MANAGEMENT OF WATER SUPPLIES FOR IRRIGATION

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PROJECT SUMMARY

Water supplies are limited in many areas of the country, particularly in the arid west where irrigated agriculture is the largest user of fresh water. Expanding urban populations and environmental water needs will potentially reduce water available for irrigation in the future. Water users are faced with requirements to more accurately document water uses and return flows. Water measurement and control in irrigated agriculture has experienced significant advances over the last two decades, yet further advancement is both possible and needed. Under this research project, we intend to develop improved water measurement technology, improved water accounting methods, and improved water control technology. New measurement methods will be developed for steep, sediment laden channels, channels with little or no head available, low-head pipelines (culverts), and submerged radial gates. A new canal automation system will be released to a CRADA partner to provide greater water control and operational flexibility to meet user needs. Water balance methods will be further developed to assist water purveyors with documenting water use, including methods to determine sources of error, which indicate where measurement effort should be focused.

OBJECTIVES

1. Flow Measurement and Accounting: We will develop a series of improvements to existing methods for measuring water flow rates and volumes in rivers, streams, canals, and culverts (low pressure or not flowing full). A series of laboratory studies is planned for currently identified water measurement problems (see research approach). We will continue to support software developed for design and calibration of long-throated flumes, will cooperate with customers to evaluate their water measurement and accounting methods, and will work toward solutions to their flow measurement problems.

2. Water Control: We will develop a series of methods, hardware, and software for improving the control of water in open-channel distribution systems typical of irrigation projects or large water supply projects. A new canal automation system currently under development will be turned over to our CRADA partner. The mechanical/hydraulic controller (DACL), used to maintain constant flow rates at canal offtakes, will be improved to make it more usable in remote sites.

NEED FOR RESEARCH

Description of Problem to be Solved

Competition for limited water resources among various users is increasing in many areas of the country, but particularly in the arid west. Irrigated agriculture is the largest user of fresh water resources and, thus, it needs to improve its water management (CAST 1996, National Research Council 1996). Important elements for improving agricultural water management are improved measurement, control, and ultimately, accountability of water resources at the irrigation project level. Water uses at the project or hydrologic unit scale

are often poorly documented making meaningful management of water supplies difficult. Also, water supplies for agriculture from large irrigation projects are often not controlled well, resulting in over-delivery to individual users and ineffective use at the farm level. As water moves downstream through various projects and uses, its quality degrades as salts, trace metals, and other contaminants are concentrated, often to the point of being unusable or having a negative impact on the environment. The objectives of this project are to develop tools for improving the management of water supplies, particularly for irrigation.

Relevance to ARS National Program Action Plan

The research is part of National Program 201, Water Quality and Management. The project falls under Component 2, Irrigation and Drainage Management. Both objectives deal with agricultural water conservation and fit under Problem Area 2.3 (Water Conservation Management), Goal 2.3.1 (Water Conservation Technologies). The research also supports Goal 2.3.3 (Agricultural Water Conservation and Environmental Quality).

Potential benefits

Large-scale water supplies will be better managed in arid regions with the tools developed here. Water measurement, accounting, and control will be improved in irrigated agriculture, supporting more rational analysis of the impact of irrigated agriculture on the environment and allowing more rational decisions by society about water allocation and use.

Anticipated Products

New technology is provided for improving the operation and management of water projects, including canal automation/control and water measurement/accounting technology.

Customers of the research and their involvement

Based on past successful technology transfer and the anticipated products, customers will include the U.S. Bureau of Reclamation (USBR), Natural Resources Conservation Service, U.S. Geological Survey, Army Corp of Engineers, Bureau of Indian Affairs, State Departments of Water Resources (particularly Arizona and California), land-grant universities, civil and agricultural consulting engineers, and water purveyors (water conservancy districts, irrigation districts, municipalities, etc.). We have cooperated with NRCS staff on the application of flow measurement technology and related research needs at all levels (field office to national) and in states across all regions of the country. Our main point of contact is Tom Spofford, Water and Climate Center, Portland OR (letter attached), who disseminates information widely within NRCS. With USBR, cooperation on water measurement and control has been mainly with the Water Resources Research Lab, Denver CO (Cliff Pugh, letter attached). They transfer our

technology to regional and area offices through manuals and technical assistance programs. Research on water-balance methods has primarily been with the Lower Colorado Region of USBR (Steve Jones), who along with other regions are transferring this technology to water purveyors through their water conservation plans. Further planned activities with Paul Matuska (letter attached) are expected to have additional impact on water conservation plans. Several water purveyors (e.g., Salt River Project, Maricopa Stanfield I&D District, Imperial Irrigation District) have been directly involved in various studies and technology transfer activities since much of this research must be conducted within real, full-size water systems. Water meter, remote monitoring, and hydrologic instrumentation manufacturers have been customers, who are expected to continue with this project (e.g., Automata, Global Water, Micrometer, Nu-Way Flume Co., Plastifab, etc.). Individual water users also will be customers, particularly for the water measurement devices.

SCIENTIFIC BACKGROUND: Refer to 2001 Annual Report

APPROACH AND RESEARCH PROCEDURES: Refer to 2001 Annual Report

PHYSICAL AND HUMAN RESOURCES: Refer to 2001 Annual Report

MILESTONES AND EXPECTED OUTCOMES

Expected outcomes include: (1) improved water measurement devices, (2) new canal automation technology, and (3) improved water use assessment methods and performance indicators.

Milestone Timeline

Research Component	end of year 1	end of year 2	end of year 3	End of year 4	end of year 5
Water Measurement and Accounting	Lab study on flow conditioning for pipes/culverts completed (Replogle)	Lab study on debris-shedding propeller meter completed (Replogle)	Field studies on surface-velocity-based method completed (Replogle)	Lab study on high sediment load flume completed (Replogle)	
		Laboratory studies on submerged radial gates completed (Clemmens)	Verification of radial gate calibration method completed (Clemmens)		Field study on water balance accuracy completed (Clemmens)
Water Control	Initial version of canal automation system turned over to CRADA partner (Clemmens)	Improved interface for canal automation system provided to CRADA partner (Clemmens/Bautista)	Final version of canal automation technology given to CRADA partner (Clemmens)		New DACL control system developed and lab testing completed (Replogle)
		Field studies of canal automation on steep canal (WM at MSIDD) completed (Clemmens)	Field application of feedforward routing method completed (Bautista)		Field studies of canal automation on canal with mild slope complete (Clemmens)
	Feedback control method for branching canals developed and simulation testing completed (Clemmens)	Simulation testing of Model Predictive Control for branching canal completed (Clemmens)		Upstream control method developed and simulation testing completed (Clemmens)	

PROGRESS

Many water delivery systems do not provide water to users at the proper time and rate of flow, resulting in water losses and decreased production. The Canal Automation Team at the U.S. Water Conservation Laboratory developed a water demand scheduling program, called SacMan Order, to help water districts manage water demands and to route changes in demand through their canal system. SacMan Order, a part of Software for Automated Canal Management or SacMan, is a computer program that accumulates water orders, keeps track of demand at any point in the system,and determines when water needs to be released from each gate structure in order to get the right amount of water to the right place at the right time. This software developed in cooperation with a CRADA partner could significantly improve the ability of canal operators to satisfy customer demands, thereby improving the efficiency of water use.

The automatic control of canals, while providing significant potential for improving water management in the west, has found little application, at least partly because existing automation schemes only consider a single in-line canal and thus do not provide control for the entire canal network. Engineers at the U.S. Water Conservation Laboratory developed a new automation scheme that can be applied to an entire canal network. The theory for control of canal networks was demonstrated through computer simulation for a majority of the canal system of the Salt River project. It demonstrated that such controls are both possible and can lead to improved canal operations, thereby improving the service to water users and potentially increasing their water use efficiency.

Methods currently in use to automate the operation of canal systems are based on simple control logic that is not always well suited for complex water distribution systems. A more flexible automatic control system, Model Predictive Control or MPC, was demonstrated at the U.S. Water Conservation Lab. to provide control at least as good as other methods, but with increased ability to handle real-world constraints. Simulation studies on the test canal of the American Society of Civil Engineers and on the Salt River Project canal network demonstrated that MPC was at least as effective as optimal control methods. The ability of MPC to handle real-world constraints will increase the likelihood of success for canal automation schemes at improving water management in the west.

Water released from the head of the canal arrives at the downstream end gradually and often over a time that is difficult to predict, thereby complicating the delivery of water to users. A comprehensive analysis of wave travel in canal by the canal automation team at the U.S. Water Conservation Lab. demonstrated that volume compensation approaches provided control as good as more complex methods. The automation team developed and verified through computer simulation that properly accounting for the volume changes in a canal pool was more important for canal control than accurately estimating wave travel times. This approach greatly simplifies the method for scheduling demand changes for a canal and should make such approaches more acceptable to canal operators.

Irrigation expansion and groundwater decline in the lower Mississippi River Valley has prompted water users to explore alternative water sources, including diversion of water from environmentally sensitive rivers. A study of water use by irrigated agriculture at a watershed
scale was conducted by the Arkansas Natural Resources Conservation Service (NRCS) and the U.S. Water Conservation Laboratory. This study demonstrated that the on-farm improvement planned by the NRCS, including storage reservoirs, tailwater pits, pipelines and booster pumps, could reduce the need for external water sources by more than 1/2 through the capture of rainfall runoff and irrigation tailwater, and that the overall irrigation efficiency is relatively insensitive to individual field application efficiency. This study demonstrates the importance of irrigation infrastructure in the humid south and their impact on reducing water diversions and groundwater pumping.

Laboratory studies on flow conditioning in pipes and culvert is continuing. The methodology for measuring velocity distributions is working, and the large 30" concrete pipe has been set up to handle the variety of tests planned. Some of the equipment for the field study extension to determine errors in flow meter installations has been purchased and is being evaluated.

The main features of the SacMan canal automation software have been field tested at the Maricopa Stanfield Irrigation and Drainage District. An initial version of the software, handling manual control systems, was turned over to our CRADA partner. The control system has been installed at the Central Arizona Irrigation and Drainage District, Eloy, AZ. The initial installation has manual control, with full automatic control being phased in over the next few years. The first full version of the software will be provided in late FY03 or early FY04.

Through cooperation with the Bureau of Reclamation, Water Resources Management Lab, we were able to analyze the data collected on radial gates by the Bureau in the early 1980s. This data supported our approach in calibrating submerged radial gates, but also showed that a wider range of data is needed to provide useful calibration. Preliminary field studies at the Salt River Project also supported our approach. In FY03, we installed brackets during canal dry-up so that we could measure the pressure below the gate at the experimental site on the Salt River Project's Arizona Canal.

NEW RADIAL GATE DESIGN

New radial-gate designs for irrigation canals relocate the gate pivots above a canal bottom seal so that the gate can swing through the bottom location and serve either as an overflow weir or as a traditional underflow orifice. The prototype gate appears fully capable of meeting operational requirements related to controlling and measuring flow rates over an extended flow range involving either overshot (weir) or undershot (orifice) modes in a restricted width that would challenge previous radial gate structures. Both floating and bed-load trash are readily handled by the dual modes of operation. Special operational procedures for trash handling are offered when two gates can be operated in opposite modes at the same time.

DESIGNING A TOTAL-LOAD, STREAM-FLOW SAMPLER

Total-load stream flow sampling has been a perpetual problem in sediment monitoring to document erosion into reservoirs and evaluate watershed treatments. This is particularly important with the recent history of major forest fires. Usually a combination of bed-load sampling devices, suspended-load suction samplers, and a flume for total flow rate, are used. A total-load sediment sampler designed on a new and simplified concept performs all three of these functions well. It requires installation in sites that can provide an over-fall height greater than the maximum stream flow depth. Design parameters are offered to allow flow accuracies to within 3%, including unbiased sediment size distributions, a major problem with previous sampling systems.

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