USCID NEWSLETTER

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The U.S. society for irrigation and drainage professionals

Schaefer, Smith, Ure Elected

In recent balloting, **Samuel L. Schaefer**, **Delbert M. Smith** and **Therese Ure** were elected to three-year terms on the USCID Board of Directors. Schaefer and Smith were elected to their second terms; Ure to her first. During their April meeting, the Board selected Smith as Secretary. Smith succeeds **Steven C. Macaulay**, who has completed his term on the Board. **Brian Wahlin** continues as President.


Schaefer


Smith


Ure

Samuel W. Schaefer is a Senior Engineer with GEI Consultants, Inc. in Santa Barbara, California. He received B.S. and M.S. degrees in Agricultural and Water Resources Engineering from South Dakota State University, Brookings, in 1984 and 1988. He has worked on Federal evaluation for irrigation in South Dakota as a Water Resources Engineer for the Water Resources Research Institute at SDSU, on various complex drainage related issues as an Agricultural Drainage Engineer for the Bureau of Reclamation in Denver, and as a Consultant in California since 2001. Presently, he facilitates the implementation of a regional integrated water management group for agricultural and community water districts in California. The agricultural districts practice conjunctive management of surface water and groundwater supplies from local, state and federal sources.

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Analytic Solution for Optimization of Groundwater-Connected Pond Seepage Losses

by Brandon House (bhouse@usbr.gov) and Subhrendu Gangopadhyay, Bureau of Reclamation, Denver, Colorado; and Roger Burnett, Bureau of Reclamation (retired), Denver, Colorado

Editor's Note: This paper was presented during the 2019 USCID Conference in Reno. Contact the author to receive the supplement that presents the derivation of the equations discussed in this paper.

Introduction

A parcel of land purchased in the southwestern United States is slated for construction of four aquaculture ponds. Once complete, the total water surface area of the ponds is expected to be approximately 59 acres with both open water and marsh areas. Due to the remote location of the site, transportation of impervious geomembrane lining material would be costly. Instead, a compacted silt liner sourced from local materials is being considered for lining the ponds. With the

(continued on page 13)

SCADA System Maintenance

by Kyle E. Feist and Charles Burt, ITRC, California Polytechnic State University, San Luis Obispo, California

Note: This paper was presented during the 2018 USCID Conference in Phoenix.

Introduction

Irrigation districts (including water user associations, water districts, private canal companies, etc.) are established to provide service to farmers into the foreseeable future. Districts primarily convey irrigation water via extensive, district-owned networks of physical infrastructure. Well-managed districts

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USCID Conference Postponed to 2021

The **13th International Conference on Irrigation and Drainage** has been re-scheduled due to the COVID-19 pandemic. It will now take place October 26-29, 2021, in Sacramento. The Conference will focus on groundwater management, and is co-chaired by **David E. Bradshaw**, **Randy Hopkins** and **Stuart Styles**. The Groundwater Resources Association of California is a cooperating organization.

Abstracts are still being accepted; visit www.uscid.org for details.¤

Inside . . .

USCID

2490 West 26th Avenue, #100A
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Telephone: 303-988-0925

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USCID

The United States Committee on Irrigation and Drainage is a National Committee of the International Commission on Irrigation and Drainage.

Mission Statement

The Mission of USCID is to promote progressive and sustainable irrigation, drainage and flood control practices in support of food and fiber production and public safety, recognizing that sustainability embodies economic, social and environmental goals.

USCID Newsletter and Membership

The *USCID Newsletter* is published in Spring, Summer and Fall for USCID Members. News items and technical articles of interest to the irrigation community are invited. Membership information is available on the USCID website.

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ICID News and Activities

ICID·CIID

ICID Meetings Re-Scheduled

Due to the COVID-19 pandemic, ICID has postponed the 71st International Executive Council Meeting and the 24th Congress. Please visit www.icid.org for updates, as conditions and restrictions continue to evolve.

71st IEC Meeting

The 71st IEC Meeting is tentatively scheduled for December 1-7, 2020 in Marrakesh, Morocco. The Meeting will be held in conjunction with the 5th African Regional Conference, organized by the Moroccan National Committee of ICID.

Four workshops will be held, organized by ICID working groups:

- Modernizing Irrigation Services
- Public-Private Partnerships in Irrigation and Drainage Operation and Maintenance
- Managing, on the Regional, State or Local Level, Water Scarcity Resulting from Conflicting Demands
- The Water-Energy-Food Nexus: Implementation and Examples of Application

24th Congress and 72nd IEC

The 24th ICID Congress and 72nd IEC Meeting will take place July 6-12, 2021, in Sydney, Australia. It will be held in conjunction with Irrigation Australia Conference & Exhibition, promising to be the largest international irrigation event held in the southern hemisphere.

The Congress theme is *Innovation and Research in Agriculture Water Management to Achieve Sustainable Development Goals*. Congress papers will address the following:

Question 62: What Role Can Information and Communication Technology Play in Traveling the Last Mile?

Question 63: What Role is Played by Multi-Disciplinary Dialogue to Achieve Sustainable Development Goals?

Special Session: Developing the Future Tools for Managing Uncertainty in Irrigation Water Supply

For more information, visit www.icid2021.com.au.□

John Hennessy

ICID President Hon. John Hennessy (United Kingdom), passed away on June 7, 2020.

Mr. Hennessy was associated with ICID since 1978 in various capacities and served as its President for a three-year term from 1990-1993. An expert in water resources development for irrigation, drainage and power generation, Mr. Hennessy worked on major water resource assignments in Africa, the Middle East and Asia. He was a fellow of the Institution of Civil Engineers, U.K., and the Institution of Water & Environmental Management, and has served on a number of engineering and scientific committees and advisory boards. He was a fellow of the Royal Society of Arts and a Lieutenant Colonel in the Engineer and Transport Staff Corps.□

INSPIRE: A New Initiative

The International Network of Service Providers for Irrigation Excellence (INSPIRE) is a proposed platform for knowledge exchange on I&D service delivery among managers of I&D systems. INSPIRE strives to become the global thought leader on I&D service delivery and on the future of irrigation management. Decision makers of large irrigation and drainage schemes form a diverse group of people, including heads of departments, local governments, WUAs and agency heads. Membership will not be restricted to a specific group, but will be based on interest in service delivery turn-around and relevance, including from developing and industrialized countries.

It is proposed that INSPIRE will be established as a technical work body and initially incubated by ICID, and that INSPIRE meetings take place as a half-day side event of regular ICID conferences and World Irrigation Forum meetings. The Forum will be chaired by an irrigation manager elected by its members, and assisted by a secretary. Neither position will be remunerated. Other (paid) positions may be created at a later stage provided that a sustainable source of finance is made available. Regional meetings can also be organized to improve accessibility and participation of a larger group of stakeholders.

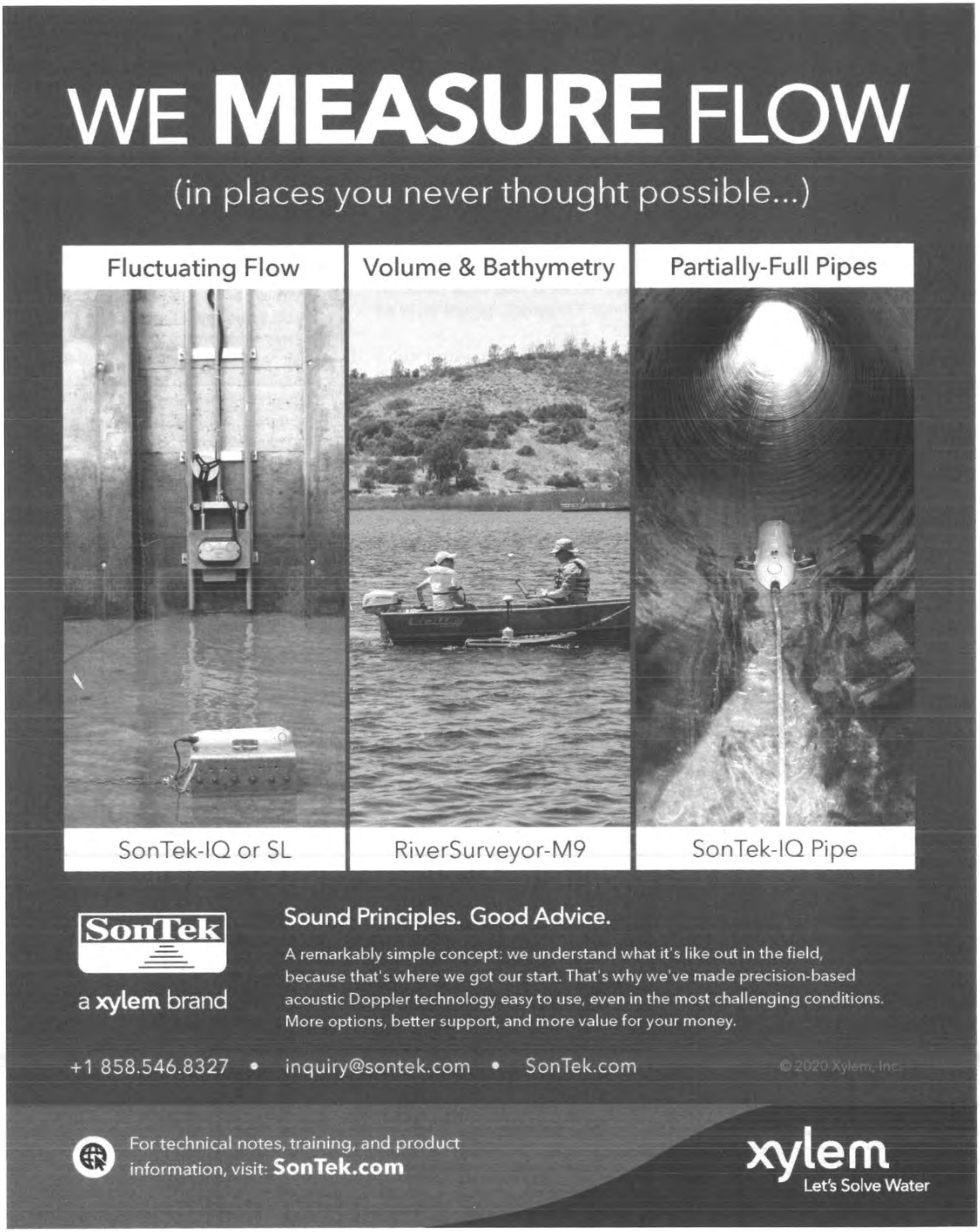
INSPIRE meetings will present and discuss hands-on experience, innovations and best practice in improving the quality of I&D services.

While I&D will be the focus of INSPIRE, experience from other related sectors can be presented when it relevant to INSPIRE's objectives.

World Bank Support

World Bank support will include contributions to exchange of knowledge and global best practice, capacity strengthening and technical assistance.

The Bank's financial support will be limited in magnitude and time, with a clear exit strategy. Other international funding institutions will be approached to join and provide support to INSPIRE. Over time, World Bank support will be scaled back and progressively replaced by alternative support, including from I&D agencies in industrialized countries, the private sector and bilateral governments. INSPIRE plans to develop for-profit activities, including training events, certification of agencies and technical assistance.□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Let's Solve Water

SCADA (continued)

tend to keep up with the maintenance demands of physical infrastructure because:

1. Deferring maintenance can result in obvious consequences and negatively impact the level of service provided by the district. Examples include:

   a. inability to deliver downstream demands due to failed pumps/gates or ruptured pipelines

   b. reduced canal flow rate capacities

   c. increased travel time on canal roads

   d. excessive weeds and canal debris

2. Most tasks and responsibilities are well-understood and achievable.

3. There is sufficient in-house labor. In fact for many districts, staff members serve dual roles: operations staff during the irrigation season and maintenance staff during the off-season.

In general, districts have also been successful at maintaining good records and documentation of physical infrastructure. For example, archiving blueprints, property titles, and easement information is intuitive for most district administrators and engineers. However, things are rapidly changing. Districts of all sizes are accelerating the implementation new technologies to meet internal and external pressures.

One example is a Supervisory Control and Data Acquisition (SCADA) system. Implementing a SCADA system involves the installation of new physical and digital infrastructure. This new "technological" infrastructure also requires specialized skills and knowledge for excellent maintenance and record-keeping. The intent of this paper is to provide readers with an outline of key SCADA-related maintenance and record-keeping items.

SCADA Maintenance Pre-Requisites

There are multiple SCADA maintenance prerequisites, or items that are considered absolute minimum requirements, for long-term SCADA system success.

Good Initial Design

With the following considerations, a good initial design can reduce the cost and overall burden for long-term SCADA system maintenance:

1. SCADA systems are composed of electronic components, which will ultimately fail, and sometimes fail unexpectedly. As such:

   a. Special attention placed on accessibility and maintainability for conduit and enclosure details can make the replacement of failed components easier.

   b. Redundancy of critical sensors and other items reduces system downtime.

   c. Special sensor installation details can reduce the negative impacts of heat and moisture, such as sensor drift and early failure.

   d. The appropriate implementation of diagnostic data and alarming can accelerate the troubleshooting process, without overtaxing operators with information and notifications.

2. Selecting hardened, industrial components that are replaceable with equivalent off-the-shelf products reduces frustration and long-term costs. It is always possible to lower the cost of SCADA projects by substituting in less expensive components. However, considering that less expensive components typically have shorter life spans, it is important to factor in the total cost of early replacement when selecting components. For example, in addition to the purchase price of the component, plus tax and shipping, other SCADA replacement costs include diagnosis (failures are not always self-evident), physical replacement, travel time and vehicle mileage, configuration, calibration, documentation and commissioning.

Adequate Maintenance Budget

Without sufficient budget, maintenance cannot be completed.

Available, Skilled Labor

Most things with SCADA systems are not visually apparent or simple. Compared with typical maintenance activities and documentation items for physical infrastructure listed in the first section of this paper, SCADA maintenance responsibilities can be obscure because:

1. Few irrigation districts employ experienced SCADA technicians.

2. SCADA systems continue to increase in complexity as new features and conveniences are added.

3. Maintenance and troubleshooting tasks require new and unique skills that are not currently provided by traditional educational institutions. In fact, the authors are unaware of any high school, trade school or higher education system that maintains a formal program for SCADA-specific training. Furthermore, not only are trained SCADA technicians hard to find, but tailored training courses for capable employees are rare, with the exception of some manufacturer-specific training.

In practice, good irrigation district SCADA technicians have some combination of general familiarity or expertise in most of the following areas:

1. Electrical and electronic circuits

2. Instrumentation

3. Programmable logic controller (PLC) and interactive display programming

4. Basic open channel and pipe hydraulics

5. Centrifugal pumps and variable frequency drives

6. Radios

7. Computer networks and administration

As the list above shows, an ideal irrigation district SCADA technician would have a diverse set of relatively specialized technical knowledge and skills. With smaller SCADA systems, it can be difficult to justify hiring a dedicated SCADA technician because there is simply not enough work. Nevertheless, there are a variety of options for irrigation districts with smaller SCADA systems:

1. Contract out maintenance tasks to integrators.

2. Hire a SCADA technician part-time in conjunction with other, nearby irrigation districts.

3. Hire or train a SCADA technician that performs other duties as well.

Access to Spare Parts and Specialized Tools

Replacing failed SCADA components is required to keep the SCADA system operational. Furthermore, component replacement and system maintenance can require specialized tools. In many cases, SCADA replacement parts and specialized tools are not available through local vendors, which brings up the question of purchasing these items before they are needed (stocking parts and tools).

Keeping Spare Parts

Single component failures can halt the functioning of all or part of the SCADA system, otherwise referred to as downtime. To reduce the duration of SCADA system downtime some districts decide to keep a stock of spare parts in storage, but many districts do not. The decision to keep a stock of spare parts depends on a number of variables including up-front stocking costs, the extend and criticality of the lost SCADA system functionality, the duration of downtime, potential early obsolescence of the component while in storage, and other factors.

A relatively basic method of estimating potential SCADA system downtime is presented in the following equation:.

$$\text{Potential downtime (hours)} = T_{notice} + T_{travel} + T_{identify} + T_{purchase} + T_{install} \quad (1)$$

Where,

T_{notice} = the time in hours to notice there is a problem/failure

T_{travel} = the travel time in hours to visit the site, sometimes requiring multiple trips

$T_{identify}$ = the time in hours required to troubleshoot the problem and identify the failed part

$T_{purchase}$ = the time in hours required to request a purchase and receive the part

$T_{install}$ = the time in hours required to install, calibrate/configure and commission the replacement part and revive the system

A potential downtime of three weeks is not unheard of. Furthermore, some districts have restrictive purchasing procedures that can delay the process further. It is recommended that readers use the equation informally to get a sense of, and prepare for, potential worst-case scenarios.

Description	Typical format	Minimum features	Other items that are convenient
Remote terminal unit (RTU) wiring diagram for all sites including radio repeaters	PDF drawing, or schematic	Individually labeled wire connections, internal and external panel layouts (with dimensions) and a bill of materials with makes, part numbers and quantities	
Tag list (for all project PLCs and dataloggers)	Spreadsheet	A database of individual programmable logic controller (PLC) tag names, with associated descriptions, units, tag addresses, and data formats	Additional details related to the configuration of communication protocols (e.g., Distributed Network Protocol (DNP) details) or details related to configuring the human-machine-interface
Radio network diagram (for all radio networks featuring repeaters, multiple radio types or elaborate routing schemes)	PDF drawing or schematic	A visual representation of the radio network topology	Labels showing the radio operating frequency or channel of each radio link
Networked hardware addressing database	Spreadsheet	A database of all Ethernet connected devices with associated Internet Protocol (IP) addresses, subnet masks, gateways and Media Access Control (MAC) addresses	Elaborate subnetting or Virtual Local Area Network (VLAN) descriptions
Base station networking diagram (for all base stations featuring more than two SCADA-related devices)	PDF drawing or schematic	A visual representation of all components and links within the private network and all public network connections. Labels should include all pertinent Open Systems Interconnection (OSI) Layer 1-3 information	Ethernet switch diagram, where ports are managed
Password list	Spreadsheet	A list of all passwords providing all levels of access, including administrative privileges to all systems with good descriptions	

Table 1. Minimum documentation items for typical SCADA systems, not including software or application files.

Minimum SCADA Record-Keeping Requirements

Proper SCADA-related record-keeping minimizes the cost of future SCADA system modifications, expansions, and some maintenance activities. Due to the complexity of modern SCADA systems, a complete set of minimum documentation items involves multiple hard/softcopy formats. Common documentation formats include:

- spreadsheets
- drawings and schematics
- executable programming/configuration software
- application files, developed/configured in the item above
- benchmarking records
- miscellaneous electronic and hardcopy files

The minimum SCADA documentation requirements are the same whether the work was completed by district personnel, consultant, or contractor. Typically documentation items are best created by the person or entity responsible for the particular item's implementation. In fact, reverse-engineering the details later on, by others, can be unjustifiably expensive or impossible, and should therefore be avoided. Furthermore, much of the documentation items are created by the developer, by default, to internally organize implementation work.

A detailed list of minimum SCADA maintenance documentation is provided in Table 1.

A basic taglist example is provided in Table 2 for clarification. While critical for documentation purposes, taglists can also be used to quickly import tags into PLC programs.

Additional record requirements and other details for software-related SCADA components are listed in Table 3. The requirements are marked conservatively. In other words, sometimes the documentation is required, but there are always exceptions. When an exception exists for items marked as required ("Y"), districts should request a written justification from the developer, describing the exception.

Name	Data Type	DNP address	DNP Class	Variable Type	Modbus Address	Description	Unit	Range (Min)	Range (Max)
Q_FB	Short floating point	17	1	Real	40033	Flow rate over flashboard	CFS	0.0	60.0
Q_SPILL		19			40037	Total spill flow rate			

Table 2. Example taglist excerpt for two internal PLC flow rate computations. In this example the tags are mapped to Distributed Network Protocol (DNP) points and Modbus registers. Note that the table also includes engineering units, expected value range and significant figures for display.

SCADA Component	Manufacturer's Software*	Software License**	Application File†	User Name and Password‡
"Smart" sensors and instrumentation (ex. acoustic Doppler velocity meters)	Y[1]	N	Y	N
PLC or datalogger	Y[1]	Y	Y	Y
Field user interface/display	Y[1]	Y	Y	Y
Unmanaged Ethernet switch	N[3]			
Managed Ethernet switch	Y[1]	N	Y	Y
"Smart" electronic gate actuator	N[2]	N	N	N
Variable Frequency Drive (for pumps)	N[1]	N	Y	N
Radios	Y[1]	N	Y	Y
Office workstation	Y	Y	Y	Y
Office server(s)	Y	Y	Y	Y
Human Machine Interface (HMI) program polling remote sites for updated data and presenting that information to the user. Examples: ClearSCADA, FactoryTalk, etc.	Y	Y	Y	Y
Office firewall	Y[1]	Y	Y	Y

* Typically requires manufacturer software, installed on personal computer or server to configure device

** Typically requires a software license, at additional cost, to fully utilize configuration software

† Configuration may be saved in an application file or text-based configuration list that can be archived on hard disk storage elsewhere for future use

‡ May require a password to view, modify or reuse application file

[1] Manufacturers are now integrating web servers in some of these devices, eliminating the need for a user to have software installed on laptops. Instead, the configuration interface is accessed via a standard web browser when networked to the device.

[2] Configuration is typically completed in the field using local buttons, remotes and/or a display integrated into the device

[3] No configuration is typically necessary. Things just "work"

Table 3. Additional minimum software-related requirements for particular types of SCADA system components.

Additional Recommendations

There are other documentation items that will make future maintenance more efficient, but are either not absolutely required, or relatively easy to reverse engineer or look up after the fact. Examples of such records include:

- A list of Federal Communications Commission (FCC) radio licenses and renewal dates. Searching for existing telemetry radio licenses can be completed using the FCC Universal Licensing System Search Tool found at: http://wireless2.fcc.gov/UlsApp/UlsSearch/searchLicense.jsp
- Software and third-party service/license and account information, including a summary of recurring fees and payment information
- A list and description of all remote access connections, including security features
- A complete list of software used for the project, the function and installation location of each (including detailed virtual machine configurations and capacity allocations)
- Radio field test results and benchmarks
- Interconnection wiring diagrams between an RTU and other site components

It is also recommended to keep multiple backup copies of the documentation in different, protected locations.

Conclusion

A number of SCADA system maintenance prerequisites are critical for long-term success, the most important of which are a good initial design/installation, and adequate budget for future operations and maintenance. Adequate documentation is also necessary for future SCADA system maintenance, expansion and modifications.

For a variety of reasons, ensuring good documentation is collected and archived can be difficult, regardless if the work was contracted out or performed in-house. The first step towards improving district documentation practices for SCADA systems is knowing what documentation is important.

Once documentation requirements are known, the next step is requiring it as part of any SCADA requirement, for both in-house and contracted work. Lastly, the documentation must be collected and verified, preferably from the person or entity doing the work. Keeping backup copies of all documentation is also a good idea.□


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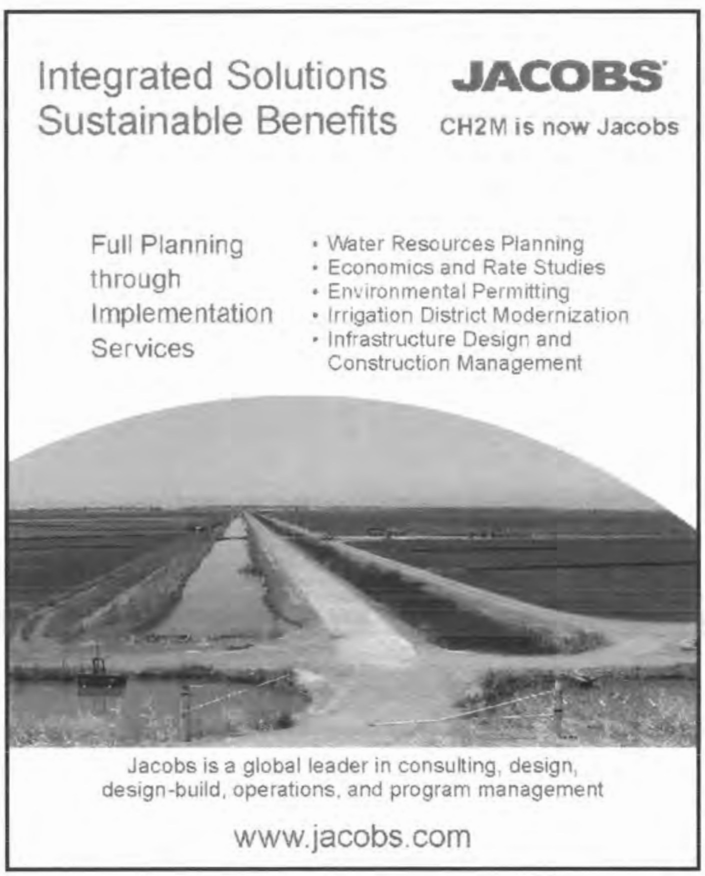
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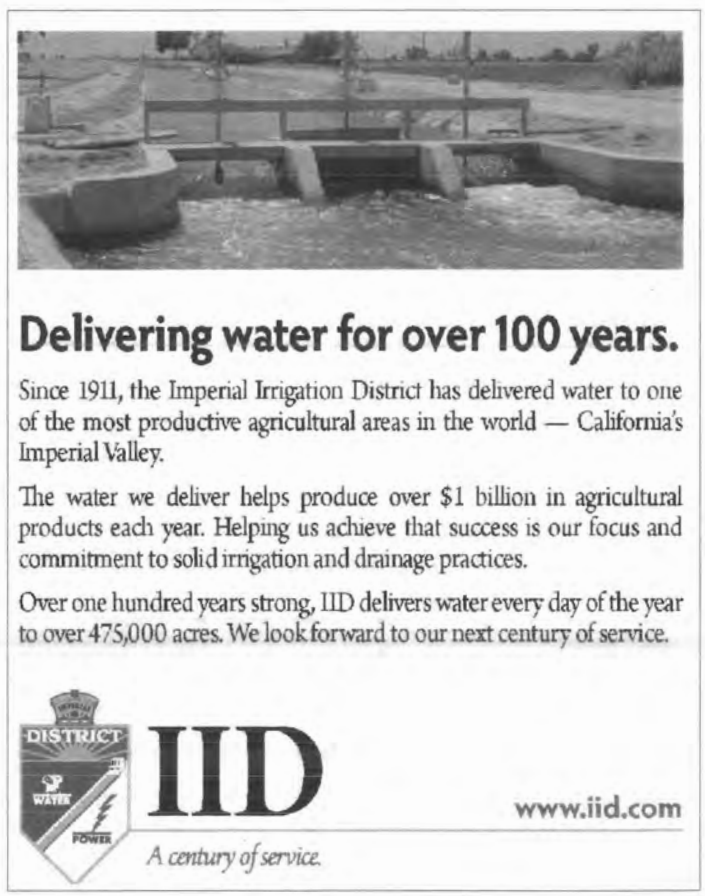
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Irrigation Beyond 2020: Evolution or Revolution?

by ICID President Hon. Prof. Dr. Chandra A. Madramootoo, James McGill Professor of Irrigation and Drainage Engineering, Dean, Faculty of Agricultural and Environmental Sciences, McGill University, Montreal, Canada, E-mail: chandra.madramootoo@mcgill.ca

Editor's note: This article is based on the speech delivered by President Hon. Madramootoo on receiving the World Irrigation and Drainage Prize, at the Third World Irrigation Forum in Bali, Indonesia, September 2, 2019.

The Last Five Decades of Irrigation Development

Positive Gains

From the 1970s to the decade commencing in 2000, the irrigation sector has undergone several positive changes, leading to growth and development in the agri-food industry. Benefits went beyond increased food production. Jobs have been created around the irrigation sector, and irrigation has led to economic prosperity and growth in income levels in rural areas. New agro-based industries have also emerged.

Irrigation no doubt played a very crucial role in reducing the impacts of famine felt in many parts of Asia, Africa and Latin America in the late 1950s and 1960s. The success of the green revolution could not have been achieved without irrigation, particularly with the production of the major cereals (rice, wheat and maize) in Asia. We have witnessed tremendous increases in food production over the decades. Inputs including high yielding varieties, agrochemicals, mechanization, and irrigation and drainage have contributed to this growth in food supply and availability. Irrigated area increased from around 140 million hectares in 1960 to over 300 million hectares by 2000, most noticeably in Asia.

During the 1980s-1990s, new irrigated commodity markets were developed and there were specialized irrigation advisory services in many countries, run mainly by the public sector, to provide smallholder irrigators with technical guidance on best water management practices. This was also a period where new irrigation schemes were built, and water storage and conveyance infrastructure was rehabilitated and modernized. New irrigation technologies, such as drip irrigation, and other forms of low pressure irrigation were introduced. Hydraulic engineering principles were more rigorously applied to the design of furrow and border-dyke irrigation systems. In the 1990s, international lending agencies and governments recognized that large-scale irrigation projects could only be sustained with stronger farmer participation and steps were taken to implement cost recovery of system operation and maintenance. Water Users Associations (WUAs) were formed and there was a push for the creation of mechanisms to support water pricing and water markets. However, these attempts were met with limited success in developing countries.

The principles of integrated water management were being promoted, and irrigation, drainage and flood control were deemed to be essential to these principles. It was felt that through this integration, water for food production would be more equitably allocated and distributed in harmony with other economic sectors and to secure environmental flows in river basins.

The global food crisis of 2008 drew the irrigation sector into focus in new ways. There was an expectation that irrigated agriculture, water harvesting and improvements to rainfed agriculture would be part of the solution to achieving food security in the developing world.

Challenges to Growth and Expansion of Irrigated Agriculture

Despite all the gains mentioned above, the irrigation sector faced numerous challenges in those five decades. The environmental impacts of large-scale irrigation, drainage and flood control projects were of primary concern. The principal impediments to the environmental sustainability of irrigated agriculture were: migration and displacement of populations who were historically settled near irrigation reservoirs, the occurrence of malaria and other waterborne diseases, siltation of reservoirs, rise in waterlogging and salinity, over-pumping of aquifers, and groundwater depletion, downstream water pollution by sediment and chemicals from irrigated lands, and impairment of downstream ecological habitats. The irrigation and drainage sector had to implement mitigative measures to counter these environmental impacts. These were of varying success. Certainly, the promotion of subsurface pipe drainage to combat the twin menace of waterlogging and salinity, and new methods of drainage water disposal were among some of the most successful practices. There were also major research and development initiatives, particularly in North America, on the role of water table management in the wet humid regions, to reduce nitrogen and phosphorus loads in drainage water.

The irrigation sector, which uses about 70 percent of global freshwater withdrawals, was also facing growing competition from other sectors including municipalities, industries, and the environment for freshwater supplies. This forced the irrigation sector to look at methods of water conservation and water savings, such as regulated deficit irrigation, alternate furrow irrigation, and alternate wet and dry irrigation. While these technologies show tremendous water savings potential at the pilot-scale, they have been difficult to scale-up for adoption by a large number of irrigators.

2020 and Beyond

As we enter 2020 and the decades to come, there are now new, very broad, and unprecedented challenges that the irrigation, drainage and flood control sector is facing.

Climate Change and Water Scarcity

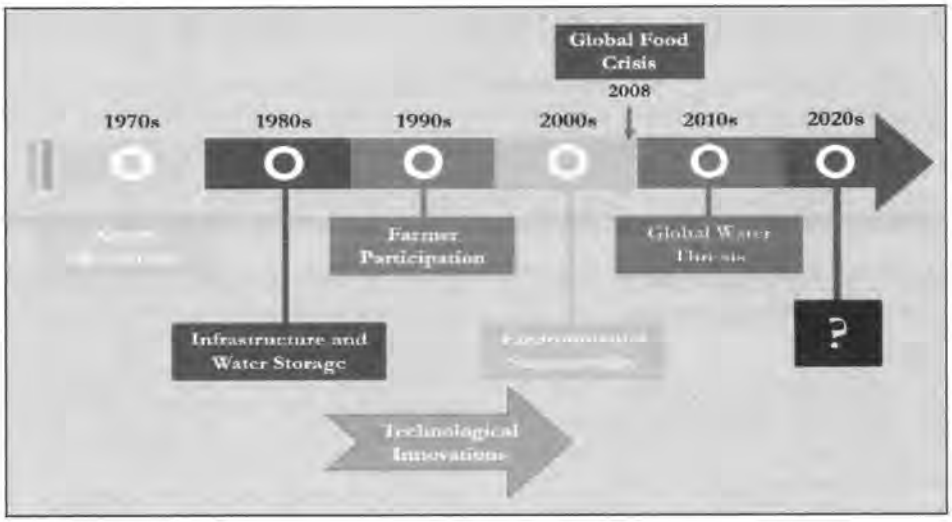
As noted in the latest report of the Inter-Governmental Panel on Climate Change (IPCC), we are likely to witness more frequent drought and flood events, as well as rising sea levels in coastal communities, in the future. The magnitude of these events is likely to be more severe for human populations and food production. Periods of drought could lead to prolonged water scarcity. Crops will, therefore, suffer more drastically from both wet and dry stresses, and consequences of significantly reduced yields. Investments in large-scale irrigation schemes will, therefore, be placed at risk. New models for handling uncertainty in irrigation, drainage and flood control design will, therefore, be required.

Greenhouse Gas Emissions

Intensification of crop production, particularly through increased fertilizer usage, will lead to higher nitrous oxide emissions in irrigated agriculture. This is already being witnessed with paddy rice production, where high methane fluxes are occurring. Improved fertilizer management, including reduced amounts, and better timing and placement, will reduce greenhouse gas (GHG) emissions and slowdown global warming. Lower anthropogenic GHG emissions will reduce negative impacts on ecosystems and food production.

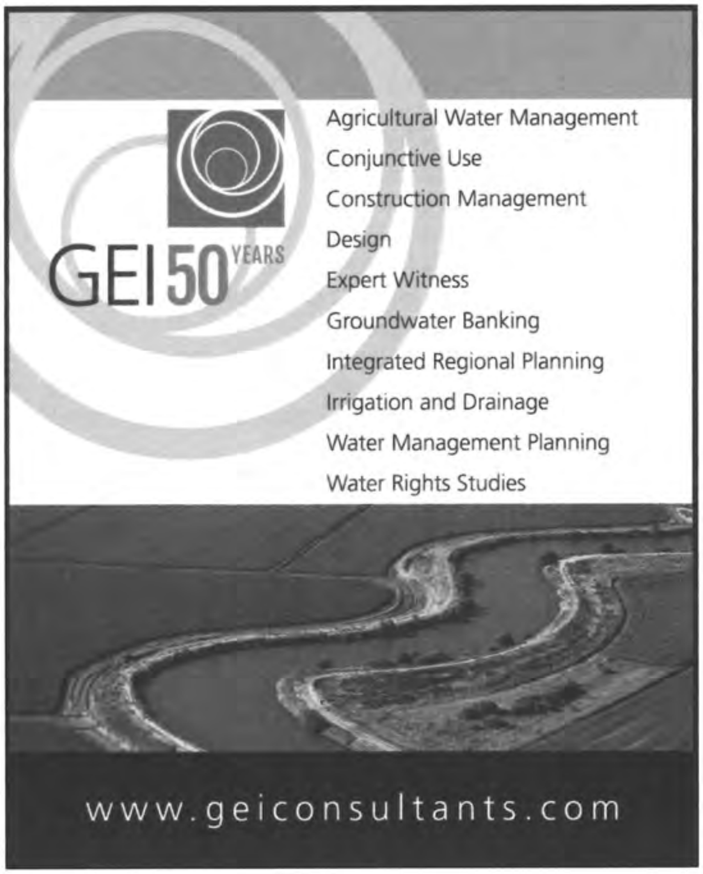
Technological Innovations

New geospatial analytical tools are enabling the mapping of fields accounting for variability in spatial landscape, elevation and soil properties. Site-specific management zones are thus being developed for irrigation farms. This is enabling the introduction of advanced water efficient technologies such as precision irrigation and variable rate irrigation. Artificial intelligence and machine learning algorithms will be introduced for the planning and allocation of water supplies in irrigation schemes. Remote sensing of soil moisture and crop canopy will be a key tool for determining ET, crop water requirements, and scheduling of irrigation. Real-time irrigation scheduling will be validated through the soil, crop, and water sensors connected via wireless sensor networks.



Concluding remarks

Many drivers of global change today will force the irrigation sector to be creative and responsive in a much more holistic manner, rather than the current narrow sectoral approach. These include political instability through migration and conflict, poverty, population growth and dietary change, food and nutrition insecurity, energy demands, land degradation, loss of biodiversity, agricultural intensification, and gender equity, diversity, and inclusivity. To integrate these aspects into the planning and design of new irrigation projects or retrofits to existing schemes, we will have to draw on new skillsets and multidisciplinary expertise going forward. The question is: will these global pressures drive evolutionary or revolutionary change in how we use water to produce food in the coming decades?□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Election (continued)

He is a Registered Professional Engineer in Colorado and California and served in the past as the Chair of the EWRI Agricultural Drainage and Water Quality Committee. As a Life Member of USCID, he has served on several conference planning committees, and was a co-chair for the USCID Conference in Reno, November 2019. Since first attending a conference in the early 1990s, he recognized the importance of the technical knowledge that USCID members provide to the irrigation and drainage profession and is interested in transfer of knowledge through the members of USCID.

Delbert M. Smith is Value Program Manager, Bureau of Reclamation in Denver, Colorado. He has more than 29 years of experience in planning, design, and construction of water resources projects. He coordinates all Value Engineering and Value Planning Studies for the Bureau of Reclamation and provides value planning for Indian water rights settlements for the Department of Interior. He has worked on international water resource projects in Jordan, Kenya, Thailand, and the Philippines. He has been involved with USCID for 25 years and co-chaired the Conference in Reno, November 2019.

Therese A. Ure is a shareholder and managing partner, Schroeder Law Offices, P.C. in Reno, Nevada. She earned her J.D. from Valparaiso University School of Law in 2006 and returned to Oregon and Nevada to continue her legal work in water and natural resources. She grew up on a farm in Eastern Oregon learning to irrigate by setting siphon tubes with her brother and sister. She is a third-generation lawyer, and fourth generation farmer. She practices law and litigates at the state and federal levels in Nevada and Oregon. The focus of her practice is all things water including agriculture, water use permitting, extensions, transfers; groundwater interference and connection, critical and limited areas; special patron rights and responsibilities, public lands (easements, permitting uses and grazing permits, and compliance issues), and agri-business. She also partners with her husband and brother in operating a feedlot and farm in Lovelock, Nevada, where they irrigate through flood irrigation. She has traveled to ICID and World Water Forum meetings in Thailand, Scotland, and Indonesia, presenting topics on conjunctive management and water use throughout the western United States. She is a member of USCID and co-chaired the Conference in Reno, November 2019.¤

Pond Seepage Losses (continued)

purchase of the land, a groundwater right of 800 acre-feet per year (afy) was included. Groundwater will be used to offset losses from the ponds due to evaporation, evapotranspiration , and seepage. Exceeding this rate would be problematic and could have legal implications. The ponds will be located on a river terrace of an intermittent river channel in a bedrock-bounded river valley. The valley is oriented west-east.

Analytical groundwater flow methods allow for the direct calculation of groundwater head without the need for numerical solvers. This has an advantage over numerical methods by simplifying the mathematical model development, producing numerically exact results, and being spatiotemporally continuous . Application of analytical methods typically requires some level of simplification of the groundwater system to develop a workable equation. Despite this simplification, valuable insights into the system can be gained from the application of analytical methods. It is also possible for analytical methods to be used in lieu of numerical methods and produce a satisfactory answer to a given question.

Analytical methods require the linearization of the groundwater flow equation. Once linearized, groundwater flow elements (e.g., pumping/injection wells, drains, gaining/losing streams, etc.) can be combined by superposition to develop a continuous equation for groundwater head within the problem domain. No-flow boundaries, aquifer thickness, and the regional groundwater gradient can also be accounted for. Here, we employ elements for: a leaky pond, a no-flow boundary, and the regional groundwater gradient to evaluate the required thickness of the compacted silt liner needed to reduce seepage from the pond to an acceptable discharge.

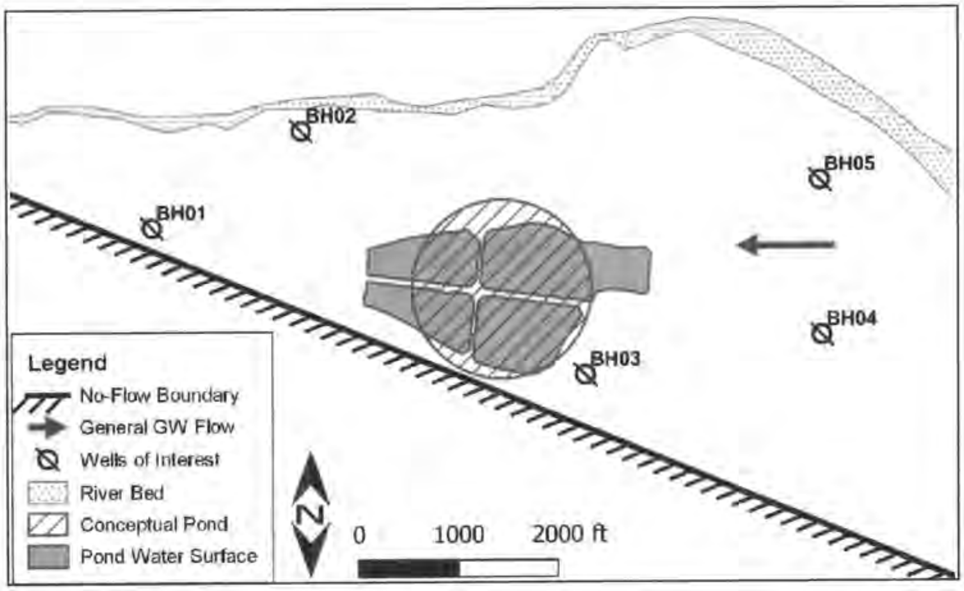

Figure 1. General site layout and conceptual model.

Methods

Conceptual Model

Groundwater flow through the river valley is generally from east to west (Figure 1). The aquaculture ponds will be located on a low river terrace approximately 2000 feet south from the river channel. Surface flow in the river channel is intermittent as most of the flow infiltrates through the river valley. South of the ponds is an older, relatively impermeable bedrock mountain range. Several ephemeral washes emanate from these bedrock mountains near the site. For this analysis, the mountain range is considered to be a no-flow boundary (Figure 1). Contributions from the ephemeral washes are infrequent and were not considered in this analysis.

To estimate the regional groundwater gradient, groundwater elevation (gwe) measurements from up- and down-gradient of the pond were used. Measurements from wells BH04 and BH01 were selected for use as the centroid of the pond lies close to the half-distance between them (Figure 1). These wells were installed in 2016, therefore their measurement record is relatively limit for evaluating low-frequency trends. However, other wells nearby (BH02, BH03, and BH05) have a period of record spanning more than a decade (Figure 1). Concurrent gwe measurements between these wells and BH04 and BH01 were available. Data from these longer period of record wells were shifted informed by the mean difference between the concurrent measurements so that a longer, pseudo-data set could be developed for BH04 and BH01. The result was a mean gwe at BH04 (up-gradient) of 594.2 ft with a standard deviation of 3.4 ft, and a mean gwe at BH01 (down-gradient) of 581.9 ft with a standard deviation of 1.1 ft.

For application to the analytical groundwater flow equation, the four proposed aquaculture ponds were conceptualized as a single, circular pond with its centroid located at the area-weighted centroid of the four ponds (Figure 1). The radius of the circle was calculated so that the area of the circle would be equal to the combined water surface area of the four ponds.

Results from a subsurface investigation indicate the material below the ponds is predominantly silt and sand. As part of this subsurface investigation, measurements of horizontal hydraulic conductivity (K) where collect for approximately the top 30 ft of material in the area where the ponds will be located. K data were collected at 0.05 ft intervals using a hydraulic profiling tool (*Geoprobe Systems*®). Arithmetic means of K data were calculated for each test site — 14 sites in total. The test sites together have a mean K of 74.0 feet per day (ft/d) and a standard deviation of 12.4 ft/d. Samples of the silt material, proposed for lining the ponds, were collected for laboratory tests. Testing estimated the K of the compacted silt to be 0.01 ft/day.

Completion depths of wells in the area and a steady-state groundwater model of the river valley suggest that the upper aquifer is shallow — ranging between 50 to 60 ft thick. Completion depths from five groundwater pumping wells near the ponds were used to estimate the aquifer thickness (locations not included in this paper). These resulted in a mean thickness of 50.5 ft with a standard deviation of 7.2 ft.

In addition to seepage losses, water is also expected to flow out of the ponds from direct, open-water evaporation and ET from the proposed marsh areas within the ponds. The areas for each were calculated as 28.5 ac and 30.5 ac for open water and marsh, respectively. An open-water evaporation rate from data collected at a nearby weather station was used to calculate evaporative losses. The same source was also used to calculate ET losses from the marsh areas. In total, these two outflows are estimated to be 330 afy.

Precipitation which falls directly on the pond water surface and marsh will contribute to replacing losses. An average annual precipitation rate for the area was calculated using a dataset spanning 1950 to 1999. This rate was applied over the area of the water surface and marsh areas of the ponds (59 ac). It is estimated that direct precipitation will contribute approximately 31 afy of inflow to the ponds.

Analytical Solution Description

An analytical groundwater flow equation was derived to evaluate seepage from the aquaculture ponds (Equation 1). Derivation of the equation was based on Strack (2017) and, and it is available from the author as a supplement of this paper — along with a complete description of variables. The equation accounts for: a west-northwest trending no-flow boundary, the regional east-to-west groundwater gradient of the valley, and seepage from the ponds. This method assumes a homogeneous K, no other sources or sinks (e.g. pumping, flow from the washes, or gains/losses from the river), and that the aquifer is shallow. The equation calculates potential (head) and streamlines/ flowlines at a given location, z, where z is a complex number of the Cartesian coordinates x and y (i.e., $z = x + iy$).

$$\Omega = -Q_{uf}\left[ze^{-i\alpha} - \frac{R^2e^{i\alpha}}{z+id} - \frac{R^2e^{i\alpha}}{z-id}\right] + \frac{Q_0}{2\pi}\ln\left(\frac{z+id}{R_\infty}\right) + \frac{Q_0}{2\pi}\ln\left(\frac{z-id}{R_\infty}\right) + \Phi_\infty \quad (1)$$

where Ω is the complex potential containing information on both head and the sterlines/flowlines, Q_0 is the seepage discharge from the pond, and other variables are defined in the supplement available from the author. The spatial origin of the equation is located at the perpendicular intersection of the no-flow boundary and the pond centroid. The solution area is constrained to a rectangular between BH04 and BH01.

By setting the potential at a point on the boundary of the pond to the water surface elevation within the pond, a derivation from Equation 1 can be made to estimate the seepage discharge from the pond with no lining:

Due to the need to simplify the groundwater system for use of an analytical solution, the uniform flow field portion of the

$$Q_0 = 2\pi\frac{\Phi_0 - \Phi_\infty + -Q_{uf}e^{-i\alpha}\left[R + id - Re^{i2\alpha}\left(1 + \frac{R}{R+i2d}\right)\right]}{\ln\left(\frac{R^2+i2dR}{R_\infty^2}\right)} \quad (2)$$

equation does not account for the no-flow boundary. It is expected that, for this application, results will not be significantly affected as the uniform flow field is slightly oblique to the no-flow boundary (Figure 1).

A *One-Percent Scaled Sensitivity* analysis was used to evaluate the effects of four input parameter on seepage from the pond using Equation 2 — up-gradient gwe, down-gradient gwe, K, and aquifer thickness. This sensitivity analysis calculates the change in seepage based on a one-percent increase to a single parameter value (Figure 2). The analysis indicates that an increase in K and aquifer thickness result in an increase in seepage; while an increase in either the up- or down-gradient gwe result in a decrease in seepage – with the up-gradient gwe producing a greater change. Note that the analysis does not indicate that the solution is more sensitive to K than other parameters considered — which may seem unintuitive. This is due to a one-percent increase in K being relatively negligible (i.e. 74.0 ft/d vs. 74.7 ft/d) as K is known to vary on a log scale (i.e. 10^1 vs 10^2).

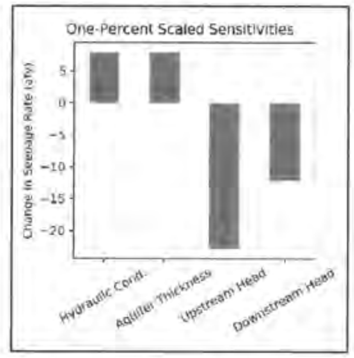

Figure 2. One-percent scaled sensitivity for seepage from pond.

Compacted Liner Thickness

Estimation of the required thickness of a compacted earthen-material pond liner to achieve an acceptable seepage discharge can be derived from Darcy's Law as:

$$x_{liner} = \frac{K_{liner} \times A_{pond}(\phi_{pond} - \phi_{gw})}{Q_{seepage}} \quad (3)$$

where x_{liner} is the thickness of the compacted lining material, A_{pond} is the area of the saturated, horizontal surface of the pond liner, ϕ_{pond} is the water surface elevation in the pond, ϕ_{gw} is the groundwater head around the pond, and $Q_{seepage}$ is the acceptable seepage discharge from the pond. Some assumption is required in choosing ϕ_{gw} as it will vary spatially over the area of the pond. As Equation 1 is not valid for solving for the head within the pond, the mean head around the boundary of the pond was used.

Results

A water balance of the pond includes outflows from ET, evaporation, and seepage and inflow from direct precipitation. Adjusting for these factors from the water available through the groundwater right yields an acceptable seepage discharge from the pond ($Q_{seepage}$) of approximately 500 afy.

Seepage from the unlined aquaculture ponds was first evaluated to assess if losses under an unlined condition were less than the acceptable losses. Using mean parameter values, seepage was calculated to be approximately 665 afy (Equation 2). This rate was input into Equation 1 to solve for head over the site using mean parameter values (Figure 3). Using Equation 2 and mean parameter values, seepage loses from the pond were also calculated. Contours of head provide insight into how the hydrogeologic system will change post-construction of the ponds. The solution indicates that a localized groundwater mound will be created by seepage from the ponds, and that seeped water will predominantly flow to the east-northeast.

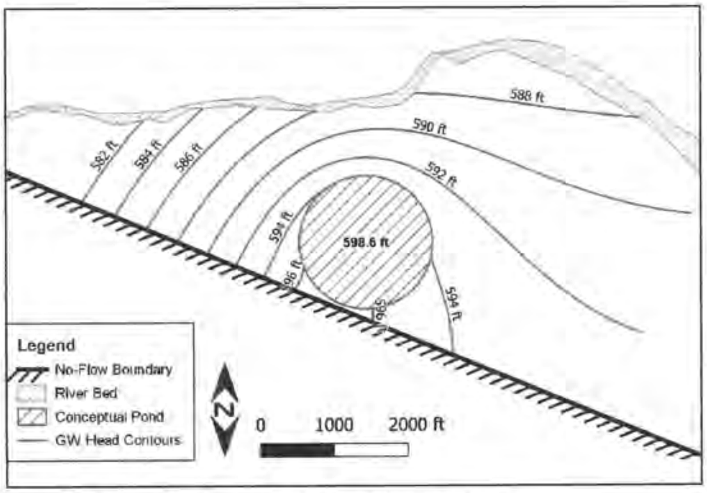

Figure 3. Potential/Head contours for the unlined pond case.

Seepage losses from the unlined pond are estimated to exceed acceptable losses by 165 afy; therefore, a lining is necessary. The mean groundwater head around the pond boundary when the pond is seeping the acceptable, 500 afy was calculated to be 593.9 ft (Equation 1). To meet the acceptable seepage losses, a compacted silt liner of approximately 2.1 ft will be required (Equation 3). The head distribution post-lining of the pond (i.e. with seepage equal to the acceptable seepage discharge) was calculated using Equation 1 and mean parameter values. The results indicate a smaller groundwater mound than in the unlined case while maintaining the general east-northeast flow (Figure 4).

Stochastic Analysis of Liner Thickness

To evaluate the uncertainty in the estimated thickness of the compacted liner, stochastic methods were employed using four input parameters: up-gradient gwe, down-gradient gwe, K, and aquifer thickness. Parameters where allowed to vary between ± 1.645 standard deviations of their respective mean. An independent, random and uniformly distributed value was generated for each parameter for each iteration. Analysis continued until a minimum number of iterations were met and the mean of the generated liner thickness dataset converged to within 10^{-3} ft — approximately 30,000 iterations. The liner thickness data were found to approximate a light/short-tailed Normal distribution with a slight left skew (a skewness of -0.03) (Figure 5).

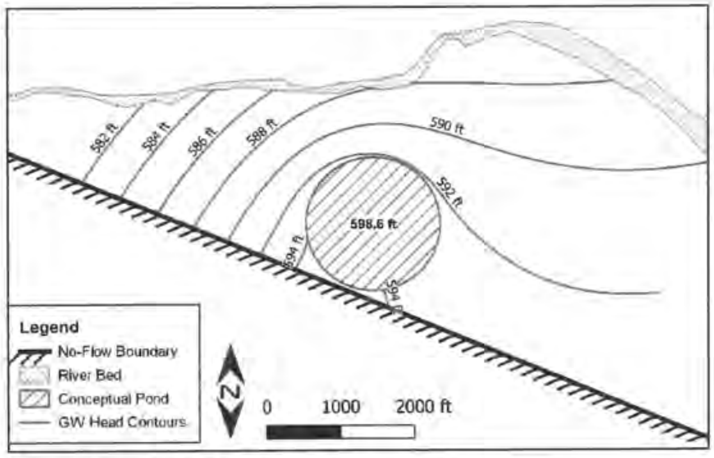

Figure 4. Potential/Head contours for the lined pond case.

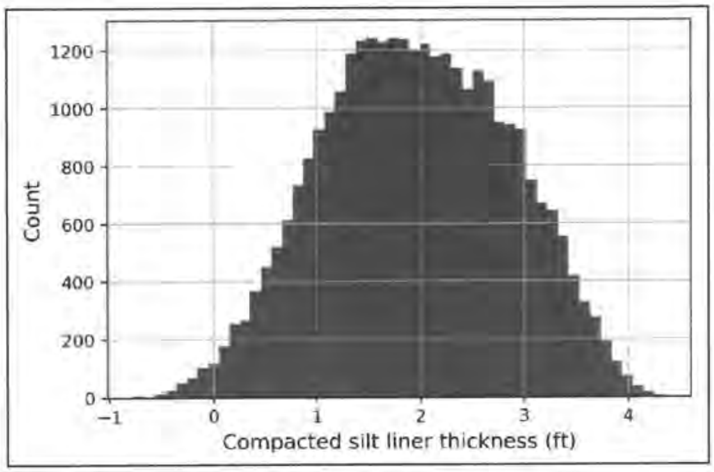

Figure 5. Histogram of liner thicknesses from stochastic analysis from approximately 30,000 iterations (number of bins = 50).

Confidence intervals for the Normally-distributed liner thickness dataset can be calculated by:

$$\overline{x_{liner}} \pm z_c \frac{\sigma_{liner}}{\sqrt{n}} \tag{4}$$

where $\overline{X_{liner}}$ is the arithmetic mean of the liner thickness, z_c is the Normal distribution critical value read from a table based on the desired confidence level, σ_{liner} is the standard deviation of the liner thickness, and n is the number of samples (in this case, the number of iterations). Using a 90 percent confidence interval, the required pond liner thickness is estimated to be 1.9 ± 0.01 ft. Note that this is less than the thickness calculated directly using mean parameter values. This is likely due to the skew of the distribution towards the left. This skew is a function of the underlying equations (Equation 1and 3).

Results of the one-percent scaled sensitivity analysis and knowledge of hydrogeologic systems suggest that the gwe at the up-gradient boundary (BH04) and K are the two parameters likely to have the greatest effect on the required thickness of the compacted silt liner. A contour plot of calculated liner thickness was generated based on changes to up-gradient gwe and K (Equation 1 and 3). The up-gradient gwe was allowed to vary between 1.645 standard deviations of its mean and K over two orders of magnitude. The result indicates that the liner thickness requirement can vary considerable within an order of magnitude change of the mean K value (Figure 6). The required liner thickness when using mean parameter values is indicated on the plot as 2.1 ft while the red-dotted lines indicate the mean parameter values of their respective parameters.

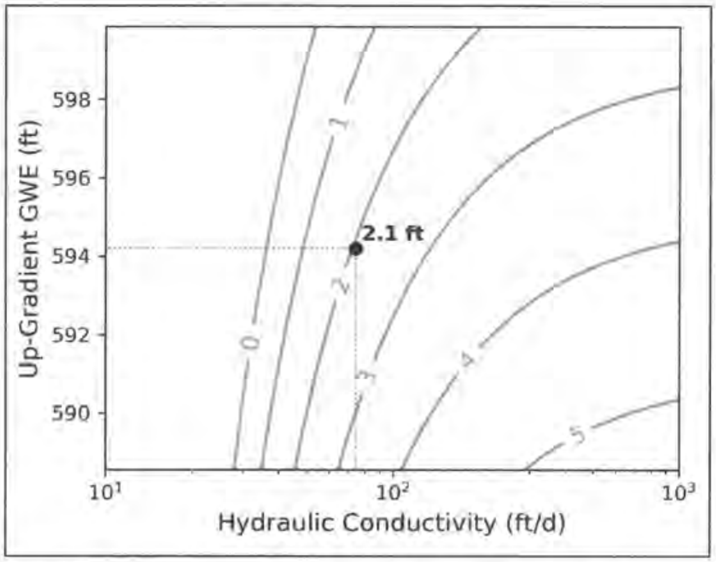

Figure 6. Contours of compacted silt liner thickness from varying up-gradient gwe and hydraulic conductivity. Dotted lines indicate mean values of their respective parameters. Dotted line and text indicate the liner thickness under mean parameter conditions.

Figure 5 suggests that as K increases, the impact of changes in the up-gradient gwe on the required liner thickness increase. at lower k values, variation in the up-gradient gwe results in less significant changes to the required liner thickness. the plot can also be used during any additional field study to update the estimate of the required thickness of the compacted silt pond liner.

Conclusions

Results indicate that under the assumptions and limitations of this analysis, the aquaculture ponds will require lining to reduce total pond losses to less than the groundwater right associated with the site. With 90 percent, confidence the aquaculture ponds would require a compacted silt liner of 1.9 ± 0.01 ft thick to reduce seepage losses to less than the acceptable discharge of 500 afy. As additional K and gwe data are collected, can be used to inform an update to this estimate.

Possible improvements to this work would be to evaluate inclusion of the no-flow boundary in the uniform flow field calculation. If it is not able to be explicitly included, it is possible that adding a series of recharging well terms on the no-flow side of the boundary could provide a similar result. If significant pumping is expected in the area near the ponds, this should also be added to the calculation. Effects of pumping could drastically alter the conclusions of this work.

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Missouri River Basin Report

Below-normal precipitation in the upper Missouri Basin during June resulted in slightly below-average June runoff. The 2020 calendar year upper basin runoff forecast, updated on July 1, is 31.2 MAF, 121 percent of average..

"The upper basin runoff forecast has been reduced by about 1 MAF due to the recent dry conditions as well as the National Weather Service's climate outlook, which is indicating that the remainder of the summer will be warmer and drier than normal. However, the 2020 calendar year runoff forecast remains above average, mostly due to the very wet soil conditions during the early months of the year. Most of the mountain snowmelt runoff has entered the reservoir system. Remaining summer runoff will depend on rainfall events," said John Remus, chief of the U.S. Army Corps of Engineers' Missouri River Basin Water Management Division.

Soils continue to dry out in the upper Missouri River Basin due to well-below normal precipitation and warmer-than-normal temperatures. Drought conditions, based on the National Drought Mitigation Center Drought Monitor, have expanded across much of western portion of the Basin.

The potential for localized flooding remains in the Missouri River Basin. The flooding potential is higher in the lower basin from locally heavy rain on the many uncontrolled tributaries downstream of the Missouri River Mainstem Reservoir System.◘

Drainage Book Revised

Modern Land Drainage 2nd edition, is a fully revised and updated edition of the 2004 edition. USCID Member **Willem F. Vlotman**, Consultant, Canberra, Australia, is one of the authors.

Modern Land Drainage describes traditional drainage formulas (Hooghoudt, Kirkham, Donnan, Ernst, Glover-Dumm) for rainfed agriculture in the humid temperature zone. Significant parts are devoted to drainage for salinity control of irrigated land in (semi-) arid zones, and to drainage of rice land in the humid tropics. Institutional, management and maintenance aspects are extensively covered, as well as the mitigation of adverse impacts of drainage interventions on the environment. The latest computer applications for drainage design in the context of integrated water management are described (DRAINMOD, HEC, SWAP, etc.). Field surveys are executed by governments, with the aid of consultants, but rarely are the end stakeholders (i.e., farmers and general public) involved from inception to planning to execution of a drainage system. Yet, during the Operation, Management and Maintenance (OMM) phase of a water management system, they are expected to takeover, run, bear and be responsible for the costs of OMM. The book describes successful methodologies and processes to be followed for engagement of stakeholders at all levels, from government to farm, from minister to farmer, and, from beginning to end. The book covers all aspects needed for sustainable drainage. The latest survey methodologies with satellites and drones are suggested to assess cause and effect. Waterlogging and salinity are the effect of something caused most likely upstream of the drainage problem location. Hence, treating the cause may be more cost-effective. Triple Bottom Line (social, environmental and financial considerations) and the water-food-energy nexus are an integral part of the drainage design process. Controlled drainage, i.e., the balance of removal and conservation of drainage water and minimizing solute transport as low as reasonably achievable (ALARA principle) is extensively described.

This work is intended for use both as a university level textbook and as a professional handbook; it is of particular value to professionals engaged in drainage development in the context of integrated water resources and river basin management, civil and agricultural engineers, government officials, university students and libraries.

Visit www.routledge.com/9780367458775 to order. Use the discount code ENG20 at checkout to receive a 20 percent discount.¤

New Members

Lynn Groundwater

Provost & Pritchard Consulting Group
2505 Alluvial Avenue
Clovis, CA 93601
Office: 559-326-1100
E-mail: lgroundwater@ppeng.com

Matt Klinchuch

Provost & Pritchard Consulting Group
130 North Garden Street
Visalia, CA 93291
Office: 559-636-1166
Fax: 559-636-1177
E-mail: mklinchuch@ppeng.com

Katherine Klug

Davids Engineering, Inc.
1772 Picasso Avenue, #A
Davis, CA 95618
Office: 530-757-6107
Fax: 530-757-6118
E-mail: katherine@davidsengineering.com

Jordan David Muell

Provost & Pritchard Consulting Group
130 North Garden Street
Visalia, CA 93291
Office: 515-360-4159
E-mail: jmuell@ppeng.com

Jose Payero

Clemson University
64 Research Road
Blackville, SC 29817
Office: 803-508-1617
E-mail: jpayero@clemson.edu

Amber Weber

Ark Valley Writing and Planning Services, LLC
5 Chaparral Circle
La Junta, CO 81050
Office: 719-688-9941
E-mail: arkvalleywps@gmail.com□

WEST News

Jeffrey B. Bradley, President of WEST Consultants, Inc., is the recipient of the 2020 Service to the Academy Award, American Academy of Water Resources Engineers. He was recognized for his significant leadership and contributions in furthering the mission and goals of the Academy. He was the founding President of AAWRE from 2004-2007.

Bradley is a nationally renowned expert with more than four decades of experience in hydraulics, hydrology and sedimentation. He received the USCID Service to the Profession Award in 2018.□

News of Members

Rhett Bergman has completed his studies at California Polytechnic State University and is now an Engineer in Training with Bennett Environmental, Inc. in Visalia, California.

The **Bureau of Reclamation** recently named David Raff as Chief Engineer. He will direct Reclamation's engineering and scientific programs in Technical Services, Dam Safety and Infrastructure, Hydropower, Research and Development, and Water Planning.

The **Glenn-Colusa Irrigation District** celebrated its 100-year anniversary in February. The District is the largest water district in the Sacramento Valley with a 100-year history of serving farmers, businesses and residents while also maintaining critical wildlife habitat.

Erika Gomez graduated from California Polytechnic State University in December 2019 and is now a staff professional with **GEI Consultants, Inc.**, in Pasadena, California.

Suat Irmak, University of Nebraska, has been named a Fellow by the Association of Agricultural and Biological Engineers.

Kul Khand has completed his studies at Oklahoma State University and is now affiliated with the USGS EROS Center in Sioux Falls, South Dakota.

Kristoph-Dietrich Kinzli, Professor at the Colorado School of Mines, was named Joint Editor of *Irrigation and Drainage*, ICID's Journal, during the Bali IEC Meeting last fall..

George Sabol has joined WEST Consultants, Inc. in the firm's Tempe, Arizona, office. He has more than 40 years of experience in hydrology, hydraulics, and structure design in the Rocky Mountain West and internationally.

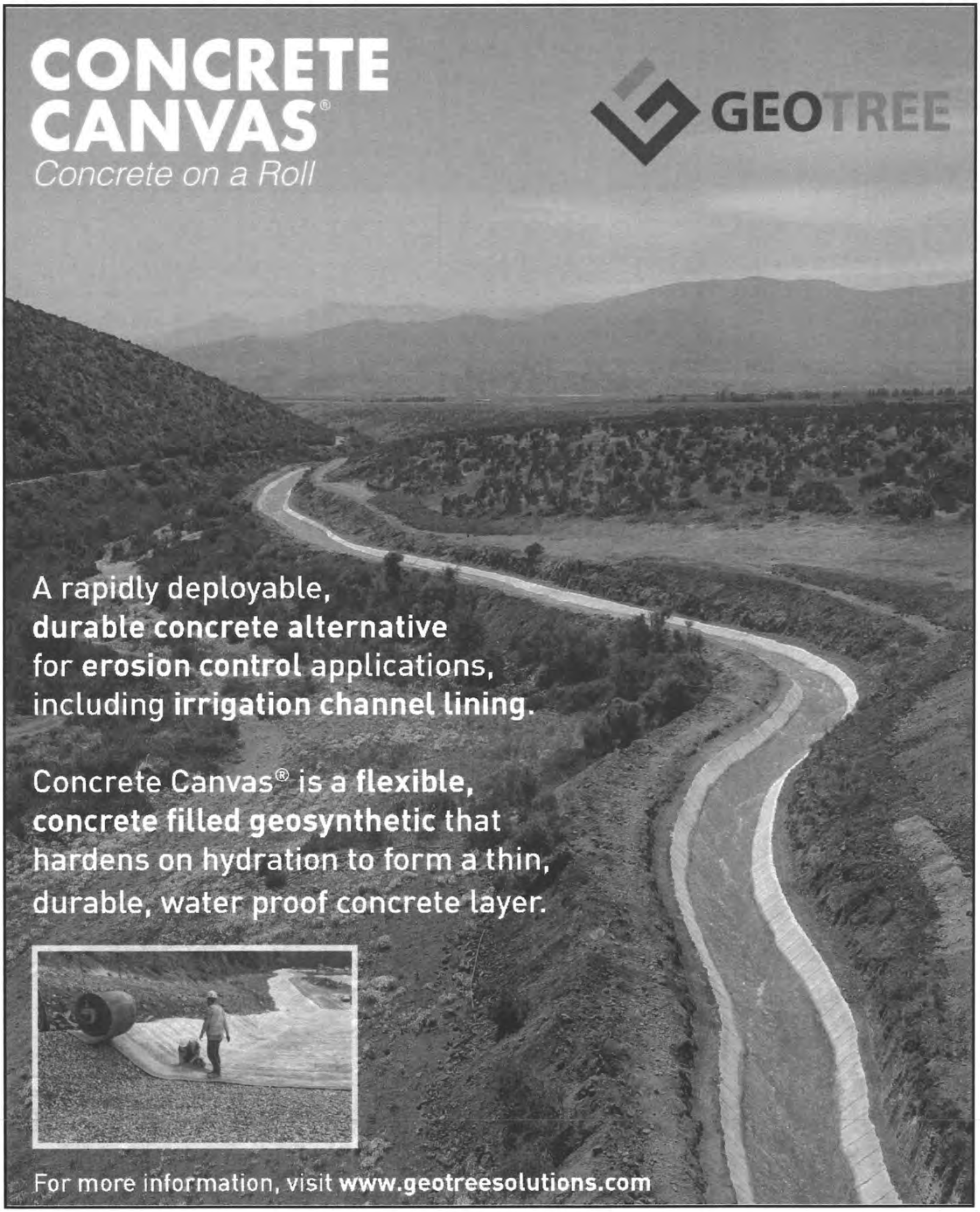
Stephen W. Smith received the 2020 Innovator Award from the Irrigation Association. The Award honors individuals who have made significant, tangible contributions to the irrigation industry within the past five years. Smith was recognized for his work toward the creation and development of the Irrigation Innovation Consortium located in Fort Collins, Colorado. Smith's work paved the way for this collaborative project focused on accelerating the development and adoption of water-efficient irrigation technologies and practices.□

Necrology

William Gianelli passed away at the age of 101 in Monterey, California on March 30. The third Director of the California Department of Water Resources, his career spanned more than 30 years in both state and federal government.

Richard B. Reidinger passed away on December 10, 2019. He had a 30-year career as an agricultural economist at the World Bank, working primarily in India, Nepal, Thailand and China. He joined USCID in 1975.

USCID Newsletter Advertisers, Spring 2020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USCID Notes

by Larry D. Stephens, Executive Vice President

Congratulations to **Therese Ure** for being elected to the USCID Board of Directors. She played a key role in making the 2019 Reno Conference a big success! Also to **Sam Schaefer** and **Del Smith** for being elected to second terms on the Board and to Del for being elected Secretary of the Board. USCID is certainly blessed to have such talented and experienced professionals who give pro bono service to the society!

Congratulations also to **Kristoph Kinzli** for being named Joint Editor of *Irrigation and Drainage*, ICID's peer reviewed Journal. Another example of important pro bono service. Also serving on the Journal Editorial Team are **Kendall De Jong** and **Saleh Taghvaeian**, and on the Journal Editorial Board is **Luis Garcia**. Please contact me if you would like to join the Editorial team and/or would be available to review papers that have been submitted for publication.

Thanks to USCID Corporate Members **In-Situ Inc.** and **SonTek** for providing webinars to USCID Members. Especially this year, when we cannot have a conference, some technical content is important. I encourage all Corporate Members to offer webinars as well. And, of course, webinars from members of water districts and universities would be most welcome. We provide this opportunity as a benefit of membership.

As reported in the page 1 article, the 2019 USCID Conference in Sacramento has been postponed to next year because of the pandemic. The Conference theme will be *Managing Limited Groundwater and Surface Water Supplies to Meet Irrigation Demands — Challenges, Opportunities and Solutions*. Conference Co-Chairs will be **David Bradshaw**, **Randy Hopkins** and **Stuart Styles**. They would welcome more USCID Members to join the Conference Planning Committee, and more abstracts are needed. The deadline for submitting an abstract is June 4, 2021. The Call for Papers is available on the USCID website, www.uscid.org. Please review the Call and send an abstract. And, I hope to see in Sacramento next year.

One final note — because of issues regarding travel, etc., caused by the pandemic, the RFP for proposals to serve as the next USCID Executive Director was withdrawn and will be re-issued early in 2021.¤

USCID Meeting

October 26-29, 2021, Sacramento, California. 13th International Conference on Irrigation and Drainage.

ICID Meetings

December 1-7, 2020, 5th African Regional Conference on Irrigation and Drainage and 71st IEC Meeting, Marrakech, Morocco.

July 6-12, 2020, 72nd IEC Meeting and 24th Congress, Sydney, Australia.

September 2020, Beijing, China. 73rd IEC and 4th World Irrigation Forum.