January 10, 2005

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

Dear Ms. Gonzales:

Please find enclosed one original, eight photocopies, and an electronic version of the proposal entitled "Development of Standardized testing for soil moisture sensors and climatologically based controllers for efficient watering regime in Turf grass and Agricultural industry."

Please feel free to contact David Zoldoske at (559) 278-2066 if you have any additional questions.

Sincerely,

Thomas McClanahan
Associate Vice President

Development of standardized testing for soil moisture sensors, climatologically-based controllers, and other equipment for high efficiency watering regimes in landscape and turf grass

A Research Proposal submitted to

CALIFORNIA DEPARTMENT OF WATER RESOURCES
CALIFORNIA BAY-DELTA WATER USE EFFICIENCY PROGRAM

By

California State University, Fresno Foundation
Center for Irrigation Technology
5370 N.Chestnut Ave., M/S OF18
Fresno, CA 93740

David Zoldoske, Edward M. Norum, Dave Goorahoo & Diganta D. Adhikari

January 11, 2005

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 standardized testing for soil moisture sensors, climatologically, based controllers, and other equipment for high efficiency watering regimes in turf grass.

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)	Name, title	David Zoldoske Director,
	Mailing address	Center for Irrigation Technology, 5370 N. Chestnut Ave.,M/S OF18 Fresno, CA 93740
	Telephone	(559) 278-2066
	Fax.	(559) 278-6033
	E-mail	davidzo@csufresno.edu

7. Grant funds requested (dollar amount): $206,193
(from Table C-1, column VI)

8. Applicant funds pledged (dollar amount): 0

9.Total project costs (dollar amount): $206,193
(from Table C-1, column IV, row n)

10. Percent of State share requested (%) 100%
(from Table C-1)

11. Percent of local share as match (%) 0
(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): 1/1/06 – 12/31/08

13. State Assembly District where the project is to be conducted: Mike Villines - 29th

14. State Senate District where the project is to be conducted: Charles Poochigian - 14th

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

Devin Nunes - 21st George Radanovich is the 19th and Jim Costa is the 20th

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

17. Location of project (longitude and latitude): N36 44.414 W119 47.167

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? 0

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.

- ☐ (a) yes, _______ median household income
- ☒ (b) no

(Provide supporting documentation.)

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.

____________________	Thomas McClanahan, Associate VP	________________
Signature	Name and Title	Date

A. PROJECT SUMMARY

The world's water supply must be sustainable and renewable in order to meet the needs of existing and future populations and to ensure that habitats and ecosystems are protected. Sound water resource management – emphasizing the careful, efficient use of water – is essential to achieve these objectives. One of the most significant areas of potential water savings can be found in the excess water applied to landscapes in the urban sector. This water has been appropriated, treated and delivered and may then be inefficiently applied because of poor irrigation management and/or distribution. This over-irrigation, estimated to be 20% to 30%, is significant particularly in urban areas prone to periodic or prolonged drought.

The challenge to the irrigation industry is to provide "efficient" irrigation systems to the consumer using technology that will be easily "adopted." Many water-efficient products are available in the marketplace including soil moisture sensors, matched precipitation rate and flow control nozzles, pressure regulators and numerous drip/micro products. However, not all products are created equal. Some products require more knowledge to properly operate than the homeowner/operator currently possesses or cares to learn.

Irrigation controllers illustrate this point. Some controllers offer very sophisticated features capable of fine-tuning the amount of water being applied. However, water savings may not be realized if the features are not fully adopted because of the requirement for a significant level of understanding and input by the operator. Documentation from the field indicates that some of these controllers are operated in "default" mode due to the operator's inability or reluctance to provide the required input. Others are simple set once for the most water intensive time of the year, and left to operate at this level throughout the season. Over-irrigation is particularly evident in the late summer and fall time period.

For the past two years, the Center for Irrigation Technology has worked closely with water purveyors and the Irrigation Association as part of their "Smart Water Application Technology" (SWAT). The ultimate goal of the SWAT program is to provide professionally designed irrigation systems, using recognized high efficiency products, with proper system installation done by certified individuals. A key component is to develop standardized testing protocols to evaluate the reliability, accuracy and repeatability of commercially-manufactured irrigation products.

Initial testing efforts have focused on soil moisture sensors and climatologically-based controllers – two types of products that can help conserve water and can be implemented in existing irrigation systems with little or no technical expertise. Following beta testing and extensive review and revisions (by industry professionals, academics and water purveyors) the protocols are now ready. The SWAT program requires manufacturers to submit their products for testing compliance to the protocols.

This project proposes to support the development and application of these industry approved testing protocols. The process will provide for the public disclosure of product performance results in meeting the protocols. These products may then be eligible for incentive and promotion programs offered by various urban water districts statewide to hasten their utilization.

B. STATEMENT OF WORK

B.1. Relevance and importance

The world's water supply must be sustainable and renewable in order to meet the needs of existing and future populations and to ensure that habitats and ecosystems are protected. Sound water resource management – emphasizing the careful, efficient use of water – is essential in achieving these objectives. One of the most significant areas of potential water savings can be found in the excess water applied to landscapes in the urban sector. This water has been appropriated, treated and delivered and may then be inefficiently applied because of poor irrigation management and/or distribution. This over-irrigation, estimated to be 20% to 30%, is significant particularly in urban areas prone to periodic or prolonged drought.

B.1.a. Problem statement and project need

The challenge to the irrigation industry is to provide "efficient" irrigation systems to the consumer using technology that will be easily "adopted." Many water-efficient products are available in the marketplace including soil moisture sensors, matched precipitation rate and flow control nozzles, pressure regulators and numerous drip/micro products. However, not all products are created equal. Some products require more knowledge to properly operate than the homeowner/operator currently possesses or cares to learn.

Irrigation controllers illustrate this point. Some controllers offer very sophisticated features capable of fine-tuning the amount of water being applied. However, water savings may not be realized if the features are not fully adopted because of the requirement for a significant level of understanding and input by the operator. Documentation from the field indicates that some of these controllers are operated in "default" mode due to the operator's inability or reluctance to provide the required input. Others are simple set once for the most water intensive time of the year, and left to operate at this level throughout the season. Over-irrigation is particularly evident in the late summer and fall time period.

To address this issue and improve water use efficiency as a whole, the Irrigation Association (IA) joined with leading water purveyors to form the Smart Water Application Technology (SWAT) project. The first goal of SWAT was to identify irrigation controllers that require limited or hands-off input for operation. A performance protocol was developed by the industry to establish the minimum controller standards. The protocol can be accessed from the IA's website located at www.irrigation.org.

Controllers that meet the protocol requirements may be eligible for rebates and/or incentives from water purveyors. Following close behind the controller testing is the evaluation of soil moisture sensors. Beyond these initial efforts, the SWAT project has identified the following philosophy:

> "Smart Water Application Technology (SWAT) is a national effort led by the Irrigation Association and supported by leading water purveyor organizations. The goal of SWAT is to achieve exceptional water use efficiency in landscape irrigation. The SWAT designation establishes performance criteria for products and defines practices that exemplify the highest standards of efficient water and energy use."

The initial SWAT effort establishes test protocols for climate-and/or soil moisture-based controllers. In the future, irrigation systems will be addressed more broadly under the SWAT umbrella, including design, system components, installation and management.

The concept is that among the many products developed by industry to provide water (and energy) to the landscape and turf areas, some do it more efficiently than others. The SWAT program plans to identify testing protocols that can be used to identify irrigation products that provide the highest level of water and energy efficiency.

The SWAT approach further recognizes that landscape and turf areas are irrigated by a system, and not just parts. Thus the expertise used to design and install the irrigation system must meet some minimum requirements. It is likely that SWAT will recognize established programs such as the Irrigation Association's Certified Irrigation Designer (CID) program to demonstrate expertise in designing water-efficient systems.

To achieve final SWAT designation, it may require a Certified Irrigation Designer to use approved or certified products in an irrigation system design that is installed by a Certified Installer. This is the most direct way to ensure that any given irrigation system will perform at peak water and energy efficiency, which is the stated goal of the SWAT program.

This SWAT effort is going on at a time when the Federal Environmental Protection Agency (EPA) is proposing the Water Smart program which is loosely based on their successful Energy Star program. Water Smart will cover a wide range of consumer products – from washing machines to plumbing fittings to irrigation products. The implementation of the Water Smart program could have a dramatic impact on the landscape and turf irrigation industry. A national effort led by the EPA would bring significant credibility to the concept of a Water Smart approved irrigation system. The consequences of this action would cause increased consumer awareness and demand for high water and energy efficiency irrigation systems.

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

Since the roll-out of Water Smart is admittedly several years behind the SWAT efforts, it is probable that the EPA will adopt many, if not all the procedures developed by SWAT. Therefore it is critical to the landscape and turf industry that the SWAT program "get it right" the first time. We are working towards voluntary standards of excellence. If industry and water purveyors cannot or are not willing to provide the required leadership, then local or regional regulatory agencies may fill the void. This proposed funding request will help insure the success of this program.

The scope and objectives of the project are rather straight forward. We propose to work closely with the irrigation industry and water purveyors to identify irrigation products and technologies that meet the level of high water use efficiency. The process will be such that after identifying and ranking the potential impact on water savings opportunities, protocols will be developed by the process established by the Irrigation Association. Protocol testing will be proofed by the Center for Irrigation Technology, and then testing services will be opened up to all parties of interest to submit products. The reporting of products successfully meeting the protocol requirements will be made public, with the information used to establish programs within urban water districts for the adoption of products and systems with high water use efficiency.

B.1.c Support for Calfed Water Use Efficiency Program Goals

The proposal is designed to meet the CALFED Bay-Delta goals of reduced water demand through "real water" conservation. Water savings will occur by reducing over-irrigation (total applied water) of agricultural crops.

B.2. Technical/Scientific Merit, Feasibility

The U.S. Department of Agriculture identifies improvements in water management as one of the primary agricultural policy objectives for the 1990's (USDA, 1994). Due to the fact that the turf grass industry location and size are population dependent, potential water savings of 20 to 30% through improved water use efficiency in landscape and turf irrigation will likely convert to a significant water saving for the water purveyors. Approximately 50% of the water used in residential homes is for outside use which translates into a 10% to 15% net savings per household. Irrigation water management involves the managed allocation of water and related inputs in irrigated crop production, such that economic returns are enhanced relative to available water. Conservation and allocation of limited water supplies is central to irrigation management decisions, whether at the field, farm, irrigation-district, or river-basin level (Marlow, 1999).

Water use efficiency is one way of addressing water quality and quantity goals. For example, the efficient use of irrigation water can also prevent pollution by reducing surface runoff, minimizing leaching through the soil profile, and providing better energy management. With respect to water flow and solute movement through soils, it is important to effectively monitor the soil moisture levels at any given time. In addition, it is essential to know the water status of soil for efficient irrigation scheduling in order to optimize water use by plants.

The proposed project is focused on identifying irrigation components that meet the protocol criteria as established by the IA process. The industry and water purveyors have provided partial to move the evaluation of climatologically-based controllers to the stage of public testing. However, the level of funding to move the SWAT program forward an accelerated pace at to meet the demand for information will require funding from other sources like Proposition 50.

The world's water supply must be sustainable and renewable in order to meet the needs of existing and future populations and to ensure that habitats and ecosystems are protected. Sound water resource management – emphasizing the careful, efficient use of water – is essential to achieve these objectives. One of the most significant areas of potential water savings can be found in the excess water applied to landscapes in the urban sector. This water has been appropriated, treated and delivered and may then be inefficiently applied because of poor irrigation management and/or distribution. This over-irrigation, estimated to be 20% to 30%, is significant particularly in urban areas prone to periodic or prolonged drought.

The challenge to the irrigation industry is to provide “efficient” irrigation systems to the consumer using technology that will be easily “adopted.” Many water-efficient products are available in the marketplace including soil moisture sensors, matched precipitation rate and flow control nozzles, pressure regulators and numerous drip/micro products. However, not all products are created equal. Some products require more knowledge to properly operate than the homeowner/operator currently possesses or cares to learn.

Irrigation controllers illustrate this point. Some controllers offer very sophisticated features capable of fine-tuning the amount of water being applied. However, water savings may not be realized if the features are not fully adopted because of the requirement for a significant level of understanding and input by the operator. Documentation from the field indicates that some of these controllers are operated in “default” mode due to the operator’s inability or reluctance to provide the required input. Others are simple set once for the most water intensive time of the year, and left to operate at this level throughout the season. Over-irrigation is particularly evident in the late summer and fall time period.

For the past two years, the Center for Irrigation Technology has worked closely with water purveyors and the Irrigation Association as part of their “Smart Water Application Technology” (SWAT). The ultimate goal of the SWAT program is to provide professionally designed irrigation systems, using recognized high efficiency products, with proper system installation done by certified individuals. A key component is to develop standardized testing protocols to evaluate the reliability, accuracy and repeatability of commercially-manufactured irrigation products.

Initial testing efforts have focused on soil moisture sensors and climatologically-based controllers – two types of products that can help conserve water and can be implemented in existing irrigation systems with little or no technical expertise. Following beta testing and extensive review and revisions (by industry professionals, academics and water purveyors) the protocols are now ready. The SWAT program requires manufacturers to submit their products for testing compliance to the protocols.

Another component of high efficiency irrigation systems as identified by the industry is soil moisture status. Soil moisture sensors are an important component of some sensor-based irrigation system controllers. The sensor provides information critical to the effective and efficient management of turf and landscape irrigation systems. With a standard time-based system controller, they act to provide a closed-loop control feedback. They may also find application by closing the loop with evapotranspiration (Et) based system controllers.

To address this issue and improve water use efficiency as a whole, The Center for Irrigation Technology is working closely with water purveyors statewide and the Irrigation Association to identify promising water saving technology for landscape irrigation. A pilot program is being conducted to identify climate based controller and soil moisture sensors which provide high water use efficiency. Two testing protocols have been developed through a national review process led by the Irrigation Association. The climate based controller protocol is now being used to evaluate controllers by the Center for Irrigation Technology. This proposal would help establish a comprehensive program aimed at finalizing the soil moisture sensor protocol as well as identifying appropriate technologies that reduce/eliminate all non-essential water use in landscape.

Landscape irrigation water is delivered via an irrigation system. The most efficient, water saving irrigation system consists of:

a) proper design,
b) utilization of water efficient irrigation parts and equipment,
c) proper installation, and
d) proper operation and maintenance.

This proposed program is designed to establish the criteria for ultimately meeting all four objectives above. Products will be tested according to the established testing protocol. Products meeting or exceeding the protocol will be put on an approved list. This list will be utilized by water purveyors as the basis for incentive and rebate programs. End users (home owners) will be encouraged and may be provided with financial incentives to adopt high efficiency water use technology.

Additionally, guidelines will be developed outlining policies and procedures that will help provide for the proper design, installation, and management of irrigation systems. Using good equipment in a poorly designed, and/or poorly installed system will not meet the total water saving goals of this program.

B.2.a. Methods, procedures, equipment and tasks

The overall goal of this project is to contribute to efforts aimed at identifying and achieving exceptional water use efficiency in landscape irrigation. Initially, the focus will be on soil moisture sensors and climatologically-based controllers. The intent is to verify the calibration accuracy of commercially available soil moisture sensors and also characterize the efficacy of irrigation system controllers. Soil moisture sensors are an important component of some sensor-based irrigation system controllers. These results can then be utilized by the water purveyors as the basis to promote widespread adoption of approved technologies.

Soil moisture sensors

During early phases of the program, work will be conducted on the testing and calibrating of commercially available sensors for accuracy, reliability and repeatability using ***SWAT's Soil Moisture Testing Protocol 4th Draft***. The draft protocol characterizes the ability of the sensor to provide reliable results when comparing individual units during multiple wetting cycles. This protocol also tests the sensors over the range of conditions encountered in typical field installations. This includes a range of soil types, a range of soil temperatures (including freezing conditions) and a range of irrigation water salinity levels. The sensor's ability to provide useful performance information when exposed to this range of expected field conditions will be evaluated. Specifically the sensor's calibration curve or set point will be determined and analyzed for stability when subjected to varying on-site conditions. The calibration curve or set points are a plot of the sensor reading versus the mass or volumetric moisture content. As currently defined, the protocol is framed to test sensors used to control turf irrigation.

Task 1: Sampling Test

The current protocol asks manufacturers to submit 20 units of sensors from which ten will be randomly selected for each test as shown below in Table 1.

Clause or Sub-Clause*	Subject of Test	Range of r^2 values
6.2.1	Calibration in a fine textured soil with 0dS/m water***	0.54 to 0.88
6.2.2	Calibration in a medium textured soil with 0dS/m water	0.99
6.2.3	Calibration in a coarse textured soil with 0dS/m water	0.99
6.3.1	Calibration at 20°C with 0dS/m water	0.97 to 0.98
6.3.2	Calibration at 30°C with 0dS/m water	0.95 to 0.99
6.3.3	Test for freezing susceptibility with 0dS/m water	*In progress*
6.4.1	Calibration when wetted with water with a conductivity of 1.0 dS/m on a medium textured soil	0.96 to 0.99
6.4.2	Calibration when wetted with water with a conductivity of 1.5 dS/m on a medium textured soil	0.99
6.4.3	3 Calibration when wetted with water with a conductivity of 3.0 dS/m on a medium textured soil	0.95 to 0.98
6.5.1	Calibration when wetted with water with a conductivity of 1.5 dS/m on a fine textured soil	0.678
6.5.2	Calibration when wetted with water with a conductivity of 1.5 dS/m on a coarse textured soil	0.9825

**These numbers refer to subsections listed in 4th draft protocol.*

Table 1 Ranges of r2 values obtained for the best fit regression equations describing the relationship between the sensor values and the calculated water contents for various tests.

Task 2: Soil sampling and collection

Soil samples will be collected or purchased for running the experiments on fine, medium and coarse textured soils. The soils shall be oven dried and screened for ease of packing around the sensor. Soils texture analysis and chemical properties of the soils will be determined.

Task 3: Soil box preparation

A standardized box specified on the 4th Draft protocol will be used to pack soils containing a fixed weight volume of the representative soil type. The box shall wet and drain the soils through a perforated bottom. The box shall allow for the determination of the net weight of the water required to bring the soil sample to field capacity. The volume of the soil shall be sufficient to permit the sensor to function without being influenced by the box. The soils in the box shall be placed and tapped so as to result in representative bulk density (range 1.2 to 1.4 kg/L). The sensors will be located in the center of the box at the depth of approximately 3.0 in. or as per manufacturer's recommendation. Sensor reading and temperature measuring device output wiring shall be arranged so as not to interfere with the procedure for weighing the box. The weight of all components, except for the soil and water shall be known.

The experiment will be run under strict environmental conditions as specified under 4th Draft protocol. Also the box is designed to represent a section of the turf grass root zone with a maximum depth of 6-7 inches. The actual depth and placement of the sensor will be recorded.

Task 4: Calibration curves and results

Summary regression analysis, similar to that show in Table 1 and Figure 1, for the calibration of the sensors in each round subjected to different wetting cycles for the different soil textures at different specified temperature and salinity of applied water will be conducted.

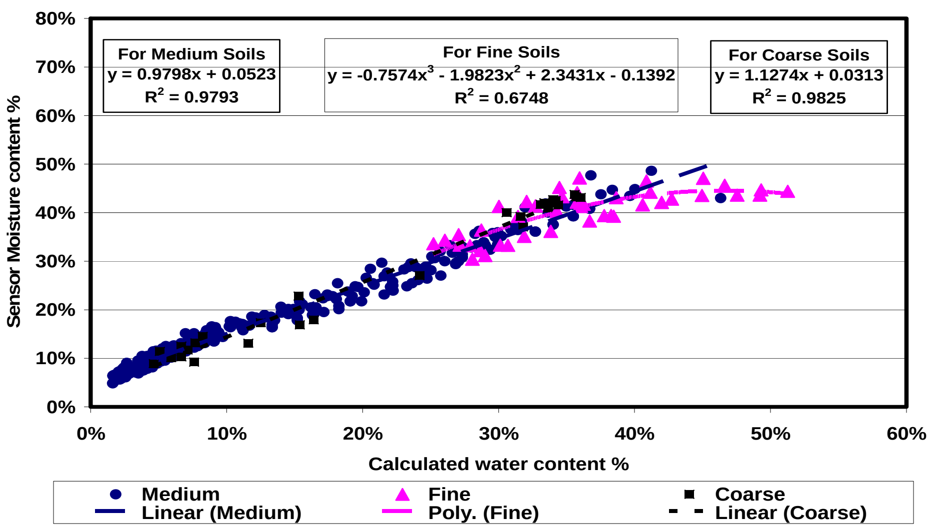


Figure 1 - Plot of soil moisture sensor reading versus calculated water contents for sensors showing best fit regressions for data obtained for in coarse, fine and medium textured soils.

Task 5: Report writing and presentation of results

Definition of results and evaluation of the calibration curve with confidence limit will be made. If the range of the moisture content values defined by the confidence limits at a given reading is so great as to leave the irrigation decision unsupported, the sensor performance will be deemed "unacceptable" for the conditions under it was tested.

See timetable on attachment 1.

Climatologically Based Controllers

SWAT's Climatologically Based Controllers 5th Draft protocol provides a procedure for characterizing the efficacy of irrigation system controllers that utilize climatological data as a basis for scheduling irrigations. They may also use on-site temperature or rainfall sensors. This evaluation concept requires the use of accepted formulas for calculating crop evapotranspiration (ETc). Commercial versions of this type of controller include the following:

- Controllers that store historical ETc data characteristic of the site
- Controllers that utilize on-site sensor as a basis for calculating real time ETc
- Controllers that utilize a central weather station as a basis for ETc calculations and transmit the data to individual home owners from remote sites
- Controllers that utilize rainfall and temperature sensors
- Control technology that is added on to existing time based controllers
- Control technology that requires a minimum of input from homeowner/operator

It is recognized that controlling the irrigation of turf and landscape is a combination of scientific theory and subjective judgments. The attempt in developing this protocol is to use only generally recognized theory and to avoid judgments involving the art of irrigation. The protocol then recognizes that only the theory of irrigation is controllable by the skill of the controller manufacturer. The protocol will measure the ability of the controllers to provide adequate and efficient irrigation while minimizing potential run-off.

The concept of climatologically controlled irrigation systems has an extensive history of scientific study and documentation. The objective of this research is to evaluate how well current controller technology has integrated the scientific data into a practical system that meets the agronomic needs of the turf and landscape plants. Also it must meet the need of apply sophisticated control algorithms with virtual hands-off input. This is the first step in an evaluation procedure that must also eventually include other secondary considerations that affect market acceptance.

Task 1: Overview

System controllers from individual companies will be installed on-site (CIT) complete with required sensors and/or communication links. The controller will be wired to 6 zones simulated by using an electronic device that will automatically record the run time signal from the controller, to the individual zone "Control Valves." Combining run times with application rate data and estimated efficiencies will provide the net irrigation application.

Task 2: Sampling

A representative of the testing laboratory will select test specimens for each test at random from a sample of at least 10 units supplied by the manufacturer.

Task 3:Test for Adequacy, Efficiency and Runoff Potential

1. Communicate with the controller manufacturers the starting date of the test run, the source of the real- time weather data, the on-site weather data history, and the peak electrical use period.

2. Communicate with the controller manufacturers the definitions of the virtual yard as given in Table 2.

3.

Item No.	Description	Zone #1	Zone #2	Zone #3	Zone #4	Zone #5	Zone #6
1	Soil Texture (1)	Loam	Silty Clay	Loamy Sand	Sandy Loam	Clay Loam	Loam
2	Slope, %	6	1	8	12	2	20
3	Exposure	75% Shade	Full Sun	Full Sun	50% Shade	Full Sun	Full Sun
4	Root Zone Working Storage (ZRWS), in.	.85	.55	.90	2.00	2.25	.85
5	Vegetation	Fescue (Tall)	Bermuda	Ground Cover	Woody Shrubs	Trees & Ground Cover	Bermuda
6	Crop (Turf) Coefficient (Kc)	See Table 2	See Table 2	N/A	N/A	N/A	See Table 2
7	Landscape Coefficient (K_L) (2)	N/A	N/A	0.55	0.40	0.61	N/A
8	Irrigation System	Pop-Up Spray Heads	Pop-Up Spray Heads	Pop-Up Spray Heads	Pop-Up Spray Heads	Surface Drip	Rotors
9	Precipitation Rate (PR), in./h	1.60	1.60	1.40	1.40	0.20	0.35
10	Estimated Application Efficiency, %	55	60	70	75	80	65
11	Gross Area, ft^2 (3)	1,000	1,200	800	500	650	1600

Table 2 - Description of Zone

4. Provide crop (turf) coefficients. See Table 3.

	Full Sun		75% Shade	
Month	**Fescue**	**Bermuda**	**Fescue**	**Bermuda**
January	0.61	0.52	0.41	0.35
February	0.69	0.64	0.46	0.43
March	0.77	0.70	0.52	0.47
April	0.84	0.73	0.56	0.49
May	0.90	0.73	0.60	0.49
June	0.93	0.71	0.62	0.48
July	0.93	0.69	0.62	0.46
August	0.89	0.67	0.60	0.45
September	0.83	0.64	0.56	0.43
October	0.75	0.60	0.50	0.40
November	0.67	0.57	0.45	0.38
December	0.59	0.53	0.40	0.36

Table 3 - Crop(turf) Co-efficients (Kc)

5. Provide basic soil intake rate and allowable surface accumulation for the soil textural classes and field slopes as shown in Table 4.

Soil Textural Class	Basic Intake Rate in./h	Allowable Surface Accumulation (ASA) in.			
		Slope, 0 to 3%	Slope, 4 to 6%	Slope, 7 to 12%	Slope, 13% <
Clay	0.1	0.2	0.15	0.1	0.1
Silty Clay	0.15	0.23	0.19	0.16	0.13
Clay Loam	0.2	0.26	0.22	0.18	0.15
Loam	0.35	0.3	0.25	0.21	0.17
Sandy Loam	0.4	0.33	0.29	0.24	0.2
Loamy Sand	0.5	0.36	0.3	0.26	0.22
Sand	0.6	0.4	0.35	0.3	0.25

Table 4 - Basic Soil Intake Rate (IR) and Allowable Surface Accumulation (ASA) as it

6. Access the valve run time monitors to determine the run times per valve as specified by the manufacturer's system. Use the run times, the specified precipitation rate, and application efficiency to calculate the net application. Develop a moisture balance calculation assuming the calculation starts with a full root zone. Continue the calculation for a time period long enough to demonstrate the controller's ability to adequately meet a range of climatic conditions. Accumulate surplus and deficit values during the evaluation period and express as system adequacy and efficiency. The Maximum Runtime allowable before runoff occurs will be calculated from the following formula:

$$RT\ (MAX) = 60\ (ASA)/(PR-SI),\ \text{minutes}$$

Where
RT (MAX) is the maximum runtime
PR is the precipitation rate
SI is the soil intake rate
ASA is the allowable surface accumulation
*Note: complete explanation can be found in the IA Protocol located at *Irrigation.org*

All time in excess of RT (MAX) will be accumulated, converted to inches of water and logged as runoff. It will also affect system adequacy and efficiency characterizations.

7. All time in excess of RT (MAX) will be accumulated, converted to inches of water and logged as runoff. It will also affect system adequacy and efficiency characterizations.

Task 4: Related Considerations

Avoid irrigating during electrical peak use periods as defined by utility servicing the location represented by the weather data records.

Task 5: Test Report

The moisture balance by zones for each manufacturer's controller will be developed. Total deficit and surplus for each zone will be calculated. The magnitude of the deficit will suggest an effect on the quality of the vegetation. The magnitude of the surplus will impact the overall operating efficiency. The total accumulated amount by which the actual free water exceeded the allowable value will be determined as a measure of run-off potential.

See timetable on attachment 1.

B.2.b. 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

A successful pilot process is already in place (Figures 1 & 2 and Tables 1 & 2). A working group of equipment manufacturers (Irrigation Association Members), water purveyors, and the Center for Irrigation Technology have worked together to establish a format for identifying potential water saving technologies. Once the technologies are identified, protocols are developed to evaluate the efficacy of the technology. Technologies meeting a minimum standard are given the SWAT designation.

C. QUALIFICATIONS OF THE APPLICANTS AND COOPERATORS

C.1. Resumes of project manager(s)

David Zoldoske, Ed.D, Director, Center for Irrigation Technology, California State University, Fresno (5% FTE)- Dr. Zoldoske has been affiliated with the Center for Irrigation Technology since 1983. He has served as a research technician, hydraulic lab manager, the assistant director, and presently serves as the CIT Director. Both the academic and private sectors respect him for his industry knowledge and expertise. Dr. Zoldoske will assume the daily oversight of the Project Manager. (See attached resume).

Edward Norum M.S., Agricultural Engineer, Center for Irrigation Technology, California State University, Fresno (10% FTE)- Norum has been affiliated with Center for Irrigation Technology since 1983. He has served as CIT Director and supervised various certification and testing programs. Both the academic and private sector respect him for his industry knowledge and expertise. Norum will assume the daily monitoring and assessment for the Climatologically Based Controllers. (See attached resume).

Dave Goorahoo, Ph.D, Research Soil Scientist, Center for Irrigation Technology, California State University, Fresno (10% FTE)- Dr. Goorahoo has been affiliated with the Center for Irrigation Technology since 1999. He has supervised various research projects for Air Quality , Water Use Efficiency and Soil Monitoring. Dr.Goorahoo will assume over see daily monitoring of the Soil Moisture Sensor testing. (See attached resume).

Diganta D Adhikari, M.S , Research database Analyst, Center for Irrigation Technology, California State University, Fresno (20% FTE)- Adhikari has been affiliated with the Center for Irrigation Technology since 2001. He has worked extensively with Dairy Air quality monitoring, was involved in the beta testing of the soil moisture sensors and worked on Westside San Joaquin valley on various Salinity projects. His expertise includes programming Data loggers, data processing, and data analysis. He will set up the laboratory and will be responsible for daily monitoring and assessment of the soil moisture sensor testing. (See attached resume).

The percentage is the amount of time they will dedicate to the grant.

C.2. Role of external cooperators

Two external cooperators have been identified for this project. The first is the Irrigation Association, who will organize meetings with the irrigation industry and water purveyors to discuss and identify priorities of the SWAT program. This effort is underway, but will be greatly enhanced through additional funding.

The second external cooperator is the Metropolitan Water District of Southern California (MWD). CIT will work closely with the Landscape Water Use Manager to ensure that proposals outcomes are useful and appropriate to augment conservation efforts within the MWD service area.

D. OUTREACH, COMMUNITY INVOLVEMENT AND DISSEMINATION

The partners working on this project will all contribute to the outreach, community involvement, and dissemination efforts. The Irrigation Association has electronic and printed material which will focus on this effort. Metropolitan Water District of Southern California (Metropolitan), its member agencies and other water purveyors throughout the state can use establish avenues of outreach, with community involvement being assured through incentive and rebate programs. Dissemination activities will be conducted by the Center for Irrigation Technology, the Irrigation Association, and the Metropolitan and other water purveyors.

The Outcomes from this project will contribute to SWAT's overall mission, and in general, California's efforts of achieving exceptional high water use efficiency in urban landscapes. Furthermore, water quality concerns from run-off of pesticides and fertilizers should be diminished. This could have a tremendous positive impact on wastewater treatment plants and environmentally sensitive waterways.

Findings and research goals will also be presented in industry journals, websites, and in press releases, among other methods. Findings will be presented at relevant workshops and seminars. Results and reports will be posted on CIT and IA websites. The Internet will be monitored for location and dates for conferences, workshops, seminars and continuing education classes at which the findings and research progress can be reported. Finally, scientific papers will be published in refereed journals, and the findings and research progress will be presented at one of the annual industry meetings and the IA show, which are normally held in October or November of each year.

1. Progress Reports: We will deliver quarterly reports to the funding agencies contract manager. These reports will provide an update on work completed in the last quarter, any unexpected difficulties encountered, and progress towards completion of the project tasks.
2. Draft and Final Reports: The final report for the project will include complete documentation of the methods used for testing, and statistical analysis of all soil, water, salinity and irrigation data collected.
3. Presentations for funding agencies and CIT: The principal investigators will make an annual presentation to the funding agencies staff and other interested stakeholders on the progress of the field campaign and new insights from analysis of the information. We are willing to conduct oral and poster/slide presentations for any sector of the turf industry or at meetings open to the public.

E. INNOVATION

By setting a high standard of performance through the testing protocol process, industry will be challenged to meet the bar through research and development. The outcomes will be targeted in line with broad stakeholder consensus. Precision irrigation has become far too complicated for non-trained professionals. It will require the substitution of technology for untrained labor. The landscape irrigation system of the future will be more like an expert system, rather than the methods currently employed. The playing field will be leveled by being able to compare baseline functions and performance. Standardization will allow for larger markets and justification for investment. Expectations include a trend line to follow other technologies of lower cost and higher performance (improved water use efficiency).

F. BENEFITS AND COSTS

F.1. Project Costs (Budget)

Salaries and Wages

For PI and Co- PI's, technicians and relevant support staff at CIT. These salaries are pro-rated in accordance with the current salaries earned by these employees and the time spent on the project. In addition, provision is made for student help in the field and laboratory assistance.

Equipment and Supplies
A major component of this $40,150 is for the purchase of Environmental Chambers, 15 Automated logging weighing scale (@$1,200.00 each),10 Automated Logging thermocouples with RS 232 capability (@ 150.00 each), 15 Specialized box designed by CIT for conducting experiments (@$120.00 each), Data loggers (@ $2,500.00 each); computers and accessory for centralized automation; Laboratory equipment.

Travel
Meetings and Conferences: Approximately 10 trips to soil sites for collecting soil samples and data collection. Travel to IA show for presentation of work in progress and various other technical sessions like American Society of Agronomy (ASA).

F.2. 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.

Estimated potential water savings is in the billions of gallons. A net reduction of 20 to 30% is the target range for homeowner and commercial water use in landscape. Ultimately the actual amount will be verified by meter readings and pumping records for each participating water district. There is no reason that every urban water district in California that provides water for landscape irrigation will not directly benefit from adopting SWAT program.

G. REFERENCES

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.

Marlow, R. L. (1999). "Agriculture Water Use Efficiency in the United States," Presented at the U.S./China Water Resources Management Conference. http://www.lanl.gov/chinawater/documents/usagwue.pdf

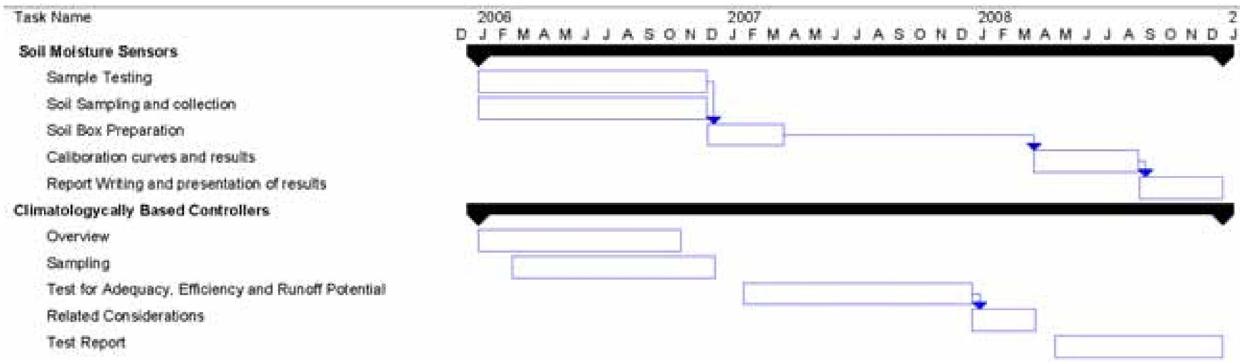
Topp., G.C (1993).Soil Water Content. Chapter 51 in Martin R. Carter, **Soil Sampling and Methods of Analysis.** Lewis Publication Boca Raton, Fl.

U.S. Department of Agriculture, Soil Conservation Service (1994). A Productive Nation in Harmony With A Quality Environment: Soil Conservation Service - Strategic Initiatives for the 1990s.

U.S EPA (2002). "Using Water Wisely in the Home" http://www.epa.gov/owm/water-efficiency/waterconservation_final.pdf

Attachments

Attachment 1. Task Schedule



Attachment 2. Project budget (in dollars)

Table C-1: Project Costs (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	$13,125	0	$13,125	$0	$13,125
	Fringe benefits	$5,905	0	$5,905	$0	$5,905
	Supplies	$750	0	$750	$0	$750
	Equipment	$2,500	0	$2,500	$0	$2,500
	Consulting services	$0	0	$0	$0	$0
	Travel	$3,000	0	$3,000	$0	$3,000
	Other	$0	0	$0	$0	$0
(a)	Total Administration Costs	$25,280		$25,280	$0	$25,280
(b)	Planning/Design/Engineering	$10,000	0	$10,000	$0	$10,000
(c)	Equipment Purchases/Rentals/Rebates/Vouchers	$45,000	0	$45,000	$0	$45,000
(d)	Materials/Installation/Implementation	$4,000	0	$4,000	$0	$4,000
(e)	Implementation Verification	$5,838	0	$5,838	$0	$5,838
(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)	$43,232	0	$43,232	$0	$43,232
(l)	Monitoring and Assessment	$75,000	0	$75,000	$0	$75,000
(m)	Report Preparation	$5,000	5	$5,250	$0	$5,250
(n)	**TOTAL**	$213,350		$213,600	$0	$213,600
(o)	Cost Share -Percentage				0	100

DAVID F. ZOLDOSKE
The Center for Irrigation Technology
Fresno, CA 93740-8021
559/278-2066

AREAS OF EXPERTISE:
- Program Leadership • Educational Development • Analytic Studies • Grant/Contract Management

EDUCATION:
EdD, Education University of La Verne, La Verne, CA (Leadership)
MS, Agriculture, California State University, Fresno, Fresno, CA (Economics)
BS, Agricultural Business California State University, Fresno, Fresno, CA

PROFESSIONAL EXPERIENCE: (*Note: Current job responsibilities include parts of three positions).*
- 1994- Present: Director (70%), Center for Irrigation Technology (CIT), California State University, Fresno. Requires administrating all aspects of the management of the Center including: planning and budgeting (currently at 21 million dollars); promotion and public relations with community and industry; liaison with advisory board; provide educational opportunities to the public, development of contracts and grants for applied research, hiring and supervision of staff; and training and publications efforts.

- 2000 - Present: Associate Director (20%), California Water Institute, California State University, Fresno. Given the charge by the Provost and funded from Proposition 13 to develop the Water Institute. Activities include developing partnerships with three sister CSU campuses, working with campus president to secure funding from CSU Chancellor's office, obtain building space, hire and supervise staff, allocate and fund campus research projects, and create an industry advisory board.

- 2002 – Present: Interim Director (10%), International Center for Water Technology, California State University, Fresno. Working directly with approximately 40 water technology companies in the San Joaquin Valley to secure funding for a proposed 50 million dollar technology center to be located on campus. Responsibilities include establishing an interim industry board, project leadership, providing liaison between the community and the University, and fund raising.

- 1996: Lecturer, Department of Agriculture, College of the Sequoias, Visalia, CA.

- 1993: Lecturer, Department of Plant Science and Mechanized Agriculture, College of Agricultural Sciences and Technology, California State University, Fresno, Fresno, CA.

- 1988 – Present: Almond Grower, owner and operator of farming operation. Activities include orchard development, cultural practices, and general business requirements for a successful farming enterprise.

- 1990 – 1993: Assistant Director, Center for Irrigation Technology (CIT), California State University, Fresno. Specific duties include developing educational programs for the irrigation industry, promotion of Center activities, developing grant and contract proposals, supervision of staff and students positions, supporting the director's duties as required, and performing special projects as assigned.

- 1986 – 1990: Hydraulic Lab Manager, Center for Irrigation Technology (CIT), California State University, Fresno. Responsible for the operations of the internationally recognized research laboratory, including program development, liaison with private sector clientele, educational efforts, and supervision of staff and students positions.

- 1983 – 1985: **Research Technician**, Center for Irrigation Technology (CIT), California State University, Fresno. Worked primarily in laboratory and field research to advance new water use efficient technologies. Assisted faculty and graduate students in conducting applied research.

- 1981 – 1982: **Research Assistant**, Department of Agricultural Economics, California State University, Fresno. Conducted research funded by US Agency for International Development.

HONORS AND RECOGNITION:

- Recognized nationally as one of 18 Environmental Stewards and Innovators in the Golf Industry by the Golfweek's Superintendent NEWS, October 26th, 2001.

- Honorary Life Membership in the American Society of Irrigation Consultants, May 2001.

- National Water and Energy Conservation Award presented to CIT by the Irrigation Association, 1998.

- Roy Williams Memorial Award presented to CIT for service to the industry by the American Society of Irrigation Consultants, 1996.

- Edwin J. Hunter Industry Achievement Award for service to the industry presented to CIT by Hunter Industries, 1994.

EDWARD M. NORUM (CV)
IRRIGATION ENGINEERING CONSULTANT

AREAS OF SPECIALIZATION:

- Irrigation Project Design, Installation, Operation and Evaluation, Project Contracting
- Irrigation Product Design, Testing, Evaluation and Marketing

SUMMARY OF POSITIONS HELD:

Principal, E.M. Norum and Associates, Fresno, California (July, 1992 to present)
Chief Engineer, National Irrigation Commission, Kingston, Jamaica (April, 1989 to July, 1992)
Chief Engineer, Agro-21 Corporation, Kingston, Jamaica (January, 1986 to April, 1989)
Executive Director, Center for Irrigation Technology, California State University, Fresno, California (March, 1982 to January, 1986)
Manager, Technical Service and Training, Lockwood Corporation, Gering, Nebraska (1979-1982)
Senior Applications and Chief Irrigation Engineer, Lockwood Corporation, Gering, Nebraska (1974-1979)
Sales Manager, Pollution Control Equipment, McDowell Manufacturing Company, DuBois, Pennsylvania (1972-1974)
Manager, Construction Division and Field Engineer, Kohala Sugar Company, Hawi, Hawaii (1962-1972)
Project Engineer, Hawaiian Sugar Planters Association, Honolulu, Hawaii (1953-1962)

DEGREES:

Master of Science Degree, Agricultural Engineering, University of Minnesota, 1958
Bachelor of Science Degree, Agricultural Engineering, University of Minnesota, 1953

PROFESSIONAL SOCIETIES: American Society of Agricultural Engineers, The Irrigation Association, Member ISO TC-23/SC-18 Irrigation Standards Committee

PATENTS: No. 2,832-202, Irrigation Flume Outlet and No. 4,086,507, Irrigation Motor Cover, and No. 4,944,327 Flow Control Valve

COUNTRIES OF WORK EXPERIENCE:

AFRICA:	Nigeria, South Africa, Swaziland, Zimbabwe
MIDDLE EAST:	Egypt, Iraq, Israel, Libya, Morocco, Saudi Arabia, Syria
EUROPE:	France, Sweden, United Kingdom, Yugoslavia
NORTH AMERICA:	Canada, United States
CENTRAL AMERICA:	Guatemala, Honduras, Mexico
LATIN AMERICA:	Venezuela
WEST INDIES:	Jamaica

PUBLICATIONS: Thirty-two separate publications including technical papers, articles and chapters for books on a full range of irrigation-related subjects.

DAVE GOORAHOO PH.D.

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EDUCATION

Ph.D. Soil Science: UNIVERSITY OF GUELPH (1994 - 1999) *Land Resource Science*
Guelph, Ontario, Canada. N1G 2W1

M.Sc. Soil Science: UNIVERSITY OF GUELPH (1991 - 1993) *Land Resource Science*
Guelph, Ontario, Canada. N1G 2W1

B.Sc. Agriculture (Upper Second Class Honours): UNIVERSITY OF THE WEST INDIES (1986 - 1990) *St. Augustine, Trinidad, West Indies*

MAJOR RESEARCH INTERESTS AND TEACHING GOALS

- Vadose zone and groundwater hydrology with emphasis on contaminant transport.
- Modeling spatial variability of soil hydraulic and transport properties.
- Interdisciplinary research with soil scientists, agronomists and environmentalists investigating the environmental impacts of agricultural practices.
- Teaching courses relating the interaction of nutrient cycling and transport of water and chemicals within the Earth-Plant-Air-Water Continuum.

PROFESSIONAL EXPERIENCE

- Oct. 2001 - Present: Adjunct Professor in Plant Science Dept., College of Agricultural Science and Technology (CAST), California State University, Fresno. Supervisor: Dr. Charles Krauter
- Dec. 1999 - Present: Research Soil Scientist at Center for Irrigation Technology, California State University, Fresno. Supervisor: Dr. David Zoldoske.
- Jul. 1999 - Dec. 1999: Post-doctoral Fellowship at Soil Science Department, University of Saskatchewan. Supervisor: Dr. R. Gary Kachanoski.
- Jul. 1998 – Jun. 1999: Visiting scholar at Soil Science Department, University of Saskatchewan, Canada.
- Jun. 1998: Graduate research assistantship. University of Guelph, Canada .

RESEARCH PROJECTS WITH OTHER CIT/CSUF STAFF

- Evaluating treatment practices for dairy effluent stream- Position: Principal Investigator
- Addition of surfactant to turf irrigation- Position: Principal Investigator.
- Spatial and temporal variability of soil salinity- Position: Co-Principal Investigator.
- Ammonia Emissions From Agricultural Operations- Position: Research Scientist.
- Integrated On Farm Drainage Management (IFDM)- Position: Research Scientist.

RESEARCH PROJECTS WITH NON-CSUF STAFF

- Ammonia Volatilization During Cotton Defoliation with Bruce A. Roberts, County Director & Farm Advisor, U.C. Cooperative Extension (UCCE), Kings County, CA.
- Comparison of Active and Passive Samplers for Monitoring Ammonia Emissions from Livestock Operations with John Pisano, Engineer, UC Riverside College of Engineering- Center for Environmental Research and Technology (CERT).
- Soil Physical Parameters for Predicting Dairy Effluent Infiltration and Saline Groundwater Upflow with Richard Soppe, Hydrologist, USDA-ARS-Water Management Research Laboratory, Fresno.
- Evaluating the effectiveness of Integrated On Farm Drainage Management (IFDM) with George Matanga, Hydraulic Engineer, U.S. Bureau of Reclamation.

TEACHING EXPERIENCE AT CSUF

- Fall 2004: PL256- Plant Water Relations. Graduate course in Plant Science Dept. CSUF.
- Spring 2002: Geol 220- Groundwater Hydrology. Co-lecturer with USDA Hydrologist, Dr. Richard Soppe. A graduate course in the Department of Earth and Environmental Science, California State University, Fresno.
- Spring 2002: Geol 177- Quantitative methods for earth Science. An undergraduate course in the Department of Earth and Environmental Science, California State University, Fresno .
- Fall Semesters 2000 and 2001. Taught course SW001- Introduction to Irrigated Soils in the Plant Science Department, California State University, Fresno.
- Spring 2001-2003: Guest lectured for Dr. S. Benes and Dr. Krauter at times in undergraduate and

graduate courses in Plant Science department.

SELECTED PUBLICATIONS

Titles of papers published in refereed journals

FITZ, D.F., J.T. PISANO, **D. GOORAHOO,** C.F. KRAUTER and I.L. MALKINA. 2003. A passive flux denuder for evaluating emissions of ammonia at a dairy farm. Journal of the Air and Waste Management Association. Aug. 03, Vol54 (8)

.

BARRY, D.A.J., **D. GOORAHOO** and M.J. GOSS. 1993. Estimation of nitrate concentrations in groundwater using a whole farm nitrogen budget. Journal of Environmental Quality **22:** 767-775.

Articles published in extension publications and refereed conference proceedings

GOORAHOO, D., G. CARSTENSEN and A. MAZZEI. 2001. A pilot study on the impact of air injected into water delivered through subsurface drip irrigation tape on the growth and yield of bell peppers. California Agricultural Technology Institute (CATI) Report # 010201.

GOORAHOO, D., C. F. KRAUTER, and G. CARSTENSEN. 2001. Diurnal and Seasonal Ammonia Emissions from Dairy Effluent. ASA, CSSA and SSSA Annual Meetings in Charlotte, NC. Annual Meeting Abstracts Compact Disk.

KRAUTER C.F., **D. GOORAHOO,** C. POTTER and S. KLOOSTER. 2001. Ammonia Emission Factors From Monitoring of Fertilizer Applications to Various California Crops. ASA, CSSA and SSSA Annual Meetings in Charlotte, NC. Annual Meeting Abstracts Compact Disk.

BENES, S.E., S.R. GRATTAN, **D. GOORAHOO**, S. SHARMASARKAR and C EROH. 2001. Use of Saline Drainage Water for Irrigation of Salt Tolerant Forages and Halophytes. ASA, CSSA and SSSA Annual Meetings in Charlotte, NC. Annual Meeting Abstracts Compact Disk.

GOORAHOO, D., S.E. BENES, S. SHARMASARKAR, C EROH, M. YAGHMOUR and S.R. GRATTAN. 2001. Integrated On-Farm drainage management (IFDM) on a commercial farm in the San Joaquin Valley, California: Seasonal soil salinity trends. International Union of Soil science Bouyoucos Conference on Sustained Management of Irrigated Land for Salinity and Toxic Element Control Abstracts p. 58. Conference at Riverside, CA.

Cassel Sharmasarkar, F., **D. GOORAHOO.**, and S. SHARMASARKAR. 2001. Electromagnetic assessment of spatial variability in soil salinity under Integrated On-Farm drainage management practices in the Westside San Joaquin Valley. International Union of Soil science Bouyoucos Conference on Sustained Management of Irrigated Land for Salinity and Toxic Element Control Abstracts p. 57. Conference at Riverside, CA.

GOORAHOO D., C. F. KRAUTER, C. POTTER, S. KLOOSTER, and D. FITZ. 2000. Ammonia emissions from nitrogen fertilizer application practices. Presented at 2000 ASA, CSSA and SSSA Annual Meetings in Minneapolis, MN. p.47 in Annual Meeting Abstracts.

GOORAHOO, D. , R.G. KACHANOSKI, and D.L. RUDOLPH. 1998. Spatial covariance of effective retardation coefficient and soil hydraulic properties. Presented at 1998 ASA,CSSA and SSSA Annual Meetings in Baltimore, MD. p.182 in Annual Meeting Abstracts.

UNPUBLISHED THESES AND PROJECTS

- 1999. Spatial variability of hydraulic and transport properties for coarse porous media. PhD. Thesis.
- 1993. The use of whole farm nitrogen budgets to estimate nitrate concentrations in groundwater for three organic farms in Bruce County. M.Sc. Thesis.
- 1990. Response of maize to N and K fertilizers in Talparo clay (A Vertisol). Third Year Research Project in B.Sc. program.

D I G A N T A   D .   A D H I K A R I

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EDUCATION

Aug 2001–Aug 2004 California State University Fresno, CA

- **M.S. Computer Science.**

June 1994– June 2000 North East Hill University Shillong, India

- **B.S. Computer Science.**

PROFESSIONAL EXPERIENCE

- Aug 04 –Present – Research Database Analyst, Center for irrigation Technology.
- June 04- Aug 04- Summer Job at Center for Irrigation Technology(CIT), CSU Fresno.
- Aug 2003 to May 2004 worked as an Intern on various projects at Center for Irrigation Technology (CIT), CSU Fresno.
  - Maintaining huge Database of Air, water and Soil data collected as part of on going research projects.
  - Configuring and programming Campbell Scientific Data loggers for water data monitoring.
  - Setup and Data retrieval of TDL Laser system setup at Dairies.
  - Maintaining and troubleshooting the ET system at Red Rock Ranch Five Points as part of the IFDM project.
  - Configuring and Data retrieval of Enviroscan Moisture Sensors
  - Running soil analysis using the AA Spectrometer.
  - Running Statistical Analysis on the Database of Soil, Water & Air Data.
  - Assisted in Phase I of the Sensor Testing protocol, being developed at Center for Irrigation Technology (CIT), CSU Fresno.

ABSTRACTS IN PUBLISHED PROCEEDINGS OF CONFERENCES OR OTHER SCIENTIFIC MEETINGS

- Goorahoo Dave, Norum Ed, Cassel Florence S., and Adhikari Diganta D. 2003. *Development of a Standardized Testing Protocol for Soil Moisture Sensors: Current Status and Preliminary Test Results.* Annual Meeting of the Irrigation Association held in San Diego California- Nov 2003.
- Adhikari Diganta D., Cassel Florence Sharmasarkar. Goorahoo Dave, 2004 *Photosynthetic responses to enriched atmospheric carbon dioxide in strawberry leaves.* Oral Presentation/ Poster to be presented at ASA-CSSA-SSSA International Annual Meetings/Conference 2004, Seattle, WA.
- Adhikari Diganta D., Goorahoo Dave.. 2004. *Response of Digital Electromagnetic Sensor to*

Soil Moisture and Electrical Conductivity. Oral Presentation given at 18th Annual CSU Research Competition 2004, CSU Northridge, CA.

- Adhikari Diganta D. and Goorahoo Dave. 2004. *Response of Digital Electromagnetic Sensor to Soil Moisture and Electrical Conductivity.* 25th Journal of Annual Central California Research Symposium 2004, CSU Fresno, CA. pg. 100.

- Adhikari Diganta D., Goorahoo, Dave. 2004. *Effect of Air Injection Through Subsurface Drip Irrigation on Growth and Yield of Crops.* Conference Proceedings of California Plant and Soil Conference 2004, Visalia. CA. pages 142-143..

- Cassel Florence Sharmasarkar. Goorahoo Dave, Adhikari Diganta D. 2004. *Evaluating percolate water quality following land application of winery processing wastewater.* Conference Proceedings of California Plant and Soil Conference 2004, Visalia. CA. pg. 174.

- Adhikari Diganta D., Goorahoo Dave. 2003. *Response of Acclima Digital TDT™ probe to Soil Moisture and Electrical Conductivity.* Poster presented at Center for Irrigation Technology (CIT) booth at IA International Show. San Diego Nov 03.

- Goorahoo Dave., Benes Sharon.E., and Adhikari Diganta D.. 2003. *Soil for Fields Irrigated with Recycled Saline Drainage Waters.* Annual Meeting of the Irrigation Association held in San Diego California- Nov 2003.

- Goorahoo Dave, Benes Sharon E., and Adhikari Diganta D.. 2003. *Infiltration in soils irrigated with saline-sodic drainage waters: experimental design and data analysis techniques*. Poster presented at California Plant and Soil Conference Feb.5-6 in Modesto, CA.

PROFESSIONAL MEMBERSHIPS

- Soil Science Society of America (SSSA).
- Agronomy Society of America (ASA).