Optimizing a Tailwater Return System

To Improve Water Quality

A Research Proposal Prepared by

The California Water Institute
California State University, Fresno, Foundation

In Collaboration With

The Del Puerto Water District

January 11, 2005

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Project Information Form

Applying for: ❑ Urban ◆ Agricultural

1. (Section A) Urban or Agricultural Water Use Efficiency Implementation Project

   ❑ (a) implementation of Urban Best Management Practice, #_____
   ❑ (b) implementation of Agricultural Efficient Water Management Practice, #_____
   ❑ (c) implementation of other projects to meet California Bay-Delta Program objectives, Targeted Benefit # or Quantifiable Objective #, if applicable _____
   ❑ (d) Specify other: _____

2. (Section B) Urban or Agricultural Research and Development; Feasibility Studies, Pilot, or Demonstration Projects; Training, Education or Public Information; Technical Assistance

   ◆ (e) research and development, feasibility studies, pilot, or demonstration projects
   ❑ (f) training, education or public information programs with statewide application
   ❑ (g) technical assistance
   ❑ (h) other

3. Principal applicant (Organization or affiliation): California State University, Fresno

4. Project Title: Optimizing a Tailwater Return System to Improve Water Quality

5. Person authorized to sign and submit proposal and contract:

   Name, title: Thomas McClanahan, VP Grants and Research/Pete Prestegard, Chief Financial Officer/CSU Foundation

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	E-mail	mmcclana@csufresno.edu
7. Grant funds requested (dollar amount): *(from Table C-1, column VI)*		$1,027,779
8. Applicant funds pledged (dollar amount):		$102,219
9.Total project costs (dollar amount): *(from Table C-1, column IV, row n)*		$1,061,882
10. Percent of State share requested (%) *(from Table C-1)*		91
11. Percent of local share as match (%) *(from Table C-1)*		9

12. Is your project locally cost effective?

Locally cost effective means that the benefits to an entity (in dollar terms) of implementing a program exceed the costs of that program within the boundaries of that entity.

(If yes, provide information that the project in addition to Bay-Delta benefit meets one of the following conditions: broad transferable benefits, overcome implementation barriers, or accelerate implementation.)

❑ (a) yes

◆ (b) no

11. Is your project required by regulation, law or contract? If no, your project is eligible.

If yes, your project may be eligible only if there will be accelerated implementation to fulfill a future requirement and is not currently required.

Provide a description of the regulation, law or contract and an explanation of why the project is not currently required.

❑ (a) yes

◆ (b) no

_____

_____

_____

_____

_____

12. Duration of project (month/year to month/year):	Jan 2006 to Dec. 2008
13. State Assembly District where the project is to be conducted:	District 9
14. State Senate District where the project is to be conducted:	District 6
15. Congressional district(s) where the project is to be conducted:	California 18
16. County where the project is to be conducted:	Stanislaus
17. Location of project (longitude and latitude)	N37 22.499 W121 05.661
18. How many service connections in your service area (urban)?	n/a
19. How many acre-feet of water per year does your agency serve?	Del Puerto WD delivers 90,000 AF/year

20. Type of applicant (select one):

❑ (a) City

❑ (b) County

❑ (c) City and County

❑ (d) Joint Powers Authority

❑ (e) Public Water District

❑ (f) Tribe

❑ (g) Non Profit Organization

◆ (h) University, College

❑ (i) State Agency

❑ (j) Federal Agency

❑ (k) Other

- ❑ (i) Investor-Owned Utility
- ❑ (ii) Incorporated Mutual Water Co.
- ❑ (iii) Specify _____

21. Is applicant a disadvantaged community? If 'yes' include annual median household income.

    (Provide supporting documentation.)

❑ (a) yes, _____ median household income

◆ (b) no

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Signature Page

By signing below, the officials declare the following:

The truthfulness of all representations in the proposal;

The individuals signing the form have the legal authority to submit the proposal on behalf of the applicant;

There is no pending litigation that may impact the financial condition of the applicant or its ability to complete the proposed project;

The individuals signing the form have read and understood the conflict of interest and confidentiality section and waive any and all rights to privacy and confidentiality of the proposal on behalf of the applicant;

The applicant will comply with all terms and conditions identified in this PSP if selected for funding; and

The applicant has legal authority to enter into a contract with the State.

_____	_____	_____
Signature	Name and title	Date
_____	_____	_____
Signature	Name and title	Date

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Optimizing a Tailwater Return System To Improve Water Quality

Executive Summary

The goal of this research project is to determine the optimal combination of farm-level water management practices for improving irrigation efficiency and enhancing water quality in conjunction with operation of a tailwater return system. We will examine farm-level strategies for reducing surface runoff and sediment loss during furrow irrigation events in the northwest portion of the lower San Joaquin Valley, where reductions in salt and sediment loads are needed to improve water quality. We will examine also the use of microsprinklers on walnuts.

Many farmers can reduce or eliminate surface runoff leaving their farms by installing tailwater return systems and re-using the water for irrigation, or by using microsprinklers instead of furrow irrigation. The initial cost of installing a tailwater return system or microsprinklers and the annual operation and maintenance costs can be substantial. We hypothesize that the annual costs of operating and maintaining a tailwater return system can be reduced substantially by improving irrigation practices to reduce surface runoff and sediment loss. Improvements also might enable farmers to generate greater values with their limited water supplies.

We will examine the following water management practices: 1) using polyacrylamide (PAM) to improve infiltration and reduce sediment loss, 2) reducing furrow length to reduce surface runoff, and 3) using microsprinklers instead of furrow irrigation. We will measure the volume of water captured in a tailwater return system and re-used for subsequent irrigation events. We will measure the salt and sediment loads in applied water and surface runoff, and we will estimate the reduction in loads discharged to the San Joaquin River. We will describe the farm-level economic implications of the practices we examine and we will present our results to farmers at regional workshops conducted in conjunction with the Westside San Joaquin River Watershed Coalition.

We will work with a cooperating farmer to compare improved irrigation practices with traditional methods in a 700-acre study area. We expect to capture 590 acre-feet of water (30% of historical use) in the tailwater return system in the first year of the study. Assuming a salt content of 400 parts per million (total dissolved solids), if the farmer re-uses that water for irrigation, the salt load leaving the farmer's property in surface runoff would be reduced by 321 tons. The farmer also would gain flexibility regarding the scheduling of water diversions from the Delta-Mendota Canal, both within a season and from one year to the next. The reduction in salt and sediment loads will contribute to improving water quality in Orestimba Creek and the lower San Joaquin River.

Optimizing a Tailwater Return System To Improve Water Quality

Statement of Work

A. Relevance and Importance

Objectives

The goal of this research project is to determine the optimal combination of farm-level water management practices for improving irrigation efficiency and enhancing water quality in conjunction with operation of a tailwater return system. In particular, we will examine farm-level strategies for reducing surface runoff and sediment loss during furrow irrigation events. Smaller volumes of surface runoff and smaller sediment loads will reduce the cost of owning and operating a tailwater return system. Such systems enable farmers to reduce substantially the discharge of salt, sediment, and pesticides from irrigated lands into surface waterways. We will conduct our research in the northwest portion of the lower San Joaquin Valley.

The farm-level strategies we examine, when implemented in conjunction with a tailwater return system, will enhance long-term diversion flexibility and reduce the discharge of salt, boron, sediment, and pesticides into Crow Creek, Orestimba Creek, and the San Joaquin River. Hence our research will contribute to improving water quality in Orestimba Creek and the San Joaquin River from its confluence with the Merced River to the South Delta Boundary. Both of these waterbodies appear on California's 303(d) List of Water Quality Limited Segments. Orestimba Creek flows into the San Joaquin River near the town of Crows Landing.

We will examine four farm-level water management practices that can be implemented in conjunction with a tailwater return system to optimize the capture and re-use of surface runoff: 1) shortening the length of furrow irrigation sets to reduce surface runoff, using gated pipe to deliver water to the lower ends of irrigated fields, 2) applying polyacrylamide (PAM) during furrow irrigation events to improve infiltration and reduce sediment loss, 3) using microsprinklers to irrigate a walnut orchard, and 4) optimizing the combined use of water supply from a delivery canal and surface runoff captured in a tailwater reservoir. We will install a tailwater return system that collects surface runoff from several fields planted in different crops. We will work with a cooperating farmer to determine the combination of management practices that will reduce effluent discharge, while also improving the productivity of applied water, at reasonable cost.

We will collect and analyze a large amount of field-level information describing the impacts of changes in water management practices on the volume

of surface runoff and the amount of sediment generated during irrigations. We will record all costs of constructing, operating, and maintaining the tailwater return system and the costs of applying polyacrylamide. We will also record any impacts on other costs of production and any impacts on crop yields. These data will enable us to describe the farm-level economic implications of improving irrigation efficiency by implementing these improvements in water management practices. We will analyze water quality samples to determine the reductions in salt and sediment loads made possible by reducing surface runoff from irrigated fields.

Rationale

Improvements in water management are needed in the lower San Joaquin Valley and elsewhere to reduce the loads of salt, sediment, and other constituents discharged from agricultural lands to the San Joaquin River. Surface water return flows from irrigation in the region carry an estimated 101,659 tons of salt to the River each year (Oppenheimer and Leva, 2004, p. E-9). Of that amount, an estimated 81,544 tons of salt (80.2%) are discharged during the irrigation season, while 20,114 tons (19.8%) are discharged during the non-irrigation season. The Regional Water Quality Control Board for the Central Valley has adopted a Total Maximum Daily Load program (TMDL) for salt and boron in the lower San Joaquin River. The likelihood of achieving the goals of the TMDL program can be enhanced substantially by reducing surface runoff from irrigated lands.

Many farmers in the region have improved their water management practices by installing microsprinklers and drip irrigation systems, particularly when irrigating perennial crops and some vegetables. The volume of surface runoff from those systems probably is quite small. Most of the surface runoff that enters the San Joaquin River likely is generated on fields irrigated with gated pipe, siphon tubes, and other forms of surface irrigation. Those systems are used on a large area in the region, particularly on lands planted in alfalfa, beans, corn, tomatoes, and melons. Traditional sprinkler systems also are used in a substantial portion of the area to irrigate permanent crops and turfgrass. Some farmers use sprinklers for pre-plant and early seasonal irrigations of some annual crops. The volume of surface runoff generated when using sprinklers generally is less than the volume generated with surface methods, although careful management is required to achieve that result.

Reducing the volume of surface runoff leaving irrigated lands can be achieved by implementing one or more of the following strategies: 1) reducing the volume of water applied during irrigation events, 2) managing irrigations more carefully to minimize the volume of surface runoff, 3) capturing all surface runoff in a reservoir, 4) operating a tailwater return system that recirculates surface runoff for use in subsequent irrigation events, and 5) replacing surface irrigation methods with carefully managed drip and microsprinkler systems. We will examine strategies to improve water management on lands irrigated with surface

methods because the potential reduction in salt and sediment loads from those lands probably is greater than on lands where farmers already use sprinklers, microsprinklers, and drip systems.

We hypothesize that combinations of farm-level strategies will be most successful in improving irrigation management. For example, farmers who operate a tailwater return system will have an incentive to reduce the volume of surface runoff they generate to minimize the cost of operating and maintaining the system. Reducing surface runoff will minimize the amount of sediment that must be collected and removed from a tailwater collection reservoir each year, while also minimizing the amount of pumping required to return surface runoff to the head end of a field for re-use in irrigation. Tailwater return systems also provide farmers with clear evidence of the volume of surface runoff generated during irrigation events. Absent a collection reservoir, many farmers might not know how much surface runoff is generated. Those farmers might gain interest in improving irrigation management practices when they observe how much runoff is collected in a tailwater reservoir.

Farmers can reduce the amount of sediment leaving their fields by irrigating more carefully and by applying polyacrylamide to minimize the amount of soil carried away from furrows during irrigation events. Farmers operating tailwater return systems will be motivated to use polyacrylamide to reduce the rate at which their tailwater reservoirs fill with sediment. Farmers gaining experience with polyacrylamide might begin using it on other fields on which tailwater return systems are not installed. An increase in the areal extent of polyacrylamide use in the region might contribute substantially to reducing the amount of sediment entering the lower San Joaquin River and, consequently, to reducing the loads of nutrients and pesticides that adsorb to soil particles.

Consistency with Current Policies

The management practices we will examine are consistent with current policies and programs designed to improve irrigation efficiency and reduce effluent loads entering waterways in the San Joaquin Valley. The California Regional Water Quality Control Board for the Central Valley has adopted a Total Maximum Daily Load (TMDL) Program for Salt and Boron. The Regional Board also has adopted a Conditional Waiver Program that addresses nonpoint source pollution from agricultural lands in the San Joaquin Valley. Both of these policy decisions will require farmers and irrigation districts to redouble their efforts to reduce effluent discharge from irrigated lands.

Farm-level tailwater return systems internalize the management of surface runoff in a nearly complete fashion. Farmers can minimize and perhaps eliminate the surface discharge of effluent from their land by installing and operating tailwater return systems. Cost-effective operation of the systems will require improvements in water management that also contribute to reducing surface runoff

and sediment loads. If tailwater return systems are installed on all fields irrigated with surface irrigation methods, the loads of salt, sediment, and other constituents entering the San Joaquin River might be reduced substantially, as required by the Regional Water Quality Control Board.

We will implement this project in the Crow Creek Drainage District, which is contained largely within the service area of the Del Puerto Water District. The Drainage District includes lands that discharge surface runoff into Crow Creek, which empties into Orestimba Creek. The Regional Water Quality Control Board has identified Orestimba Creek as a source of effluent entering the San Joaquin River. Orestimba Creek also is listed individually as an impaired waterbody on California's 303(d) List of Water Quality Limited Segments and it appears also on a list of Preliminary Phase II Monitoring Sites pertaining to the Conditional Waiver Program for Irrigated Lands. The pollutants of concern in Orestimba Creek include azinphos-methyl, chlorpyrifos, and diazinon. Agriculture is a potential source for all of those pollutants. Reducing the discharge of surface runoff into Crow Creek will be helpful in improving water quality in Orestimba Creek and, subsequently, the San Joaquin River.

Support for Calfed Water Use Efficiency Program Goals

The area drained by Crow Creek and Orestimba Creek is within Sub-Region 10, the Valley Floor West of the San Joaquin River. Our project will contribute to achieving the following Targeted Benefits in Sub-Region 10:

Targeted Benefit	Location	Category of Targeted Benefit	Beneficiaries
98	San Joaquin River	Reduce native constituents to enhance and maintain beneficial uses of water	Ecosystem and municipal and industrial users
100	Orestimba Creek	Reduce pesticides to enhance and maintain beneficial uses of water	Ecosystem and municipal and industrial users
101	San Joaquin River	Reduce pesticides to enhance and maintain beneficial uses of water	Ecosystem and municipal and industrial users
104	San Joaquin River at Vernalis	Reduce salinity to enhance and maintain beneficial uses of water	Ecosystem and municipal and industrial users
106	All affected lands	Decrease flows to salt sinks to increase the water supply for beneficial uses	Ecosystem and municipal and industrial users
108	All affected lands	Provide long-term diversion flexibility to increase water supply for beneficial uses	Ecosystem and municipal and industrial users

We will contribute to Targeted Benefits 98 and 104 by reducing the volume of surface runoff entering Orestimba Creek and the San Joaquin River. The surface runoff contains salt and boron. We will estimate the reduction in salt load achieved by improving water management and capturing surface runoff in the tailwater return system. The management practices we examine might be implemented by many farmers on the west side of the San Joaquin Valley in efforts to achieve the load reductions required by the TMDL Program for Salt and Boron that has been adopted for the lower San Joaquin River.

We will contribute to Targeted Benefits 100 and 101 by reducing the sediment in surface runoff and in discharges to Orestimba Creek and the San Joaquin River. We will reduce in particular the discharge of pesticides that adsorb to soil particles. We will collect and analyze water samples for sediment content. We expect to reduce sediment loads in two ways: 1) applying polyacrylamide to irrigated furrows to reduce the sediment load in each acre-foot of surface runoff, and 2) shortening furrow lengths to reduce the volume of surface runoff generated during irrigation events. We will use results of the water quality analysis to estimate the reductions in sediment loads achieved during the study.

We will contribute to Targeted Benefits 106 and 108 by encouraging greater re-use of surface runoff in the region. Farmers operating tailwater return systems can reduce their diversions from water delivery canals at some times during the irrigation season. This creates the opportunity to reschedule water for delivery at other times when the incremental value might be enhanced. For example, some farmers might gain greater flexibility regarding the allocation of water between pre-irrigation, seasonal, and post-season irrigations. Some farmers also might gain the opportunity to re-schedule water deliveries from one crop year to the next by re-using their surface runoff for irrigation. Re-scheduling can enhance the regional economic values generated with limited water supplies by enabling farmers to maximize the incremental values of applied water.

B. Technical / Scientific Merit, Feasibility

Overview

We will install a tailwater return system at the lower end of a set of farm fields in the Crow Creek Drainage District. The system will be large enough to collect surface runoff from about 700 acres of irrigated lands operated by a single individual. That farmer will work with us to implement a set of management activities designed to improve irrigation efficiency, reduce surface runoff from irrigated fields, and reduce the volume of surface runoff entering Crow Creek. The management activities will include using polyacrylamide, reducing the length of furrows, and using gated pipe for selected irrigation events. We will compare also the surface runoff generated on the farmer's walnut orchards irrigated with surface methods and microsprinklers.

Reducing the length of furrows enables farmers to use shorter set times for irrigation events, while improving distribution uniformity and reducing surface runoff. Many farmers in the Broadview Water District implemented this practice to reduce irrigation deliveries when their water supply became limiting in the early 1990s (Wichelns *et al*., 1996). The cost of irrigation increases when using shorter furrow lengths. A gated pipeline is required and more labor is needed to manage the additional points at which water is placed in the furrows. Some land is lost to production when shorter furrow lengths are implemented by placing two additional ditches in the middle of a field (one tailwater ditch and one head ditch). The loss of land can be avoided by using a line of gated pipe in place of the head ditch and eliminating the tailwater ditch. Any excess water in furrows on the upper end of the field will flow beneath the gated pipe, contributing to irrigation of the lower end of the field. We will examine this alternative in our study.

Polyacrylamide (PAM) has been shown to increase infiltration and reduce surface runoff from furrow-irrigated fields by as much as 90% (Lentz and Sojka, 2000). Farmers using PAM can reduce soil nutrient losses, increase nutrient use efficiency, and reduce the loads of nitrogen and phosphorous discharged to receiving waters (Lentz *et al*. 2001). The reactive phosphorous in surface runoff has been reduced by more than 75% by applying PAM in furrows during irrigation events (Entry and Sojka, 2003). The estimated cost of applying PAM ranges from $7 to $13 per hectare, or from $2.83 to $5.26 per acre (Entry and Sojka, 2003). Thus farmers can apply PAM for just a small increment in the total cost of producing crops in the San Joaquin Valley.

PAM also is effective in improving infiltration and reducing runoff and sediment loss from sprinkler irrigated fields (Bjorneberg and Aase, 2000; Santos *et al*., 2003). Hence, successful demonstration of PAM's effectiveness on field crops in the study region might encourage farmers using sprinklers to include PAM application as a management practice. We will examine the use of PAM on a

walnut orchard irrigated with microsprinklers and we will compare the surface runoff from that field with surface runoff from a furrow-irrigated orchard.

Site Description

The research site is located about one mile southeast of the town of Crows Landing in the Crow Creek Drainage District (Figure 1). Irrigation service to lands in the study area is provided by the Del Puerto Water District, which is a collaborator on this research proposal. We have selected a set of nine farm fields that are each about 80 acres in size (Figure 2). The fields extend eastward from the Delta-Mendota Canal to Medlin Road. The southern boundary of the fields is about one-quarter mile north of Anderson Road, while the northern boundary is about one-half mile south of Fink Road.

Walnuts are planted on three of the fields (Fields 4, 5, and 6) and alfalfa is planted on one field (Field 2). Crops planted on the remaining five fields during the course of the study will include dry beans, melons, and tomatoes. Irrigation water is obtained directly from turnouts on the Delta-Mendota Canal and from farmer-operated wells. We will record all water deliveries to individual fields. Deliveries will include surface water from the Delta-Mendota Canal, groundwater, and surface runoff captured in the tailwater return system. We will install the meters and other devices needed to measure field-specific water deliveries.

The site is considered to be prime farmland, with a slope of about 0.8%. The land slopes from west to east, falling from the Delta-Mendota Canal toward the San Joaquin River. Soils on the site include: 1) Vernalis clay loam, 2) the Vernalis-Zacharias complex, and 3) Capay clay. These soils are very deep brown clay loams that are well drained to moderately well drained, on slopes of less than 1%. The available water capacity is high. These soils generally are used for row, field, and orchard crops.

The Crow Creek Drain passes through the study area in the form of an underground pipeline. The Drain collects surface runoff from lands within and upslope of the study area. The Drain empties into Orestimba Creek at a distance of about 1.25 miles from the eastern border of the study area. One goal of our study is to reduce the volume of surface runoff entering the Crow Creek Drain during the irrigation season. We will estimate the reductions in surface runoff, sediment load, and salt load entering Crow Creek.

Environmental Documentation

This research project will be implemented on agricultural land. We will install a tailwater return system that enables a farmer to re-use surface runoff and we will examine improvements in farm-level irrigation practices. It is our understanding that environmental documentation is not necessary for such a research project.

Research Design

We will install a tailwater settling pond (reservoir) and pump station at the lower end of Field 8, just north of Medlin Road (Figure 3). The reservoir will be capable of capturing surface runoff from Fields 1 through 5 and 7 through 10. The runoff from Field 6 will not be captured. We will install underground pipelines that will carry water from the reservoir uphill to the head ends of Fields 1 and 3. The farmer will be able to place the returned surface runoff into his delivery system at the upper ends of his fields. This will enable the farmer to optimize the use of surface runoff captured in the reservoir. For example, the farmer will be able to use surface runoff from an irrigation event on Field 4 to supplement a subsequent irrigation event on Field 6. We will record how the farmer uses the captured surface runoff throughout each irrigation season.

We will compare the volume and turbidity of surface runoff generated during irrigation events on fields with and without improvements in management practices. To the extent possible, we will establish comparisons on fields with the same crop, but different irrigation practices. For example, we will compare the surface runoff generated when irrigating dry beans with conventional furrows and no PAM to the surface runoff generated when using shorter furrows or PAM. We will also compare surface runoff and sediment loss on walnut orchards irrigated with microsprinklers and traditional surface methods.

Some of the details of the research design will be established as we proceed because we are working with a cooperating farmer. His decisions regarding crops and cultural practices will reflect market conditions. We will prepare to analyze as many combinations of improvements in practices as possible by installing metering devices that will enable measurement of water deliveries and surface runoff on all fields within the study area. Although it is customary to prepare a firmly established experimental design prior to embarking on a research project, we believe some degree of adaptability will be optimal in this situation. Our goal is to examine the potential for reducing surface runoff and sediment loss on farms in a region where improvements in irrigation efficiency and water quality are needed. We are confident that by working with a cooperating farmer we will be able to identify and examine strategies that might contribute to those goals. We look forward to adapting our research design somewhat, over time, as we gain information from our empirical results and from our interactions with the cooperating farmer.

An Irrigation Specialist at the California Water Institute will work closely with Del Puerto Water District staff, the cooperating farmer, and the Field Technician to determine the optimal design of water management comparisons before the start of each irrigation season. Some of the comparisons we will evaluate are described in the following section of this proposal.

Comparison of Management Practices

1. Using Polyacrylamide with Furrow Irrigation

We will establish every year a two-field comparison in which polyacrylamide (PAM) is applied during selected irrigation events on one of the fields. We will measure the volume of water applied on both fields throughout the irrigation season. We will observe the volume of surface runoff generated on each field and we will collect water quality samples to measure salt, boron, and sediment content in the runoff. We will record the costs of applying PAM and we will discuss any management issues regarding PAM with the cooperating farmer. We will conduct such a comparison in all three years of the study. The fields and crops might change during the study as a result of changes in the cooperating farmer's cropping pattern.

2. Reducing the Length of Furrows

We will establish a two-field comparison in which the cooperating farmer reduces the length of furrows (irrigation runs) on one of the fields by placing a line of gated pipe across the midpoint of the field. This practice increases water use efficiency by improving distribution uniformity, and reducing both seepage and surface runoff. We will measure the volume of water applied to both fields and we will observe the rate of surface runoff. We will collect water quality samples to measure the salt, boron, and sediment in the surface runoff from both fields. We will record the costs of using gated pipe to reduce furrow length and we will discuss any management issues regarding this practice with the cooperating farmer. We will conduct such a comparison in all three years of the study. The fields and crops might change during the study as a result of changes in the cooperating farmer's cropping pattern.

3. Using Microsprinklers to Irrigate Walnuts

We will compare the volume of water applied on three walnut orchards (fields) irrigated with surface methods to the volume of water applied on a similar orchard (field) irrigated with microsprinklers. We will examine also the impact of reducing furrow length on one of the surface-irrigated walnut orchards and the impact of using PAM on another. We will measure the volume of water applied to all fields and we will observe the rates of surface runoff. We will collect water quality samples to measure salt, boron, and sediment content in the runoff from all fields. We expect there will be little or no surface runoff from the orchard irrigated with microsprinklers. We will examine the costs of using microsprinklers and we will discuss any management issues regarding this practice with the cooperating

farmer. We will conduct these comparisons in all three years of the study, provided the walnut orchards remain in production.

Summary of Comparisons of Management Practices

We will conduct the following comparisons of management practices during all three years of this research project.

Management Practice	The Comparison	Crops Involved
Using Polyacrylamide	Traditional irrigation vs. using PAM for some irrigation events	Dry beans, tomatoes, melons, and/or other vegetables
Using Polyacrylamide	Traditional irrigation vs. using PAM for some irrigation events	Walnuts
Shortening Furrows	Traditional irrigation vs. shortening furrow lengths using gated pipes	Dry beans, tomatoes, melons, and/or other vegetables
Shortening Furrows	Traditional irrigation vs. shortening furrow lengths to reduce surface runoff	Walnuts
Using Microsprinklers	Surface irrigation vs. microsprinklers	Walnuts

The crops and fields involved in our comparisons of management practices will change over time with changes in the cooperating farmer's cropping pattern. We will establish the ability to measure field-specific water deliveries on all fields in the study area, so we can conduct comparisons on any fields. We will examine the volume and quality of surface runoff in all three seasons. That activity is largely independent of the distribution of crops and irrigation methods within the study area.

We will make incremental improvements in the research design over time in response to information we receive from three sources: 1) discussions with the cooperating farmer, 2) input we receive during workshops with other farmers in the region, and 3) observations of the Field Technician. In our view this adaptive approach to examining water management practices will enhance the value of information we develop. Farmers and water district personnel will view our

comparisons and the results we obtain more favorably if we incorporate their insight and suggestions as we design comparisons for years 2 and 3.

Schedule of Tasks and Deliverables

We will implement the project during three years. We will construct the tailwater return system and install flow meters during the early portion of the first year. We will gather and analyze information regarding management practices in all three years. The complete schedule of tasks and deliverables is shown below. We assume a project start date of January 1, 2006 with an ending date of December 31, 2008.

Task	Description	Schedule
2006		
1	Conduct the design and survey work for the tailwater return system	Jan. 2006 to Mar. 2006
2	Solicit proposals for constructing the system	Mar 2006 to Apr. 2006
3	Construct the tailwater return system and install flow measuring devices	May 2006 to June 2006
4	Begin collecting surface runoff, measuring field-specific water deliveries, and taking water quality samples for laboratory analysis	June 2006 to Aug. 2006
5	Begin comparing water management practices	July 2006 to Aug. 2006
6	Analyze information from the 2006 season	Sep. 2006 to Dec. 2006
7	Conduct outreach and communication	Sep. 2006 to Dec. 2006
8	Prepare annual report (deliverable)	Nov. 2006 to Dec. 2006
2007		
9	Make plans for comparisons in 2007 season	Dec. 2006 to Jan. 2007
10	Implement comparisons in the 2007 season	Mar. 2007 to Aug. 2007
11	Collect water flow and quality data for 2007	May 2007 to Aug.2007
12	Analyze information from the 2007 season	Sep. 2007 to Dec. 2007
13	Conduct outreach and communication	Sep. 2007 to Dec. 2007
14	Prepare annual report (deliverable)	Nov. 2007 to Dec. 2007
2008		
15	Make plans for comparisons in 2008 season	Dec. 2007 to Jan. 2008
16	Implement comparisons in the 2008 season	Mar. 2008 to Aug. 2008
17	Collect water flow and quality data for 2008	May 2008 to Aug.2008
18	Analyze information from the 2008 season	Sep. 2008 to Dec. 2008
19	Conduct outreach and communication	Sep. 2008 to Dec. 2008
20	Prepare final report (deliverable)	Nov. 2008 to Dec. 2008

C. Monitoring and Assessment

Overview

The goal of our monitoring and assessment program is to generate a comprehensive set of information that will enable farmers, district staff, and water agency personnel to gain valuable insight regarding the potential to improve water productivity and water quality by implementing selected water management practices. We will demonstrate those practices in collaboration with a farmer who has been irrigating crops on the west side of the San Joaquin Valley for many years. He has agreed to work with us in establishing companion fields on which we will compare his traditional irrigation methods with practices we recommend for reducing applied water, surface runoff, and sediment loss. We will work together to establish comparisons in which most cultural practices are the same on both fields, except for the practices we are examining.

We will evaluate the farm-level and regional implications of improvements in water management practices by collecting and analyzing field-level data during three irrigation seasons. We will compare the amount of water applied and the volume and quality of surface runoff generated on fields that have been irrigated using traditional and improved management practices. We will describe also any differences in crop yields and costs of production that might be attributable to differences in management practices. We will also characterize and compare the distribution uniformity of irrigation events using satellite images of irrigated fields. We will record the volume of water collected in the tailwater reservoir and returned to the upper ends of fields for re-use in irrigation. We will estimate the value of water collected in the reservoir using current prices for water in the region.

Measuring Applied Water

Most of the water applied to fields in the study area is diverted directly from one of three turnouts on the Delta-Mendota Canal. Diverted water is placed in farmer-owned ditches and delivered by farmers to one or more fields as needed during the irrigation season. The Del Puerto Water District determines water charges for farmers using meters installed at the turnouts on the Delta-Mendota Canal. The District does not own or operate any secondary or tertiary canals and it does not manage or record field-specific water deliveries.

The goals of this project require that we measure the volume of water applied to each field. Hence, we will install field-level meters at six locations in the study area. The meters will enable us to measure field-specific water deliveries during the irrigation season.

We will also install meters on seven irrigation wells that might be used by the cooperating farmer during the project. The farmer’s primary source of

irrigation water is his allocation from the Central Valley Project, delivered through the Delta-Mendota Canal. The farmer uses groundwater only in years when his allotment of CVP water is not sufficient for irrigating all of his fields. It is likely that one or more wells will be used during the course of the project, given that the District expects to receive only 65% of its contractual supply in normal water years. When groundwater is used for irrigation we will measure the volume and we will obtain a water quality sample to determine the EC and boron content.

Summary of Water Sample Collection and Analysis

We will collect and analyze water samples obtained from the following sites in each year of the research project. Water samples will be analyzed at the Soil and Water Quality Laboratory at the California Water Institute. Our goal is to determine the salt, boron, and sediment content of each water sample. The analytes measured will be TDS, TSS, turbidity, and Boron. The data will be used to calculate changes in salt, boron, and sediment loads made possible by implementing improvements in farm-level water management practices.

Sample Category	Location	Frequency	Number Per Year
DMC Turnouts (3)	Turnouts from the DM Canal	Four times during the season	12
Irrigated Fields	Head ends of irrigated fields	Five samples each in 7 fields	35
Irrigated Fields	Tail ends of irrigated fields	Five samples each in 7 fields	35
Groundwater for Irrigation	Each of 7 wells in the study area	Beginning and end of season	14
Tailwater Return	Delivery point of the TWRS	Twice a week during the season	36
Inflow to Crow Creek	Site above the study area	Once per week during the season	18
Discharge to Crow Creek	Discharge point from study area	Once per week during the season	18

As shown above, we will collect 168 water samples each year to assess the water quality impacts of the management practices we examine. We will collect and

analyze additional samples to ensure quality control. Hence we will analyze a total of 200 samples per year.

DMC Turnouts:	There are three turnouts and we will collect one sample from each turnout, four times during the eighteen week irrigation season (12 samples).
Head ends of Irrigated Fields:	We plan to conduct comparisons on 7 fields each season. If we collect water samples during 5 irrigation events on each field, we will collect 35 water samples.
Tail ends of Irrigated Fields:	We plan to conduct comparisons on 7 fields each season. If we collect water samples during 5 irrigation events on each field, we will collect 35 water samples.
Groundwater for Irrigation:	There are 7 irrigation wells in the study area. The farmer uses groundwater only when his surface water supply is not sufficient for irrigation. We will obtain water samples when the wells are first being used, and before they are shut off. We expect to obtain 14 samples per season.
Tailwater Return:	We plan to collect water samples from the return flow twice a week. During the 18-week season we will collect 36 samples.
Inflow to Crow Creek:	We will collect samples at a site just above the study area with a frequency of once per week during the irrigation season (18 samples).
Discharge to Crow Creek:	We will collect samples at the site where surface runoff leaves the study area with a frequency of once per week during the irrigation season (18 samples).

The Senior Researcher will compile results and estimate the loads of salt, boron, and sediment at all of the monitoring sites. She will estimate also the reduction in loads to Orestimba Creek and the San Joaquin River made possible by implementing the improved water management practices. That information will be shared with the Economist, who will calculate the average cost of reducing effluent loads.

Daily Measurements of Water Quality and Volume

We will establish a program of daily data collection that will be implemented by the Field Technician during the irrigation season. The Field Technician will carry an EC/TDS meter to measure water salinity in the field. He or she will carry also data recording sheets for noting flow rates, meter readings, and daily observations regarding irrigation events. The Senior Researcher and the Field Supervisor will design the data recording sheets. The Field Technician's daily data collection routine will include the following sites and information. He or she will also make notes concerning the weather, air temperature, and other pertinent observations.

Sites	Data to be Collected	Observations
Turnouts on the DMC	EC, DO, temperature, pH, flow (cfs), meter reading (AF)	Which fields are irrigated
Head ends of irrigated fields	EC, DO, temperature, pH, flow (cfs), meter reading (AF)	Irrigation practices
Tail ends of irrigated fields	EC, DO, temperature, pH, flow (cfs), meter reading (AF)	Surface runoff conditions
Groundwater wells	EC, DO, temperature, pH, flow (cfs), meter reading (AF)	Which fields are irrigated
Tailwater return points	EC, DO, temperature, pH, estimated flow	Which fields are irrigated
Inflow to Crow Creek	EC, DO, temperature, pH, estimated flow	Turbidity (visual estimation)
Discharge to Crow Creek	EC, DO, temperature, pH, estimated flow	Turbidity (visual estimation)

The information collected each day by the Field Technician will be very helpful in describing irrigation events and surface runoff conditions throughout the irrigation season. The Field Technician will have numerous opportunities to visit with irrigators and irrigation supervisors to discuss their activities and any issues

that arise regarding traditional or improved water management practices. This qualitative component of the research project will provide information that can be obtained only by implementing the project on farm fields with the cooperation of a farmer and his irrigation personnel.

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Qualifications of Applicants and Cooperators

The California Water Institute

The California Water Institute is an academic center of excellence for research, education, and analysis of policy issues regarding water resources. The Institute was established by the California State Legislature in the year 2000, and is based at the **California** State University, Fresno campus.

The mission of the California Water Institute is to improve the management of water and related natural resources. We accomplish this mission by describing and analyzing important policy issues regarding water resources in a manner that contributes to discussion and selection of public policy alternatives. We conduct applied, collaborative research that will enhance understanding of natural resource management. We also conduct educational programs, provide information to the public, and disseminate the results of our research and policy efforts.

Researchers at the California Water Institute are highly qualified technical experts and policy analysts who have examined issues involving water, energy, land, air, and other natural resources for many years, in California and throughout the world. Areas of expertise include water technology, hydrology, air and water quality, soil and water chemistry, water supply and demand, economics, and environmental science. Additional expertise is available in academic departments at the California State University, Fresno. Pertinent disciplines include, biology, chemistry, engineering, natural resources, agriculture, and economics.

The California Water Institute conducts its programs in an open, collaborative environment, without bias toward any parties involved in natural resource issues. The Institute seeks solutions that are consistent with scientific knowledge and technological developments, and with pertinent economic and policy considerations.

The Del Puerto Water District

The Del Puerto Water District is a California Special District formed under the provisions of Division 13 of the Water Code. The District encompasses about 45,000 acres of irrigable land along the west side of Stanislaus, San Joaquin and Merced Counties. The District extends from Vernalis in the north to Santa Nella in the south. Stanislaus County serves as the principal county for the District.

The District is under contract with the U.S. Bureau of Reclamation for its water supply, which is delivered from the Delta-Mendota Canal, a feature of the Central Valley Project. The District was organized on March 24, 1947 to obtain and deliver water to landowners within its geographical boundaries. On June 10, 1953 the District entered into a long-term water service contract with the Bureau.

The original District included only about 3,500 acres of farmland near Patterson. On March 1, 1995, the District was reorganized to include ten other local districts with similar water service contracts. Those contracts were assigned to Del Puerto Water District and subsequently renegotiated into a single contract that now provides for the delivery of up to 140,210 acre-feet of water annually to about 45,000 acres of farmland adjacent to the Delta-Mendota Canal.

The District's contractual entitlement is the sole source of water supply to its lands, though privately developed groundwater is available on a limited basis throughout the District. The District's use of its contractual supply is subject to California Water Code requirements, federal Reclamation law, place-of-use restrictions associated with the Bureau of Reclamation's State-issued water diversion permit, and shortages imposed under the provisions of its contract.

Unlike most water districts, Del Puerto does not have a delivery system to operate and maintain. All water is delivered "canal-side" from the Delta-Mendota Canal through metered turnouts licensed to the District by the federal government. The Delta-Mendota Canal is fed by water released from northern reservoirs such as Shasta and Folsom Reservoirs and pumped from the Sacramento-San Joaquin Delta through the Bureau of Reclamation's Tracy Pumping Plant.

Over the years, farmers in Del Puerto have produced more than 30 different commercial crops. Current major crops include almonds, tomatoes, apricots, dry beans, walnuts, alfalfa, grains, melons, cherries, citrus, broccoli, cauliflower and bell peppers. Perennial crops are grown on almost 20,000 acres in the District, while much of the remaining land is planted in alfalfa and high-value row crops such as tomatoes, beans, broccoli, and melons (DPWD 2003 Crop Report). Conservative estimates suggest that farmers in Del Puerto generate more than $60 million in annual gross farm income, supporting thousands of jobs (and families) directly and indirectly through their agricultural base.

The District received its full contractual supply for most of its first forty years. This has not been the case during the most recent 14 years. Drought conditions beginning in the early 1990's and legislative and regulatory restrictions

imposed on the Central Valley Project beginning in 1992 have caused persistent shortages in the District's water supply. While a full contract supply provides for about 3 acre-feet per irrigable acre, we estimate that in normal hydrological years, the Central Valley Project will provide the District with only 65% of its contract supply, or 2 acre-feet per irrigable acre.

Currently there are 243 direct landowners and 61 tenant water users in Del Puerto Water District. The average landholding is 185 acres, with ownership ranging from fewer than 20 acres to 640 acres. Tenant farming occurs on more than half of the land area, with tenancies ranging in size from 40 acres to just over 5,000 acres. Even in the case of large tenancies, the operators of lands within Del Puerto primarily are small family farmers or family partnerships that depend on farm income for their livelihoods.

The District is governed by a seven-person Board of Directors elected by division from among the landowners. The Manager is William Harrison, who assumed the role of General Manager and Secretary in 1977 from his father, Lawrence, who served in this position from the District's inception in 1947.

Del Puerto operates with a staff of just four persons because it does not have a delivery system to operate and maintain. The annual administrative budget is about $500,000. This administrative cost has remained stable for the last ten years, but water costs for the base contractual supply have risen from $4 to almost $40 per acre-foot. The cost of purchasing additional water to make up for shortfalls in contract supplies can exceed $150 per acre-foot in some years.

In recent years, Del Puerto has taken numerous steps to improve irrigation efficiency and reduce surface runoff. We have administered a $4,000,000 State Revolving Fund Loan that has enabled farmers to purchase equipment for about 80 on-farm irrigation improvement projects. The District also has implemented a $500,000 Proposition 13 grant to support 26 on-farm drainage reduction projects.

The programs we have implemented contribute to improving irrigation efficiency and enhancing water quality. Higher technology irrigation systems enable farmers to generate greater value with their limited water supplies. At the same time, reducing drainage water volume is essential in addressing San Joaquin River water quality standards. By implementing additional on-farm projects like these, Del Puerto Water District expects to substantially reduce the volume of surface runoff from farmland in the District.

Mary McClanahan, Co-Principal Investigator

Ms. McClanahan is Senior Researcher of Natural Resources with the California Water Institute. She has over 25 years experience in the field of natural resource assessment and management. She has served as Principal Investigator and Co-Principal Investigator on numerous projects. She has managed staff and budgets on many technical projects, including soils/vadose zone investigations, water quality monitoring, establishment and assessment of BMPs to reduce agricultural runoff, riparian habitat identification and plant community mapping, studies of rivers and tributaries to identify contaminants and sources, and investigation of plant and animal populations in wildlands.

Ms. McClanahan has developed, managed, and conducted research projects assessing impacts to terrestrial and riparian systems, and authored restoration plans for highly altered ecosystems in California and throughout the United States. As part of this work, she has supervised technical staff and coordinated with scientists, clients, and legal representatives. Her research has focused on restoration ecology and ecological relationships in terrestrial, riparian, and microbial communities. Other research projects have included vadose zone analysis, the impact of agricultural practices on surface and groundwater quality, and the structure and function of grassland ecosystems.

Selected publications include:

Cassel, F.S., M. McClanahan, S. Sharmasarkar, and D. Goorahoo, 2002. Evaluation of Various BOD Loading Rates for Land Application of Food Processing Wastewater. United States Environmental Protection Agency, CP – 82933401 – 0.

Cassel, F.S., M. McClanahan, S. Sharmasarkar, and D. Goorahoo, 2003. Effects of BOD Loading on Percolate Water Quality Following Land Application of Food Processing Wastewater. Presented at the California Plant and Soil Conference, American Society of Agronomy, Modesto, California, February 5-6.

Longley, K. and M. McClanahan, 2002. Coordination of SB 390 and TMDLs, In: Helping Irrigated Agriculture Adjust to TMDLs, Proceedings of the 2002 Water Management Conference, U.S. Committee on Irrigation and Drainage, Sacramento, California, Oct. 23 to 26, pp. 45-51.

Dennis Wichelns, Co-Principal Investigator

Mr. Wichelns is Chief Economist with the California Water Institute and Professor of Agricultural Economics at the California State University, Fresno. He has graduate degrees from the Univ. of Maryland and the Univ. of California, Davis. Since 1985, Mr. Wichelns has maintained an active program of research and consulting activities in California, with particular emphasis on irrigation and drainage issues in the San Joaquin Valley. He has worked also on World Bank and USAID projects in Egypt, Central Asia, and China. His current research includes analysis of water supply and demand issues in California, transboundary competition for water resources, virtual water, desalination, and the special role that improvements in water management can play in reducing poverty, improving environmental quality, and enhancing food security in developing countries.

Mr. Wichelns serves as Co-Editor in Chief of *Agricultural Water Management* and he is Advisor to the Board of Directors for the U.S. Committee on Irrigation and Drainage. In 2003 and 2004 he served on the California Bay-Delta Authority Finance Plan Independent Review Panel.

Selected publications include:

Wichelns, D., 2004. New Policies Are Needed to Encourage Improvements in Irrigation Management. Journal of Irrigation and Drainage Engineering 130(5):366-372.

Oster, J.D. and D. Wichelns, 2003. Economic and Agronomic Strategies to Achieve Sustainable Irrigation. Irrigation Science 22(3-4):107-120.

Wichelns, D., 2003. Enhancing Water Policy Discussions by Including Analysis of Non-water Inputs and Farm-level Constraints. Agricultural Water Management 62(2):93-103.

Wichelns, D., D. Cone, and G. Stuhr, 2002. "Evaluating the Impact of Irrigation and Drainage Policies on Agricultural Sustainability," Irrigation and Drainage Systems 16(1):1-14.

Wichelns, D., 2002. "An Economic Perspective on the Potential Gains From Improvements in Irrigation Water Management," Agricultural Water Management 52(3):233-248.

Tim Jacobsen, Irrigation Specialist and Agronomist

Mr. Jacobsen serves as an agronomist and irrigation specialist in the Center for Irrigation Technology (CIT) at CSU Fresno. He has more than 20 years of experience working on field-level demonstration projects and research efforts in the San Joaquin Valley. He serves also as a water resources education specialist at CIT and he has been involved in many educational and outreach projects since joining the Center in 2000. Mr. Jacobsen's areas of specialty include: 1) irrigation, 2) plant and soil water relations, 3) plant and soil fertility, and 4) soil remediation.

Mr. Jacobsen has held several positions with agricultural production and engineering firms, including Crop Care Services Inc. and Boyle Engineering Corporation in Fresno and the West Side Pump Company in San Joaquin, California. He has a Master of Science Degree in Plant Science from CSU Fresno. He has been certified as an Irrigation Designer by the Irrigation Association and he is a California Certified Agronomist and Pest Control Advisor.

Theresa Sebasto, Program Specialist

Ms. Sebasto has been working in the marketing and communications arena for major corporations and programs in California's Central Valley for several years. Her contributions to these in-house marketing departments include experience in developing and managing marketing and communications campaigns from conceptualization through product/program launches. She has organized major events, tradeshows and educational curricula, and she has managed corporate, community, and government-relations programs.

Ms. Sebasto serves on the Board of Directors of the Fresno County Farm Bureau and she is a member of the Fresno Advertising Federation and the Central Valley Chapter of California Women for Agriculture. Ms. Sebasto is an alumnus of California State University, Fresno and she is involved in all aspects of producing almonds, citrus fruit, and alfalfa hay on her family's farm in Fresno County.

Outreach, Community Involvement, and Acceptance

We will incorporate the views of farmers, irrigation district personnel, and regional water quality experts in formulating our research design and we will communicate the results of our work to those same individuals. We will accomplish these goals through the following components of our research and outreach program:

1. We will work closely with the manager and staff at Del Puerto Water District in designing and implementing the project.

2. We will work closely with a cooperating farmer to compare traditional water management practices with innovative practices for which the likelihood of implementation in the region is substantial.

3. We will conduct at least one workshop per year in the region. In addition, we will describe our research program and present results at meetings of a regional water quality coalition.

4. We will seek input from the Westside San Joaquin River Watershed Coalition and other groups regarding innovative management practices we can examine in years 2 and 3 of our program.

5. We will publish the results of our research in newsletters and other media that are available to farmers and water district personnel.

Outreach, community involvement, and acceptance will occur also as the result of our collaboration with a farmer in the study area. We will be comparing traditional practices and innovative BMPs in a field setting that lies between the Delta-Mendota Canal and Medlin Road, about one mile from the town of Crows Landing. Many farmers will have the opportunity to observe the tailwater return system and to inquire about our research program. Farmers also will lean about the program at Board Meetings of Del Puerto Water District. We anticipate numerous conversations in which we describe the goals and design of our program to farmers in the region. We expect those conversations to generate input from farmers regarding the appropriateness and acceptability of the practices we are examining.

The outreach component of the project will be managed by a Program Specialist and an Irrigation Specialist at the California Water Institute. They will be assisted by other project personnel, including the Field Technician and Del Puerto Water District staff.

Innovation

None of the methods examined in this research, by itself, is innovative. Many farmers in several states have used tailwater return systems and polyacrylamide to reduce the discharge of sediment from farmland into waterways. Many farmers also have reduced the lengths of their furrows to improve distribution uniformity and reduce surface runoff. The innovation we provide is the combination of these management practices to achieve the goals of improving irrigation efficiency and reducing effluent discharge. We innovate also by conducting the research in a farm setting where we will compare traditional practices with improved practices.

Our project will generate both research and demonstration values because we have selected a site where improvements in water management and water quality are needed very soon to comply with recent regulatory actions, such as the adoption of a TMDL for salt and boron in the Lower San Joaquin River, and the Conditional Waivers Program for Irrigated Lands. Many farmers in the region have joined an agricultural water quality coalition that will address nonpoint source pollution from irrigated lands. The Westside San Joaquin River Watershed Coalition has begun monitoring several sites in the region to determine the volume of surface runoff and the loads of undesirable constituents entering the San Joaquin River from lands on the west side of the River. Our work will contribute to that effort in three ways:

1. We will generate new information regarding surface runoff and constituent loads that will complement the Coalition's monitoring program.

2. We will determine cost effective methods for reducing surface runoff and constituent loads.

3. We will work with Coalition members to communicate the results of our work and to encourage adoption of improved management practices.

The information we develop regarding water management practices will be helpful in other regions of California where similar reductions in surface runoff and constituent loads are needed to enhance water quality. For example, farmers in the Grassland Subarea of the San Joaquin Valley produce some of the same crops produced by farmers in our study area. Those farmers also must reduce surface runoff and constituent loads to comply with water quality regulations. Hence, the results or our research regarding cost effectiveness of water management practices should be of interest to farmers in the Grassland Subarea.

Costs and Benefits

Initial Costs

The largest component of initial costs is the installation of a tailwater return system that will include a reservoir, an underground pipeline, and other hardware required to carry water from the reservoir to the upper ends of fields for re-use in subsequent irrigation events. We have developed preliminary estimates of the engineering cost and the cost to furnish and install all components of the tailwater return system. The estimated total costs of designing and installing the system, including contingencies, are $62,450 and $361,680 (Appendix Tables 1 and 2).

We will purchase and install a gated pipeline system to reduce the length of furrow runs in order to reduce the amount of water applied and the amount of water lost as runoff or seepage. The estimated cost of the gated pipe system, including hydrants, valves, and contingencies, is $31,013 (Appendix Table 3).

We will be installing also several flow meters and other hardware required to measure the volume of water collected in the tailwater reservoir and the amount of water applied on each irrigated field in the project area. Field-specific water delivery information is essential for understanding the relationship between the management practices we are examining and changes in the volume and quality of surface runoff. We will install several in-line flow meters to measure field-specific water deliveries in areas where one turnout from the Delta-Mendota Canal serves more than one field. We will also install meters on all irrigation wells in the study area to measure any use of groundwater during the course of the study. We will install flow meters also on the pipeline used to distribute the collected tailwater among irrigation delivery points. The estimated cost of furnishing and installing these devices is $47,630 (Appendix Table 4).

Annual Costs

The annual costs of the project include: 1) the research, analysis, and outreach programs conducted by specialists at the California Water Institute, 2) the supplies and travel required to support those efforts, 3) laboratory analysis of water quality samples at the California Water Institute, 4) the wages, in-field travel, and supplies required to support the Field Technician, 5) the purchase and application of polyacrylamide (PAM) in furrows during selected irrigation events, 6) the supervision, oversight, and analysis provided by Del Puerto Water District staff, 7) the farm labor and materials needed to conduct and evaluate comparisons of water management practices, and 8) the electricity needed to pump tailwater uphill from the reservoir to the head ends of irrigated fields.

Researchers at the California Water Institute will work closely with the Manager and staff at Del Puerto Water District to collect, examine, and describe the information generated during this three-year study. A Water Management

Specialist at the District will supervise and coordinate all field activities. The Specialist will train and supervise the Field Technician and he will ensure that all field-level data are collected and compiled with the care required to ensure meaningful analytical results. The Specialist will work closely with a Senior Researcher and an Economist at the California Water Institute in examining and interpreting the data, and in determining optimal adjustments in project activities during the course of the study. Both the Senior Researcher and the Economist will make many visits to the District and the study area to observe irrigation practices and operation of the tailwater return system. They will also visit with the cooperating farmer occasionally to gain insight regarding the farm-level implications of changes in water management practices.

All of the individuals involved in the study will contribute also to outreach and communication activities. District staff and Institute researchers will participate in scheduled meetings of the Westside San Joaquin River Watershed Coalition and other groups interested in learning about Best Management Practices to improve water quality in the region. We will also publish summaries of our results in the Coalition's newsletter and in other publications distributed within the northwest subarea of the lower San Joaquin River. We are including the cost of a Program Specialist with the California Water Institute to assist in coordinating outreach and communication activities for this project.

The estimated cost of personnel at the California Water Institute, including fringe, is $84,224 in Year 1 of the project (Appendix Table 5). The estimated cost of travel and supplies to support the Institute's activities are $4,800 and $1,200, while the estimated cost of analyzing 200 water quality samples at the Institute's Soil and Water Testing Laboratory is $14,000 in Year 1 (Appendix Table 6).

The Field Technician will work for 18 weeks each year during the irrigation season. The Technician's primary responsibilities will include: 1) observing irrigation and drainage activities within the study area, 2) compiling field notes that describe key irrigation and drainage activities, such as the starting and stopping times of all irrigation events, 3) visiting regularly with irrigators and field supervisors to communicate information regarding project activities, 4) collecting meter readings from flow meters installed on components of the water delivery system and the tailwater return system, and on irrigation wells when those wells are operating, 5) measuring the electrical conductivity (EC) of irrigation water when reading the flow meters, 6) estimating the flow of surface runoff from fields during irrigation events, 7) collecting water quality samples and transporting samples to the laboratory for analysis, 8) entering all of the data and field notes into spreadsheets and word processing files in a timely fashion, and 9) obtaining satellite imagery of fields in the study area from the internet. Those images might be helpful in describing the distribution uniformity of irrigation events.

Researchers at the California Water Institute will work closely with the Manager and staff at Del Puerto Water District to locate an individual to serve as Field Technician. This is a very important position and we must hire someone who

can accept substantial responsibility for collecting and recording information with sufficient care and reliability. The estimated cost of the Field Technician, including wages, fringe, in-field transportation, and supplies, is $18,348 in Year 1 (Appendix Table 7). The District's cost of supervising the Field Technician is included as an in-kind contribution provided by the District.

The District staff and the Field Technician will assist the cooperating farmer in obtaining and applying polyacrylamide to selected fields. The estimated costs of the materials and application are $1,439 and $800 in Year 1 (Appendix Table 8). The project will pay for the materials, while the cooperating farmer will provide the labor for application as an in-kind contribution.

In-kind Contributions

Both the Del Puerto Water District and the cooperating farmer will provide substantial in-kind contributions to this research effort. The District will train and supervise the Field Technician. The estimated cost of those activities, including staff time, office costs, and travel within the study area, is $14,575 in Year 1 (Appendix Table 9). The cooperating farmer will absorb the cost of labor to apply polyacrylamide (PAM) to furrows and to conduct irrigations with shorter furrows than those pertaining to traditional irrigation practices. The estimated labor costs of those activities are $800 and $825 in Year 1 (Appendix Table 10). The largest component of in-kind contributions is the cost of electricity for pumping tailwater collected in the reservoir uphill to the head ends of irrigated fields. The estimated volume of water collected in the reservoir is 590 acre-feet per year and the estimated cost of electricity for pumping is $25.00 per acre-foot. Hence, the estimated in-kind contribution for this activity is $16,225 in Year 1 (Appendix Table 10). Hence the sum of estimated in-kind contributions is $32,425 in Year 1.

We estimate the annual costs for Year 2 and Year 3 by increasing the estimated costs for Year 1 by 5% in both years. A summary of all costs, including the in-kind contributions, for Years 1, 2, and 3 is presented in Appendix Table 11.

Project Benefits

The primary benefit of this research project will be the knowledge gained by examining water management practices that can be used in conjunction with a tailwater return system to improve irrigation efficiency and enhance water quality. The knowledge will pertain to irrigation and water quality issues in the northwest portion of the lower San Joaquin Valley and in other regions where similar improvements in water management and water quality are needed. It is challenging to assign *a priori* a quantitative estimate to the value of an improvement in knowledge, but we can provide a qualitative description of potential benefits.

Successful implementation of the management practices we examine in this study will enable farmers to optimize the use of their limited water supply, while also contributing to improvements in water quality. State and federal agencies have invested large sums in motivating farmers to improve irrigation methods and to reduce the discharge of drainage water from irrigated lands. One hypothesis motivating this research is that some combinations of water management practices might be helpful in achieving both objectives. In addition, the strategies we examine might be less expensive for farmers and the public than alternative programs. For example, the cost of reducing or eliminating the discharge of surface runoff from some irrigated lands by operating a tailwater return system might be smaller than treating the effluent to remove undesirable constituents or modifying other cultural practices that generate the effluent.

The initial cost of a tailwater return system can be substantial. The annual costs of operation and maintenance will vary with the volume of water captured and re-used, and the amount of sediment that must be removed from the reservoir each year. The sum of annualized installation costs and annual operation and maintenance costs might be affordable if the system enables farmers to generate greater benefits with their limited water supply and, perhaps, to avoid more costly alternatives for achieving farm-level water quality objectives. Affordability can be enhanced also by minimizing the amounts of water and sediment captured in the tailwater reservoir. Minimizing tailwater volume will reduce the annual cost of pumping water uphill to be re-used with irrigation deliveries. Minimizing sediment will reduce the annual cost of dredging the reservoir and placing the collected soil in some other location.

We will examine these components of potential farm-level benefits. The tailwater reservoir we construct will be capable of collecting 600 acre-feet of surface runoff each year. We expect to capture between 300 and 600 acre-feet. The lower volume can be achieved if we are successful in reducing surface runoff through improvements in irrigation water management. We are using an expected volume of 590 acre-feet (30% of historical deliveries) in preparing the budget for the project. The cooperating farmer will be paying for the electricity required to pump the tailwater from the reservoir to head ends of irrigated fields.

The water that is captured and re-used for irrigation has an economic value that can be estimated using the farm-level price of water. In 2005, farmers in Del Puerto Water District will be charged about $40 per acre-foot for Central Valley Project water delivered through the Delta-Mendota Canal. The market price of supplemental water that farmers might purchase if their CVP supply is not sufficient might range from $60 to $135 per acre-foot. Hence the lower bound economic value of water captured and re-used for irrigation in 2005 would be $12,000 (300 acre-feet times $40 per acre-foot, while the upper bound value would be $81,000 (600 acre-feet times $135 per acre-foot).

Cost Tables, Figures, and Appendices

Applicant: California State University, Fresno Foundation

Table C-1 (A): Project Costs Initial Investment Costs
Furnish and Install the Tailwater Return System, the Gated Pipe, and the Water Meters

	Category (I)	Project Costs $ (II)	Contingency % (ex. 5 or 10) (III)	Project Cost + Contingency $ (IV)	Applicant Share $ (V)	State Share Grant $ (VI)
	Administration[1]					
	Salaries, wages	0	0	0	0	0
	Fringe benefits	0	0	0	0	0
	Supplies	0	0	0	0	0
	Equipment	0	0	0	0	0
	Consulting services	0	0	0	0	0
	Travel	0	0	0	0	0
	Other	0	0	0	0	0
(a)	Total Administration Costs	0		0	0	0
(b)	**Planning/Design/Engineering** [A]	**50,000**	10	**55,000**	0	**55,000**
(c)						
(d)	Materials/Installation/Implementation					
	Tailwater return system [B]	328,800	10	361,680	0	361,680
	Gated pipe system [C]	28,194	10	31,013	0	31,013
	Meters for measuring water [D]	43,300	10	47,630	0	47,630
	Subtotal Materials and Installation	**400,294**		**440,323**		**440,323**
(l)	Monitoring and Assessment [A]	2,000	10	2,200	0	2,200
(m)	Report Preparation [A]	5,000	5	5,250	0	5,250
	Subtotal of Initial Investment Costs	**457,294**		**502,773**		**502,773**
(n)	**Indirect Costs at 15%**	**68,594**		**75,416**		**75,416**
(o)	**TOTAL**	**525,888**		**578,189**	0	**578,189**
(p)	Cost Share -Percentage				0	100

Notes

1 Excludes administration O&M.
A See Appendix Table 1 for details.
B See Appendix Table 2 for details.
C See Appendix Table 3 for details.
D See Appendix Table 4 for details.

Applicant: **California State University, Fresno Foundation**

Table C-1 (B): Project Costs **Year 1: Annual Costs of Project Activities**

	Category (I)	Project Costs $ (II)	Contingency % (ex. 5 or 10) (III)	Project Cost + Contingency $ (IV)	Applicant Share $ (V)	State Share Grant $ (VI)
	Administration[1]					
	Salaries, wages [E]	60,758	0	60,758	0	60,758
	Fringe benefits [E]	23,466	0	23,466	0	23,466
	Supplies [F]	1,200	0	1,200	0	1,200
	Travel [F]	4,800	0	4,800	0	4,800
	Other (Lab Analysis) [F]	14,000	0	14,000	0	14,000
(a)	**Total Administration Costs**	**104,224**		**104,224**	0	**104,224**
	Subcontractor Expenses					
	Field Technician wages [G]	10,080	10	11,088	0	11,088
	Field Technician fringe [G]	4,032	10	4,435	0	4,435
	Field Technician travel [G]	1,368	10	1,505	0	1,505
	Field Technician supplies [G]	1,200	10	1,320	0	1,320
	Polyacrylamide (PAM) [H]	1,309	10	1,440	0	1,440
(b)	**Subtotal of Subcontractor Expenses**	**17,989**	10	**19,788**	0	**19,788**
	In-kind Cost Contributions					
	Supervising and oversight [I]	13,250	10	14,575	14,575	0
	Labor to apply PAM [H]	727	10	800	800	0
	Labor to shorten furrows [J]	750	10	825	825	0
	Pumping tailwater return [J]	14,750	10	16,225	16,225	0
(c)	**Subtotal of In-kind Contributions**	**29,477**	10	**32,425**	**32,425**	0
(d)	**Subtotal of Project Expenses**	**122,213**	10	**124,012**	0	**124,012**
(e)	**Indirect Costs: 15% of Project Expenses**	**18,332**		**18,602**	0	**18,602**
(f)	**TOTAL**	**170,022**		**175,038**	**32,425**	**142,614**
(g)	**Cost-Share Percentage**				**19**	81

Notes

1 Excludes administration O&M.
E See Appendix Table 5 for details.
F See Appendix Table 6 for details.
G See Appendix Table 7 for details.
H See Appendix Table 8 for details.
I See Appendix Table 9 for details.
J See Appendix Table 10 for details.

Applicant: **California State University, Fresno Foundation**

Table C-1 (C): Project Costs **Year 2: Annual Costs of Project Activities**

	Category (I)	Project Costs $ (II)	Contingency % (ex. 5 or 10) (III)	Project Cost + Contingency $ (IV)	Applicant Share $ (V)	State Share Grant $ (VI)
	Administration[1]					
	Salaries, wages [E]	63,796	0	63,796	0	63,796
	Fringe benefits [E]	24,639	0	24,639	0	24,639
	Supplies [F]	1,260	0	1,260	0	1,260
	Travel [F]	5,040	0	5,040	0	5,040
	Other (Lab Analysis) [F]	14,700	0	14,700	0	14,700
(a)	**Total Administration Costs**	**109,435**		**109,435**	0	**109,435**
	Subcontractor Expenses					
	Field Technician wages [G]	10,584	10	11,642	0	11,642
	Field Technician fringe [G]	4,234	10	4,657	0	4,657
	Field Technician travel [G]	1,436	10	1,580	0	1,580
	Field Technician supplies [G]	1,260	10	1,386	0	1,386
	Polyacrylamide (PAM) [H]	1,374	10	1,512	0	1,512
(b)	**Subtotal of Subcontractor Expenses**	**18,888**	10	**20,777**	0	**20,777**
	In-kind Cost Contributions					
	Supervising and oversight [I]	13,913	10	15,304	15,304	0
	Labor to apply PAM [H]	763	10	840	840	0
	Labor to shorten furrows [J]	788	10	866	866	0
	Pumping tailwater return [J]	15,488	10	17,036	17,036	0
(c)	**Subtotal of In-kind Contributions**	**30,951**	10	**34,046**	**34,046**	0
(d)	**Subtotal of Project Expenses**	**128,324**	10	**130,212**	0	**130,212**
(e)	**Indirect Costs: 15% of Project Expenses**	**19,249**		**19,532**	0	**19,532**
(f)	**TOTAL**	**178,523**		**183,790**	**34,046**	**149,744**
	Cost-Share Percentage				**19**	81

Notes

1 Excludes administration O&M.
E See Appendix Table 5 for details.
F See Appendix Table 6 for details.
G See Appendix Table 7 for details.
H See Appendix Table 8 for details.
I See Appendix Table 9 for details.
J See Appendix Table 10 for details.

Applicant: **California State University, Fresno Foundation**

Table C-1 (D): Project Costs **Year 3: Annual Costs of Project Activities**

	Category (I)	Project Costs $ (II)	Contingency % (ex. 5 or 10) (III)	Project Cost + Contingency $ (IV)	Applicant Share $ (V)	State Share Grant $ (VI)
	Administration[1]					
	Salaries, wages [E]	66,986	0	66,986	0	66,986
	Fringe benefits [E]	25,871	0	25,871	0	25,871
	Supplies [F]	1,323	0	1,323	0	1,323
	Travel [F]	5,292	0	5,292	0	5,292
	Other (Lab Analysis) [F]	15,435	0	15,435	0	15,435
(a)	**Total Administration Costs**	**114,907**		**114,907**	0	**114,907**
	Subcontractor Expenses					
	Field Technician wages [G]	11,113	10	12,225	0	12,225
	Field Technician fringe [G]	4,445	10	4,890	0	4,890
	Field Technician travel [G]	1,508	10	1,659	0	1,659
	Field Technician supplies [G]	1,323	10	1,455	0	1,455
	Polyacrylamide (PAM) [H]	1,443	10	1,587	0	1,587
(b)	**Subtotal of Subcontractor Expenses**	**19,833**	10	**21,816**	0	**21,816**
	In-kind Cost Contributions					
	Supervising and oversight [I]	14,608	10	16,069	16,069	0
	Labor to apply PAM [H]	802	10	882	882	0
	Labor to shorten furrows [J]	827	10	910	910	0
	Pumping tailwater return [J]	16,262	10	17,888	17,888	0
(c)	**Subtotal of In-kind Contributions**	**32,498**	10	**35,748**	**35,748**	0
(d)	**Subtotal of Project Expenses**	**134,740**	10	**136,723**	0	**136,723**
(e)	**Indirect Costs: 15% of Project Expenses**	**20,211**		**20,508**	0	**20,508**
(f)	**TOTAL**	**187,449**		**192,980**	**35,748**	**157,232**
	Cost-Share Percentage				**19**	**81**

Notes

1 Excludes administration O&M.
E See Appendix Table 5 for details.
F See Appendix Table 6 for details.
G See Appendix Table 7 for details.
H See Appendix Table 8 for details.
I See Appendix Table 9 for details.
J See Appendix Table 10 for details.

Applicant: California State University, Fresno Foundation

Table C-1 (E): Project Costs

All Project Costs
The Sum of Annual Costs of Project Activities and the Initial Investment Costs

	Category (I)	Project Costs $ (II)	Contingency % (ex. 5 or 10) (III)	Project Cost + Contingency $ (IV)	Applicant Share $ (V)	State Share Grant $ (VI)
	Administration[1]					
	Salaries, wages [E]	191,540	0	191,540	0	191,540
	Fringe benefits [E]	73,977	0	73,977	0	73,977
	Supplies [F]	3,783	0	3,783	0	3,783
	Travel [F]	15,132	0	15,132	0	15,132
	Other (Lab Analysis) [F]	44,135	0	44,135	0	44,135
(a)	**Total Administration Costs**	**328,566**		**328,566**	0	**328,566**
	Subcontractor Expenses					
	Field Technician wages [G]	31,777	10	34,955	0	34,955
	Field Technician fringe [G]	12,711	10	13,982	0	13,982
	Field Technician travel [G]	4,313	10	4,744	0	4,744
	Field Technician supplies [G]	3,783	10	4,161	0	4,161
	Polyacrylamide (PAM) [H]	4,127	10	4,539	0	4,539
(b)	**Subtotal of Subcontractor Expenses**	**56,710**	10	**62,381**	0	**62,381**
	In-kind Cost Contributions					
	Supervising and oversight [I]	41,771	10	45,948	45,948	0
	Labor to apply PAM [H]	2,292	10	2,521	2,521	0
	Labor to shorten furrows [J]	2,364	10	2,601	2,601	0
	Pumping tailwater return [J]	46,499	10	51,149	51,149	0
(c)	**Subtotal of In-kind Contributions**	**92,926**	10	**102,219**	**102,219**	0
(d)	**Subtotal of Project Expenses**	**385,276**	10	**390,948**	0	**390,948**
(e)	**Indirect Costs: 15% of Project Expenses**	**57,791**		**58,642**	0	**58,642**
(f)	**Sum of Annual Costs**	**535,994**		**551,809**	**102,219**	**449,590**
	Cost-Share Percentage (Annual Costs)				**19**	81
(g)	**Initial investment Costs [K]**	**457,294**		**502,773**		**502,773**
(h)	**Indirect Costs at 15%**	**68,594**		**75,416**		**75,416**
(i)	**Subtotal Initial investment Costs [K]**	**525,888**		**578,189**	**0**	**578,189**
(j)	**Sum of All Project Costs**	**1,061,882**		**1,129,998**	**102,219**	**1,027,779**
	Cost-Share Percentage (All Costs)				**9**	91

Notes

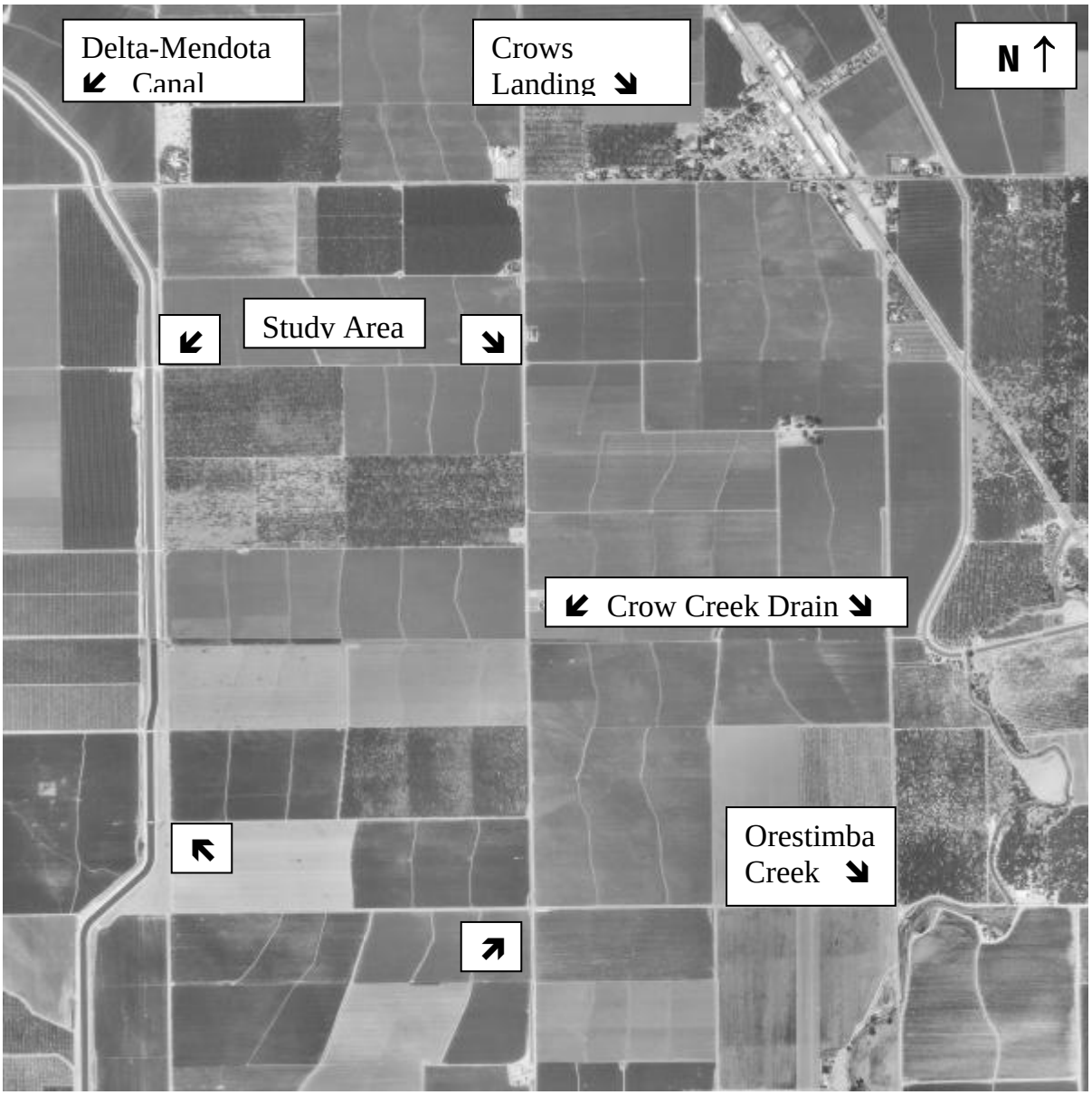
1 Excludes administration O&M.
E See Appendix Table 5 for details.
F See Appendix Table 6 for details.
G See Appendix Table 7 for details.
H See Appendix Table 8 for details.
I See Appendix Table 9 for details.
J See Appendix Table 10 for details.
K See Table C-1 (A) for details.

Table C-5: Project Annual Physical Benefits (Quantitative and Qualitative Description of Benefits)

QUALITATIVE DESCRIPTION - REQUIRED OF ALL APPLICANTS[1]				QUANTITATIVE BENEFITS –(where data are available) [2]
Description of physical benefits (in-stream flow and timing, water quantity and water quality) for:	**Time Pattern and Location of Benefit**	**Project Life: Duration of Benefits**	**State Why Project Bay-Delta benefit is Direct[3], Indirect[4] or Both**	**Quantified Benefits (in-stream flow and timing, water quantity and water quality)**
Bay-Delta: We will reduce surface runoff to Orestimba Creek, a tributary to the Lower San Joaquin River, which flows into the Delta. As a result, we will reduce the loads of salt, boron, and sediment entering the River and Delta. The loads of pesticides that adsorb to soil particles also will be reduced as a result of reducing the sediment load.	Effluent loads will be reduced primarily during the spring and summer when farmers are irrigating crops. The locations of benefit include the Orestimba Creek Watershed, the Lower San Joaquin River and the Bay/Delta region.	The project life is 3 years. Benefits will continue beyond that time if farmers adopt the management practices we examine in the study, such as using PAM and shortening furrow lengths when using tailwater return systems.	The Bay/Delta benefits are Direct. We will contribute to Targeted Benefits 98, 100, 101, 104, 106, and 108 during the life of the project. We will reduce native constituents, salt, and pesticides entering the Bay/Delta by reducing surface runoff from irrigated farmland. We will increase diversion flexibility both in the near-term and the long-term by enabling farmers to re-use a portion of their surface water supply from the Delta-Mendota Canal.	We expect to reduce surface runoff by 300 to 600 acre-feet per year. Assuming an average salinity of 400 ppm TDS, this represents a reduction in salt load ranging from 163 to 326 tons per year. The load reduction will occur largely during the spring and summer when farmers are irrigating. Farm-level re-use of surface runoff will enhance water supply flexibility during the irrigation season. It might also enable some farmers to gain flexibility in rescheduling a portion of their surface water supply from one year to the next.
Local: We will demonstrate how farmers can reduce surface runoff and re-use collected tailwater to enhance the values they generate with limited water supplies. We will determine optimal strategies for managing return systems.	Benefits will accrue during the irrigation season and, perhaps, between seasons as farmers gain flexibility regarding their surface water supplies.	The benefits of this 3-year project will continue for as long as farmers implement the water management practices.	**Not Applicable**	Farm-level re-use of surface runoff will enhance water supply flexibility during the irrigation season. It might also enable some farmers to gain flexibility in rescheduling a portion of their surface water supply from one year to the next.

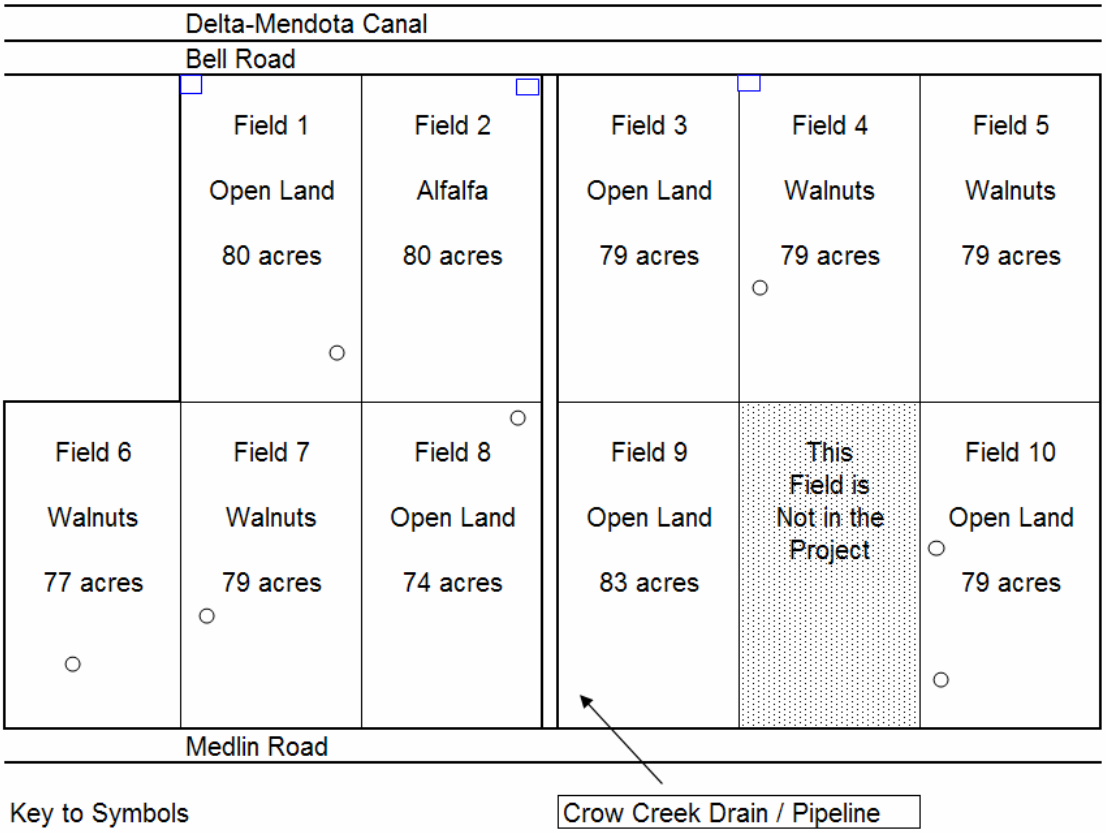
Figures

Figure 1. The Study Area and the Town of Crows Landing, as seen in a USGS photograph taken on July 29, 1999



The citation for this photograph is the USGS, 70 km E of San Jose, California, United States 29 Jul 1999. Arrows denote the four corners of the study area. The scale is approximately 1 mile per 2 inches on the printed page.

Figure 2. Existing, Pre-project Description of Farm Fields in the Project Area

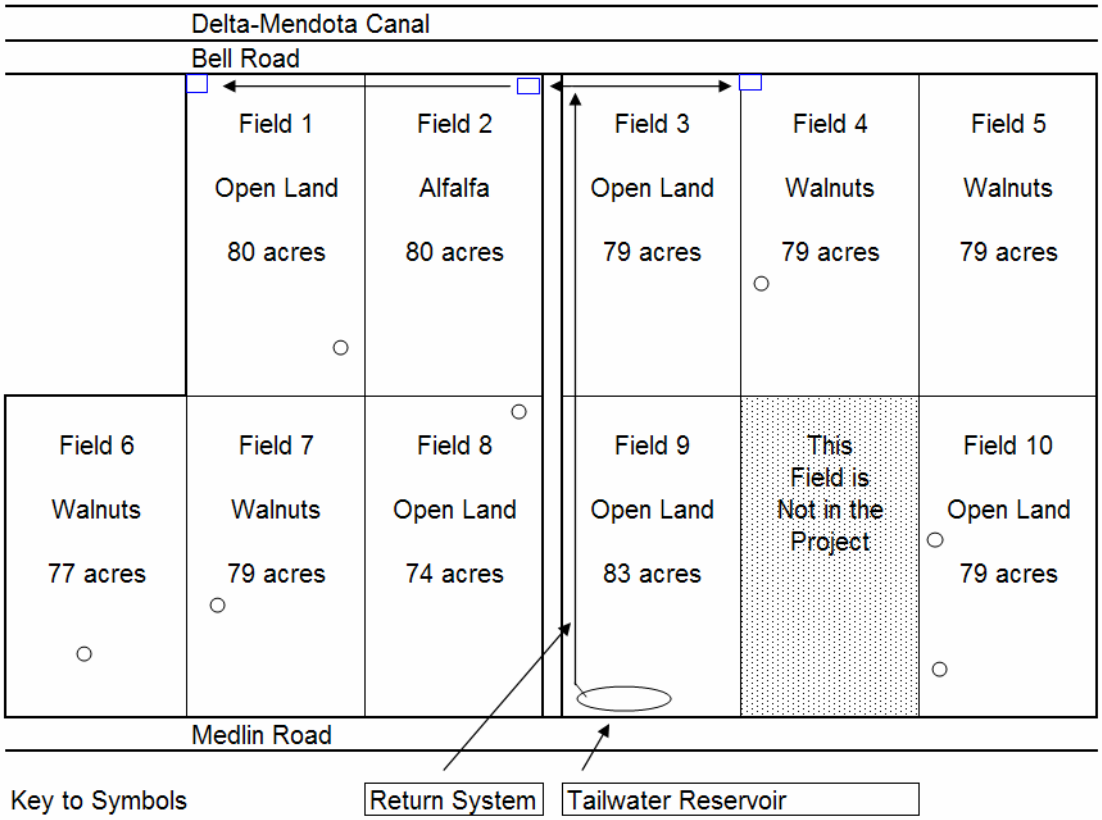


Key to Symbols

Irrigation turnout - There are three turnouts from the Delta-Mendota Canal.

Irrigation well - There are seven wells in the study area.

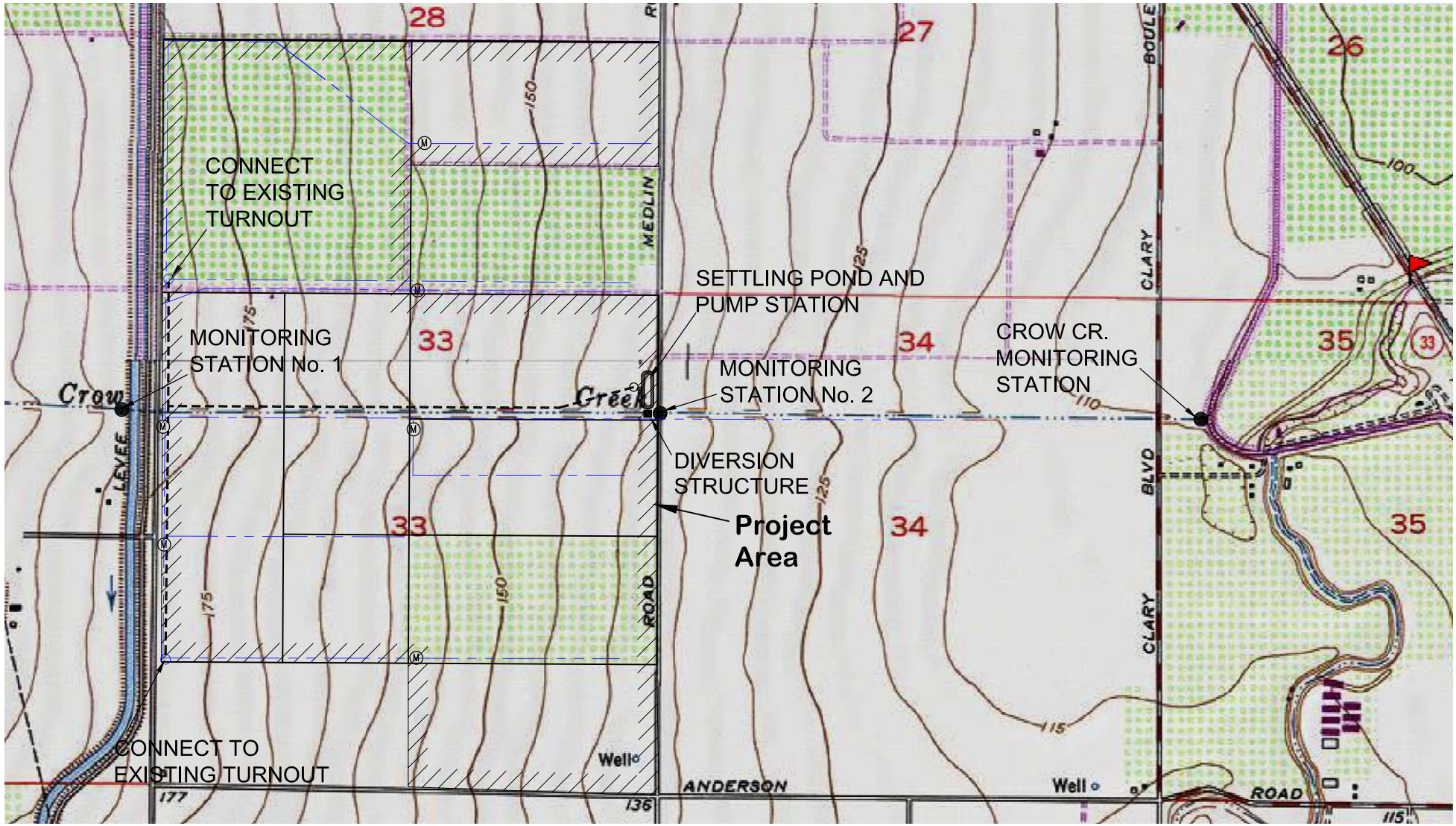
Figure 3. The Tailwater Reservoir and Return System

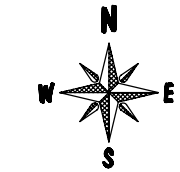


Key to Symbols

□ Irrigation turnout - There are three turnouts from the Delta-Mendota Canal.

○ Irrigation well - There are seven wells in the study area.





APPROXIMATE
SCALE IN FEET
0 1,500

Del Puerto Water District

Prop. 50 WUE Proposal
Optimizing a Tailwater Return System
Project Area

LEGEND

Ⓜ	FIELD LEVEL METER
———	DELIVERY SYSTEM
●	DRAINAGE MONITOR
- - - - -	TAILWATER RETURN PIPELINE

SUMMERS ENGINEERING, INC.
Consulting Engineers
HANFORD CALIFORNIA
JANUARY 2005

Appendices

Appendix Table 1.
Estimated Costs of Engineering and Design
for the Tailwater Return System

Item	Net Amount	Contin-gency	Total Cost
Planning, Design, Engineering	50,000	0.10	55,000
Monitoring and Assessment	2,000	0.10	2,200
Report Preparation	5,000	0.05	5,250
Total Cost	57,000		62,450

Appendix Table 2.
Estimated Costs of Materials and Installation for the Tailwater Return System

Item	Description	Quantity	Unit	Unit Cost ($/unit)	Total Cost ($)
1.	Furnish & Install (F&I) 15" PVC Class 125 Pipe	4,900	Linear Feet (LF)	18	88,200
2.	F&I 10" PVC Class 125 Pipe	3,900	LF	10	39,000
3.	F&I Turnout Connection	2	Each	15,400	30,800
4.	F&I Excavated Material for Storage Pond	7,000	Cubic Yards	8	56,000
5.	F&I Diversion Structure & Connections		Lump Sum		25,000
6.	F&I Pump Station and Manifold		Lump Sum		67,300
7.	F&I Air Release Valve Installation	2	Each	3,000	6,000
8.	F&I Flow Metering Stations	3	each	5,500	16,500
			Subtotal		328,800
			Contingencies (10%)		32,880
			Total Cost		361,680

Appendix Table 3.
Estimated Cost of the Gated Pipe System

Item	Amount	Units	Unit Price	Total Cost
Gated pipe, 10-inch with PVC gates every 30 inches	6,420	feet	3.49	22,406
Hydrants, 12-inch by 10-inch singles	2	each	520	1,040
Hydrants, 12-inch by 12-inch doubles	3	each	1,011	3,033
End plugs, valves, etc.				1,065
Labor to install the valves				650
Subtotal				28,194
Contingency 10%				2,819
Total Cost				31,013

Appendix Table 4.
Estimated Cost of Meters for Measuring Water Deliveries, Groundwater, and Crow Creek Drainage Water

Item	Quantity	Unit Cost	Total Cost
Field level water delivery meters			
16" Meters with remote mounting kit, tube, vault, and installation	6	4,300	25,800
Groundwater pumping meters			
16" Electronic meters with above-ground installation	7	2,000	14,000
Portable water quality meter for use by the Field Technician	1	3,500	3,500
Subtotal			43,300
Contingency 10%			4,330
Total Cost			47,630

Appendix Table 5.
Estimated Costs of Research, Program, and Clerical Personnel

Year 1

Item	Time on Project	Net Amount	Fringe Rate	Fringe Amount	Total Cost
Senior Economist	12 weeks	29,304	0.33	9,670	38,974
Senior Researcher	12 weeks	11,976	0.29	3,473	15,449
Irrigation Specialist	8 weeks	7,798	0.51	3,977	11,775
Program Specialist	4 weeks	3,894	0.37	1,441	5,335
Clerical Staff	12 weeks	7,786	0.63	4,905	12,691
Total Cost		60,758		23,466	84,224

Year 2

Item	Time on Project	Net Amount	Fringe Rate	Fringe Amount	Total Cost
Senior Economist	12 weeks	30,769	0.33	10,154	40,923
Senior Researcher	12 weeks	12,575	0.29	3,647	16,221
Irrigation Specialist	8 weeks	8,188	0.51	4,176	12,364
Program Specialist	4 weeks	4,089	0.37	1,513	5,602
Clerical Staff	12 weeks	8,175	0.63	5,150	13,326
Total Cost		63,796		24,640	88,436

Year 3

Item	Time on Project	Net Amount	Fringe Rate	Fringe Amount	Total Cost
Senior Economist	12 weeks	32,308	0.33	10,662	42,969
Senior Researcher	12 weeks	13,204	0.29	3,829	17,033
Irrigation Specialist	8 weeks	8,597	0.51	4,385	12,982
Program Specialist	4 weeks	4,293	0.37	1,588	5,882
Clerical Staff	12 weeks	8,584	0.63	5,408	13,992
Total Cost		66,986		25,872	92,857

Note: Net wages are increased by 5% each year to account for potential increases in salaries and fringe expenses at CSU Fresno.

Appendix Table 6.
Estimated Costs of Supplies, Travel, and Laboratory Analysis

Year 1

Item	Amount	Units	Cost per Unit	Total Cost
Supplies	12	weeks	100.00	1,200
Travel	48	person trips	100.00	4,800
Laboratory Analysis	200	samples	70.00	14,000
Total Cost				20,000

Year 2

Item	Amount	Units	Cost per Unit	Total Cost
Supplies	12	weeks	105.00	1,260
Travel	48	person trips	105.00	5,040
Laboratory Analysis	200	samples	73.50	14,700
Total Cost				21,000

Year 3

Item	Amount	Units	Cost per Unit	Total Cost
Supplies	12	weeks	110.25	1,323
Travel	48	person trips	110.25	5,292
Laboratory Analysis	200	samples	77.18	15,435
Total Cost				22,050

Note: The cost estimates are increased by 5% each year to account for potential increases in the per unit costs, over time.

Appendix Table 7.
Estimated Costs for a Field Technician

Estimated Wages and Benefits		
Wage rate	14	dollars per hour
Hours	40	hours per week
Weeks	18	weeks per year
Wages	10,080	dollars per season
Fringe, at 40%	4,032	dollars per season
Subtotal	14,112	
Contingency at 10%	1,411	
Budget Amount	15,523	dollars per season

Mileage Reimbursement for In-Field Travel		
Miles per day	40	
Cost per mile	0.38	
Daily cost	15.20	
Days per year	90	
Annual Cost	1,368	
Contingency at 10%	137	
Budget Amount	1,505	dollars per season

Supplies for collecting and mailing water quality samples		
Cost per month	300	dollars per month
Months per season	4	months
Annual Cost	1,200	dollars per season
Contingency at 10%	120	
Budget Amount	1,320	dollars per season

Summary	Net Amount	Contin-gency	Total Cost
Wages	10,080	1,008	11,088
Fringe	4,032	403	4,435
Mileage	1,368	137	1,505
Supplies	1,200	120	1,320
Total	16,680	1,668	18,348

Appendix Table 8.
Estimated Cost of Polyacrylamide (PAM) for Dry Beans and Walnuts

Cost of material		
Soil Floc 100D	1.80	per pound, in 50-pound sacks
Application rate	1.00	pound per acre, per event
Cost of Labor		
Application	1.00	per acre, per event
Sum of These	2.80	per acre, per event

Dry Beans		
Apply during pre-irrigation and three subsequent irrigations.		
Applications	4	events
Cost per event	2.80	per acre, per event
Cost per acre	11.20	per acre, per season
Acres in field	83	acres
Cost per season	929.60	per season
Summary	Per Season	
Cost of Materials	598	budget
Cost of Labor	332	in-kind
Sum of These	930	

Walnuts		
Apply after each cultivation, about 5 times per season.		
Applications	5	events
Cost per event	2.80	per acre, per event
Cost per acre	14.00	per acre, per season
Acres in field	79	acres
Cost per season	1,106	per season
Summary	Per Season	
Cost of Materials	711	budget
Cost of Labor	395	in-kind
Sum of These	1,106	

Summary	Budget Materials	In-kind Labor	Total
Dry Beans	598	332	930
Walnuts	711	395	1,106
Subtotal	1,309	727	2,036
Contingency 10%	131	73	204
Total Costs	1,439	800	2,239

Appendix Table 9.
Estimated Cost of Supervising the Field Technician and Overseeing Field Activities

District Staff Time		
Time during season	10	hours per week
Length of season	18	weeks
Time out-of-season	2.5	hours per week
Length of time	34	weeks
Total staff time	265	hours
Hourly rate: wages, benefits, vehicle, etc.	50	per hour
Subtotal	13,250	
Contingency 10%	1,325	
Total	14,575	

This estimated Total Cost is included as an in-kind cost contribution by the Del Puerto Water District.

Appendix Table 10.
Summary of In-kind Cost Contributions

Item	Description	Net Amount	Contin-gency	Total Cost	Source
			($/year)		
District Staff	Supervision and oversight	13,250	1,325	14,575	Water District
PAM Application	Labor to apply PAM	727	73	800	Farmer
Furrow Labor	Labor to shorten furrows	750	75	825	Farmer
Electricity	Pumping tailwater return	14,750	1,475	16,225	Farmer
Total In-kind Cost Contributions		29,477	2,948	32,425	

Notes:
The Furrow Labor cost is estimated by multiplying $5 per acre by 150 acres.
The Electricity cost is estimated by multiplying $25 per acre-foot by 590 acre-feet, which is 30% of historical water use.

Projecting the in-kind contributions over 3 years, assuming annual increases of 5 percent

Cost Category	Year 1	Year 2	Year 3	Sum
Net Amount	29,477	30,951	32,498	92,926
Contingency	2,948	3,095	3,250	9,293
Total Contribution	32,425	34,046	35,748	102,219

Appendix Table 11.
Summary of Estimated Direct and Indirect Costs and In-kind Contributions

Item	Year 1	Year 2	Year 3	Total
CSU Fresno Faculty and Staff	84,224	88,436	92,857	265,517
CSU Fresno Supplies, Travel, Laboratory	20,000	21,000	22,050	63,050
Subtotal of CSU Fresno Direct Costs	104,224	109,436	114,907	328,567
Indirect Costs at 15% of Direct Costs	15,634	16,415	17,236	49,285
Sum of CSUF Direct and Indirect Costs	119,858	125,851	132,143	377,852
Subcontractor Expenses				
Installation of Tailwater Return System, Gated Pipe System, and Meters	502,773			
Field Technician Wages, Fringe, Travel, and Supplies for Water Quality Samples	18,348	19,265	20,229	57,842
Polyacrylamide (PAM)	1,439	1,511	1,587	4,538
Subtotal of Subcontractor Expenses	522,561	20,777	21,816	565,153
Indirect Costs at 15% of Direct Costs	78,384	3,117	3,272	84,773
Sum of Subcontractor Direct and Indirects	600,945	23,893	25,088	649,926
Project Summary				
Sum of Direct Costs	626,785	130,212	136,723	893,720
Sum of Indirect Costs	94,018	19,532	20,508	134,058
Sum of Direct and Indirect Costs	720,803	149,744	157,231	1,027,778
In-kind Contributions	32,425	34,046	35,748	102,219
Total Project Budget	753,227	183,790	192,980	1,129,997

Appendix 12. Letters of Support

Del Puerto Water District
Earl Perez, Owner, Perez Farms