DEVELOPMENT OF A STANDARDIZED PROCEDURE FOR RAPID IDENTIFICATION AND QUANTIFICATION OF CANAL SEEPAGE

A Research Proposal submitted to

CALIFORNIA DEPARTMENT OF WATER RESOURCES
CALIFORNIA BAY-DELTA WATER USE EFFICIENCY PROGRAM, Section B

by

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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 Foundation
4. Project Title:	Development of a standardized procedure for rapid identification and quantification of canal seepage
5. Person authorized to sign and submit proposal and contract:	Name, title: Thomas McClanahan, Associate Vice President Mailing address: CSUF - Foundation, 4910 N. Chestnut Ave, Fresno, CA 93726 Telephone: (559) 278-0840 Fax.: (559) 278-0992

6. Contact person (if different)

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7. Grant funds requested (dollar amount): $215,196
(from Table C-1, column VI)

8. Applicant funds pledged (dollar amount): $54,088

9.Total project costs (dollar amount): $269,284
(from Table C-1, column IV, row n)

10. Percent of State share requested (%) 80%
(from Table C-1)

11. Percent of local share as match (%) 20%
(from Table C-1)

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.

☐ (a) yes

(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.)

☒ (b) no

11. Is your project required by regulation, law or contract? ☐ (a) yes
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. ☒ (b) no

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

12. Duration of project (month/year to month/year): 01/2006 to 12/2007

13. State Assembly District where the project is to be conducted: 3rd District

14. State Senate District where the project is to be conducted: 1st District

15. Congressional district(s) where the project is to be conducted: 2nd District

16. County where the project is to be conducted: Butte County

17. Location of project (longitude and latitude): 39°31' latitude and -121°30' longitude

18. How many service connections in your service area (urban)? SFWPA has 6,485

19. How many acre-feet of water per year does your agency serve? Cooperator SFWPA serves 28,000 ac-ft for irrigation and urban

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

Signature Page

By signing below, the official declares the following:

The truthfulness of all representations in the proposal;

The individual signing the form has 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 individual signing the form read and understood the conflict of interest and confidentiality section and waives 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

A. PROJECT SUMMARY

Seepage from irrigation canals is a serious water supply and management problem in California Bay Delta sub-regions. Thus, it is important to identify the locations and rates of seepage along the canals to conserve water in these sub-regions. Canal lining is one of the Efficient Water Management Practices (EWMPs) endorsed by the Agricultural Water Management Council (AWMC) to reduce seepage. There are generally two approaches to canal lining; a *programmatic approach* where the objective is to identify the canal reaches where lining would produce the least-cost water savings, and a *specific approach* where canal reaches have been identified with high seepage rates. Most canal lining falls in the *specific approach* category. This project proposes to develop a standardized procedure to quickly and cost-effectively identify canal reaches with high seepage rates following a *programmatic approach*. Identification of these reaches will ensure that canal sections with the lowest marginal cost per volume ($/acre foot of water saved) are lined first.

To achieve this goal, we plan to use the electromagnetic inductance (EM) technology to identify locations of canal seepage and determine the rate of seepage at those locations using ponding tests. The Center for Irrigation Technology (CIT) at California State University, Fresno has developed and completed the initial testing (Lost Hills Water District) of a Mobile Assessment (MA) System utilizing the electromagnetic inductance (EM) technology to identify canal seepage locations. The EM technique is used to determine variations of soil water content and texture along canal banks down to 20 feet. The benefits of the MA system are that rapid measurements can be performed over relatively large areas. This proposed research will build on the initial tests by developing a relationship between EM measurements and seepage rates determined at selected locations by ponding tests. This relationship will then be used to estimate seepage rates for all EM-surveyed reaches.

Monitoring and verification of water savings resulting from canal lining is also important. Guidelines to monitoring and verification for the *specific approach* have been developed and are available on the AWMC web site. The ponding tests used to measure seepage rates in this *programmatic approach* extend the monitoring and verification to a larger population of reaches in a cost-effective manner.

The proposed procedure will be tested on 20-30 miles of open, unlined sections of South Feather Water and Power Agency (SFWPA)'s Palermo canal. The SFWPA, formerly Oroville-Wyandotte Irrigation District, is located in Butte County, California, in CALFED sub-region 5. The Palermo canal flows from Lake Oroville Dam to the Lower Wyandotte Road with a capacity of 25 cubic feet per second. The SFWPA delivers about 7,000 acre-feet of water annually to the Palermo canal and it is estimated that an average of 5,700 acre-feet (81%) is lost to seepage.

The project will partially address CALFED Quantifiable Objectives 46 and 47 for sub-region 5 (Lower Feather River and Yuba River) by helping to a) reduce ET of non-commercial plants grown around seepage areas, and 2) increase water storage in Lake Oroville and decrease required diversions to SFWPA canals. The research will also contribute to increase in-stream flow (Objective 38) in sub-region 5. Furthermore, the standard procedure developed by this research can be applied in appropriate conditions across all CALFED sub-regions as well as to

other regions of California. The resulting programmatic approach to identification of canal reaches for lining both lowers the cost of water savings and provides necessary data for effective monitoring and verification.

B. STATEMENT OF WORK

B.1. Relevance and Importance

B.1.a. Problem statement and project need

Seepage from irrigation canals is a serious water management problem in California Bay Delta sub-regions. Canal seepage reduces irrigation efficiency, diverts water unnecessarily from natural waterways, and may contribute to contaminant loading from soils, thereby impacting groundwater quality. Seepage is a problem particularly at the South Feather Water and Power Agency's Palermo Canal where conveyance losses can reach up to 90%. The South Feather Water and Power Agency (SFWPA) is located in Oroville, Butte County, CA, which is included in CALFED sub-region 5. The Palermo canal is primarily earthen ditch with a capacity of 25 cubic feet per second (cfs) originally constructed in the late 1800's. The canal flows approximately 65,000 feet from Lake Oroville Dam to Lower Wyandotte Road with an average width of five feet and an average depth of three feet (Attachment 1). At Lower Wyandotte Road, the main canal is diverted into smaller canals with an average width of two feet. The total length of the canal is approximately 33 miles. The SFWPA delivers about 7,000 acre-feet (AF) every year to the Palermo canal. It is estimated that an average of 5,700 AF of water is lost annually in the Palermo canal due to seepage, which represents more than 80% of the total water volume diverted into the canal. Thus, there is an urgent need to identify the locations and rates of seepage along the Palermo canal in order to conserve water in sub-region 5.

The goal of the proposed research is to develop and test a standardized procedure to rapidly and cost-effectively identify the locations and rates of seepage along certain reaches of the Palermo canal. This will allow the prioritization for lining selected canal reaches where significant seepage reduction can be achieved at the lowest cost. Seepage rates have tremendous spatial variability along irrigation canals. Low seepage rates and corresponding minimum losses are observed on a high percentage of irrigation district's canals (Attachment 2-Figure 1). This can be explained by the low hydraulic conductivity of soil adjacent to the canal or this can be due to sediment settling on the canal wetted perimeter and "clogging" of the seepage flow path. Conversely, high seepage rates are found on short stretches of canals where soil hydraulic conductivity is higher (sandy soils) and higher flow velocities preclude sedimentation and consequent clogging of the seepage flow path. Thus, identifying the canal reaches with high seepage rates becomes a critical step to insure cost effectiveness of lining. As shown in Attachment 2-Figure 2, the lining cost per acre-foot of water saved can decrease rapidly if canal reaches with high seepage rates are lined.

B.1.b. Nature, Scope, and objectives of the project

To achieve this goal, we propose to use the electromagnetic inductance (EM) technology to obtain soil moisture and texture data along extensive lengths of canal reaches. These data will then be classified into four to five significant groups. Within each group, the cooperators will identify one or two locations to quantify the rate of seepage using ponding tests. The seepage rates within and across groups will be used to develop a relationship to estimate seepage rates along the entire lengths surveyed and assess its accuracy.

The EM technique is a very useful and cost effective tool to measure electrical conductivity and other soil parameters, such as moisture content and texture. The principle of the EM technology is as follows: the EM instrument transmitter coil induces an electromagnetic field in the ground, which in turn creates a secondary magnetic field that is measured by the receiver coil. The ratio of both fields provides a measure of the depth-weighted apparent electrical conductivity (EC) in a volume of soil below both coils. Since EC of a soil is a function of its salt content, water content, and texture, use of the EM technique can be very valuable for canal seepage assessment. The EM technique only requires above-ground measurements along canal banks, so canal operations need not be interrupted during the investigation. Additionally, when used with a mobilized system, the EM method allows continuous measurements along many miles of canal, thus providing an indication of the spatial variability of seepage losses along the canal.

A recent comprehensive review on seepage identification and measurement determined nine techniques for seepage assessment (ANCID, 2000). According to this review, ponding tests are generally accepted as the most reliable method to determine seepage rates. Other significant advantages are that the test procedures are relatively simple and can be used on both lined and unlined canals. Inflow-outflow water measurements are sometimes used to estimate seepage losses; however, the probable error in flow measurement is typically large relative to the seepage rate, leading to important uncertainty in the computed seepage rate. Ponding tests will be used in this project to quantify the rates of seepage located with the EM method. The soil moisture contents computed from the EM measurements will be correlated with the seepage rates obtained from the ponding tests for various soils and ranges of moisture content. Since ponding tests can only be performed at selected locations along the canal, the correlation equation will be used to extrapolate seepage rates at all EM measurement points. In two Australian studies, Sinclair Knight Merz (1998, 1999) obtained good correlations between high electrical resistivity (low conductivity) estimated from EM surveys and high seepage rates computed from ponding tests.

The hypothesis of the research is that the EM technology can be used in conjunction with ponding tests to determine seepage rates along miles of canal reaches, considering that soil moisture content is proportional to seepage rates. The specific objectives of the proposed study are:

(1) Develop a standardized procedure for quickly and cost-effectively identifying canal reaches with high seepage rates using electromagnetic and ponding techniques, and

(2) Test this procedure at SFWPA's Palermo canal to identify canal reaches for lining that will result in least-cost water savings.

B.1.c. Support of California Bay-Delta Program Goals

The goals of the Water Use Efficiency Program as defined by the California Bay-Delta Program include "water quantity, water quality, and in-stream flow and timing improvements that directly or indirectly provide benefits to the Bay-Delta." The proposed project contributes to several of these goals, as defined for sub-region 5 (Lower Feather River and Yuba River) but also for many other CALFED sub-regions. The project will directly and indirectly provide benefits toward the following targeted objectives:

Water Quantity:

- Provide long-term diversion flexibility to increase the water supply for beneficial uses (Objective 47).
- Decrease non-productive ET to increase the water supply for beneficial uses (Objective 46).

In-stream Flow/Timing:

- Provide flow to improve ecosystem conditions (Objective 38)

More specifically, the proposed project will help reduce seepage along the Palermo canal, and therefore will contribute to:

1) increasing water storage in Lake Oroville and decreasing required diversions to SFWPA canals, thereby providing additional water for Feather River and Delta water quality, hydroelectricity production, and irrigation for downstream farming communities,
2) improving the aquatic ecosystem of the Feather River by increasing water flow, and
3) decreasing ET of non-commercial plants grown around seepage areas.

These above-described benefits can also be transferred to all other CALFED sub-regions.

The project will also provide benefits to the SFWPA by rapidly and cost-effectively identifying the canal reaches with high seepage rates. Results from this project will then be used by SFWPA to line those particular reaches (see separate 2005 Water Use Efficiency Program PSP being submitted by SFWPA). Identifying the canal reaches with high seepage rates will result in the lowest lining cost per acre-foot of water conserved. If this rapid procedure for identifying and quantifying canal seepage is applied in many irrigation and water districts across the CALFED Bay-Delta regions, the economic impact can be measured in millions of dollar savings to the state of California.

B.1.d. Integration with Local and Regional Integrated Water Resources Plans

The proposed research is consistent with the Butte County Integrated Water Resources Plan and the Northern California Water Association Integrated Water Management Plan.

Butte County Integrated Water Resources Plan

The goal of the proposed project is consistent with the water use efficiency planning objective of the Butte County Integrated Water Resources Plan. Identifying of least-cost SFWPA canal reaches to line satisfies the Butte County Department of Water and Resource Conservation mission "To manage and conserve water and other resources for the citizens of Butte County." The development of a rapid and cost-effective procedure to quantify seepage at other regional water purveyors for least-cost lining projects is also consistent with those goals.

Northern California Water Association Integrated Water Management Plan

This proposal is consistent with the water use efficiency section of the Northern California Water Association (NCWA) integrated water management program. This proposal has been discussed with NCWA staff and members, who have been supportive of the project as consistent with the goals of the NCWA integrated water management program.

Additionally, the proposed project is consistent with the following objectives of the CALFED Water Use Efficiency Program:
Reduce existing irrecoverable losses
Achieve multiple benefits, including increasing water availability for irrigation or in-stream flow, enhancing water quality, and reducing diversion impacts.

B.1.e. Demand Management Activities

Agricultural water management plans developed in California either through the United States Bureau of Reclamation (USBR) water conservation program or through the Agricultural Water Management Council (AWMC) Water Management Planning require the evaluation of agricultural water management practices pertaining to lining canals. SFWPA as an agricultural water provider has pursued evaluation and implementation of canal lining and seepage reduction projects in the past. SFWPA recognizes the benefit of utilizing the technology developed by CIT and is seeking to implement this technology to identify canal-lining opportunities and to develop a priority for implementing future projects consistent with the AWMC EWMP B5 (canal lining).

SFWPA has adopted an Urban Water Management Plan in accordance with the Urban Water Management Planning Act evaluating 15-demand management measures. Demand Management Measure –3 evaluates distribution system audits, leak detection and repair. SFWPA began an aggressive distribution system pipe replacement program in 1995 and has expended nearly 8 million dollars to date and significantly reduced unaccounted-for water. SFWPA seeks additional opportunities to continually reduce the amount of unaccounted-for water. Open canal systems feed SFWPA's urban water treatment facilities and contribute significantly to water distribution system losses. Consistent with Urban Water Demand Management –3, SFWPA is seeking to utilize the EM technology to identify unaccounted water loss in the distribution system and to prioritize repairs.

B.1.f. Linkage to Existing Water Management Activitie*s*

Development of the canal seepage identification and quantification procedure is expected to facilitate the existing canal lining water management activities of SFWPA by providing a proven and rapid method to identify canal reaches with high seepage rates. This will enable SFWPA to conserve water and increase the confidence in the savings estimates by identifying the correct reaches to line.

B.2. Technical/Scientific Merit, Feasibility

B.2.a. Methods, procedures, equipment

The project will be conducted over two years by the Center for Irrigation Technology (CIT) at California State University, Fresno, in collaboration with SFWPA and Davids Engineering Inc. (DE). We propose to use the EM technique to identify locations of seepage along 20-30 miles of open, unlined sections of the Palermo canal at SFWPA, located in Butte County, CA. Using the EM technology will allow researchers to determine variations of soil water content and texture along those canal sections down to 20 ft. Soil water content and texture information will be used to categorize canal reaches with respect to seepage potential. Representative canal reaches from each category will then be selected for ponding tests. Based on this information, a seepage equation, or model, will be selected, calibrated with the ponding tests and used to develop seepage estimates for the remaining reaches surveyed with the EM meter.

<u>EM surveys</u>

A Mobile Assessment (MA) System is available at the Center for Irrigation Technology to perform extended EM surveys along canal banks. The MA system is comprised of four basic components mounted on a truck or an ATV: (1) an electromagnetic (EM) induction sensor, (2) a global positioning system (GPS) receiver, (3) a computer, and (4) a hydraulic soil sampler (Attachment 3 – Figure 1).

(1) The sensor used will be an EM-31 meter (Geonics Limited, Ontario, Canada) capable of measuring soil electrical conductivity and indirectly soil moisture down to a depth of 20 ft. The EM-31 operates at a frequency of 9.8 kHz and consists of a transmitter coil and a receiver coil with a control unit in the center. The instrument has a fixed inter-coil spacing of 12 ft, which allows measurement depths of 10 and 20 ft in the horizontal (meter parallel to the surface) and vertical (meter perpendicular to the surface) dipole modes, respectively. In this study, the EM-31 sensor will be placed in a plastic carrier-sled attached about 10 ft behind the ATV to avoid any EM reading interference due to metallic objects. (In a 2001 WUE funded project that has been completed, see section C.3., a similar sensor, the EM-38, was used by CIT to assess soil salinity down to 3 ft in agricultural fields).

(2) An AgGPS® 132 receiver (Trimble Navigation Limited) will be used in conjunction with the EM sensor to provide the geographical coordinates of each measurement point. The GPS data will be differentially corrected to an accuracy of 3 ft.

(3) Two serial RS232 digital interfaces will connect the EM sensor and GPS receiver to an on-board laptop computer that will instantaneously record the EM readings along with their GPS location. Survey and statistical (Lesch and Rhoades, 1999) software will be used to record and analyze the data, respectively.

(4) The hydraulic soil sampler will allow sampling down to a depth of 20 ft if necessary. The actual depth of sampling will be based on the depth to groundwater, depth to rock, and estimated depth of seepage.

Researchers and technicians at CIT have been using the MA system and related software for several years.

The MA system will be driven along one or two paths on the downslope side of the surveyed sections. Distance from the center of the canal will be recorded. Depending on the estimated depth of canal seepage, the EM instrument will be oriented in the horizontal (10 ft) or vertical (20 ft) dipole mode. Surveys will be conducted at a speed of 3-4 mph, with readings taken every 5 seconds.

Since EM measurements are relative, calibration of the data through soil sampling will be necessary after the surveys to obtain absolute soil water content and texture values. An optimal sampling plan will be generated using the ESAP software (Lesch et al., 1999); this plan will comprise 12 locations characterizing the spatial distribution of EM readings along the canal. At these sites, soil samples will be collected in 1- to 2-ft increments using the hydraulic soil sampler. The samples will be analyzed for water content, texture, and electrical conductivity following standard analytical methods (Rhoades, 1996; Klute, 1986). Estimates of soil water content and texture will then be obtained for the entire survey area using the ESAP software. Contour maps showing the distribution of these two parameters will be generated with the ArcGIS software (Environmental System Research Institute, 2001). Examples of the soil water content maps that will be produced are presented in Attachment 3 - Figure 2.

Ponding Tests

The ponding method applies a water balance to an isolated reach of canal to determine the seepage losses. The losses represent the volume of water seeping through the canal over time, after accounting for evaporation. Ponding tests will be conducted following accepted procedures (USBR, 1968). A section of the canal will be blocked off with embankments at each end and then filled with water. The tests will be performed after bank storage has been satisfied and the water table in the adjacent areas has stabilized so that conditions are representative of those during the irrigation season. As the water level in the section declines, the level is measured as regular time intervals and time is recorded.

Some important parameters that will be considered for our ponding tests are highlighted below:

- **Length -** In general, the pond should be long enough so that the sum of the pond end areas represents a very small percentage (not more than 3%) of the total wetted area.
- **Location -** The ponded areas will be selected to represent groups of soil types and ranges of soil moisture identified by the EM surveys. However, reaches where it is difficult to determine the wetted cross section and where turnout leakage cannot be stopped should be avoided.

- **End Structures –** Where feasible, existing check structures or check drops will be used to pond water; these structures generally have foundations or cut-off walls that reduce lateral seepage.
- **Wetted Perimeter -** The average wetted perimeter will be calculated by measuring the side slope, top and bottom widths at different stations along the canal reach. Cross sections should be measured at least every half mile and at every point of change in canal geometry.
- **Canal Elevations –** Relative elevations will be measured to within 0.1 ft. Perimeter and elevation measurements should help establish the shape of the canal.
- **Water Surface Elevations -** During the ponding tests, elevation readings will be taken at stilling wells located at the head and tail of the canal section. Measurements should be recorded to the nearest 0.01 ft.
- **Evaporation –** Evaporation must be measured using an evaporation pan.
- **Depth -** The starting depth in the pond should be slightly higher than the design or operating depth of the canal to secure data above and below that level.
- **Measurement -** Measurement of the rate of drop in the water surface will begin after the pond is filled, all gages are set and the recorder is operating. Generally, the pond will drop quickly during the initial stages of the test and will then level off and remain relatively constant. Pond seepage should be calculated using the measurements taken after the pond losses have stabilized. Elevation measurements should be taken often enough to adequately characterize the seepage losses.
- **Reporting –** Seepage rates will be reported as $ft^3/ft^2/day$.

B.2.b. Task list, deliverables, schedule, and projected costs

The schedule for accomplishing the following-described tasks is presented in Attachment 4. The deliverables and estimated costs for all tasks are detailed in Attachments 5 and 6.

Task 1 - Develop Reconnaissance Seepage Survey Plan
Canal reaches will be selected for a systematic reconnaissance seepage survey based on capacity (preference for larger canals), access, and knowledge of potential seepage locations. The survey plan is expected to cover 20-30 miles of open, unlined reaches of the Palermo canal. The plan will also include 1-2 miles of accessible canal that was previously lined with shotcrete using funds from the 2001 DWR Water Use Efficiency project awarded to SFWPA.

Deliverables: Map showing canal reaches to be surveyed.

Task 2 – Develop Water Balance for Canal Reaches Selected in Task 1
Subject to the availability of data, a water balance will be developed for the SFWPA canal reaches selected in Task 1. The approach will be to use operational and other records to estimate monthly system inflows and outflows, including allowances for canal evaporation, and to estimate seepage as the water balance closure term. While often associated with some uncertainty, this type of water balance analysis ordinarily is not time consuming, and can be very useful for establishing the range of total seepage loss incurred from the system. This effort will

include interviews with day-to-day system operators, who often have impressions of system loss based on operating experience.

Deliverables: Water balance schematic with average annual volumes.

Task 3 – Develop Conceptual Seepage Model
Review of published research findings (ANCID, 2000) coupled with experience on other projects, indicates that seepage loss from irrigation canals is governed by many inter-related factors. Typically, the most prominent factors are: channel configuration (channel top width and depth); operational patterns of starting and shutting off canals and laterals; hydraulic conductivity of underlying soils (in both the vertical and horizontal directions); presence of clogging layers due to sedimentation and how such layers are affected by operations and maintenance (O&M) activities; presence of shallow groundwater tables, and the position of such water tables in relation to the canal invert. Field inspections coupled with review of available information will be conducted to identify which of these factors must be considered, or may be neglected, in the case of the SFWP system. Based on this determination, the various equations (or models) that have been developed to estimate seepage losses will be reviewed, and an appropriate equation will be chosen to proceed with the investigation.

Deliverables: Conceptual seepage model.

Task 4 – Develop GIS Analytical Tool
Available data pertaining to the parameters noted above (see Task 3) will be compiled and digitized for loading into an ARCGIS database. Available data regarding shallow water table elevations or depths will also be compiled and mapped. This tool will be used in the categorization and selection of reaches for ponding tests in Task 6.

Deliverables: GIS maps and database.

Task 5 – Conduct Reconnaissance Seepage Surveys
CIT will use the Mobile Assessment (MA) System to conduct the reconnaissance seepage surveys of the canal segments identified in Task 1 following methodology described in B.2.a. These surveys will include the required soil sampling and laboratory analyses to calibrate the EM measurements. Analyses of the data will provide maps of soil water content and texture along the canal reaches surveyed. Maps for each depth sampled as well as depth-average maps will be produced.

Deliverables: Maps showing canal reaches surveyed with soil water content and texture.

Task 6 – Analyze Reconnaissance Seepage Surveys to Select Locations for Ponding Tests
Based on the EM results, canal reaches will be categorized according to soil water content and texture. Representative canal reaches will be selected for ponding tests in each group deemed significant considering the locations of structures and turnouts. Ideally, test reaches would be bounded by check structures on one or both ends, and would have no or few turnouts. Consideration of SFWPA operating requirements, including ability or inability to shut down a canal for two to three days to conduct a ponding test, will be an important parameter in the

selection of reaches for the ponding tests. The number of reaches selected for testing will depend on the number of groups, the estimated cost of performing the tests, the availability of SFWP field staff, operational considerations, and other factors. It is expected that a minimum of one or two ponding tests will be conducted for each significant group.

Deliverables: Map showing locations for ponding tests.

Task 7 – Conduct Ponding Tests
Ponding tests are recommended here to provide the highest possible level of confidence in the seepage loss estimates. Each of the selected reaches will be hydraulically isolated from the system using check gates or temporary earthen plugs, or a combination of the two. It will then be filled to a level slightly higher than the normal operating depth. When the test starts, the rate of water level decline will be monitored regularly over time to estimate the volume of seepage loss. Computations will be performed to convert the seepage volume into a seepage rate (typically in ft3/ft2/day).

Deliverables: Raw ponding test results with seepage rates

Task 8 – Infer Seepage Estimates for all Canal Reaches Surveyed

The calculated seepage rates and the EM survey results will be used to derive values for the variables in the selected seepage equation (see Task 3). The equation will then be used as a calibration model to compute seepage losses for canal reaches belonging to each significant group. In this way, estimates of seepage will be developed systematically for all the SFWPA canal reaches surveyed with the MA system. Recommendations of the canal reaches to be lined will then be provided to SFWPA based on seepage rates and water savings estimates.

Deliverables: Seepage rate estimates for all EM-surveyed reaches

Task 9 – Prepare Seepage Loss Analysis Technical Memorandum
A seepage loss analysis will be performed to evaluate the volumes of water lost to seepage along all EM surveyed reaches. This analysis will be used to determine the most cost-effective canal reaches to line, i.e., the canal segments having the highest seepage rates and where lining will result in the greatest water savings. A technical memorandum will be prepared to document the ponding tests, analyses, data and results of the seepage loss analysis. This technical memorandum will serve to document and verify the water savings that will occur from lining selected canal reaches of the SFWPA distribution system.

Deliverables: Seepage loss analysis technical memorandum

Task 10 – Prepare EM and Ponding Test Seepage Survey Procedure Technical Memorandum
A technical memorandum will be prepared to document the steps and analyses required to quickly and cost effectively identify the low-cost canal reaches for lining, including EM-31 surveys and ponding tests. This technical memorandum will provide clear, concise steps for districts to use the EM survey in conjunction with ponding tests to develop and document seepage rates in portions of their distribution system.

Deliverables: Technical memorandum for EM and ponding test seepage survey procedures and final report.

Task 11 – Conduct Field Days for Research Outreach

Results from the study will be disseminated to irrigation districts, USBR, and universities during two field days at SFWPA and California State University, Chico (CSUC). The field day at SFWPA will show the use of the MA system and EM technology in-situ. Then, at the end of the project, a second field day conducted at CSUC will present the results of the project and describe the standardized procedure developed to identify and quantity seepage rate rapidly and cost-effectively along canal banks.

Deliverables: Two field days at SFWPA and California State University, Chico.

B.2.c. Environmental documentation

This is not a CEQA project as defined by the California Code of Regulations, Title 14, Division 6, Chapter 3, Section 15378.

B.3. Monitoring and Assessment

Results from each task will be documented and deliverables will be included in quarterly reports submitted to DWR. Evaluation of the project will also be conducted quarterly and after completion of each task. Water savings estimates will be documented and verified for the reaches selected from the EM survey. These water savings estimates will be one factor in the selection of reaches for lining in a Section A PSP proposal submitted by SFWPA.

Success of the project will be determined based on task completion, deliverables, dissemination and outreach of the research to interested parties as described below. Project success will also be recognized if, following development and testing, the seepage procedure can be utilized to identify the least-cost canal reaches to line and can be transferred throughout the California Bay-Delta Program area.

This is a research proposal to develop a procedure for a programmatic approach to monitoring and assessment of canal lining. For a District undertaking a programmatic approach to canal lining, this procedure will develop seepage rates for the entire length of canal reaches on which it is utilized. These seepage rates can then be converted to volumes lost and estimated savings based on known seepage rates through the planned lining material. This information feeds directly into the canal lining monitoring and verification protocol recommended on the Agricultural Water Management Council web site. The success of this proposal will be evident by the interest and use of the procedure developed.

C. QUALIFICATIONS OF THE APPLICANTS AND COOPERATORS

C.1. Resumes of project manager(s)

See enclosed resumes of Dr. Florence Cassel and James R. Tischer (CIT).

C.2. Role of external cooperators

The study will be conducted in cooperation with South Feather Water and Power Agency and Davids Engineering, Inc. Resumes of Matt Colwell (SFWPA) and Dr. Bryan Thoreson (DE) are also attached.

South Feather Water and Power Agency

South Feather Water and Power Agency, formerly known as Oroville-Wyandotte Irrigation District, was established in 1919. Located in Butte County, SFWPA supplies water for domestic and agricultural uses, generates electricity and provides recreational activities for the public. SFWPA provides water to approximately 400 irrigation customers through 110 miles of open, mostly unlined ditches across a service area of roughly 31,000 acres. These ditches constitute a modification and expansion of the ditch network constructed by early miners during the California gold rush. The ditches traverse hillsides following the terrain for miles and meandering the contours into ravines and canyons to cross the natural drainage. The Agency has taken a progressive posture promoting water conservation.

The proposed research will be tested at SFWPA and its engineers and managers will collaborate with CIT to accomplish each task described above. SFWPA will provide technical information related to the Palermo canal distribution system. Agency staff will also clear scrub brush, trees, and weeds overgrowing in many areas of the canal, making a track wide enough for an ATV to pull the EM-31 sensor on the downstream side of the canal bank.

Davids Engineering, Inc.

Davids Engineering, Inc. (DE) has extensive experience developing strategic water conservation plans and documenting and verifying volume of water conserved. DE will develop water balances for the reaches surveyed and a canal seepage model based on available information. DE will coordinate with SFWP and CIT to design a strategic plan for the reconnaissance seepage surveys. Based on the survey results, DE will define a plan for ponding tests to quantify the seepage rates and develop water savings estimates of the reaches surveyed. DE will assist CIT in developing a standardized procedure for canal seepage rapid reconnaissance surveys linked to ponding tests to quickly and cost effectively identify the least-cost canal reaches for lining.

C.3. Previous water use efficiency grant projects

CIT grant project

CIT was awarded a grant project under the Water Use Efficiency Program in 2001. The goal of the project was to assess and map soil salinity using the EM technology in farms implementing drainage management practices within their boundaries. The purpose of these management practices was to conserve fresh canal water by utilizing drainage water produced within the farm. The project was successful in locating areas of very high salinity through the soil salinity maps. The maps were then used by the farmers as decision-making tools for improving their drainage and irrigation management practices. The results of this project have been detailed in the final report to DWR (Cassel et al., 2003). This report has been extensively used by engineers from DWR-Fresno and by Westside farmers involved in the drainage program. The research work was also reported in an article published by *California Farmer* in September 2002 (pp16-19).

SFWPA grant project

The SFWP agency lined about 9,900 feet of the Palermo canal with assistance from the 2001 Water Use Efficiency Program. This lining was successful in addressing Quantifiable Objective #38 in Sub-Region #5. The District is happy with the results of this lining and plans to line additional reaches of canal.

Before implementing canal improvements, diversions averaged 21 cfs. The first improvement was the installation of a 700 ft-long piped section. After completion of the piping project, diversions were expected to range between 19 and 21 cfs. However, diversions have now been reduced to 15 cfs. The District believes that this reduction in diversion is entirely due to the canal lining project funded in 2001. Water savings observed from this project were approximately 1,000 AF, which were greater than the anticipated savings of 695 AF.

D. OUTREACH, COMMUNITY INVOLVEMENT AND DISSEMINATION

Project findings will be disseminated to DWR, irrigation districts, USBR, cooperators, Sacramento Valley water interests, public, and the scientific community. Two field days will be conducted at SFWPA and California State University, Chico, to show the use of the MA system and EM technology *in-situ* and to present the results of the project and inform interested parties on the newly developed procedure for rapid identification and quantification of canal seepage.

Research results will be published through popular trade/local journals to inform the public on (1) the innovative EM-ponding test technique for canal seepage assessment, and (2) on the potential water savings following lining of the canal reaches having high seepage losses. Research papers will also be published in refereed journals to document the methods and results obtained from this study to the scientific community. Description of the study and findings will be made available on the CIT web site. The project work will also be presented at professional and technical meetings using maps, photographs, posters, and slides. The level of details and scientific concepts will be based on the target audience.

E. INNOVATION

The EM technology has traditionally been used for salinity assessment in the United States (Slavish, 1990; Hendrickx et al., 1992; McKenzie et al., 1997) and other countries (Diaz and Herrero, 1992). However, the EM data are not only related to electrical conductivity (salinity) but also depend on soil moisture and texture. Therefore, the EM technique can be used to estimate soil moisture content along irrigation canals and can be a valuable new tool for identifying canal reaches with high seepage rates in the CA-Bay Delta sub-regions. Very limited information is available on the use of the EM technology for seepage assessment. Studies have been conducted in Australia and indicated that the EM meter is useful in identifying seepage (Akbar et al., 2000). However, this technique has not been utilized and documented in California for locating canal seepage.

Preliminary testing conducted by CIT indicates that the EM technology can be used effectively as a non-invasive means of measuring soil water content and detecting canal seepage, thereby making it possible to achieve significant water savings throughout irrigated agriculture in California. Furthermore, combining this innovative technology with a limited regime of ponding tests is expected to result in a quick, cost-effective method to determine which canal reaches to line in order to obtain the most water savings at the lowest expenditure.

F. BENEFITS AND COSTS

F.1. Project Costs (Budget)

The state funding request is $215,196, which represents 80% of the total project costs calculated at $269,284. A contingency provision of $15,625 has been estimated for the project. Cost-share will be provided in terms of cash match ($32,000) from the California State University Agricultural Research Initiative Program (ARI) and in-kind match from SFWPA ($22,088). The detailed budget for this two-year project is presented in Attachment 7. The total administrative costs will include secretarial salaries and benefits to maintain the contract; supplies for reports, maps, and manuscripts; travel to the research site, meetings and conferences; and university indirect costs. Planning/Design/Engineering costs will be for conducting Tasks 1, 2, 3, and 4. Provision is made to purchase equipment necessary for conducting the ponding tests and EM surveys. Costs for fields days, monitoring and assessment, and report preparation will cover Tasks 5 through 11, and will mostly include salaries and benefits for the investigators, cooperators, technicians and students involved in the project.

F.2. Potential benefits of study and estimates of total expected water savings

The research will provide important information to anyone interested in reducing canal seepage in the CALFED Bay-Delta area and conserving irrigation water, as well as on the use of EM technology for rapid canal surveys. The study will directly benefit irrigation/water districts and power agencies that need to identify a quick and relatively inexpensive procedure to locate

seepage along thousand miles of canals and take very important economic decisions regarding canal lining.

Hundreds thousands of acres feet of water are estimated to seep from irrigation canals in the California Bay-Delta sub-regions. Much of this seepage is an irrecoverable loss as it enters saline or otherwise unusable groundwater. Although much of the canal seepage in the Sacramento Valley enters a groundwater system from which it can be reused, reducing this seepage often results in significant in-stream timing and water quantity and quality benefits.

This project is expected to identify and prioritize canal reaches for lining of SFWPA's Palermo Canal. SFWPA is submitting a section A companion grant application (entitled "Palermo Canal Seepage Reduction Project") for the 2005 WUE PSP to implement lining on those prioritized canal reaches. This research will provide quantified water conservation savings for the section A project. If the lining is conducted on 3 miles of the canal, water savings can be estimated between 700 and 1700 acre-feet annually. Refined estimates will be obtained from this project.

As mentioned above, the proposed project will help reduce seepage along the Palermo canal, and therefore will contribute to:

1) increasing water storage in Lake Oroville and decreasing required diversions to SFWPA canals, thereby providing additional water for Feather River and Delta water quality, hydroelectricity production, and irrigation for downstream farming communities,
2) improving the aquatic ecosystem of the Feather River by increasing water flow, and
3) decreasing ET of non-commercial plants grown around seepage areas.

These above-described benefits can also be transferred to all other CALFED sub-regions.

G. REFERENCES

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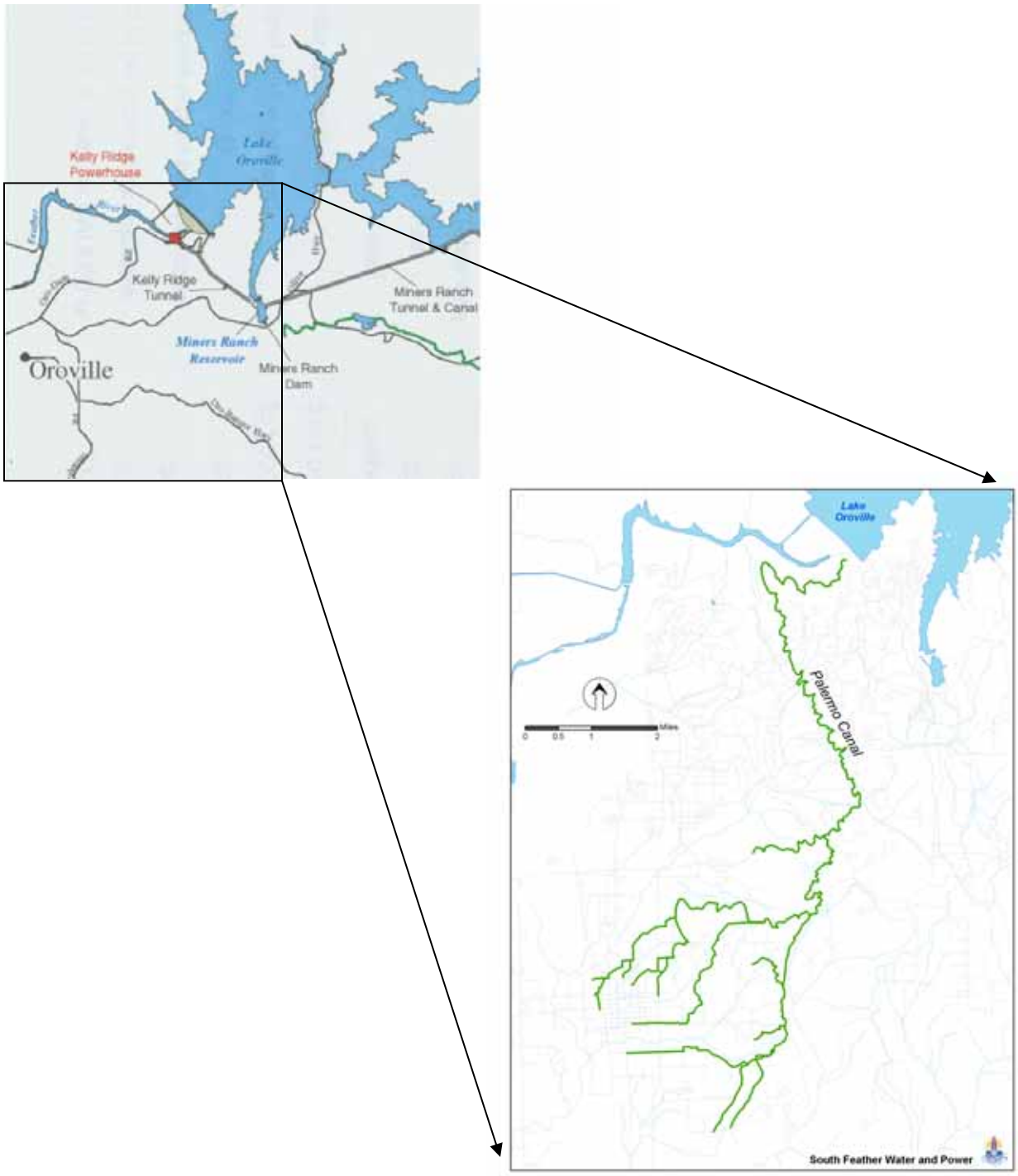
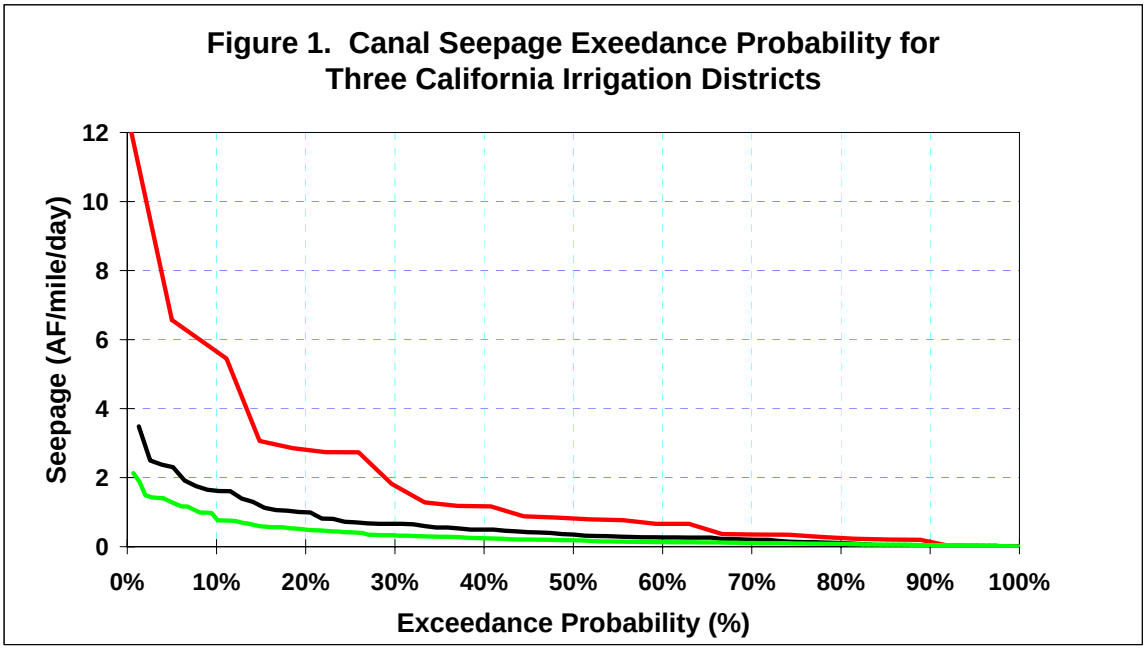
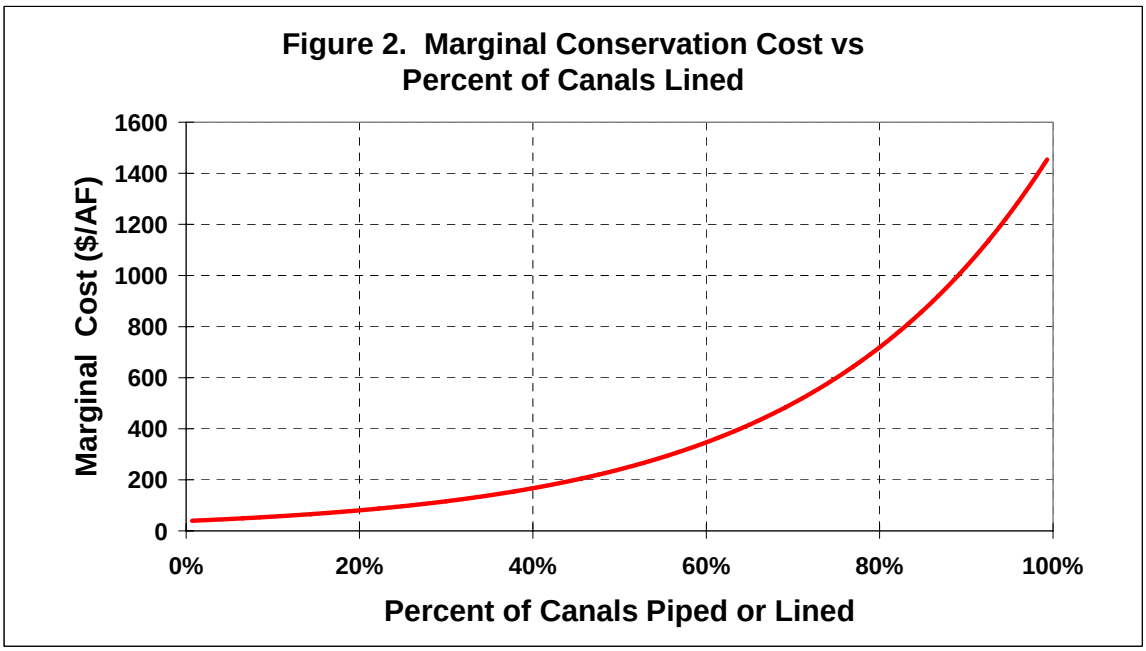
Attachment 1 - Schematic of Palermo canal at SFWPA



Attachment 2- Canal Seepage Exeedance Probability for Three California Irrigation Districts





Attachment 3- Mobile Assessment System

Figure 1. Mobile Assessment (MA) system available at CIT to conduct canal seepage surveys

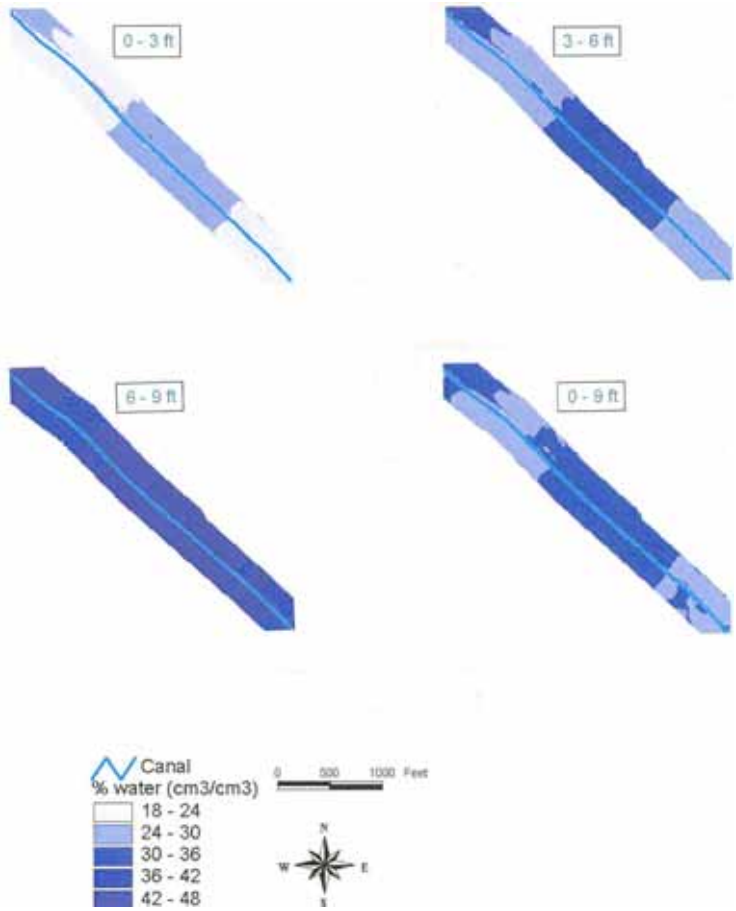


Figure 2. Maps of soil water content distribution along an irrigation canal

Attachment 4- Task Schedule

Task	Description	2006												2007											
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
1	Develop Reconnaissance Seepage Survey Plan																								
2	Develop Water Balance for Canal Reaches Selected in Task 1																								
3	Develop Conceptual Seepage Model																								
4	Develop GIS Analytical Tool																								
5	Conduct Reconnaissance Seepage Surveys																								
6	Analyze Reconnaissance Seepage Surveys to Select Locations for Ponding Tests																								
7	Conduct Ponding Tests																								
8	Infer Seepage Estimates for all Canal Reaches Surveyed																								
9	Prepare Seepage Loss Analysis Technical Memorandum																								
10	Prepare EM and Ponding Test Seepage Survey Procedure Technical Memorandum																								
11	Conduct Field Days for Research Outreach																								

Attachment 5- Task deliverables

Task No.	Task Description	Deliverables
1	Develop Reconnaissance Seepage Survey Plan	Map Showing Canal Reaches to be Surveyed
2	Develop Water Balance for Canal Reaches Selected in Task 1	Water Balance Schematic with Average Annual Volumes
3	Develop Conceptual Seepage Model	Conceptual Seepage Model
4	Develop GIS Analytical Tool	GIS Maps and Database
5	Conduct Reconnaissance Seepage Surveys	Map Showing Canal Reaches Surveyed with Soil Water Content and Texture
6	Analyze Reconnaissance Seepage Surveys to Select Locations for Ponding Tests	Map Showing Locations for Ponding Tests
7	Conduct Ponding Tests	Raw Ponding Test Results with Seepage Rates
8	Infer Seepage Estimates for all Canal Reaches Surveyed	Seepage Rate Estimates for all EM Surveyed Reaches
9	Prepare Seepage Loss Analysis Technical Memorandum	Seepage Loss Analysis Technical Memorandum
10	Prepare EM and Ponding Test Seepage Survey Procedures Technical Memorandum	EM and Ponding Test Seepage Survey Procedures Technical Memorandum
11	Conduct Field Days for Research Outreach	Two field days at SFWPA and California State University, Chico

Attachment 6- Requested and match funds by task

TASK No.	TASK DESCRIPTION	DWR REQUEST	MATCH FUNDS		*TOTAL PROJECT BUDGET*
			ARI (cash)	SFWPA (in-kind)	
1	Develop Reconnaissance Seepage Survey Plan	**$ 6,716**		$ 1,056	***$ 7,772***
2	Develop Water Balance for Canal Reaches Selected in Task 1	**$ 10,730**		$ 1,056	***$ 11,786***
3	Develop Conceptual Seepage Model	**$ 10,916**		$ 528	***$ 11,444***
4	Develop GIS Analytical Tool	**$ 8,392**		$ 528	***$ 8,920***
5	Conduct Reconnaissance Seepage Surveys	**$ 13,400**	$ 32,000	$ 5,280	***$ 50,680***
6	Analyze Reconnaissance Seepage Survey to Select Locations for Ponding Tests	**$ 13,679**		$ 1,056	***$ 14,735***
7	Conduct Ponding Tests	**$ 21,415**		$ 9,240	***$ 30,655***
8	Infer Seepage Estimates for all Canal Reaches Surveyed	**$ 15,602**		$ 1,056	***$ 16,658***
9	Prepare Seepage Loss Analysis Technical Memorandum	**$ 23,116**		$ 1,056	***$ 24,172***
10	Develop EM and Ponding Test Seepage Survey Procedures Technical Memorandum	**$ 36,976**		$ 1,232	***$ 38,208***
11	Conduct Field Days for Research Outreach	**$ 10,560**			***$ 10,560***
Contingency		**$ 15,625**			***$ 15,625***
Total direct costs		**$ 187,127**	$ 32,000	$ 22,088	**$ 241,215**
University indirect costs (15% of DWR request)		**$ 28,069**			**$ 28,069**
TOTALS		**$ 215,196**	$ 32,000	$ 22,088	***$ 269,284***
Percentage of total project budget		***80%***	*12%*	*8%*	***100%***

Attachment 7- Table C1. Project budget (in dollars)

	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	$4,092	0	$4092	$0	**$4,092**
	Fringe benefits	$1,637	0	$1,637	$0	**$1,637**
	Supplies	$1,000	0	$1,000	$0	**$1,000**
	Equipment	$0	0	$0	$0	**$0**
	Consulting services	$0	0	$0	$0	**$0**
	Travel	$9,096	10	$10,006	$0	**$10,006**
	Other	$0	0	$0	$0	**$0**
(a)	Total Administration Costs	$15,825		$16,735	$0	**$16,735**
(b)	Planning/Design/Engineering	$46,393	10	$51,032	$3,168	**$47,864**
(c)	Equipment Purchases/Rentals/Rebates/Vouchers	$4,000	10	$4,400	$0	**$4,400**
(d)	Materials/Installation/Implementation	$0	0	$0	$0	**$0**
(e)	Implementation Verification	$0	0	$0	$0	**$0**
(f)	Project Legal/License Fees	$0	0	$0	$0	**$0**
(g)	Structures	$0	0	$0	$0	**$0**
(h)	Land Purchase/Easement	$0	0	$0	$0	**$0**
(i)	Environmental Compliance/Mitigation/Enhancement	$0	0	$0	$0	**$0**
(j)	Construction	$0	0	$0	$0	**$0**
(k)	Other (Specify) - Field days	$7,039	5	$7,391	$0	**$7,391**
(l)	Other – University Indirect Rate	$28,069	0	$28,069	$0	**$28,069**
(m)	Monitoring and Assessment	$93,231	10	$102,554	$48,632	**$53,922**
(n)	Report Preparation	$59,103	0	$59,103	$2,288	**$56,815**
(o)	**TOTAL**	$253,660		$269,284	$54,088	**$215,196**
(p)	Cost Share -Percentage				20	80

[1]- excludes administration O&M.

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EDUCATION

Ph.D.	1998	*Soil-Water Physics and Agronomy*, University of Wyoming, Laramie, WY.
M.S. + B.S.	1994	"Diplôme d'Ingénieur en Agriculture", *Agricultural Engineering*, Ecole Supérieure d'Agriculture d'Angers (E.S.A.), France.

PROFESSIONAL EXPERIENCE

- 2001- Present: *Soil and Water Scientist*, Center for Irrigation Technology, California State University, Fresno.
- 1998-2001: Elected *Executive Council Member-at-Large* to the Pacific Division of American Association for Advancement of Sciences, San Francisco, CA.
- 1999-2000: *Research Scientist and Associate* (Post-Doctoral) of Soil-Water Sciences and Agronomy, Department of Plant Sciences, University of Wyoming, Laramie, WY.
- 1995-1998: *Research and Teaching Assistant* (Doctoral) of Soil-Water Physics and Environmental Sciences, Department of Renewable Resources, University of Wyoming, Laramie, WY.

RESEARCH INTEREST

- Soil salinity and canal seepage assessment using electromagnetic (EM) induction methods.
- Site-specific salinity management using variable rate technology for seeding and gypsum applications.
- Remote sensing techniques (satellite/aerial imagery) to predict crop performance, evapotranspiration, and irrigation needs.
- Agro-chemical contamination in soil and water systems; Water flow and chemical transport in soils.
- Effects of land application of food-processing effluent waters on soil and groundwater quality.
- Irrigation system design, management, and water application scheduling (drip, sprinkler, flood).
- Economic best management practices for sustainable crop production and pollution control.

HONORS, AWARDS AND PROFESSIONAL SERVICES

- Nominated for the Outstanding Research Award, College of Agricultural Sciences & Technology, California State University Fresno (2002 & 2003).
- Nominated for the Outstanding Dissertation Award, University of Wyoming (1999).
- Biographical citations and certificates in recognition of Outstanding Merit, Accomplishment, Academic Excellence and Achievement, Community Leadership - Who's Who Among Students in American Universities & Colleges (1998, 1999), Dean's List Among Students (1998), Gamma Sigma Delta, Honor Society of Agriculture (1997), Phi Kappa Phi Honor Society (1997), and Alpha Zeta (1996).
- Peer-reviews of research papers and proposals for Journal of Environmental Quality, Precision Agriculture, Wine Institute, and California State University - Agricultural Research Initiative Program.
- Member of American Society of Agronomy and Soil Science Society of America.

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- California Department of Water Resources - CALFED Water Use Efficiency Program: *Assessing Spatial and Temporal Variability of Soil salinity on Farms Implementing Integrated Drainage Management Practices*. $175,010 (2001-2003). F. Cassel S., D. Goorahoo, D. Zoldoske, and P. Canessa.

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2. **Cassel S., F.**, D. Zoldoske, E. Norum, and T. Jacobsen. 2003. Detecting Canal Seepage using the Electromagnetic Induction Technique. Technical Conference of the Irrigation Association, San Diego, CA.
3. **Cassel S., F.**, D. Zoldoske, and M. Spiess. 2003. Assessing Spatial and Temporal Variability of Soil Salinity on Farms Implementing Integrated Drainage Management Practices. Final Report. California Department of Water Resources, CALFED Agricultural Water Use Efficiency Program, Sacramento, CA, 35 pp.
4. **Cassel S., F.**, B. Taylor, B. Roberts, and D. Zoldoske. 2003. Precision Farming Applications in Cotton Systems of California. Final Report, Cotton Incorporated, Cary, NC. 19 pp.
5. **Cassel S., F.**, M. McClanahan, S. S., and D. Goorahoo. 2003. Evaluation of Various BOD Loading Rates for Land Application of Food-Processing Wastewater. Final Report. United States Environmental Protection Agency, Washington D.C., 22 pp.
6. **Cassel S., F.**, T. Jacobsen, E. Norum, P. Canessa, and D. Zoldoske. 2002. Rapid Assessment of Seepage Potential in Earthen Canals using Electromagnetic Survey. Quarterly Research Report, U.S. Bureau of Reclamation, Sacramento, CA. 8pp.
7. **Cassel S., F.**, D. Zoldoske, T. Jacobsen, and E. Norum. 2002. Use of Electromagnetic Survey to Assess Potential Canal Seepage. Proceedings, California Plant and Soil Conference. California Chapter of American Society of Agronomy and California Plant Health Association. Fresno, CA. p.169.
8. **Cassel S., F.**, M. McClanahan, D. Goorahoo, S. S., J. Kipps, S. Klein, R. Crites, and J. Smith. 2002. BOD loading impact on land application percolate water quality. Water Environment Federation 75th Annual Technical Exhibition and Conference, Alexandria, VA. 19 pp.
9. **Cassel S., F.**, S. S., S. Miller, G. Vance, and R. Zhang. 2001. Assessment of drip and flood irrigation on water and fertilizer use efficiencies for sugarbeets. *Agricultural Water Management*. 46(3):241-251.
10. **Cassel S., F.**, S. S., L. Held, S. Miller, G. Vance, and R. Zhang. 2001. Agro-economic analysis of drip irrigation for sugarbeet production. *Agronomy Journal*. 93:517-523.
11. **Cassel S., F.**, S. S., R. Zhang, G. Vance, S. Miller, and M. Reddy. 2000. Modeling nitrate movement in sugarbeet soils under flood and drip irrigation. *International Commission of Irrigation and Drainage Journal*. 49:43-54.

James R. Tischer
Regional Program Manager

Education
B.S. Agriculture, Irrigation & Drainage, University of California, Davis, CA

Additional Training
Fellow, California Agricultural Leadership Program

Experience Summary
Mr. Tischer has a long history of successful assignments at the water/energy/resource stewardship interface having served as president of a large pump and well drilling contractor, manager of a large central California resource conservation district and as executive director of a large statewide agricultural non-profit organization
He was responsible for managing a successful water conservation program involving detailed technical assistance and cost-share program to encourage farmers and districts to efficiently manage resources via irrigation Best Management Practices. Collaborators included major academic institutions, private consulting engineers, federal and state agencies.

Selected Experience
Mr. Tischer is currently assigned as a regional program manager for the Agricultural Pumping Efficiency Program managed by the Center for Irrigation Technology at California State University, Fresno. Additionally he serves as the renewable energy team leader for development of solar and biofuels for the International Center for Water Technology at CSU, Fresno.

- The Agricultural Pump Efficiency Program is funded by the California Public Utilities Commission in all four Investor Owned Utility (IOU) areas from San Diego in the south to Redding in the north. The $9.6 million effort seeks to improve electric and natural gas pump efficiency via incentivised pump tests, cost-share on needed pump repairs, education and technical assistance. Phase 1 of the APEP is on target to save approximately 13.5 million kilowatt hours of electricity and 305,000 therms of natural gas.
- Mr. Tischer is responsible for water agency, irrigation industry and farmer liaison as well as APEP management and goal attainment in northern California.
- Developing and implementing the International Center for Water Technology Solar Initiative to encourage the conversion of 250,000 horsepower of electric and diesel powered irrigation pumps to grid-hybrid solar units from 2005-15.
- Promoting the development, funding and widespread adoption of oilseed based biofuels as a replacement for petroleum fuels in water pumping and general agricultural and industrial use.

Mr. Tischer completed an assignment as executive director of the Community Alliance for Family Farmers a statewide small-farmer agricultural advocacy group prior to joining the Center for Irrigation Technology at CSU, Fresno. While at CAFF he was instrumental in the following:

- Successfully completing a comprehensive strategic planning effort involving CAFF's membership, staff and board members.
- Successfully applying for and being awarded several large habitat restoration and education grants from CalFed and other funding institutions.
- Expanding CAFF's statewide membership base.

Mr. Tischer also served as the executive director of the Westside Resource Conservation District a 1.2 million acre special district in Fresno County. While at WRCD he accomplished the following:

- Served as the first manager of the newly formed district setting up management systems, developing funding sources and promoting effective liaison projects with area farmers and ranchers, water districts, cities, federal and state agencies, universities and community members.
- Managed a comprehensive WRCD water conservation and management effort to promote Best Management Practices and cost-share irrigation system improvements for farmers and ranchers. The Program involved fostering effective collaboration and goal attainment between private engineering consultants, the Department of Water Resources, Bureau of Reclamation and major academic institutions.
- Developed local, state and federal funding sources to promote WRCD priority projects especially in the management of subsurface agricultural drainage and creek and streambed habitat restoration.

In the area of renewable energy and large scale project management, Tischer served as director of fuel procurement for the permitting, construction and startup of four California biomass plants with a total capitol cost of $320 million. The annual biomass fuel budget for the four plants was $28 million. All four plants continue to be operational.

Organizations

American Solar Energy Association
National Biodiesel Board
California Irrigation Association

MATTHEW S. COLWELL
604 Arbutus Avenue
Chico, CA 95926
530.343.8231 home
530.321.3860 cell
colwellms@cdm.com

EDUCATION and LICENSE

Bachelor of Science Degree: California Polytechnic State University, San Luis Obispo.
Major: Agricultural Engineering
California Registered Civil Engineer RCE52171

EXPERIENCE

- *South Feather Water & Power Agency, Oroville, CA*

WATER DIVISION MANAGER - - Responsible for Water Division management under direction of the General Manager. Responsibilities include personnel management of 34 employees and operations of domestic, irrigation and water treatment systems serving 7000 customers. Service area includes 38,000 acres, 112 miles of irrigation canals, and 140 miles of domestic water distribution system.

- *CDM Inc. Sacramento, CA*

PROJECT MANAGER - - Responsible for all phases of project management of water resource related projects, including client relations, project schedule and budget. Supervised support staff for completion of multiple phase analysis and report development. Responsible for water resources discipline business development. Projects include:

Agricultural Water Management Council, CALFED Water Use Efficiency Program: Analyzed water district agricultural water management practices for affects on statewide water use efficiency objectives.

Butte and Tehama Counties: Participated in the development of Butte and Tehama County water inventory and analysis plans. Participated in the development of Butte County Integrated Water and Resource Conservation Plan.

Sonoma County Water Agency: Developed agricultural water demands for the feasibility of recycled wastewater reuse.

Lake County Flood Control and Water Conservation District: Developed Lake County Water Inventory and Groundwater Management Plan Expansion Project. Developed Groundwater Assistant Program Grant Application (AB 303) for the Project.

Colusa Basin Drainage District: Developed Scope, Schedule, and Budget for the Freshwater Creek Basin Integrated Resource Management Plan.

- *Optimal Water, Inc. Chico, CA*

REGIONAL MANAGER - - Management and facilitation of water asset management and water marketing strategies for public and private water agencies. Develop and implement water-marketing programs. Assist water management agencies in structuring and negotiating water transactions. Comprehensive knowledge and expertise in water transfers/exchanges, groundwater banking programs, and California hydrology. Extensive water contacts with local, state and federal officials.

- *Western Canal Water District, Richvale, CA* *Nov 1998 – Aug 2001*

  GENERAL MANAGER -Management of 70,000-acre agricultural water delivery system under direction of a five member elected Board. Responsible for all District management functions including 12 staff members, $1.4 million operating budget and $14 million assets. Direct and implement policy related to diverted surface irrigation water in accordance with State water rights law. Actively represent the District with extensive coordination with local, State and Federal agencies on water policy issues. Direct capital improvement projects including planning, environmental documentation, and financing. Actively participate in professional associations (ACWA, NCWA, BBWUA, NSVWF). Special issues include open system operation, water measurement, groundwater, conjunctive use, water banking, endangered species concerns.

- *California Department of Water Resources, Sacramento, CA* *Mar 1988 – Nov 1998*

  ASSOCIATE ENGINEER, Water Resources - -Direct the operations of the California State Water Project (SWP) within the mandated policies and regulations and to optimize uses of available water in a flexible, environmentally sensitive and reliable manner. Planned and analyzed operations of multiple SWP water supply, flood control, and hydroelectric facilities for industrial, municipal and agricultural uses. Maintained compliance with USCOE, SWRCB San Francisco Bay/San Joaquin Delta, and FERC standards. Maintained and analyzed endangered species protection measures set in USFWS, CDFG, NMFS, and EPA biological documentation. Operations planning on daily, weekly, monthly, and annual time steps including demand and hydrologic analysis. Performed extensive communication with SWP contractors for operations support and analysis. Provide technical support for CALFED pertaining to operations of the SWP. Familiar with CVPIA, FERC, San Francisco San Joaquin Bay Delta Water Quality Control Plan, State and Federal Bay Delta Accord and AFRP issues. Provide extensive coordination of CVP/SWP operations to optimize and balance the many factors competing for the available water supply.

  ASSOCIATE / ASSISTANT ENGINEER, Water Resources - -Developed, improved and implemented stochastic hydrology models for the issuance of seasonal and weekly snowmelt forecasts and water year runoff for state and federal water projects, irrigation districts, municipal utilities, and the general public. Provided hydrologic guidance for operational decisions for major multipurpose reservoirs. Produced Sacramento and San Joaquin River streamflow forecasts used to set water quality and fishery standards in the Sacramento-San Joaquin Delta. Installed, maintained and monitored remote hydrometeorological data acquisition locations. Utilized a wide variety of data sources, software and hardware to conduct complex hydrologic studies. Issue flood bulletins on major rivers in cooperation with the California-Nevada River Forecast Center. Real time operations of the Sacramento Watershed Model.

  JUNIOR CIVIL ENGINEER - -Responsible for State Water Project surveillance including operation, monitoring and maintenance of hydraulic piezometer, slope indicators and vertical ground settlement devices on dams, canals, pumping plants and pipelines. Other duties include surveying, design and supervision of civil projects, and computer operation for data management.

Bryan P. Thoreson, P.E.
Principal Engineer, Project Manager

Education
Ph.D., Agricultural Engineering, University of Arizona, Tucson, AZ.
M.S., Agricultural Engineering, South Dakota State University, Brookings, SD.
B.S., Agricultural Engineering, South Dakota State University, Brookings, SD.

Professional Registrations
Registered Civil Engineer, California (No. C56194)
Registered Civil Engineer, Washington (No. 36249)

Experience Summary
Mr. Thoreson has more than 10 years of professional experience in water resources and irrigation engineering. He specializes in irrigation water conservation, having skills and experience in the areas of irrigation scheduling, assessing and improving on-farm application efficiency, flow measurement, data management, and irrigation and drainage system operations and maintenance (O&M). Mr. Thoreson has extensive experience in software development and application related to irrigation engineering, including development, deployment and maintenance of customized Oracle SQL databases. Throughout his work, he has consistently demonstrated a unique command of both theoretical principle and practical application. He has authored numerous papers on improved irrigation practice and operations and maintenance procedures. Mr. Thoreson joined Davids Engineering in 1997 and serves as principal engineer, project manager and project engineer.

Selected U.S. Experience

Mr. Thoreson is currently an irrigation engineer with Davids Engineering, applying his skills in the areas of flow measurement, data base management and irrigation water conservation on projects for a variety of clients.

- Develop and review technical descriptions of drainwater recycling, tailwater recovery systems, system automation and canal lining water conservation measures with the ultimate goal of specifying technical procedures for verifying water savings.
- Support, through data analyses, the verification of water conservation achieved by projects implemented by IID under its Water Conservation and Transfer Program with Metropolitan Water District of Southern California (MWD).
- Assist the Imperial Irrigation District (IID) efforts to integrate water measurement data collection and quality control functions into a computerized (Oracle) information system. The system is designed to store an inventory of operations and flow measurement structures, history of structure maintenance and time series flow data for the irrigation water distribution system. The system collects and stores all the information necessary for, and computes water savings resulting from 16 water conservation projects.
- Assist the Benton Irrigation District (BID) with the development of a water balance and comprehensive water conservation plan to meet the Yakima River Basin Water

Enhancement Project requirements. Water losses identified by the water balance are being aligned with conservation measures with the ultimate objective of formulating a water conservation plan.

- Assist in the development of an integrated canal and drainage network model to assess water quality impacts of on farm conservation activities in the 200,000 ha area served by the Imperial Irrigation District system. The model has over 5,500 demand nodes serving farms and over 1,000 drain nodes where water quality parameters can be assessed over the anticipated 75 years of output. The model runs on a monthly time step and is based on 12-years of detailed water delivery, cropping and flow data.
- Assist the Turlock Irrigation District (TID) with the data analyses related to the development of an integrated water resource management plan.
- Assist the Merced Irrigation District (MID) with the development of a water balance and water management plan to meet the AB3616 Memorandum of Understanding (MOU) requirements. Water losses identified by the water balance are being aligned with efficient water management practices specified in the MOU.
- Assist the Turlock Irrigation District (TID) with the development of a water balance and water management plan to meet the AB3616 MOU requirements. Water losses identified by the water balance are being aligned with efficient water management practices specified in the MOU.

Prior to joining Davids Engineering, Mr. Thoreson was an engineer with the Imperial Irrigation District (IID), Imperial, CA. While with IID, Mr. Thoreson was responsible for carrying out the following tasks:

- Led development efforts to integrate IID's water measurement data collection and quality control functions into a computerized information system (Oracle).
- Used farmer input along with analysis of historical data to estimate IID's potential to conserve irrigation water. Estimated irrigation water conservation potential and associated project costs for the District's Water Requirements and Availability Study.
- Supervised IID canal and drain flow data collection and documentation used for verification of a 35-year joint program designed to conserve and transfer 106,000 acre-feet of water per year from IID to Metropolitan Water District (MWD) of Southern California.
- Developed current metering and discharge rating program following USGS procedures. Coordinated with a retired USGS current metering specialist to develop and present a current metering training to IID water measurement personnel.
- Designed and evaluated flow measurement sites in the irrigation distribution and drainage collection systems.
- Developed calibration and data quality control procedures for IID canal and drain flow measurement sites.

Professional Organizations

U.S. Committee on Irrigation and Drainage--Associate Editor of Irrigation and Drainage Managing Water for Sustainable Agriculture
American Society of Civil Engineers
American Society of Agricultural Engineers

January 5, 2005

Debra Gonzalez
California Department of Water Resources
Office of Water Use Efficiency
P.O. Box 942836
Sacramento, California 94236

Dear Ms. Gonzalez:

The Butte County Department of Water & Resource Conservation has worked cooperatively for the past year with South Feather Water and Power Agency (SFWPA) to secure federal funds for canal lining projects. These projects are coordinated with the County's Integrated Water Resources Planning efforts.

SFWPA is a multipurpose agency providing irrigation water, treated domestic water and hydroelectric power. The agency is seeking assistance from DWR (Proposition 50, Water Use Efficiency Program) for furthering its efforts in water use efficiency and conservation by identifying and minimizing open channel conveyance system losses. The proposed program (Program) will utilize innovative research techniques to quantify water seepage and losses to the system and then proceed on a priority basis with canal-lining projects.

The Program will work cooperatively with Fresno State and the Center for Irrigation Technology to utilize the Mobile Assessment (MA) System to conduct reconnaissance canal seepage surveys. The results will be reported to assist SFWPA to infer seepage estimates for canal reaches and to prioritize canal-lining projects. SFWPA will implement canal lining projects based information obtained from reconnaissance studies.

We will continue to seek the authorization supported by Congressman Doolittle in this year's federal authorization, and this Water Use Efficiency Program will help quantify the benefits of canal lining. We heartily endorse this creative water use efficiency project that will allow us to quantify water savings more accurately.

Sincerely,

Ed Craddock, Director

To promote the economic, social and environmental viability of Northern California by enhancing and preserving the water rights, supplies and water quality of our members.

January 4, 2004

Debra Gonzalez
California Department of Water Resources
Office of Water Use Efficiency
P.O. Box 942836
Sacramento, CA 94236-0001

RE: Support of 2004 WUE Grant Funding for the South Feather Water and Power Canal Seepage Reduction Program

Dear Ms. Gonzalez:

The Northern California Water Association (NCWA) supports the South Feather Water and Power's (SFWP) Canal Seepage Reduction Program 2004 Water Use Efficiency grant application.

NCWA represents 70 agricultural water districts and agencies, private water companies, and individual water rights holders with senior rights and entitlements to the surface waters of the Sacramento Valley. NCWA's members also have overlying and appropriative water rights to groundwater resources in Northern California, from the Northern reaches of Shasta County to Sacramento County, from the edge of the Sierra Nevada Mountains in El Dorado County to Glenn County which extends to the Coast range.

Through this program, SFWP will work cooperatively with California State University, Fresno and the Center for Irrigation Technology to utilize the Mobile Assessment (MA) System in conducting reconnaissance canal seepage surveys. The results will be reported to assist SFWP to develop seepage estimates for canal reaches and to prioritize canal-lining projects. SFWP will implement canal lining projects based upon information obtained from the reconnaissance studies. The program will be implemented in cooperation with, and support of, the Sacramento Valley Water Management Program.

We support and encourage you to fund the South Feather Water and Power Canal Seepage Reduction Program.

Sincerely,

Todd N. Manley
Director of Government Relations