Group Coordination Committee
Management Practices Evaluation Program
East San Joaquin Water Quality Coalition
Sacramento Valley Water Quality Coalition
San Joaquin County and Delta Water Quality Coalition
Westlands Water Quality Coalition
Westside San Joaquin River Watershed Coalition

July 29, 2016

Pamela Creedon, Executive Officer
Adam Laputz, Assistant Executive Officer
Sue McConnell, Senior Program Manager
Central Valley Regional Water Quality Control Board
11020 Sun Center Drive, #200
Rancho Cordova, CA 95670-6114

Re: Re-submission of the Management Practice Evaluation Program Final Work Plan and Quality Assurance Project Plan

Dear Ms. Creedon, Mr. Laputz, and Ms. McConnell

On behalf of the East San Joaquin Water Quality Coalition, Sacramento Valley Water Quality Coalition, San Joaquin County and Delta Water Quality Coalition, Westlands Water Quality Coalition, and Westside San Joaquin River Watershed Coalition, the Management Practices Evaluation Program Group Coordination Committee (MPEP GCC) is submitting the revised MPEP Work Plan.

The Work Plan includes the MPEP administrative structure, the general MPEP study design and modeling components, and the timeline for the MPEP studies, reporting, and outreach. If the Work Plan is approved in a timely manner, the MPEP GCC will have contractors in place to develop the study designs in for submission on November 30, 2016.

This letter will be submitted with an original signature to the Central Valley Regional Water Quality Control Board.

Sincerely,

Parry Klassen
MPEP GCC Chair

MANAGEMENT PRACTICE EVALUATION PROGRAM

Work Plan

July 29, 2016

Submitted by:
East San Joaquin Water Quality Coalition
Sacramento Valley Water Quality Coalition
San Joaquin County and Delta Water Quality Coalition
Westlands Water Quality Coalition
Westside San Joaquin River Watershed Coalition

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Table 1 provides the MPEP GCC responses to the comments provided by the Regional Water Board.

Table 1. Response to comments from Central Valley Regional Water Quality Control Board received on June 17, 2016.

No.	Original Section	Original Page	Comment	MPEP GCC Response
1.	-	-	Please include an Executive Summary that presents the overall approach and steps that will be taken to achieve the MPEP objectives.	An Executive Summary is added.
2.	Technical Coordinators	7	Please identify the Technical Coordinators who will oversee the development of the Study Plans.	A Request for Qualifications is being sent for Field Coordinators (updated term from Technical Coordinators) and Consultants to implement studies. This is further detailed under Crop Specific Field Coordinators and Consultants.
3.	MPEP Study Design Conceptual Approach	8	The Work Plan states that several of the phases will be completed concurrently. However, the Work Plan also states that the literature review will inform the special study selection and design process. Please clarify how the phases will occur and what information will be gained from each phase that will support the subsequent phases. Is each phase independent or how will key information from each phase be used moving forward?	Language has been added to provide clarification of the overlapping phases. A timeline to illustrate phase start and end dates (Figure 3) is also included. The clarification is provided in the MPEP Work Plan including deliverables from each phase and the degree of interdependence among phases.
4.	Phase 1	8	Please identify all of the literature and studies that will be reviewed to prepare the management practice compilation as a bibliography appendix.	An initial review has been included in Appendix A. the review is ongoing and will be completed by November 1, 2016. It is not possible to identify all of the literature because the search for relevant literature is in progress.
5.	Phase 1	8	Please identify where the literature review results and compilation of practices will be reported.	The MPEP GCC will develop an annotated list of studies and management practices that are identified during the literature review. In

No.	Original Section	Original Page	Comment	MPEP GCC Response
				addition to the annotated list, the MPEP GCC will provide a short report with an evaluation of the efficacy of the management practices. The report and annotated list will be provided to each Coalition and the Regional Water Board so it can be shared with growers.
6.	Phase 1	8	Please clarify if the results of the literature review will be used to select the management practices for the special studies or what compilation of practices will be used for (e.g., early implementation, recommendations to growers).	A short report with an evaluation of the management practices is now included as a deliverable for Phase I (see No. 5 above). The information obtained through the initial literature review will be used to identify practices that can be communicated to growers as protective of groundwater. The initial review will allow the Coalitions to provide information immediately to their members, speed the adoption of additional practices if needed, and result in improved groundwater quality. The method(s) by which adoption of practices and improvement in grower performance is measured and tracked is a focus of each Coalition's Groundwater Quality Management Plan.
7.	Phase 2	9	Please include a map of the Coalitions that are included in the MPEP group and the high vulnerability areas in each Coalition region.	Map included.
8.	Phase 2	10	Please identify the constituents to be assessed. Is nitrogen the only constituent that will be considered in the MPEP?	A section has been added to the Work Plan, Constituent of Concern. Nitrate is the only COC in the MPEP.
9.	Phase 2	15	Please include a map of the soil types present in the MPEP group region.	The SSURGO soils maps contain a very large amount of information and a large number of soil types. It is not clear what specific "soil types" are

No.	Original Section	Original Page	Comment	MPEP GCC Response
				being requested and why. When a study site is selected, soil types will be identified in the study plan.
10.	Phase 2	9	Please include a map of the 12 study areas that will be included in the MPEP. Specific farms need not be identified, but the general locations of the studies should be shown, particularly for the first series of studies.	The 12 study areas have not been identified. Each study area will be identified in each individual study plan. Maps of their location will be provided with the study plans. However, it is anticipated that study sites will be located in soil series that are in high vulnerability areas.
11.	Phase 2	11	Please identify the 12 combinations of soil type, crop, irrigation method, and fertilizer application that will be included as MPEP special studies.	The 12 combinations have not been identified. Each suite of management practices will be identified in each individual study plan but generally can be described as following the 4Rs for nitrogen applications and efficient irrigation practices currently used by growers. This can vary between each crop and soil type of the planting. Additional combinations of management practices will be identified and incorporated into the modeling conducted in Phase III.
12.	Phase 2	12	Please identify the management practices that the MPEP GCC has assumed to be most protective of groundwater that will be the initial focus of the MPEP special studies.	Please see response to Comment No. 11.
13.	Phase 2	14	Please include the prioritized list of crops and management practices to be studied that the MPEP GCC has established.	The crops are identified in Table 4 and include almonds, walnuts, processing tomatoes, premium wine grapes, and silage corn.
14.	Phase 2	16	Please state what groundwater monitoring will be conducted during the special studies.	Groundwater monitoring is expected to be conducted during some of the MPEP field studies.

No.	Original Section	Original Page	Comment	MPEP GCC Response
			Does the GCC plan to install any monitoring wells?	The MPEP GCC currently is reviewing potential study locations and determining if suitable wells are present. The MPEP GCC will monitor groundwater when monitoring is expected to provide data that can be used to evaluate the efficacy of management practices.
15.	Phase 4	17	Please provide a brief overview of how each of the landscape-scale modeling tools work (e.g., inputs, outputs, uncertainty) and the pros and cons of each.	The delay in identifying the model to be used is a result of the current discussions about collaboration between the north and south MPEP groups. A meeting of the representatives of the two groups is scheduled on August 11 to discuss this issue. If cooperation between the two groups involves sharing of modeling responsibilities, the northern MPEP group will use the model selected by the southern MPEP group; SWAT. If the two groups determine that cooperation is not possible, the northern MPEP group will move forward with the landscape model selection process.
16.	Phase 4	17	Please provide the decision-making criteria that will be used to determine which landscape-scale modeling tool will be used.	See response to No. 15 above.
17.	Reporting	18	Please clarify if one comprehensive MPEP Annual Report will be prepared for submission by all of the Coalition's, or if the study regions will be separated out into different Coalition-specific reports based on study location.	One report will be prepared for all MPEP Coalitions and submitted in each participating Coalition's Annual Report.
18.	Outreach	18	Please present a universal process that the Coalitions will use to conclude the MPEP effort. It is unclear how the outcome of each of the 4 phases will come together to	There is now a section in the MPEP Work Plan titled "Conclusion of MPEP activities" that explains the process the GCC will use to assess whether the MPEP studies and modeling are

No.	Original Section	Original Page	Comment	MPEP GCC Response
			achieve greater protection of groundwater.	completed.
19.	Outreach	18	Please indicate what the outcome will be for the results of the MPEP. Will a website or pamphlet, etc., be produced to tell growers which management practices are effective based on site conditions and crop type?	Each Coalition has its own outreach program that can consist of mailings, annual reports, websites, and special publications to members. MPEP Annual Reports will be produced by the MPEP GCC and it will be the responsibility of each Coalition to provide the necessary outreach. The description of that outreach may be provided in the Groundwater Quality Management Plan, but that is at the discretion of each member Coalition.
20.	Timeline	19	Please use actual dates in the timeline versus the month count, so it is clear when the milestones will be achieved and progress reports can be expected.	Dates now included as well as a graphic of the timeline.
21.	Timeline	19	Please describe the rank and priority of the studies in the master schedule for the MPEP work.	The GCC is evaluating the management practices associated with the high priority crops as well as the availability of appropriate study locations. A description of the process for identifying the upcoming studies is included in the MPEP Work Plan. The Coalition will develop the first study plans by November 30, 2016 and then identify the next two study plans to be developed in subsequent months. This allows the MPEP GCC and the Regional Water Board to discuss the next set of studies to be performed without delaying the initiation of the field studies.

Executive Summary

The Central Valley Regional Water Quality Control Board (Regional Water Board) requires that third-party groups conduct a Management Practices Evaluation Program (MPEP). The goal of the MPEP is to identify whether existing site-specific and/or commodity-specific agricultural management practices are protective of groundwater quality. Five Central Valley third-party groups formed the MPEP Group Coordination Committee (MPEP GCC) to jointly conduct MPEP studies in the Central Valley. The participating coalitions include the East San Joaquin Water Quality Coalition, Sacramento Valley Water Quality Coalition, San Joaquin County and Delta Water Quality Coalition, Westlands Water Quality Coalition, and the Westside San Joaquin River Watershed Coalition.

The MPEP organization includes the MPEP Group Coordination Committee (MPEP GCC), a Technical Advisory Committee, an Administrative Coordinator, two Field Coordinators, and contractors responsible for completing the studies. The MPEP GCC includes the Executive Directors of each Coalition, a grower/member of each Coalition's Board of Directors, and an alternate for each member of the respective Board of Directors. The role of the MPEP GCC is to approve field study plans and modeling efforts, and allocate funds for the work. A Technical Advisory Committee (TAC) was formed to provide the expertise from multiple disciplines that the range of crops and studies is expected to demand. These technical experts are drawn from California Department of Food and Agriculture, University of California faculty, University of California Cooperative Extension, the International Plant Nutrition Institute, consulting companies, and commodity groups.

The goal of the MPEP program is to determine which management practices are protective of groundwater. The primary constituent of concern for the MPEP studies is nitrate. Specifically, the objectives of the MPEP stated in each of the Coalition's Orders are:

1) Identify whether site-specific and/or commodity-specific management practices are protective of groundwater quality within high vulnerability areas.
2) Determine if commonly implemented management practices are improving or may result in improving groundwater quality.
3) Develop an estimate of the effect of Member's discharge of constituents of concern on groundwater quality in high vulnerability areas. A mass balance and conceptual model of the transport, storage, and degradation/chemical transformation mechanisms for the constituents of concern or equivalent method approved by the Executive Officer, must be provided.
4) Utilize the results of evaluated management practices to determine whether practices implemented at represented Member farms (i.e., those not specifically evaluated, but having similar site conditions), need to be improved.

To address these four objectives, the MPEP will be implemented in four phases that overlap in time: Phase 1, develop information about management practices already demonstrated to be protective of groundwater in some agricultural settings (Objective 1); Phase 2, initiate field studies on the amount of N moving past the root zone under different management practices (Objective 1); Phase 3, modeling of

leaching on N past the root zone on the field scale (Objectives 2, 3, and 4); and Phase 4, estimate the amount of N leaching at a larger scale (Objectives 2 and 4).

During Phase I, the MPEP GCC will develop an annotated list of studies and management practices that are identified as being protective of groundwater. Field studies carried out during Phase II will be conducted across all of the GCC member Coalition regions. Each MPEP field study will require a detailed study plan that will be provided to the Regional Water Board prior to the initiation of the study. In each study plan, the location of each study will be provided along with the details of the study design such as plot size, equipment used to sample for nitrate, and frequency of sampling. All samples will be collected and processed according to the MPEP Quality Assurance Project Plan (QAPP) submitted in June 2016.

The field studies conducted during Phase II will focus on vadose zone process. Groundwater will be monitored in studies where monitoring is expected to result in meaningful information, i.e. shallow groundwater with a short transit time from the surface to first encountered groundwater. In Phase III, modeling will be used to address two of the objectives of the MPEP program; (Objective 2) determine if commonly implemented management practices are improving or may result in improving groundwater quality, and (Objective 3) develop an estimate of the effect of Member's discharge of constituents of concern on groundwater quality in high vulnerability areas. The model that the Coalitions intend to use is the 1-dimensional version of Hydrus which can be used to model the movement of water and solutes in the unsaturated and saturated zones. Hydrus is one of the best tools available to investigate a large range of management practices that may not be possible to study in the field due to time and cost constraints. Modeling can greatly speed the evaluation of management practices as model runs can be performed over a few weeks compared to a 2 or 3-year period needed to perform a field study.

Determining if management practices are improving or may result in an improvement in groundwater quality (Objective 2) likely requires extension of the modeling effort to the landscape level. The MPEP GCC is currently investigating the use of SWAT (Soil and Water Assessment Tool) as the modeling platform for this effort. As members across a large area adopt practices that are more protective of groundwater than what they currently use, there is the anticipation that groundwater quality will improve. The landscape model will be used to determine how much improvement can be expected given the range of practices that could be adopted.

Regulatory Background

In accordance with the terms of the General Order, and to assist its members, third parties are required to prepare a Groundwater Quality Management Plan (GQMP) for nitrates, under certain conditions. In general, a GQMP is required to employ a strategy of implementation that includes actions for meeting stated goals and objectives, which includes seeking compliance with receiving water limitations, educating members and identifying, validating and implementing management practices. It must also include a monitoring system that is designed to measure the effectiveness of the actions outlined in the GQMP. This monitoring system can be part of the GQMP or can be embedded in the Groundwater Trend Monitoring Program, another required element of the General Orders.

Nitrate in groundwater is of particular concern for agricultural operations because the act of farming necessarily requires nutrients in the soil to be replenished, and nitrogen in organic and synthetic fertilizers can transform to nitrate and leach to groundwater. The presence of nitrates in groundwater at levels that meet or exceed the drinking water standard of 10 mg/L as N, when the groundwater is used for domestic and municipal drinking water purposes, can have adverse impacts on public health. It is unknown at this time if commonly used management practices can help completely prevent, or minimize, nitrogen in organic and synthetic fertilizers from transforming to nitrates that then reach the groundwater.

Because of this unknown, and because it is necessary for the Regional Water Board to determine if commonly used management practices are effective in protecting groundwater quality from reaching unhealthy concentrations of nitrates, the Orders require the ESJWQC (and all other third-parties) to implement a Management Practices Evaluation Program (MPEP). The stated objectives of the MPEP are to:

- Identify whether site-specific and/or commodity specific management practices are protective of groundwater quality within high vulnerability groundwater areas,
- Determine if newly implemented management practices are improving or may result in improving groundwater quality,
- Develop an estimate of the effect of the Members' discharges of constituents of concern on groundwater quality in high vulnerability areas. A mass balance and conceptual model of the transport, storage, and degradation/chemical transformation mechanisms for the constituents of concern, or equivalent method approved by the Executive Officer, must be provided.
- Utilize the results of evaluated management practices to determine whether practices implemented at represented Member farms (i.e., those not specifically evaluated, but having similar site conditions), need to be improved.

Upon completion of the MPEP, and the Management Practices Evaluation Report, third parties are required to update and/or amend its GQMP to incorporate the findings from the MPEP. In other words, as management practices are found to be effective (or not) in preventing or minimizing the leaching of nitrates to groundwater, the GQMP should be revised to assist members in identifying appropriate management practices. Member implementation of identified management practices should be designed to assist members in meeting applicable groundwater receiving limits (and by extension the General Order). To the extent the MPEP shows that current used management practices are not effective in protecting groundwater quality, the third party in conjunction with other experts and entities shall propose and implement new/alternative management practices.

The Orders allow third-parties to meet associated MPEP requirements by conducting such evaluations on their own, or as a collective group of third parties. (General Order, p. 31.) The work plan provided here represents the framework for conducting the MPEP under the group option for five of the third parties. The participants in this MPEP include: East San Joaquin Water Quality Coalition, Sacramento Valley Water Quality Coalition, San Joaquin County and Delta Water Quality Coalition, Westlands Water Quality Coalition, and Westside San Joaquin River Watershed Coalition.

Besides meeting direct requirements in the Orders, the MPEP serves to assist members and third parties in meeting other Basin Plan requirements. In particular, the Basin Plan incorporates statewide policies. Relevant here are the State Board's Statement of Policy with Respect to Maintaining High Quality of Waters in California, Resolution No. 68-16 (hereafter referred to as "Resolution 68-16" or "Antidegradation Policy"), and Policy for Nonpoint Source Pollution (Nonpoint Source Policy). With respect to the Antidegradation Policy, regional boards are required to maintain high quality waters (i.e., those waters that are better than water quality objectives) unless the regional board finds that the degradation is consistent with the maximum benefit to the people of the state, and the discharge is subject to waste discharge requirements that result in best practicable treatment or control (BPTC) of the discharge, and the highest water quality consistent with maximum benefit to the people of the state will be maintained. What constitutes BPTC is not defined in law, but the State Water Board has identified various factors for consideration of BPTC. Such factors include comparisons of existing methods, evaluation of performance data, and consideration of methods used by similarly situated dischargers. (See, e.g., General Order, Attachment A, p. 34.) Results of the MPEP will be instrumental in identifying and determining what constitutes BPTC for different crops in different areas of the Central Valley.

Where there are not high quality waters, the State Water Board has indicated that permit limitations should be more stringent than Basin Plan objectives if such limitations can be met using best efforts, which are limitations expected to be achieved using reasonable control efforts. Like with determining BPTC, the MPEP will be instrumental in identify what is considered best efforts, or reasonable control methods, where there are not high quality waters.

The Nonpoint Source Policy identifies five key elements for programs that are designed to control nonpoint source pollution, which includes discharges from irrigated agriculture. The MPEP, in conjunction with the GQMP and other monitoring and reporting requirements in the Orders, ensures compliance with at least two of the five key elements. The two most applicable key elements are the need to describe practices to be implemented and processes being used to select and verify proper implementation of practices (key element #2), and the need for feedback mechanisms to determine if the program is achieving its purpose (key element #4). Notably, the Sacramento County Superior Court recently evaluated the Central Coast Conditional Waiver, and found that it was not consistent with the Nonpoint Source Policy largely because the Court did not believe that there was a requirement/process within the program that verified if "implemented management practices were effectively controlling the relevant discharge." Unlike the Central Coast Conditional Waiver, the General Order includes the MPEP, which fulfills this need. Moreover, the Management Practices Evaluation Report that must be submitted upon completion of the MPEP identify what management practices are protective of groundwater quality for a range of conditions.

In summary, the MPEP serves multi-purposes within the framework of the Orders. The work plan provided here sets forth how the MPEP will be conducted and address the four objectives established in the MRP. In general, the work plan establishes four phases of implementation:

- Phase 1 – Inventory effective management practices;

- Phase 2 – Perform field studies;
- Phase 3 – Model N dynamics at the field level; and,
- Phase 4 – Extend model to landscape level. Upon completion of the first phases, an evaluation of knowledge gained, and identification of next and/or additional steps will occur.

Moreover, as results and information from the MPEP are available, the GQMP will be modified and members will be educated regarding appropriate management practices.

Introduction

The Central Valley Regional Water Quality Control Board (Regional Water Board) requires that third-party groups conduct a Management Practices Evaluation Program (MPEP). The goal of the MPEP is to identify whether existing site-specific and/or commodity-specific agricultural management practices are protective of groundwater quality. Third party groups are required to initiate an MPEP in high vulnerability groundwater areas. The initial step in the MPEP is to develop a work plan that describes the tools and/or methods to be used to associate management practice activities on the land surface with the effect of those activities on underlying groundwater quality. This document is the Work Plan that provides the framework for all of the studies that will be conducted as part of this program.

The MPEP is envisioned as the vehicle for developing studies that will provide that critical information on management practices. As management practices are identified as being protective of groundwater quality, Coalition members in areas with similar characteristics, crops and conditions will be encouraged to implement those types of practices. Additionally, Groundwater Quality Trend Monitoring Programs (GTMP) implemented in each coalition region will evaluate potential changes in regional groundwater conditions. Monitoring data collected before and during the MPEP studies through the GTMP will inform the conclusions regarding the effect of the evaluated practices on groundwater quality.

Five Central Valley third-party groups have formed an organization, the MPEP Group Coordination Committee (MPEP GCC) to jointly conduct MPEP studies in the Central Valley. The participating coalitions include (**Figure 1**):

- East San Joaquin Water Quality Coalition,
- Sacramento Valley Water Quality Coalition,
- San Joaquin County and Delta Water Quality Coalition,
- Westlands Water Quality Coalition, and
- Westside San Joaquin River Watershed Coalition.

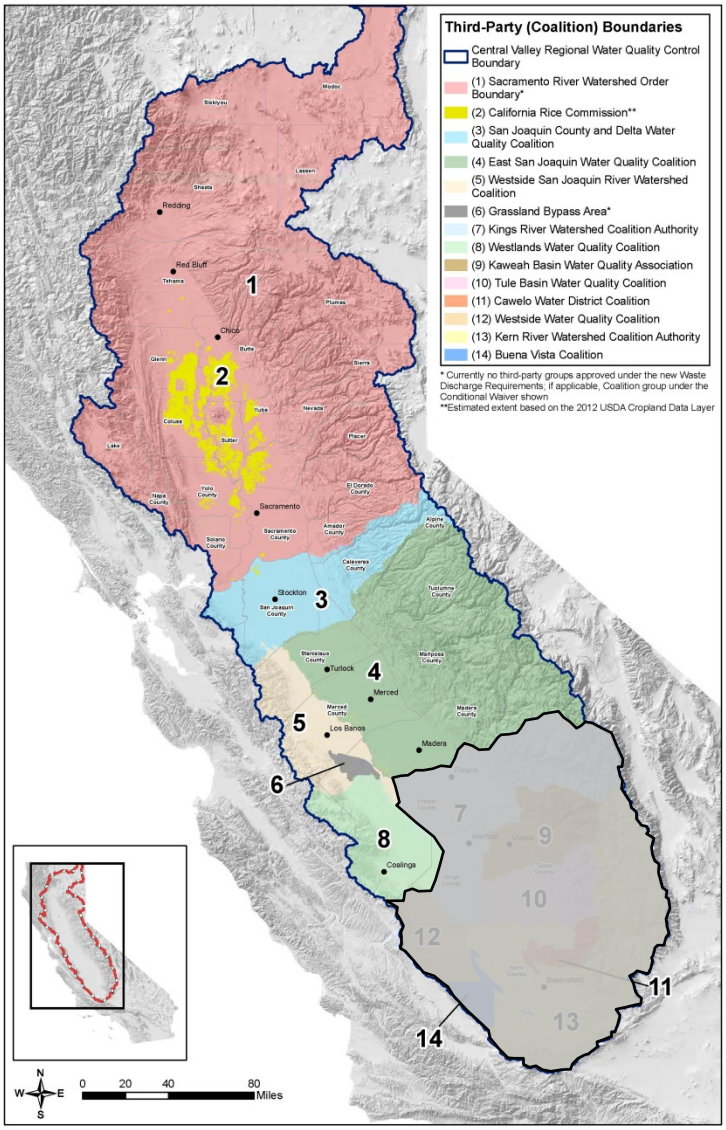

Figure 1. The five member Coalitions of the MPEP GCC. The California Rice Commission (number 2 in the map) is not a member of the MPEP GCC. The Grasslands Coalition (number 6 in the map) is also not a member but is participating as part of the Westside San Joaquin River Water Quality Coalition.

A letter was sent to the Regional Water Board on September 23, 2014 describing the MPEP GCC organization, members, participating individuals, and memorandum of agreement (Westlands Water Quality Coalition and Sacramento Valley Water Quality Coalition were added to the MPEP GCC after the letter was submitted). A letter of approval for that approach was received on June 25, 2015.

Within six years of the implementation of the MPEP, the MPEP GCC will submit a Management Practice Evaluation Report (MPER), describing management practices that are protective of groundwater quality for the range of conditions found at farms covered by MPEP studies or modeling. Information from the report will be used by the Regional Water Board staff and third-party members to identify the types of management practices that should be implemented in certain areas based on site-specific conditions.

Coalition MPEP Process – Administration and Technical

The MPEP process for developing individual MPEP studies is provided in **Figure 2** below.

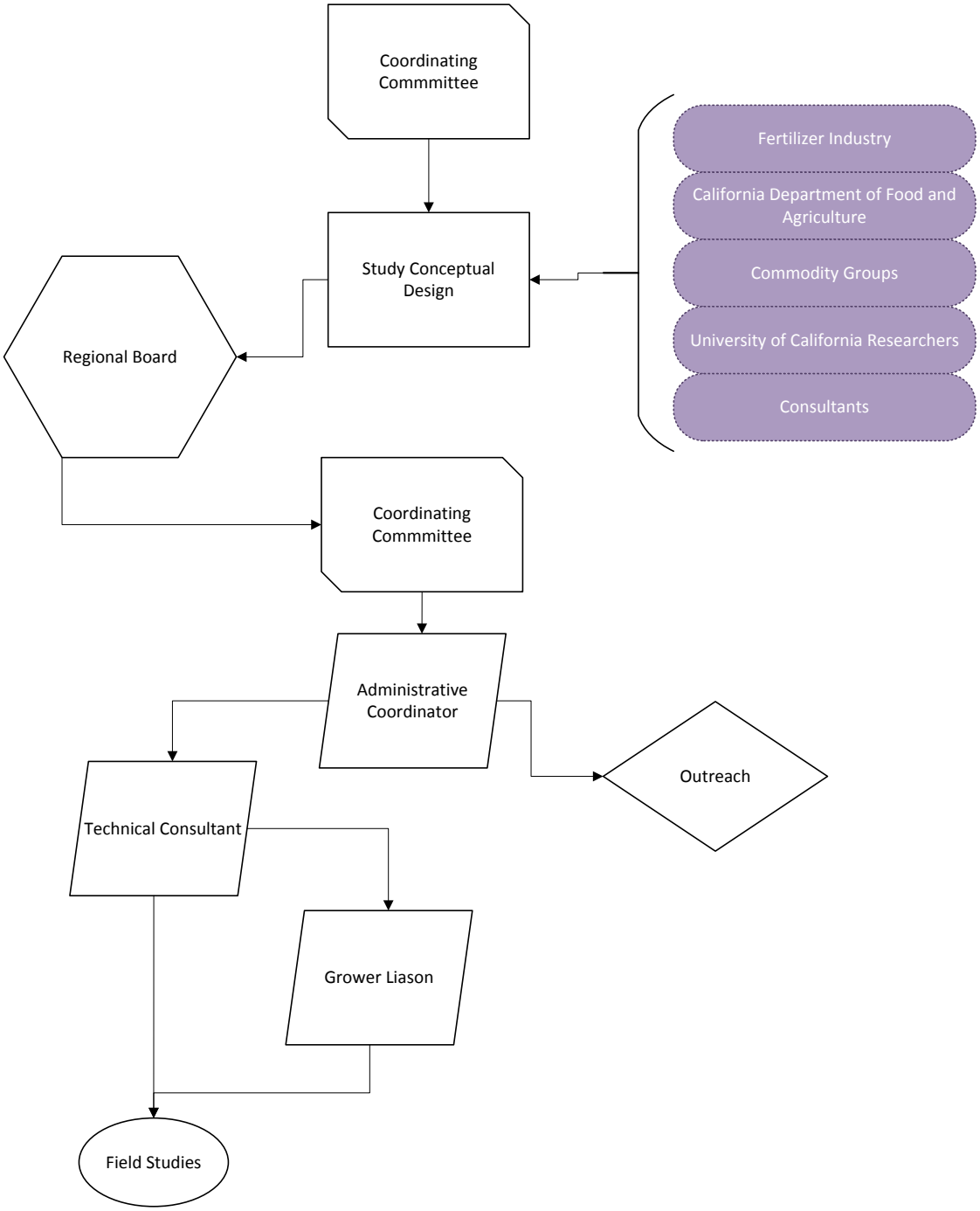

Figure 2. Process for study design implementation. Currently two Field coordinators are planned although the GCC may contract with a single Field Coordinator.

The MPEP organization includes the MPEP GCC, a Technical Advisory Committee, an Administrative Coordinator, two Field Coordinators, and contractors responsible for completing the studies. The role of each entity is described below.

MPEP Group Coordination Committee

The MPEP GCC is made up of representatives from five Central Valley water quality coalitions. These coalitions cover more than 5 million acres of irrigated cropland. On May 1, 2014, a Memorandum of Agreement (MOA) was established among the East San Joaquin River Watershed Coalition (ESJWQC), the San Joaquin County Resources Conservation District on behalf of the San Joaquin County and Delta Water Quality Coalition (SJCDWQC), and the San Joaquin Valley Drainage Authority on behalf of the Westside San Joaquin River Watershed Coalition (WSJRWC). The MOA provides supplemental information to the Coordination Agreement for the Management Practices Evaluation Group Option (effective 5/1/2014) and additional detail about the operation of the MPEP GCC. The MOA was later signed by the Sacramento Valley Water Quality Coalition (SVWQC) and the Westlands Water Quality Coalition (WWQC). The role of the MPEP GCC is to direct the development, preparation, and implementation of the MPEP Group Work Plan and reporting.

The MPEP GCC includes the Executive Directors of each Coalition, a grower/member of each Coalition's Board of Directors, and an alternate for each member of the respective Board of Directors (**Table 1**). Parry Klassen (ESJWQC) serves as Chair and Joe McGahan (WSJRWC) is the Vice Chair.

Table 2. MPEP GCC members. The Chair and Vice Chair are also voting members of the MPEP GCC.

Name	Coalition	MPEP GCC Responsibility
Parry Klassen	ESJWQC	Chair MPEP GCC
Bill Brush	ESJWQC	Voting Member
Alan Reynolds	ESJWQC	Alternate
Michael Wackman	SJCDWQC	Voting Member
John Herrick	SJCDWQC	Voting Member
Diego Olagaray	SJCDWQC	Alternate
Joe McGahan	WSJRWC	Vice Chair, MPEP GCC
Dan Roberts	WSJRWC	Voting Member
David Cory	WSJRWC	Alternate
Bruce Houdesheldt	SVWQC	Voting Member
Lester Messina	SVWQC	Voting Member
Kelly Huff	SVWQC	Alternate
Charlotte Gallock	WWQC	Voting Member
Jose Gutierrez	WWQC	Voting Member
Russ Freeman	WWQC	Alternate

The MPEP GCC will approve studies and modeling, and allocate funds for the individual studies. The MPEP GCC has contracted with CURES (Coalition for Urban Rural Environmental Stewardship) to be the Administrative Coordinator to manage the projects and guarantee that work is progressing in a timely manner, and the contractors are within budget. The MPEP GCC has worked with the Technical Advisory

Committee (see below) to develop the MPEP Work Plan; the MPEP Work Plan will guide the development of individual Study Plans. The Study Plans provide the detail about the individual MPEP studies that will be performed by the contractors.

The MPEP GCC will contract with Field Coordinators who will oversee the development of the individual MPEP Study Plans and manage the studies as they are conducted. Nitrogen use is sufficiently different between annual crops and perennial crops that a single expert may not be able to provide the level of expertise that is necessary to develop an acceptable study plan for the specific crops in those categories. However, the decision as to contract with one or two Field Coordinators will be made when qualifications are reviewed.

Technical Advisory Committee

A Technical Advisory Committee (TAC) was formed to provide the expertise from multiple disciplines that the range of crops and studies is expected to demand. The TAC has met with the MPEP GCC multiple times to receive input on the development of the Work Plan. The TAC will work with the MPEP GCC to develop the individual MPEP Study Plans. These technical experts are drawn from California Department of Food and Agriculture, University of California faculty, University of California Cooperative Extension, the International Plant Nutrition Institute, consulting companies, and commodity groups.

The TAC is made up of the following individuals:

- Dr. Patrick Brown, UC Davis Department of Plant Sciences
- Dan Munk, UCCE Farm Advisor
- Allan Fulton, UCCE Irrigation and Water Resources Advisor
- Dr. Doug Parker, Director, California Institute for Water Resources, UC Division of Agriculture and Natural Resources
- Dr. Rob Mikkelsen, International Plant Nutrition Institute
- Dr. Tim Hartz, UCCE Vegetable Crops Specialist, Department of Vegetable Crops
- Dr. Lowell Zelinski, Precision Ag Consulting
- Dr. Gabriele Ludwig, Almond Board of California
- Charles Rivara, California Tomato Research Institute
- Mark Cady, CA Department of Food and Agriculture
- Dr. Barzin Moradi, CA Department of Food and Agriculture
- Vicki Kretsinger Grabert, Luhdorff and Scalmanini Consulting Engineers

All study designs will be reviewed by the TAC and modified as necessary in response to comments. Once the design described in the Study Plan is approved by the TAC, it will be submitted to the Regional Water Board for review.

Administrative Coordinator

The MPEP GCC has contracted with the Coalition for Urban Rural Environmental Stewardship (CURES) to serve as MPEP Administrative Coordinator. CURES is performing the administrative functions for the program such as managing funding development, creating Scope of Work documents, managing the selection process for the Field Coordinators, working with the Field Coordinators to select contractors

for individual studies, working with contractors to develop budgets and contracts, and tracking study progress.

Technical Consultant and Crop Specific Grower Liaison

The MPEP GCC is releasing a Request for Qualifications (RFQ) for Consultant(s) to act as Technical Coordinator and Grower Liaisons who will work together with the MPEP GCC to develop and implement study designs. To allow for flexibility, the MPEP GCC is requesting Statement of Qualifications (SOQs) for both the Technical Consultant and Field Liaison and the MPEP Consultant which should include the following minimum qualifications:

MPEP Technical Consultant

Role: Develop the crop specific Study Plan in collaboration with the Grower Liaison, MPEP TAC and MPEP GCC. Once the Study Plan is approved, the MPEP Technical Consultant will implement the Study Plan including the collection and analysis of samples according to the MPEP QAPP, analysis of results, graphical and tabular representation of data, study implementation progress reports and final study design write up.

Grower Liaison

Role: Assist with Study Plan development and works closely with the cooperating grower and the grower's agronomist or Certified Crop Advisor (CCA) to ensure that the study plan implementation is coordinated with existing growing practices and field activities of the grower cooperator. The Grower Liaison will assist the MPEP Technical Consultant in documenting fertilizer and irrigation applications and acts a liaison between the MPEP Technical Consultant who is implementing the study design and the grower.

When the MPEP GCC contracts with the Technical Consultant and Grower Liaison for crop specific study designs, the MPEP GCC will provide the Regional Water Board with their names and qualifications.

Regional Water Board Review

Prior to initiating any field studies, the location of the study (including but not limited to hydrogeologic setting, relevance to high vulnerability areas, etc.), crop(s) involved, management practice(s) evaluated, and final study design will be provided to the Regional Water Board for comment. After Regional Water Board comments are received, the final design will be revised as necessary and provided to the MPEP GCC for final approval and funding. Studies will be conducted in high vulnerability areas or areas that have been proposed as high vulnerability but not yet approved by the Regional Water Board.

Timeline – Contracting and Study Plan Development

The MPEP Grower Liaisons and Technical Consultant contracted to develop the individual study plans should be identified and under contract by mid-August. At that time, they will initiate the development of the first study plans. The Field Coordinators and Contractors will work with the MPEP GCC to identify the initial crops (currently proposed to be almonds or walnuts, grapes, tomatoes or corn), management practices, locations, and cooperators for the studies. The first study plans will be developed by

November 30, 2016 and provided to the Regional Water Board for review. The initial studies will be initiated as soon as the study plans are approved.

MPEP Study Design – Conceptual Approach

The objectives of the MPEP program are to determine if management practices implemented by members are protective of groundwater (Order R5-2012-0116-R2, Attachment B, Section IV.B). The primary constituent of concern for the MPEP studies is nitrate.

Specifically, the objectives of the MPEP stated in each of the Coalition's Orders are:

1) Identify whether site-specific and/or commodity-specific management practices are protective of groundwater quality within high vulnerability areas.
2) Determine if commonly implemented management practices are improving or may result in improving groundwater quality.
3) Develop an estimate of the effect of Member's discharge of constituents of concern on groundwater quality in high vulnerability areas. A mass balance and conceptual model of the transport, storage, and degradation/chemical transformation mechanisms for the constituents of concern or equivalent method approved by the Executive Officer, must be provided.
4) Utilize the results of evaluated management practices to determine whether practices implemented at represented Member farms (i.e., those not specifically evaluated, but having similar site conditions), need to be improved.

To address these four objectives, the MPEP will be implemented in four phases that overlap in time: Phase 1, develop information about management practices already demonstrated to be protective of groundwater in some agricultural settings (Objective 1); Phase 2, initiate field studies on the amount of N moving past the root zone under different management practices (Objective 1); Phase 3, modeling of leaching on N past the root zone on the field scale (Objectives 2, 3, and 4); and Phase 4, estimate the amount of N leaching at a larger scale (Objectives 2 and 4).

Constituent of Concern

Nitrate is the COC in the MPEP. It is the single constituent listed by all five Coalitions in their Groundwater Assessment Reports as a COC. Although detections of pesticides occur in wells in all Coalition regions, the concentrations are low relative to MCLs and many are legacy pesticides that are not applied currently. Consequently, studying management practices to prevent leaching of legacy pesticides is nonsensical. For the current use pesticides that have been detected in groundwater, the detections are sufficiently isolated that these chemicals do not rise to the level needed to trigger field studies or modeling.

MPEP Deliverables

The MPEP will generate numerous deliverables during its existence which are summarized in Table 3 below. The specific deliverables from each of the four phases are discussed in the descriptions of each phases below (also summarized in Table 3 below). The MPEP GCC general deliverables include Annual

Reports to the MPEP GCC Coalitions and the Regional Water Board, and the Final MPEP Report at the six-year deadline. These are described below.

Table 3. List of deliverables.

Deliverable to the Regional Board	Deliverable Date	Who
Literature Review	November 1, 2016	MPEP GCC
Joint MPEP Annual Progress Report	May[1] 2016, annually	MPEP GCC
MPEP Field Studies Final Reports	Upon completion of each study	MPEP GCC
Management Practice Evaluation Report	May 2023, every 6 years	MPEP GCC

[1]The Westside Coalition will submit their reports in their November semi-annual report.

MPEP Annual Progress Report

Each year, the MPEP GCC will provide an annual report to each of the member organizations and the Regional Water Board based on study progress reports provided by the MPEP Contractors. This report will outline progress to date and the planned activities for the upcoming year including studies that will be completed, new studies to be initiated, and an update of the work documenting the efficacy of management practices in preventing the leaching of nitrate to groundwater. Specific information in the MPEP Annual Progress Report will include:

- All data (including analytical reports)
- Tabulated summary of data collected to the date of the report
- Summary of activities conducted under the MPEP
- The number and location of monitoring wells relative to each other (if applicable) and other types of monitoring devices
- Evaluation of the impact on groundwater by activities at the farm operation being monitored
- An assessment of whether the specific phases are on schedule

The MPEP Annual Progress Report will be provided to each MPEP Coalition in time to allow them to insert the report in their own Annual Report by reference or in its entirety.

The MPEP is undertaking an endeavor never before done by either the University or private industry in California, other states in the U.S. or Europe. To be sure, it will be an iterative, evolving process. Because there is still so much to learn about practices that can prevent leaching of nitrate to groundwater under the various cropping systems found in the MPEP GCC Coalition region, new knowledge will be generated every year with each field study and each modeling run. Consequently, at this point it is not clear what is the most appropriate study or modeling effort to conduct during the life of the MPEP. As each study and each modeling run are completed, it is expected that the MPEP GCC will better understand which crops, practices, and climatic conditions will be appropriate for the next study. As described below, it is not possible to conduct field studies on all combinations of soils, crops, fertilizer and irrigation management practices that are the focus of the MPEP. And, it is not possible at this time to select the subset of combinations (see **Table 4** below) for inclusion in field studies that will allow the MPEP GCC to optimize limited resources and also provide the most and best information to its members on protective practices. For some combinations of management practices, the literature review may

lead to the conclusion that it is not necessary to perform field studies to further document that they are protective of groundwater.

In each year's Annual Progress Report, the MPEP GCC will provide to its member Coalitions and the Regional Water Board the planned activities in the upcoming year for each of the phases described below. It will also include the anticipated activities in the following year for each of the phases to allow the member Coalitions and the Regional Water Board to evaluate their options and discuss the progress of the MPEP. The set of anticipated activities for the next year provides all parties with an opportunity to discuss and modify the field studies or the focus of modeling runs without delaying the current year's activities. The MPEP Annual Progress Report will be provided to the MPEP GCC by April 25th of each year to be included in the Coalition's Annual Report (or Semi-Annual Reports of the Westside San Joaquin River Water Quality Coalition) to be submitted to the Regional Water Board by May 1 of each year. The Westside San Joaquin River Watershed Coalition will submit its report in November of each year.

MPEP GCC Final Report – Management Practice Evaluation Report

After the first six years of the MPEP, the GCC will provide an evaluation of the knowledge gained and determine the next steps that need to be accomplished to meet the objectives outlined above. Included in the Management Practice Evaluation Report will be:

- List of management practices evaluated through field studies or modeling in the MPEP that are protective of groundwater. The evaluation will include a discussion of the range of conditions under which a determination of protective can be made. The assessment of the range of conditions will be accompanied by the degree of certainty of the assessment.
- Evaluation of the conditions under which each management practice evaluated by the MPEP GCC is considered protective of groundwater.
- Discussion of where in the MPEP GCC Coalition region each of the management practices can be recommended to growers as protective of groundwater.
- Technical justification for all evaluations and conclusions.

Although the evaluation of management practices is not required until the end of six years (May 2023), several field studies and numerous modeling studies will be completed prior to the issuance of the Management Practice Evaluation Report. The results of the studies and modeling runs will be shared in each MPEP Annual Progress Report (to be submitted to the Regional Water Board as a component of each Coalition's Annual Report) and, if appropriate, the information will be provided to members of each MPEP GCC Coalition. Information transmitted to coalition members may be an assessment of the degree to which the evaluated practice(s) are protective and the conditions under which the conclusions are valid. Each Coalition may conduct their outreach and education to their members differently but will keep their members informed and updated on MPEP activities in relation to GQTMP results and NMP Summary Analysis results as they become available.

Conclusion of MPEP activities

The MPEP GCC intends to evaluate whether a combination of irrigation and fertilizer application practices are protective of groundwater on a selected number of crops. Although the number of crops is

limited, the evaluation is to be conducted on the top five crops in the in high vulnerability areas of the Coalitions which includes 90% of the irrigated acreage in the HVAs of the MPEP GCC Coalitions. However, there are more than 100 additional crops grown in HVAs and an additional 50 – 100 crops grown across the entirety of the MPEP GCC region. It is not possible to perform field studies on these minor acreage crops. There is neither adequate time nor sufficient funding to evaluate all practices across all crops and all soils by either field studies or modeling. The two key questions are:

1. When will the MPEP GCC Work Plan be complete?
2. How can the Coalitions recommend protective practices to members who grow minor crops that are not studied under the MPEP?

Conclusion of field studies and field-specific modeling

The MPEP GCC will cease field studies and modeling when management practices protective of groundwater can be encouraged for implementation on 90% of the HVA acreage across the entire region covered by the MPEP GCC Coalitions. The management practices can be identified through field studies, modeling, or existing literature. Technical justification and the level of certainty accompanying the justification will be available to support the endorsements and can be provided to members if they request it. Because the conclusions and technical justification will have been provided to the Regional Water Board in each year's Annual Report, no additional discussion will be necessary before the practices are presented to growers as effective in protecting groundwater. The MPEP GCC does not believe that is possible to specify a time period to accomplish the completion of the field studies and modeling. As field and modeling studies are completed, the MPEP GCC and the Regional Water Board will develop a better understanding of when the Work Plan will be completed.

Remaining 10% of irrigated acreage

The studies and modeling involve a variety of irrigation practices, fertilizer application approaches, and soils that are common across all of the Coalition's HVAs. The results of the studies depend to some extent on the specific crop, the pattern and density of roots in the root zone, the depth of the root zone, the crop nitrogen demand, and ET_c. However, there will be sufficient similarities between those crops studied and modeled during the MPEP process and the minor crops grown across the Coalition's region to allow the MPEP GCC to encourage the adoption of specific management practices for those minor crops. Prior to the endorsement of the management practices, the MPEP GCC will engage the field coordinators and the MPEP TAC to assist the MPEP GCC in establishing the similarities between the crops studied and the other crops in the MPEP GCC Coalition region. If necessary, Hydrus modeling will be used to confirm the applicability of the results of the original MPEP studies to the remaining crops. Once these similarities are established, the MPEP GCC will encourage the implementation of management practices by growers of minor crops.

The discussion of each phase of the MPEP process is provided below.

Phase I – Inventory of effective management practices

There are two purposes for conducting an inventory of management practices by reviewing the relevant literature. First, if reliable information is available to conclude that a practice(s) is effective in

preventing leaching of nitrogen under a specific set of conditions, that information can be provided to growers immediately. The extent of existing implementation of that practice can also be documented. Second, the information known about the ability of various management practices to protect groundwater quality will help guide the development of the latter MPEP studies and the modeling.

There have been a large number of studies on nitrogen use efficiency (NUE defined as the amount of nitrogen used by the crop relative to the amount applied) in a variety of crops. A majority of these studies have been performed to guide the development of fertilizer application rates. For example, the CDFA FREP has developed a website that provides fertilization guidelines for 17 crops based on NUE studies. What is unclear from the large majority of these studies is the eventual fate of nitrogen fertilizer that is not utilized by the crop. There are several potential losses of nitrogen including leaching to groundwater, direct volatilization, and denitrification. Although the NUE of a crop may be known, very little is known about the amount of nitrate leaching to groundwater.

Some studies have been performed that evaluate the efficacy of management practices specifically with respect to the amount of nitrogen leaching through the vadose zone to groundwater. For example, Baram et al. (2016) measured the amount of nitrate leaching past the root zone in pistachio and almond orchards under three sets of management practices (see Figure 3 below). However, this type of study is uncommon in the published literature.

The MPEP GCC has already initiated the compilation of practices that have been demonstrated to be effective, or have the potential to reduce the amount of nitrogen leaching to groundwater. This review of the literature will be complete by November 1, 2016. The practices identified during the literature review may not be possible to extend to every field as not all practices are equally effective in all locations, soil types, or crops. Consequently, the evaluation of practices will consist of the list of management practices, the state of the knowledge about their effectiveness in reducing leaching, caveats (e.g. not effective on sandy or clay soils), and degree of uncertainty about their efficiency in preventing leaching of nitrate. As the MPEP continues over time and the results of new studies are published, the MPEP GCC will augment the list of effective practices obtained through periodic literature reviews.

The information obtained during the review of management practices and their potential to reduce leaching of nitrate provides the foundation for the later field studies and, more importantly, the modeling. Because time and the amount of funding available are extremely limited relative to the potential number of management practices that can be evaluated, modeling is expected to be the method by which the effectiveness of practices under conditions found in the MPEP GCC region is validated. Many of the practices identified to date have been studied in locations outside the Central Valley of California. Consequently, it is not clear if their efficacy in reducing leaching of nitrate below the root zone is similar under the soil and climatic conditions found in the MPEP region. The MPEP GCC believes that it may not be justified to use these practices in full field studies, but may collect limited field data and use modeling to verify that the practice(s) is effective in reducing leaching. However, the MPEP GCC may believe that a full field study is justified based on the data presented in the literature.

The practices and relevant information will be obtained from the published literature, and gray literature (e.g. university extension bulletins or farm trade publications). The first review will be of the

studies on nitrogen use efficiency used to develop fertilization guidelines posted on the CDFA FREP website. Dr. Daniel Geisseler, a Cooperative Extension Specialist at UC Davis, is completing the development of other nitrogen removed coefficients that will be used to calculate the amount of nitrogen removed at harvest for numerous crops. The literature used for that work will be reviewed for information on management practices and their relative efficacy in preventing leaching of nitrate to groundwater. If necessary, additional practices will be identified and information on their efficacy accumulated by searching the peer reviewed and gray literature. Discussions with experts on the MPEP TAC will also be used to verify the information from the literature, and complete the review.

Phase I Deliverable

The MPEP GCC will develop an annotated list of studies and management practices that are identified during the literature review. The list will provide a suite of practices from which growers can choose to implement on their farming operation. In addition to the annotated list, the MPEP GCC will provide a short report with an evaluation of the efficacy of the management practices and future efforts, if any, needed to fully evaluate the efficacy of the practices under the conditions found in the five MPEP GCC Coalition regions. The evaluation of each study will include but is not necessarily limited to:

- Crop/commodity
- Nitrogen application information (type, timing, rate, location)
- Irrigation method, timing, and rate
- Study location
- Study year
- Study duration
- Study conditions
- Evaluation method used in the study (e.g., modeling, soil cores, lysimeters, groundwater monitoring)
- Conclusions
- Applicability to MPEP GCC Coalition region

An initial list of studies evaluated during the literature review and the literature sources that will be searched for additional studies are provided in **Appendix A**. The full review will be available to the Regional Water Board and will be used by the MPEP GCC member Coalitions in their outreach to members on groundwater protection.

Phase II - Field Studies

Location/Cooperator Identification

The Coalitions in the joint MPEP program have identified the groundwater high vulnerability areas within their boundaries (some designations are still being reviewed by the Regional Water Board). Each Coalition's high vulnerability areas have crops and general soil types in common which means that studies can be coordinated and conducted at several locations in the Valley and be applicable in several areas within the MPEP GCC region.

The MPEP GCC has identified several locations in which the first studies could be performed. The representatives from the five Coalitions are gathering information to determine if the locations are suitable for study. The initial locations and crops under consideration include processing tomatoes in the Westlands Water Quality Coalition, corn in the Sacramento Valley Water Quality Coalition, walnuts in the East San Joaquin Water Quality Coalition, and grapes in the San Joaquin County and Delta Water Quality Coalition region. The information being obtained to make a decision about the studies include:

- Depth to groundwater and availability of wells in the immediate vicinity of the field to sample
- Management practices used by the grower
- Irrigation system
- Soil type
- Fertilizer application timing, method, and rate (in general)

Figure 3 is a conceptual diagram of how these three factors will be evaluated when prioritizing study designs.

Figure 3. Conceptual diagram of the relationship between priority locations, crops and management practices that will be evaluated when deciding on study designs to prioritize.

The MPEP GCC will provide the locations of the field studies in the first two study plans to be submitted to the Regional Water Board by November 30, 2016. Once the location of the first two studies are selected, the MPEP GCC will immediately start identifying the location of the second set of MPEP studies. Although the information developed during the literature review is expected to be used as a guide for modeling, it is possible that the information available about a specific set of management practices may lead to a field study. For example, information from the literature review may indicate that a particular practice is effective in reducing leaching in sandy soils. However, its performance in clayey soils may not be well understood and modeling may not be sufficient to provide the confidence to the MPEP GCC to encourage growers to adopt the practices. Therefore, the Coalitions may want to

conduct a field study of the practice in a clayey soil prior to encouraging members to adopt the practice. It is anticipated that the field studies will extend across the range of conditions in the MPEP GCC area (**Table 4**). However, because of the cost of performing field studies, the Coalitions will rely heavily on the use of modeling (see Phase III below) to extend the results of the field studies to the site-specific conditions in each Coalition region. Data from the field studies will be used to parameterize the models for the evaluation of management practices through modeling.

Table 4. Potential factors to be used to develop specific studies.

Potential stratification of MPEP studies
Soil Type
Clay
Loam
Sand
Crops
Almonds
Walnuts
Processing tomatoes
Premium wine grapes
Silage corn
Irrigation methods
Flood
Furrow
Pressurized
Fertilizer applications
Broadcast
Side dress
Fertigation – Low Frequency
Fertigation – High Frequency
Pump & Fertilize

Conceptual Study Design

Each MPEP field study will require a detailed study plan that will be provided to the Regional Water Board prior to the initiation of the study. In each study plan, the location of each study will be provided along with the details of the study design such as plot size, equipment used to sample for nitrate, and frequency of sampling. All samples will be collected and processed according to the MPEP Quality Assurance Project Plan (QAPP) submitted in June 2016. The rationale behind the study design and the conceptual design are provided below.

To determine if management practices are protective of groundwater, the processes that determine the comparative availability of nitrate for leaching should be measured under site-specific conditions. Nitrate is soluble and moves where water moves. Consequently, if water moves past the root zone and nitrate is present in the water, that water could eventually leach the nitrate to groundwater. Mechanisms that minimize the movement of water and nitrate past the root zone include

reducing/eliminating excess applied water that is not captured by roots, or increasing the conversion of the nitrate to a form of N (e.g. organic N) that is retained in the root zone (immobilization) or lost as N2 gas (denitrification). Conversely, conditions that prevent the conversion of a non-nitrate form of N to nitrate (nitrification) also reduce the potential for leaching.

Measurements of leaching can be done using a combination of soil cores (shallow and deep), pore water samplers, and moisture sensors to measure the mobile pool of N (pore water), total N (soil cores), and the flux of water moving past the root zone (tensiometers and water content sensors). These methods generate the data that can be used to compare different management practices to evaluate which is most effective in preventing leaching of nitrate to groundwater (see example **Figure 2** below, which is Figure 7 from Baram et al. (2016)). Baram et al. (2016) made the significant conclusion that although the amount of variability in the soil profile is significant, it is possible to successfully characterize the amount of nitrate moving past the root zone by using the mean concentration of nitrate in suction lysimeters and soil cores. This conclusion allows the MPEP GCC to move forward with studies at a reasonable cost.

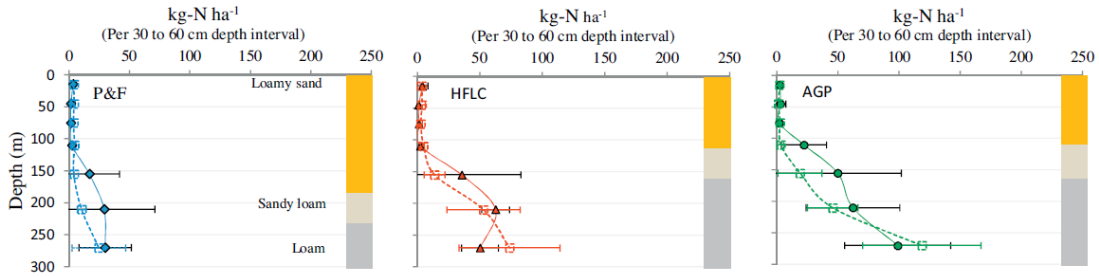

Fig. 7. Nitrogen quantities (Kg-N ha^{-1}) in the soil profile under the almond orchard in Madera at February 2014 (full symbols) and February 2015 (hollow symbols). All the values were normalized to the water content and represent integration of 30–50 cm intervals. The left panel represents sampling sites under the P&F treatment, the middle panel represents locations under the HFLC treatment and the right panel represents locations under the AGP treatment. The lithological profile at each site is presented at the right side of each panel.

Figure 4. Comparison of the amount of N in the soil profile in fields with three different management practices. Taken from Baram et al. (2016). P&F refers to Pump & Fertilize, HFLC is High Frequency Low N Application rates, and AGP is Advanced Grower Practice which consists of standard N applications without counting the contribution of NO3 in irrigation water.

The MPEP studies will measure parameters that allow empirical estimates of leaching and a crude mass balance of the nitrogen in the system. To estimate mass loading of nitrogen to groundwater, it is necessary to measure the concentration of nitrate in the leachate, and the volume of water moving past the root zone. Recognizing that nitrate that is not taken up by a crop is not all lost to groundwater, the field studies may measure any of the following:

- Mobile pool of N
- Immobile pool of N
- Flux of N
- Flux of water
- Confirm with well monitoring the concentration of nitrate in groundwater when feasible (shallow groundwater and permeable soils)

Measurement techniques and parameters may include any or all of the following:

- Lysimeters for pore water and mobile fraction of nitrogen (e.g. suction, capillary lysimeters)
- Soil cores for soil texture, total N, soil moisture, carbon content
- Tensiometers for H_2O flux
- Soil moisture probes for soil moisture content
- Neutron probes for H_2O flux
- Use of harvested material or permanent tissue for N removed from the field and sequestered in woody tissue (if appropriate)
- Soil nitrogen, organic and inorganic
- Irrigation water for NO_3 concentration
- Manure for N concentration

The specific measurements and the methodology used in each study will be a function of the conditions at the specific field site including the crop, soil, and irrigation practice(s). Each study will require a site-specific study plan that will be submitted to the Regional Water Board along with any study-specific QAPP modifications prior to initiating each study.

Management Practices

There is a wide range of management practices used by members on their farming operations. Coalition outreach efforts to date have focused on using nitrogen fertilizer according to the "four R's" developed by the International Plant Nutrition Institute (IPNI); right place, right time, right rate, and right source. This framework for practices resonates with growers making adoption of new practices a relatively straightforward process. Consequently, outreach efforts in the future will continue to focus on the four R's. Superimposed on these fertilizer management practices are irrigation management practices that are often important in preventing nitrate from being moved below the root zone. Several practices are reasonably assumed to be more protective of groundwater in many high vulnerability areas including for example, split applications of fertilizer timed to crop demand or consumption, accounting for nitrate in groundwater (if used as a source of irrigation water), injecting low concentrations of liquid nitrogen fertilizer into drip or microsprinkler irrigations at times that match important plant growth stages.

The MPEP GCC will focus initially on those practices assumed to be most protective of groundwater, i.e. practices that reduce or prevent the movement of nitrate past the root zone. If necessary, comparisons among practices can be made although these comparisons are difficult because of the differences between fields that can compromise the interpretation of the results. However, in separate studies for example, single applications of fertilizer and flood irrigation can be compared to split applications. Or, split applications can be modeled using parameters developed using field studies. These comparisons are potential studies in Phase II of the MPEP. The selection of management practices involved in the studies will be determined based in part on the literature review conducted in Phase I, and what are considered by a particular crop industry (commercial growers, commodity group, University specialists, agronomists working on that crop) to be the optimal practices currently used by growers to produce that crop. The final selection will be made by the MPEP GCC. The specific practices to be evaluated in a study will be provided to the Regional Water Board in the individual Study Plan(s).

The management practices that are proposed for evaluation may include:

- Maximization of irrigation efficiency (e.g. use of crop ET for irrigation scheduling) where applicable and based on the crop and conditions, low pressure micro irrigation systems or efficient surface water management practices.
- Split/multiple nitrogen fertilizer applications throughout the growing season based on the crop nitrogen consumption curve.
- Consideration/utilization of nitrate in irrigation water (if test site has nitrate in supply water).
- In season tissue/petiole testing to determine if an in season nitrogen application is necessary.
- Adjusting N rates based on expected crop yield.
- Proper P and K rates based on soil/crop needs.
- Other practices that may improve the efficiency of nitrogen applications or crop utilization of nitrogen (crop dependent).

Study Design

A full and detailed study design will be prepared for each study conducted. The design will follow the general design provided below. The Field Coordinators will work with the Technical Consultants to ensure that the specific designs contain the elements discussed below and if not, ensure that there is adequate justification for any deviation and alternative methods/samples collected to allow an adequate evaluation of the efficacy of the target management practices.

After the general location and crop/management practice(s) for a study have been selected, individual fields will be identified as specific sites for the study. Each field will likely be sampled in the winter following adequate rain to saturate soils and throughout two irrigation seasons. In some locations, winter rains occur infrequently and at least one mid-winter irrigation event on perennial crops generally occurs. If this is the case, sampling will be conducted after the winter irrigation event(s). Sampling protocols (i.e. frequency, timing) will be adjusted as necessary to meet the objectives of each study which will be crop, management practice and location specific.

Samples can be collected from the soil, soil pore water, irrigation water, and crop tissue (total leaf N) as appropriate for the specific study. The critical N pools are nitrate inputs in irrigation water, fertilizer, and manure and/or compost (if applied by the grower cooperator). Other essential plant nutrient elements may be measured, based upon specific conditions. Knowledge of overall crop nutrition status can reveal correlative features with regard to nitrogen assimilation.

Groundwater monitoring wells may be utilized to evaluate impacts on groundwater. However, the use of wells will be determined in each Study Plan and will be based on conditions such as depth to groundwater and soil conditions. The relatively short duration of the field studies, two to three years, does not allow for the impact of management practices to be identified when groundwater is relatively deep. Although high vulnerability ground in the Coalition's regions are often found in areas with high infiltration rates and shallow groundwater, those terms are relative and it could take several years for the water applied at the surface to reach groundwater. At the locations selected for the individual studies, it is possible that the transit time and paths from nitrogen application to nitrate entering groundwater would not result in useful information being obtained from groundwater monitoring. Conversely, studies conducted in locations where applications on the surface are expected to reach

groundwater within a single year or growing season suggests that samples collected from shallow wells could provide useful data on the change in groundwater quality. Each study will consider the potential for groundwater monitoring to yield useful information and a decision will be made about the installation of monitoring wells on a case by case basis.

Information collected for each study will include as appropriate, the date and amount of irrigation water applied, tissue N content at date of fertilization (if available), date of fertilizer application, method of application, amount and type of fertilizer applied, amount of nitrate in irrigation water (if any), any compost/manure applied, concentration of nitrate in soil pore water, concentration of nitrate in the soil, organic carbon content of the soil, and soil moisture. Data on nitrogen removed at harvest, N removed in the pruning's that are removed from the field (in the case of perennial crops), and the incremental incorporation of N into perennial tissues (when appropriate) will be collected (**Table 5**).

Table 5. Critical processes and pools of nitrogen.

Process	Measurements	Medium and method
Monitor Constituent (nitrate) concentration in soil water	NO_3 applied (fertilizers and irrigation water), concentration of NO_3 in soil, within root zone; concentration of NO_3 in leachate water below the root zone.	Soil solution above and below the root zone (suction lysimeters at selected depths)
Immobilization/Mineralization Assessment	Organic carbon, NO_3, NH_4 TKN soil, Total Nitrogen, TOC, %O.M.	Soil (cores) at selected soil profile depths.
Nitrification/denitrification	NH_4, NO_3, NO_2	Leachate (suction lysimeter)
N removed/sequestered	Organic N	Tissue analysis

Phase III – Modeling of N Dynamics at the Field Level

The MPEP field studies will have a focus on vadose zone process. Groundwater will be monitored in studies where monitoring is expected to result in meaningful information, i.e. shallow groundwater with a short transit time from the surface to first encountered groundwater. The studies use field measurements to estimate nitrate leaching past the root zone and nitrogen removed from the field at harvest. Modeling will be used to address two of the objectives of the MPEP program; (Objective 2) determine if commonly implemented management practices are improving or may result in improving groundwater quality, and (Objective 3) develop an estimate of the effect of Member's discharge of constituents of concern on groundwater quality in high vulnerability areas.

Even though groundwater monitoring wells may be used to monitor groundwater quality, it is unlikely that groundwater monitoring will yield sufficient information to successfully address Objectives 2 and 3 in a reasonable timeframe. Studies of the vadose zone similarly will not yield sufficient information to address Objectives 2 and 3. Because the field studies are unable to generate the data needed to address these objectives, the MPEP GCC will employ modeling to make an estimate of the discharge of

nitrate to groundwater. Where appropriate, field studies and groundwater monitoring will be used to validate the model results.

Once a field study is generating data, a model of processes in the vadose zone will be parameterized and run for the field site at which the study is being conducted. The model that the Coalitions intends to use to evaluate leaching in a single field is the 1-dimensional version of Hydrus which can be used to model the movement of water and solutes in the unsaturated and saturated zones. The 1-dimensional aspect indicates that movement is tracked vertically in the soil column. Hydrus 1D is used to estimate mass flow of water past the root zone, while account for NO_3 transport, exchange dynamics, diffusion, and nitrification of ammonia fertilizers, and root water uptake (passive). The model inputs include volumetric water content at two depths measured on a time step of an hour or less, irrigation water volume, placement and timing of water and fertilizer, fertilizer form, CIMIS weather data for the surface boundary conditions, and FREP water and nutrient root uptake timing (assumed to be distributed evenly around the trunk of each tree in a cylinder). Model outputs will include soil water content, nitrate concentration and water flux and leaching below the active root zone. Model outputs will be verified with continued soil water content monitoring as well as with access tube sampling of pore water for nitrate analysis. An Excel file of Hydrus inputs and outputs can be provided upon request.

The Hydrus model will be calibrated for the field sites used for the field studies. Once the model is parameterized for the study site, the parameters can be modified to reflect changes in management practices. Hydrus contains a large number of parameters that can be adjusted to reflect changes in management practices such as application rate of nitrate, application timing (e.g. at the middle or end of the irrigation event), type of nitrogen applied, irrigation method, and irrigation rate. Any or all of these factors can be changed in different model runs to evaluate their impact on the amount of nitrate reaching groundwater. If the physics of the system are represented correctly, adjusting many of the input parameters (management practices) requires no additional calibration (e.g. changing timing of applications).

Hydrus is one of the best tools available to investigate a large range of management practices that may not be possible to study in the field due to resource constraints. Modeling can greatly speed the evaluation of management practices as model runs can be performed over a few weeks compared to a 2 or 3-year period needed to perform a field study. Demonstrating the efficacy of management practices relative to other practices is the one of the key objectives of Hydrus modeling. Although it may not be possible to absolutely accurately estimate the amount of nitrate leaching past the root zone, if the relative amount of leaching under a variety of management practices can be estimated, outreach to growers can be initiated much sooner with solid recommendations about which practices are more protective of groundwater under the conditions modeled.

Phase IV – Landscape Level Model

Determining if management practices are improving or may result in an improvement in groundwater quality (Objective 2) likely requires extension of the modeling effort to the landscape level. As members across a large area adopt practices that are more protective of groundwater than what they currently

use, there is the anticipation that groundwater quality will improve. However, it is unclear how much improvement can be expected given the range of practices that could be adopted.

The 1D Hydrus model is the best tool to estimate the amount of nitrate reaching groundwater at a specific location, i.e. what is the reduction in nitrate reaching groundwater under an individual field with a change in a management practice. But, 1D Hydrus will not be able to estimate the change in groundwater quality at the scale of the aquifer. This effort requires a model that can be applied at the landscape scale.

The MPEP GCC is currently investigating the use of SWAT (Soil and Water Assessment Tool) as the modeling platform for this effort. The SWAT model may be used by the southern Coalitions in their MPEP work to link management practices implemented on the land surface with groundwater quality. The two MPEP groups are exploring if it is possible to extend the SWAT model to the northern portions of the Central Valley. Hydrus and SWAT share a physical model of water flow, and if this module (Green-Ampt) in SWAT is selected for model runs, field parameters from Hydrus can be incorporated into a larger scale SWAT model. If not, the outputs from the Hydrus model could be used to generate the empirical parameters for SWAT's NRCS Curve Number approach. Alternatively, it may be possible to use Hydrus at the landscape scale using ArcGIS and the 3-dimensional version of Hydrus.

2016 Pilot Study in Walnuts

CURES (the Coalition for Urban Rural Environmental Stewardship) received a grant from CDFA FREP to perform a study to investigate nitrate leaching past the root zone in walnuts. The study was initiated in March 2016 and will be completed in 2018. The design of the study is based on the conceptual model provided above, and the proposal with the design is provided as **Appendix B**. CURES is successfully collecting data and is evaluating practices in two walnut orchards near Ceres, CA. Each of the MPEP GCC Coalitions is contributing financially to the project to expand the scope of the study. This study is viewed as a pilot project for the proposed field studies to be performed for under the MPEP Work Plan. In addition, data collected during the CDFA FREP Walnut study will be stored within the same database design in which data collected from the field studies will be stored.

Integration of MPEP with other WDR elements

The Coalition's General Orders require that both members and Coalitions become involved in several elements related to groundwater quality. These elements are focused on minimizing reduce the amount of nitrogen leaching, documenting that practices are implemented, and monitoring the groundwater to document improved quality.

Member responsibilities:

- Farm Evaluation Plan – grower completion, submit to 3rd Party
- Nitrogen Management Plan (NMP) Worksheet– grower completion, retain on operation
- Nitrogen Management Plan (NMP) Summary Report – grower completion using the NMP Worksheet, submit to 3rd Party

Coalition responsibilities:

- Management Practices Evaluation Program – 3rd Party, submit report to Water Board annually as progress reports and every 6 years as a report
- Groundwater Assessment Report – 3rd Party, submit to Water Board every 5 years
- Groundwater Quality Management Plan – 3rd Party, submit to Water Board, progress report annually
- Groundwater Trend Monitoring Program – 3rd Party, submit to Water Board, report annually

An additional element that has grown out of the nitrogen reporting process is the NMP Technical Advisory Work Group which was tasked with determining the most reasonable grower reporting metric. This metric allows an estimate of the amount of nitrogen removed from the field relative to the amount applied, and therefore is an estimate of the potential amount of N leached to groundwater.

Preliminary analyses conducted by each Coalitions were provided in their Groundwater Assessment Report which identified locations where groundwater is or has the likelihood of being contaminated with nitrate. Management of nitrate in these high vulnerability areas require immediate attention to prevent further degradation of groundwater quality and eventually improve groundwater quality over time. Management of nitrate is accomplished through the implementation of management practices that prevent leaching to groundwater.

Unlike surface water, there are several challenges in the process that prevent immediate implementation of management practices including:

- Practices that are documented to be effective in preventing leaching are not fully vetted and it is difficult to recommend practices to members that are known to be maximally effective under all conditions
- Reasonable metrics that can be evaluated to determine the potential for improved groundwater quality over time have not been developed or are too simplistic to be useful in a regulatory setting

To address these challenges, the Coalitions implemented several interacting programs to facilitate compliance with the requirements of the Orders; these programs include the submission of information on irrigation and nitrogen management practices (FEP) and nitrogen applications (NMP Summary Report), development of appropriate reporting metrics (NMP TAWG), the implementation of effective management practices (GQMP, MPEP), and the monitoring of groundwater quality to document improvements (GTMP); these programs are described briefly below.

Groundwater Quality Management Plan

Each Coalition is required to develop a Groundwater Quality Management Plan (GQMP) which outlines the process that Coalition will follow to improve groundwater quality. The GQMP establishes a set of performance goals and measures that ensure that the management plan can be evaluate its actions to determine if adequate progress is being made toward improving groundwater quality. Implementation

of practices is tracked through Farm Evaluation Plans and Nitrogen Management Plans, and improved water quality is tracked through the Trend Monitoring Program.

Farm Evaluation Plans

Members are provided with a survey that requests information about management practices used on several aspects of their farming operation including erosion control, prevention of discharge of agricultural chemicals to surface water, and practices in place that are understood to minimize the discharge of agricultural chemicals to groundwater (e.g. wellhead protection). The surveys are distributed to all members and are returned to the Coalitions each year.

NMP Technical Advisory Work Group (NMP TAWG)

Metrics must be reported by members to the Coalitions to allow an adequate evaluation of their nitrogen applications, the amount of nitrogen removed from the fields, and the potential risk for leaching nitrate to groundwater. To assist the Coalitions and Regional Water Board with the development of an appropriate metric, a technical advisory workgroup was formed. The NMP TAWG process involved experts from State and Federal government agencies, academia including both UC faculty and UC Cooperative Extension personnel, commodity groups (e.g. tomatoes and almonds), and industry (International Plant Nutrition Institute). The TAWG met numerous times and recommended that growers report the amount of nitrate applied, and the ratio of nitrogen applied to yield. From these two metrics, the Coalitions could calculate the yield from each field. As per requirements from the Regional Water Board, the yield of many crops can be converted to the amount of nitrogen removed by multiplying the yield by a crop conversion constant (converts yield on a per acre basis to the amount of N removed per acre).

MPEP

As indicated above, the efficacy of many management practices in preventing leaching of nitrate to groundwater is not known. The MPEP is the vehicle for evaluating the effectiveness of management practices that can be implemented to protect groundwater (prevent leaching of nitrate past the root zone which will result in improved groundwater quality). To conduct the studies that evaluate the efficacy of management practices, the Coalitions formed a larger group to fund and manage the studies that will document the effectiveness of practices.

Groundwater Trend Monitoring Program (GTMP)

Once management practices are implemented, there is the expectation that groundwater quality will improve. The Groundwater Trend Monitoring Program is the vehicle to document improvements in groundwater quality over time. Each Coalition is developing their individual groundwater monitoring network and monitoring program that will be able to document any improvements in water quality. What is unclear is the time necessary for each Coalition's monitoring program to detect improved groundwater quality. Because the transit time for nitrate applied to the surface may be decades in

many areas, it is expected that improvements may not be immediate. Consequently, it is expected that any improvement in groundwater quality will not be detectable for a significant period of time.

Table 6. Integration of General Order programs

	Farm Evaluation Plan	NMP Worksheet / Summary Report	NMP Summary Report Analysis	NMP TAWG	GAR	GQMP	GTMP	MPEP
Who	*Grower*	*Grower*	*Coalition*	*Coalition / Experts*	*Coalition*	*Coalition*	*Coalition*	*Coalition*
Information on management practices	X	X				X		X
Information on nitrogen applications		X	X					
Determine tool box of "right" practices (right time, right place, right type, right amount)				X				X
Education on practices, new technology, crop uptake information and leaching			X	X		X		X
Determine areas with high nitrates and prioritization of crop / location for outreach					X	X	X	
Impact of practices on crop growth		X	X	X				
Impact of practices on groundwater (field level)						X		X
Impact of practices on groundwater (landscape level)							X	X

Integration

Growers are expected to implement the practices vetted through the MPEP, and report the implementation through the Farm Evaluation Plans. Nitrogen Summary Reports (depending on the practices implemented) provide an estimate of the potential risk to groundwater through the use of the A/R or A/Y metrics. The Coalitions also will report on the implemented practices in their annual reports. Finally, improved groundwater quality is documented through the GTMP monitoring and reporting.

Member Education and Outreach

A summary of the report in lay terms will be developed for release to Coalition members and interested stakeholders. A methodology will be developed to extend the information to Coalition members and encourage the adoption of practices found to increase the protection of groundwater. Each Coalition has developed an approach to outreach and education that meets the needs of their membership including but not limited to large meetings for growers, small meetings, individual outreach, literature development, mailings, and websites. Each Coalition will be able to disseminate to its members the status and results from the studies as they become available.

Timeline and Master Schedule

With the exception of a brief period of time at the beginning and the end of the MPEP, the Phases I, II, and III will be conducted concurrently. Phase IV will be initiated later in the MPEP, at this point it is anticipated that sufficient information will be available to initiate the SWAT modeling in the 5th year. There are several pre-MPEP activities that will take place to allow the MPEP to be initiated as soon as possible after Regional Water Board approval of the Work Plan. The timeline is provided in **Figure 5** and is described below.

Pre-MPEP activities

- Receive SOQs for Field Coordinator(s) and Consultants
- Contract with Field Coordinator(s) and Consultants to design and implement first two MPEP field studies
- Develop cooperator ingress/egress agreement
- Initiate Phase I Literature Review (duration - 2 months)

December 2016 – November 2017

- Development of individual Phase II Study Plans for 4 studies (duration – 0 - 6 months for first two studies, 6 – 12 months for next two studies)
- Phase II studies (Study duration – 24 – 36 months)
- Phase III Hydrus model parameterization and calibration
- Outreach to members on results of literature review, field study plans and potential outcomes of studies
- Progress report in Coalition's Annual Monitoring Reports

December 2017 – November 2018

- Development of individual Phase II Study Plans for 4 studies (duration – 12 - 18 months for first two studies, 18 – 24 months for next two studies)
- Phase II studies (Study duration – 24 – 36 months)
- Phase III Hydrus modeling – evaluation of alternative management practices
- Outreach to members on status and/or results of field studies
- Progress report in Coalition's Annual Monitoring Reports

December 2018 – November 2019

- Development of individual Phase II Study Plans for 4 studies (duration – 24 - 30 months for first two studies, 30 – 36 months for next two studies)
- Completion of first 4 MPEP field studies
- New Phase II studies (Study duration – 24 – 36 months)
- Phase III Hydrus modeling – evaluation of alternative management practices
- Outreach to members on status and/or results of field studies
- Progress report in Coalition's Annual Monitoring Reports

December 2019 – November 2020

- Completion of four MPEP field studies
- Phase III Hydrus modeling – evaluation of alternative management practices
- Outreach to members on status and/or results of field studies
- Progress report in Coalition's Annual Monitoring Reports

December 2020 – November 2021

- Completion of four MPEP field studies
- Phase III Hydrus modeling – evaluation of alternative management practices
- Develop Phase IV landscape model
- Outreach to members on status and/or results of field studies
- Progress report in Coalition's Annual Monitoring Reports

December 2021 – May 2023

- Write Management Practices Evaluation Report
- Phase III Hydrus modeling – evaluation of alternative management practices
- Phase IV landscape model
- Outreach to members on status and/or results of field studies
- Progress report in Coalition's Annual Monitoring Reports

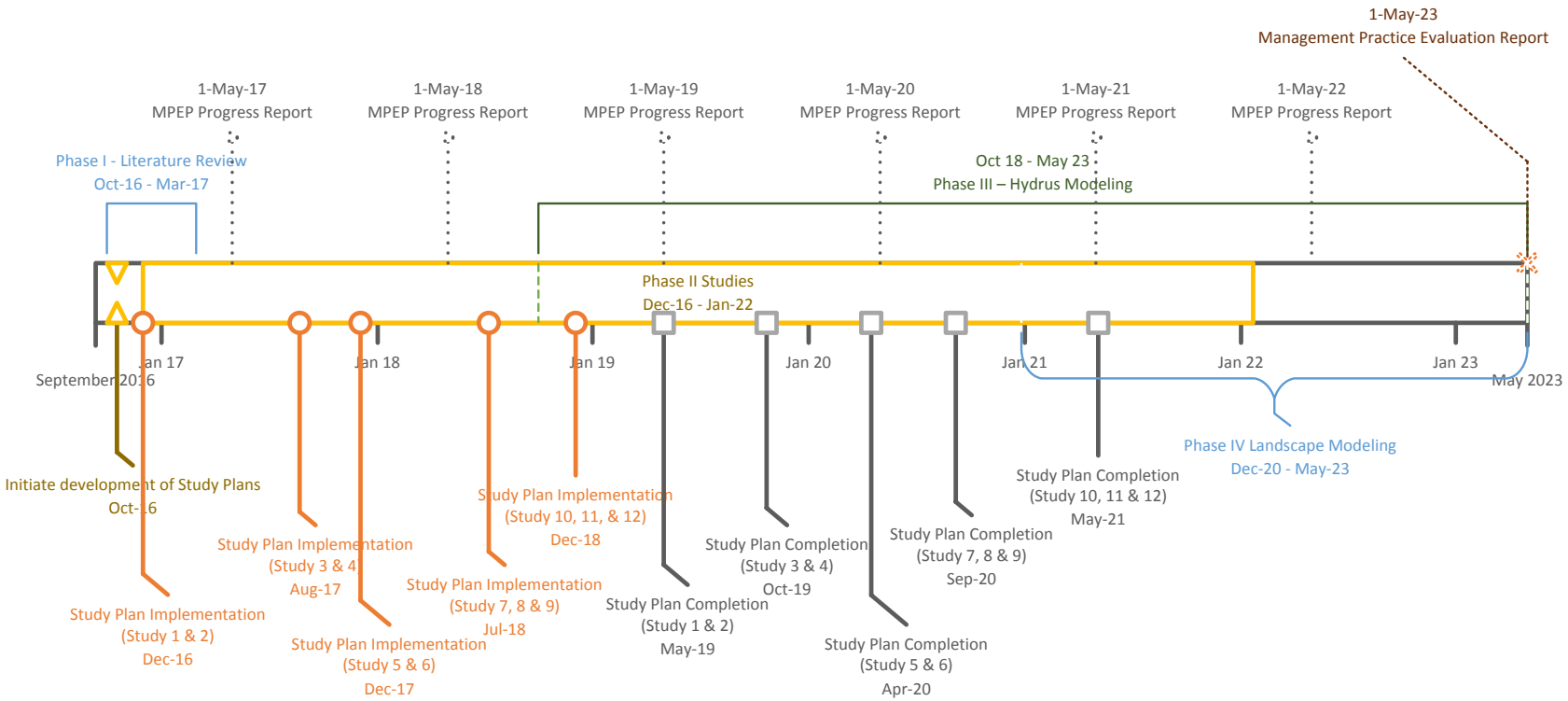

Figure 5. MPEP GCC Work Plan Phase I-IV Timeline and Deliverables for the first six years.

References

Baram, S., V. Couvreur, T. Harter, M. Read, P. H. Brown, J. W. Hopmans, and D. R. Smart. 2016. Assessment of orchard N losses to groundwater with a vadose zone monitoring network. Agricultural Water Management. 172:83-95.

Appendix A

Initial literature reviewed for evaluation of management practices

N management practices that are protective of groundwater

Findings

Baram, S., (2016) – High frequency, low concentration (HFLC) vs. standard split fertigations with and without accounting for N in supply water. (With some flood events, in Pistachio and Almond in CA) Finding: timing during fertigation is most important; HFLC did give significant benefits over well timed split fertigation, and flooding flushed more N down the profile.

Hanson, B., J. Šimůnek, and J. W. Hopmans (2006) Drip tape position (surface vs. subsurface) and injection time (beginning, middle and end) of fertigation with Urea-Ammonium Nitrate (UAN) in California. The surface drip injection was more effective, and injection in the middle was most effective at improving NUE (and protecting groundwater). This paper is entirely about modeling without a groundtruthing component.

Hanson, B., J. W. Hopmans and J. Šimůnek (2008) This paper is about localized leaching of salts around a drip line (which does not require as much water as flood leaching) and no mention is made of the goal of ground water protection.

Li, Gui-Hua, et al. (2011) Coated urea improved N retention in surface and decreased N losses, as compared with uncoated urea in a corn/wheat rotation in China.

Li, Y., et al. (2015) Impacts of direct seeding rice on soil N dynamics, including leaching losses (as compared with transplanting). Maybe not the most relevant in aerobic systems, but talks about redox dynamics and about NH4 retarding N leaching.

Nakamura, K., et al. (2004) Split application reduces N leaching in sand and andisol in Japan. 2 applications was sufficient for andisol, but splitting into 3 applications gave more improvements. Splitting into 6 gave no additional benefits on either soil. This is one of the most ground-truthed and thorough parameterizations of the model that I have yet encountered.

Quin, W., et al. (2016) Split application vs. lumped, wet vs. dry years, irrigation water and nitrogen annual application rates were all considered together with yield, and optimal N, applied in split application, with 80% ET irrigation had best N use efficiency (NUE) without reducing yield. (this is protective of groundwater)

Ravikumar, V., et al. (2011) This paper uses the model to make recommendations of fertigation amount, timing. Sugarcane, india, groundtruthed with tensiometers and root depth and radius throughout season.

Tafteh, A., and A. R. Sepaskhah (2012) Alternate furrow flooding of canola could prevent 50% of leaching losses under canola as compared with all furrow (continuous).

Weng-Zhi, Z., et al. (2013) This is a column experiment (no plants) to calibrate Hydrus, showing that different rates of urea application to the surface followed by different rates of water application

resulted in different distributions of urea, ammonium and nitrate throughout the profile. The researcher concludes that cutting back on water can keep N from leaching, even when applying a high rate of urea.

References

Li, Gui-Hua, Lin-Ping Zhao, Schu-Xiang Zhang, Y. Hosen, K. Yagi (2011) Recovery and leaching of 15N-labeled coated urea in a lysimeter system in the North Chinal Plain. Pedosphere 21(6):763-772.

Li, Y., J. Šimůnek, Z. Zhang, L. Jing, L. Ni (2015) Evaluation of nitrogen balance in a direct-seeded-rice field experiment using Hydrus 1D. Agricultural Water Management 148:213-222.

Nakamura, K., T. Harter, Y. Hirono, H. Horino, and T. Mitsuno (2004) Assessment of root zone nitrogen leaching as affected by irrigation and nutrient management practices. Vadose Zone Journal 3:1353-1366.

Hanson, B., J. Šimůnek, and J. W. Hopmans (2006) Evaluation of urea-ammonium-nitrate fertigation with drip irrigation using numerical modeling. Agricultural Water Management 88:102-113.

Hanson, B., J. W. Hopmans and J. Šimůnek (2008) Leaching with subsurface drip irrigation under saline, shallow groundwater conditions. Vadose Zone Journal 7:810-818.

Quin, W., M. Heinen, F. B. T. Assnck, O. Oenema (2016) Exploring optimal fertigation strategies for orange production using soil-crop modeling. Agriculture, Econsystems and Environment 223:31-40.

Ravikumar, V., G. Vijayakumar, J. Šimůnek, S. Chellamuthu, R. Santhi, K. Appavu (2011) Evaluation of fertigation scheduling for sugarcane using a vadose zone flow and transport model. Agricultural Water Management 98:1431-1440.

Tafteh, A., and A. R. Sepaskhah (2012) Application of HYDRUS-1D model for simulating water and nitrate leaching from continuous and alternate furrow irrigated rapeseed and maize fields. Agricultural Water Management 113:19-29.

Weng-Zhi, Z., H. Jie -shang, W. Jing-wei, X. Chi (2013) Modeling soil salt and nitrogen transport under different fertigation practices with Hydrus-1D. Advance Journal of Food Science and Technology 5:592-599.

Appendix B

CDFA FREP Walnut Study Proposal

Coalition for Urban Rural Environmental Stewardship

PROJECT PLAN / RESEARCH GRANT PROPOSAL

CDFA FERTILIZER RESSEARCH & EDUCATION PROGRAM

A. Cover Page

1. Project Title

Evaluation of the Multiple Benefits of Nitrogen Management Practices in Walnuts

2. Project Leaders

Parry Klassen: Project Director/Principle Investigator (PI), Coalition for Urban Rural Environmental Stewardship (CURES), 1480 Drew Ave. #130, Davis, CA 95618, 559-288-8125, pklassen@unwiredbb.com

Allan Fulton: Co-PI, University of California Cooperative Extension Division of Agriculture and Natural Resources Tehama County, 1754 Walnut St., Red Bluff, CA 96080, 530-527-3101, aefulton@ucanr.edu

3. Project Cooperators

Alan Reynolds: Board Chairman, East San Joaquin Water Quality Coalition, 1201 L Street, Modesto, CA, 209-394-6200, alan.reynolds@ejgallo.com

Joseph McGahan: Executive Director, Westside San Joaquin River Watershed Coalition, 559-582-9237, jmcgahan@summerseng.com

Bruce Houdesheldt: Executive Director, Sacramento Valley Water Quality Coalition, 916-442-8333, bruceh@norcalwater.org

Michael Wackman: Executive Director, San Joaquin County & Delta Water Quality Coalition, 916-684-9359, michaelkw@msn.com

4. Supporters

Parry Klassen: Chair, Management Practices Evaluation Program Group Coordinating Committee (MPEP GCC), 1201 L Street, Modesto, CA, 559-288-8125, pklassen@unwiredbb.com

Doug Parker: Director, California Institute for Water Resources, University of California Agricultural and Natural Resources, 1111 Franklin St., 10th Floor, Oakland, CA 94607, 510-987-9124, doug.parker@ucop.edu

Adam Laputz: Assistant Executive Officer, Central Valley Regional Water Quality Control Board, 11020 Sun Center Drive, #200, Rancho Cordova, CA 95670, 916-464-4726, Adam.Laputz@waterboards.ca.gov

Renee Pinel: President and CEO, Western Plant Health Association, 4460 Duckhorn Drive, Suite A, Sacramento, CA, 95834, 916-574-9744, reneep@healthyplants.org

David Ramos, Ph.D.: Production & Post-Harvest Research Consultant, California Walnut Commission, 101 Parkshore Dr. Ste. 250, Folsom CA 95630, 916-932-7070, deramos@ucdavis.edu

5. CDFA Funding Request Amount/Other Funding

Funding requested from California Department of Food and Agriculture, Fertilizer Research and Education Program: $109,381.20 (2015/2016), $81,362.30 (2017), and $34,250.40 (2018) for a total of **$224,993.90**. Central Valley Irrigated Lands Regulatory Program Third Party Groups (CV Coalitions) have pledged funds for this project however due to the timing of this proposal an exact amount could not be determined at this time. It is anticipated that each Coalition will be able to contribute $5,000 ($5,000 in 2016 and $5,000 in 2017) per year as well as in-kind services in the form of technical review and member outreach. The pledge needs to be confirmed by each respective board of directors in March 2015.

Alan Reynolds: Board Chairman, East San Joaquin Water Quality Coalition, 1201 L Street, Modesto, CA, 209-394-6200, alan.reynolds@ejgallo.com; **ESJWQC Contribution: $10,000**

Joseph McGahan: Executive Director, Westside San Joaquin River Watershed Coalition, 559-582-9237, jmcgahan@summerseng.com; **WSJRWC Contribution: $10,000**

Bruce Houdesheldt: Executive Director, Sacramento Valley Water Quality Coalition, 916-442-8333, bruceh@norcalwater.org; **SVWQC Contribution: $10,000**

Michael Wackman: Executive Director, San Joaquin County & Delta Water Quality Coalition, 916-684-9359, michaelkw@msn.com; **SJCDWQC Contribution: $10,000**

6. Agreement Manager

Parry Klassen: Coalition for Urban Rural Environmental Stewardship, 559-288-8125, pklassen@unwiredbb.com, 1480 Drew Ave. #130, Davis, CA 95618

B. Executive Summary

1. Problem

Nitrate is a major contaminant in Central Valley groundwater and elevated levels are attributed primarily to leaching of nitrogen fertilizers past the root zone. Growers who belong to Central Valley Water Quality Coalitions (CV Coalitions) are under new requirements per the Irrigated Lands Regulatory Program to keep “on farm” a Nitrogen Management Plan (NMP) to track nitrogen fertilizer applications. A key component of the NMP is reporting nitrogen consumption during the growing season with the assumption that the remaining nitrogen is lost to groundwater. Determining crop consumption is one of several requirements of the Management Practices Evaluation Program (MPEP) that five CV Coalitions are cooperatively implementing (East San Joaquin Water Quality Coalition, Westside San Joaquin River Watershed Coalition; San Joaquin County and Delta Water Quality Coalition; Sacramento Valley Water Quality Coalition; Westlands Water Quality Coalition). The MPEP has specific objectives including identifying management practices that are protective of groundwater quality, determining whether newly implemented management practices are improving or may result in improving groundwater quality, developing an estimate of the effect of Member’s discharge of nitrate on groundwater quality

and utilizing the results to determine whether practices need to be improved. There are data gaps in understanding the effectiveness of management practices on reducing the amount of nitrate transported through the root zone of walnuts. This project will document the amount of nitrogen applied and the movement and distribution of nitrate from the point of application through the root zone in 2 walnut orchards. This project will evaluate the movement of nitrogen through the root zone during rain and irrigation events over a two year period.

2. Objectives, Approach, and Evaluation

Objective 1: **Identify the management practices being implemented to reduce the amount of nitrogen moving through the root zone for Orchard 1 and Orchard 2.**

Approach: Fields will be identified with the assistance of the cooperating CV Coalitions and the California Walnut Commission. Management practices implemented by growers will include split fertilizer applications (based crop load and UC/industry expertise on optimal timing), and testing of soils/irrigation water/petiole-leaf to better understand crop nitrogen need and the amount of nitrogen and nutrients needed for optimal production. In addition, both orchards will use microsprinkler irrigation as a management practice to reduce the potential for leaching. Measurements will be collected over two years (two storm seasons and two irrigation seasons). Note: exact management practices beyond those listed will be determined once cooperator(s) have been identified. Two years will be necessary to ensure that the nitrogen measurements are repeatable from year to year and the study includes annual variability in weather and pest pressures. The BMPs will be implemented for at least two years allowing for changes in yields as a result of the BMPs and full evaluation of leaching potential.

Evaluation: Management practices for nitrogen fertilizer applications and irrigation timing will be identified for both fields prior to the implementation of the study. Throughout the two year study, practices performed by the grower such as nitrogen applications and irrigation events will be recorded. Total yield and root zone nitrate results will be compared over the two years to account for the effect of the implemented BMPs on the amount of nitrate leaching and changes (if any) in yield.

Objective 2: Determine the amount and timing of nitrogen moving through the root zone.

Approach: The study will be conducted in 5 acre plots in two different fields. The fields will be located within the cooperating CV Coalition boundaries (Madera County north to Shasta County). Each field will be sampled in the winter following adequate rain to saturate soils and throughout two irrigation seasons. Samples will be collected from:

- Lysimeters to evaluate the amount of nitrogen in the water moving through the root zone;
- Soil to evaluate the amount of nitrogen in the soil;
- Irrigation water to evaluate the amount of nitrogen in water used during irrigation that is in addition to fertilizer applications;
- Crop tissue at appropriate time intervals including harvest.

Soil permeability will be measured with a constant head permeameter during each of the three time periods (sets) during both years of the study. Permeability will be measured at the same time that soil samples are collected. Permeability measurements will be used to assess the heterogeneity of the field with respect to soil hydraulic conductivity. Tissue samples, including the roots (where possible) will be collected at randomly selected locations in each field throughout the growing season. Samples will be collected from the lysimeters after winter rain events to better determine the movement of residual nitrogen in the soil as a result of rain.

***Evaluation**:* Data collected from the field studies will be recorded in an electronic database, analyzed and summarized in interim and final reports. The reports will evaluate nitrate leaching in the two fields. Results will be placed in the context of previous studies on nitrogen leaching in walnuts.

Objective 3: **Identify the multiple benefits of nitrogen management practices implemented in Orchard 1 and Orchard 2 including potential cost savings (reduced water costs, reduced amount of money spent on fertilizer) and groundwater protection (reduction in the amount of nitrogen that is moving through the root zone).**

Approach: Costs for implementing the practices will be quantified for each individual management practice. Elements to be evaluated include: cost of water, cost of fertilizer applications, labor costs, and additional costs for practices such leaf, water and soil analysis. The benefit of protecting groundwater will be estimated by using the information obtained regarding the movement of nitrogen through the root zone.

Evaluation: The costs of implementing identified management practices will be quantified and the benefit of protecting groundwater will be estimated. The evaluation of these benefits will be included with outreach materials to encourage growers to implement similar practices.

Objective 4: Determine if additional practices could be implemented to further reduce the amount of nitrogen moving past the root zone.

Approach: Once the amount and timing of nitrogen moving through the root zone is determined, the range of management options can be evaluated to determine if it is possible to reduce nitrogen moving past the root zone. The range of management options will be identified with the assistance of Allan Fulton of UC Davis Cooperative Extension (Co-Principle Investigator) and Dr. David Ramos of the California Walnut Commission.

Evaluation: An analysis of management options will be performed after the two year study with the assistance of the California Walnut Commission, crop specialists with UCANR, CDFA and other experts in walnut production and included in the final report.

Objective 5: Disseminate results to growers of walnuts.

Approach: Walnut growers will be provided the results of this study through the Outreach component of this project. Field Days will be conducted during the study time period to demonstrate the management practices implemented; these will be scheduled once the project is approved for funding. In addition, at the conclusion of this project and summary write up will be provided to the CV Coalitions for use in coalition member outreach.

Evaluation: During the Field Days, the participants will be surveyed to determine the effectiveness of the demonstration. The number and types of outreach materials will be recorded.

3. Audience

Initially walnut growers and their crop advisors, water quality coalitions, UC Extension Farm Advisors, State and Regional Water Quality Control Boards and the FREP program are the target audience for knowledge gained from this project. Eventually the results of this project and other CURES' related projects will also be relevant and beneficial to growers with many annual crops in California's Central Valley. The information will help guide the selection of practices used by members of CV Coalitions who are required to use nitrate management practices known to minimize contamination of groundwater with nitrates and be compliant with groundwater protection regulations. Study results will help fill knowledge gaps and identify benefits to growers who implement multiple nitrogen management practices including better understanding of the efficacy of these practices in protecting groundwater resources while maintaining expected crop yield potential and quantifying cost savings.

C. Justification

1. Problem

Elevated levels of nitrate present in groundwater in Central Valley locations are being attributed, in part, to inputs from farming practices. The Central Valley Water Board estimates that approximately three million acres of irrigated lands overlay groundwater aquifers that have high levels of nitrogen or are vulnerable to nitrate contamination. In the Central Valley, approximately 33,000 landowners/operators are affected by the new ILRP requirements to implement practices to protect groundwater. Similar groundwater issues are problematic in other regions of California as well. The objective of the NMP and the MPEP is to better manage and understand the amount of nitrate that is leached to groundwater when Best Management Practices (BMPs) are implemented while also assuring that these processes are indeed effective. This project will document the uptake of nitrate fertilizer by the walnut crop and the movement and distribution of nitrate through the root zone in a walnut orchard. The resulting data will assist FREP, growers, water quality coalitions, Western Plant Health Association (WPHA), Certified Crop Advisors, UC Extension Farm Advisors, and the state and regional Water Boards in understanding nitrogen behavior, movement and distribution as fertilizer moves through the soil. Additionally, the results of this study can be used in the other agricultural areas of California where groundwater contamination with nitrate is of critical concern.

2. FREP Mission and Research Priorities

This study supports FREP's goals of filling the information gap in the understanding nitrogen behavior, movement and distribution as it moves from the point of application through the soil and past the root zone. The study results will assist with the evaluation and advancement of the environmentally safe and agronomically sound use of nitrogen fertilizers. The data from this project will also be useful, in combination with other research, to support FREP's goal of assessing the quantity of nitrates from nitrogen fertilizers accumulating in groundwater.

3. Impact

The research will provide growers and crop advisors with information needed to quantify the loss of nitrate through the root zone for selected management practices. This information can be used by growers to adjust their management practices and reduce the amount of nitrate lost to groundwater. Additionally, the information generated by this project will help growers optimize their nitrate applications and save money in their farming operation. The BMP recommendations will be vital to walnut growers in the Central Valley, who are an important part of the approximately 33,000 landowners/operators who farm nearly 7 million acres of land and are impacted by the new ILRP requirements to improve nitrogen and irrigation practices to minimize nitrate discharges to ground and surface water.

In addition, the research techniques and protocols developed during this study will be the demonstration to the Regional Board that this study design can be replicated in other locations and with other crops to evaluate the efficacy of management practices. The information generated by this project will be critical in allowing the CV Coalitions to meet the compliance measures outlined in their Waste Discharge Requirements.

4. Long-Term Solutions

Over the long-term, implementation of the nitrate BMPs evaluated by this project will contribute to measureable reductions in nitrate discharges to groundwater, and thereby contribute to the restoration of groundwater drinking water resources. The restoration of groundwater will reduce the regulatory compliance costs of all users of water. In addition, evaluating nitrate BMPs can reduce the economic cost of over fertilization providing growers with a potentially significant cost savings within their operation. Additionally, the reduction of impacts to groundwater reduces treatment costs associated with domestic supply wells which can allow expanded use of lower cost groundwater for domestic uses.

5. Related Research

Research: The management of fertilizer applications can be done only with knowledge of the 4 R's (right time, right place, right source, and right rate) for each crop. Very little is known about the 4 R's for most of the crops grown in the Central Valley. Studies are just beginning to be performed to develop nutrient

budgets and optimum fertilizer management in walnuts. DeJong et al. (2014[1]) determined that depending on variety and location, approximately 25 – 30 lbs N/ton (1% - 1.5%) is removed in harvested biomass (nuts and hulls) in walnut orchards. However, DeJong et al. found that there was more variability between sites across cultivars than between cultivars. Soil nutrient loss varied spatially from sandy loam to silt loam to clay loam. Early analytical results indicated that soil variability was high even within a small portion of an orchard but initial results showed leaching of nitrate as early as late July and increasing towards the end of the season with heavy precipitation events. Leaching did not appear to occur during the growing season due to the limited movement of water below the root zone.

There is little other research being conducted although there is some work on carrots (Allaire-Leung et al. 2001[2]) and some recent work has been performed using tomatoes (e.g., Hartz and Hanson 2009[3], Hartz and Bottoms 2009[4]). A majority of the research involves evaluating practices that optimize the use of applied N. Hartz and Hanson (2009) reported that conventionally-irrigated tomatoes need 100 – 150 lbs of nitrogen per acre because there is an additional substantial contribution from residual soil NO_3 and from the mineralization of organic N in the soil during the growing season.

Hartz and Hanson (2009) and Hartz and Bottoms (2009) reported:

- Early season NO_3-N analysis of soils can guide application rates during the growing season,
- Nutrient uptake (including P and K in addition to N) is slow until fruit set begins and then accelerates significantly,
- The majority of the accumulation of N occurs between flowering and fruit maturity,
- Nutrient uptake slows significantly in the last weeks before harvest and it is unnecessary to apply fertilizer during this period (right time),
- Several smaller fertigation events during the period of rapid uptake are optimal (right rate and right place),
- Leaf N analysis early in the growing season is the best measure of nitrogen status and can provide an indication of the nitrogen sufficiency status of the crop.

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[1] DeJong, T, K. Pope, P. Brown, B. Lampinen, J. Hopmans, A. Fulton, R. Buchner, and J. Grant. 2014. Development of a nutrient budget approach and optimization of fertilizer management in walnut. Walnut Research Reports, California Walnut Board

[2] Allaire-Leung, S. E., L. Wu, J. P. Mitchell, and B. L. Sanden. 2001. Nitrate leaching and soil nitrate content as affected by irrigation uniformity in a carrot field. Agricultural Water Management 48:37-50.

[3] Hartz, T. and B. Hanson. 2009. Drip irrigation and fertigation management of processing tomato. University of California Vegetable Research and Information Center. 11 pgs.

[4] Hartz, T. K. and T. G. Bottoms. 2009. Nitrogen requirements of drip-irrigated processing tomatoes. HortScience 44:1988-1993.

Although Hartz and Hanson (2009) and Hartz and Bottoms (2009) reported that leaching of N from drip irrigated tomatoes should be low during the season, estimates of in-season leaching are not available and it is not clear how much NO_3 may be lost from the root zone during the winter season.

Dr. Patrick Brown and his colleagues have developed a significant amount of information about the 4 R's in the context of minimizing leaching of nitrate to groundwater in almonds and pistachios (e.g. Hopmans et al. 2010[5]). Dr. Brown and Mr. Fulton are currently involved in research projects with walnuts that are addressing the loss of nitrate through the root zone although those projects are in their early stages and no results are widely available. Although permanent crops are very different from annual crops, there does appear to be commonality in the results of research on N use in annual crops and almonds including:

- The concentration of nitrate in the fertigation system during a fertigation event influences the efficiency with which N is used. Root nitrogen uptake is also influenced by previous nitrate inputs to the system and suggests that providing small amounts of nitrate over time are more efficiently used compared to larger applications (right rate).
- The majority of the accumulation of N occurs between flowering and fruit maturity,
- Nutrient uptake slows significantly in the last weeks before harvest and it is unnecessary to apply fertilizer during this period (right time),
- Leaf N analysis early in the growing season is the best measure of nutrient status and can provide an indication of the nutrient sufficiency status of the crop.

In addition to the research cited above, CURES has conducted research in walnuts in an orchard near Stockton. Although one of the major aspects of that research was to identify a reliable method of sampling nitrate below the root zone, additional information was collected on the effectiveness of a "right rate" management practice. Briefly, thirty suction lysimeters were placed in an orchard and samples were collected after each irrigation event throughout the irrigation season. Sources of nitrate included irrigation water, nitrate applied during fertigation, residual soil NO_3-N, and mineralized N. The orchard experienced some leaching of nitrate below the root zone as measured by the concentration of nitrate in water collected in lysimeters located below the roots (CURES report to CDFA in preparation).

Outreach: For over 15 years, CURES in collaboration with academic, commodity, professional, regulatory and non-profit organizations, has been instrumental in testing the efficacy of BMPs for improving water quality and facilitating widespread implementation and adoption of BMPs and Integrated Pest Management (IPM). CURES has produced numerous publications on BMPs for reducing off-site

[5] Hopmans, J. W., M. M. Kandelous, A. Olivos, B. R. Hanson, and P. Brown. 2010. Optimization of water use and nitrate use for almonds under micro-irrigation. Almond Industry Conference, Modesto, CA.

movement of sediments, nutrients and pesticides to surface water, irrigation management practices and practices for supporting healthy populations of pollinators, and assembled region-specific collections of these technical bulletins in binders entitled "BMP Handbook," with distribution to approximately 7,500 growers, PCAs, and agricultural organizations in the Central Valley. The BMP publications and the results of water quality related BMP studies are posted on CURES website: www.curesworks.org. Additionally, by utilizing a group of experts participating in the MPEP effort, the contribution will be from a broader base and in the process educate those in the agricultural community who are less likely to be knowledgeable about nitrogen research and options.

CURES project leader, Parry Klassen, has extensive experience in production agriculture. Mr. Klassen also serves as Executive Director of the East San Joaquin Water Quality Coalition. This organization represents more than 3,900 landowners in Madera, Merced and Stanislaus counties under the Irrigated Lands Regulatory Program. Among other responsibilities, Klassen manages the grower outreach and education programs and also actively participates in CV-SALTS and the MPEP effort on behalf of the East San Joaquin Water Quality Coalition.

Bill Jones, CURES' field specialist, has more than 30 years of professional experience in crop nutrition, irrigation water chemistry, and soil fertility management in a variety of crops in California. His recent projects include pre-plant assessments of soil fertility, irrigation water, selection and application of organic amendments, and plant nutrition management on farms in Tulare, Kern, and Fresno Counties.

Allan Fulton, the project's co-PI has more than fifteen years of experience working with orchard irrigation and soil management including evaluating off-site water quality impacts. He has worked with orchard managers on integrated water management concepts and groundwater hydrology.

MLJ-LLC and its principal Dr. Michael L. Johnson and field manager Matthew Zane, bring over 25 years of experience in basic and applied science to problems involving water quality. MLJ-LLC employs several environmental scientists that have experience with similar studies conducted in the Salinas Valley using romaine lettuce. MLJ-LLC staff are available to work on this project at all times as needed and necessary.

6. Contribution to Knowledge Base

Some information is available on the management of nitrate in walnuts with the assumption that proper nitrogen applications (fertigation), use of subsurface drip irrigation, and standard yields results in minimal or no leaching of nitrate to groundwater. However, this has yet to be demonstrated for walnuts and there is little known about potential leaching of nitrate during the fallow winter season. This project will confirm the conclusions made in previous studies of walnut nutrient management and provide growers with the information necessary to come into compliance with their WDRs. In addition, this study will allow the Management Practices Evaluation Program Group Coordinating Committee (MPEP GCC) to develop a template study design that can be used across several orchard crops in the Central Valley.

7. Grower Use

The nitrogen practices implemented during the study will be considered characteristic of what the "early adopters" of that crop are currently using. Most of the practices are already being used widely but not often simultaneously in a field. For instance, drip/microirrigation is widely used in the Central Valley. But drip irrigation, tissue/leaf sampling, split applications of nitrogen, pre- and post-crop soil testing, soil moisture sensors, and other newer practices, may not all be used at once in a single orchard. This project is intended to show that when all the "best" practices for the cropping conditions are used, nitrate movement to groundwater can be minimized/eliminated and, presumably, increased production will cover the cost. Once data are developed on the effectiveness of these practices when used in combination, growers will be motivated to adopt the measures by pressure currently exerted by regulatory agencies to protect groundwater resources. Information will also be provided to growers on the costs of the practices and potential yield or quality benefits that might be expected by their adoption.

D. Objectives

Objective 1: Identify the management practices being implemented to reduce the amount of nitrogen moving through the root zone for Orchard 1 and Orchard 2.

Objective 2: Determine the amount and timing of nitrogen moving through the root zone.

Objective 3: Identify the multiple benefits of nitrogen management practices implemented in Orchard 1 and Orchard 2 including potential cost savings (reduce water costs, reduce amount of money spent on fertilizer) and groundwater protection (reductions in the amount of nitrogen that is moving through the root zone).

Objective 4: Determine if additional practices that could be implemented in order to further reduce the amount of nitrogen moving through the root zone.

Objective 5: Disseminate results to growers of walnuts.

E. Work Plans and Methods (for multi-year projects, include a work plan for each year)

1. Work Plan

Task 1 – Project Management: Project management will occur throughout the duration of the project to ensure that Tasks 2 – 6 are being completed on time and on budget. This task will ensure that **Objectives 1-5** are met. Project Management will include coordination of the study team personnel including the Co-PI, Project Advisor, Project Cooperators, Project Supporters and the Subcontractor MLJ-LLC. **Task Products** include progress reports and invoices submitted in a timely manner to CDFA. This task will continue throughout the project term.

Task 2 – Grower Identification: The cooperator grower will be identified based on availability and willingness to participate with the assistance of the Project Team in order to meet **Objective 1**. **Task Products** include the recording of management practices implemented to increase the efficiency of nitrogen use including application timing and irrigations. This task will occur prior to the implementation of sampling and during both years of the study. Grower identification will be completed 3 months after project initiation (October 2015).

Task 3 – Study Design: The Study Design will be refined once the cooperator growers and the fields are identified. The **Task Product** is the study design which will include mapping of the fields, review of soil map data to ensure comparability between fields, determination of the grid cells for the sampling and scheduling of sampling. This will be included in the Summary Report. The Study Design is essential for meeting **Objective 2** in combination with Task 4 – Sampling. The Study Design will be agreed upon by the Project Team prior to initiation of sampling of a rain event which is scheduled to occur between November 2015 and March 2016.

Task 4 – Sampling: Sampling will include soil, pore water, irrigation water and plant tissue N. The study will also include permeability measurements in order to meet **Objective 2.** Sampling will occur after a rain event each year (November – March) and approximately 4 irrigation events (this may include a pre-irrigation event). The Sampling Design (Task 3) will refine the sampling schedule in order to meet **Objective 2**. **Task Products** include sample collection and receipt of results from the laboratory/field sampling.

Task 5 – Data Management: Results obtained from sampling (both laboratory and field results) as well as management practice information (details regarding timing and rates of applications) will be recorded in an electronic database. Data will be analyzed to evaluate differences in nitrate leaching between orchards **(Objective 2)** and estimate costs for implementing practices **(Objective 3). Task Products** include an electronic database of results to be used for data analysis in the Summary Report. Data Management will begin with the first sample collection (2015/2016) and end with the draft Summary Report (2018).

Task 6 – Summary Report: The Summary Report will include the identification of management practices, sample design, analysis of results, evaluation of nitrate leaching between fields, a cost analysis of BMP implementation, identification of additional practices that could be implemented, and documentation of outreach efforts **(Objectives 1-5). Task Products** include a draft Summary Report that will be disseminated to the Project Team for comments/edits. A final Summary Report will incorporate comments from the Project Team and submitted to CDFA. Information from the Summary Report will be utilized in outreach materials.

Task 7 –Outreach: Outreach will include Field Day demonstrations and dissemination of results to growers and CV Coalitions. Field Days will be conducted to demonstrate the management practices being implemented and the results from the Summary Report will be distributed to the MPEP GCC and

CV Coalitions to meet **Objective 5. Task Products** include outreach materials summarizing the conclusions of the study.

Table 7. Work Plan Tasks and Subtasks by Year.

Task / Subtask	Task Products	7/2015 – 12/201	1/2016 – 12/201	1/2017 – 12/201	1/2018 – [illegible]	Completion Dates
1. Project Management	Progress Reports, Invoices	x	x	X	X	June 2018
2. Grower Identification	Agreement with grower List of management practices	x				October 2015
3. Study Design *3.1. Assess Field Comparability* *3.2. Map Sample Locations* *3.3. Determine Sampling Locations*	Study Design	x				December 2015
4. Sampling *4.1. Preparation/Cleanup* *4.2. Equipment Installation* *4.3. Sample Collection*	Sample Collection /Analysis	x	x	X		January 2018
5. Data Management / Analysis *5.1. Field Data Entry* *5.2. Laboratory Data Review / Entry* *5.3. BMP Cost Estimates* *5.4. Database Management*	Electronic database	x	x	X	X	March 2018
6. Summary Report *6.1. Draft Report* *6.2. Final Report*	Draft Report Final Report			X	x x	March 2018 June 2018
7. Outreach *7.1. Conclusion Summaries for Outreach* *7.2. Field Days*	Outreach Materials		x	X	X	June 2018

2. Methods

Field Characteristics: Two orchards with similar management practices and irrigation systems will be selected in a geographically similar location. Both orchards will be adequately characterized to ensure they meet the necessary parameters of the study. Characterization will include soils, irrigation timing and volume, and irrigation system design. A 5 acre study plot will be selected within each of the two orchards and 15 grid cells will be established in each plot. Field heterogeneity will be addressed by first consulting NRCS soil maps and attempting to locate 5-acre study plots that lie within a single soil type. Depending on the parameter, between 5 and 15 measurements will be collected. For lysimeters, 15

samples will be collected from each plot during each irrigation event. Further analysis of heterogeneity will be done using statistical analysis on a combination of soil nitrate data and field hydraulic conductivity data developed from permeability measurements. Both irrigation efficiency and irrigation distribution uniformity are important factors determining the spatial variability in the rate at which nitrate moves through the soil. The location of each of the 5 acre study plots will be selected to address these factors. Irrigation timing and volume data at both sites will be gathered using a pulse output water meter and data logger. Soil permeability will be calculated using measurements obtained from a compact constant head permeameter. Soil samples and pore water samples will be collected and analyzed for nitrate to quantify movement through the root zone. Tissue samples will be collected to calculate the amount of nitrogen in various plant tissues. Gross yield data and nitrate results from tissue samples collected at harvest will be used to quantify the amount of nitrate removed at harvest.

Permeability: Each year 10 measurements of saturated hydraulic conductivity (K_{sat}) will be made on each of the 5 acre plots using a compact constant head permeameter (Amoozemeter). Field saturated hydraulic conductivity (K_{sat}) will be measured within 7 randomly selected grid cells at a well depth of 24 inches and a constant head depth of 12 inches.

Soil N: Three sets of 15 soil samples will be collected and analyzed for N each year. The first soil collection will occur prior to any pre-irrigation. A second soil collection will occur approximately half way through the crop cycle. The third set will be collected immediately after the harvest. Soil will be collected from five randomly chosen locations. Using a spoil probe, soil from a single hole will be collected from three depth intervals; 0-24 inches, 24-48 inches and 48-72 inches. Each set of cuttings will be homogenized and transferred to a 4-oz glass container. The samples will be submitted to the laboratory and analyzed for nitrate as N (EPA 300.0) and percent solids (SM 2540G). N mineralization potential will be measure by Solvita soil respiration or water extractable organic C and N. Mineralization potential is necessary to understand the conversion of organic N to NO_3 which then becomes an available source of nitrate for the crop. Samples will be collected at the same time as samples are collected for NO_3 analysis of soil.

Irrigation Water N: Samples of irrigation water will be collected and analyzed for nitrate. Three samples will be collected during the growing season; at the time of initial irrigation, mid-season, and at the time of the final irrigation.

Pore Water N: Suction lysimeters will be used to quantify N concentrations past the root zone. Suction lysimeters will be installed in each grid cell at a depth of 42-44 inches. For each sampling event, a manual suction of 60-75 PSI will be pulled on each lysimeter using a hand pump. Using a syringe, samples will be collected between 16 and 24 hours after suction has been pulled. Samples will be delivered to the laboratory within 24 hours to be analyzed for nitrate as N (EPA 300.0). Samples will be collected during a minimum of three irrigation events and will capture at least one fertigation event. Funding provided by cooperators will be used to sample and capture the remaining irrigation/fertigation events.

Plant Tissue N: Two sets of 10 tissue samples will be collected and analyzed for N content and percent moisture each year. The first collection will occur approximately halfway between planting and harvest. The second set will be collected the day prior to harvest. A tree from 10 randomly chosen grid cells within the 5 acre study area will be selected for tissue sampling. Leaf and fruit samples will be collected from each tree. In addition, an attempt will be made to collect root and woody tissue samples from each of the trees. If this is not feasible, previous studies on N content of roots and woody tissue for walnut trees will be evaluated and incorporated into the study.

Data Analysis: Measured parameters (e.g. concentration of nitrate in leachate, plant tissue N, soil residual N, mineralization rate) will be compared between fields using standard statistical procedures such as repeated measures ANOVA. Analyses such as plot characterization will be done with multivariate methods such as Principal Components Analysis. The relationship between the concentration of nitrate leaching past the root zone and other variables such as the amount of nitrate in irrigation source water, fertigation rate will be analyzed graphically because the sample size of 2 (or 3 if possible) precludes statistical analyses. Spatial variability in permeability the concentration of NO_3 in soils and leachate collected by lysimeters will be analyzed using standard spatial statistics.

3. Experimental Site

The study area will consist of two 5 acre blocks; each block will be located in a different walnut orchard located near Chico, CA. The orchards will be selected based on similar management and irrigation practices and both will be irrigated via surface drip. CURES is currently working with UCCE and the California Walnut Commission to identify cooperators. Identification of orchards in which to conduct the study is the first objective of the study.

F. Project Management, Evaluation and Outreach

1. Management

This project, as with the other projects for which CURES is seeking FREP funding, will be managed by a specific project team described below along with oversight by the MPEP GCC and the MPEP Technical Committee (members listed below). CURES is using this project as the pilot for additional studies to be performed over the next several years and these planned studies will also be managed by the MPEP GCC. The MPEP GCC has responsibility to perform studies to demonstrate that management practices used in irrigated crops grown in the Central Valley are protective of groundwater resources. While the project team will have responsibility for the activities and deliverables of this project, the MPEP GCC and its Technical Committee will provide feedback, advice and ongoing guidance to this project. It is expected that the project will be managed using a process that after the first year is completed, may result in adjustments in the study design to ensure that the most accurate and useful information is developed. Any changes to this project would be reviewed and approved by FREP contract managers before they are undertaken.

Coalition for Urban Rural Environmental Stewardship

PROJECT PLAN / RESEARCH GRANT PROPOSAL

CDFA FERTILIZER RESSEARCH & EDUCATION PROGRAM

The project director and principal investigator, Parry Klassen, is Executive Director of the Coalition for Urban Rural Environmental Stewardship (CURES), a non-profit, 501c3 organization. Mr. Klassen has a B.S. in Agricultural Communication from California State University, Fresno, and is a commercial fruit grower in Fresno County. Mr. Klassen has been closely involved with the formation of Central Valley watershed coalitions since 2002 with CURES and as executive director of the East San Joaquin Water Quality Coalition. CURES, under the management of Mr. Klassen, has worked in collaboration with academic, commodity, professional, regulatory and non-profit organizations and has been instrumental in testing the efficacy of BMPs for improving water quality and facilitating widespread implementation and adoption of BMPs and IPM. Mr. Klassen and CURES staff will manage this project, facilitate communication and collaboration among the cooperating entities through conference calls and team meetings, ensure that the study goals and objectives are being addressed throughout the project, oversee the field research, deliver outreach presentations, work with the grower cooperator to assist with management practice implementation and study logistics coordination, and gather and compile all supporting materials from collaborators and subcontractors to submit reports, invoices and deliverables to the FREP Grant Manager on time and on budget.

The project Co-PI, Allan Fulton, earned his Master's in Soil and Irrigation Science from Colorado State University, Fort Collins in 1986. Mr. Fulton has more than fifteen years of experience supporting the California walnut industry through applied research and education programs as an Extension Specialist with the University of California. Mr. Fulton will provide oversight and technical support for the research project.

The MPEP GCC is made up of five Central Valley water quality coalitions and encompasses more than 5 million acres of irrigated cropland. The participating coalitions include the East San Joaquin Water Quality Coalition, Westside San Joaquin River Watershed Coalition, the San Joaquin County and Delta Water Quality Coalition and the Sacramento Valley Water Quality Coalition who are all cooperators of this study. The MPEP GCC includes the Executive Directors of each Coalition, a member of each Coalition's Board of Directors, and an alternate for each member of the respective Board of Directors. In 2014, the MPEP GCC formed a Technical Committee to provide oversight and direction to all its crop research projects. The committee is made up of the following individuals:

- Dr. Patrick Brown, UC Davis Department of Plant Sciences
- Dan Munk, UCCE Farm Advisor
- Allen Fulton, UCCE Irrigation and Water Resources Advisor
- Doug Parker, Director, California Institute for Water Resources, UC Agricultural and Natural Resources
- Dr. Rob Mikkelsen, International Plant Nutrition Institute
- Dr. Tim Hartz, UCCE Vegetable Crops Specialist, Department of Vegetable Crops
- Lowell Zelinski, Precision Ag Consulting
- Dr. Gabriele Ludwig, Almond Board of California
- Charles Rivara, California Tomato Research Institute
- Mark Cady, CA Department of Food and Agriculture

- Barzin Moradi, CA Department of Food and Agriculture

The MPEP GCC is working with its Technical Committee to develop a conceptual study design for all its studies performed under the MPEP, including the proposed project. The MPEP GCC contracted with CURES to serve as MPEP Administrator. The MPEP GCC will collaborate with CURES to provide project outreach, and has pledged in-kind funding for this project.

Michael L. Johnson will be responsible for conducting the research guided by the Co-PIs and the MPEP Technical Committee. Dr. Johnson is the President and Managing Partner of MLJ-LLC and brings over 25 years of extensive experience to this project. Dr. Johnson spent 26 years as an academic scientist, first at the University of Kansas and the last 18 years were spent as a research scientist at UC Davis. Dr. Johnson has considerable experience conducting research including both field and laboratory studies. Dr. Johnson retired from UC Davis Center for Watershed Sciences in 2010.

2. Evaluation

This study does not include new technologies and barriers to adoption are not anticipated.

Throughout the study, practices performed by the grower such as nitrogen applications and irrigation events will be recorded. Data collected from the field studies analyzed and summarized in interim and final reports. Study results will be compared to previously performed studies on the crop. The costs of implementing identified management practices will be quantified and the benefit of protecting groundwater will be estimated. The evaluation of these benefits will be included with outreach materials to encourage growers to implement similar practices. An analysis of management options will be performed after the two year study with the assistance of the California Walnut Commission, crop specialists with UCCE, CDFA and other experts in walnut production and included in the final report. During the Field Days, the participants will be surveyed to determine the effectiveness of the demonstration. The number and types of outreach materials will be recorded.

3. Outreach

CURES, on behalf of the MPEP GCC, will organize multiple outreach efforts throughout and following the two year field trial. The MPEP GCC will promote Field Days in which growers and interested parties are invited to the study site to view the project in process. Once the data gathered during the study are analyzed, CURES will compile a PowerPoint presentation and organize meetings for Coalition members who grow walnuts. These meetings will be held in all of the participating Coalition regions. In addition, each of the participating Coalitions will be provided outreach materials (e.g. presentations, summary results) to include in their Annual Member Meetings. A summary of the project and results will be compiled into a written publication that will be distributed to growers, commodity groups, California crop advisors, and other interested parties. Specific dates for Field Days will be set based on progress of the studies, and the availability of growers and participating CV Coalitions. CURES will update FREP regarding meeting dates as they are set.

G. Budget Narrative

The budget attached in the budget template is based on funds being available as of July 2015. The funds included in the attached budget template include 2015 funds in the 2016 estimate.

a. Personnel Expenses

CURES staff are listed below including the number of hours estimated to work on the study project per year. The Annual Total includes all wages and benefits. CURES staff will manage contracts, invoicing and progress reports and ensure that subcontractors remain on schedule and within budget.

Personnel, Title (% full time)	*Hrs / Yr*	*Wage/ Hour*	*10% Benefits*	*10% Overhead*	*Wage/ Hour*	*Annual Total*
Parry Klassen, Project Director/PI (2%)	60	$130.00	$13.00	$13.00	$156.00	$9,360.00
William Jones, Project Manager (4%)	60	$110.00	$11.00	$11.00	$132.00	$7,920.00
Clint Phelps, Assistant PM (2%)	60	$50.00	$5.00	$5.00	$60.00	$3,600.00
Tamara Watson, Contracts Manager (1%)	24	$60.00	$6.00	$6.00	$72.00	$1,728.00
Kara Stuart, Administrative Assistant (3%)	120	$35.00	$3.50	$3.50	$42.00	$5,040.00
TBD, Bookkeeper (2%)	36	$30.00	$3.00	$3.00	$36.00	$1,296.00

b. Operating Expenses

Supplies: $300 over the duration of the project is included for office-related expenses including teleconferencing, copies, and document sharing website.

Equipment: All equipment needed for this project will be supplied by the subcontractor(s).

Travel: It is estimated that three (3) CURES staff will travel a total of 5 trips per year (averaging 200 miles round trip @ $0.56 per mile) which will include lodging ($90 a night) and meals ($56 for 3 meals). Travel costs is $4,000 for 2015/2016, $4,000 for 2017 and $2,300 in 2018.

Professional/Consultant Services: Allan Fulton (University of California, Davis) will assist CURES with grower identification and outreach and is budgeted $2,500 per year to pay for supplies and travel. MLJ-LLC will perform Task 3 (Study Design) through Task 7 (Summary Report) completing the sampling, analysis and report summaries. MLJ-LLC's budget includes personnel ($98,860), equipment/supplies ($8,603.50), transportation ($9,920) and analytical costs ($29,648) associated with sampling and conducting the field trials. MLJ-LLC will manage data collected as part of this study and work with the Project Team on developing the draft and final Summary Reports.

Other Expenses: No Other Expenses have been identified.

c. Other Funding Sources

As part of their commitment to the MPEP, four CV Coalitions have pledged funds for this project. Due to the timing of the proposal, the pledges are estimated but are expected to be a total of $80,000 over two years.

H. Budget Template (see attached excel spreadsheet)

I. Appendices

Appendix 1: Project Leaders

Resume: Parry Klassen

Executive Director

East San Joaquin Water Quality Coalition

Coalition for Urban Rural Environmental Stewardship

Central Coast Groundwater Coalition

Parlier, CA

559-288-8125

pklassen@unwiredbb.com

Education

Bachelor of Science Degree in Agricultural Communications; emphasis in agronomy and journalism. California State University, Fresno, 1981.

Employment History

September 2004 to Present – Executive Director, East San Joaquin Water Quality Coalition. Manage the activities of this non-profit entity formed to assist members to be in compliance with the Irrigated Lands Regulatory Program. Responsibilities include managing relations with the Regional Water Board and coalition subcontractors and implementing outreach programs on improving water quality in the coalition region. www.esjcoalition.org

August 1999 to Present – Executive Director, Coalition for Urban/Rural Environmental Stewardship. Responsibilities include managing the non-profit organization and working with clients on a variety of research and communications projects. Research projects focus on evaluating management practices to protect surface and groundwater; outreach programs consist of developing publications, organizing meetings, presentation development and performance, media outreach and other communications functions. All projects are performed by forming alliances with various agricultural organizations to achieve the project goals. www.curesworks.org

January 2012 to Present – Executive Director, Central Coast Groundwater Coalition

Manage the activities of this non-profit entity created to fulfill the groundwater monitoring requirements of landowners and growers located in the Central Coast region of California.

Responsibilities include managing subcontractors who perform well sampling and implementing the outreach program directed at 573 members who farm 204,000 acres in the region.

www.centralcoastgc.org

1997 to 2004 -- Communications Consultant, Freelance Writer.

Worked on a variety of communications projects including media relations, issues management, and writing. Projects included copy writing and editing, organizing meetings, presentation development and performance, media outreach and other communications functions. Clients included Crop Life America, Almond Board of California, California Tree Fruit Agreement and other agricultural entities.

1995 – 1997 – Communications Manager, Western Plant Health Association – Manage communications activities for this trade association based in Sacramento.

1981 to 1995 -- Reporter and Editor

Reporter and editor for a number of agricultural publications, including *Farm Chemicals, California Farmer, Western Fruit Grower,* and *American Vegetable Grower* magazines. Also written extensively about greenhouse and ornamental crops, cotton, and related agricultural subjects.

Farming Background

1991 to present -- Own and operate fruit farm near Parlier.

1988 to 1990 -- Rented peach orchard in Ohio for direct market sales.

1979 to 1980 -- Worked during college on cotton and vegetable farm.

1970 to 1975 – Actively involved in family tree fruit farm in Reedley, CA. Growing, packing, and shipping operation included 150 acres of peaches, plums, nectarines, and vegetables. (Farm sold in 1975).

Resume: Allan Fulton

J. Allan E. Fulton - Irrigation and Water Resources Farm Advisor

University of California Cooperative Extension, Tehama, Glenn, Colusa, and Shasta Counties

Home Contact:

20810 Bare Road, Red Bluff, CA 96080

Home: (530) 527-1018

Employer Contact:

University of California Cooperative Extension

1754 Walnut Street, Red Bluff, CA 96080

EDUCATION

Master of Science, Soil and Irrigation Science, Colorado State University, Fort Collins, CO, 1986

Bachelor of Science, Agronomy, Colorado State University, Fort Collins, CO, 1983

WORK EXPERIENCE

Irrigation and Water Resources Farm Advisor, Tehama, Glenn, Colusa, and Shasta Counties, University of California Cooperative Extension, Red Bluff, CA, 2000 – Present.

Develop, demonstrate, and extend irrigation and soil management practices for orchard and agronomic crops that sustain production, use water efficiently, and prevent off-site water quality impacts. Extend knowledge to water users in the northern Sacramento Valley concerning groundwater hydrology and integrated water management concepts. Educate water users of non-point source water quality regulations facing irrigated agriculture and the role of watershed management approaches to respond.

Managing Agronomist, den Dulk Farming Company, Kingsburg, CA 1997 – 2000. Co-managed 1100 acres of orchard and vine crops and 2400 acres of alfalfa and row crops near Hanford, California. Responsible to oversee management of irrigation, soil quality and plant nutrition, and pest management.

Soils, Water, and Winter Grains Farm Advisor, Kings County, University of California Cooperative Extension, Hanford, CA 1986 –1997. Develop, demonstrate, and teach irrigation management practices for orchard and agronomic crops that use water efficiently, reduce agricultural drainage and runoff. Investigate and provide information on soil and water amendments to manage soils with slow water infiltration resulting from irrigation water supplies of lower water quality. Evaluate salt tolerance of agronomic crops, trees, and halophytes. Study blending and cyclical approaches to re-use saline-sodic agricultural drainwater for irrigation. Research and extend knowledge on all agronomic aspects of irrigated wheat and barley production.

RECENT PROFESSIONAL ACTIVITY AND PUBLIC SERVICE

- Past President, California Chapter American Society of Agronomy, 2013/14
- Member of UC ANR Strategic Initiative Panel for Water, Dec. 1, 2011 - Nov. 30, 2013
- Technical editor for Tehama County AB-3030 Groundwater Management Plan Update. 2012
- Chair, Tehama County AB3030 Technical Advisory Committee. 2009
- Current member of the Glenn County Groundwater Technical Advisory Committee since 2001
- California Groundwater Resources Association, Affiliate. – "Groundwater Monitoring: Design, Analysis, Communication and Integration with Decision Making. Invited presenter, February 2009, Conference Speaker, Anaheim, CA

Recent Publications: Allan Fulton

Ayars, J. E., A. Fulton, and B. Taylor. Subsurface Drip Irrigation in California - Here to Stay? Agricultural Water Management Journal. January 2015. journal homepage: www.elsevier.com/locate/agwat.

O' Geen, Anthony, Thomas Harter, Helen Dahlke, Fogg, Graham, Samuel Sandoval, Allan Fulton, Saal, Matt, Paul Verdegaal, Rachael Elkins, Franz Niederholzer, Chuck Ingels, and David Doll. A Soil Survey Decision Support Tool for Groundwater Banking in Agricultural Landscapes. Submission for publication in California Agriculture. October, 2014. Pending peer review.

Fulton, A., J. Grant, R. Buchner, and J. Connell. Using the Pressure Chamber for Irrigation Management in Walnut, Almond and Prune. May 2014. UC ANR Publication 8503. http://anrcatalog.ucdavis.edu/Details.aspx?itemNo=8503.

Fulton, Allan. Technical Editor. Tehama County Flood Control and Water Conservation District Coordinated AB 3030 Groundwater Management Plan 2012. pp. 196. November 2012. http://www.tehamacountypublicworks.ca.gov/Flood/documents/2013_GWMP/1_GWMP_TOC.pdf.

Fulton, A. and the California Department of Water Resources, Northern District. Northern Sacramento Groundwater Newsletter Series (thirteen issues). April 2003 – June 2011.

http://cetehama.ucdavis.edu/Agriculture/Groundwater_Management.htm

Stewart, William, Allan Fulton, William Krueger, Bruce Lampinen, and Ken Shackel. A five-year study of Regulated Deficit Irrigation (RDI) in almond: Reducing consumption on a low water holding soil. California Agriculture. April-June 2011, Vol. 65 No.2 pp 90-95.

Fulton, Allan, Larry Schwankl, Kris Lynn, Bruce Lampinen, John Edstrom, and Terry Prichard. Using EM and VERIS technology to assess land suitability for orchard and vineyard development. Journal of Irrigation Science.DOI 10.1007/s00271-010-0253-1. December 2010.

Fulton, A., B. Sanden, and J. Edstrom. Soil Evaluation and Modification. Chapter 7. Prune Production Manual. Buchner, R. P., Editor. University of California, Agriculture and Natural Resources. In-Press. . July 17, 2010.

Fulton, A. and B. Sanden. Salinity Management. Chapter 6. Prune Production Manual. Buchner, R. P., Editor. University of California, Agriculture and Natural Resources. In Press. July 17, 2010.

Long, Rachael., Allan Fulton, and Blaine Hanson. Protecting Surface Water from Sediment-Associated Pesticides in Furrow-Irrigated Crops. Publication 8403. University of California, Agriculture and Natural Resources. March 2010. Pp. 16.

Long, Rachael F., Blaine R. Hanson, Allan E. Fulton, and Donald P. Weston. Mitigation techniques reduce sediment in runoff from furrow-irrigated cropland. California Agriculture. Division of Agriculture and Natural Resources. University of California. Vol. 64. No. 3. Pp. 135-140.

Buchner, R.P., Fulton, A., Gilles, C., Lampinen, B., Shackel, K., Metcalf, S., Little, C., Pritchard, T. and Schwankl, L. “Effects of Regulated Deficit Irrigation on Walnut (Juglans regia) Grafted on Northern California Black (Juglans hindsii) or Paradox Rootstock.” Proceedings 5th International Symposium on Irrigation of Horticultural Crops. Mildura, Australia. January 2007.

Lubell, M. and A. Fulton. Local Policy Networks and Agricultural Watershed Management. Journal of Public Administration Research and Theory. Advance Access published November 4, 2007.

Current Projects, Time Commitments and Impacts on Proposed Project – Allan Fulton

Project Title or Creative Activity/ Duration	Role (PI, Co-PI, etc.)	Collaborators (with affiliation)	Support Source

Coalition for Urban Rural Environmental Stewardship

PROJECT PLAN / RESEARCH GRANT PROPOSAL

CDFA FERTILIZER RESSEARCH & EDUCATION PROGRAM

Project Title or Creative Activity/ Duration	**Role (PI, Co-PI, etc.)**	**Collaborators (with affiliation)**	**Support Source**
Almond Water Production Function Research	Provide oversight of Tehama County field experiment. Work routinely with grower cooperator. Impose irrigation treatments, oversee field assistant and collection of water, crop development, and yield data. Involved in data analysis and reporting to Almond Board of California.	Ken Shackel, Professor, Plant Sciences, UCD, David Doll, UCCE Farm Advisor, Merced County, Blake Sanden, UCCE Farm Advisor, Kern County, and Bruce Lampinen, UCCE Statewide Extension Specialist	Almond Board of California
Evaluating Physiological Indicators of Early Season Water Stress in Walnut	Provide oversight of Tehama County field experiment. Work routinely with grower cooperator. Impose irrigation treatments, oversee field assistant and collection of water, crop development, and yield data. Involved in data analysis and reporting to Walnut Research Board.	Ken Shackel, Professor, Plant Sciences, UCD and Bruce Lampinen, UCCE Statewide Extension Specialist	California Walnut Research Board
Evaluation of water use and crop coefficients in mature walnuts.	Co-PI. Arranged two orchards to conduct experiment, routinely maintain instrumentation and collect field data. Involved with data analysis and extension of results.	Richard Snyder, Co-PI, UCCE Specialist, Cayle Little, Co-PI California Department of Water Resources, and Richard Buchner, Farm Advisor, UCCE, Tehama County	California Department of Water Resources and Tehama County
Evaluation of water use and crop coefficients in French Prune.	Co-PI, Arranged one orchard to conduct experiment, routinely maintain instrumentation and collect field data. Involved with data analysis and extension of results	Richard Snyder, Co-PI, UCCE Specialist, Cayle Little, Co-PI California Department of Water Resources, and Richard Buchner, Farm Advisor, UCCE, Tehama County	California Department of Water Resources and Tehama County

Project Title or Creative Activity/ Duration	**Role (PI, Co-PI, etc.)**	**Collaborators (with affiliation)**	**Support Source**
UC-ANR Web-based Irrigation Scheduling and Nitrogen Management Tool for California Crops	Leader in the development of modules and algorithms that expand UC ANR's Crop Manage web-based irrigation scheduling to almond and walnut orchard crops.	Michael Cahn, UCCE Monterey County, and Khalid Bali, UCCE, Imperial County.	California Department of Water Resources
Nitrogen Management Training for California Certified Crop Advisors (CCA's)	Served on a UC ANR Steering Committee chaired by Water Strategic Initiative Leader, Doug Parker. Committee developed curriculum for a 1 1/2 day training and certification session on nitrogen management in irrigated agriculture. I co-authored and presented curriculum related to irrigation management and its interaction with nitrogen managment and I contributed to the development of an interactive training exercise on nitrogen management decision making.	Doug Parker, UC ANR Water Strategic Initiative Leader, Patrick Brown, Professor Plant Sciences, Tim Hartz, UCCE Statwide Vegetable Crops Specialist, Stuart Pettygrove, UCCE Emeritus, Larry Schwankl, UCCE Emeritus, Dan Munk, UCCE Farm Advisor, Fresno County, and others.	California Department of Food and Agriculture

Resume: Michael L. Johnson, LLC

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Education – Dr. Michael L. Johnson

Ph.D. 1984, University of Kansas
M.A. 1977, University of Colorado
B.A. 1974, University of Colorado

Past Positions

Research Scientist, Center for Watershed Sciences, John Muir Institute of the Environment, 2008 – 2010
Adjunct Associate Professor, Department of Medicine and Epidemiology, School of Veterinary Medicine, 2004 - 2010
Associate Research Scientist, John Muir Institute of the Environment, 1998 – 2008
Director, Lead Campus Program in Ecotoxicology, UC Toxic Substances Research & Teaching Program 2000-2005
Associate Researcher, Department of Civil and Environmental Engineering, 1992 - 1998
Lecturer, Department of Environmental Toxicology, 1998-99
Lecturer, Department of Wildlife, Fish, and Conservation Biology, UC Davis, 1993 - 1995
Assistant Scientist, Kansas Biological Survey, 1991-1992
Adjunct Assistant Professor, Department of Systematics and Ecology, University of Kansas, 1989-1992
Research Associate, Kansas Biological Survey, 1988-1991
Postdoctoral Research Associate, Department of Systematics and Ecology, University of Kansas, 1987-1988
Lecturer, Department of Mathematics, University of Kansas, 1984-1987

Related Project /Experience

Study Title: Establishing cost efficient methods to measure nitrate movement beyond the root zone when using nutrient BMPs in California Specialty Crops

Project Abstract: This project was funded by a Specialty Crop Grant by the California Department of Food and Agriculture (CDFA) and was awarded to the Coalition of Urban and Rural Environmental Stewardship (CURES). Michael L. Johnson, LLC (MLJ-LLC) was a subcontractor to the project and implemented the monitoring design, data review and storage, data analysis and results write up. The project's main goal was to establish a reliable and repeatable scientific method to characterize the movement of nitrogen fertilizers beyond the plant root zone. After a literature review, the project focused on evaluating the ability of using an Automated Monitoring System (UMS) versus a traditional suction lysimeters system to collect water samples in cauliflower, lettuce and walnut fields below the root zone. Both methods were able to effectively collect water and nitrate concentrations varied across

the fields and at different depths. Due to the lower expense of lysimeters, they were used in a field trial in two lettuce fields to evaluate the amount of nitrogen leaching past the root zone. One of the adjacent lettuce fields received the normal amount of nitrogen and the other received half that amount. The results of the study were affected by significant differences in permeability between the two fields. However, the results of the two year study on both methodology and management practice effectiveness have found that using a lysimeter system to characterize movement of nitrogen fertilizers past the root zone is both cost effective and reliable. The protocols used within the field trial on lettuce are being further refined based on the study results and will assist growers in both the Central Valley and Central Coast better understand the amount of nitrogen leaching past the root zone for specific crops.

Project Methods:

Samples were collected in 2014 to optimize the depths of sampling in the vegetable crops and develop a process for determining the number of instruments that are needed to adequately sample water moving past the root zone at a larger scale (part or all of a planting block depending on size). Sampling occurred in 2014 after initial storm events within Stockton, Salinas and Gonzales locations and continued during additional winter storms and irrigation events in 2014. To better understand variability in soil characteristics that can affect moisture content and water movement, hydraulic conductivity and/or soil texture analysis of soil samples were also conducted in 2014. The results from the additional winter sampling and analysis were then used to develop a field trial on lettuce utilizing lysimeters to measure the difference in nitrogen concentration in fields with different nitrogen management practices. The field trial found that the amount of nitrate present in the soil prior to planting did not differ between the two fields and therefore any differences in nitrate concentrations measured in the water moving past the root zone were due to the amount of nitrate applied during the crop cycle. However, the permeability between the two fields was found to be significantly different; one field had twice the hydraulic conductivity as the other. The field with the higher hydraulic conductivity received the lower amount of nitrate. The nitrate concentrations in the water samples collected below the root zone were twice as high in the field with the highest hydraulic conductivity even though half as much nitrate was applied. There were no differences in moisture content, crude protein, or total N content of the trimmed tissue or the Romaine heads between the two sides.

Grants and Contracts

University of California (All grants as Principle Investigator unless noted otherwise)
Identifying pharmaceuticals in the Sacramento River. State Water Resources Control Board June 2007 – March 2011 ($20,037)

Review of ammonia in the Delta. State Water Resources Control Board June 2008 – March 2010 ($40,697)

Coalition for Urban Rural Environmental Stewardship

PROJECT PLAN / RESEARCH GRANT PROPOSAL

CDFA FERTILIZER RESSEARCH & EDUCATION PROGRAM

Identifying pharmaceuticals in the Napa River and tributaries. Napa Sanitation District November 2008 – June 2010 ($75,000)

Pelagic Organism Decline. State Water Resources Control Board June 2008 – March 2010 ($450,000)

QAPP development for permitting operations. California Urban Water Agency July 2008 – September 2008 ($8,835)

Identifying pharmaceuticals in Sonoma Creek and tributaries. Sonoma County Water Agency April 2007 – June 2009 ($75,000)

Regional Data Center – California Environmental Data Exchange Network. State Water Resources Control Board May 2007 – present ($299,500)

Evaluation of the toxicity of biodiesel fuels. California Air Resources Board June 2007 – June 2009 ($185,000)

Effect of Light Brown Apple Moth pheromones on honey bees. California Department of Food and Agriculture December 2007 – December 2009 ($187,425)

Guidance Document and Recommendations on the Types of Scientific Information to be Submitted by Applicants for California Fuels Environmental Multimedia Evaluations. California Air Resources Board. June 2007 – May 2009 ($55,110)

Phase II Continuation of Monitoring of Agricultural Drainage Water Quality in the Central Valley of California. CAL EPA Water Control Board. December 2003 – June 2008 ($2,337,837)

City of Ukiah Healthy Waterways Study. City of Ukiah. July 2006 – December 2008 ($35,000)

Review & Assessment of Apalachee I BMPs and Monitoring Needs, Task 2. El Dorado County. November 2004 - January 2009 ($17,472)

Review & Assessment of Apalachee I BMPs and Monitoring Needs, Task 3. El Dorado County. November 2004 – January 2005 ($17, 472)

Identification of Bacterial Sources for the East San Joaquin Water Quality Coalition. East San Joaquin Water Quality Coalition. July 2006 – December 2006 ($7,123)

Coalition for Urban Rural Environmental Stewardship

PROJECT PLAN / RESEARCH GRANT PROPOSAL

CDFA FERTILIZER RESSEARCH & EDUCATION PROGRAM

Bacterial Source Identification Analysis. East San Joaquin Water Quality Coalition. April 2007 – June 2008 ($16,673)

Identification of Bacterial Sources for the Sacramento Valley Water Quality Coalition. July 2006 – December 2007 ($6,600)

Lake County Healthy Waterways Study. Lake County. August 2005 – February 2008 ($34,500)

Detection of Fecal Contaminants in Groundwater. Lake County. March 2007 – December 2008 ($6,840)

Scientific Peer Review of Public Health Goal Documents. CAL EPA – Office of Environmental Health Hazard Assessment. July 2005 – August 2005 ($3,000)

Feather River PRISM. Coalition for Urban/Rural Environmental Stewardship. January 2005 – January 2008 ($70,000)

Feather River Prop 50 Monitoring and Modeling. California State Water Resources Board November 2005 – December 2007 ($143,331)

Identification of Bacterial Sources for the San Joaquin County & Delta Water Quality Coalition. San Joaquin County and Delta Water Quality Coalition. July 2006 - December 2006 ($7,300)

Tahoe Basin Toxicity Testing. California Department of Transportation October 2005 – May 2008 ($6,281)

Total Maximum Daily Load Monitoring. State Water Resources Control Board March 2007 – February 2008 ($139,500)

Central Valley Bioassessment 2005-06. Central Valley Regional Water Quality Control Board, December 2005 – December 2006 ($276,048)

El Dorado County Department of Transportation Sampling and Analysis of Water Runoff. Eldorado County Department of Transportation February 2004 – February 2008. ($475,000)

Using a sensitive Japanese Medaka (Oryzias latipes) fish model for the detection of endocrine disruptors in ground water. State Water Resources Control Board, June 2004 – May 2006 ($238,000) (Co-PI, S. Teh PI)

Central Valley Bioassessment 2004-05. Central Valley Regional Water Quality Control Board, April 2004 – June 2005 ($228,000)

Using a sensitive Japanese Medaka (Oryzias latipes) fish model for endocrine disruptors screening. U.S. Environmental Protection Agency, October 2003 – September 2006 ($399,167) (Co-PI, S. Teh PI)

Fire and fuels management, landscape dynamics, and fish and wildlife resources: study design for integrated research on the Plumas and Lassen National Forests -- Small mammal distribution, abundance, and habitat relations. USDA-Forest Service, 2002-2007. ($1,604,000); (Co-PI, D. Kelt PI)

TMDL monitoring of Central Valley Watersheds 2002-03. Central Valley Regional Quality Control Board, December 2002 – August 2003 ($340,147)

Review of Angora Meadows Monitoring Data. El Dorado County, March – May 2003 ($2,061)

Ecotoxicology Lead Campus Program. UC Toxic Substances Research and Teaching Program, June 2000 – June 2004 ($1,266,594)

Central Valley Bioassessment 2003-04. Central Valley Regional Water Quality Control Board, June 2003 – June 2004 ($186,620)

Review of Public Health Goals Draft Documents for 1,1,2,2-Tetrachloroethane, Chlorobenzene, Simizine, and 1,1-Dichloroethane. Office of Environmental Health Hazard Assessment, Cal EPA, December 1998 – January 2003. ($6,000)

Review of SFBRWQCB Risk Based Screening Levels for Ecological Receptors. UC Berkeley, April 2003 – June 2003 ($2,000)

Water quality modeling for the Shasta River dissolved oxygen and temperature TMDLs. North Coast Regional Water Quality Control Board, December 2003 – December 2004, ($115,000) Co-PI, (J. Quinn, PI)

TMDL monitoring of Central Valley Watersheds 2003-04. Central Valley Regional Water Quality Control Board, November 2003 – March 2004, ($259,973)

Statewide toxicity testing research project. California Department of Transportation. June 2000 – June 2003 ($1,710,000)

Simplex modeling of an urban watershed. Vallejo Sanitation and Flood Control District. August 2000 – August 2001 ($29,000)

Perchlorate exposure in drinking water. California Department of Health Services. (Co-PI, G. Fogg, P.I.) June 1999 – September 2001 ($222,603)

FREP project. California Department of Food and Agriculture, February 2000 – March 2000 ($4,000)

Estrogenicity of selected herbicides and adjuvants. California Department of Transportation. October 1998 – June 2002 ($241,627)

Simplex modeling of an urban watershed. Fairfield-Suisun Sewer District. December 2000 – December 2001 ($10,000)

MTBE analysis in California. University of California Toxic Substances Research and Teaching Program (Co-PI). January 1998 - October 1998 ($220,000)

TMDL analysis of North Coast watersheds (North Coast River Loading Study). California Department of Transportation, July 1997-June 2002 ($1,541,173)

The impact of stormwater runoff on North Coast rivers (Small Stream Crossing Study). California Department of Transportation, November 1997-June 2002 ($1,820,144)

San Pablo Bay National Wildlife Refuge vegetation monitoring plan. California Department of Transportation, July 1997-June 2002 ($419,250)

Small mammal survey of the Alhambra Creek Wetlands. California Department of Transportation, September 1997-October 1997 ($12,000)

Baseline vegetation survey of the East San Pablo Bay Unit of the San Pablo Bay National Wildlife Refuge. California Department of Transportation, July 1996-March 1997 ($50,000)

An integrated assessment of a linked wetland-nearshore estuarine ecosystem at Mare Island Naval Shipyard. University of California Toxic Substances Research and Teaching Program, July 1996-June 1997 ($363,000)

An integrated assessment of a linked wetland-nearshore estuarine ecosystem at Mare Island Naval Shipyard. University of California Toxic Substances Research and Teaching Program, July 1995-June 1996 ($160,000)

Coalition for Urban Rural Environmental Stewardship

PROJECT PLAN / RESEARCH GRANT PROPOSAL

CDFA FERTILIZER RESSEARCH & EDUCATION PROGRAM

An integrated approach to assessing water management options in a major watershed: Extending a hydrodynamic-water quality model to include biological and politico-economic components (Co-PI). U.S. Environmental Protection Agency (EPA-NSF), October 1996-September 1999 ($1,292,627)

Development of an ecological risk assessment model. Year 2. California Environmental Protection Agency, July 1995 - June 1996 ($40,000)

Salt marsh hydrology and mitigation of flooding. California Department of Transportation, October 1995 - June 1996 ($50,000)

Salt marsh modeling. National Biological Survey, November 1994 - October 1995 ($59,325)

UC Davis Environmental Education Partnership (UCDEEP). (Co-PI) Department of Defense, October 1994 - September 1995 ($1,660,207)

An integrated ecological assessment of three wetlands sites at Mare Island Naval Shipyard. University of California Toxic Substances Research and Teaching Program, July 1994 - June 1996 ($79,453)

Development of an ecological risk assessment model and symposia. California Environmental Protection Agency, July 1994 - June 1995 ($250,000)

A regionalized assessment of the influences of rural nonpoint source pollution on the ecological integrity of stream ecosystems and evaluation of associated pollution control management: Data management and data analysis (Year 2). Subcontract to University of Kansas, June 1993 - June 1994 ($23,000)

Hydrodynamic modeling of Pt. Mugu Lagoon. U.S. Fish and Wildlife Service, August 1993 - December 1993 ($5,000)

Feasibility study of alternate wetland restoration plans for the Napa Marsh Unit of the San Pablo Bay National Wildlife Refuge. U.S. Fish and Wildlife Service, January 1993 - December 1994 ($85,286)

A regionalized assessment of the influences of rural nonpoint source pollution on the ecological integrity of stream ecosystems and evaluation of associated pollution control management. Phase I. Selection of watersheds. U.S. EPA, Region IX, August 1992 - June 1993 ($29,000)

An assessment of the effects of nonpoint source pollution on the biotic integrity of Walnut Creek, and the role of riparian vegetation in mitigating nonpoint source pollution: Data management and data analysis. Subcontract to University of Kansas, October 1992 - September 1995 ($35,443)

A regionalized assessment of the influences of rural nonpoint source pollution on the ecological integrity of stream ecosystems and evaluation of associated pollution control management: Data management and data analysis (Year 1). Subcontract from the University of Kansas, June 1992 - June 1993 ($23,000)

University of Kansas
Data for validation of EPA modeling. U.S. EPA - ERL Duluth, August 1990 - March 1991 ($7500)

A regionalized assessment of the influences of rural nonpoint source pollution on the ecological integrity of stream ecosystems and evaluation of associated pollution control management (Year 1). U.S. EPA, June 1991 - June 1992 ($1,250,000)

A regionalized assessment of the influences of rural nonpoint source pollution on the ecological integrity of stream ecosystems and evaluation of associated pollution control management (Year 2). U.S. EPA, June 1992 - June 1993 ($1,450,000)

An assessment of the effects of nonpoint source pollution on the biotic integrity of Walnut Creek, and the role of riparian vegetation in mitigating nonpoint source pollution. U.S. EPA, August 1992 - July 1995 ($325,000)

PUBLICATIONS

Gaines, M. S. and **M. L. Johnson**. 1982. Home range size and population dynamics in the prairie vole, *Microtus ochrogaster*. *Oikos* 39:63-70.

Abdellatif, E., K. B. Armitage, M. S. Gaines, and **M. L. Johnson**. 1982. The effect of watering on a prairie vole population. *Acta Theriologica* 27:243-255.

Gaines, M. S. and **M. L. Johnson.** 1984. A multivariate study of the relationship between dispersal and demography in populations of *Microtus ochrogaster* in eastern Kansas. *American Midland Naturalist* 111:223-233.

Johnson, M. L. and M. S. Gaines. 1985. The selective basis for emigration of the prairie vole *Microtus ochrogaster*: Open field experiment. *Journal of Animal Ecology* 54:399-410.

Gaines, M. S., C. L. Fugate, **M. L. Johnson**, D. C. Johnson, J. R. Hisey, and D. Quadagno. 1985. Manipulation of aggressive behavior in male prairie voles (*Microtus ochrogaster*) implanted with testosterone in silastic tubing. *Canadian Journal of Zoology* 63:2525-2528.

Danielson, B. J., **M. L. Johnson**, and M. S. Gaines. 1986. An analysis of a method for comparing residents and colonists in a natural population of *Microtus ochrogaster*. *Journal of Mammalogy* 67:733-736.

Johnson, M. L. and M. S. Gaines. 1987. The selective basis for dispersal of the prairie vole, *Microtus ochrogaster*. *Ecology* 68:684-694.

Gaines, M. S. and **M. L. Johnson**. 1987. Phenotypic and genotypic mechanisms for dispersal in *Microtus* populations and the role of dispersal in population regulation. In, B. D. Chepko-Sade and Z. Halpin (eds.). Mammalian Dispersal Patterns: The Effect of Social Structure on Population Genetics. The University of Chicago Press, Chicago, IL.

Boonstra, R., C. J. Krebs, M. S. Gaines, **M. L. Johnson**, and I. M. T. Craine. 1987. Natal philopatry and breeding systems in *Microtus*. *Journal of Animal Ecology* 56:655-673.

Johnson, M. L. and M. S. Gaines. 1988. Demography of the western harvest mouse, *Reithrodontomys megalotis*, in eastern Kansas. *Oecologia* 75:405-411.

Johnson, M. L. 1989. Exploratory behavior and dispersal: a graphical model. Canadian *Journal of Zoology* 67:2325-2328.

Hedrick, P. W., M. S. Gaines, and **M. L. Johnson**. 1989. Owl feeding habits on small mammals. *Occasional Papers of the Museum of Natural History* 133:1-7.

Gaines, M. S., E. M. Abdellatif, **M. L. Johnson**, and K. B. Armitage. 1990. The effect of aggression on dispersal and related demographic parameters in *Microtus ochrogaster* populations in Eastern Kansas. In, R. H. Tamarin, R. S. Ostfeld, S. R. Pugh, and G. Bujalska, (eds.). Social Systems and Population Cycles in Voles. Birkhauser Verlag, Basel

Johnson, M. L. and M. S. Gaines. 1990. Evolution of dispersal: theoretical models and tests using birds and mammals. *Annual Review of Ecology and Systematics* 21:449-480.

Gaines, M. S., N. C. Stenseth, **M. L. Johnson**, R. A. Ims, and S. Bondrup-Nielson. 1991. A response to solving the enigma of population cycles with a multifactorial prespective. *Journal of Mammalogy* 72:627-631.

Johnson, M. L., D. G. Huggins, and F. deNoyelles. 1991. Ecosystem modeling with LISREL: A new approach for measuring direct and indirect effects. *Ecological Applications* 1:383-398.

Gaines, M. S., G. R. Robinson, R. D. Holt, **M. L. Johnson**, and J. E. Diffendorfer. 1992. The effects of habitat fragmentation on small mammal populations. In, D. R. McCullough and R. H. Barrett (eds.). Wildlife 2001: Populations. Elsevier Science Publishers, Ltd., London.

Robinson, G. R., R. D. Holt, M. S. Gaines, S. P. Hamburg, **M. L. Johnson**, H. S. Fitch, and E. A. Martinko. 1992. Diverse and contrasting effects of habitat fragmentation. *Science* 257:524-526.

Huggins, D. G. and **M. L. Johnson**. 1992. Ecological consequences of the control and elimination of macrophytes in small ponds by atrazine and grass carp. In, Proceedings from the Regional Lake Management Conference, North American Lake Management Society. June 1991.

Johnson, M. L., D. G. Huggins, and F. deNoyelles, Jr. 1993. Structural equation modeling and ecosystem analysis. In, R. L. Graney, J. H. Kennedy, and J. H. Rodgers, Jr. (eds.). Aquatic Mesocosm Studies in Ecological Risk Assessment. Lewis Publishers, Boca Raton, FL.

Huggins, D. G., **M. L. Johnson**, and F. deNoyelles, Jr. 1993. The effect of atrazine on aquatic ecosystems: An assessment of direct and indirect effects using structural equation modeling. In, R. L. Graney, J. H. Kennedy, and J. H. Rodgers, Jr. (eds.). Aquatic Mesocosm Studies In Ecological Risk Assessment. Lewis Publishers, Boca Raton, FL.

Johnson, M. L., L. Holmes, A. Salveson, M. S. Denison, and D. M. Fry. 1998. Environmental estrogens in agricultural drain water from the Central Valley of California. Bulletin of Environmental Contamination and Toxicology 60:609-614.

Venkatram, A., L. Burns, C. Chen, J. Irwin, and **M. Johnson**. 1998. Model testing and validation. In, K. H. Reinert, S. M. Bartell, G. R. Biddinger (eds.). Ecological Risk Assessment Decision-Support System: A Conceptual Design. Proceedings from SETAC Ecological Risk Assessment Modeling Workshop; 1994 Aug 23-28; Pellston MI. Pensacola FL: Society of Environmental Toxicology and Chemistry. 120 p.

Pagel, J. E., D. A. Bell, and **M. L. Johnson**. 1998. When is an endangered species recovery complete: Is de-listing the American Peregrine Falcon appropriate? Proceedings of the 63rd Transactions of the North American Wildlife Conference.

Hansen, L. J. and **M. L. Johnson**. 1999. Conservation and Toxicology: Integrating the disciplines. *Conservation Biology* 13:1225-1227.

Hansen, L. J. and **M. L. Johnson**. 1999. Conservation and Toxicology: The need to integrate the disciplines. *Environmental Toxicology and Chemistry* 18:2121-2122.

Scow, K. M., G. E. Fogg, D. E. Hinton, and **M. L. Johnson**, eds. 2000. Integrated Assessment of Ecosystem Health. Lewis Publishers, Boca Raton, FL. (Book Editor)

Mayfield, R. L., D. Van Vuren, and **M. L. Johnson**. 2000. Demography of an insular endemic rodent, Peromyscus maniculatus santacruzae, on Santa Cruz Island. *Southwestern Naturalist* 45:508-513.

Van Vuren, D., **M. L. Johnson**, and L. Bowen. 2001. Impacts of feral livestock on island watersheds. *Pacific Science* 55:285-289.

Torres, K. C. and **M. L. Johnson**. 2001. Bioaccumulation of metals in plants, arthropods, and house mice in a seasonal wetland. *Environmental Toxicology and Chemistry* 20:2617-2626.

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Appendix II: Cooperators

Appendix III: Supporters