2003 SUSTAINABLE IRRIGATION/ANCID TRAVEL FELLOWSHIP

Water Woes in the South-Western United States

Travel report on a visit to California and Arizona
2 May – 1 June 2004

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EXECUTIVE SUMMARY

As the recipient of the 2003 Sustainable Irrigation/ANCID Travel Fellowship Award, I travelled to the south-western United States (California and Arizona) from 2 May – 1 June 2004. During this time, I visited eight water and agricultural organisations and participated in two field tours.

The primary aim of my Travel Fellowship was to investigate water management practices, such as water use efficiency and water conservation, in the semi-arid environments of California and Arizona. Like in Australia, water is becoming an increasingly scarce resource in the south-west, and I wished to find out what solutions existed to dealing with this problem. In addition, I wanted to learn more about efficient irrigation in the south-west, and also gain an insight into how efficient irrigation practices were promoted.

Several of the key observations I made in relation to the aims of the Fellowship are:

- Water resources in the south-west are managed by Federal and State government departments as well as by regional water districts.
- Water management practices are varied but aim to improve management of both surface and groundwater resources, and include:
    - Developing water management plans and targets for reducing demands of high water use sectors (e.g. agriculture and urban),
    - Recharging aquifers with surface water to mitigate over-extraction impacts and store water for use in dry years,
    - Actively conserving water by converting to efficient irrigation and delivery systems, and
    - Recycling drainage water for use on salt-tolerant crops and for meeting salinity targets in the Colorado River.
- Irrigators in the south-west are dealing with water issues much the same as irrigators in Australia, such as:
    - Water and soil quality problems (build up of salts and other ions),
    - Pressure to reduce agricultural water use, increase water use efficiency and maintain or increase crop yields, and
    - Competition with environmental and urban users for access to the same limited water resources.
- Irrigation scheduling methods have been improved through the establishment of a weather station network, allowing irrigators more accurate weather and evapotranspiration data for calculating crop water needs.
- Training courses are available to promote efficient irrigation and on-farm water management practices, with the aim of reducing agricultural water use.

Recommendations I can make to the Australian irrigation industry from the findings above include:

- Increase awareness of water scarcity and make this a major focus of water management (e.g. through developing water management plans).
- Further develop options for improving water productivity (to increase crop yields with a reduced volume of water applied) to make every drop count.
- Expand/establish automated weather station networks to allow more accurate water use efficiency calculations and advance irrigation scheduling methods.
- Further investigate the potential for developing on-farm drainage management projects and demonstrating the benefits of such a scheme (e.g. reduced drainage water volumes requiring disposal, alternative water supply for irrigation).
- Encourage the adoption of best management practices for on-farm water use.

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INTRODUCTION

The Sustainable Irrigation/Australian National Committee on Irrigation and Drainage (ANCID) Travel Fellowship Award of $AUD 7,000 (all values are expressed in Australian dollars, AUD) exists to provide an opportunity for a young scientific achiever to ‘study and research overseas practices and experiences in a nominated field considered important to the Australian irrigation industry’. I was very fortunate to be awarded the Fellowship in 2003, and using the award (along with supplemental funding provided by my employer, Central Irrigation Trust), I travelled to the south-western United States in May 2004.

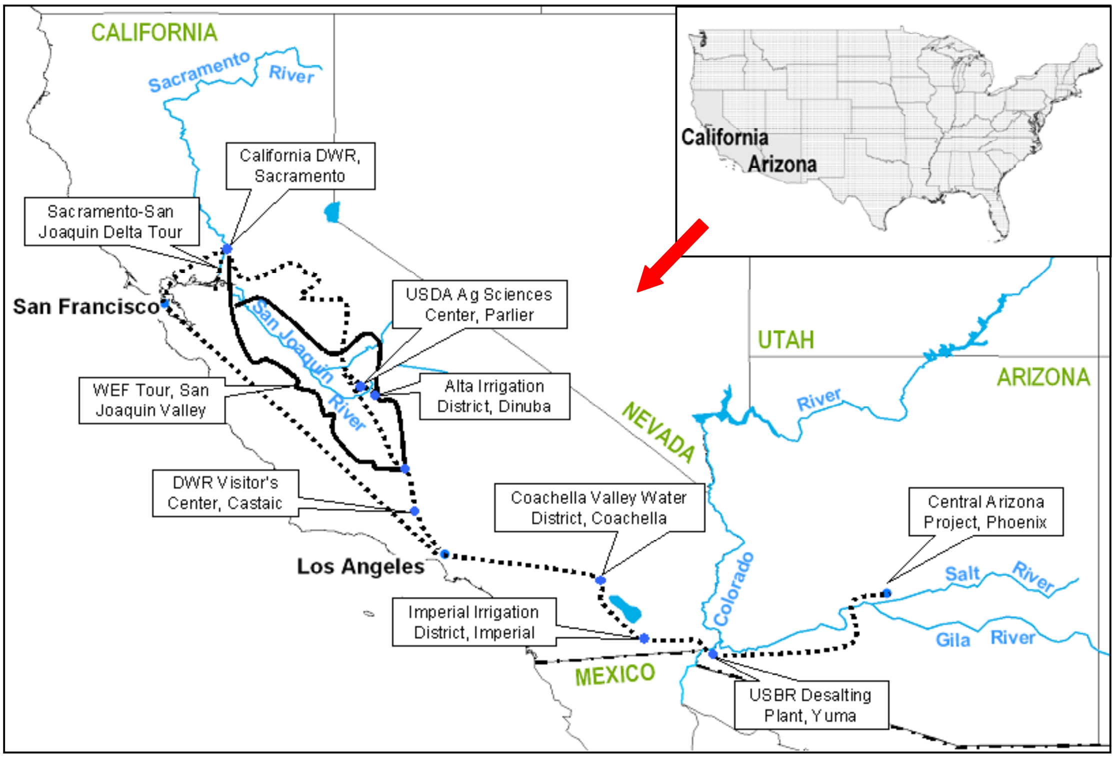
Central Irrigation Trust (CIT) is the largest rural water authority in South Australia, supplying River Murray water to domestic, parks and ovals, industrial and irrigation customers throughout 13,800 Ha of irrigated horticultural properties. I have been employed with the Trust since completing a Bachelor of Science (Environmental Biology) degree with Honours in 2001. My position at the Trust has three distinct roles, each being involved with major projects that deal with important issues facing the irrigation industry. I am the Trust’s Water Quality Officer (developing monitoring programs for nutrients and pathogens in irrigation and drainage systems), one of two Field Officers (conducting crop surveys using GIS aerial photography mapping programs and providing water use efficiency support to growers), and a Land and Water Officer (assisting CIT irrigators in trading water with other River Murray regions both in South Australia and interstate).

The primary aim of my Travel Fellowship was to investigate water management practices in California and Arizona, such as the implementation of water use efficiency, water conservation and recycling. These two states host arid to semi-arid climates like we experience here in Australia, and I wanted to find out what methods have been developed to deal with the increasing scarceness of water resources in the south-west, and bring back information on these methods to apply here in Australia, as we are facing similar water shortages. In addition, I wished to learn more about irrigation efficiency in these states, identifying examples of efficient systems and gaining an insight into how efficient irrigation practices were promoted within the irrigation industry and community.

STUDY TOUR

My visit to the United States was for a total of 31 days (from 2 May to 1 June 2004). During this time, I visited eight water and agricultural organisations, and participated in two field tours, details of which are outlined below (also see timetable in Appendix 1). Figure 1 shows the locations of the organisations visited and my path of travel through California and Arizona.

Figure 1. A map of the United States, highlighting California and Arizona in the south-west (inset), and the path showing where I travelled during the Fellowship.



California

California Department of Water Resources, Sacramento
The Department of Water Resources (DWR) is responsible for developing the State Water Plan, managing and maintaining water resources and recreation sites, and educating the public about water issues. The Department manages the State Water Project (SWP), a 1000 km storage and delivery system providing reliable water supplies to central and southern areas of the state (where the majority of irrigated agriculture and population lie). The Department has many divisions of operation with environmental, agricultural and resource planning functions. The Office of Water Use Efficiency manages the California Irrigation Management Information System (CIMIS) and its weather stations, provides financial assistance to water agencies, technical expertise to irrigators (through irrigation system evaluations), and conducts water use efficiency planning (for conservation, recycling and reuse of both urban and agricultural water).

Delta Tour, California Department of Water Resources, Sacramento-San Joaquin Delta
Michael Miller, from the Office of Water Education, hosted a tour around the Sacramento-San Joaquin Delta, a vital resource for the state's drinking and

agricultural water supplies, and also an important habitat for many plant and animal species (California Department of Water Resources 1995). During the day, we discussed land subsidence, flood control, water supply, water quality standards, and ecosystem restoration, which are all major water management issues in the Delta. We also visited the State Water Project's Skinner Fish Facility (fish from the intake channel are collected here and reintroduced into the Delta, protecting them from SWP pumps) and Harvey O Banks Pumping Plant (water is pumped 74 m uphill from here into the California Aqueduct for supplying to southern California).

Central Valley Tour, Water Education Foundation, San Joaquin Valley

The Water Education Foundation (WEF) is a non-profit organisation providing information about water issues, along with education opportunities (such as field tours for water industry professionals and policy makers) to help resolve water resource problems in the west. On the Central Valley Tour, we spent three days travelling around the western and eastern sides of the San Joaquin (Central) Valley, studying water issues in the field and listening to speakers from 21 different federal, state, and regional organisations (a list is presented in Appendix 2). Topics discussed included irrigation in the Valley, wildlife reserves, water supply availability, agricultural drainage, land retirement, State Water Project, Central Valley Project (Federal project), water storage, endangered fish protection, habitat restoration, water quality, groundwater banking, flood control, and water rights.

United States Department of Agriculture - Agricultural Research Service's San Joaquin Valley Agricultural Sciences Centre, Parlier

The USDA-ARS San Joaquin Valley Agricultural Sciences Centre is a large research facility with over 80 staff conducting laboratory and field investigations in the San Joaquin Valley. The Centre's Water Management Research Laboratory (WMRL) aims to develop water efficient irrigation and drainage management practices, improve agricultural productivity and sustainability, and reduce negative environmental impacts of irrigation. My visit to the Centre involved discussing phytoremediation trials with Gary Bañuelos (whereby plants are used to take up high concentrations of naturally occurring selenium and boron from soil), and I spoke with Rick Schoneman about the Centre's twin lysimeter project (measuring use of shallow groundwater by crops to evaluate the potential for reducing drainage water) and visited an on-farm drainage water management project at Red Rock Ranch.

Alta Irrigation District, Dinuba

Alta Irrigation District (AID), on the eastern side of the Central Valley, was established in 1888 as the second public irrigation district in California (Morison 1988). The district's total area of 52,000 Ha includes 34,000 Ha of agricultural land, with permanent plantings (e.g. stonefruit) and several dairy farms. AID only supplies water to agricultural customers, who have voting rights and a voice through the Board of Directors. Around 209,000 megalitres (ML) of high quality Kings River water is delivered to 3000 farmers each year (at a fixed charge of $AUD 15/ML), through 560 km of open, unlined canals and 48 km of pipelines. Water is ordered by mobile phone and ditch-tenders monitor turnouts on the canals. Groundwater recharge is an important goal for the district, as additional water to supplement surface allocations for agriculture must come from privately owned groundwater wells (conjunctive use).

Vista del Lago Visitor's Centre, Castaic

The Visitor's Centre overlooks Pyramid Lake, a recreational area and major water storage facility for the State Water Project and Los Angeles Department of Water and Power, and is managed by the California Department of Water Resources (DWR). Inside the Centre are interpretive displays, scale models, interactive media and educational resources relating to the State Water Project and the importance of water in the lives of Californians. Staff at the Centre offer tours to over 130,000 visitors each year from school groups and the general public, and also provide information on various water-related issues through a selection of printed media.

Coachella Valley Water District, Coachella

The Coachella Valley in south-eastern California was a desert prior to the establishment of irrigation in the region. Today, the Coachella Valley Water District annually supplies an average of 405,000 ML of Colorado River water to over 1,000 accounts on 27,000 Ha of irrigated land, and 148,000 ML of groundwater to over 90,000 urban meters (Coachella Valley Water District 2003). Their 800 km irrigation delivery scheme includes gravity fed underground pipelines and the 195 km Coachella branch of the All-American Canal. Irrigation water costs $AUD 15/ML, while domestic supplies are charged at $AUD 280/ML. Over 40 different crop types are grown in the Valley, with table grapes, citrus and date plantings covering the largest area. The District, formed in 1918, is governed by a Board of five directors representing agricultural and urban interests. Additional district services include irrigation and urban wastewater collection, reclamation, flood protection, groundwater management and water conservation (CVWD has recently developed a water management plan to address water use in the Valley).

Imperial Irrigation District, Imperial

Imperial Irrigation District (IID) covers an area of over 429,000 Ha in the Imperial and Coachella Valleys in southern California. Field crops dominate most of the 190,000 Ha of irrigated area (e.g. alfalfa, sudangrass, wheat, bermudagrass and sugar beets). Since the establishment of IID in 1911, the District's Board of five Directors have worked with staff in managing the direction of IID's water and power services, which today supply water to 6,000 accounts, and electricity to 114,350 residential, commercial and industrial customers (Imperial Irrigation District 2003). Around 3.8 million ML of Colorado River water is imported and distributed throughout the Valley via a system of 2800 km of canals, including the 130 km All-American Canal. Approximately 98 % of this water is used for agriculture (delivery cost $AUD 17/ML); the remaining 2 % is sold to cities in the Valley for urban drinking water supplies. A key aim for IID is to use its water as efficiently as possible, which is currently occurring via water conservation agreements with large southern California urban water agencies.

Arizona

United States Bureau of Reclamation, Yuma Desalting Plant, Yuma

The Yuma Area Office of the United States Bureau of Reclamation administers Colorado River water deliveries and maintains the river channel along the Arizona-California border, from Nevada to Mexico. In addition, the office manages salinity control projects, and offers technical support and training about water conservation. Also based at the Yuma Office is the Water Quality Improvement Centre, a research facility providing opportunities for partnership investigations into improving reverse osmosis methods (along with testing alternative water treatment methods), and operating a small scale desalting plant which supplies drinking water for the office.

Central Arizona Project, Phoenix

One of two major water supply projects in Arizona, the Central Arizona Project (CAP) aims to supply Colorado River water to its customers in a cost-effective and environmentally sound manner, promoting responsible water use and resource management. The CAP is publicly-owned, and managed by the Central Arizona Water Conservation District. Constructed from 1973 to 1993 and funded through a long-term loan from the Federal Government, the Project was designed to deliver an average of 1.84 million ML of water per year to contracted water utilities and irrigation districts (to serve urban and agricultural customers) and Native American communities in central and southern Arizona. The CAP delivery scheme extends for 537 km across southern Arizona, and includes 15 pumping plants (one a dual purpose hydroelectric/pumping plant) that lift water more than 800 m, one storage reservoir, and automated canal gates to regulate flow (monitored from the Control Centre using a supervisory control and data acquisition computer system, SCADA). The Project also manages groundwater resources by operating aquifer recharge programs.

KEY FINDINGS

The increasing scarcity of water supplies in the south-west, along with the increased awareness of this as a major water issue, has enabled (and in some cases forced) the development of innovative practices to address this problem. Several concurrent years of drought in the south-west have confirmed that many water resources are already overallocated and overused, such as the Colorado River which supplies drinking water to over 25 million people and agricultural supplies to over 1.4 million Ha of land (Newcom 2001; The Council of State Governments 2003). My visit to California and Arizona demonstrated the great importance of water to the growth of the irrigation industry in these states, and has shown many methods of dealing with issues of water management (e.g. water use efficiency, conservation and recycling), to reduce the impact of scarce supplies on the industry. Several of these key findings are listed below.

Managing Agricultural Water Use

In 1982, the California Department of Water Resources (DWR) and University of California, Davis, established a network of automated weather stations (owned by DWR, water agencies, universities and industries), in a move towards assisting irrigators to improve their scheduling practices and on-farm water management. Currently, there are 125 active stations located throughout the state in the California Irrigation Management Information System (CIMIS) program, collecting data of various climatic parameters (e.g. rainfall, wind speed, air temperature and humidity) at regular intervals (Figure 2). This data is fed to a central database at the DWR Sacramento Office, where quality control assessments are completed and the data is made available to registered users (registration is free of charge) on the CIMIS website, www.cimis.water.ca.gov. Evapotranspiration values for a reference crop of grass (ET_o) are calculated from the climatic information using the Penman-Monteith and modified Penman equations, and are also available on the website. Since station site features influence the accuracy of ET_o estimates, new stations must be installed according to a list of siting criteria, standardising the sites and ET_o calculations based on well-researched crop characteristics (Eching and Moellenberndt 2000; Eching 2002).

Figure 2. CIMIS weather station (Source: California Department of Water Resources).

A cost-benefit analysis of the CIMIS program in 1997 (Parker, Cohen-Vogel, Osgood & Zilberman 2000) found that the annual cost to the State Government (over $AUD 1 million) was far outweighed by the benefits obtained by over 3000 registered users. Since 1997, the number of registered users has increased to 7000 (data requests via the internet are 70,000 per year), and includes farmers, consultants, water agencies, lawyers, urban landscape planners and pest control managers. Parker *et al.* (2000) also reported that use of CIMIS data in irrigation management annually created significant financial savings (over $AUD 80 million) through reduced water use (saving an estimated 130,000 ML) and increased crop yields. Benefits were not limited to water management, however, with other CIMIS users applying the data to investigations into tracking mosquito populations and monitoring air quality.

Coachella Valley Water District (CVWD) has also addressed high agricultural water demands (along with that of urban and golf course uses) in its recently published Water Management Plan. The plan was developed from the District's long-term commitment to water conservation (the plan is for 35 years), as urban development and agricultural production in the desert Valley rely on local groundwater and imported surface water supplies. Falling groundwater tables and a rapidly growing population have encouraged the District to actively manage existing and future water resources (Coachella Valley Water District 2002a). Table 1 lists the minimum conservation goals for urban, golf course and agricultural uses reported in the Plan, to ultimately reduce the total water demand of the Valley by approximately 7 % by 2015. Conservation is only one feature of the plan, with groundwater recharge and elements of source substitution also included.

Table 1. Targets for reducing urban, golf course and agricultural water use in the Coachella Valley (taken from Coachella Valley Water District 2002b).

Water Use Category	Minimum Demand Reduction Target
Urban Use Golf Course Irrigation* Agricultural Irrigation	10 % by 2010 5 % by 2010 7 % by 2015
Total Demand	Approximately 7 % by 2015

* Only courses existing in 1999 will be subject to this target (courses built after 1999 will be evaluated on a case-by-case basis).

Measures to conserve water by the agricultural sector include improving irrigation efficiencies from 70 to 75 % by converting to more efficient irrigation systems (e.g. from furrow to drip systems and upgrading existing irrigation system designs), in addition to conducting on-farm water audits which investigate irrigation practices and water use efficiencies of all irrigated properties (Coachella Valley Water District 2002b). The District also offers free water management courses to further promote water conservation and irrigation scheduling, and increase awareness of key water issues in the Valley. By the end of 2004, it is estimated that over 20,000 ML of Colorado River water will be saved as a result of agricultural water conservation (Coachella Valley Water District 2004).

Groundwater Management and Recharge

Groundwater overdraft, a common water use issue in the south-west, has been an important focus of the Central Arizona Project (CAP) since their aquifer recharge programs began in 1996. Over 60 years of human exploitation of Arizona's groundwater resources (at a rate exceeding natural recharge) has resulted in lowered water tables, sediment compaction, land subsidence and surface fissures, along with increased groundwater pumping costs (Gelt 1992; Bartolino & Cunningham 2003). Subsidence is a particular concern for the CAP open canal delivery scheme (Figure 3a). A subsidence investigation in 1999 found that part of the main canal was subsiding at 6 cm/year (Central Arizona Project 2004). Following this, the canal lining was raised to prevent water overflowing the canal and reducing the delivery capacity of the system (Figure 3b).

Figure 3. a) Central Arizona Project canal, b) Maintenance on a subsiding part of the canal to raise the lining (Source: Central Arizona Project), c) Agua Fria spreading basins, one of the recharge project sites (Source: Central Arizona Project).

The CAP Recharge Program involves diverting spare surface water (from their Colorado River entitlement) into a total of 87 Ha of spreading basins, where the water naturally infiltrates into the aquifer, raising the level of the water table (Figure 3c). By the end of 2005, the CAP aims to have seven individual recharge projects in operation throughout south-central Arizona, storing over 560,000 ML of water (Central Arizona Project 2004). This approach to groundwater management has been very successful in recharging local aquifers, with the water table underneath one of the project sites having risen by over 75 m in two years. Other benefits are also expected from the program, such as reducing pressure on groundwater supplies through encouraging customers to use surface water over groundwater, mitigating land subsidence, and creating a reserve supply of water for the state that can be recovered in drought years.

Water Conservation

In 1988, Imperial Irrigation District (IID) signed an historic water conservation agreement with the Metropolitan Water District of Southern California (MWD), who supplies drinking water to over 18 million people near Los Angeles. The agreement has enabled IID to upgrade their distribution scheme by lining canals with concrete and automating system deliveries, in addition to improving agricultural water use practices through on-farm irrigation management programs. MWD has provided over $AUD 297 million to fund these conservation measures, in exchange for use of the water saved. Over 129,000 ML of Colorado River water has been conserved each year and transferred from agricultural uses in IID to MWD's urban supplies. Another conservation agreement was developed in 1998, between IID and the San Diego County Water Authority (SDCWA), whereby a $AUD 468 million investment from SDCWA will allow a transfer of up to 246,000 ML of conserved water each year through to 2011 (Imperial Irrigation District 2001). Rural-urban partnerships such as these are becoming more common, as California is trying to reduce its water use (the state has used significantly more than its annual entitlement of Colorado River water each year since 1985) and meet the demands of its rapidly growing population (Newcom 2001; Wade and Devine 2003).

Drainage Water Recycling

The reuse of irrigation drainage water in the south-west has been attracting increased attention as a viable water management practice, for application on both small and large scales. A reduced number of options for drainage water disposal on the western side of the San Joaquin Valley in central California has forced farmers to rethink their water management practices. Shallow water tables, clay layers, naturally saline soils and selenium toxicity all combine to make drainage water management more challenging on this side of the Valley (United States Department of Agriculture n.d.). Selenium is a particular problem because there is a narrow margin between beneficial and toxic levels of this naturally occurring trace element present in westside soils. Water moving through the soil picks up the biologically available forms of selenium, creating selenium-enriched drainage water. Originally, drainage water from westside farms was collected in a drain and discharged into the Sacramento-San Joaquin Delta, via a wildlife habitat called Kesterson Reservoir. In the early 1980's, high numbers of dead and deformed birds were discovered at the reservoir, and the concentration of selenium through the food chain was found to be the cause (Mahoney 2001). The reservoir and drain have since been closed, leaving irrigators with limited opportunities for drainage water disposal.

An Integrated On-Farm Drainage Management Project (IFDM) on the western side of the Valley has proven to be a successful example of reusing drainage water for irrigating salt tolerant crops since it was established in 1986. At Red Rock Ranch, the 250 Ha farm where the project is operating in a partnership (e.g. with the United States Department of Agriculture), the aim is to manage salt, trace elements and drainage water in an environmentally safe and economical manner (Drainage Reuse Technical Committee 1999). The property is divided up into planting zones, ranging from salt intolerant to salt tolerant crops. Fresh irrigation water is first used for irrigating high-value salt sensitive crops. Subsurface drains collect the drainage water from these crops, then the drainage water is blended with tail water runoff and used for irrigating another, slightly more salt tolerant crop. This process is repeated for use on a series of crops with increasing tolerances to salt, until the drainage water collected after irrigation of the final crop (highly salt tolerant halophytes) is evaporated for salt harvesting.

The project has reused 90 % of the drainage water produced on the property as an alternative water supply, supplementing limited local freshwater supplies and reducing the impact on shallow water tables (United States Department of Agriculture n.d.). It has also increased yields for cotton crops grown at the farm, and through the natural removal of selenium from the soil by plant uptake, produced marketable selenium-enriched products (Bañuelos 2002). The achievement of the IFDM Project as turning a problem into a resource has been recognised through many awards, and attracted interest from other western Valley farmers eager to establish similar sustainable practices on their drainage-impacted lands.

Construction of the world's largest desalination plant to process saline drainage water (around 18,000 EC) into freshwater via reverse osmosis treatment, was completed in 1992 at Yuma, Arizona (Figure 4). The plant was designed to produce 276 ML of desalted water per day, which would then be discharged into the Colorado River to lower its salinity. In 1944, the United States signed an International Water Treaty with Mexico, guaranteeing Mexico (as the end user of the river) at least 1.84 million ML of good quality water per year. The desalting plant was built to enable the United States to comply with salinity targets established in the treaty, and ensure the water Mexico received was of acceptable quality.

Figure 4. The process area inside the Yuma Desalting Plant, showing hundreds of pressure vessels that contain reverse osmosis membrane elements (Source: United States Bureau of Reclamation, Yuma).

After only six months of operating the desalting plant, a heavy flood event damaged the canal which carried drainage water to the plant, and operations at the plant were shut down. The plant is now maintained in ready-reserve status, and it is estimated that it will cost over $AUD 20 million for plant rehabilitation and environmental impact studies (regarding discharge of the saline by-product into a wetland habitat in Mexico) before operations can be resumed at the plant.

RECOMMENDATIONS

Water management has been, and will continue to be, a major challenge for all water users, resource planners and the irrigation industry, both in the south-west United States and here in Australia. Management is particularly difficult when considering a natural resource that is becoming increasingly scarce, and when there is no method of accurately predicting how much of it will be available in the future. This further complicates plans for estimating potential demands and pressures that will be placed on water resources over time.

At present, we need to focus our attention on developing new methods (and advancing existing practices) for dealing with the many different aspects of water use to actively address the scarcity of water, and increase awareness of this as a major water management issue. This report has discussed several innovative practices relating to water management in California and Arizona, areas with similar dry climates to Australia. We can only learn from the problems and successes of these practices and their implementation to improve the ways in which we address and achieve similar goals here.

On a large scale, developing a water management plan for a whole region or individual irrigation district (as was prepared for Coachella Valley Water District) is useful for identifying key user groups and their water needs. Combined with assessing other local demands, this evaluation process can create a better picture of where the region is heading in regards to its future water use and where growth is likely to occur (in urban, agricultural and environmental sectors, for example). Once the key sectors for growth have been identified, consultations with representatives of those sectors (and community members) can quantitatively estimate expected water demands, and even establish achievable conservation targets for reducing water use of specified user groups. A final activity involving the creation of different proposals for consideration, and a decision to act on a preferred choice (based on evaluation of those proposals), may then provide planned direction for water management of the region's major water users.

As for the Australian irrigation industry, one major water management issue that needs to be addressed is the productivity of water. The high water demand of agriculture has been a target for those competing with the industry for access to water supplies for several years, and farmers have been feeling the pressure to reduce their water consumption while maintaining crop yields. Maximising water productivity, through increasing crop yields with the same volume of applied water, is one method of making every drop of water count (Tanji & Kielen 2002). This approach can encourage improved irrigation management practices and increase the profitability of irrigated agriculture. Two of the options available for further investigation and development to maximise water productivity include improving water use efficiency and reusing drainage water.

There are several methods available to assist irrigators to improve their on-farm water use efficiency and irrigation scheduling, such as soil moisture monitoring, advances in irrigation system designs, plant moisture monitoring, and use of climatic information to estimate crop water requirements (United States Department of Agriculture 2003). Localised climatic data may be collected through automated weather station networks and made available to irrigators via internet websites and publications (e.g. the CIMIS Program in California). Establishing such a network that is based in a region, but has the potential to be expanded over a greater area, will not only benefit irrigators, but also those involved in reporting on water use efficiencies.

Central Irrigation Trust is working in partnership with our regional catchment management board and other organisations to improve water use efficiencies of irrigated properties through the 'Improving Irrigation Efficiency Project'. A feature of the Water Allocation Plan for the River Murray Prescribed Watercourse (WAP), all irrigators in the River Murray Irrigation Management Zone are required to be 85 % efficient in their water use by June 2005 (River Murray Catchment Water Management Board 2002). Using aerial photographs, property visits to survey crop and irrigation system information, and combining this with consumption data, we can calculate the water use efficiency of all properties receiving irrigation supplies in our nine districts.

The water use efficiency calculation recommended by the WAP uses long-term average rainfall as a measure of additional applied water to the crop, and this is not an accurate representation of the actual climates experienced, especially during the current drought. Access to the latest weather data through the Trust's small pilot network of five stations (within one district) has greatly improved the accuracy of the water use efficiency calculations, and allowed our irrigators more current information on how they are progressing towards the 85 % efficiency goal. Standardising weather stations and siting characteristics will also benefit data users, enabling comparisons to be made between sites and a confidence that the data is as accurate as possible.

Water use efficiency may lead to applying only the volume of water that a crop needs, while reusing water allows you to get as much out of the water as possible. On one hand, reusing drainage water can create an alternative water supply (and reduce the demand on other available water supplies), but also allow the productivity of water to be increased, particularly if the water is reused for irrigation. In addition, reuse reduces the volume of drainage water requiring disposal on or off the farm in evaporation basins, and hence lessens the environmental impacts of irrigation. On the other hand, drainage water reuse may also decrease the water available to downstream users, as water that would have originally percolated through the soil and into underlying aquifers, or moved off the property as runoff into nearby waterways, has been captured and kept on the property (Wolff & Stein 1999).

Drainage water in some areas of Australia is of sufficient quality to be reused on a wide range of crops, whereas in the Riverland region of South Australia, where drainage flows collect high concentrations of salt naturally present in the soil, drainage water is often highly saline. This may restrict the variety of crops that can be irrigated with drainage water to those with a greater tolerance to salt. Water salinity should not be seen as a limitation to the applications for drainage water reuse, however, because of developments into genetically enhancing the salt tolerances of existing marketable crops (e.g. the salt tolerant forage species *Distichlis spicata*), which then creates further profit from the water (National Dryland Salinity Program 2001). Blending saline drainage water with fresh irrigation water, or even slowly converting irrigation water from fresh to saline supplies as plants mature can also be useful if a crop is moderately salt tolerant (Drainage Reuse Technical Committee 1999). Investigations into enhancing salt tolerances of horticultural crops should be continued so that reuse schemes are not confined to pastures and grasses, and can be demonstrated to be successful for a range of crop types.

Establishing on-farm drainage management projects where drainage water is reused for irrigation on local farms here in Australia will demonstrate not only the benefits of such a scheme, but also allow them to see the details of operations behind the project. On-farm drainage management projects have been successful in the United States (e.g. Red Rock Ranch), and there is great potential for their success here. The development of incentive schemes can also further encourage the reuse of drainage water, along with supportive policies for drainage water management on a regional scale (Oster & Wichelns 2003).

The Australian irrigation industry is heading towards many challenges and changes, and we are already experiencing some of these with an increased focus on water use efficiency, water conservation and improved irrigation practices. These water management issues will become more crucial in meeting the future water needs of the irrigation industry. Adoption of best management practices will ultimately increase the effectiveness and efficiency of irrigation and natural resource management together, to demonstrate an active role in advancing the sustainability of the irrigation industry in the future.

APPENDIX 1

Detailed itinerary of my time in California and Arizona on the Travel Fellowship.

Date	Activity	Organisation and Location	Contact Person/s
Sun 2 May 2004	Travel	Adelaide-Melbourne-Los Angeles CA-San Francisco CA	
Mon 3 May 2004	Free Time		
Tues 4 May 2004	Travel Arrangements	Organising arrangements for travel and visits for the following week	
Wed 5 May 2004	Free Time		
Thurs 6 May 2004	Travel	San Francisco CA – Sacramento CA	
Fri 7 May 2004	Free Time		
Sat 8 May 2004	Free Time		
Sun 9 May 2004	Free Time		
Mon 10 May 2004	Visit	California Department of Water Resources, Sacramento CA	Michael Miller (Tour Coordinator), Barbara Cross (Chief, Land and Water Use Section), Tom Hawkins (Senior Land and Water Use Analyst), David Sandino (Staff Counsel III), Baryohay Davidoff (Chief, Agricultural Council Support), Simon Eching (Chief, Program Development), Fawzi Karajeh (Chief, Recycling and Desalination Branch)
Tues 11 May 2004	Field Tour	California Department of Water Resources, Sacramento-San Joaquin Delta CA	Michael Miller (Tour Coordinator),
Wed 12 May 2004	Field Tour	Water Education Foundation, Central Valley CA	Judy Maben (Education/Tour Director)
Thurs 13 May 2004			
Fri 14 May 2004			
Sat 15 May 2004	Free Time		
Sun 16 May 2004	Free Time		

Detailed itinerary of my time in California and Arizona on the Travel Fellowship (continued).

Date	Activity	Organisation and Location	Contact Person/s
Mon 17 May 2004	Travel	Sacramento CA – Fresno CA	Charles Bollinger (Retired Tour Guide, California Department of Water Resources)
Tues 18 May 2004	Visits	USDA-ARS/San Joaquin Valley Agricultural Sciences Centre, Parlier CA Red Rock Ranch, Five Points CA Alta Irrigation District, Dinuba CA	Gary Bañuelos (Soil Scientist), Rick Schoneman (Agricultural Engineer) Chris Kapheim (General Manager)
Wed 19 May 2004	Travel Visit	Fresno CA – Los Angeles CA Vista del Lago Visitor's Centre, Castaic CA	Charles Bollinger (Retired Tour Coordinator, California Department of Water Resources) Gary Moore (Visitor Guide)
Thurs 20 May 2004	Free Time		
Fri 21 May 2004	Free Time		
Sat 22 May 2004	Free Time		
Sun 23 May 2004	Travel	Los Angeles CA – Palm Springs CA – Indio CA	
Mon 24 May 2004	Visit	Coachella Valley Water District, Coachella CA	Bob Keeran (Public Information Associate)
Tues 25 May 2004	Visit	Imperial Irrigation District, Imperial CA	David Bradshaw (Assistant General Superintendent, Resources Planning and Management)
Wed 26 May 2004	Visit	USBR Yuma Desalting Plant, Yuma AZ	Angela Adams (Program Analyst, Desalting Group)
Thurs 27 May 2004	Travel	Yuma AZ – Phoenix AZ	
Fri 28 May 2004	Visit	Central Arizona Project, Phoenix AZ	Earl Zarbin (Communications Representative)
Sat 29 May 2004	Free Time		
Sun 30 May 2004	Free Time		
Mon 31 May 2004	Free Time		
Tues 1 June 2004	Travel	Phoenix AZ – Chicago IL – London, United Kingdom	

APPENDIX 2

A list of the key speakers from the Water Education Foundation's Central Valley Tour.

Name	Organisation
Carl Hauge	California Department of Water Resources
Valerie Curley	United States Bureau of Reclamation
Frances Mizuno	San Luis & Delta-Mendota Water Authority
Scott Lower	Grasslands Water District
Dennis Woolington	United States Fish & Wildlife Service
Steve Chedester	San Joaquin River Exchange Contractors Water Authority
Chase Hurley	Panoche Water District
Chris White	Central California Irrigation District
Thad Bettner	Westlands Water District
Doug Davis	Tulare Lake Drainage District
Richard Harriman	Attorney
Ken Bonesteel	Kern Water Bank Authority
Mark Larsen, Jim Stadler	Kaweah Delta Water Conservation District
Randy McFarland, Ron Jacobsma	Friant Water Users Authority
James Chandler	Orange Cove Irrigation District
David Orth	Kings River Conservation District
Gary Serrato	Fresno Irrigation District
Steve Spratt	San Joaquin Parkway & Conservation Trust
John Buada	Vulcan Materials Company
Kevin Kauffman	Stockton East Water District
Lowell Ploss	San Joaquin River Group Authority

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