare County. This is currently a nonbearing orchard: the grower will graft a new variety to the current rootstock and will not begin commercial production of the new variety for at least two years. The trees are spaced at every 10 feet on the row and the tree rows are 18 feet apart. There is one emitter anchored a few inches away from each tree. The soil surface appears to be sandy loam to loam; physical texture analysis will be conducted to determine the exact texture at sampled depths. The field is under micro sprinkler system, Supernet Junior made by Netafim. The micro sprinklers are designed to deliver 13-gallons per hour per emitter and are set to give a solid coverage between and within the tree rows. Center for Irrigation and Technology (CIT) will evaluate the irrigation system components and measure the distribution uniformity of the water delivery to assure a proper, environmentally safe pesticide application and efficient irrigation.

Study Design

Due to potential budgetary constraints in the second year, this study has been designed as either a one-year modeling study or a replicated two-year study with treatments randomly assigned within each year. If adequate resources are available, the two-year study plan will be implemented.

The irrigation design and small field size constricts the experimental design. The three treatments must be applied in large blocks with no replication within a year with each block measuring 600 feet by 72 feet. Each block is divided into three sections and each section is subdivided into 57 subplots for sampling purpose (Figures 1 and 2). Each subplot will be divided into 3 sub-subplots of 10’by 6’.

There will be four treatments (Figure 1). The first treatment (T1) is the control where no preemergence herbicide will be injected. The second treatment (T2) is the application of the desired rates in a single chemigation application. The third treatment (T3) is a split application of the desired rate in two chemical applications split over time. The fourth treatment (T4) is a split application of the desire rate in three chemical applications split over time. The buffer rows between T 3 and T 2 as well as between T 2 and T 4 will be used for control plot, T 1. The treatment will be randomly assigned to block each year.

A potential for confounding of the measure for efficacy exists if the herbicide treatments produce different concentrations in soil before the start of the second year of the study. Results from the last sampling will be used to determine if concentrations in soil differ between treatments and whether they are at levels that could potentially affect the next year's treatment. If the levels are potentially confounding to the second year treatments then irrigation water will be applied to move residues down into the soil, lowering concentrations in the biologically active area. Data from the background sampling for the next year will check the effect of the irrigation treatments.

Pesticide Product Information

Simazine (Princep 4L, EPA Reg. No. 100-526, 4 lbs / gal) and pendimethalin (Prowl H2O, EPA Reg. No. 241-418, 3.8 lbs / gal) will be used in this study**.**

This study is being conducted under a Research Authorization, # 701016, issued by DPR's Registration Branch because simazine, the principle active ingredient of interest, is not currently labeled for application to nectarines through a chemigation system. Pendimethalin**,** which is labeled for application through an irrigation system, has been included to improve control of grasses–a plant family that is less sensitive to simazine and a common weed in orchards.

Pesticide Application Information:

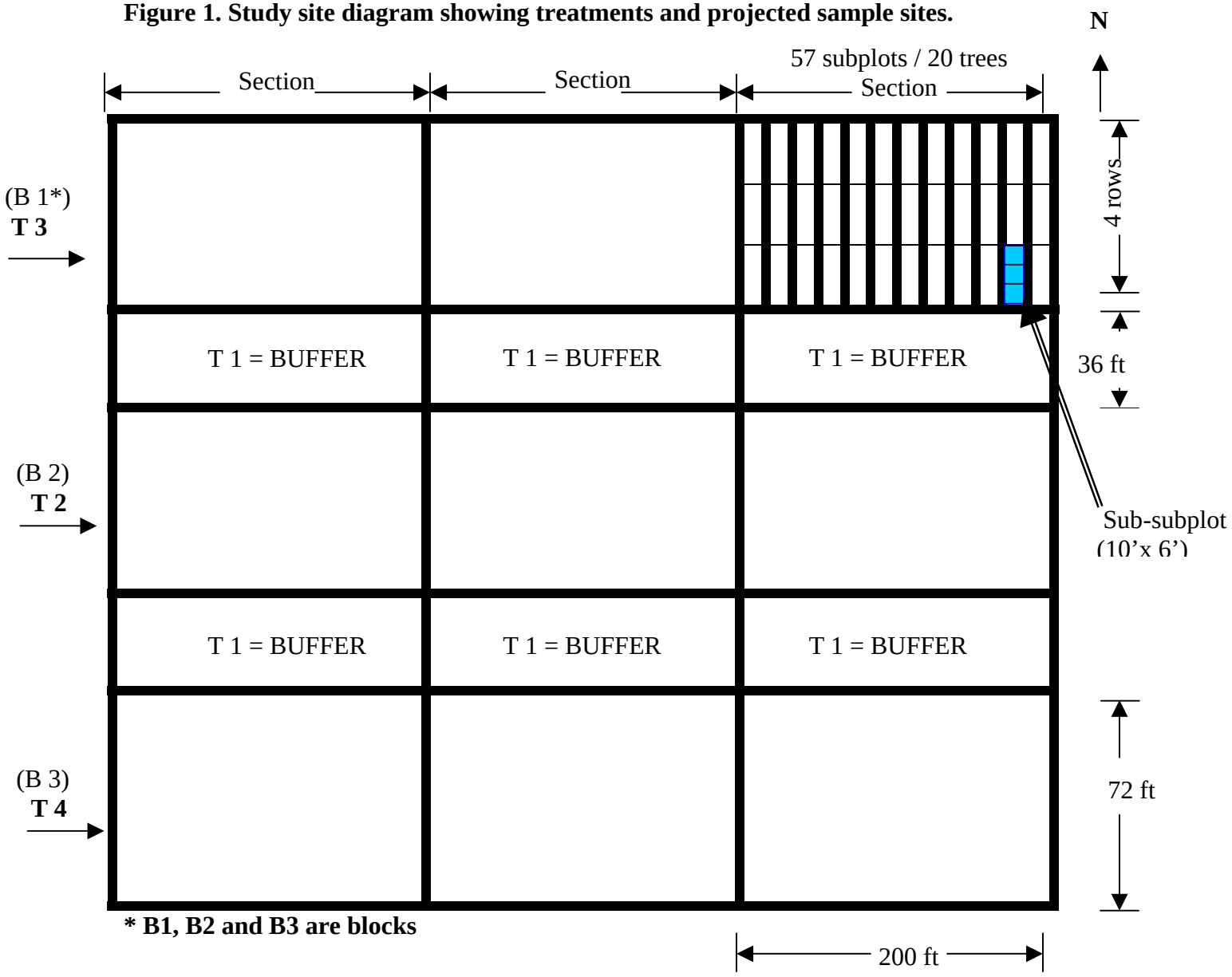
Princep 4 L, simazine, will be used at two qts/A for a single application, at 1 qt /A on two split applications and at 0.66 quarts/A for three split applications. Prowl H20, pendimethalin, will be used at 4.0 quarts/A for a single application, 2.0 quarts/A for a two split applications and at 1.3 quarts/A for three split applications.

The calculated amount of Princep 4L and Prowl H_2O per treatment will be mixed and then diluted with water at least 7% per volume before being injected in irrigation system through a venturi injection system. All plots will be pre irrigated for 30 minutes before the injection. The pre-irrigation will allow the irrigation system to stabilize and allows the operator to check for any leak on the system.

Since this study is also being conducted as a grower demonstration, the applications will comply with all pesticide label requirements for applying simazine and pendimethalin through a chemigation system. For simazine, chemigation requirements are currently found in the Special Local Need labeling that was issued for the use of Princep 4L Herbicide (EPA Reg No 100-526, EPA SLN No. CA-050004) on citrus in Fresno and Tulare Counties. For pendimethalin, chemigation instructions are found on the regular label. Since this is currently a nonbearing orchard, label required preharvest intervals do not apply.

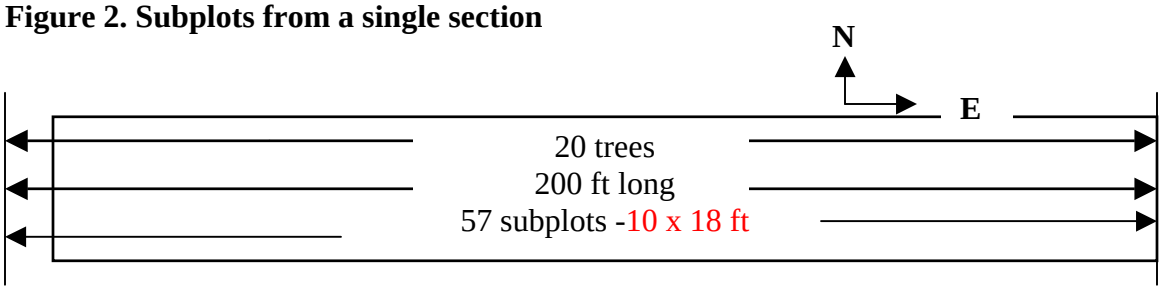
The Project Leader will notify the County Agricultural Commissioner and the appropriate Enforcement Branch Regional Office before conducting the pesticide applications as stated on SOP ADMIN 003.01**.**

Figure 1. Study site diagram showing treatments and projected sample sites.



*** B1, B2 and B3 are blocks**

Figure 2. Subplots from a single section



19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	**1**
20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39

72 ft

Irrigation Management

The grower will employ efficient irrigation management practices throughout the study period. For the purposes of this study, irrigation shall be managed so that the ratio of the amount of irrigation water applied divided by the net irrigation requirement is 1.33 or less for six months following application of the pesticide. To ensure appropriate irrigation management for the duration of the study, evapotranspiration data from, California Irrigation Management Information System will be regularly collected to calculate how much water to be used per irrigation. The amount of water to apply during each irrigation will be calculated as the cumulative daily evapotranspiration (ET) values from the last to the next irrigation times the crop coefficient. The crop coefficient adjusts the cumulative ET value to match the specific water requirements of the crop and growth stage. An additional 33% more water is allowed to this value to adjust for non-uniformity of water application.

V. Sampling Methods

Background and Tank Mix Emitter Samples:

Before injection of chemicals, water samples from four emitters per treatment will be randomly selected and sampled. Two samples per treatment will be submitted for analysis and the remaining samples will be stored and analyzed if results indicate unanticipated contamination. Each sample will be collected into a one liter amber bottle.

During the injection, water from the emitters will be sampled to determine actual concentration of chemicals in the irrigation water as compared to the calculated concentration. Six emitters, two per section per treatment, will be randomly selected and sampled during the pesticide injection. The samples will be collected half way through the chemigation runtime, starting from the emitter closest to the injection point to the furthest one. Half way through the chemigation runtime, the irrigation flow rate should be constant and stable. The collection of the samples can only be started 10 to 20 minutes after the injected products have been seen or detected on the furthest emitter from the injection point. For the collection of the sample, the head of the selected emitter will be removed and the sample collected directly into a one-liter amber bottle. This process requires the use of personal protective equipment. The uniformity of the irrigation system will be used to estimate the uniformity of the pesticide application.

Soil Samples:

Soil samples will be analyzed for the presence of simazine and its breakdown products, 2-amino-4-chlor-6-ethylamino-5 triazine (ACET) and diamino chlorotriazine (DACT). Since the site has a history of pesticide use, including simazine, background soil samples will be collected before the pesticide applications occur to determine the presence and concentration of simazine, ACET and DACT. The background soil samples will also be analyzed for soil texture and organic matter content. The first post-application soil sample will be taken one day after each application. Soil will be sampled at 45-day and 90-day intervals after each application to determine the potential for subsequent leaching (Table 1).

Soil core samples will be obtained to the 60-inch depth at 6-inch segments. Each core will be a composite of three sub-cores taken from one section measuring 200 feet by 72 feet (Figure 1). Each sub-core will be taken from one randomly selected subplot from within one section (Figure 2). Subplots will not be resampled within one treatment year.

- Background samples: All segments from six composite samples (two cores per treatment block / 60 samples total) will be submitted to the laboratory for analysis.
- Post application samples: Six segments from the first three feet of each composite core sample will be submitted to the laboratory for analysis. The remaining four segments from the deepest two feet will be stored and analyzed if results indicate movement past three feet.

Samples will be collected according to the following DPR Standard Operating Procedures (SOPs):

- SOP FSSO002.00 Soil Sampling, Including Auger and Surface Soil Procedures (Garretson 1999).
- SOP FSSO001.00 for soil bulk density determination (Garretson 1999).
- SOP METH001.00 for soil water content (Garretson 1999).

Efficacy:

The prevalent practice for these growers is to adhere to an annual application of pre-emergence herbicides that results in a clean orchard floor and low weed seed populations. Thus, efficacy concerns will focus on determining if the chemigation applications provide a continued clean orchard floor. Before the start of the study, contact herbicide may be used throughout the plots to burn back any existing vegetation. There will be no further use of contact herbicide.

The evaluation will be based on digital rating through out most of the study, then near the end of the study, a more rigorous appraisal based on dry weight clipping from randomly selected locations within each subplot will be taken. For digital evaluation, five digital pictures per subplot/ per evaluation will be randomly taken. The individual area for each digital picture would be 4 x 4 feet. A tripod may be used to facilitate the taken of pictures. The percentage of weed control will be calculated digitally. At the end of year one as well as at the end of study, the weed dry weight will be taken from randomly selected locations within each subplot. The area of each subsample will be 16 square feet (4 x 4). The dry weight may be extrapolated from the fresh weight by drying a portion of each fresh weight subsamples.

Table 1. Sampling Plan – First Year[1]

Sampling Plan	Application Dates	T 2		T 3		T 4		Total Samples
		Single App		2 Splits		3 Splits		
		Sample Date	Sample #	Sample Date	Sample #	Sample Date	Sample #	
Background Soil		Nov. 16[2]	20	Nov. 16	20	Nov. 16	20	60
Background Water[3]		Nov. 16	2	Nov. 16	2	Nov. 16	2	6
0 DAA[4] - Emitter Samples[5]	Nov. 28	Nov. 28	6	Nov. 28	6	Nov. 28	6	18
1 DAA (Soil)		Nov. 29	18	Nov. 29	18	Nov. 29	18	54
45 DAA (Soil)		Jan12	18	Jan12	18	Jan12	18	54
0 DAA - Emitter Samples	Feb. 26			Feb 26	6	Feb 26	6	12
90/1 DAA (Soil)		Feb. 27	18	Feb. 27	18	Feb. 27	18	54
135/45 DAA (Soil)		Apr. 12	18	Apr. 12	18	Apr. 12	18	54
0 DAA - Emitter Samples	May 27					May 27	6	6
180/90/1 DAA (Soil)		May 28	18	May 28	18	May 28	18	54
225/135/45 DAA (Soil)		Jul12	18	Jul12	18	Jul12	18	54
270/180/80 DAA (Soil)		Aug 26	18	Aug 26	18	Aug 26	18	54
358 DAA (Soil)		Nov. 16	18	Nov. 16	18	Nov. 16	18	54
Total Soil Samples			162		162		162	492
Total Emitter Samples			8		14		20	42
QC samples			**~16**		**~16**		**~16**	**48**
Total Samples			**188**		**194**		**200**	**582**

[1] If there are adequate resources to complete the two-year study then, this sampling plan will be implemented with amended application and sampling dates.
[2] All dates are estimates. If there is significant divergence from this plan, the project leader will submit a protocol amendment.
[3] Four samples will be taken–two will be sent to the lab and two will be stored.
[4] DAA = Day After Application.
[5] Emitter Samples are equivalent to tank mix samples.

VI. Data Analysis/Presentation

Year 1:

- A full statistical analysis is not possible but the pertinent data and observations will be summarized in a memorandum.
- In addition to the graphic presentation, the LEACHM model will be used to provide an estimate of pesticide movement for all treatments (Hustson and Wagenet, 1992). The LEACHM model has been applied to and calibrated to DPR field data (Spurlock et al., 2006) and is used to evaluate requests to register new pesticide active ingredients or now uses of previously registered pesticides (Troiano and Clayton, 2004). The level of correspondence between the LEACHM model projections and the field data will be determined through a number of statistical measures derived to compare model results such as the Coefficient of Determination (Legates and MaCable Jr., 1999) A high degree of correspondence will provide confidence in the application of LEACHM to other chemigation management scenarios.

Year 2:

- At end of year two, the comparisons between treatments will be determined graphically. The adequacy of the treatments will be determined through the level of observed weed control in relation to the location of residues in the soil column. Significant movement of the residues past the surface soil will indicate potential for leaching.
- Potential differences in soil distribution of residues between treatments will be determined through a combination of univariate and multi-variate analysis of variance (ANOVA). .

VII. Timetable

Table 2: Study Timetable

Approximate Starting date	Approximate Ending date	Activity	Responsibility of Study activity
Year One			
Early July 2007	July 2007	Meeting with grower	DPR and CIT
Sept. 2007	Sept. 2007	Determination of study location on stone fruit area	CIT[6] and DPR
Sept.2007	Sept.2007	Setup of backflow valve	CIT
Oct. 2007	Oct. 2007	Setup of Irrigation system	CIT/DPR
Early Nov.	Nov. 2007	Evaluation of irrigation system efficiency	CIT
Mid Nov.	Nov. 2007	Coring of background soil samples	DPR Fresno

[6] CIT is a Center for Irrigation and Technology at California State University Fresno.

Approximate Starting date	Approximate Ending date	Activity	Responsibility of Study activity
Nov. 2007	Nov. 2007	Infiltrometer test on the field	DPR Fresno
Nov. 2007	Feb.2007	Texture Analysis	DPR Fresno
Nov. 2007	Nov. 2007	Bulk density	DPR Fresno
Early Nov.	Nov. 2007	Setup of experimental plots	DPR
Nov.	Nov. 2007	Testing irrigation system	CIT/DPR Fresno
Nov. 2007	Nov. 2007	Testing injection system	CIT/DPR Fresno
Nov.	Nov. 2007	Collection of background water samples	DPR
Late Nov	May 2008	Injection of treatments	CIT/DPR Fresno
Late Nov	May. 2008	Collection of soil and water samples	DPR Fresno
December	Sep. 2008	Collection of efficacy data	CIT/DPR Fresno
December	Dec. 2008	Analysis of soil and water samples	CDFA Lab
Dec. 2008	Mar. 2009	Memo for first year data	DPR Fresno
Year Two			
Nov. 2008	Nov. 2008	Background soil samples	DPR Fresno
Nov. 2008	Nov. 2008	Testing of irrigation system	CIT/DPR Fresno
Nov. 2008	Nov. 2008	Testing injection system	CIT/DPR Fresno
Late Nov	May 2009	Injection of treatments	CIT/DPR Fresno
Nov 2008	May. 2009	Collection of soil and water samples	DPR Fresno
Dec. 2008	Sep. 2009	Collection of efficacy data	DPR Fresno
Dec. 2008	Dec. 2009	Analysis of soil and water samples	CDFA Lab
May 2010	May 2010	Data Analysis, reporting and publication of results.	DPR Fresno

VIII. Chemical Analysis and Quality Control

Water Samples: The CDFA laboratory has developed analytical methods for analysis of simazine in water samples. The analytes are analyzed with Hewlett Packard High Performance Liquid Chromatography 1050 with a UV Variable Wavelength Detector. The reporting limits are 0.1 ppb.

Soil Samples: The CDFA laboratory will analyze soil samples for simazine and the breakdown products, DACT and ACET. The analytes are analyzed by a ThermoQuest/ThermoSeparation HPLC with a Finnigan LCQ Deca mass spectrometer (Finnigan/ThermoQuest, San Jose, CA)(APCI/LC/MS/MS) with a C-8 or C-18 column (Agilent Zorbax® SB-C8 reported in method). The reporting limits are 10 ppb.

Quality control procedures for both analytical methods will follow established SOP QAQC001.00 for Chemistry Laboratory Quality Control (Segawa 1995).

IX. Budget

Table 3. Estimated Study Budget

Budget Component	Units	Expense/unit ($)	Total component expense estimate ($)
1st "year" (Nov 2007 – early Nov 2008)			
CIT Contract ($14,490 allocated to 2007/2009)			$9,000
Student helpers	1500 hours	$10.00 / hr	$15,000
DPR Staff PY	0.5 PY	~$100,000 / PY	$50,000
Pesticide sample analysis	522 samples	$300 – emitter samples; $650 - soil samples	$357,000
Analytical QC (~10%)	52 samples	$650 - soil samples	$33,800
1 Year Study Total			**$464,800**
2nd "year" (late Nov 2009 – Nov 2009)			
CIT Contract ($14,490 allocated to 2007/2009)			$5,490
Student helpers	1500 hours	$10.00 / hr	$15,000
DPR Staff PY	0.5 PY	~$100,000 / PY	$50,000
Pesticide sample analysis (completion of full 2 year study)	468 samples	$300 – emitter samples; $650 - soil samples	$317,400
Analytical QC (~10%)	47 samples	$650 - soil samples	$30,500
2nd Year Subtotal			**$418,390**
2 Year Study Total			**$883,190**

Table 4: Estimated Laboratory Analytical Expenditures by Fiscal Year

	1 Year Study	2 Year Study
FY 2007/2008	$251,500	$251,500
FY 2008/2009	$105,500	[redacted]
FY 2009/2010	[redacted]	$317,500
Total	$357,000	$105,500
		$674,500

X. Contract Information

- Contract Number: 05/0083C
- Contractor: California State University, Fresno Foundation
- Contract manager: Dr. David Zoldoske, Center for Irrigation Technology
- Contract Project Coordinator: Dr. John Troiano, DPR Environmental Monitoring Branch
- Amount: $14,490 allocated for 2007-2009 (contract total is $53,015)
- Time period: March 15, 2006 through January 31, 2009
- Description of services: The contractor will be coordinating studies that provide testing and demonstration of application of pesticides through irrigation systems (chemigation) as a mitigation method for preventing contamination of ground water.

XI. References

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