2006 Rain Bird Intelligent Use of Water™ Summit

A Look at Global Conservation Initiatives and Strategies

Wednesday, January 4, 2006 ··· 10:30 a.m. to 12:30 p.m.
Hilton Hotel, Pasadena

When the well is dry,
we know the worth of water.
—Benjamin Franklin

Summit Panelist Papers

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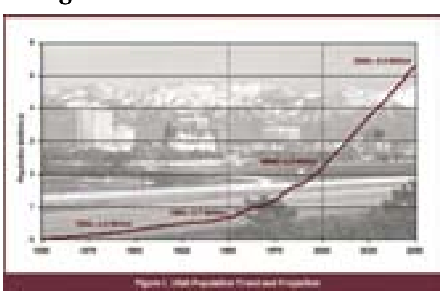
Eric Klotz is a Registered Professional Engineer in the state of Utah. He obtained a BS degree in Civil Engineering from Michigan Technological University in 1983. Upon graduating he began working for the Utah Division of Water Resources (DWRe). Eric currently manages the Water Conservation, Education and Use Section of the DWRe. The DWRe is responsible for the orderly and timely planning, development, utilization, conservation and protection of Utah's water Resources.

Eric was born in Detroit, Michigan and grew up in the northern suburbs of Detroit. Eric and his wife Debbie currently live in North Salt Lake City. They have two daughters; Callie, 10 and Natalie, 8. Eric enjoys skiing, hiking, camping and traveling.

STATE OF UTAH WATER CONSERVATION PLAN

Background



Utah is currently the fifth fastest growing state in the nation. From 1990 to 2000, Utah's population increased by more than 510,000 people to over 2.2 million. Recently released population data indicates the population increased by another 300,000 since 2000. It is expected that by 2050 the state's population will be about 5.4 million. As Utah's population increases so will the demand for its limited water resources. If Utah's current municipal and industrial (M&I) per capita water demands are not reduced, it will put tremendous pressure on the state's developed water supplies, as well as take an intense effort to find new water sources.

Utah is the second driest state in the nation and regularly experiences drought cycles, but its residents are among the highest consumers of water. Utah's M&I per capita use of 267 gallons per capita per day (gpcd) is the second highest in the nation. The hot, dry summers are one of the major factors contributing to this, as it necessitates high irrigation needs for lawns and gardens. Additionally, most of the population lives in close proximity to snow-capped mountains, which provide most of the water supply. This proximity and the fact that the supply is of very high quality result in low water rates. Low rates are believed to be a disincentive to water conservation to the public.

Because Utah's M&I per capita water use is the second highest in the nation, the Utah Division of Water Resources (DWRe) recognized there were some incredible opportunities for water conservation to play a major role in meeting the future water needs of the state. In 1994, the DWRe outlined a conservation goal to reduce M&I per capita use in the state by 25 percent by 2050. At that time, Utah's M&I water needs were about 900,000 acre-feet/year.

Without water conservation the water needs of the state would increase to nearly 2,000,000 acre-feet/year by 2050 By lowering the 1995 public community system per capita water use from 321 gpcd to 240 gpcd by 2050, the state's water needs would be a little more than 1,500,000 acre-feet/year. The accomplishment of this goal is equivalent to a total decrease in demand of nearly 500,000 acre-feet/year and represents the largest single component in meeting Utah's water needs in the next 50 years.

Utah's M&I Water Conservation Plan

The DWRe has discussed this goal publicly since 1995, but it was not formally published until 2001 when it appeared in the Utah State Water Plan: Utah's Water Resources—Planning for the Future. The goal was based on modeling and research, which indicated that M&I water use can reasonably be reduced by 25 percent or more. In 2003, the DWRe formally published "***Utah's Municipal and Industrial Water Conservation Plan***" that outlines in detail how this goal will be implemented.

In general, the plan to reduce per capita water use in Utah requires a public education program. The program stresses the importance of indoor conservation initiatives and reducing outdoor landscape water use by increasing irrigation efficiencies. The DWRe believes that through public education, the state's residents will reduce the per capita use by at least 25 percent without the need for draconian measures.

The plan outlines eight strategies to ensure the goal will be achieved. Many of these incorporated existing DWRe planning activities, but some are new programs recently implemented. The eight strategies are as follows:

1) Emphasizing water conservation in state water plans.
2) Implementing Board of Water Resources' water conservation policies.
3) Administering the Water Conservation Plan Act.
4) Supporting the public information program of the Governor's Water Conservation Team.
5) Managing the state's water education program.
6) Researching new water conservation technologies and practices.
7) Recommending Best Management Practices for Utah's water providers.
8) Setting the example of efficient water use at state-owned facilities.

1) Emphasizing Water Conservation in State Water Plans

Wise and efficient use of Utah's water resources has long been a part of the water planning efforts of the DWRe. Since the legislative authority to provide comprehensive statewide water planning was granted to the DWRe in the 1960s, this role has been refined over the years. This has led to the publishing of State Water Plans and individual hydrologic River Basin Plans. These plans provide useful water data, present important local water issues and contain specific water conservation recommendations. Future water needs presented in the plans are calculated using the state's specified 25 percent reduction in per capita use. Thus, water conservation becomes an integral part of the water planning process. Throughout the planning process, extensive inter-agency and public review is utilized. These plans are then distributed to universities, local libraries, legislators, mayors, water service providers, environmental groups and others in the general public who are interested in contributing to the state's various water planning efforts. The plans become a "road map" for local decision makers to utilize in meeting future water needs and solving complex water issues.

2) Implementing the Board of Water Resources Water Conservation Policies

An important task for the DWRe is assisting the Board of Water Resources (Board) as it dispenses state funding for water development. The eight members of the Board (representing different hydrologic basins across the state) have the use of three revolving-type funds to assist irrigation companies, water districts and municipalities develop their water resources. The Board and DWRe have long been vocal proponents of water conservation. Evidence of this exists in the strong policies on water conservation that the DWRe has successfully encouraged the Board to adopt. This conservation ethic is also apparent in the Board's current requirements for water project funding, which include stricter water conservation requirements than any other water funding board in the state. Recently, the Board has strengthened its water conservation policies and now requires that all project sponsors requesting financial assistance do the following before receiving funds:

- Submit a "Water Management and Conservation Plan", which specifies water conservation measures.
- Pass a time-of-day watering ordinance, prohibiting watering between 10 a.m. and 6 p.m.
- Implement a progressive water rate structure, which provides an incentive for customers to reduce their water use.

3) Administering the Water Conservation Plan Act

Recognizing the importance of water conservation to Utah's future, the Utah Legislature passed the Water Conservation Plan Act (Act) in 1998 and revised it in 1999 and 2004. The Act requires water conservancy districts and retailers with more than 500 drinking water connections to prepare a Water Conservation Plan and submit it to the DWRe. This requirement includes systems that provide water to about 93 percent of Utah's population. The Act also stipulates that Water Conservation Plans are to be updated and resubmitted every five years.
When the DWRe receives a plan, it is reviewed by staff and evaluated based on its likelihood to produce measurable water conservation results. The DWRe then provides the water supplier with feedback on how the plan can be improved.

4) Supporting the Public Information Program of the Governor's Water Conservation Team

In 2001, the Governor of Utah organized the Governor's Water Conservation Team (Team). The Team is chaired by the Director of the DWRe and made up of key water officials from the state's five largest water conservancy and metropolitan water districts, a representative from the Governor's Office of Planning and Budget, the Rural Water Association of Utah, the Utah Water Users Association, and the landscape industry.

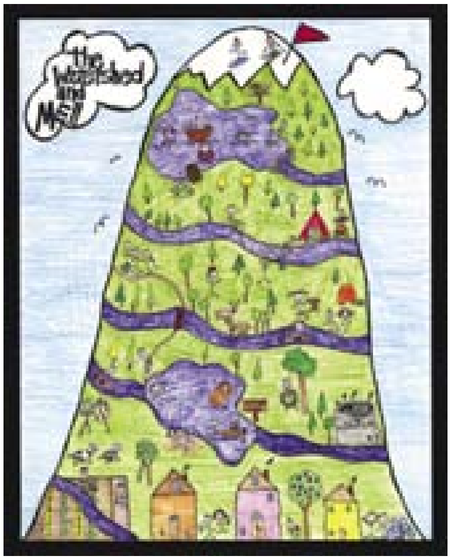
The mission of the Team is to develop a long-term statewide water conservation ethic that will result in a reduction of M&I per capita water use of at least 25 percent. Building upon the successes and name recognition of Jordan Valley Water Conservancy District's "Slow the Flow" campaign, the team has worked together to create a media campaign through TV and radio spots and newspaper inserts that is beginning to develop a water conservation ethic among Utah's citizens. The DWRe provides valuable support for the public information program of the Team. This program is designed to inform the public by providing water conservation information. The DWRe helps manage a comprehensive water conservation media campaign and distributes printed materials.

The DWRe also provides information through a water conservation web page, a water-wise plant tagging program and water conservation workshops.

www.conservewater.utah.gov

5) Managing the State's Water Education Program

The DWRe has long promoted a water education program for students, which includes a strong water conservation component. An education program is crucial to sustainable water demand reduction. An effective program helps students understand their place in the water cycle. This enables them to make informed decisions about water and how they use it. By developing awareness and knowledge of water resources, the state is equipping the leaders of the future with the skills they will need to make sound water management decisions. Programs include teacher education, student outreach, educational resources, water fairs and the Young Artists Water Education Poster Contest.



2005 Poster Contest Winner

6) Researching New Water Conservation Technologies and Practices

In order to develop a strong water conservation program for the state and support the recommendations, the DWRe studies issues related to water conservation. Many of these studies deal with how water conservation practices affect overall water usage. These studies have included several water conservation issues related to residential water use, secondary system water use, secondary meters, water ordinances, turf irrigation studies, "smart" irrigation controllers and water education mailings. The DWRe also acts as a clearinghouse for water conservation studies conducted by other water providers, both locally and nationally. The results of these studies are shared with interested entities and help the public make informed decisions regarding water conservation.

7) Recommending Best Management Practices for Utah's Water Providers

The DWRe recommends that the state's water providers use Best Management Practices (BMP's) in their water conservation programs. Water providers should implement a mixture of these practices tailored to fit their own unique needs. These BMP's are not mandated, however, the DWRe feels that the implementation of these practices will assist the state in achieving its water conservation goal. They are as follows:

BMP 1 - Comprehensive Water Conservation Plans

BMP 2 - Universal Metering

BMP 3 - Incentive Water Conservation Pricing

BMP 4 - Water Conservation Ordinances

BMP 5 - Water Conservation Coordinator

BMP 6 - Public Information Programs

BMP 7 - System Water Audits

BMP 8 - Large Landscape Conservation Programs

BMP 9 - Residential Water Survey Programs

BMP 10 - Plumbing Standards

BMP 11 - School Education Programs

BMP 12 - Commercial, Industrial and Institutional Water Conservation Programs

BMP 13 - Reclaimed Water Use

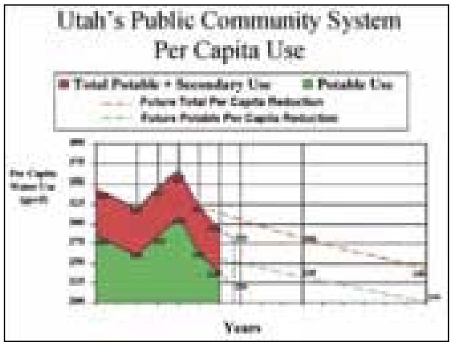
BMP 14 - Smart Controller Technology

8) Setting the Example of Efficient Water Use at State-Owned Facilities

The DWRe is encouraging the managers of state-owned facilities and other local government facilities to implement water conservation practices. It is important that the government set a good example of water conservation for its citizens. To help accomplish this, the DWRe has provided guidelines and offered expertise to incorporate water-wise landscapes at new state facilities and attempt to retrofit existing facilities. Recently, the DWRe has replaced the front landscape of the Department of Natural Resources (where the DWRe is located) facility with a water-wise demonstration garden. Additionally, the DWRe is assisting the Division of State Parks and Recreation with water audits and retrofitting existing landscapes at their facilities.

Results

The DWRe feels the strategies that have been implemented are working. An intensive program has monitored water usage of the water providers across the state. Recent water use studies indicate that total per capita water use statewide has decreased from 321 gpcd in 1995 to 293 gpcd in 2000 (a 9 percent reduction). Per capita water use has reduced an additional 8 percent, to 267 gpcd, since 2000. This amounts to a total reduction of 17 percent since the goal was adopted. The DWRe understands that some of the reduction is due to the response to the media campaign relating to the recent 6-year drought. Some of this reduction may be lost in the short term now that the drought appears to be over. The challenge now is to ensure that Utahns continue to use water efficiently even in times of plenty. The state's economic future, as well as the quality of life, is dependent on how well Utah's citizens adopt a water conservation ethic to ensure a dependable future water supply.



Stuart Styles

Dr. Stuart W. Styles, P.E.*
Doctorate: *Ag Engineering - UC Davis - 2001*
Masters: *MBA - Cal Poly San Luis Obispo - 1988*
Undergrad: *Ag Engineering - Cal Poly San Luis Obispo - 1984*
Professor at Cal Poly San Luis Obispo. *Teaches core engineering courses for Cal Poly as well as numerous short courses through the ITRC.*
Director of the Cal Poly Irrigation Training and Research Center (ITRC).

Recent ITRC projects have included developing modernization plans of irrigation districts in the western United States. Recent international projects have included modernization training missions in Azerbaijan, Egypt, India, Iran, Kyrgyzstan, Malaysia, Philippines, Thailand, Turkey, and Vietnam.

FLOW RATE MEASUREMENT IN IRRIGATION SYSTEMS

Background

Water and arable land were once considered globally abundant and renewable resources. As we enter the 21st century, however, water is becoming recognized as one of the world's increasingly valuable and scarce natural resources, and the irrigation community worldwide is recognizing the need to adopt sustainable farming practices to conserve water and avoid damaging productive farm land. Competing demands for water are already leading to conflict where regional supplies are limited. As the strain on the world's water resources continues to intensify, difficult decisions about water use and allocation will be made, and farmers, industrialists and the general population will be forced to implement conservation programs.

Why is flow measurement important?

Effective and practical flow measurement is the key to good water management. If you can't measure it, you can't manage it. Growing competition from urban and environmental uses along with major advances in flow measurement technology are responsible for increased interest among agricultural water users for practical information about flow measurement. Irrigation districts and farmers are seeking ways to extend the use of their existing water supplies through best management practices. Attention to good flow measurement procedures will usually result in water conservation through a reduction in excess deliveries to users or through the prevention of overwatering, which can reduce yields and have negative environmental impacts.

What should be measured and where?

A common question is what should be measured and where? While an accurate daily measurement of the instantaneous flow rate entering a canal from a storage reservoir is useful for operators in setting the flow to match the day's water orders, it may not accurately reflect the total volume of water delivered. It is usually not sufficient for flow control and record keeping purposes to only know a single flow rate entering a water delivery system at one moment in time because flow rates change over time. However, totalizers that accumulate individual flow measurements and automatic recorders are now widely available for many flow measurement devices.

The specific locations and types of devices that are selected to measure and record flow will depend on many factors, including accuracy requirements, cost, ability to pass sediments and debris, head loss, construction requirements, range of expected flow rates, calibration and other considerations. However, at each strategic location in the system where the flow must be controlled and at each delivery point to a user, there must be an appropriate flow measurement device that has been properly designed for that purpose.

There is no perfect device for measuring flow in all canals and pipelines. The flow measurement data required for control, monitoring, and safety purposes will not be the same.

IRRIGATION CONSUMER BILL OF RIGHTS

A properly designed irrigation system is easier to fine tune to a specified level of performance than a poorly designed system. In conjunction with irrigation dealers and manufacturers, ITRC developed the Irrigation Consumer Bill of Rights in 1995. This program has been in place for 10 years to provide a list of questions that customers should ask irrigation dealers prior to purchasing equipment.

Some dealers have adopted the program and provide answers in writing. The questions address such topics as warranties, pump efficiencies, filtration, distribution uniformity, flow measurement, plant water requirements, etc. Below are sample flow measurement questions/answers:

Does the flow meter measure both flow rate and volume applied?

The flow rate provides information on the performance at a specific minute. Flow rate changes over time can indicate plugging, leaks, decreases in pump efficiency, or other problems. Totalizers which record the volume of water (acre-feet, gallons or cubic feet) are essential for irrigation scheduling.

Knowing the total volume applied (acre-feet) and recording the volume applied per irrigation is an invaluable tool for monitoring the total irrigation water applied throughout the season. A person must know how much of a resource is being used if the resource is to be managed wisely.

Does installation follow manufacturer's recommendations with regard to lengths of straight pipe, pipe diameter, and straightening vanes?

Flow meters must be chosen and installed correctly since turbulent or swirling water significantly affects a meter's accuracy. General recommendations are to place a meter at least 8-10 pipe diameters downstream of any in-line valves or bends, and 4 pipe diameters upstream of any bends. (10 pipe diameters in a 4" pipe equals 40"). Straightening vanes are also recommended upstream of the meter if the water is relatively clean. Meters should be placed downstream of filters, if possible, to minimize clogging and wear.

The Irrigation Consumer Bill of Rights was first adopted by the California Ag Irrigation Association, and later by the Irrigation Association. This program is helping customers to compare the quality of bids, improve efficiency and minimize conflicts after purchase.

CANAL MEASUREMENTS

Irrigation districts, farmers, and other environmental water users need to accurately measure the rate and volume of flows at key points in their water distribution and delivery systems. A key device that has traditionally been used is a Replogle Flume. This is a standard measurement device recommended by the Water Measurement Manual of the USBR (3rd Edition 2001). The Water Measurement Manual should be consulted for detailed discussions on the flumes.

Flumes

A flume is a specially shaped open channel flow section which may be installed in a canal, lateral or ditch to measure the rate of flow of water. A control section is created by narrowing the canal or by a combination of narrowing the channel and raising the channel bottom.

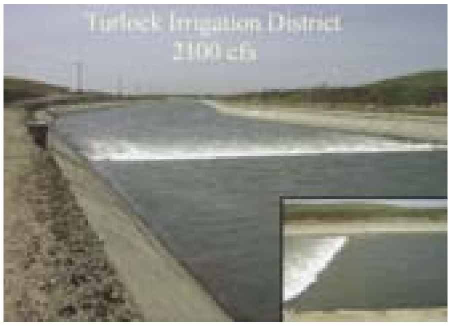


Figure 1. New Replogle Flume installed at the Turlock Irrigation District

Hydroacoustic Meters

A Hydroacoustic flow meter provides remote velocity sampling and integrated flow measurement based on the physical principle called the Doppler shift. This type of device is used in places where a traditional device such as a Replogle Flume would not work. These devices can be used in canals or pipelines.

The sensors can either project a continuous or pulsed beam of acoustic signals at angles above the horizontal position of the sensor. Flow velocity is calculated by averaging the measured variations in sound frequency reflected back from particles in the water. Depth is measured with a ceramic-based pressure transducer integrally mounted in a surface mount velocity sensor and the device calculates the flow rate.

In general, there are three categories for Hydroacoustic meter installations, which can be loosely defined as small, medium and large flow measurement sites. The low-cost Hydroacoustic meters (less than $3,000) are being widely accepted for small flow rates up to 50 CFS. The most expensive Hydroacoustic meters (about $20,000) seem to be accepted for high flow rate sites up to 5,000 CFS.

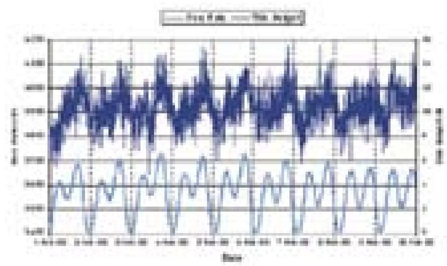


Figure 2. Data set from Hydroacoustic meter installed at the Delta Mendota Canal. Note the flow rate is about 3,900 CFS (cubic feet per second) and fluctuates due to the tidal effect.

There are significant differences in the performance of the Hydroacoustic meters. The more expensive meters definitely have more “out of the box” accuracy, which means that if they are installed in a good measurement site the time and energy to calibrate the unit can be significantly less.

PIPELINE MEASUREMENTS

A key device that has traditionally been used for pipeline measurements is a propeller meter. This is a standard measurement device recommended by the Water Measurement Manual of the USBR (3rd Edition 2001). The Water Measurement Manual should be consulted for detailed discussions on pipeline meters.

Propeller Meters

This method of flow measurement is based on measuring the velocity of the water by turning a propeller in the water. The readout of a flow meter typically gives both instantaneous flow rate (needle gauge) and volume (totalizer). By combining the velocity of the water with the known area of flow, the flow rate can be shown. The volume is generated by “counting” the number of revolutions of the propeller.

Advantages:
Easy to use for pipe (pressurized) flow.
Can have a low relative installation cost.

Disadvantages:
Turbulence in the water makes accurate measurements difficult.
Material can easily plug the propeller.

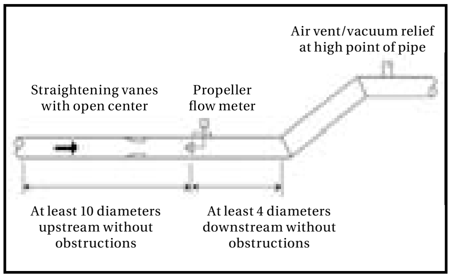


Figure 3. Standard propeller meter installation. Note the required distance upstream and downstream without obstructions.

Transit Time Doppler Meters

The operation of a transit-time ultrasonic flow meter is based on the following principle: when ultrasonic pulses are transmitted through a moving liquid, the pulses that travel in the same direction as the fluid flow (downstream), travel slightly faster than the pulses that travel against the flow (upstream). The units use various digital signal-processing techniques, including cross-correlation, to determine transit times and use these to calculate flow velocity. Hence, the measured difference in transit times is proportional to the flow velocity.

Advantages:
Non-mechanical. Portable, small and lightweight unit.
If properly installed, can be used for flow velocities as low as 0.2 ft/sec with reasonable accuracy.

Disadvantages:
Care must be taken with all connections and wire since they don’t appear to be robust.
The correct transducer size and the location of the transducer are critical. The unit does not work correctly if the transducers are not spaced as recommended by the flow computer.
Data can spike high and low. If a flow control device is connected to the meter, the control may be erratic.

Figure 4. Standard ultrasonic installation. Note that these meters can be installed in a remote favorable location with good hydraulic characteristics.

Magnetic Meters

This type of meter measures flow using the Faraday law of electromagnetic induction. This law states that as a conductor moves through a magnetic field, a voltage is produced. The magnitude of this voltage is directly proportional to the velocity at which the conductor moves through the magnetic field. When the flow approaches the sensor from directly in front, then the direction of the flow, the magnetic field and the sensed voltage are mutually perpendicular to each other.

Hence, the voltage output will represent the velocity of the flow at the electrodes. The sensor is equipped with an electromagnetic coil that produces the magnetic field. A pair of carbon electrodes measure the voltage produced by the velocity of the conductor, which in this case is the flowing liquid. The measured voltage is processed by the electronics and output as a linear measurement of velocity.

Advantages:
Appears to have good repeatability.
Becoming the standard for some entities that need an accurate device that works through a full flow range.
Accurate to 0.5% volumetric accuracy.
Disadvantages:
The cost has come down considerably.
Requires a spool for installation.

Figure 5. Installation of magnetic meters at the ITRC Pump Testing instrumentation at Cal Poly San Luis Obispo.

SUMMARY

This paper presented some key ideas for the installation and operation of flow measurement devices. Attention to good flow measurement procedures will usually result in water conservation.

Effective and practical flow measurement is the key to good water management. Obviously, "if you can't measure it, you can't manage it."

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(Footnotes)

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THE PERILS OF GROUNDWATER PUMPING

The excessive "mining" of our aquifers is causing environmental degradation on a potentially enormous scale.

The next time you reach for a bottle of spring water, consider that it may have come from a well that is drying up a blue-ribbon trout stream. The next time you dine at McDonald's, note that the fries are all the same length. That's because the farmers who grow the potatoes irrigate their fields, perhaps with groundwater from wells adjacent to nearby rivers. The next time you purchase gold jewelry, consider that it may have come from a mine that has pumped so much groundwater to be able to work the gold-bearing rock that 60 to 100 years will pass before the water table recovers. The next time you water your suburban lawn, pause to reflect on what that is doing to the nearby wetland. And the next time you visit Las Vegas and flip on the light in your hotel room, consider that the electricity may have come from a coal-fired power plant supplied by a slurry pipeline that uses groundwater critical to springs sacred to the Hopi people.

These and countless other seemingly innocuous activities reflect our individual and societal dependence on groundwater. From Tucson to Tampa Bay, from California's Central Valley to Down East Maine, rivers and lakes have disappeared, and fresh water is becoming scarce. Groundwater pumping—for domestic consumption, irrigation, or mining—causes bodies of water and wetlands to dry up; the ground beneath us to collapse; and fish, wildlife, and trees to die. The excessive pumping of our aquifers has created an environmental catastrophe known to relatively few scientists and water management experts and to those who are unfortunate enough to have suffered the direct consequences. This phenomenon is occurring not just in the arid West with its tradition of battling over water rights, but even in places we think of as relatively wet.

As a country, we have dramatically increased our reliance on groundwater. This increase has dried up rivers and lakes, because there is a hydrologic connection between groundwater and surface water. Yet the legal rules governing water use usually ignore this link. This disconnection between law and science is a major cause of the problem. So too is our refusal to recognize the unsustainability of our water use. Significant reform is necessary if we are to prevent further degradation of our rivers, streams, lakes, wetlands and estuaries.

Groundwater use and consequences

Groundwater pumping in the United States has increased dramatically in the past few decades. For domestic purposes alone, groundwater use jumped from 2.9 trillion gallons in 1965 to about 6.8 trillion gallons in 1995, or 24,000 gallons for every man, woman, and child. But domestic consumption is only a small fraction of the country's total groundwater use, which totaled almost 28 trillion gallons in 1995. Farmers used two-thirds of that to irrigate crops; the mining industry, especially for copper, coal and gold production, pumped about 770 billion gallons. Groundwater constitutes more than 25 percent of the nation's water supply. In 1995, California alone pumped 14,500 billion gallons of groundwater per day. Groundwater withdrawals actually exceeded surface water diversions in Florida, Kansas, Nebraska and Mississippi. In the United States, more than half of the population relies on groundwater for their drinking water supply. Groundwater pumping has become a global problem because 1.5 billion people (one-quarter of the world's population) depend on groundwater for drinking water.

Groundwater is an extraordinarily attractive source of water for farms, mines, cities and homeowners because it is available throughout the year and it exists almost everywhere in the country. During the various ice ages, much of the country was covered with huge freshwater lakes. Water from these lakes percolated into the ground and collected in aquifers. Unlike rivers and streams, which are few and far between, especially in the West, aquifers exist below almost the entire country.

The legal system has fostered our increasing use of groundwater by developing two sets of rules for allocating rights to divert water from rivers and lakes. In the East, the riparian system allows owners of property on rivers or lakes to divert water for a variety of purposes. In the West, the prior appropriation doctrine—the essence of which is "first-in-time, first-in-right"—gives superior rights to the earliest diverters. However, the legal system developed a completely different set of rules for controlling groundwater use. When U.S. courts developed groundwater law in the 19th century, hydrology was an infant science. In 1850, the Supreme Court of Connecticut explained that the movement of water beneath the surface of the earth moved according to principles that could not be known or regulated. "These influences are so secret, changeable, and uncontrollable, we cannot subject them to the regulations of law, nor build upon them a system of rules, as has been done with streams upon the surface," the court said. This reasoning made sense in 1850; since then, however, the law in most states has not kept pace with advances in the science of hydrology. As a consequence, the legal rules have failed to conform with physical reality. Principles of either riparianism or prior appropriation govern surface water, whereas the "reasonable use" doctrine governs groundwater pumping. Under this doctrine, an owner of land may pump as much water as he or she desires so long as it is for a "reasonable use," which is essentially no restriction whatsoever.

Overdrafting or "mining" groundwater creates serious problems. Because water is heavy, about two pounds per quart, more energy is needed to lift water from lower levels. The costs of this energy may be substantial: In Arizona, the electric energy to run a commercial irrigation well may cost $2,000 per month. The drilling of new and deeper wells may be required, which is often a considerable expense. Pumping from lower levels may produce poorer quality water because naturally occurring elements, such as arsenic, fluoride, and radon, are more prevalent at deeper levels in the earth, and the earth's higher internal temperature at these levels dissolves more of these elements into solution. As the water deteriorates in quality, it may violate U.S. Environmental Protection Agency regulations, requiring either that the water be subject to expensive treatment processes or that the well be turned off, thus eliminating that source of water. Along coastal areas, overdrafting may cause the intrusion of saltwater into the aquifer, rendering the water no longer potable. This problem is quite serious in California, Florida, Texas and South Carolina. Another consequence of overdrafting is the prospect of land subsidence, in which the land's surface actually cracks or drops, in some cases dramatically. In California's San Joaquin Valley, the land surface dropped between 25 and 30 feet between 1925 and 1977. Land subsidence has damaged homes and commercial structures and reduced property values. Pumping north of Tampa Bay in Pasco County has cracked the foundations, walls and ceilings of local residents' homes, resulting in lawsuits, insurance claims and considerable ill will.

A final consequence of groundwater pumping is its impact on surface water, including lakes, ponds, rivers, creeks, streams, springs, wetlands and estuaries. These consequences range from minimal to catastrophic. An example of the latter is the Santa Cruz River in Tucson. Once a verdant riparian system with a lush canopy provided by cottonwood and willow trees, groundwater pumping has lowered the water table, drained the river of its flow, killed the cottonwood and willow trees, and driven away the local wildlife. The river has become an oxymoron—a dry river—a pathetic desiccated sandbox.

How does a river go dry?

Fueled by the energy of the sun and the force of gravity, water continually moves through a succession of different phases, called the hydrologic cycle. The sun's energy evaporates seawater from the oceans' surface, leaving behind the salts and circulating the water into the atmosphere. After wind currents carry the moisture-laden air over land, the increase in relative humidity eventually causes the water to condense and produces precipitation. When the water falls to earth, some of it immediately evaporates into the sky, another portion runs off the land to creeks, streams, and rivers, and some infiltrates the ground, in a process known as recharge. A portion of the groundwater near rivers and streams eventually emerges from the ground, in a process called discharge, to augment the surface flows of rivers or streams. Groundwater pumping essentially interrupts this cycle by removing water, directly or indirectly, that would otherwise discharge from aquifers to rivers, streams and other surface water bodies.

Groundwater and surface water are not separate categories of water any more than liquid water and ice are truly separate. The designations groundwater and surface water merely describe the physical location of the water in the hydrologic cycle. Indeed, groundwater and surface water form a continuum. In some regions of the country, virtually all groundwater was once stream flow that seeped into the ground. The converse is also true but not obvious. Consider the following puzzle: Where does water in a river come from if it has not rained in a while? The water comes from groundwater that has seeped from the aquifer into the river, in what's known as base flow.

Groundwater pumping has dried up or degraded 90 percent of Arizona's desert streams, rivers and riparian habitats.

Whether water will flow from the river to the aquifer or vice versa depends on the level of the water table in the aquifer and on the elevation of the river. If the water table is above the elevation of the river, water will flow laterally toward the river and augment the flow in the river. In most regions of the country, this is the process that occurs. But as groundwater pumping lowers the water table, the direction of the flow of water changes. Once the water table is below the elevation of the river, water flows from the river toward the aquifer. This is what groundwater pumping did to the Santa Cruz River. It dried up the Santa Cruz by lowering the level of the water table below the elevation of the river. Groundwater pumping literally sucked water from the river and produced horrible environmental consequences. First, of course, the flow in the river disappeared, as did water-dependent species. Then, the trees and shrubs died as groundwater pumping lowered the water table below the root zone of the vegetation.

In Arizona, groundwater pumping has dried up or degraded 90 percent of the state's once perennial desert streams, rivers and riparian habitats.

Some marvelous habitat remains healthy but faces an uncertain future. For example, the San Pedro River is southeastern Arizona supports an estimated 390 species of birds (almost two-thirds of all species seen in North America). The area is so special that Birder's Digest, the Nature Conservancy, the American Bird Conservancy and the National Audubon Society have given the river special designation. However, the population of the city of Sierra Vista and Cochise County is exploding, and all of this growth is dependant on groundwater. Local politicians and developers fear that environmental issues may retard growth. It is possible that the San Pedro River will suffer the same fate as the Santa Cruz.

Not surprisingly, some developers maintain that groundwater pumping has not caused the lower flow levels in the San Pedro River. To be sure, there will always be a problem of determining the causal relationship between groundwater pumping and environmental degradation. Scientific uncertainty attends many disputes over the impact of pumping on a particular river or spring. Some of this debate is in good faith, an honest disagreement about what the evidence suggests and the computer models predict. Other positions seem animated by gross self-interest. With so much money at stake, developers pay consultants handsome fees to help obtain lucrative permits to pump.

In considering other examples of environmental problems caused by groundwater pumping, the first thing to note is that the impact of groundwater pumping on the environment is not confined to the arid West. Consider Florida. One of the wettest states in the country, with an average of more than 54 inches of rain a year, Florida has always had a problem with water. Historically, the problem was too much water. In a state surrounded on three sides by ocean and with enormous aquifers and extremely high water tables, the problem was how to get rid of the water. Although that story is relatively well known, another version of Florida's water woes is not.

Florida's population jumped from 2.7 million people in 1950 to 16 million in 2000, making Florida the fourth most populous state. A region that is experiencing particularly explosive growth is Tampa Bay. In search of additional supplies during the 1970s, Tampa Bay Water (the local water utility) purchased large tracts of rural areas in adjoining counties and drilled a huge number of wells. By 1996, groundwater withdrawal had risen to approximately 255 million gallons per day, a 400 percent increase over 1960 levels. When lakes and ponds began to dry up—one study found that fewer than 10 of 153 lakes in the region were healthy—Tampa Bay Water knew it had a public relations disaster on its hands. Homeowners who had bought lakefront property only to watch it dry up were not amused. In response, Tampa Bay Water began to dump hundreds of thousands of gallons of water per day into the dry lakebeds. Where did Tampa Bay Water get this additional water? From groundwater pumping. Yet this additional groundwater would inevitably drain back into the ground in search of the water table. It was like trying to keep water in a colander.

Tampa Bay is not the only area where officials have tried to mask the consequences of groundwater pumping. In San Antonio, Texas, Paseo del Rio, or River Walk, has become the city's most popular tourist attraction. A 2.5-mile section of the San Antonio River that flows through the heart of downtown, River Walk anchors a $3.5 billion-per-year tourist industry. Most tourists would be surprised to learn that the river they enjoy is the creation of dams, floodgates, and groundwater pumped from the Edwards Aquifer and dumped into the San Antonio River above River Walk. The San Antonio River was once navigable through the River Walk stretch, but it dried up because of groundwater pumping. In short, the city of San Antonio pumps millions of gallons a day of groundwater into the river in order to create an economically useful fiction. As San Antonio has continued to expand, the San Antonio Water System began to search for new sources of water and to look for ways to reuse existing supplies. In 2000, the system began to dump treated municipal effluent into River Walk as a substitute for groundwater. The water creating the illusion of a real river is still groundwater, but it has been used before.

We must increase water rates so that all users pay the replacement value of the water.

Americans use groundwater to grow all kinds of things, even when there is no need to do so. Until rather recently, many U.S. farms were "dryland" farmed, meaning that the farmers had no irrigation system. However, Americans' love affair with processed foods caused some potato farmers to shift from dryland to irrigation farming. The problem with dryland potatoes is that their size, shape, and texture depend heavily on seasonal weather patterns. During the growing season, potatoes need constant moisture or they will have knobs and odd shapes. A misshapen or knobby potato is perfectly edible, but it is not an acceptable potato for the fast-food industry. In 1988, McDonald's began to offer consumers "super-sized" meals with larger portions of french fries served in rectangular boxes with flat bottoms. Only potatoes grown through irrigation produced a uniform length fry that would jut out of the super-size box just the right amount so that the consumer could grasp the potato between index finger and thumb and dip it in ketchup. The desire for the perfect fry is felt by the trout in north central Minnesota, where potato farms rely on groundwater that is very closely connected hydrologically to blue-ribbon trout streams. Increased pumping to support additional potato production threatens the survival of trout.

For a final example, consider the country's newfound fascination with bottled water. Sixty percent of Americans drink bottled water, which is now the fastest growing product among the top 50 supermarket categories. Between 1978 and 2001, consumption rose 1,300 percent to 5.4 billion gallons, or about 43 billion 16-ounce bottles. A major beneficiary of the bottled-water craze is the Perrier Group of America. Most consumers know Perrier as the importer of green bottles of spring water from France. But Perrier also sells bottled spring water under 14 other brand names, including Arrowhead, Calistoga, Deer Park, Zephyrhills, Poland Spring, Ozarka and Ice Mountain. Indeed, Perrier has become the largest U.S. bottler of water (ahead of Pepsi and Coke) with a 32 percent market share. To supply its needs in the United States, Perrier relies on approximately 50 locations around the country, yet it must relentlessly search for new sources to satisfy the growing demand.

One place where Perrier looked was the Mecan River in Wisconsin. A blue-ribbon trout stream, the Mecan has been carefully protected by the state. Beginning in the 1950s, Wisconsin acquired more than 6,000 acres on the Mecan and surrounding tributaries. In 1999, Perrier proposed building a bottling plant and drilling wells on land near Mecan Springs. Environmental groups were aghast at the prospect, for they knew that the cool, underground spring water was critical to the fragile ecology of the river. But under Wisconsin law, the state could not halt Perrier's commercial operation unless the pumping would interfere with the municipal water supply, and it would not. Perrier proposed to pump 720,000 gallons per day from a well located immediately adjacent to the springs. In the end, Perrier decided not to proceed with this plant, in part because of substantial opposition from local residents. However, the problem of the impact of pumping spring water has not gone away. It has simply changed locations. In 2001 and 2002, Perrier opened bottling plants in Tennessee, Michigan and California.

The urgent need for reform

In the United States, the impact of groundwater pumping on the environment is an example of what biologist Garrett Harden called "the tragedy of the commons." The legal rules governing groundwater use encourage exploitation of the resource: They reward rational economic individuals by permitting them to pump enormous quantities of groundwater, regardless of the environmental impact. Most states have failed to eliminate the gap between law and science. In lieu of legal reform, Americans have shown limitless ingenuity in devising technological fixes for water supply problems. These so-called solutions have altered the hydrologic cycle in order to sustain existing usage.

As our water use spirals upward, we must begin to rethink the economic structure by which we value (and usually undervalue) our water resources. At the same time, we must act to protect our rivers, springs, wetlands, lakes and estuaries from groundwater pumping. There is considerable urgency. Because groundwater moves so slowly, it may take years or decades of groundwater pumping before the effect on the environment is apparent. The hidden tragedy and irremediable fact is that groundwater pumping that has already occurred will cause environmental damage in the future.

Congress should create a program to reward states that protect their environments from groundwater pumping.

We must reform the system. A cure will not come quickly or easily, but nature has enormous regenerative capacity. The solution involves charting a new course for the future based on wise policies, then making a commitment to stay the course. It can be done. In the process, state and local governments must play a critical role.

To control the impact of groundwater pumping on the environment, we must combine a command-and-control model of government rules and regulations with the market forces of transferable rights and price incentives. Any meaningful reform must do two things: protect the rights of existing users by creating quantified water rights that are transferable and therefore valuable; and break free of the relentless cycle of increasing use by placing restrictions on individual freedom to pump groundwater.

States should foster a market in water rights by allowing the easy transferability of rights from existing users to newcomers. Enormous quantities of groundwater are used for extremely low-value economic activities. State law must facilitate the movement of water from these uses to higher-value ones by establishing a water rights market as the mechanism for accomplishing this shift. But water markets are not the only solution.

Government rules and regulations deserve a prominent place in our reform efforts as we attempt to protect the environment. The states should undertake a number of very specific reforms. First, states should carefully craft water conservation standards. A water conservation program seems, intuitively, like a good idea: Let's save water. However, the experience of some western states with conservation standards sends a mixed message. If the states attempt to impose elaborate and detailed conservation standards, the regulated groups will fight tooth and nail over every sentence in the proposed regulation. This process can consume enormous amounts of time, energy and money. The lesson for states is that it is better to embrace simple conservation standards that are easy to administer and implement. They are likely to have the most practical effect in terms of actually saving water and will avoid prolonged political struggle. In other words, it is easier to pick low-hanging fruit.

Second, states should establish minimum stream flows and protect those flows from pumping of hydrologically connected groundwater. Through a combination of statutes, judicial decisions, and administrative rules, the state of Washington has developed a system that other states should emulate. The legislature authorized the State Department of Ecology to establish minimum water levels for streams and lakes to protect fish, game, other wildlife resources and recreational and esthetic values. The minimum levels become appropriations within the prior appropriation system and offer protection against subsequent groundwater pumping.

Third, states should prohibit the drilling of new wells in areas that are hydrologically connected to surface flows. Generally speaking, the farther a well is from a watercourse, the less significant the impact of groundwater pumping from that well will be. States have two options for this problem: They can make the ban on wells near watercourses turn on a hydrologic analysis of the particular region, or they can use a bright-line rule that simply prohibits drilling wells within, for example, a mile of the river. Oregon has moved in this direction.

Fourth, states should impose an extraction tax on water pumped from any well within a certain distance of a river, spring, or lake. This tax would have two benefits: It would encourage existing pumpers to conserve water, and it would create an incentive for new pumpers to locate wells farther away from watercourses.

Fifth, states should require any new pumper to offset or mitigate the impact on the environment. It makes no sense to allow developers to drill new wells in an aquifer already under stress. Arizona has a mitigation program that requires developers to demonstrate an "assured water supply." One way to do so is for the developer to purchase and retire agricultural rights.

Sixth, states, especially through local governments, should use financial incentives as a significant part of water policy. Quite simply, we are not paying the true cost of water. When homeowners or businesses receive a monthly water bill from the utility, that bill normally includes only the extraction costs of drilling the wells, the energy costs of pumping the water, the infrastructure costs of a distribution and storage system, and the administrative costs of the water department or company. Water rates, with rare exceptions, do not include a commodity charge for the water itself. The water is free.

Even though water is a scarce commodity, most Americans have not yet faced the condition that economists call scarcity, which occurs when people alter their consumption patterns in response to price increases. Our habits of water use will not change until the cost of water rises sufficiently to force an alteration. Therefore, we must increase water rates so that all users pay the replacement value of the water, which includes not just the cost of drilling a new well but also the cost of retiring an existing user's well.

Economists agree that significant price increases would create incentives for all users to conserve. All farmers, homeowners, businesses, or industrial users could then decide which uses of water to continue and which to curtail. Rate increases would encourage the elimination of marginal economic activities and the movement of water toward more productive uses.

Seventh, whenever a water rights transfer occurs, the states should require that a small percentage of the water be dedicated for environmental purposes. States should not get too greedy with this environmental dedication, however, or it will be self-defeating. The prospective parties to a transfer will, of course, consider the economic consequence of the dedication on their proposed transfer. If the dedication is too onerous, the sale or lease will not take place. But a modest dedication program has great potential for environmental restoration.

Eighth, both the state and federal governments should commit resources to purchasing and retiring groundwater rights to protect critical watersheds and habitat. Some might argue that the federal government should preempt the area, given how poor a job the states have done. However, Congress has historically deferred to the states with respect to water laws. Proposals for federal regulation of groundwater will give rise to a chorus of howls from states' rights advocates, especially those in the West, who, as author Wallace Stegner once observed, conceive the role of the federal government as "Get out! And give us more money!"

Congress certainly has constitutional authority to impose federal regulations on groundwater pumpers, yet there are two good reasons why it should not do so. First, it would provoke a bruising political battle. The political capital expended to win that fight could be better spent elsewhere. Second, the impact of groundwater pumping on the environment is nuanced and site-specific, depending enormously on the particular hydrologic characteristics of an aquifer. Imposing a uniform federal template on the nation is likely to exclude some pumping that should be regulated and to include some pumping that poses no serious risk of harm. Offering the carrot of federal funds is a far better approach than wielding the stick of federal regulation. Under its taxing and spending power, Congress should create a program funded by federal tax dollars to reward states that protect their environments from groundwater pumping (a gentle form of coercion). A host of federal programs, such as highway funding, give the states money but attach conditions.

The impact of groundwater pumping on the environment is enormous. And it is getting worse. As the drought that is gripping the country continues, cities, farmers and individual homeowners are scrambling in search of additional water supplies. They have often focused on groundwater; indeed, well-drilling businesses around the country are booming. The drought has prompted the media to pay remarkable attention to water issues. In the summer of 2002, the New York Times ran a four-part front-page series, and U.S. News & World Report, Newsweek, and National Geographic ran cover stories. Yet none of these stories, or any others to my knowledge, mentioned that groundwater pumping has environmental consequences.

Recommended reading

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IF YOU CAN'T TAKE THE HEAT...

Nearly all age levels for organized sports are now using rubber-infill-fields (RIF). Those that manage both synthetic and natural grass surfaces observe substantial improvement in their grass fields because of the option to move some activities onto the synthetic turf, especially during wet conditions.

Even though RIF fields are constructed with very repeatable materials they react differently as climate, season and environmental conditions change. Just as with grass fields, temperature, rainfall and humidity can effect the playing conditions on and above RIF fields. In most cases rainfall improves the playing surface conditions of RIF fields, yet most fields are constructed without irrigation systems that could be used to maximize playing quality.

I spent 20 days in August measuring temperature and humidity on RIF fields in Iowa, Colorado, Maryland, Oklahoma and California. The footing and playability of RIF fields may remain consistent throughout changing seasons and regions; however the heat generated at the surface and in the playing space above the surface can substantially increase during the summer. Heat load to players is a concern among trainers especially during two-a-day practices in July and August. To reduce player heat load, morning practice is usually held on the RIF field while afternoon practice is held on grass. Schedules often change, however, to fit weather conditions and coaching desires. In all cases it is best to have a synthetic option and a grass option to maintain flexibility in choosing the best playing surface for changing conditions.

Summer temperatures usually peak from 12-5 p.m. Three things were apparent from these summer observations: 1) Grass surfaces are much cooler than non-irrigated RIF surfaces; 2) non-irrigated RIF surface temperatures can be as high as 177° F; and 3) surface temperature of RIF fields can be reduced by 33 percent with proper use of irrigation cycling. Data in the table was collected at a high school athletic facility in San Diego. The Bermudagrass practice field had not been watered for five days before data collection and it was just beginning to show signs of moisture stress.

At the Denver Broncos training facility the cooling effect of grass was even more noticeable. On a day when the local weather reported a high of 80 degrees, the measured peak surface temperatures for non-irrigated RIF, irrigated RIF, and well-watered Kentucky bluegrass were 150, 105, and 83 degrees, respectively. Watering the RIF reduced surface temperature by 30 percent while grass reduced surface temperature by 45 percent.

The best cooling effect occurred when 0.10 inches of water was applied each hour from 11 a.m. until 4 p.m.

Increasing wind and decreasing humidity enhanced the cooling effect but it also required more irrigation water. It shouldn't be too difficult to develop an irrigation strategy that will cool the field if you have an irrigation system that supplies multiple cycles during the day.

On one trial area we thoroughly soaked the RIF by running a hose on it for more than an hour. The water rapidly drains through the synthetic surface and puddles disappeared in less than a minute, a real advantage of an RIF field. It was surprising, however, to note that some of the sand and rubber appeared to be hydrophobic and did not wet. The heavily watered test area soon dried out on the surface and temperatures quickly increased as the sun heated the dry surface.

For cooling to occur, a film of water needs to be on the surface. Lick your finger and blow on it to get the idea of cooling the surface. There is much to learn about RIF fields and the January 2005 STMA conference in Phoenix has six hours of instruction dedicated to this topic.

After taking data on an RIF field for four hours it became evident that there is an undeniable heat load issue during the summer. At the professional, college and high school level where trainers are involved, it is likely that RIF field use will be limited when heat is a problem. A greater concern is for youth programs, summer camps and contracted tournaments where events are less likely to be canceled and participants could dangerously overheat.

The heat load problem on RIF fields is manageable with irrigation, the problem is that most fields have been constructed without irrigation. The market is competitive and the cost of an irrigation system is not an attractive selling point by RIF contractors, but consumers need to know that synthetic turf without irrigation is an inferior product and in some situations a dangerous and liable commodity.

I spent my summer vacation watering rubber, sand and fibers; it didn't grow but it did provide a better playing surface. If you are putting in a new RIF field listen to the companies that are trying to sell you irrigation, they are looking out for your bottom line.

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QUESTIONS?

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Prior to starting with the Turf Research and Advisory Institute (Vic) in 1983, John was undertaking research into the effects of effluent water on soils, crops and pastures and this lead to a career in turfgrass research and extension. John was a partner in a consultancy company for 6 years before joining the Australian Golf Course Superintendents Association (AGCSA) in 2000 as a research and consulting turf agronomist.

John works in research and consultancy with a wide range of clients including golf, bowls, sportsfields and local government and has expertise in soils, drainage, water management and turfgrass selection and evaluation.

Through the AGCSA he is working with the Australian Golf Union as an advisory agronomist for the Australian Open.

John lectures in soils, drainage, irrigation management, project management, environmental management and construction at several campuses. In addition he has presented papers at numerous turf conferences and seminars. He has also presented and had published, research papers at the 1993 and 1997 International Turfgrass Research Society conferences.

John was a Board member of the International Turfgrass Society from 2001 - 2005.

THE USE OF RECYCLED WASTEWATER FOR TURF IRRIGATION – THE POTENTIAL SAVIOUR FOR AUSTRALIAN TURF

INTRODUCTION

Water is essential for sustaining and maintaining the quality of life that we are used to in Australia. For most Australians in urban environments their water arrives at the turn of a tap, clean and free of disease. Because we expect a high quality water source, it is often taken for granted and there is very little concern shown for the economic, environmental and social costs associated with its supply.

Australia is a dry continent with 80 percent of the continent having an average annual rainfall less than 600 mm (BOM, 2005). The mean annual runoff from the continent of Australia is 12 percent of precipitation, compared to 38 percent in Europe and North America AsoE, 2001), largely due to high evaporative losses. Consequently Australia's water resources are scarce and essentially finite.

In Australia, 70–75 percent of the total water used is used for irrigated agriculture with 21 percent used for urban and industrial purposes (ASoE, 2001). From 1985 to 1996/97 there has been a 75 percent increase in the volume of water used for irrigated agriculture with a 55 percent increase in the use of water for domestic and industrial purposes. Over the past five years Australia has been in drought with well below average rainfall in all areas of the country resulting in water restrictions for domestic, commercial and horticultural applications. The use of water for irrigating turf is generally seen as a low priority and consequently many turf areas have deteriorated as a result of insufficient or a complete lack of water. There is a need to carefully prioritize where the water is used and whether it is in households, agriculture, irrigating turf or industry. Acknowledging that the available water is finite there is a need to redistribute this water and to exploit alternative sources, particularly where the irrigation of turf is involved.

The maintenance of a high quality turf relies on having access to a good quality and constant water source. The time is approaching where high quality potable (drinking) water will not be available for turf areas and lower quality water, high in salts and other contaminants, will have to be used. As a consequence of droughts, the cost of potable water and the lack of potable water available for irrigating turf, many turf managers have been forced to use alternative water sources such as recycled wastewater and saline bore water.

RECYCLED WATER REUSE IN AUSTRALIA

With the greater demands on our water supplies for domestic consumption, there is less water available for irrigation purposes. With the increase in urban development there is not only a greater demand for potable waters but there is also more wastewater generated. The treatment of this wastewater and its disposal has become a significant environmental issue and in particular, the disposal or reuse of wastewater must be done in an ecologically sustainable manner so as to avoid the degradation of soils and water. Reuse of wastewater on turf areas is seen as a means of meeting these environmental objectives.

Recycled wastewater in Australia, is primarily treated sewage effluent and is increasingly being used for irrigating turf. In a Department of Resources and Energy (1983) report, it identified that in Australia the total amount of treated sewage was about 1,300 gigalitres/annum of which 56 gigalitres/annum (4.4 percent) is reused in irrigation. By 2000, the volume of effluent produced was about 1,900 gigalitres of which 9 percent was reused (ASoE, 2001).

In a recent survey of Australian golf courses, undertaken by the Australian Golf Course Superintendents Association (2005), it was determined that there was about 15,000 megalitres of treated effluent used over about 3,700 hectares. In a survey of Queensland sewage treatment plants, it was determined that about 33 percent of the treated effluent applied to land was used on golf courses (Bryan et.al., 1994). In Victoria, Melbourne Water is aiming for 20 percent reuse by 2010 and is examining the potential for reusing wastewater on recreational turf and in particular golf courses, from existing treatment plants as well as by "sewer mining" and treating on-site. Treated wastewater is an important water resource for irrigation purposes and in the future it may be the only source of supplemental water available for turf culture. Most new golf course developments in Australia, particularly those on the east coast, have to use treated effluent for irrigation as a requirement for obtaining a development permit.

Wastewater can contain a range of contaminants including salts, nutrients, heavy metals, viruses and bacteria that can limit the reuse options. The use of wastewater that has a heavy contaminant load can have implications for human health, cause soil degradation and result in uncontrolled discharge of nutrients to surface and ground water. The other important component of the sustainability equation is maintaining the playing quality of the turf area.

The reuse of wastewater will be in the future, if not already, an integral part of the ecological sustainable development and integrated catchment management philosophies concerning water quality (EPA 1996). There is now strong encouragement to reuse treated wastewater for irrigation purposes in order to protect the quality of surface waters. In most states of Australia, there are environment protection policies that demand wastewater no longer be discharged to surface waters and that it is reused. The general philosophy, and in some cases legislation, demands there be no discharge of wastewater to waterways. As a consequence, there are numerous reuse schemes being established around Australia to use wastewater for turf irrigation.

The reuse of wastewater has a strong community appeal and it seems to be the right thing to do. However, if a reuse scheme is to be sustainable for a long period and most authorities define this as at least 50 years, then there is a need to undertake an extensive investigation before the scheme is implemented. Once the scheme is implemented it must then be monitored to ensure that it is sustainable and does not present an environmental risk.

GUIDELINES FOR THE REUSE OF RECYCLED WASTEWATER

Most of the state authorities responsible for the reuse of wastewater, such as the Environment Protection Authority (EPA) and the various State Health Authorities, have in conjunction with Departments of Agriculture and Water Authorities produced guidelines for wastewater reuse. These guidelines do vary from state to state, however, the underlying philosophies are similar and most use the ANZECC (2000) water quality guidelines and the National Health and Medical Research Council and Australian Water Research Council Guidelines (1987) as their base documents.

The emphasis in the guidelines is public exposure to the recycled water and the potential human health implications. Recycled water is characterized as either A, B or C class (see table 1) with A class water being of high purity from a human health perspective with few restrictions on its use. With the lower classes of water there are greater restrictions on its use particularly as it relates to restricted entry periods and proximity to neighboring properties.

WASTEWATER QUALITY FOR IRRIGATING TURF

The development and maintenance of a quality turf surface depends on the availability of a good quality water supply. All irrigation waters, including wastewater, contain varying concentrations of soluble salts and other elements. These may include sodium, calcium, magnesium, potassium, chloride, bicarbonate, sulphate, boron and nitrate. Of significant importance for wastewater use on turf areas is the nutrient content and in particular the nitrogen and phosphorus concentrations.

In Australia, the key constituents of recycled wastewater are soluble salts, sodium, bicarbonates and nutrients. In a recent survey of Australian golf courses using recycled wastewater (AGCSA, 2005), increasing salinity, sodium and bicarbonates were the main problems reported as affecting soil conditions and turf health. Recycled water salinity levels are typically approaching 1,000 mg/L, sodium approaching 200 mg/L and bicarbonates at 200 mg/L. Even on sandy soils the sodium and bicarbonates result in cation imbalances and nutritional disturbances, with golf courses using acid and gypsum injection to counteract the adverse effects.

Nitrogen levels can be very high in wastewater (greater than 15 mg/L) and the main impact is on grass growth. Every time the turf is irrigated, it is fertilized with a soluble source of nitrogen that is readily taken up by the plant. Uncontrolled and lush growth can occur, resulting in a soft, thatchy and disease-prone turf. In many reuse schemes that involve fine turf, greens are not irrigated with recycled water for this reason.

Class	Water quality objectives	Range of uses
A	Indicative objectives • <10 *E. coli* org/100mL • Turbitity <2NTU • <10 / 5 mg/L BOD/SS • pH 6 - 9	**Urban (non-potable):** with uncontrolled public access **Agricultural:** e.g. human food crops consumed raw **Industrial:** open systems with worker exposure potential
B	• <100 *E. coli* org/100mL • <20 / 30 mg/L BOD/SS • pH 6 - 9	**Agricultural:** e.g. dairy cattle grazing **Industrial:** e.g. washdown water
C	• <1000 *E. coli* org/100mL • <20 / 30 mg/L BOD/SS • pH 6 - 9	**Urban (non-potable):** with ***controlled*** public access **Agricultural:** e.g. human food crops cooked/processed, grazing/fodder for livestock **Industrial:** systems with no potential worker exposure
D	• <10000 *E. coli* org/100mL • <20 / 30 mg/L BOD/SS • pH 6 - 9	**Agricultural:** non-food crops including instant turf, woodlots, flowers **Industrial:** systems with no potential worker exposure

Table 1: Classes of reclaimed water .

Phosphorus is another important element that has to be dealt with and applications in excess of what the soil can absorb and the plant will take up, can be leached into ground and surface waters. The use of recycled water on sandy soils always presents environmental concerns. Phosphorus concentrations vary from 4 – 10 mg/L with concentrations at 10 mg/L or greater providing phosphorus in excess of plant requirements and increasing the potential for leaching into the ground water. On several new schemes, phosphorus removal as part of the wastewater treatment process is being undertaken to reduce the pollution potential.

When using recycled wastewater it is very important to estimate the annual nutrient load, as this will have a significant effect on the fertilizer program, soil management and the health and quality of the turf. The nutrient content is an important economic consideration as well as environmental (Harivandi et.al. 1997). Even if the concentration of nutrients is relatively low, because they are applied on a regular basis, the nutrients are efficiently used by the turfgrass and can adversely effect the quality of playing surfaces.

SITE EVALUATION AND MONITORING

In evaluating the feasibility of using recycled wastewater it is important to determine whether or not the system can cope with the potential nutrient and salt loads and if a long-term, sustainable turf system can be maintained. There is no point in establishing a recycling system because it seems like a good thing if in the long term it is going to result in site degradation.

Where recycled wastewater is to be used there is usually a requirement to prepare an Environmental Management Plan (EMP) that describes the site conditions, water quality and how the system will be managed in a sustainable manner. For example, if the water is high in sodium, the EMP may state that a gypsum injection system will be installed and "x" tonne/ha of gypsum will be applied.

A site assessment is essential if the EMP is to be meaningful and must look in detail at all greens, tees and fairways to determine the following conditions:

- Soil types
- Drainage
- Salinity
- Grass species
- Phosphorus retention
- Proximity and quality of ground and surface waters
- Topography
- Geology of the site
- Irrigation requirements
- Nutrient loads
- Ability of the site to cope with extra demands because of the wastewater e.g. extra growth, runoff contaminant

Once the site assessment is completed and an irrigation program implemented, it is then necessary to initiate a monitoring program. The site assessment will identify key areas that can be used as indicators and include monitoring:

- Surface and groundwater
- Each of the major soil types
- Representative greens and tees

The monitoring program is an important method of reviewing the EMP and determining what modifications may need to be made in managing the use of the wastewater.

Recycled wastewater is a valuable resource, however, it contains nutrients, salts and other possible contaminants. For this reason, a detailed site evaluation and thorough knowledge of the quality of the recycled wastewater is required so that an appropriate management strategy can be put in place.

THE USE OF RECLAIMED WATER AT THE BARWON HEADS GOLF CLUB – A CASE STUDY

The Barwon Heads Golf Club decided to undertake the $1.45 million project following four years of water restrictions, during which time there was a period of approximately 14 months where irrigation was only permitted using hand-held hoses on greens and tees. The reclaimed water project became viable with the development of a new golf facility (Thirteenth Beach Golf Course) on the Club's western boundary.

The supply source of the "C" class treated wastewater is the local water authority plant approximately 8 km to the west. The entire project was privately funded via the Thirteenth Beach and Barwon Heads Golf Clubs. Because of the high salinity, the Club elected to irrigate greens, tennis courts and sensitive areas with a new

Chemical Analysis Water Characteristics	Average 2003/2004	Comment
pH, units	7.5	Slightly alkaline
Electrical conductivity (microS/cm @25C)	2170	High
Salinity by calculation (mg/L)	1310	High
Total alkalinity, as CaCO3 (calc.)	173	Low - moderate
Bicarbonate, as HCO3 (mg/L)	211	Low - moderate
Carbonate, as CO3 (mg/L)	<1	Low
Calcium, as Ca (mg/L)	33	Low
Magnesium, as Mg (mg/L)	29	Low
Hardness, calculated as CaCO3	199	-
Chloride, as Cl (mg/L)	350 - 400	High
Sodium, as Na (mg/L)	286	High
Residual Sodium Carbonate (calc.)	-0.6	Low
Sodium Adsorption Ratio - SAR (calc.)	8.8	Marginal
Iron, as Fe (mg/L)	0.1	Low
Manganese, as Mn (mg/L)	0.2	Low
Total Nitrogen (mg/L)	6 - 10	Moderate
Total Phosphorus (mg/L)	5 - 11	High

Table 2: Typical analysis of treated effluent used for irrigating the Barwon Heads Golf Course.

potable water supply, with reclaimed wastewater used on all other areas.

The Australian Golf Course Superintendents Association, with funding from the Barwon Heads Golf Club and Horticulture Australia, established a trial at the Barwon Heads Golf Club to monitor the effects of irrigating with recycled wastewater (HAL, 2005). This project provided an excellent opportunity to monitor both soils and water on a site that has not previously used recycled wastewater.

The typical analysis of the treated effluent is detailed in Table 2.

The main concern with the effluent is the high salinity, high sodium and high chloride. Observations to date indicate that there has been an excellent response to the water and no deleterious effects on either turf or soils.

The results of the trials after three years of monitoring the soil conditions at 0 – 100 mm, 100 – 200 mm and 200 – 300 mm indicate that:

1. **Total soluble salts** increased at all depths of the soil profile with the application of the effluent water, however, following autumn and winter, rains the total soluble salts return to normal levels. The greatest concentration of salts is in the 0 – 100 mm layer at the end of the irrigation season.
2. **Available and Total Phosphorus:** Both forms of phosphorus naturally fluctuate, however, there has been very little change in total phosphorus since the start of using effluent water. The phosphorus concentration in the water is high and it was expected that there would be some phosphorus accumulation. However, the volume of effluent applied to the fairways has been relatively low and therefore the quantity of phosphorus was at manageable levels and it appears that the couchgrass has assimilated the applied phosphorus.
3. **Total Nitrogen:** There has been very little change in the concentration of total nitrogen due to the application of the effluent water. In fact, there has been a substantial drop in total nitrogen from the April 2003 to the August 2003 sampling. The reduction is most likely due to leaching caused by the autumn and winter rainfall.
4. **Exchangeable Cations:** The exchangeable sodium increased slightly with the use of effluent water, however, this dropped considerably after the autumn and winter rainfall events. On the unirrigated site (fairway 2) for the April 2003 samples, the increase in the sodium percentage was considerably more than the fairways irrigated with effluent water and this is again due to the dry conditions and wind laden salt deposits, without the benefit of any leaching from irrigation.

The fairway soils contain some calcium carbonate nodules and the calcium component is most likely off-setting the sodium applied in the effluent.

CONCLUSION

The critical nature of Australia's water supply has forced turf managers to utilize lower quality water sources and in particular treated effluent. The dissolved constituents offer challenges in terms of managing salts, sodium, bicarbonates and nutrients in order to maintain high quality turf surfaces and to prevent soil and water degradation.

Recent studies have shown that a high, salinity-treated effluent with moderate nutrient levels can be successfully used on couchgrass (Cynodon dactylon) fairways with a high degree of soil and water management.

In the medium- to long-term, recycled wastewater may be the only water available for turf irrigation which will require:

- A high degree of soil and water management.
- Water treatment (e.g. gypsum and acid injection).
- Change to more drought and salt tolerant grass types.
- Improved water application efficiency to assist in the management and leaching of salts.
- Changes in expectations for turf condition and quality.
- Regular monitoring of soil and water conditions.

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TURF'S FOOTPRINT

As population, standard of living and disposable income have increased over the years, so has the demand for residential construction. Spurred by low mortgage rates that have prevailed in recent years, the U.S. construction market has maintained a strong pace.

With this residential construction comes the need for grounds (including turf, shrubs, trees and hardscapes) that must be maintained. Well-maintained landscapes can bring 15 percent more value to the price of a home. So it is an important part of the residential investment.

Of course keeping landscapes well maintained requires inputs (water, fertilizer, mowing, pest management). If you consider maintained turf acreage alone (mowed, fertilized, irrigated), you are looking at about 50 million acres—a significant amount. Because of the significance of turf's footprint, it is crucial that inputs be effectively managed to minimize impact on the environment and the cost to maintain the property.

Speaking of cost, the professional turf market is no small entity. USDA estimated the professional turf industry at about $40 billion. The turf industry ranks number three as an agricultural commodity nationally, and in many states, such as Maryland, New Jersey, Pennsylvania, Florida and North Carolina, turf is the number one or two agricultural commodity.

Market Definition:

The professional grounds-care industry is divided into three distinct demographic groups: Landscape services (including primarily landscape contractors and lawn care operators), golf course superintendents and crew, and institutional grounds managers at fixed sites, such as schools, parks and government/municipal facilities.

Market Size:

Grounds Maintenance Work Force (U.S. Department of Labor, Bureau of Labor Statistics, 2002)[1]

Grounds maintenance workers held about 1.3 million jobs in 2002, distributed as follows:

• Landscaping and groundskeeping workers	1,074,000
• Supervisors/managers	150,000
• Tree trimmers and pruners	59,000
• Pesticide handlers, sprayers, and applicators, vegetation	27,000

Market Forecast:

Based upon U.S. Department of Labor data[1], landscaping, grounds keeping, nursery, greenhouse and lawn service occupations are expected to have a 1.969 percent compounded annual growth rate (CAGR) from 2002 to 2012. A revenue forecast cannot be provided due to the horizontal nature of this industry.

Market Segments:

A. Landscape and Garden Services:

- 87,658 U.S. businesses with total annual sales of $20,405.8 billion in 2003[2]
- Customer plan to purchase most common services in 2004[3]
  - Mowing (13%)
  - Fertilization and weeding lawns (10%)
  - Landscape maintenance (8%)
  - Tree care (7%)
  - Pest management of lawn (7%)
  - Landscape installation (5%)

B. Golf Courses:

- 14,827 U.S. golf courses (18-hole equivalents) in 2003[4]
- 72 percent are open to public

C. Institutional:

- 84.4 million acres of national parks in 2003[5]
- 5,655 state parks comprising 13 million acres in 2002[6]
- 5,000 park and recreation departments estimated in 2002[7]
- 93,273 K-12 public schools (14,559 independent school districts), 27,223 K-12 private schools, 4,182 colleges/jr. colleges/universities in 2004[8]
- 3,981,670 miles of highways in U.S. in 2002[9]
- 19,431 municipal governments and 16,506 township governments[10]
- 87,900 government units in U.S., including the federal government, 50 state governments and 87,849 units of local government. 38,971 general-purpose local governments (3,034 county governments, 35,937 subcounty governments (including 19,431 municipal governments and 16,506 township governments). The remainder are special purpose governments (including 13,522 school district governments and 35,356 special district governments) in 2002.[10]
- 19,581 public and private airports in 2003[11]
- 519 military installations in 1995[12]
- 28,714 sports facilities (professional, college/university, other schools, park & rec.), 775,124 fields comprising 6,826,758 acres in 2003[13]

D. Landscape Architects:

- 6,486 establishments[14]

E. Irrigation Contractors

- 1,811 businesses with annual sales of $969.8 million, 2004[15]

MARKET DEFINITIONS

Landscaping Services (U.S. Bureau of Labor Statistics, North American Industry Classification System (NAICS) code number 561730)

This industry comprises (1) establishments primarily engaged in providing landscape care and maintenance services and/or installing trees, shrubs, plants, lawns or gardens, and (2) establishments primarily engaged in providing these services along with the design of landscape plans and/or the construction (i.e., installation) of walkways, retaining walls, decks, fences, ponds and similar structures.

Golf Courses (NAICS 71391 and 71394)

Golf courses include regulation-length courses, par-3 courses and executive-length courses and are categorized as daily fee, municipal or private. The National Golf Foundation defines golf courses in terms of 18-hole equivalents (number of holes divided by 18).

Institutional Grounds Care

This industry grouping includes all fixed-site grounds facilities with the exception of golf courses. For example, parks, schools, universities, resorts and hotels, apartment complexes, municipal/government facilities, office and industrial parks, cemeteries, roadsides, military bases and airports are facilities included in this industry group.

Landscape Architectural Services (NAICS 541320)

This industry comprises establishments primarily engaged in planning and designing the development of land areas for projects, such as parks and other recreational areas, airports, highways, hospitals, schools and land subdivisions, as well as commercial, industrial and residential areas, by applying knowledge of land characteristics, location of buildings and structures, use of land areas and design of landscape projects.

MARKET CHARACTERISTICS

Market Maturity:

Landscaping services: Growth market

The number of landscaping service establishments are growing, and as private residential building continues to stay healthy, so does the demand for these services. As of October 2004, The U.S. Department of Commerce stated that the residential housing starts rose 6.4 percent to a seasonally adjusted rate of 2.03 million units. This sets the stage for a record in housing starts if the trend continues through November and December 2004. Non-residential construction Industry analysts forecast a 2 to 4 percent decline in residential housing starts in 2005.

Non-residential construction market is trending just the opposite of residential housing. Non-residential construction peaked in about 2000, and experienced a downturn shortly after. The market has been depressed since then, but analysts expect a rebound in 2005. Just as with residential construction boom, increased non-residential construction will be favorable for landscape installation and maintenance.

Golf Courses: Mature market

Although growth rate of new golf course introductions began slowing in 2001 and has remained at a historical low, positive growth continues in the total number of golf courses. During the 1990's the annual increase in the number of new golf courses averaged about 340 per year. Between 2000 and 2003 the annual number of new golf courses fell from 266 to 102 in 2003.

Institutional Grounds Care: Mature market

This sector, like landscape services, is tied to construction, but its tie is to public and private non-residential construction, whereas landscape services is tied to residential and private non-residential construction.

Landscape Architectural Services: Growth market

The number of landscape architectural service establishments is growing, and as building continues, so does the demand for these services.

Environmental Direction of the Turf Market

Because of the prevalence of turf and associated maintenance inputs, turf managers should adopt practices that bring out the beneficial aspects of turf while being mindful of environmental impact and resource conservation. Proper irrigation design and responsible management of irrigation control systems is one way that turf managers conserve water and avoid unnecessary expenditures. Whether it is water, fertilizer, pesticides or seed, responsible turf managers know that "more is not better" from a financial, agronomic or environmental perspective.

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