Finding the Balance — Improving Infrastructure, Water Management, and the Environment in a World with Limited Funding and Ample Regulations

Tenth International Conference on Irrigation and Drainage

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USCID

The U.S. society for irrigation and drainage professionals

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Preface

The papers included in these Proceedings were presented during the **USCID Tenth International Conference on Irrigation and Drainage**, held October 24-27, 2017, in Sacramento, California. The Theme of the Conference was ***Finding the Balance — Improving Infrastructure, Water Management, and the Environment in a World with Limited Funding and Ample Regulations***.

Irrigation districts, water entities, and federal/state agencies face a wide variety of issues every day as they try to effectively and efficiently provide water to their customers. These issues range from "big picture" items such as how to properly manage their water supply, determining where water is located in the district on a minute-to-minute basis, addressing environmental issues and regulations, and maintaining the district's infrastructure.

Understanding water balance concepts, whether they be on the farm, district or basin level, is essential for groundwater basin management and proper development of water conservation programs. Environmental issues, and the regulations associated with them, can be daunting to a district. In addition, irrigation district maintenance, especially with older districts, can be a drain on financial resources if not addressed properly. Groundwater recharge has the potential to address both water management and environmental issues. However, there are many questions and complexities surrounding groundwater recharge

The goal of this Conference was to assist water districts by providing tools and case studies to address this wide spectrum of issues while also identifying funding sources that districts can use to assist with their operations. The authors of papers presented in these Proceedings are professionals from government agencies, the private sector and academia.

USCID and the Conference Co-Chairs express gratitude to the authors, session moderators and participants for their contributions.

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Conference Co-Chairs

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INTERACTION BETWEEN GROUNDWATER AND SURFACE WATER: WATER AND FISHERIES MANAGEMENT ISSUES AND CHALLENGES

Steve Macaulay, P.E.[1]
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ABSTRACT

This paper addresses the water management issues and challenges related to a key portion of California's new groundwater management law: the need to manage groundwater resources to minimize impacts to streamflow resources.

California's 2014 Sustainable Groundwater Management Act (SGMA) defines sustainable groundwater management as the management and use of groundwater without causing specific "undesirable results". One such undesirable result is defined as:

> *Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.*

Meeting this new requirement will involve (1) judgment (what do "significant" and "unreasonable" mean?), (2) sufficient technical understanding of groundwater - surface water connections in each basin, and (3) adequate data on groundwater levels, stream flows and stream resources to form the basis of water management decisions.

The conference presentation will explore issues related to this new requirement, and is intended to complement the ½ day conference panel discussion on surface water / groundwater interactions.

Groundwater interconnections with stream systems have important implications to water and fishery managers and will need to be addressed in many groundwater sustainability plans. The consequences of SGMA actions to water and fishery resources will be potentially significant. It is essential to have a combination of both technical and policy coordination to address specific issues in the various groundwater basins. A long-term view is essential to assuring that water managers, technical specialists, regulatory agencies, and local governments establish effective decision processes and stakeholder engagement processes to design and implement their Groundwater Sustainability Plan.

Interdisciplinary interaction and technical analysis is not new to western states, and many have regulations pertaining both to the extraction of groundwater and the interaction between groundwater and surface water. Conference attendees will hear more about this in the ½ day panel discussion.

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INTRODUCTION

SGMA Legislative Background

California Governor Jerry Brown's administration supported development of the three bills that collectively became SGMA as a continuation of the Governor's January 2014 California Water Action Plan[3]. Action 6 of the Water Action Plan was to "Expand water storage capacity and improve groundwater management". For 20 years beginning in the early 1990s the California Legislature passed a number of bills that guided voluntary actions at the local level to plan and manage groundwater resources. In addition, largely in response to the State Drought Water Bank in the severe drought of the early 1990s, a number of counties passed ordinances that sought to regulate groundwater extractions to the extent such pumping directly or indirectly supported marketing of surface water supplies in their counties to other regions of the state. While there are examples of collective efforts to put more focus on groundwater management, in most cases there were no requirements to manage groundwater in a way that promoted long-term sustainability of surface and groundwater resources. Adjudicated basins, where a basin has been in overdraft and local groundwater users petitioned the courts for engagement, have had some success in establishing a balance between surface and groundwater uses.

Land use has played a pivotal element in the long-term trend of depleting groundwater supplies in both urban and agricultural areas. The impacts of land use on groundwater supply has been magnified by a number of factors including drought (1987-1994 and 2011-2015), declining reliability of a number of surface water supplies, changes in agricultural water use, and a concern about losing the physical connection between streams and groundwater in some areas of California. By the early 2000's these concerns were shared to some degree by a wide range of water users, environmental groups and the public. This came to a head in the spring and summer of 2014, in the fourth year of a severe drought. The Association of California Water Agencies had earlier developed a new conceptual model for groundwater management that had local agencies in control with support by state agencies. In addition, key environmental groups, and in particular The Nature Conservancy, took a direct interest in legislative proposals and were involved in legislative negotiations.

Following many months of negotiations, the Legislature passed three separate bills that were signed by Governor Brown in September of that year.

[3] California Department of Water Resources. Groundwater Sustainability Program, Draft Strategic Plan, March 2015, page 11.

What SGMA Says and Why

SGMA actions by groundwater sustainability agencies (GSAs) are driven by the six "undesirable results" set forth in the law. These are[4]:

(1) Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon.

(2) Significant and unreasonable reduction of groundwater storage.

(3) Significant and unreasonable seawater intrusion.

(4) Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies.

(5) Significant and unreasonable land subsidence that substantially interferes with surface land uses.

(6) Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.

Appropriate to this paper is (6) above. This interconnection of surface water and groundwater is also addressed as a new factor in assessing basin priorities (California Water Code Section 10933), "…including adverse impacts on local habitat and local streamflows".

DWR's March 2015 Draft Strategic Plan notes that one key outcome of SGMA is that "…Surface water and groundwater are managed as "a single resource" to sustain their interconnectivity, provide dry season base flow to interconnected streams, and support and promote long-term aquatic ecosystem health and vitality…."

The law provides that each local designated Groundwater Sustainability Agency (GSA) develop its own groundwater sustainability plan, consistent with regulations adopted by DWR. Such regulations allow each GSA to evaluate the potential for "undesirable results", with broad public input as part of the process for developing its Groundwater Sustainability Plan (GSP). It will be up to the GSP to address the nature of the terms "significant" and "unreasonable" as they apply to all undesirable results.

Initial Implementation

Throughout 2015, 2016 and into 2017 DWR developed required SGMA implementation regulations and additional "best management practices" (BMPs) guidance documents. The regulations pertinent to this paper are those regulating the development of GSPs[5]. These regulations require addressing of groundwater elevations, the identification of

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[4] California Water Code Section 10721(w).

[5] http://www.water.ca.gov/groundwater/sgm/pdfs/GSP_Emergency_Regulations.pdf

interconnected surface water systems and trends in depletion of those systems, groundwater-dependent ecosystems, a complete water budget, and other requirements that either directly or indirectly address the "undesirable result" of depletion of surface water systems.

Five BMPs were developed: (1) monitoring protocols, (2) monitoring, (3) hydrogeologic conceptual models, (4) water budget, and (5) modeling[6]. To a large extent the BMP documents provide additional guidance supplemental to the GSP regulations. Most of the BMP documents addressed the connection between surface water and groundwater in some manner, including this statement from the Water Budget BMP:

> *Unless additional inflows or supplies are developed, increases in groundwater extraction may eventually result in a hydraulic disconnection between the surface water and groundwater systems in basins where these systems are currently interconnected. Groundwater systems that are disconnected from the surface water system will still receive recharge from the surface water system. However, all further extraction from the groundwater system may be largely balanced through a decline of groundwater in storage and/or a reduction of subsurface outflow from the basin over time.*

More on this topic is addressed in the following sections.

THE INTERACTION BETWEEN SURFACE WATER AND GROUNDWATER

GSPs will be required to demonstrate a good understanding of physical interactions (including short-term vs. long-term considerations) between groundwater and surface water based on data and provide predictive analyses at a sufficient resolution and accuracy to enable management policy and action.

Nature of Physical Interaction

The physical nature of groundwater surface water interaction is deceptively simple, yet difficult to quantify and manage. It all starts with elevation (or groundwater "head" in hydrogeology parlance). When groundwater head adjacent to a surface water body is higher than the water surface elevation, groundwater will tend to discharge to the surface water. In this case, a surface water body is "gaining" water from groundwater. When groundwater head adjacent to a surface water body is lower than the water surface elevation, surface water will tend to discharge (or seep) to the groundwater. In this case, a surface water body is "losing" water to groundwater. While the head differences govern whether a system is gaining or losing, the rate and volume of water flowing between the two is a function of many other variables and processes. Of course, the rate and volume of this interaction is of most interest to water managers. The variables that control rates and volumes include the physical properties of the stream bed and the aquifer, the

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[6] http://www.water.ca.gov/groundwater/sgm/bmps.cfm

complexity of the stream channel and groundwater flow patterns, the seasonality of the system and the time frame over which rate and volume calculations are carried out.

The following figures (U.S. Geological Survey Circular 1139[7]) have been used extensively to describe the interconnections – or lack of connections in many circumstances – between surface water and groundwater. These figures seem the most relevant to SGMA as GSAs deal with the interconnection issues. Figure 1 shows the characteristics of a gaining stream, whereby streamflow is augmented by groundwater contributions. Figure 2 shows the characteristics of a losing stream, whereby streamflow is reduced by water loss into the aquifer. In both these cases there is a physical connection between the stream and the aquifer, controlled generally by groundwater elevations.

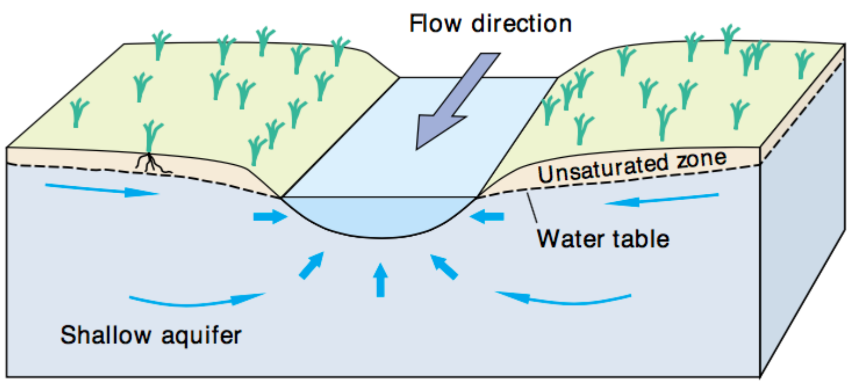

Figure 1. Gaining Stream

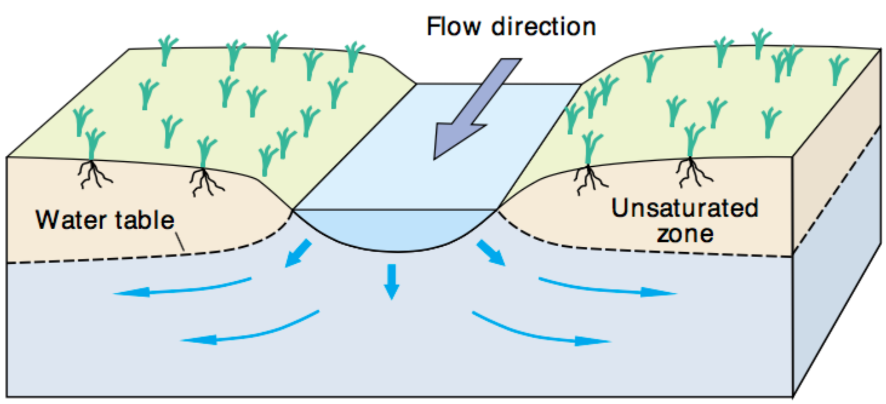

Figure 2. Losing Stream

[7] U.S. Geological Survey Circular 1139, "Ground Water and Surface Water, A Single Resource", Denver, Colorado 1998.

Figure 3 depicts the circumstance where there is no physical connection between the stream and the aquifer. Under such conditions water from the stream enters an unsaturated zone: groundwater does not contribute to streamflow, but stream losses contribute to aquifer storage.

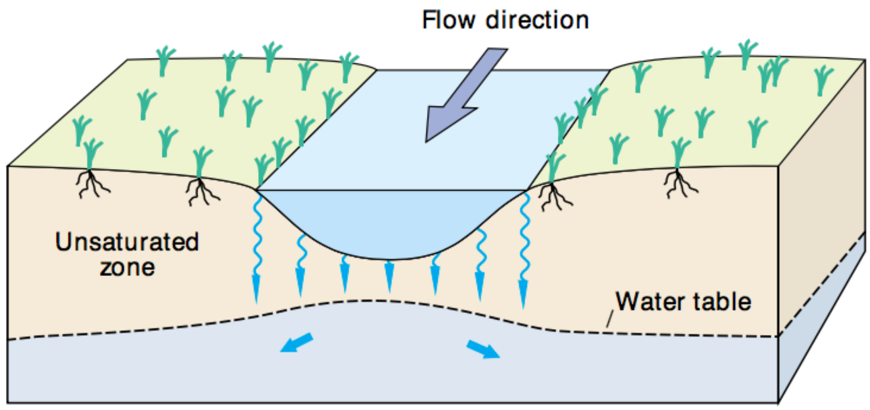

Figure 3. Disconnected Stream

Modeling Tools

While it is possible to directly measure the rate and volume of water moving between groundwater and surface water, it is not common and often very difficult. Therefore, modeling tools are necessary to both analyze historical conditions and to predict future conditions. Time is an important integrating variable in these models and can create a dilemma for both practitioners and stakeholders. Standard hydrologic and engineering models of surface water systems are typically developed to capture processes on a daily time scale (often minutes in the case of storm flows). Accommodating the longer-term hydraulics of groundwater inflows/outflows in these models is often awkward. Conventional models of groundwater flow, on the other hand, are typically developed to capture monthly or annual processes and often cannot accommodate the fine-scale time frame of surface water flows (especially flood flows).

While there has been "convergence" in the technical coupling of groundwater and surface water models, the issues of model accuracy and precision are still relevant in selecting technical approaches to specific problems or settings. While these new models have improved the precision of calculations, the accuracy of model predictions are still founded on first principles, availability of data, and objectives of the analysis.

PLANNING CONSIDERATIONS

Definitions and Questions

SGMA carefully attempts to emphasize local management leaves open a number of issues for resolution in the context of stakeholder discussions.

- Avoiding a blanket prescription of specific sustainability goals;
- Allowing for local discussion and definition of what constitutes "reasonable and significant" with respect to undesirable results; and
- Providing a baseline for evaluating undesirable results, but stating that "*The plan may, but is not required to, address undesirable results that occurred before, and have not been corrected by, January 1, 2015*"

DWR provides clarification about interconnectivity in the Groundwater Sustainability Plan Emergency Regulations adopted in June 2016. These Emergency Regulations define two terms that will guide development of GSPs in the content of groundwater and surface water interconnectivity (Article 2, Definitions):

- *(m) "Groundwater dependent ecosystem" refers to ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface.*
- *(o) "Interconnected surface water" refers to surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted.*

SGMA will generate a number of questions and concerns that undoubtedly will arise regarding the issue of interconnected groundwater and surface water. The definitions provided by DWR in and of themselves generate some fundamental questions:

- Groundwater dependent ecosystems appear to be defined as aquatic ecological communities that are in a gaining condition (where groundwater is "emerging" to the ecosystem). Does this mean that ecosystems in "losing" condition (where surface water is discharging to groundwater) do not need to be analyzed? There are likely to be situations where groundwater pumping would increase the amount of water that is discharging from surface water to groundwater, possibly impacting ecological communities.
- Interconnected surface water is defined as surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted. Here, the definition of the baseline condition comes into play. Does this mean that surface waters that had become "disconnected" from groundwater in 2015 (perhaps temporarily) are exempt from analysis? Does this exempt surface waters that had become "completely depleted" in 2015?

These are important framing questions that GSAs will need to discuss and resolve in the context of defining sustainability goals and setting thresholds for management that do not cause significant and unreasonable undesirable effects. In a more technical context, GSAs will be considering questions such as:

- Should streamflow effects be expressed as a percentage of streamflow or should other ecologic and hydrologic metrics be considered, such as stream depth, statistical variability, or weighted usable habitat area?
- Should streamflow effects be analyzed in a steady state or transient analysis? Transient (i.e. time-varying) analyses are valuable because they can address both seasonal-scale lag time of pumping effects from a well (or series of wells) and cumulative carryover effects on the entire system from year to year.
- How should issues of accuracy and precision (both spatial and temporal) be addressed for surface water analysis as compared to groundwater?

These issues, and others, will influence how analyses in GSPs are integrated and interpreted by both water managers and water users.

Fisheries Management

Fishery agencies (California Department of Fish and Wildlife, U.S. Fish and Wildlife Service, Natural Marine Fisheries Service / NOAA Fisheries) are tasked with managing actions to protect fishery resources. Historically such actions have included regulatory restrictions on release of water from reservoirs, restrictions on surface water diversions, and other actions to protect or improve habitat conditions. In some cases, such regulatory restrictions are embodied in regulatory actions by the State Water Resources Control Board, through terms and conditions on permitted surface water rights. To date, most restrictions have been driven by the California Endangered Species Act, Federal Endangered Species Act, California Environmental Quality Act (CEQA), and National Environmental Policy Act (NEPA), tailored to each species listed under these Acts and the current conditions of species populations, habitats and threats. For example, the National Marine Fisheries Service Final Recovery Plan for winter-run, spring-run and steelhead (NMFS, 2014) contains extensive analysis and actions addressing key life stages and ecosystem indicators.

Habitat restoration and fish passage improvements are important elements of most fisheries management programs and are (relatively speaking) simple to propose and develop. In-stream flow provisions are also important aspects of fisheries management, but can be more difficult to propose and develop because of water rights, which have an established legal standing that can be very complex to resolve in the context of competing beneficial uses.

An early indication of how these fishery agencies might approach the interconnection issues is review of what SGMA describes as “Alternative Submittals” (hereinafter referred to as Alternative Plans). Alternative Plan requirements are set forth in SGMA[8] and had a due date of January 1, 2017. This provision is in SGMA presumably to allow

[8] California Water Code Section 10733.6.

early compliance with aspects of SGMA requirements for already well-managed basins, in lieu of a SGMA GSP. The abbreviated general requirement for Alternative Plans is to show "An analysis of basin conditions that demonstrates that the basin has operated within its sustainable yield over a period of at least 10 years". Alternative Plans were subject to a public comment period that ended in April 2017. Although DWR has not specified its timeline for reviewing these alternative plans, the intent is to review them in accordance with the requirements of a SGMA GSP. Of the 24 Alternative Plans submitted to DWR, six of them received comments related to surface water depletion and fisheries. Both the California Department of Fish and Wildlife (CDFW) and the National Marine Fisheries Service (NMFS) submitted comments on Alternative Plans.

Both CDFW and NMFS asserted that the analyses presented in several of the Alternative Plans were not sufficient to demonstrate the absence of undesirable effects. This theme was echoed in other comments. Lack of a surface water/groundwater model is also suggested as a limitation to the analyses. NMFS also expressed concern in one instance that protection of fisheries was not explicitly stated as a management goal and that some management strategies did not leverage existing tools developed to address fisheries protection. It is likely that any basin with established or sensitive aquatic ecosystems is likely to be scrutinized by fisheries agencies with respect to surface water depletion and potential effects of the GSP. However, it is not clear whether perceived deficiencies with respect to fisheries management in a GSP will become a basis for rejection by DWR.

Basin Management

GSPs will become another layer in an already complex overlay of water supply, water quality, land use, and economic development plans that are constantly being developed, revised, or updated at the local, state and federal level. The preparation of each GSP will involve public input, with some expectation that this process will generate extensive dialogue among a wide variety of interests. For those basins where the interconnection is at issue, the water management implications could be extensive. The implications of GSP actions will depend on the technical nature of the interconnections as well as the management goals, objectives and timelines established in the GSP. Similar to undesirable effects related to water quality, the difficulty will be in distinguishing SGMA-driven groundwater supply issues from other applicable planning and regulatory efforts. GSPs should not "re-invent the wheel".

Successful GSP implementation will require a robust and clearly described basin water balance to allow predictive tools to forecast the adequacy of possible water management actions that prevent undesirable effects related to streamflows. There will undoubtedly be uncertainties regarding both the baseline condition and the effects of proposed management actions. In many cases, adequate water balance information and predictive tools may not be available in many initial GSPs submitted in 2020/2022, and stakeholders should not expect full resolution of issues in the first iteration of planning. As DWR has indicated, this is a marathon, not a sprint. Even so, it is possible that some early water management actions related to streamflow management will be proposed in some basins.

One of the more obvious GSP management actions pertaining to streamflows would be related to siting and extraction limitations of wells near stream systems. How such water management actions would be implemented will test the GSP's institutional structure as well as the collaborative framework of groundwater users in the basin. GSPs are also required to address groundwater replenishment actions, to the extent that additional replenishment can help establish a sustainable groundwater balance and address all categories of "undesirable results". A concern raised by several water managers early in SGMA implementation (Personal Communication, May 2015) is that additional diversion of stream flood flows to replenish groundwater basins could be restricted by fishery agencies to protect stream habitat and maintain hydrologic function during higher flow periods. In discussions at that time, the frustration by water managers is that they might be prevented from protecting future stream flows through additional replenishment, in order to protect then-current stream flows. This concern seems to be grounded in the current regulatory framework that focuses on current-year fisheries conditions and does not necessarily consider implications to future conditions. The concept of adaptive management may prove to be crucial in addressing these issues and will require collaboration and trust among all stakeholders.

The Long View of Impacts is Important

Whether it is water or fishery management actions, the long view is essential. SGMA requires that groundwater basins be sustainable, which is a long-term concept. While designing GSP actions to avoid undesirable results is essentially a compliance concept, it also should take the long view into account, particularly with respect to surface water depletion as the effects of compliance or non-compliance with regards to fisheries and aquatic ecosystems do not appear immediately. This will require a different approach to management, particularly by stakeholders and agencies that typically respond and take actions year-by-year.

One example illustrates the dilemma facing water users and fishery agencies: management actions that divert additional surface water resources to replenish groundwater and prevent further impacts to stream resources. This potentially conflicts with the practice of fishery agencies to manage resources on an annual basis, looking primarily at impacts of potential water management actions on fishery resources in the year that it occurs. This historical approach could make it difficult for water agencies to acquire water rights to divert additional surface water unless and until the fishery agencies and the State Water Resources Control Board (California's agency regulating surface water rights) more clearly recognizes how SGMA's dual objectives of replenishing groundwater and avoiding stream resources impacts will work together. In many cases, the potential impacts of streamflow diversion on current fish populations will need to be weighed against the potential benefit to future fish populations from enhanced groundwater conditions.

If adequate institutional protections can be put in place, it seems appropriate that additional surface water diverted in wetter years and during spring freshets to replenish groundwater could be viewed by all parties as one action helping to avoid future stream resource impacts. If properly designed, the range of variability and hydrologic function of a stream system can still be preserved while putting more surface water to work in the form of groundwater recharge. The idea is to establish a new equilibrium over time that benefits both groundwater and surface water and supports all beneficial uses. This is what we refer to as the "long view".

IMPLICATIONS OF GROUNDWATER SUSTAINABILITY PLANS

As California begins to craft GSPs in many regions and institutional settings across the state, the implications of these plans on both the policy and technical approaches to water management will not be known for years, or perhaps decades. By more explicitly including groundwater into overall management considerations, the scope of watershed-scale hydrologic analysis will increase. SGMA's emphasis on local management responsibility indicates an effort to establish a framework for sustainable management in a local context, which creates opportunities and challenges.

- The ability of stakeholder groups to work together collaboratively and constructively during GSP development will "set the tone" for both implementation and the long-term outcomes in these basins.
- The ability of technical staff and consultants to clearly and concisely explain both the complexity and simplicity of various hydrological processes will shape attitudes and create intuition on the importance of groundwater
- The ability of stakeholders to resolve real and/or perceived water right issues through the GSP process could create new ways to address water management conflict that do not rely on courts.

There are a number of open technical (and to some extent policy) issues that will need to be addressed as GSPs are developed. In addition, it will be essential to see how DWR applies its GSP regulations, with the first opportunity DWR's review of "alternative plans" which are required to be in substantial compliance with the topics covered in the GSP regulations. The authors expect some initial DWR reviews of alternative plans to be released in the first half of next year. The open technical issues include, but are not limited to:

- Judging the adequacy of forecasting tools for sustainable groundwater management, recognizing that this is likely to vary from basin to basin and improve over time
- Judging when data is adequate to support modeling forecasts of sustainable groundwater conditions
- Determination of when a GSP is complete enough to meet the requirement of addressing the surface water interconnection issues and satisfy issues pertaining to aquatic ecosystems and fish habitat

CONCLUSIONS

Groundwater interconnections with stream systems, as they will need to be addressed in many groundwater sustainability plans, have important implications to water and fishery managers. Since the consequences to water and fishery resources are so important, it is essential to have a combination of adequate data, water balance and predictive tools in place before resource actions are taken. GSPs will need to address the groundwater / surface water interconnection “undesirable result” category (and in fact, each of the six categories) in sufficient detail to determine which are “significant” and “unreasonable” enough to cross a threshold of importance, based on a combination of available data and tools as well as SGMA regulations and DWR Best Management Practices documents.

A long-term view is essential to assuring that groundwater basins are sustainable, and “undesirable results” are avoided. We should not expect full resolution of all issues in the initial GSPs, and it may take several GSP iterations to fully address all management issues (both water and fisheries) to assure sustainability. SGMA has a 20-year implementation horizon for achieving sustainability, basin-by-basin, with the anticipation that implementation will be phased as data, tools and actions are developed. Further, each GSP will need to show that it will achieve sustainability over the next 50 years. The door needs to be open for early management actions. This has implications to water managers, regulatory agencies, local government and the decision process to be put in place by groundwater sustainability agencies to implement groundwater sustainability plans.

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DWR, BMP 1: Monitoring Protocols, Standards, and Sites

DWR, BMP 2: Monitoring Networks and Identification of Data Gaps

DWR, BMP 3: Hydrogeologic Conceptual Model

DWR, BMP 4: Water Budget

DWR, BMP 5: Modeling

State of California, various sections of California Water Code

U.S. Geological Survey Circular 1139, “Ground Water and Surface Water, A Single Resource”, Denver, Colorado 1998

IRRIGATION WATER GOVERNANCE AND GROUND WATER MODELING IN ONTARIO CANADA

Rebecca Shortt, P.Eng.[1]

ABSTRACT

Groundwater management through a permitting system has been in place in Ontario since 1963. The basis of the legislation is riparian rights with a mandate to not impact other users or the natural environment. Any person seeking to take greater than 50,000L on any one day must apply for a permit from the provincial government. Since 2005 all proponents of water-taking proposals (including irrigation) must demonstrate (through a formal study by a qualified professional) that the proposed taking will not impact other users or the natural environment.

Since 2000 the province of Ontario, Canada has invested in significant groundwater studies (both quantity and quality) to assess the risks to municipal drinking water supplies. The studies produced by these assessments have generated significant knowledge capital which has the potential to be used by farmers seeking to invest in groundwater irrigation supplies. The Grand River Conservation Authority (GRCA) used the generated aquifer yields along with climate change forecasts to outline potential scenarios for increased withdrawals of groundwater for irrigation. The study results show that for many of the sub watersheds groundwater is available for irrigation expansion. The Grand River Watershed covers 680,000 ha of which 70% is agricultural land. Less than 1% of the total watershed area is currently irrigated. This paper will incorporate the results of a paper by Shifflett et al from the GRCA and present it in the context of the *Ontario Water Resources Act,* 1990, which is the basis of the permitting system.

Through the discussion, the paper will examine the tension between the benefits to private enterprise (irrigator) and the public interest in maintaining a strong agricultural sector. Where should the costs of good water management fall?

INTRODUCTION

The province of Ontario, has a long history of both surface and ground water permitting through legislation based on riparian rights. This paper will examine the system particularly with respect to managing groundwater and explore some challenging questions.

The water permitting process was established in Ontario in 1963 through the Ontario Water Resources Act and associated regulations. The act states that "no person shall withdraw more than 50,000 L/day (~1/2 acre-inch or 27,160 US gal) of water without a permit from the director". This applies to all water supplies, both surface and

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groundwater. The requirement applies to all users, including farmers, municipalities, water bottlers, golf courses, industries, etc., however some exceptions apply. Personal household use, firefighting and livestock watering are exempt from the permitting requirement. Recently the Act was updated to include these exempted uses in some cases, to be consistent with Ontario's commitments under the Great Lakes-St. Laurence River Basin Sustainable Water Resources Agreement (formerly known as the Great Lakes Charter).

Individual Permit to Take Water (PTTW) holders are required by the legislation to record their takings on a daily basis and to report these daily totals to the Ministry of Environment and Climate Change (MOECC) at the end of each year.

Irrigation in Ontario is used on less than 2% of cropped land because of the generally humid climate. This represents in drought years, approximately 150,000 acres irrigated. However irrigation is important for production of high value crops (tobacco, potatoes, vegetables, fruit and ornamentals) particularly on sandy soils. Irrigation, even in limited quantities, requires large volumes of water as compared to many other uses such as industrial or municipal.

Irrigation in Ontario is primarily done by traveling guns and drip irrigation systems. Irrigated production is located primarily in southwestern Ontario, along the north shore of Lake Erie and west of Lake Simcoe.

DISCUSSION

Historically most conflicts around irrigation water taking have occurred in between irrigators or between irrigators and the natural environment. There are few instances in Ontario where irrigation and municipal/industrial takings are strongly hydrologically connected. The majority (>96%) of irrigation water used in Ontario is sourced on the farmer's property or near to the farmer's property (ground water pond, stream, well, runoff pond). Only 2 large communal water distribution systems exist in the province which serve a total of 5,500 acres. Because most irrigators are not serviced by a communal water distribution system, the individual farmers interact directly with the Ministry of Environment and Climate Change (MOECC) for their Permit To Take Water (PTTW).

PTTWs are issued where the proponent (irrigator) can demonstrate that the proposed taking will not impact other users or the natural environment. This demonstration must be done at the farmer's cost, by a qualified professional, and a formal report must accompany the PTTW application (some specific cases where impact from pumping is unlikely are described in the Act and are exempt from this level of demonstration).

Some of the key challenges with this system are as follows:

- What level of study is required to satisfy the requirements of protecting the natural environment and other users?

- How to do a water taking impact study in an area where very little ground water or surface water data is available (common in rural Ontario). Is the farmer expected to develop stream flow or aquifer yield data?
- Farmers may not be adept at managing hydrological/environmental consulting contracts (Cost ranges $5K-$50K)

The MOECC, responsible for this regulation, has developed technical guides for consultants outlining the requirements for both surface water and ground water impact studies.

Another key question is what level of impact is acceptable? Small takings from large sources will have almost no potential for impact. However as the rate of taking approaches the flow or yield of the source, at what point is the impact unacceptable? For surface water takings PTTW are often denied if the taking exceeds 10% of the 7Q20.

Six of the past 20 years have had low precipitation (drought) which has led to water shortages in a few watersheds. Big Creek, Big Otter Creek, Catfish Creek, Whitemans Creek and Innisfil Creek are heavily used natural streams (no level control or augmentation). Each of these creeks has between 100 to over 1,000 agricultural takers. Each of these creeks are also partly ground water fed and support, to greater or lesser degrees, populations of cold water fish. The primary water conflicts in dry summers exist between agricultural irrigation takers (who want to increase their takings because of the drought) and the natural environment (fish and other aquatic life, stressed because of already low water levels). Most agricultural water takers in these sub watersheds withdraw water either directly from the creeks (or their tributaries) or from shallow groundwater (either sand points or ground water fed ponds). In many of these sub watersheds, irrigators have been encouraged to develop alternative water sources, either from the shallow ground water or deep ground water. The objective has been to decrease the amount of direct stream takings by reducing or eliminating the dependence of irrigators on direct stream takings during periods of low water (drought).

The Grand River Conservation Authority (GRCA), responsible for a large watershed (680,000 ha) draining into Lake Erie (Fig. 1), undertook a study to determine the feasibility of more irrigation takings from groundwater. This addressed potential expansion of irrigation both in Whiteman’s Creek, an already heavily irrigated sub watershed, as well as other sub watersheds which currently have few irrigators. Seventy percent of the watershed is agricultural land, however less than 1% of that land is currently irrigated.

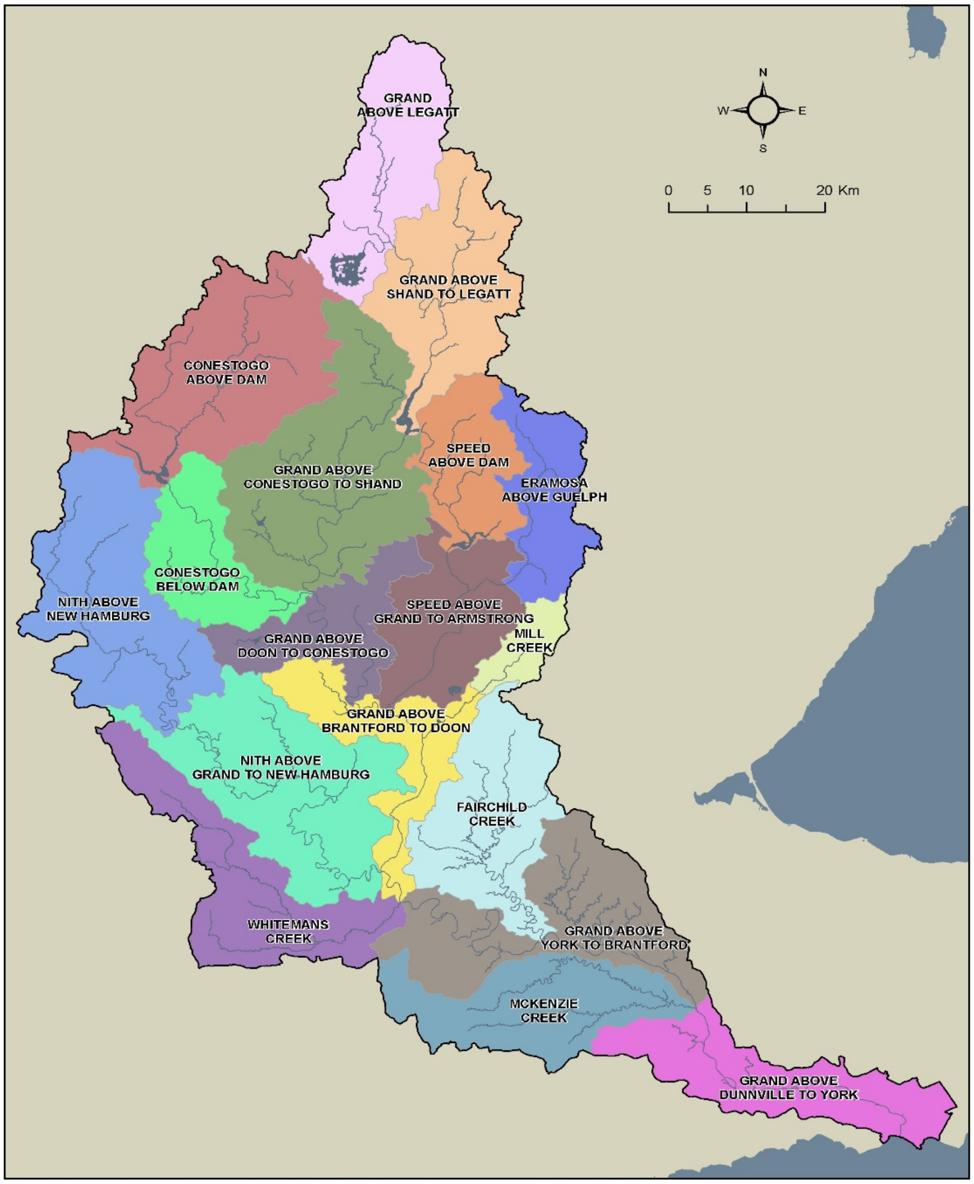

Figure 1. Subwatersheds in the Grand River watershed

Since 2000 the province of Ontario, has invested in significant groundwater studies (both quantity and quality) to assess the risks to municipal drinking water supplies (Drinking Water Source Protection). The GRCA used the generated aquifer yields along with climate change forecasts to outline potential scenarios for increased withdrawals of groundwater for irrigation. The study results show that for many of the sub watersheds groundwater is available for irrigation expansion.

Five scenarios of progressively more irrigated production were assessed where irrigated area across the watershed was: similar to current (scenario 1), increased by 10% (scenario 2a), increased by 25% (scenario 2b), 10% of sandy soils (scenario 3a) and 5% of all cropland (scenario 3b).

Following this 2014 investigation, the GRCA received approval and funding to complete a more in-depth study in the Whitemans Creek sub-watershed. The study objective was to assess the groundwater supplies for two small municipal systems (Village of Bright and Bethel Road wellfield for the Town of Paris). However the study included an exhaustive analysis of the extensive irrigation takings. Additional provincial funding was received to include investigating the complexities around these takings and the environmentally sensitive cold water fishery.

The study was conducted by EarthFX, a consulting firm specializing in integrated surface water/groundwater modelling. The consultant developed a GSFLOW model which will be used for the sub watershed risk assessment. The model includes an extended irrigation demand module to evaluate current and future irrigation water demand scenarios. Results of the assessment are still pending.

CONCLUSION

While studies and results such as these are very positive for irrigated production in this area, there remains the challenge for the rest of the province to understand ground water supplies and future irrigation opportunities. Information and models developed through other Municipal Groundwater Studies can be leveraged as done in the GRCA to identify places for irrigation expansion and support PTTW applications. However, site specific studies in support of PTTW applications remain a significant cost of a water supply development project.

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A PERSPECTIVE ON THE POTENTIAL AGRICULTURAL IMPACTS OF THE SUSTAINABLE GROUNDWATER MANAGEMENT ACT OF 2014

Steven R. Knell, P.E.[1]

ABSTRACT

The Sustainable Groundwater Management Act of 2014 (SGMA) will have a profound impact on agriculture in California. The extent and breadth of these impacts has yet to be played out but they will assuredly exert challenges to California agriculture politically, financially and as an agricultural producer of commodities that feed our nation.

The magnitude of those challenges will be felt differently depending on the location and access to surface water for agricultural producers. In Stanislaus County there appear to be three broad "camps" developing with regard to surface water access.

Camp 1 are agricultural lands that reside within the boundaries of an irrigation district. These districts have good surface water supplies through development and perfection of senior water rights on the eastside of the San Joaquin Valley making for limited reliance or need on the use of groundwater in meeting crop water demands in their service areas.

Camp 2 are agricultural lands that have access to surface water supplies in most years but may rely on groundwater at various times to meet crop water demand. These lands are predominately State and Federal Water Contractors on the westside of the San Joaquin Valley and south of the delta. They have unfortunately gravitated to this position due to the loss of about 1.3 million acre feet of water supply from their renegotiation of their federal and state contracts to meet delta environmental demands. These agricultural lands may look to Camp 1 lands to firm up some of their surface water shortfalls.

Camp 3 is comprised of agricultural lands that lie wholly outside of an irrigation district and have no surface water access. A large part of these lands are now permanent crops developed generally on rangelands in the eastern foothills of the Central Valley that had never been irrigated and are wholly dependent on groundwater to meet their needs.

Both the Modesto and Tuolumne Groundwater subbasins were prioritized as "high priority basins" and thus subject to SGMA regulations, but unlike the rest of the basins in the Central Valley, are not categorized as "critically over-drafted basins."

As county agencies pursue compliance with the Sustainable Groundwater Management Act the discussions on impacts are beginning to take place. This paper will provide an early perspective regarding the politics and water challenges each camp may face in complying with SGMA.

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BACKGROUND

Oakdale Irrigation District

The Oakdale Irrigation District (OID) was organized on November 1, 1909, under the Wright Act. Today, the OID has a developed service area encompassing approximately 80,900 acres, of which an estimated 65,000 acres are irrigated producing a variety of agricultural crops, largely irrigated pasture, nut crops, corn (silage) and rice.

Approximately sixty percent of OID's service area lies south of the Stanislaus River and is within the Modesto Groundwater Subbasin. The remaining forty percent of the service area lies north of the Stanislaus River and is within the Eastern San Joaquin Groundwater Subbasin (Figure 1). OID operates and manages 27 agricultural deep wells and 43 reclamation pumps to supplement surface irrigation supplies, in addition to operating and maintaining 18 domestic wells. OID manages more groundwater well systems than any other single user within its service area, including the cities of Oakdale, Riverbank and Escalon combined.

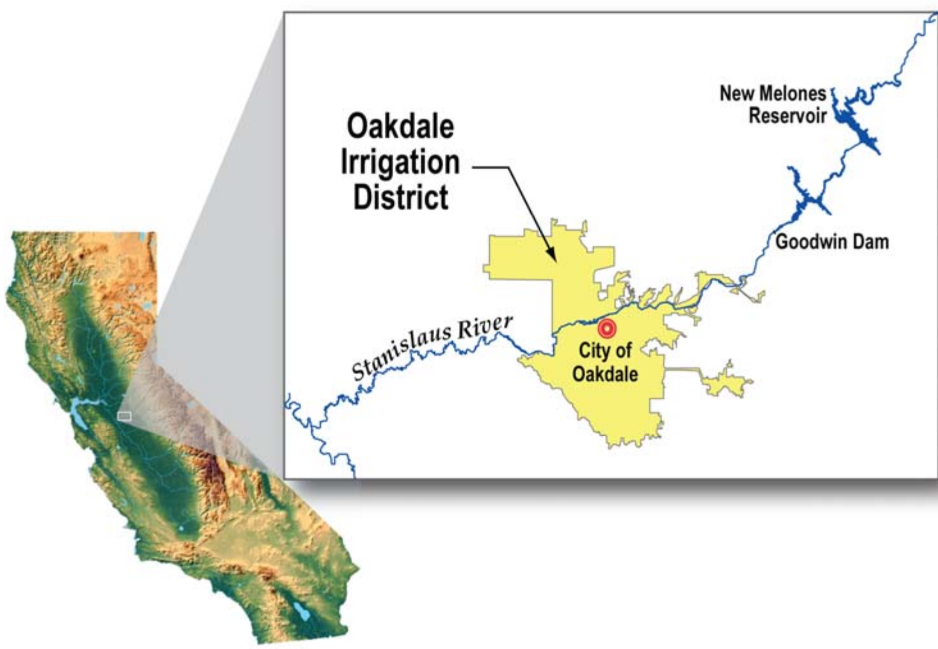

Figure 1. Location of Oakdale Irrigation District

GSA for Modesto Groundwater Subbasin

OID, in cooperation with other members of the Stanislaus and Tuolumne Rivers Groundwater Basin Association (STRGBA), developed an Integrated Regional Groundwater Management Plan (IRGMP) for the Modesto Subbasin in 2005 far before the enactment of SGMA. Early in May 2017, the members of STRGBA, that being

Modesto Irrigation District, Oakdale Irrigation District, the cities of Modesto, Riverbank, Oakdale, Waterford and the County of Stanislaus, submitted paperwork to the Department of Water Resources to be the representative Groundwater Sustainability Agency (GSA) for the Modesto Groundwater Subbasin, compliant with SGMA (Figure 2) . The next task of the GSA will be to develop a Groundwater Sustainability Plan (GSP) by 2022. The Modesto Subbasin is not a critically over-drafted basin but a high priority basin which allows an additional 2 years to the GSP deadline.

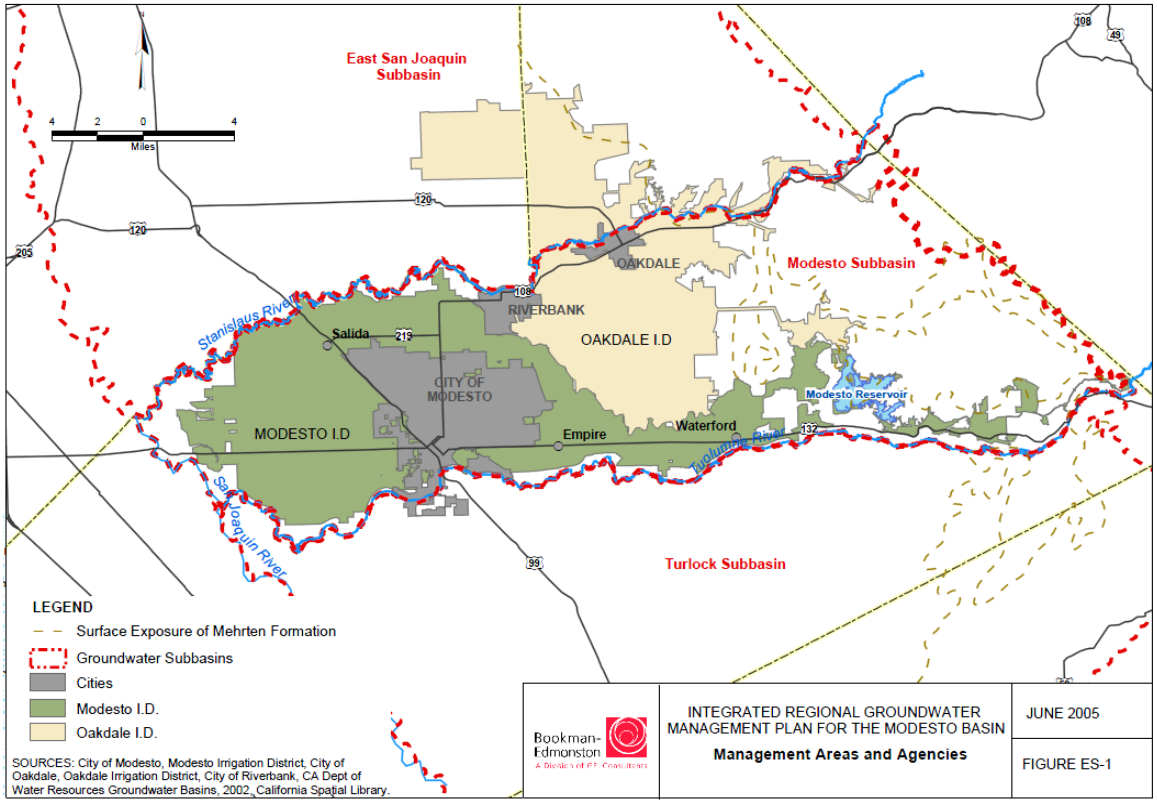

Figure 2. Modesto Subbasin

Extent and Importance of Groundwater

Water use in California today totals about 43 million acre feet (MAF) (USGS). The source of that supply is 28 MAF (66.6%) from surface water and 15 MAF (33.3%) from groundwater. Per the State's Department of Water Resources 2014 Drought Report, during times of drought, upwards of 60% of California's water supply can come from groundwater.

Agriculture's dependence on groundwater is significant and for good reason, groundwater is agriculture's primary tool for managing water supply volatility. Without groundwater to replace surface water in a drought, many agricultural lands in Camp 2, outlined in the Abstract, would experience significant crop cutbacks or impacts as a result of a water shortfall. Oddly, droughts don't impact Camp 3 lands as they pump 100% of the time, drought or no drought.

Groundwater Sustainability Management Act (SGMA)

The Water Education Foundation Layperson's Guide to Groundwater, has a great summary of the Sustainable Groundwater Management Act (SGMA). It states;

"SGMA took effect January 1, 2015, based on the tenet that sustainable groundwater management means meeting future needs while balancing the more immediate needs of the economy, environment and public health and safety. SGMA requires agencies in medium and high priority groundwater basins to form GSAs."

The diversity of each GSA structure has turned into a geo-political effort for some basins. For comparison; the Modesto Subbasin in Stanislaus County, except for a very small number of parcels in the far eastern area absorbed by Tuolumne County, is made up of one (1) GSA with 7 member agencies. In contrast, the Eastern San Joaquin Subbasin has sixteen (16) GSAs that have formed. All sixteen GSA's have agreed to manage the subbasin activities through a Joint Exercise of Powers Agreement.

Sustainability

Not a topic for detailed addressment in this paper but GSA's will be tasked to define specifically what "sustainability" means in their subbasin. DWR provides a broad definition of certain sustainability parameters, such as:

Sustainability goal: The existence and implementation of one or more groundwater sustainability plans that achieve sustainable groundwater management by identifying and effectuating the implementation of measures targeted to ensure that the applicable basin is operated within its sustainable yield.

Sustainable groundwater management: The management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results.

Sustainable yield: The maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus that can be withdrawn annually from a groundwater supply without causing an undesirable result.

If one views an underground aquifer as nothing more than a storage reservoir below ground the issue of sustainability becomes clearer. In reservoir management, the facility operator manages the inflows and outflows of the reservoir for long-term viability and predictability. In wet years, the reservoir is refilled as much as possible while taking advantage of the abundant water supplies. Conversely in drought, the management of reservoir outflows needs to occur in such a way to avoid a "crashing" of the system, at which point an empty reservoir serves no one's benefit. Management of a reservoir's downward trend in a dry year is done with the potential that successive or multiple dry years may occur. After all, this is California, and management of reservoir outflows to extend the drawdown of storage over multiple years is a good practice.

In broad terms, for an underground aquifer to be sustainable it will likely have a defined operating range. During dry cycles these aquifers will be drawn down to their lower operating range to meet water demands. During wet cycles these aquifers will be refilled to their upper operating range. The key to sustainability will be an operations plan that has the capacity to manage both the drawdown and refill of these underground reservoirs.

<u>Drawdown versus Refill Management Challenge</u>

Figure 3 reflects 24 deep wells of OID's that have been reported to DWR's California Statewide Groundwater Elevation Monitoring (CASGEM) program. The chart represents a 12 year period but it is the trend line to which I wish to focus the reader on.

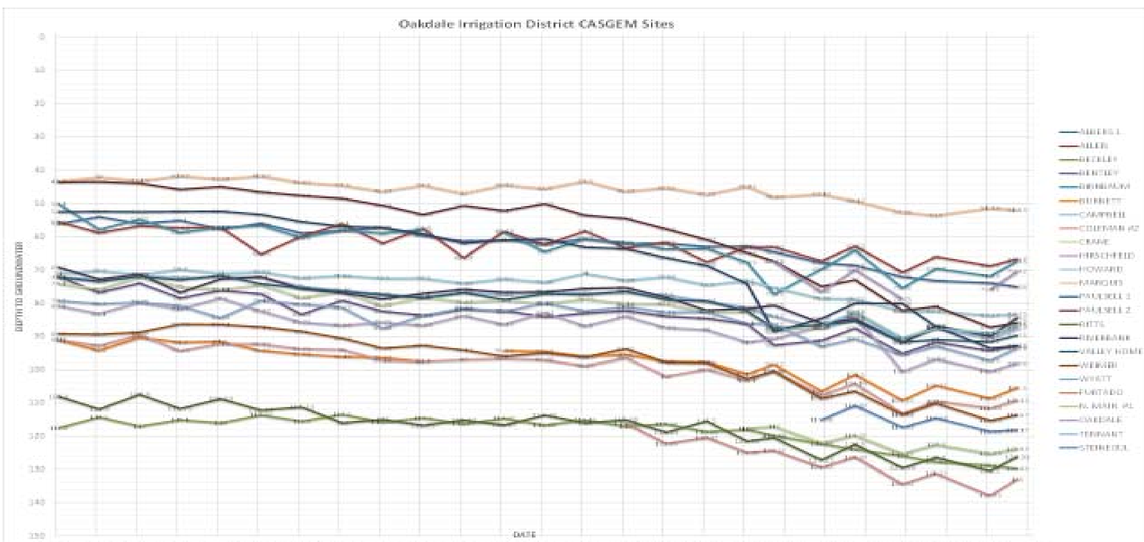

Figure 3. OID CASGEM Wells

Since the construction of OID's deep well system back in the mid-1940's and early 50's OID began monitoring the aquifer change at each well. The trend line over time has always been downward at a consistent decline of 0.5-0.75 feet per year.

A combination of two factors has increased that trend line to 1.0 foot per year since 2012. One factor is an extensive and historic drought and the second factor has been a boom of new orchards that have been planted in the eastern foothills. These are Camp 3 lands, all pumping groundwater. OID has estimated that over 36,000 acres of Camp 3 lands now exist to its east, extracting around 100,000 acre feet per year of groundwater. That's 100,000 acre feet from an aquifer that since 1940 has not shown signs of recovery or sustainability and adds significantly to the Modesto subbasin' s problems.

FINANCIAL IMPACTS OF SGMA

GSA Management Costs

Each GSA will incur management costs. The structure of a GSA staffing chart outlining that structure will depend on the management agencies of the GSA. What we can assume though is that "somebody" will be in charge. There will be data collection and this will involve field staff for that purpose. Since little information has been put together for the 127 defined alluvial groundwater basins in our State subject to SGMA, this job will be expensive. Most of California is at the infancy of its groundwater knowledge and this means lots of work to collect lots of information if the intent is to make good management decisions.

This data will need to be put into a working model or some analytical tool and digested for decision makers. Somebody has to manage this analytical tool. Somebody has to monitor water users and collect usage information and enforce compliance. Take all the above and potentially throw in a clerical person, some desks, chairs, computers, a couple of trucks, office rent and 60% labor overhead for public employees and your operating budget can easily get into the $1-$1.5 million range. How this annual operations cost will be funded and determining the appropriate contribution from each management agency will be a challenge.

GSP Management Costs

After GSA formation will come development of policy and operating procedures followed by development of compliance and enforcement regulations and other operating protocols. Once this administrative task is done, GSP development can begin.

Consultants will likely be brought in to do this heavy lifting. Modeling or other analytical tools will be used to provide the best project options for enhancing recharge. Once projects are selected, likely for a 5-10 year capital program a Programmatic Environmental Impact Report (PEIR) will be developed. OID went down this path for its Water Resource Plan in 2004-2006 and that cost was $1.7 million back then. Likely that cost will be closer to $2-$2.5 million and will take about the same time to complete. Spread that cost over 3-years and add it to the $1-$1.5 million annual operating budget and you have your near term "start-up" costs for the GSA.

Next you have to fund construction of these projects and the cost of capital works to achieve groundwater sustainability will be expensive. Southern California and areas in the eastern Los Angeles Basin have historically been ahead of the rest of the State in the area of recharge development.

A quick browse of websites shows the diverse extent of costs. The Chino Basin DYY Program Expansion Project developed costs for two recharge projects; (1) a basin recharge project and (2) an injection well project. Both designed to recharge 10,000 acre feet per year. The basin recharge project was $32 million on a 34 acre project site. The injection well project was $20.1 million on a 1.1 acre project site utilizing 11 injection wells. Not unexpectedly for the LA basin, land acquisition accounted for 50% of the project costs. Granted, in the Central Valley, land costs are much cheaper than south of the Tehachapi's but the population density in the Central Valley is much less and the actual per capita cost may not be that different.

The Stanford Woods Institute for the Environment looked at a host of different project types and estimated the cost variability for recharge projects at $90 - $1,100 per acre foot.

These are ballpark numbers at best but the point to be made is, the civil works necessary in each groundwater basin to enhance or improve recharge will be costly and additive to the administrative and program development costs.

Let's not forget the long-term annual operation and maintenance costs for these civil works. That aspect of a project, maintenance management, leads to another expense and another set of labor and equipment costs. Depending on the variability of the civil works to be managed, i.e. storm water conveyance and capture systems, percolation reservoir/systems, injection well systems, etc. will determine the extent of costs.

Apportioning Basin Costs of SGMA

So far the revenue centers from meeting SGMA compliance include;

- GSA Management
  - Administrative Staff
  - Engineering and Technical staff
  - Field Staff for data collection, monitoring and enforcement
- GSP Development
  - Planning and document development
  - Programmatic EIR to cover the impacts of the Plan
  - CEQA on each project that is built
- GSP Implementation
  - Civil Works that improve recharge
  - Management of pump reductions or in lieu recharge actions
  - Operation and Maintenance of civil works

Generating the revenues to fund the GSA management, GSP development and the implementation of GSP projects in a fair and equitable manner will be both challenging and political.

POLITICAL IMPACTS OF SGMA

When determining the mechanisms to assess new fees and/or taxes pursuant to the implementation of SGMA our hope as taxpayers is that it be fair and equitable. On that note, a couple of thoughts come to mind.

1. Having a sustainable groundwater system in the basin is a benefit to everyone. Therefore everyone should contribute to that benefit at "some" level.
2. There are those in the basin who get more of a benefit from or are more reliant upon pumping groundwater than others and as such, they should pay more.

Collectively these two thoughts lead to a "base rate" and "user rate" fee or taxing system for generating revenue, common in public sectors for utilities.

Base Rate

Mechanisms under a "base rate tax" or assessment include such things as a uniform property tax increase, either through a valuation system or a parcel tax. Another mechanism is a County Sales Tax increase wherein a portion of the added sales tax money is assigned to GSA funding. As a pass-through tourist county for Sierra recreational visitors, a sales tax increase has the distinction of generating some of that funding from non-residents.

Each one of these "taxes" would be subject to Proposition 218 approval by the voters of the County and that has its own challenges.

User Rate

Mechanisms for a "user rate tax" include such things as a fixed well head fee. Another option is a tax based on a per-acre-foot or million-gallon-a-day (MGD) usage of groundwater as measured through a metering system, etc. User rates, depending on what Camp they are in, have the greatest potential to bring politics into the picture because of the diverse nature of the users, as explained below.

User Off-Set Considerations

Camp 1 Assessment Considerations: As you recall, Camp 1 lands within the Modesto Subbasin include lands within the Modesto Irrigation District and the Oakdale Irrigation District. Each of the irrigation districts act politically as a unit representing their customers/constituents in the GSA. Both districts have water balances as outlined in their respective Ag Water Management Plans which show them to be net positive contributors to the aquifer. Meaning they put more water into the aquifer on an annual basis through canal leakage, agricultural deep percolation losses, drain losses, regulating reservoir losses, etc. than is extracted from the groundwater within their service areas. "Off-sets" on any well tax or pumping fees/taxes need to be a consideration when operating within an irrigation district. Those that contribute to the positive recharge of the basin should not be assessed at the same rate as those who mine the aquifer and provide no recharge.

Camp 2 Assessment Considerations: Camp 2 are agricultural lands that have access to surface water supplies in most years but may rely upon groundwater a portion of the time to meet crop water demand. In years in which ample surface water is available Camp 2 lands operate indistinguishable from Camp 1 lands. Their distribution systems and associated transmission losses contribute to aquifer recharge.

When water is in limited supply and groundwater pumping increases as a result, assessments should be proportionate to usage in those years.

Camp 3 Assessment Considerations: Camp 3 is comprised of agricultural lands that lie wholly outside an irrigation district and have no surface water access. As 100% extractors of water there is little opportunity for an off-set to costs.

Municipal (City) Assessment Considerations: Much like the different Camps of Ag lands, so go the Cities. For instance the cities of Oakdale, Waterford and Riverbank are 100% reliant on groundwater and provide no positive contribution to the aquifer. Modesto Irrigation District (MID) and the City of Modesto developed a cooperative service arrangement back in 1994. The City of Modesto and MID built a Water Treatment Plant and MID operates that plant providing about 50% of the City's water demand from MID's water right.

Assessments to cities who are 100% reliant on groundwater as compared to cities who have diversified systems of groundwater and surface water should likewise have a proportionate assessment scale to fund SGMA.

Politics of Resource Management

In hindsight, the unabated development of Camp 3 Ag lands, again those lands 100% reliant on groundwater, can be viewed today as a failed land use policy. It is these lands who have, to a large extent, created the overdraft conditions GSAs must now address in the Central Valley.

Unfortunately, as is becoming evident in the Southern Central Valley, the math is adding up to about a 3 million acre foot groundwater deficit that needs to be overcome. Just on the numbers, that's about 1 million acres of Ag ground that may need to be retired in order to offset that deficit. Many don't think that's going to be the end number but it gives pause for everyone to think about the Valley's future.

SGMA compliance in the Modesto Subbasin will face similar choices. In a review of the Urban Water Management Plan of each City in the subbasin and of the Ag Water Management Plan (AWMP) of each irrigation district, the total basin pumping draw on the underground aquifer is about 200,000 acre feet annually.

The two irrigation district and their ag water users, per AWMP data, put in about 80,000 acre feet in more recharge than their extractions, bringing the impact on the aquifer to about 120,000 acre feet annually (200,000 – 80,000). Approximately 60,000 acre feet of the remaining 120,000 acre feet of extractions is coming from the Camp 3 lands in the eastern basin. But for Camp 3 actions, groundwater sustainability in the subbasin would be within reach with existing water resources.

AGRICULTURAL IMPACTS FROM SGMA

There is not enough surface water available to make up for the groundwater demands that have been placed on the Valley's regional aquifers by agriculture. We would be shortsighted to not think that fallowing of lands will not somehow be a part of the solution as we move towards SGMA compliance. The southern Central Valley is already digesting this future even while in the early stages of GSA formation.

There will need to be a balancing act within the 3 Camps discussed in this paper. Camp 1 may have available surface water supplies after meeting its internal needs for SGMA compliance but how much is yet to be determined. Camp 2 lands have a variable need for surface water; maybe 0-1 acre foot in wet years and 2-3 acre foot in dry years. It's a doable but still uncertain future for them. Camp 3 lands, who need 3 acre feet each and every year will likely be hardest hit.

Other notable impacts to agriculture may include:

- A shift of agriculture from unsustainable or marginally sustainable basins to basins of greater sustainability.
- Land prices will be reflective of that shift.
- As the availability of water tightens we can expect the price of water on the market to rise substantially.
- Feed crops and forage crops will likely not be economical to grow in the Valley, thereby forcing those crops to be grown elsewhere and trucked in.
- The changing farm economics will likely firm up the growing of higher valued permanent crops in order to meet those changing economies.
- Land acquisitions by well financed or positioned farms will likely occur only to be fallowed for the use of their water allocation in maintaining their current operations.

Since agriculture is the economic driver of the San Joaquin Valley it can be most assured that every business sector will see some impact of SGMA in the coming years.

Our collective focus should be on working towards collaborative solutions and developing planning documents and innovative projects over the next 10-20 years that will minimize these impacts. Storm water capture and storage has served Southern California well and will be a likely asset in GSPs developed in our Sub-Basin. Similarly, reclaimed water use projects that take treated city water for use on Ag lands will also grow.

WATER QUALITY CONTROL PLAN FOR THE BAY-DELTA

The State Water Resources Control Board (SWB) initiated a Water Quality Control Plan (WQCP) for the Sacramento, San Joaquin Bay Delta in 2009. In October 2016, the SWB released a revised Draft WQCP and Substitute Environmental Document (SED). Comments on that document closed in January 2017.

The Draft WQCP/SED has the potential to have a major impact on the availability of surface water from the Stanislaus, Tuolumne and Merced Rivers by taking 40% of the unimpaired flow from February through June for the improvement of delta water quality and fisheries.

At a time when everyone is grappling with SGMA and groundwater sustainability issues, the State is proffering a plan to take substantial surface water resources out of the basin for environmental purposes. The State is taking two bits out of the Central Valley apple; taking 40% of the region's surface water resources while at the same time eliminating a key solution to solving its groundwater problems, that being recharge of available surface water supplies. The remnant options the State has left the Central Valley with are fallowing of Ag lands and economic ruin for communities dependent on an Ag economy. The State's answer to the outcry during the public comment period was to offer to the Central Valley that this is just a "significant and unavoidable impact" of the WQCP.

A legal remedy is likely the only course of action available to address the State's poorly prepared and single focused solution (i.e. taking water) to improving the delta environment. Unfortunately the legal route only adds water uncertainty for everyone for the next 8-10 years.

CONCLUSIONS

Achieving groundwater sustainability will be costly, it will be politically charged and lawsuits will likely be the norm in the short-term as we gravitate to finding fairness and equity in the solution. There will be economic pain as agriculture adjusts to a new paradigm of tightened water resources. All the while this is going on, the population will continue to grow and the ability to produce food for our nation will continue to be taxed. There is no clear certainty in the Central Valley's future under SGMA but hopefully with collaborative thinking, innovation and practical approaches we will reach effective solutions with the least impacts to our way of life.

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SUSTAINABLE GROUNDWATER MANAGEMENT – A COOPERATIVE AGREEMENT BETWEEN MODESTO IRRIGATION DISTRICT AND THE CITY OF MODESTO

Carrie Loschke[1]
John Mauterer[2]
John B. Davids, P.E.[3]
Gordon Enas, P.E.[4]

ABSTRACT

Faced with the pressures of increased residential and commercial development, the City of Modesto (City) and the Modesto Irrigation District (MID) have addressed their different but interconnected problems in the Modesto Sub-basin with a cooperative sustainable solution.

By the 1980s, the City faced a significant decline in the quality and quantity of its sole water supply, groundwater, and the City had few sustainable alternatives to meet its expanding water supply needs. MID, a historical surface water supplier for irrigation, shares the Modesto Sub-basin with the City, and was also faced with the consequences of the sub-basin's unsustainability. In 1992, the City and MID entered into a cooperative agreement by which MID would deliver up to approximately 33,000 acre-feet (AF) of treated surface water annually to the City through construction and operation of the Modesto Regional Water Treatment Plant (MRWTP). In late 1994, the MRWTP was completed and full production began in January of 1995.

Over the last twenty two years, approximately 700,000 AF of treated surface water has been delivered to the City. Absent this cooperative agreement, it is almost certain that this water would have come from groundwater supplies jeopardizing the long-term sustainability of the Modesto Sub-basin. The results - groundwater levels have rebounded nearly forty feet beneath the City, proof that pro-active, local cooperative agreements can work to achieve sustainable groundwater management. The City and MID have now built upon the success of Phase I with the recent completion of the Phase II Expansion project increasing the capacity for up to approximately 67,000 AF of treated surface water delivery on an annual basis.

Following passage of the Sustainable Groundwater Management Act in the fall of 2014, MID's experience with the MRWTP serves as compelling evidence that it is local cooperative agreements that will bring and maintain sustainability in sub-basins throughout the State.

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INTRODUCTION

Modesto Groundwater Sub-basin

The Modesto Groundwater Sub-basin as shown in Figure 1 is identified as sub-basin 5-22.02 in the State of California – Department of Water Resources (DWR) Bulletin 118 (Bulletin 118).[5] It has a surface area of approximately 250,000 acres and lies between the Stanislaus River to the north; the Tuolumne River to the south; the San Joaquin River to the west; and basement rock of the Sierra Nevada foothills to the east. The northern, western, and southern boundaries are shared with the Eastern San Joaquin, Delta-Mendota, and Turlock Groundwater Sub-basins, respectively.

The Modesto Groundwater Sub-basin is located in the northern portion of the San Joaquin Valley, a structural trough about 200 miles long and 70 miles wide. The valley is filled with up to 32,000 feet of marine and continental sediments deposited during its periodic inundation by the Pacific Ocean and erosion of the surrounding mountains, respectively. Only the upper 800 feet of these sediments contains water that is considered potable or suitable for agricultural and urban use. These sediments are generally categorized as consolidated and unconsolidated sediments, and are typically coarse-grained in the east and fine-grained to the west, having been deposited as coalescing alluvial fans by rivers originating in the Sierra Nevada Mountains. The sediment beds dip towards the west.

Local agencies in the Modesto Groundwater Sub-basin include the Modesto Irrigation District and the Oakdale Irrigation District; the cities of Modesto, Oakdale, Riverbank, Waterford; and Stanislaus County. The Stanislaus and Tuolumne Rivers Groundwater Basin Association (STRGBA) established in 1994 by nearly all of the local agencies within the Modesto Groundwater Sub-basin is the DWR-recognized groundwater monitoring entity under California Statewide Groundwater Elevation Monitoring Program (CASGEM).[6]

In September 2014, Governor Brown signed legislation known as the Sustainable Groundwater Management Act (SGMA)[7] . SGMA creates a framework for sustainable, local groundwater management which allows local agencies to develop groundwater sustainability plans tailored to regional economic and environmental needs. In 2017 STRGBA and Tuolumne County (who falls within the fringes of the Modesto Sub-Basin), officially filed notice with DWR to become Groundwater Sustainability Agency's (GSA's). STRGBA is now the exclusive GSA for that portion of the Modesto Sub-basin (DWR Basin No. 5-22.02) which falls within Stanislaus County.

[5] http://www.water.ca.gov/groundwater/bulletin118/update_2003.cfm
[6] Cal. Water Code §10920 et seq.; http://www.water.ca.gov/groundwater/casgem/
[7] http://www.water.ca.gov/groundwater/sgm/index.cfm

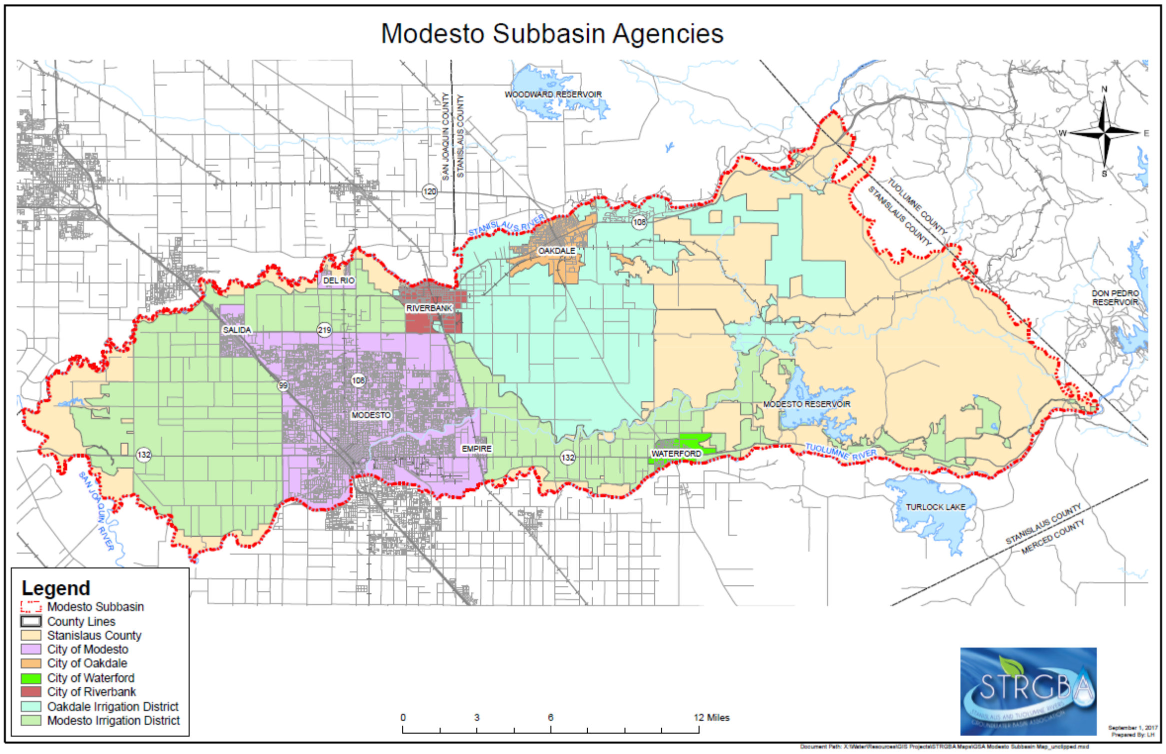

Figure 1. Modesto Groundwater Sub-Basin

Developed land uses within the Modesto Groundwater Sub-basin are concentrated in 2 major categories: irrigated agricultural and urban land uses. Bulletin 118 estimates the amount of groundwater stored within the Modesto Groundwater Sub-basin at approximately 5,000,000 AF. For the area underlying MID's and the City's service areas, over 60% of groundwater recharge occurs through surface water deliveries to irrigators.[8]

Modesto Irrigation District

The MID was organized in July 1887 under the California Irrigation District Law[9] by a vote of the local populace. MID is governed by a five-member, locally-elected Board of Directors and has been providing irrigation service since 1904, electric service since 1923, and wholesale domestic water service since 1994.

The MID is located in eastern Stanislaus County, California, in the northeast portion of the San Joaquin Valley. The irrigation and electrical service area comprises a 560 square mile area. MID has senior water rights to divert from the Tuolumne River, which has an annual average runoff of approximately 1,850,000 AF - varying between a low of 382,680 AF in 1977 to a high of 4,632,000 AF in 1983. MID policies and operations are tailored to account for this highly variable surface water supply. Additionally, MID

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[8] http://www.mid.org/water/gw/default.html
[9] Cal. Water Code § 20500 et seq.

operates approximately 100 groundwater wells (production and drainage) within the Modesto Groundwater Sub-basin to augment and/or complement the surface water supply. MID's drainage and production wells produce between 15,000 AF and 30,000 AF of additional supply each year.

MID irrigation infrastructure includes part ownership in a 2,030,000 AF multi-purpose storage reservoir and 168 megawatt hydroelectric facility, the New Don Pedro Dam and Reservoir; La Grange diversion dam, an earth and masonry dam first built in 1883; Modesto Reservoir with 28,000 AF of storage; the MRWTP, with a 30 plus million gallon per day (mgd) production capacity upgraded to approximately 60 mgd; approximately 100 groundwater wells; and approximately 208 miles of irrigation conveyance infrastructure.

The MID serves approximately 3,100 irrigation customer accounts; has an irrigation service area of approximately 100,000 acres; has an annual irrigated acreage of approximately 60,000 acres; and provides potable surface water on a wholesale basis to one customer, the City. Portions of the cities of Modesto and Riverbank as well as the communities of Waterford, Empire, Salida and parts of Del Rio are located within the District's service area.

City of Modesto

The City was incorporated in 1884 and occupies approximately 40 square miles (25,600 acres), most of which overlaps the District's irrigation service area, with a population of approximately 200,000. The City has been providing potable water service to its urban area since 1895 and is the largest retail water supplier in Stanislaus County. Until 1995, the sole source of water supplies to the City was groundwater from the Modesto and Turlock Groundwater Sub-basins. In 1995, the City began providing domestic water service to the communities of Waterford, Hickman, Del Rio, Empire, Salida, Grayson, and parts of Ceres and Turlock, and now serves approximately 260,000 domestic water customers.

City facilities include approximately 110 supply wells with a total production capacity of 110 mgd; a transmission and distribution system of approximately 940 miles of pipeline; 8 at-grade storage tanks with a total storage capacity of 12,100,000 gallons; and 2 wastewater treatment plants operating under National Pollutant Discharge Elimination System Permit no. CA0079103.

THE PROBLEM

Modesto Groundwater Sub-basin Conditions

Groundwater elevation measurements of the Modesto Groundwater Sub-basin date back to at least 1952.[10] By 1990, groundwater pumping exceeded recharge and localized

[10] Draft Environmental Report for the Modesto Surface Water Treatment Plant (October 1989), at page 4-26

groundwater levels in the sub-basin declined. Between approximately 1960 and 1990, groundwater levels in the Modesto Groundwater Sub-basin underlying the District and the City had declined by approximately 50 feet.

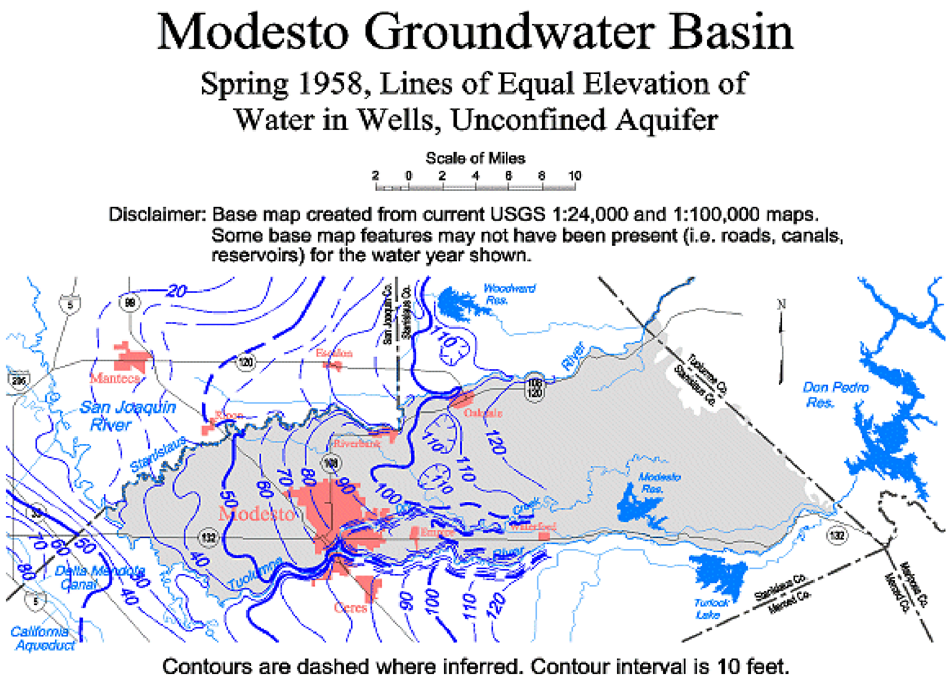

Figure 2. Modesto Sub-basin groundwater contour map (1958)

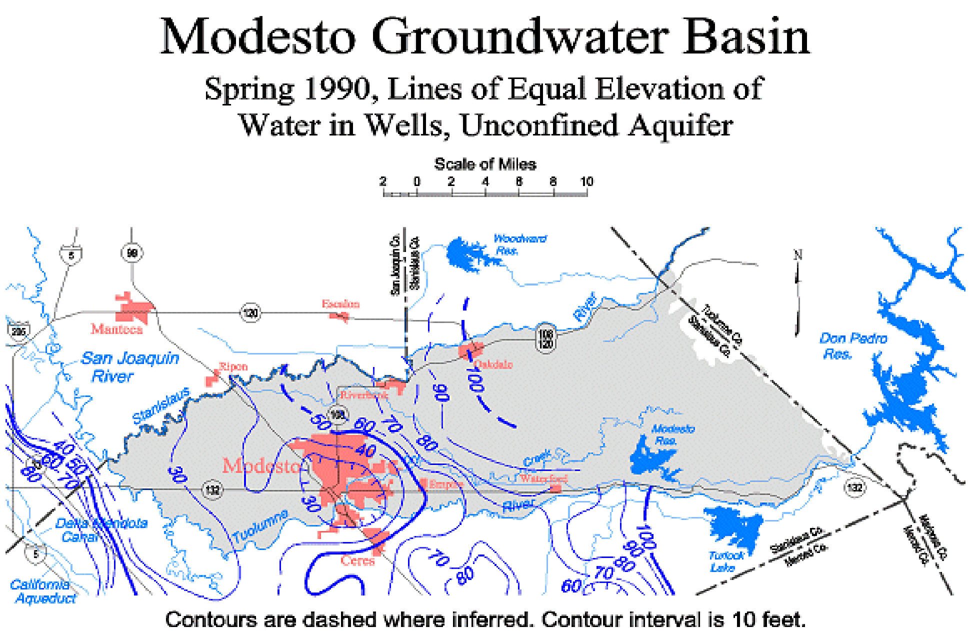

Figure 3. Modesto Sub-basin groundwater contour map (1990)[11]

[11]http://www.water.ca.gov/groundwater/data_and_monitoring/south_central_region/GroundwaterLevel/basin_contour.cfm?map=mode_e90.gif

By 1990 as shown in Figure 3, a significant cone of depression had developed under the City's downtown area. During the spring of 1983 (which was an unusually wet year), groundwater elevations varied from 35 feet above sea level in the center of the pumping depression to 60 feet above sea level along the northeastern boundary of the City's urban area. Depth to groundwater typically varied from 50 to 70 feet.[12]

In addition to the decline in groundwater level, the groundwater quality was also declining by the 1990's.[13] For example, Figure 4 includes summary data compiled in 1989 regarding the major inorganic constituents in the groundwater underlying the Modesto area.[14]

Table 4-4: GROUNDWATER QUALITY(a)

Area (Data Well)	Drinking Water Standards(b)	Maximum	Minimum	Average
MODESTO				
Nitrate	45	56	0.9	20
Sodium	20	195	8.5	46
Hardness	80-100	524	48	170
TDS	500	883	114	352
Chloride	250	395	7.0	55

Notes : (a) All measurements are shown in milligrams per liter (mg/l) and are based upon sampling records from 1966 to 1983.

(b) Nitrate standard is the only enforceable standard. All other values listed represent reasonable goals.

Source: Montgomery Engineers 1984

Figure 4. City of Modesto Water Quality Table (1984)

Between mid-1960 and 1990, the concentrations of these constituents steadily grew in a number of area wells.[15] Also by 1990, approximately 10 City wells had tested positive for synthetic organic compounds in excess of state action levels, forcing their closure until the levels were reduced.[16]

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[12] Draft Environmental Report for the Modesto Surface Water Treatment Plant (October 1989), at page 4-25

[13] Draft Environmental Report for the Modesto Surface Water Treatment Plant (October 1989), at page 2-1

[14] Draft Environmental Report for the Modesto Surface Water Treatment Plant (October 1989), Table 4-4 at page 4-28

[15] Draft Environmental Report for the Modesto Surface Water Treatment Plant (October 1989), at page 4-27

[16] Draft Environmental Report for the Modesto Surface Water Treatment Plant (October 1989), at page 4-27

City Groundwater Use

Groundwater pumping from the City urban area averaged approximately 44,000 AF between 1970 and 1990, and reached 57,000 AF by the mid-1990's.[17] In conjunction with the Del Este Water Company, which was ultimately acquired by the City in 1994, annual domestic water use in the area for the MRWTP was approximately 60,500 AF per year. The City commissioned the U.S. Geological Survey in 1971 to collect hydrologic data and develop a computer model of the groundwater system underlying the Modesto area.[18] The groundwater model indicated that groundwater levels underlying the urban area would continue to decline if no other source of water was developed.[19] At the time that the MRWTP was under consideration, the City anticipated that its water supply demands would increase to 80,000AF by 2020.[20]

The decline in water quality, combined with increasingly strict standards from state and federal regulators, have forced the City to take an average of 2.3 wells out of service each year from approximately 1990 to 2004. The City had a diminishing supply that required more expensive treatment in order to meet existing needs. Additionally, it needed to secure additional supply for the anticipated increase in demand.

District Groundwater Use

The primary source of recharge to the Modesto Groundwater Sub-basin occurs through agricultural irrigation using Tuolumne River surface water supplied by MID.[21] In addition to its normal surface water allotments and during times of additional available surface water, MID has historically administered an extensive conjunctive-use program with its irrigators whereby additional available surface water (over and above the base allotment) would be provided in an effort to further recharge groundwater aquifers. This conjunctive use program offsets the District's risk from the variable Tuolumne River supply.

The MID's then-assessment of the future of its supply "safety net," the conjunctive use program, was that the groundwater basin was in a state of decline and required action from the agencies that were, and are, dependent on the sub-basin's health. An unsustainably managed groundwater sub-basin wouldn't allow for the MID, or its irrigators, to sustainably utilize available groundwater resources during years of decreased surface water supply.

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[17] MRWTP Phase Two Expansion Draft Supplemental EIR (MID/COM, 2004), at page 3.4-2, citing to STRGBA (1995)
[18] Draft Environmental Report for the Modesto Surface Water Treatment Plant (October 1989), at page 2-4
[19] Draft Environmental Report for the Modesto Surface Water Treatment Plant (October 1989), at page 2-4
[20] Draft Environmental Report for the Modesto Surface Water Treatment Plant (October 1989), at page2-1; citing to Montgomery Engineers report (1989).
[21] http://www.mid.org/water/gw/default.html

THE SOLUTION

To responsibly address the sub-basin problems, MID, the City and a small investor-owned water utility, the Del Este Water Company, embarked upon a cooperative agreement.[22] The solution was an innovative conjunctive use program between the MID and the City.

The cooperative agreement, reflected in contract as the Treatment and Delivery Agreement (1992), required MID to construct and operate a 30 mgd surface water treatment plant to treat Tuolumne River water and allowed the City to "blend" the MID's high quality surface water with the City's blemished groundwater. The Treatment and Delivery Agreement provided for parity in cost and the annual quantity of delivered water as between the MID's agricultural and urban customers.

The MRWTP was designed to be constructed in 2 phases: the Phase One project that would treat approximately 30 mgd (33,600AF) annually, and the Phase Two project, in which MID would expand the MRWTP to treat approximately 60 mgd (67,200AF) annually.[23] Phase One included construction of the MRWTP, which is a complex of buildings, tanks, a laydown yard, parking areas and landscaping;[24] the Terminal Reservoir storage facility and pump station; and transmission pipeline from the MRWTP to the Terminal Reservoir/pump station. Phase Two included a 36 mgd submerged membrane treatment plant with flocculation and sedimentation treatment for the waste stream, four high service treated water pumps, additional pumping capacity and bypass operations at the Terminal Reservoir Pump Station and replacement of critical infrastructure of the Phase One systems which were at the end of their service life.

The MRWTP is governed by the Domestic Water Policy Committee (Policy Committee), which consists of 2 City Council members and 2 members from the MID Board of Directors. The Policy Committee oversees the management and operation of the MRWTP and meets at least twice each year but can, and has, met more often when significant projects are in process.[25]

The MRWTP's environmental review was performed by circulation and eventual adoption of a Draft Environmental Impact Report (October 1989) and then a Final Environmental Impact Report (March 1990).[26] Construction began in 1990; concluded by January 1995;[27] and full scale production deliveries began later that same year. The construction of Phase 2 was completed in 2016 and has just recently become fully operational.

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[22] Because Del Este Water Company was acquired by the City as a milestone of the contemplated conjunctive use program, DEWC's participation is acknowledged but will be treated as one-and-the-same as the City.

[23] MRWTP Phase Two Expansion Draft Supplemental EIR (MID/COM, 2004), at page 2-2

[24] MRWTP Phase Two Expansion Draft Supplemental EIR (MID/COM, 2004), at page 3.1-2

[25] http://www.mid.org/water/domestic/default.html

[26] Modesto Irrigation District Board Resolution 90-50

[27] Joint 2010 Urban Water Management Plan (District/City), at page 1-2

Today, the MID's efforts towards sustainable groundwater management are ever increasing. MID continues to own and operate approximately 100 wells for the benefit of its irrigators; utilizes conjunctive use programs with both MID irrigators and the City, which includes the MRWTP and plays an active role as a member of STRGBA-GSA for the Modesto Sub-basin.

Going forward, MID will continue to address the challenges of sustainable groundwater management, more generally, and the SGMA implementation, more specifically. The STRGBA-GSA will serve as the sub-basin's forum by which all the local agencies including MID can work together to establish a Groundwater Sustainability Plan, under the SGMA. Additionally, MID engages in cooperative efforts with neighboring sub-basin groundwater management efforts such as the East Turlock and West Turlock Groundwater Basin Associations and at a more regional level with the Stanislaus County Water Advisory Committee and Technical Advisory Committee (est. 2014).

The City's supply portfolio is approximately 48% surface water and approximately 52% groundwater,[28] with actual use of approximately 65,000 AF in 2010. The City continues seeking additional sources of supply. The MRWTP's Phase Two expansion is up and operating and expected to double the MRWTP's production capacity up to approximately 67,000 AF per year.

[28] Joint 2010 Urban Water Management Plan (District/City), at page ES-4

METRICS OF SUCCESS[29]

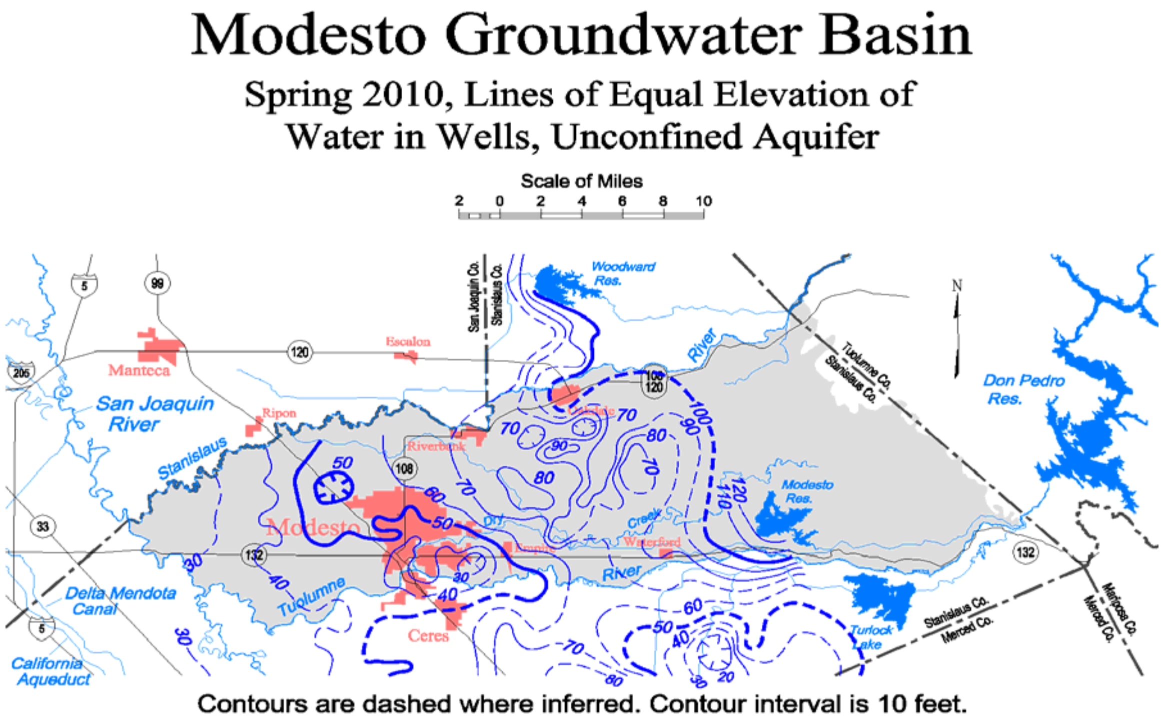

Figure 5. Modesto Sub-basin groundwater contour map (2010)

Success of Treatment Plant

The City's issues with groundwater quality had significantly improved by 2010 with only 21 out of 113 production wells taken out of service due to water quality issues. In addition to wellhead treatment, the City also coordinated its groundwater pumping so that it could "blend" MID's high quality surface water with the City's groundwater to dilute the contaminants and improve overall water quality for the City's customers.[30] Further, the City has implemented ongoing sampling and well monitoring programs as well as a capital program that requires water quality studies, the identification of new wells and a wellhead treatment program.[31]

The MID has been successful at meeting the supply needs of both the City with the MRWTP and its agricultural customers. The City has continued its growth pattern and, at least as of 2015, still projects its water demand to be approximately 69,500 AF by 2020.[32] Since the MRWTP has gone into service, the District has continued to provide uninterrupted irrigation service to its irrigators. To date, STRGBA's data gathering and

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[29]http://www.water.ca.gov/groundwater/data_and_monitoring/south_central_region/images/groundwater/mode_e10.gif
[30] Joint 2010 Urban Water Management Plan (District/City), at page 7-2
[31] Joint 2010 Urban Water Management Plan (District/City), at page 7-1
[32] Joint 2015 Urban Water Management Plan (District/City), at page 7-11

supply planning activities confirm the continued health of the groundwater basin and, by extension, the health of the MID's "safety net," the conjunctive use program with the irrigators.

The resilience of the Modesto Groundwater Sub-basin has proven itself to be an invaluable resource as California's epic drought lasted for five consecutive years (2011-2016). The City has implemented water use restrictions in accord with state law[33] but has otherwise provided uninterrupted municipal service to its customers. While the drought forced MID to reduce its historical irrigation allotment from 42 inches to 24 inches in 2014 to 16 inches for the 2015 season, MID and its irrigators have continued to operate by drawing upon the sustainable groundwater reserves maintained for such an occurrence.

Bulletin 118 showed groundwater levels in the Modesto Groundwater Sub-basin had declined nearly 15 feet between 1970 and 2000. Since the MRWTP came online in 1995, Bulletin 118 reports that groundwater levels in the Modesto Groundwater Sub-basin have risen approximately 6 feet from 1996 to 2000. Additionally, the 2010 groundwater contour map (Figure 5) reflects the healthier groundwater basin with a reversal of the cone of depression and restoration of subsurface flow paths under the City.

Factors of success

The cooperative agreement, manifested in the MRWTP and its related contracts, occurred because the decision makers had very practical understandings of the local needs. The routine water supply planning functions of MID and the City ensured that each would squarely face the challenge of groundwater sustainability and each party had the expertise and motivation to make prudent resource planning decisions.

Politically speaking, the decision makers behind the MRWTP, MID and the City, were directly elected by the ratepayers that would benefit from the cooperative agreement and pay for those benefits. There was a simplicity and "fairness" to the arrangement that dampened the type of local opposition that can often derail large water supply projects.

Perhaps most importantly, the historical proximity of the MID and the City allowed the parties to develop their sustainable groundwater management efforts more organically, to include the discussions and decisions through the 1980's leading up to the MRWTP, the establishment of STRGBA in 1994 and the STRGBA-GSA today. In this manner, groundwater sustainability efforts were appropriately paced to make the difficult but prudent decisions with all appropriate buy-in from necessary parties.

[33] 22 California Code of Regulations 863-866 (2015); State of California Office of the Governor Executive Order B-29-15

HOW THE MRWTP EXPERIENCE MAY INFORM SGMA IMPLENTATION

The recent drought, coupled with the passage of the SGMA, require the MID to presently address the same type of resource planning and analysis that it faced in the early 1990's. The following are important takeaways from the MRWTP experience that merit consideration in sustainable groundwater management discussions moving forward.

Don't recreate the wheel

The most critical factor to the success of the conjunctive use program and by extension the continued sustainability of the Modesto Groundwater Sub-basin, was that the local agencies already had well-established groundwater management organizations in place when important changes required action. For example, MID and the City had concluded all preliminary discussions, the contractual arrangement, and most of the MRWTP's construction of Phase I before the California Legislature passed AB 3030 (1992), which mandated the establishment of Groundwater Management Plans. As another example, STRGBA was established in 1994 and had been actively managing the Modesto Groundwater Sub-basin for almost a decade before the California Legislature passed the Integrated Regional Water Management Planning Act in 2002; SBX7-6 in 2009, which mandated participation in the statewide CASGEM program with DWR; and the SGMA in 2014. Each time a new set of groundwater laws or requirements have been adopted, MID's long-term investment in STRGBA activities have served it well as a firm foundation upon which to start compliance efforts. The passage of the SGMA has provided MID the latest opportunity to build off of the good work that's been going on in the Modesto Groundwater Sub-basin for the last 20-plus years.

Local agencies are best suited to create durable agreements

The contracts that drove construction of the MRWTP were possible because MID and the City were able to accurately align the benefitted parties, the burdened parties and the water supply provider. While the City's customers paid for the construction and currently pay for the operation of the MRWTP, they received a more sustainable water supply and a sustainably managed groundwater basin. The MID benefited from the rebounded health of the Modesto Groundwater Sub-basin allowing MID to maintain its conjunctive use program with its irrigators, which has proven to be a necessary "safety net" in prolonged periods of diminished surface water supply.

The MID's main lesson to apply to the SGMA implementation from the MRWTP experience is to "stay the course," which means to continue MID's significant investment in the gathering of technically sound science; significant coordination with existing local agencies within the community; and entering into long-term, prudent cooperative agreements as necessary.

GROUNDWATER MANAGEMENT IN YUBA COUNTY, CALIFORNIA

W. Martin Roche, P.E.[1]

ABSTRACT

Groundwater is a very important component of California's water supply. 85 percent of the population depends on groundwater for at least part of their water supply and over 5 million acres of land are irrigated with groundwater. The estimated groundwater storage capacity is estimated to be at least 10 times the storage capacity of surface reservoirs. Much of the groundwater capacity is in the Sacramento Valley of northern California, including the Yuba River Basin in Yuba County. The Yuba County Water Agency (YCWA) in coordination with the California Department of Water Resources (DWR) is managing groundwater in conjunction with its surface water supply from New Bullards Bar Reservoir on the Yuba River. Starting in 1991, water users within the YCWA service area increased groundwater pumping to allow YCWA to transfer surface water to users outside of the area. In 2005 the YCWA adopted a groundwater management plan to protect the safe yield of the North Yuba and South Yuba groundwater subbasins. YCWA is also engaged in the Yuba River Accord which allows it to operate in a way that protects fisheries and local water-supply reliability and provides revenues for local projects, as well as protecting fisheries in the Sacramento-San Joaquin Delta and improving state-wide water management.

In 2014 California's Governor Jerry Brown signed three bills that together form the Sustainable Groundwater Management Act (Act) to respond to concerns of groundwater overuse, to ensure reliability of groundwater resources, and to address the impact of climate change on California's water resources and economy.

This paper discusses the groundwater resources of the Sacramento Valley in general and Yuba County in more detail, the management of groundwater in conjunction with surface water by the YCWA, the development of Groundwater Sustainable Agencies in Yuba County as mandated by the Act, and the proposal to share revenues of water sales outside of the area made possible by conjunctive use with groundwater with all the citizens in Yuba County.

INTRODUCTION

Groundwater is a very important component of California's water supply. 85 percent of the population depends on groundwater for at least part of their water supply and over 5 million acres of land are irrigated with groundwater. The estimated groundwater storage capacity is estimated to be at least 10 times the storage capacity of surface reservoirs. Much of the groundwater capacity is in the Sacramento Valley of northern California, including the Yuba River Basin in Yuba County. The Yuba County Water Agency (YCWA) in coordination with the California Department of Water Resources (DWR) is managing groundwater in conjunction with its surface water supply from New Bullards

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Bar Reservoir on the Yuba River. Starting in 1991, water users within the YCWA service area increased groundwater pumping to allow YCWA to transfer surface water to users outside of the area. In 2005 the YCWA adopted a groundwater management plan to protect the safe yield of the North Yuba and South Yuba groundwater subbasins. YCWA is also engaged in the Yuba River Accord which allows it to operate in a way that protects fisheries and local water-supply reliability and provides revenues for local projects, as well as protecting fisheries in the Sacramento-San Joaquin Delta and improving state-wide water management.

GROUNDWATER IN THE SACRAMENTO VALLEY

The average annual runoff in the Sacramento River Basin is over 22 million acre-feet per year, over one third of the total runoff in all of California. The Sacramento Valley includes some of the foremost groundwater basins in the state, with good well yields and generally good water quality in most basins. During the years 2005 to 2010, over 2.7 million acre-feet of groundwater was used in the area, about 30% of the total water use. In addition to agricultural irrigation, many cities, including Sacramento, Chico, and Redding, obtain part or all of their water supply from groundwater. It appears that there is potential for much greater groundwater use in the Sacramento Valley.

YUBA COUNTY WATER AGENCY

The Yuba County Water Agency (YCWA) was formed in 1959 (Figure 1). Major facilities include the New Bullards Bar Dam and Reservoir on the North Yuba River, Our House Diversion Dam and Lohman Tunnel on the Middle Yuba River, Log Cabin Diversion Dam and Camptonville Tunnel on Oregon Creek, the New Colgate and New Narrows Power Plants, and five water conveyance facilities. The New Bullards Bar Reservoir has a capacity of just over 966,000 acre-feet with a flood control reservation of 170,000 acre-feet. The agency has contracts to supply a total of just over 343,000 acre-feet of water to eight irrigation districts and other water entities.

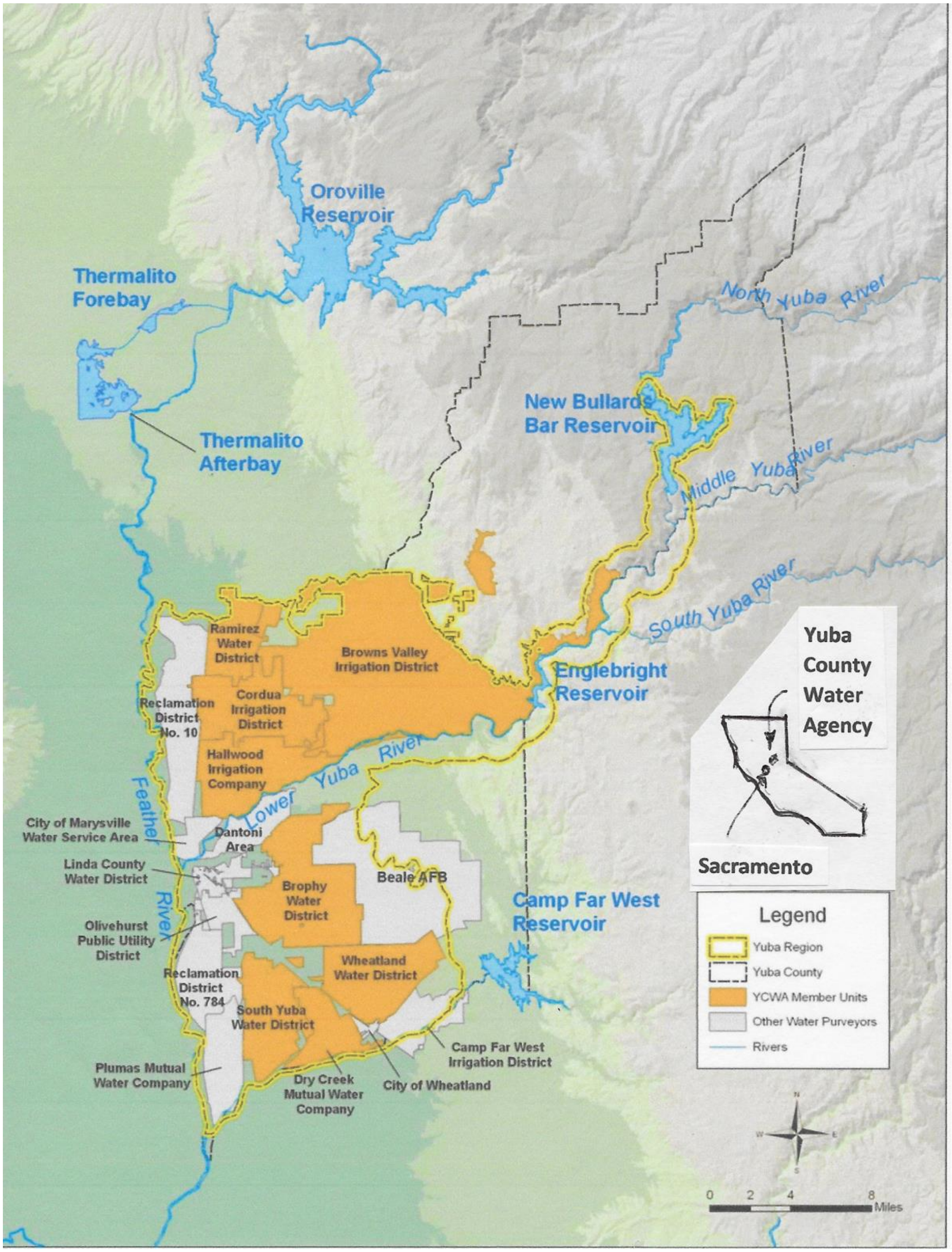

Figure 1. Yuba County Water Agency

GROUNDWATER MANAGEMENT IN YUBA COUNTY

The groundwater basin in Yuba County consists of two subbasins; the North Yuba subbasin north of the Yuba River and the South Yuba subbasin south of the Yuba River. All of the urban areas in the subbasins depend on pumping groundwater for their municipal and industrial water supply. These areas include Marysville, Olivehurst, Linda, Wheatland, and Beale Air Force Base.

Before 1960 the groundwater basin level in Yuba County was about 30 feet below the surface in the North Yuba subbasin and about 65 feet below the surface in the South Yuba subbasin. By the early 1980's surface water from the New Bullards Bar Reservoir used for irrigation had caused the water table level to rise to about 20 feet below the surface in the area over the North Yuba subbasin. In the area over the South Yuba subbasin, where surface water was not yet available for irrigation, the water table level had dropped to 110 feet below the surface (Figure 2). Since that time, development of the irrigation system to serve the area over the South Yuba subbasin has brought the water table level up about 90 feet, to about 20 feet below the ground surface (Figure 3). By 2005 the estimated increase in groundwater storage in the South Yuba subbasin has been estimated at over 360,000 acre-feet.

THE SUSTAINABLE GROUNDWATER MANAGEMENT ACT

In September 2014 Jerry Brown, the Governor of California, signed three bills which formed the Sustainable Groundwater Management Act (SGMA). The legislation resulted from growing concern throughout the state of overuse of groundwater, reliability of groundwater supply, the multiyear drought, and the potential impact of climate change. The SGMA recognizes that the sustainability of groundwater basins can be best managed by local and regional stakeholders. Of the over 500 groundwater basins in California, 127 basins are classified as high or medium priority, with 96 percent of groundwater use coming from these 127 basins. The North and South Yuba River subbasins are included in the medium category. A reevaluation of groundwater basins which have been modified is currently underway and may result in the North Yuba River Basin being reclassified as a low priority basin.

The legislation provides for the formation of Groundwater Sustainability Agencies (GSAs) to carry out effective local sustainable groundwater management. The formation of GSAs was scheduled to be completed by June 30, 2017. The GSAs will be tasked with developing Groundwater Sustainability Plans (GSPs) that will include a description of the geographic and institutional aspects of the GSA, a description of the physical setting and current conditions in the basin, goals, definitions, and criteria related to sustainable management in the basin, a monitoring program to show progress towards plan objectives, and a comprehensive plan of actions and projects that will be needed to meet the sustainability goals for the basin. Sustainability within each GSA must be reached within 20 years of the approval of the GSP. In Yuba County, the YCWA, the Cordua Irrigation District, and the City of Marysville have applied to the State of California to become GSAs.

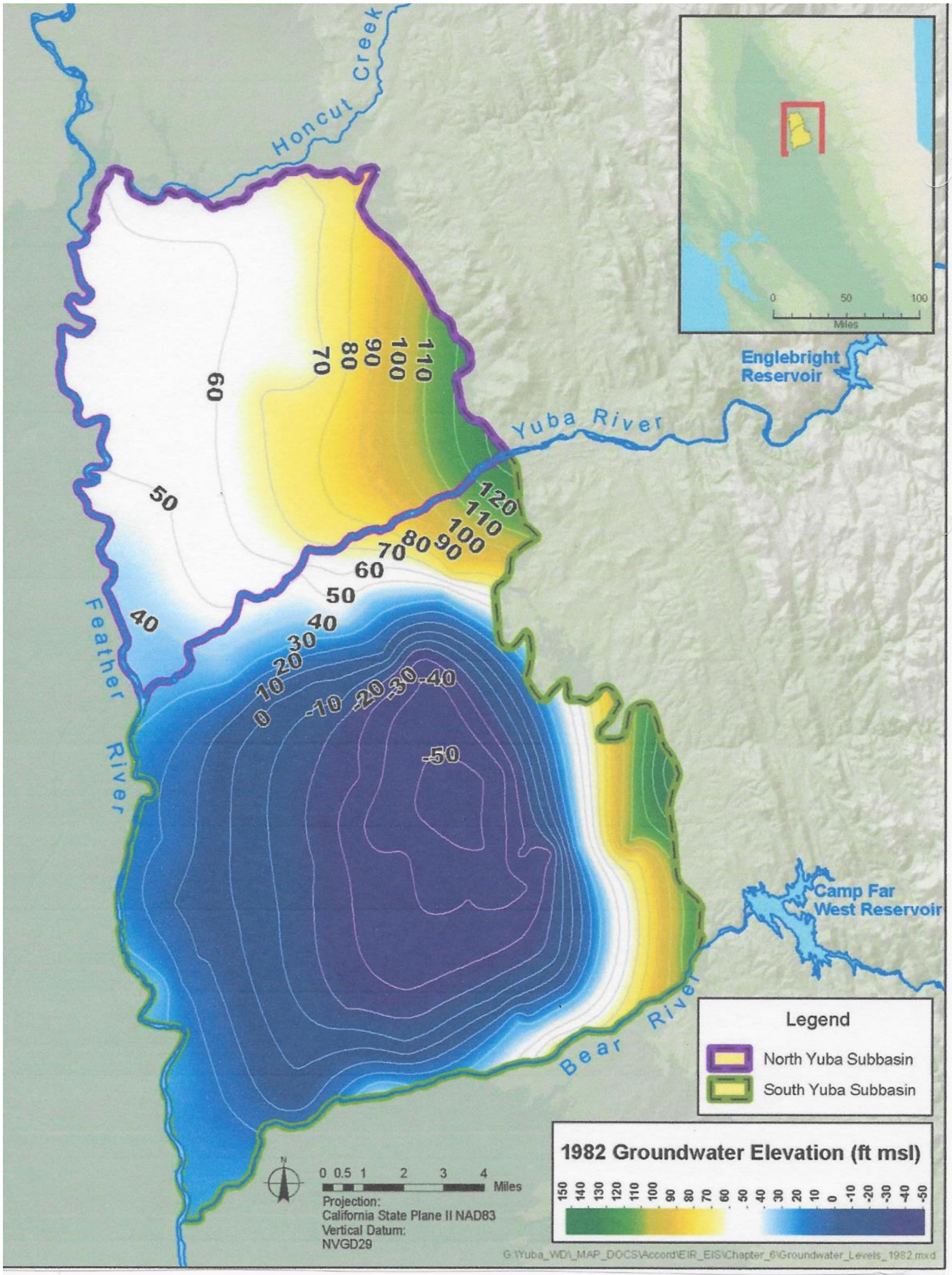

Figure 2. Groundwater Level in the Yuba River Basin in 1982.

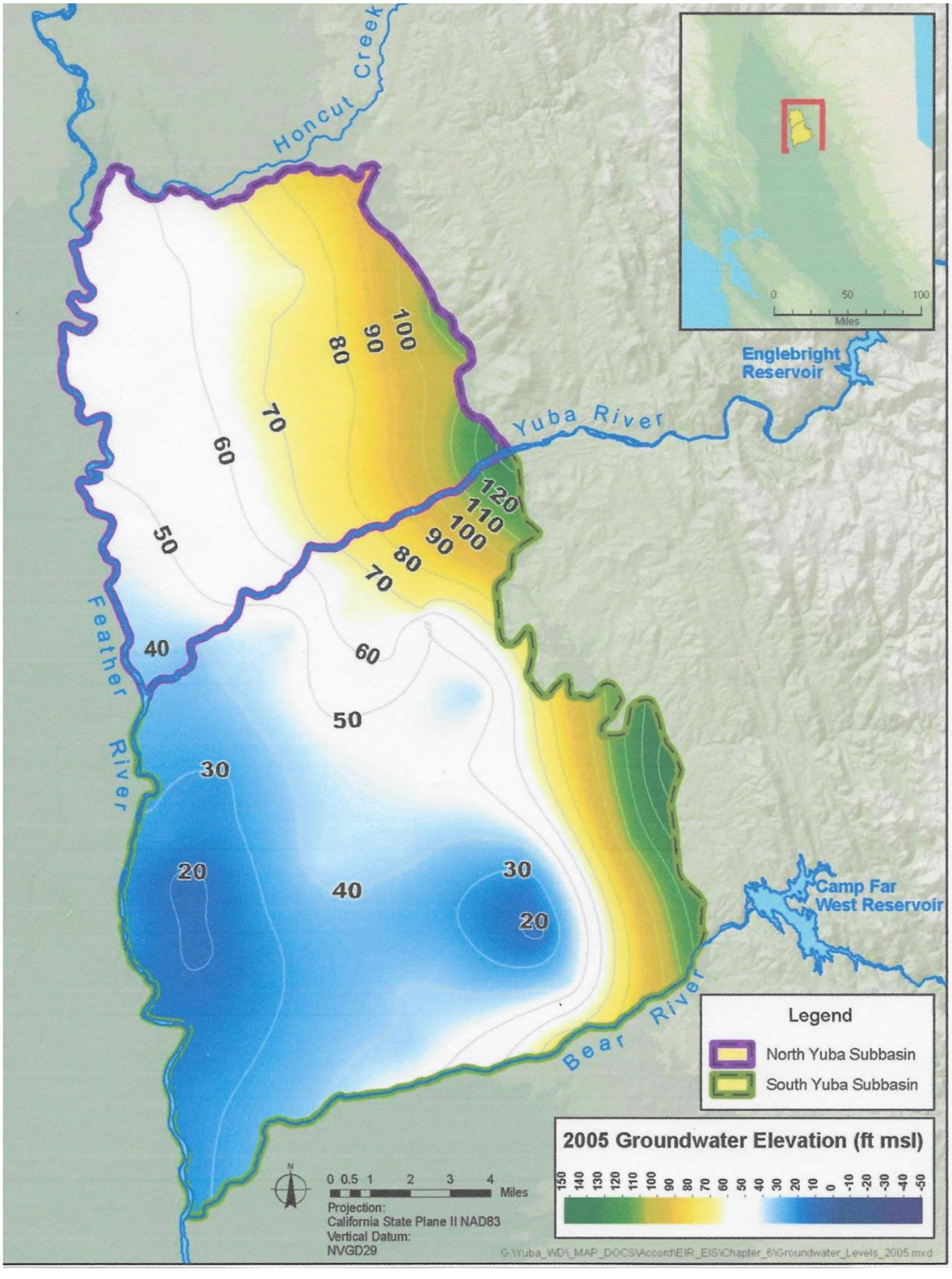

Figure 3. Groundwater Level in the Yuba River Basin in 2005.

GROUNDWATER REVENUE DISTRIBUTION INITIATIVE

The purpose of the Yuba County Recharged Groundwater Revenue Distribution Initiative (Initiative) is to allow groundwater substitution (GWS) transfers to continue while compensating the citizens of Yuba County for the sale of the County's surface water and to continue to monitor and preserve the County's groundwater resource. Management of the two groundwater sub-basins in the County (North and South) would continue to be administrated by the YCWA and other agencies in accordance with state law.

The rationale for the initiative is that the construction of the New Bullards Bar Dam was funded in part by Yuba County property taxes, therefore the citizens of the County should all share in the revenues generated by the sale of surface water made possible by GWS. The distribution of funds would be as follows:

1. The first $15 per acre-foot would go to YCWA for management of the water sales and the two groundwater basins.
2. The next $110 per acre-foot would go to GWS well owners that participate in the groundwater substitution transfer.
3. Of the remaining revenue, 25% would go to all Yuba County property taxpayers, with the same percentage reduction for each taxpayer.
4. 25% would be distributed to ten entities that depend on groundwater, including the cities of Marysville and Wheatland and several water districts.
5. 50% would go to eight water districts which are the eight member units of the YCWA.

In recent years GWS transfer water sales revenues have been over $34,000,000 in 2013, over $28,000,000 in 2014, and over $19,000,000 in 2015, with the price for water being as high as $665 per acre-foot.

CONCLUSIONS

Groundwater is a very important component of California's water supply. Groundwater supplies about 30 percent of the water use in the Sacramento River Basin, with potential for much more use. In Yuba County, groundwater plays a major role in both irrigation and urban water supplies. The Sustainable Groundwater Management Act will lead to more efficient and sustainable use of groundwater in California. The Yuba County Recharged Groundwater Revenue Distribution Initiative is designed to allow groundwater substitution transfers to continue while compensating the citizens of Yuba County for the sale of the County's surface water.

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GROUNDWATER INTERACTION WITH SURFACE WATER - A 30-YEAR PERSPECTIVE FROM THE PACIFIC NORTHWEST

Bob Anderson, LHG[1]

ABSTRACT

When I started as a young hydrogeologist in 1987, one of my first projects was to site and install a new groundwater well for a fish hatchery. My strategy (straight from a textbook) was to site the well as close to the river as possible and maximize induced infiltration from the adjacent river to the well. After careful planning and consideration, I selected a well location and drilled a completely non-producing well…. practically a "duster"! After some geophysical investigation, I finally found a location that produced ample groundwater – one of those sneaky side-channel features in the floodplain. Feeling successful, I tested the well, installed a water level monitoring device (a paper chart recorder in those days) and wrote my report. However, when we installed the permanent pump that summer, the well production had dropped by a factor of five! What happened? We pumped and monitored through the fall, and after a large fall rainstorm, water levels in the well popped up, and production was back to its design capacity. Two other stream-aquifer projects followed, and my first "publication" in 1988 was for a local conference and titled *"Hydraulic Continuity - Three Case Histories of Variable Connection between Groundwater and Surface Water."*

In the years since those first projects, I have seen many examples of the physical nature of groundwater-surface water interaction and the significant shift in the policy and legal issues surrounding groundwater-surface water interaction in Washington State. My groundwater development strategies from 1987 would be entirely ridiculous now, and the transient behaviors observed in that first well over the summer would be difficult, if not impossible, to incorporate into a permit for pumping today. Between 1995 and 2005, Washington State worked through a number of technical, planning and legal issues related to groundwater-surface water interactions. Technical guidance was developed; case studies were evaluated; court cases were brought and settled (several at the State Supreme Court level); and legislation was passed (the Watershed Planning Act) to set a framework for continued management of the State's water resources. Like California's Sustainable Groundwater Management Act (SGMA), Washington's watershed planning efforts dealt directly with the issues related to managing groundwater and surface water as one resource.

As I work on SGMA efforts in California, I have varying degrees of déjà vu, pessimism, and optimism. While the environment and landscapes differ, the physics remains the same, as do stakeholder issues and perceptions surrounding this simple, yet confounding connection between visible and invisible waters.

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TECHNICAL AND POLICY BACKGROUND

Interactions between groundwater and surface water touch on a number of varied technical and policy issues. In broad terms, it is reasonable to characterize many of these issues as being “after the fact” or “ex post facto”. The technical and policy issues regarding stream-aquifer interaction were not the subject of analysis until many underpinnings were already well established through analysis as independent water types and systems. Below are some background technical considerations and a brief history of relevant policy in Washington State.

Technical

The concept of interaction between groundwater and surface water is not new, and the basic technical concepts are deceptively simple – water flows downhill and at a rate proportional to the resistance to flow (both below ground and above ground). Winter (1999[2]) states it well: “*The interactions of streams, lakes, and wetlands with groundwater are governed by the positions of the water bodies with respect to groundwater flow systems, geologic characteristics of their beds, and their climatic settings.*”

When groundwater head adjacent to a surface water body is higher than the water surface elevation, groundwater will tend to discharge to the surface water (it is “gaining” water from groundwater). When groundwater head adjacent to a surface water body is lower than the water surface elevation, surface water will tend to discharge (or seep) to the groundwater (it is “losing” water to groundwater). While the head differences govern whether a system is gaining or losing, the rate and volume of water flowing between the two systems is a function of many other variables and processes. The rate and volume of this interaction is of great interest to water managers. The physical variables that control rates and volumes include:

- The physical structure of the aquifer system. This includes its geometry, layering, and boundaries.
- The hydraulic properties of the aquifer system – This is generally expressed in terms of hydraulic conductivity (how easily water can move through the subsurface) and storage coefficient (how much water a unit volume of the subsurface can hold).
- The physical structure of the surface water system. This includes geometry, sinuosity, slope, and channel or basin structure.
- The hydraulic properties at the base of the surface water system. This includes both a hydraulic conductance (how easily water can move though the base of the surface water body) and a hydraulic “roughness” (how easily water moves along the base of the surface water body).

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[2] Winter, T. Hydrogeology Journal (1999) 7: 28. https://doi.org/10.1007/s100400050178

The timescale and spatial extent over which rate and volume calculations are carried out is one of the more daunting issues in evaluating the groundwater-surface water interaction.

- Surface water flows typically vary on a time scale of days and often minutes in the case of storm flow events. These flows can vary from place to place as tributaries converge; as side-channels convey water through the floodplain; and as irrigation canals move water into cultivated areas. The monitoring methods and data analysis tools applied to surface water flows have adapted to this network concept and time scale. Specific gaging locations are monitored, and the data are analyzed statistically to create flow probability distributions, hydrographs, and other characterizations of flow variability. Spatial analyses are also carried out to characterize channel depth, velocity, and erosive potential. All of this information becomes aggregated into classifications like "watershed units", "sub-basins", "mean annual flows", "peak flows", the now infamous "100-year flood".

- Groundwater flows typically vary on a time scale of months, years, or sometimes decades. Like surface water, these flows vary from place to place as subsurface geology changes; as recharge or discharge areas influence groundwater flow; and as wells extract water from the subsurface. The monitoring methods and data analysis tools applied to groundwater flow are more limited and rely primarily on information collected from a borehole drilled into the subsurface. Specific aquifers or aquifer zones are monitored and combined with measurements at other wells to create maps of groundwater flow fields, hydrographs, and other depictions of subsurface flow . Tests are conducted to characterize the physical properties and geochemical characteristics of aquifers. All of this information becomes aggregated into classifications like "upper and lower aquifer units", "confining units and aquitards", "hydraulic gradients", "flow paths", and "transmissivity".

To a policy maker, local stakeholder, land manager or planner, the overlapping terminology between groundwater and surface water practitioners can become confusing. In addition, because time is such an important integrating variable for both groundwater and surface water, the mathematical tools used in for analysis are important considerations that can create a dilemma for practitioners. Standard hydrologic and engineering models of surface water systems, responding on a daily time scale at a specific point, often cannot accommodate the long-duration and more geographically variable nuances of groundwater inflows/outflows. Conversely, conventional models of groundwater flow, responding on a monthly or annual time step, often cannot accommodate the fine-scale time frame of surface water flows.

The most progress in resolving this dilemma has come from the groundwater modeling community where "fully coupled" flow models help by simultaneously solving rate and volume equations for both systems. While there has been convergence in the technical coupling of groundwater and surface water analysis, the issues of model accuracy and precision are still relevant in selecting technical approaches to specific problems or settings. The newer "fully coupled" models have improved the precision of calculations, but the overall model accuracy is still founded on first principles of hydrologic analysis; the availability of representative data; and the objectives of the modeling analysis.

Policy

Washington State has a long history of environmental policy that has directly addressed the interaction of groundwater and surface water. In 1971, Washington was the first state to adopt comprehensive in-stream flow rules that have the effect of conditioning or preventing new appropriations of water. The Water Resources Act of 1971 was also accompanied by the 1971 Water Well Construction Act, that required well driller certification and agency notification of well installation. Through the late 1970's and early 1980's, water resource management activity was relatively quiet as water pollution, superfund, and contamination issues were addressed. The 1990's, however, were ushered in by new legislation (The Growth Management Act or GMA), which included provisions that required significant planning activity across the state and established a clearer link between the development of land and water availability. Following GMA, numerous court cases ensued relating to water management. Of the various court cases that arose since 1991, two rulings established the legal connection between groundwater and surface water:

1. *Hubbard v. Department of Ecology (1994).* The State Court of Appeals ruled that the connection between groundwater and surface water (referred to as hydraulic continuity) may exist even when the point of withdrawal of the groundwater is located several miles from the affected stream and would result in only small and delayed effects on the flow of the river. The decision also affirmed that, where surface and ground water is connected, instream flows established by rule are treated as water rights and should be protected from impairment by any subsequent ground water withdrawals.

2. *Postema v. Pollution Control Hearings Board, et al. (2000).* This case centered on issues related to agency obligations when analyzing an application to withdraw groundwater that is connected to surface water (i.e. in "hydraulic continuity"). The Supreme Court ruled that the legal test of impairment (i.e., whether the withdrawal of groundwater affects the volume of surface water that it is connected with) is "no impairment" and that impairment can be determined from a computer model. Many refer to this legal test as the "one molecule" test. Essentially, one molecule of stream depletion, even if predicted through a computer model, constitutes impairment.

While legal cases have been a significant driver of water policy since 1991, other factors have also significantly shaped water management policy in the Pacific Northwest, most notably the federal Endangered Species Act (ESA). Although instream flow protections were already in place, the ESA reinforced the importance of understanding and managing groundwater interactions with streams. Many endangered salmonids spend "critical life stages" in rivers during periods of the year that can be dominated by groundwater baseflow. In response to GMA, legal findings, and the ESA, the State of Washington enacted a Watershed Planning Act in 1998 in an attempt to provide a framework and locally driven process to address water issues throughout the state. This framework is founded on legislatively defined geographic areas known as Water Resource Inventory Areas (WRIAs), or watersheds. The act was designed to allow local governments and citizens to voluntarily join together, with advice from state agencies, to develop watershed management plans. Between 1998 and 2006, 37 of the state's 48 WRIAs developed watershed management plans that evaluated the availability of both surface water and groundwater.

Since the late 2000's, the new paradigm of hydraulic continuity has been managed through a combination of often complex mitigation approaches, water transfers and water banks, and agency application of "over-riding consideration of public interest" to develop or expand water use in a constrained policy environment. The courts continue to be a forum for resolving water policy but local initiatives and watershed management activity are still important tools for water managers, policy makers, and practitioners.

EXAMPLES FROM THE PACIFIC NORTHWEST

Contrary to popular belief, the Pacific Northwest does have a dry climate across a large geography east of the Cascade Mountains, with many areas receiving less than 10 inches of precipitation annually. Mountain snowpack drives the seasonal hydrologic cycle, with surface water reservoirs and groundwater aquifers provide important storage for meeting water demands in the summer. Variability in snowpack is a growing concern throughout the region. Strong continuity between groundwater and surface water is pervasive and, as described above, court decisions have affirmed this continuity in relation to water rights. Below are a few project examples that have shaped my view of hydraulic continuity from both a technical and policy perspective. Figure 1 shows the location of these various examples.

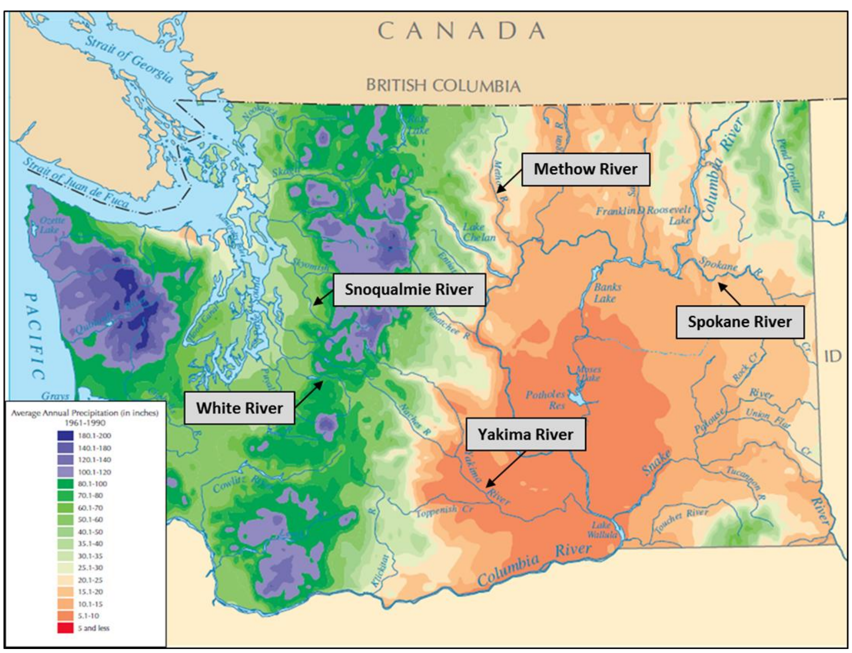

Figure 1. Location of Project Examples

White River

My first professional project was a wellfield developed for a fish hatchery on the White River with a total capacity of 2,200 gallons per minute (gpm) from six wells. The wells were located within 1,000 feet of the river and under static conditions groundwater levels fluctuated as water levels in the river changed. During an initial 2-month test of the wellfield in the spring (March-April) at 1,000 gpm, drawdown stabilized at 3 feet after three days and then started fluctuating slightly in response to changes in river stage. A second 3-month test (also at 1,000 gpm) conducted in the late summer (August-October) exhibited a much different response. River stage declined about one-foot during the course of the test, but pumping groundwater levels did not stabilize and dropped between 7 and 10 feet during the test (including at an observation directly adjacent to the river). A fall freshet flow occurred in October and streamflow increased significantly to over 3,000 cubic feet per second (cfs) (while still pumping). Groundwater levels throughout the wellfield areas rebounded immediately, and then returned to a drawdown of about 3 feet (similar to the spring test). The reduced hydraulic connection between the spring and fall tests was attributed to a slightly lower wetted perimeter of the stream and deposition of fine glacial silt in the riverbed during low summer streamflows. Combined, these factors reduced the total streambed conductance and caused the wellfield to mine aquifer storage during the summer. That storage, however, was completely restored during the fall freshet.

Methow River

The Methow River was one of the original "poster children" in the 1990's related to the nexus among groundwater, streamflow and fish habitat. The river is fed by a pristine watershed consisting primarily of wilderness area and forest service land. The economy is supported by a combination of irrigated agriculture, tourism, and forest harvest. The upper portion of the river valley is about 2 miles wide with over 120 feet of highly transmissive alluvium incised into bedrock. Salmon habitat is excellent throughout the valley, even though reaches in the uppermost portion of the river are known to dry up during the late summer. In response to a proposed groundwater development, an early generation MODFLOW model was developed in 1990 to evaluate the impact of pumping on streamflow. The significant result of the modeling effort was that, although pumping did indeed reduce streamflows, pumping did not accelerate the natural drying up of river reaches. Since those early studies in the 1990's, multiple planning studies, hydrologic models, fish habitat surveys, irrigation improvements, land-use restrictions, and lawsuits have followed, all with varying levels of success. The "bigger" issues of groundwater interaction for the various towns, irrigation companies and resorts in the valley have largely been addressed. In 2011, the State's water and fisheries agency produced a collaborative diagnostic "Atlas" to characterize watershed health and prioritize restoration efforts based on weighted scoring "cube" that assesses habitat, fish status, and flow (including groundwater baseflow) in all tributaries. However, the issue of individual domestic wells, and how to manage their impact on streamflows, is still not fully resolved. The policy and regulatory issues surrounding "water availability" for individual parcels supplied by a domestic well have recently been reviewed by the state supreme court (the "Hirst Decision[3]"), creating further pressure for state and county regulators to develop a consistent approach.

Snoqualmie River

In the early 1990's, the Puget Sound area was growing rapidly and the need to increase regional water supply became an important planning and political issue. In the foothills of the Cascades, less than 35 miles from regional water infrastructure, lay the Snoqualmie Aquifer, a large untapped aquifer capable of supplying up to 40 million gallons per day (about 60 cfs) of water supply. The engineering for a pipeline was simple, the water quality was excellent, and the surrounding land use was favorable. By 1993, a group of individual water utilities was prepared to advance the project. The problem was hydraulic continuity and minimum instream flow levels set on the Snoqualmie River in the 1970's. The Snoqualmie is a relatively large basin with a mean annual flow of about 3,000 cfs. During the winter, flood flows of over 20,000 cfs can occur and summer baseflow is on the order of 500 cfs. Anadromous salmon spawn in the lower reaches of the River, but cannot pass Snoqualmie Falls. Instream flow levels were set based on streamflow statistics and, therefore, even under natural conditions, flows are often less than the minimum level. Much like the Methow River in Eastern Washington, the Snoqualmie was a prominent proving ground for concepts surrounding groundwater surface water interaction. By this time, the idea that there would be impacts to streamflows was not at issue, and substantial effort went into characterizing the aquifer and modeling the seasonal impacts from pumping across multiple scenarios using MODFLOW. The modeling consistently showed that, while pumping impacts would occur, the prolific nature of the basin during the winter months would consistently "refill" the groundwater system and year-over-year groundwater storage declines would be unlikely. The issue was the significance of stream impacts as they occurred, and whether they needed to be (or could be) mitigated. Many ideas were tested, but agencies and stakeholders could not agree on acceptable mitigation. The most ambitious mitigation concept was to use the Snoqualmie River as conveyance for groundwater and, rather than build a pipeline, construct a treatment plant downstream adjacent to existing infrastructure to treat surface water that had been augmented by upstream groundwater pumping.

In the end, competing projects were successful at enhancing the regional water supply and the Snoqualmie Aquifer project was shelved as a regional water supply. The Snoqualmie did, however, become the subject of the first "water-for-water" mitigation applied to the approval of a new water right for a local water utility. By securing a

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[3] In October 2016, a Washington State Supreme Court decision changed how counties decide to approve or deny building permits that use wells for a water source, particularly where wells are adjacent to streams with instream flow provisions. The ruling requires the Whatcom County to make an independent decision about legal water availability for so-called permit-exempt domestic uses. It appears to set legal precedent that applies in other counties where there are instream flow rules that were not intended to regulate permit-exempt water uses. It is unclear how the decision affects areas of the state where there are no instream flow rules.

contract for surface water from a reservoir in an adjacent basin, the City of North Bend was able to secure a new water right for about 1 MGD (2.5% of the originally anticipated regional supply). The approved mitigation plan required them to return the volume of surface water impact from their well to the Snoqualmie River whenever streamflows dropped below the instream flow level. A real-time operational control system was installed that measured flow in the river and automatically discharged water from the adjacent reservoir to the river. The conveyance from the adjacent basin reservoir to the Snoqualmie River was gravity-based, thanks to an existing pressure relief system installed around the reservoir. Annual compliance reports are submitted documenting the mitigation applied. This system has been successfully operating since 2009.

Spokane River

The Spokane River is located in Eastern Washington and stakeholders in the watershed were early participants in the State's watershed planning program. The Spokane River is underlain by a massive coarse gravel aquifer known as the Spokane Valley Rathdrum Prairie (SVRP) Aquifer. The SVRP Aquifer underlies about 370 square miles and extends into Idaho. It can support huge production wells of 3,000-6,000 gallons per minute and has a total volume of about 10 trillion gallons, making it one of the most productive aquifers in the country. The Spokane River is in direct communication with the SVRP and there is a variable distribution of gaining and losing reaches along the river. Groundwater discharge to the river can be as high as 400 cfs in some reaches, with groundwater losses of 40 to 50 cfs in other reaches. In the early 2000's the Spokane Watershed Planning entity funded the development of a coupled surface/ground water flow model using a relatively new (at that time) modeling code, MIKE-SHE.

The objective of the modeling was to improve the overall simulation capability in the watershed and to simulate a number of scenarios that were of interest to the watershed planning group. After constructing and calibrating the model, it was used to simulate pre-development conditions in the watershed, conditions at a +20-year growth horizon, aquifer injection, relocation of existing groundwater supply wells, and full exercise of all municipal water rights in the basin. All model results were expressed in terms of differences in groundwater levels and differences in streamflows compared to a current base case.

As an early application of MIKE-SHE, there were a number of difficulties created by the computational intensity of the model itself and the availability of data to calibrate the model. The model encompassed over 1,000 square miles and was developed using a uniform grid spacing of ¼-mile. It included simulation of all major hydrologic processes, including saturated flow, unsaturated flow, overland flow/runoff, channel flow, snowmelt, and various forms of groundwater and surface water abstraction. Despite some of the limitations on the precision of the model, as a tool to compare scenarios, it was both useful and accurate in illustrating the magnitude of impact of various scenarios. The model scenarios informed several important elements of the watershed plan, including siting of future wells, County policies toward water availability determinations, and pursuit of enhanced recharge projects. Unfortunately, the model also illustrates the difficulties watershed groups face to fund and maintain a complex sophisticated model.

Over time, as financial resources dwindled and the capabilities of MODFLOW improved, the MIKE SHE model was overtaken by a USGS effort developed using MODFLOW.

Yakima River

The Yakima Basin is the most economically significant agricultural region in Washington and has a complex system of private, municipal, tribal and federally managed water supply systems. Both surface water and groundwater are used extensively throughout the basin. In drought conditions, surface water deliveries are curtailed in many areas in order to maintain environmental flows in the Yakima River, which supports endangered salmon populations. Groundwater that is in hydraulic continuity with the Yakima River is also subject to curtailment under certain circumstances. The Yakima has seen a plethora of studies and projects related to streamflows, fisheries enhancement, and groundwater management. Like many Western watersheds, water storage is seen as the ultimate "solution" to competing needs and groundwater storage has been evaluated in multiple forms as part of that effort. Unlike all of the previous case studies, in the Yakima the issues have focused around "reverse streamflow depletion" – assessing streamflow accretion from enhanced groundwater recharge and storage. Three examples are summarized below:

- Surface infiltration into alluvial aquifers during early spring run-off from ponds and unlined irrigation canals during irrigation ramp-up has been evaluated in the upper portions of the basin, but has proved difficult to quantify, track and manage. The structure of the upper Yakima Basin is such that, although enhanced infiltration helps the overall water balance, it does little to enhance irrigation deliveries at an operational level.

- Municipal aquifer storage and recovery (ASR) has been successful, but has challenged some of underlying concepts in Washington ASR regulations regarding "allowable recovery" of water that is injected into the aquifer. ASR is a viable storage approach for municipal entities that have access to a treated water supply. It is less viable for irrigators and has neutral effects on streamflows when used solely for seasonal shifting of water supply (e.g. pumping spring injection water during the summer). Some of the more interesting modeling simulations of ASR in the basin have shown that there could be measurable benefits to streamflow if an ASR system was managed to focus on injection of water for a period of 10 years or so to establish a new stream-aquifer equilibrium prior to initiating withdrawal cycles.

- Deep aquifer storage in basalts that had been mined of aquifer storage has also been evaluated as a potential supply for direct irrigation use. There are documented areas of relatively distinct "blocks" of basalt that are isolated from other "blocks" and have been depleted of storage from pumping. While there are engineering challenges, the concept of refilling these empty blocks is appealing. The cost of treating water in order to inject it into a subsurface aquifer, however, is currently prohibitive. Regulatory measures to allow lesser degree of treatment for irrigation supply have been considered, but are currently not viable.

SUMMARY AND CONCLUSIONS

Hydrology has been a subject of investigation and engineering for millennia. As a result, our understanding of the various interactions within the hydrologic cycle has evolved within many different scientific practices and disciplines. In the case of groundwater, many of the important geologic and watershed factors governing the interaction of streams, lakes, and wetlands with groundwater were not appreciated and integrated into the field of hydrology until the 1960's. We are clearly moving towards a more fully integrated approach to managing watersheds, particularly in the Western US. However, obstacles remain that, in many respects, are remnants of the evolution of technical and policy approaches toward groundwater and surface water that have evolved since settlement in the Western US. The intersection between legal certainty (in the form of water rights and contracts) and hydrologic uncertainty (in the form of data, modeling precision, and conceptual setting) has created many difficult problems for us to solve. We face future uncertainties related to climate change and the accumulation of changes from 170 years of development in Western watersheds that is founded largely on the availability of water. It is vital that we apply sound scientific principles, tools and analysis, but also that we agree on common goals and objectives for managing our watersheds. Programs like the Sustainable Groundwater Management Act in California and the Watershed Planning Act in Washington provide the appropriate forum and framework for action. However, as Yogi Berra said, "the future ain't what it used to be".

KEEPING GROUNDWATER IRRIGATING: OREGON'S COMPLEX GROUNDWATER REGULATION

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Sarah R. Liljefelt[2]
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ABSTRACT

Groundwater in Oregon has been regulated by statute since 1955. Since its enactment, the Groundwater Code created a priority system for water use rights issued under the code, and recognized surface water- groundwater connection (and potential interference). Although the Oregon Water Resources Department has historically regulated junior groundwater users when their uses interfered with more senior surface water and groundwater rights, the frequency and extent of recent regulation (as well as denials of water use applications) begs the question of whether regulation is a necessary outgrowth of more fully subscribed water resources, or a shift in policy away from utilization of the State's water resources to promote economic and general welfare. This paper will consider the State's approach for modeling groundwater-surface water interactions, as well as designations in groundwater basins to limit groundwater use.

INTRODUCTION

In arid regions of the western United States, states adopted the prior appropriation doctrine as the water regime for the doctrine's ability to incentivize development of water resources and place them to efficient beneficial use. John F. Kennedy, as late as the mid-1960s, remarked that "[e]very drop of water which goes to the ocean without being used for power or used to grow, or being made available on the widest possible basis is a waste…"[4] While the historic goals of maximizing the beneficial use of water have not changed, application of the beneficial use doctrine has shifted in more recent history. For example, in some states an "instream water right" creates a beneficial "non-use" recognized by the law that would previously be considered waste. This shift in policy has, at times been implemented within regulations and agency actions, rather than by legislative enactments.

Much of Oregon's water code is unchanged since originally enacted. The prior appropriation system maximizes the economic and social beneficial use of water resources. Prior appropriation protects senior water users with relatively earlier propriety dates. The phrase "first in time, first in right" is often used to describe this principle of

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[4] Kennedy, John F., Remarks at the Hanford Washington, Electrical Generating Plant (September 26, 1963).

protecting older established uses from those later in time. When there is insufficient water available to provide water to all surface water users, the users with the most senior rights receive water allocations.[5] Today, these basic components still apply, but in new, complex ways.

For example, the interaction of groundwater and surface water were recognized in the original version of the Groundwater Code. Groundwater users may be regulated, like surface water users, when their water use substantially interferes with other groundwater users.[6] A lack of surface water may also cause Oregon Water Resources Department ("OWRD") to regulate groundwater users adjacent to the surface water source in the same priority line as if they were surface water users, when the groundwater is hydraulically connected and OWRD determines the well creates potential for substantial interference with the stream.[7] The distribution system relies on OWRD regulations to determine the interaction between these two water sources. These regulations are not entirely objective either in their wording or their application to determine the effects of groundwater pumping on surface waters.

In application, a "guilty until proven innocent" system is employed. Assumptions in OWRD's regulations place burdens on water right holders to show their use *does not injure others* instead of OWRD justifying their claims of potential for substantial interference. Further in practice, there is little, if any, proof that is found acceptable to OWRD in response to allegations of interference. The burden shift leads to needless restrictions on junior users in the name of protecting senior water rights, regardless of whether additional protection is actually achieved. The increasing use of presumptions and restrictions in the name of protecting senior water users indicates an agency policy shift away from allocations based upon beneficial use, general welfare, and economic prosperity to a groundwater preservationist policy.

OREGON'S CONJUNCTIVE MANAGEMENT RULES FOR GROUNDWATER REGULATION

In times of drought, surface water users may "call" on the water use rights of some groundwater users if the source of water for the well is hydraulically connected to the stream and there is a potential for substantial interference with the surface water rights.[8] Hydraulic connection is defined by regulation as the ability of water to flow between surface water to an adjacent aquifer.[9] However, adjacency itself is not defined.

OWRD currently interprets "adjacent aquifer" to mean any source of groundwater appropriated by a well that is within one mile from the surface water source, regardless of aquifer depth and any intervening confining layers. Therefore, in applying this interpretation, OWRD's application of the hydraulic connection test is "a given" in any

[5] OAR 690-250-0100(2).
[6] OAR 690-250-0110(2).
[7] OAR 690-250-0120(2).
[8] OAR 690-009-0040(1).
[9] OAR 690-009-0020(6).

situation where a well is within one mile of a surface water source, and the regulation loses all meaning as a gateway regulatory requirement.

Next, OWRD determines if there is a potential for substantial interference between the groundwater use and existing rights from the surface water source. If a well produces water from a "hydraulically connected" aquifer, potential for substantial interference is ***assumed*** if ***any*** of the following apply: 1) the point of appropriation (the well) is within a quarter mile from the edge of the surface water source; 2) the rate of appropriation is greater than five cubic feet per second ("cfs") and the well is within a mile from the edge of the surface water source; 3) the rate of appropriation is greater than once percent of a minimum perennial streamflow or instream water right and the well is within a mile from the edge of the surface water source; or 4) the appropriation if continued for 30 days would result in stream depletion greater than 25 percent the rate of appropriation and the well is within a mile from the edge of the surface water source.[10] The regulation allows OWRD to calculate stream depletion using a model.[11]

Moreover, OWRD has discretion find that any "hydraulically connected" wells not meeting the above test create the potential for substantial interference based upon consideration of the following factors: 1) the potential for a reduction in streamflow or surface water supply; 2) the potential to impair or detrimentally affect the public interest as expressed by an applicable closure on surface water appropriation, minimum perennial streamflow, or instream water right with a senior priority date; 3) the percentage of the ground water appropriation that was, or would have become, surface water; 4) whether the potential interference would be immediate or delayed; and 5) potential for a cumulative adverse impact on streamflow or surface water supply.[12] OWRD's interpretation of "hydraulic connection" to include any groundwater aquifer appropriated by a well within one mile of a surface water sources creates a presumption of potential for substantial under the regulations in nearly all circumstances.

Finally, the regulations require OWRD to determine if regulation of the well at issue would create "effective and timely" relief to the surface water source. For wells located over 500 feet from the surface water source, but less than one mile, OWRD's determination must be made on the basis of "best available information," using equations and graphical techniques, or a computer program or model.[13]

OWRD currently uses an analytical model developed by Bruce Hunt in 2003 to make determinations about effective and timely regulation. In the authors' experience, OWRD chooses model parameters in such a way that unrealistically increases the model outputs for stream depletion and relief. Moreover, at least with regard to OWRD's application of the model to the Upper Klamath Basin, the authors have witnessed OWRD substitute a "specific yield" value for the "porosity" parameter in the model, as well as eliminate the

[10] OAR 690-009-0040(4).
[11] *Id*.
[12] OAR 690-009-0040(5).
[13] OAR 690-009-0050(2). The "effective and timely" determination for water users within the Upper Klamath Basin is currently made under OAR Chapter 690 Division 25, and includes additional procedures.

streambed conductance parameter from the equation altogether. Therefore, in the circumstances the authors have reviewed, OWRD does not apply the Hunt 2003 model consistently or in a way that is scientifically defensible, to the detriment of junior water users, with no added benefit to senior water users.

INCONSISTENT APPLICATION OF "AQUIFER"

"Aquifer" is defined by regulation to mean, "a water-bearing body of naturally occurring earth materials that is sufficiently permeable to yield useable quantities of water to wells and/or springs."[14] In Oregon, well drillers are required to file well bore reports with OWRD after drilling new wells. Depending upon the location, the reports may show multiple "aquifers" within the regulatory definition. OWRD applies the definition of "aquifer" inconsistently, depending on the situation.

When OWRD processes applications to change the point of appropriation (the well) through transfers or permit amendments, OWRD views the aquifer as a very narrow and particular water bearing strata within a borehole. The water use right allows water use from the particular source of water that was developed by the original well or proposed in the original application. The original and new well must access the same aquifer by law, and OWRD may deny the application or place additional conditions on the transfer or permit amendment to ensure the narrow and particular source of groundwater is appropriated.[15]

Moreover, OWRD will at times identify violations of Oregon well construction standards. One such type of violation is failing to seal off different aquifer layers, resulting in the potential for comingling water between different water bearing zones.[16] The authors have witnessed OWRD activity in multiple circumstances to seek compliance with well construction standards to avoid alleged comingling of different aquifers. Again, when it comes to well construction standards, OWRD employs a very narrow and particular definition of "aquifer."

In stark contrast to the examples above, in cases of new permit applications or regulation based on priority, OWRD uses a broader conceptualization of the definition for "aquifer." As explained above, when it comes to regulating off junior groundwater users, all groundwater sources below the surface water source are part of the "adjacent aquifer," regardless of intervening confining layers or the presence of multiple water bearing zones. In that circumstance, OWRD applies an aquifer system approach to regulate off as many groundwater users as possible, and deny new groundwater permits.

As discussed, OWRD uses very different conceptualizations of the term "aquifer" in different situations. The only uniting factor that the authors can derive from OWRD's uneven application, is the consequence to restrict groundwater use to the highest extent possible under the regulations.

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[14] OAR 690-008-0001(1).
[15] OAR 690-380-2110(2).
[16] *See, e.g.,* OAR 690-210-0150.

"HYDRAULIC CONNECTION" WHIPLASH

OWRD's regulations create a paradox in which certain wells are "too connected" to a surface water source to acquire a new water use right, or cause the well to be regulated as if it were surface water. On the other hand, the same well may be "not connected enough" to be used as an alternate point of appropriation to withdraw surface water.

When OWRD reviews a new groundwater application, OWRD must determine whether water is available from the proposed source.[17] If the proposed point of appropriation is within one mile of a surface water source, OWRD determines, as outlined above, whether there is hydraulic connection between the groundwater and surface water source, and potential for substantial interference between the proposed use and existing rights from the surface water source.[18] If OWRD makes (seemingly inevitable) determinations finding hydraulic connection and potential for substantial interference, the availability of the surface water source will be reviewed as if the surface water source were the source of water requested in the groundwater application. If water is not available during the season or at the quantity requested, OWRD denies the application. In this situation, the source of groundwater is "too connected" to obtain a new groundwater use right.

On the other hand, it is often the case that groundwater pumped from the same well is "not connected enough" to transfer a surface water point of diversion to the well. Surface-to-groundwater transfer applications require that the proposed changed point in diversion be hydraulically connected to the surface water source and affect the surface water "similarly."[19] "Similarly" is defined by regulation to mean that the use of groundwater would result in stream depletion of at least 50 percent of the rate of appropriation within ten days of continuous pumping.[20] OWRD currently uses the Hunt 2003 model to determine if groundwater use would affect the surface water source "similarly." Again, OWRD chooses the model parameter values, and it is the authors' experience that OWRD rarely finds wells connected enough to complete surface-to-groundwater transfers.

Thus, OWRD's hydraulic connection determinations harm water users at every turn. New applications are not permitted, while transfers are not possible.

GROUNDWATER ANALYSIS IN SURFACE WATER APPLICATIONS

Surface water use applications were historically less complicated than groundwater use applications for the main reason that the regulations regarding hydraulic connection and potential for substantial interference were not applicable. Within the last year that has completely changed, and the authors have witnessed OWRD applying groundwater application analysis to surface water applications.

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[17] OAR 690-310-0080(1)(b).
[18] See generally, OAR Chapter 690 Division 9.
[19] OAR 690-380-2130.
[20] OAR 690-380-2130(11)(b).

Under statute and regulation, OWRD must conduct a water availability analysis for surface water applications.[21] "Water is available" is a defined regulatory term, meaning "[t]he requested source is not over-appropriated…during any period of the proposed use."[22] Further, "over-appropriated" is defined by regulation, as applied to surface water, as "a condition of water allocation in which…[t]he quantity of surface water available during a specified period is not sufficient to meet the expected demands from all water rights at least 80 percent of the time during that period."[23] Therefore, the statutes and regulations focus on the "source" of water requested in the application, and whether water is available in that source for new appropriation.

Very recently, OWRD has added an additional step to its surface water availability analysis; OWRD not only looks at the requested source of water, but will also look at subsurface flows that "may" be hydraulically connected to other, completely different surface water sources, and defer to the water availability of those different surface water sources. Thus, not only is the water availability of the requested source of water important, but now the availability of other surrounding surface water sources is now also at issue! If water is not available in that different source of surface water, OWRD will not issue the permit.

First, this technique is troubling because the statutes and regulations do not permit OWRD to conduct this type of analysis. Second, it is troubling because there are not statutes or regulations that guide OWRD's analysis of subsurface connection from one surface water source to another surface water source through the subsurface geology. In the circumstances the authors have witnessed, OWRD has used a very cursory hydrogeological analysis, containing many assumptions and factual errors, to make loose conclusions about "possible" hydraulic connections to deny surface water applications. Such analysis flies in the face of the law and prior agency policy, and has the sole consequence of allowing OWRD to deny more applications than it would without the new analysis.

NEW GROUNDWATER AREA DESIGNATIONS

Since enacting the Ground Water Code, the Water Resources Commission has the power to designate Critical Ground Water Areas ("CGWAs") by regulation.[24] CGWAs may be designated for several reasons, including declining groundwater levels, substantial interference between wells, overdraft of groundwater, or water quality degradation, and allows OWRD to, for example, close the area to any new appropriations, limit the total withdrawal from the aquifer, and refuse applications for new groundwater permits. Limits to use of groundwater within CGWAs may only be enforced after a contested case hearing.[25]

[21] ORS 537.150(4)(b); OAR 690-310-0080(1)(b).
[22] OAR 690-300-0010(57)(a).
[23] OAR 690-400-0010(11)(a).
[24] ORS 537.730 et seq.
[25] ORS 537.742.

Due to the cost and delay associated with contested case hearings (trials at the administrative level), OWRD uses basin plans to restrict new uses of groundwater in certain areas. Basin plans are adopted by regulation without contested case hearings, and are found at the end of OWRD's regulations in Oregon Administrative Rules Chapter 690. Basin plan restrictions limit future groundwater appropriations to specified uses, but to not restrict existing water consumption under valid water use rights within the area.

Groundwater Limited Areas have been used by OWRD for many years and restrict groundwater appropriations in certain groundwater basins to certain uses. Recently, we have seen the rise of additional groundwater designations to restrict groundwater appropriation. In Harney County, after about one year of ceasing groundwater application processing, OWRD finally passed a regulation designating the Greater Harney Valley Groundwater Area of Concern in the Malheur Basin rules in 2016.[26] In 2017, OWRD designated the Walla Walla Subbasin as a Serious Water Management Problem Area.[27] In such areas, OWRD is purportedly collecting and analyzing data to study and better manage groundwater.

CGWAs and other limited areas are oftentimes restricted based upon the source aquifer. For example, the basalt aquifer in the Cooper-Bull Mountain CGWA is restricted from further development. Again, the term "aquifer" varies depending on OWRD's purposes. As a result, water may still be available at depths other than the regulated aquifer, in this circumstance.

OWRD is able to regulate existing and future water use through the designation of CGWAs and other limited groundwater basin designations. It is somewhat troubling that new classifications of limited groundwater basins are being designated by OWRD without statutory basis. Further, it is troubling to see OWRD simply stop processing groundwater applications without any foundation, only to pass a rule a year or more in the future limiting groundwater appropriation in the area.

PROTECTION OF SENIOR WATER USERS, OR STEALTH ISSUE ADVOCACY WITHIN OWRD?

Stealth issue advocacy has been identified as a growing concern in natural resources management.[28] This form of advocacy, also called normative science, hides policy preferences behind scientific determinations using shaky scientific foundations. The average person, including members of the public or judges presiding over trials, may be unaware of the advocacy disguised by "science."[29] However, long-time water users, water consultants, and other water professionals have seen a marked change in OWRD's operations.

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[26] OAR Chapter 690 Division 510.
[27] OAR Chapter 690-507-0030.
[28] *See* Jarvis, T., *Stealth Issue Advocacy*, Oregon Geologist Examiner Newsletter 1, 1 (Winter 2013). *Available at* www.oregon.gov/osbge/pdfs/Newsletters/GeologistExaminer_Winter2013.pdf
[29] *Id.*

At one time, the Water Code and OWRD's regulations were applied by OWRD in a matter that water use was permitted to support economic development unless actual scientific evidence of lack of availability or interference with existing water use rights prohibited the use or justified regulation. Now, the approach applied by OWRD has shifted by 180 degrees, so that any possibility of interference, as determined by individual staff persons, places an insurmountable burden on the water user to prove otherwise, and no amount of scientific evidence will appease the agency.

Of course, one would expect a degree of increased difficulty associated with appropriation of new water use rights as water uses become more subscribed within the State. It is the degree and selective nature of how restrictive policies are being carried out by OWRD that is suspect and disappointing. A judge recently suggested that OWRD would likely reconsider its regulatory policies going forward after receiving the evidence presented at trial. The authors of this paper are not so optimistic, and it seems that without court orders requiring OWRD to follow the law, the agency is poised to only become more restrictive to the detriment of all water users without an associated benefit to senior users.

CONCLUSION

In conclusion, if you anticipate needing a water use right, apply now; tomorrow OWRD may find another, more inventive way to deny your application.

DESIGN SUMMARY OF THE MCMULLIN ON-FARM FLOOD CAPTURE AND RECHARGE PROJECT

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David Munro[2]
David Merritt[3]
Don Cameron[4]
Philip Bachand, Ph.D.[5]

ABSTRACT

Flows of 500 to 4,500 cubic feet per second (cfs) released from Pine Flat Reservoir and diverted into the North Fork of the Kings River enter the James Bypass. As these flows approach 4,500 cfs, the James Weir is operated for minimal restrictions, risking downstream flooding. Diversion of flows will reduce downstream flood risks, particularly from reducing damages associated with 10- to 100-year flood events (Bachand et al. 2013; 2016).

The long-term infiltration rates in the area range from 2 to 3 inches per day (in/d) (Bachand et al, 2013, 2014). The total project area for Phases 1, 2, and 3 is approximately 20,000 acres of agricultural lands with approximately 25% planned for flood capture (Bachand and Bachand, 2014).

The design includes the main conveyance system which provides the hydraulic backbone for diverting flood flows, conveyance to the participating farm fields, and supplying the On-Farm Flood Capture and Recharge (OFFCR) system. The **Main Conveyance System** includes an expandable 500 cfs turnout, canal modifications, road and canal crossings, and an expandable pumping station. The main canal will be designed to convey 500 cfs. The north and the east legs will be designed to convey 400 and 300 cfs, both will be expandable. All canal systems will be constructed with non-compacted bottoms which will contribute to the infiltration area. The main conveyance system is required for Phase 1 and will be the foundational for the expansion planned under Phases 2 and 3.

INTRODUCTION

Flood flows due to high precipitation and or snowmelt are released from Pine Flat

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Reservoir or contributing streams and enter the Kings River below Pine Flat Dam. These flows are diverted into the South and North Forks of the Kings River with the North Fork tying into the Fresno Slough which joins the San Joaquin River and ultimately ends up in the San Francisco Bay. Diverting and capturing these flood flows at the James Bypass will help alleviate potential flood damage downstream (Bachand et al, 2013; 2017) as well as help address the ground water overdraft in the Lower Kings Basin for which the area near Helm is considered ground zero (Bachand et al. 2012, 2014, 2016). The project location is shown in Figure 1.

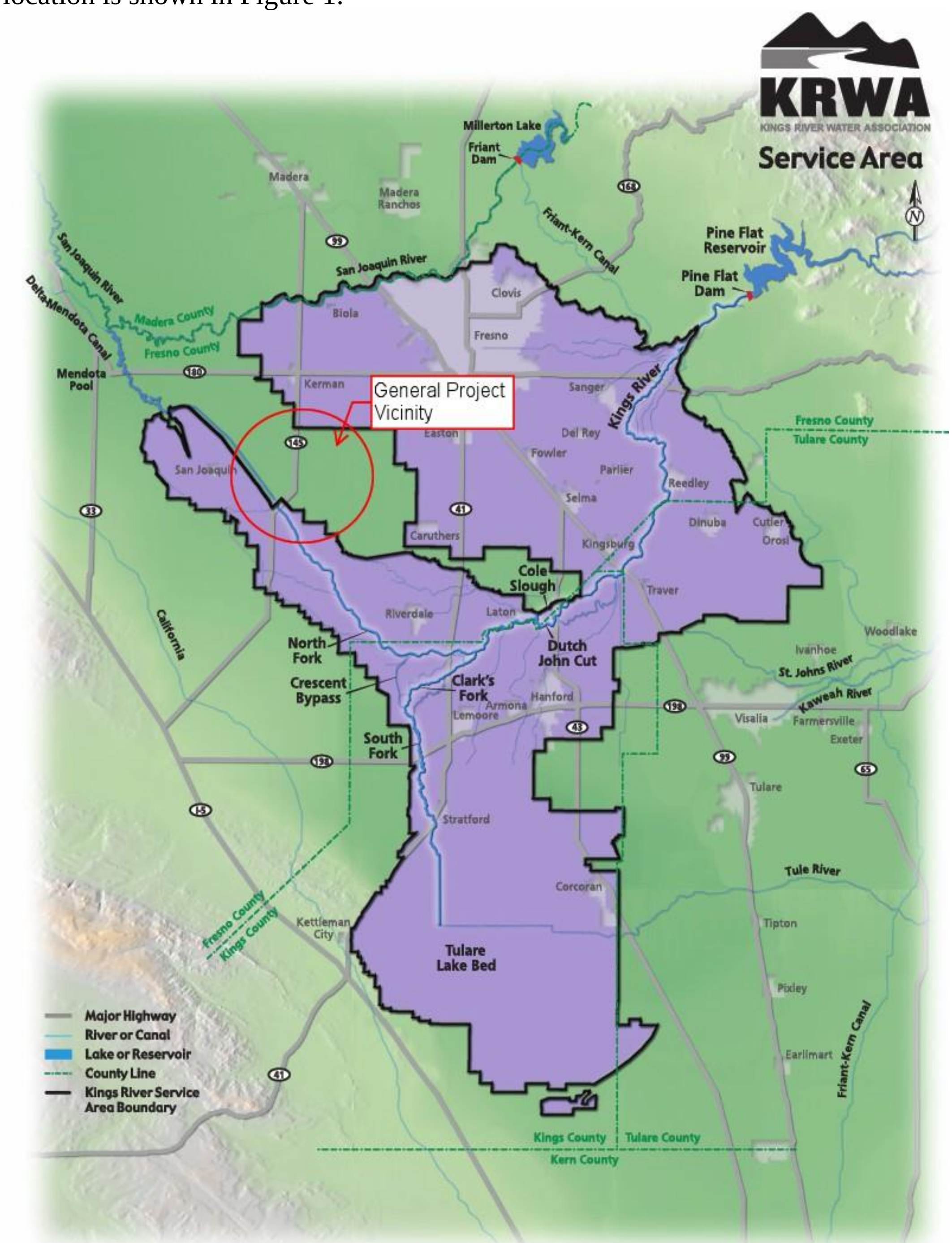


Figure 1. General Project Vicinity, KRWA 2017

An example of flood flows at the proposed turnout site is shown in Figure 2.

Figure 2. Flood flows along the James Bypass, February 2017 (Provost & Prichard).
Note: The James Bypass is a stretch of the Kings River extending from State Route (SR) 145 near Helm to Mendota. This section is also known as the Fresno Slough and is only wet during flood flow conditions. During the remaining periods, this river is dry.

Historically, Terranova Ranch has captured and utilized flood flows when they are present. The water has been spread on crop lands such as vineyards, alfalfa and pistachios under *in lieu* recharge. More recently, Terranova Ranch has captured flood flows for direct recharge, both in 2011 (Bachand et al 2012; 2014) and this year. Utilizing existing farm lands to capture and recharge flood flows allows ranch management to continue their farming practices and replenish the groundwater table.

These have been pioneering efforts in OFFCR and offer the potential for regional compliance with California's 2014 Sustainable Groundwater Management Act (SGMA). Initial envisioning and study of this novel approach was funded through an NRCS Conservation Innovation Grant (Bachand, 2010). That and subsequent studies have led to numerous scientific and engineering publications, reports and presentations that address technical approach, feasibility, capacity, costs, water quality, and crop effects instrumental in developing the OFFCR (e.g., Ariyama et al, 2017; Bachand et al, 2012, 2013, 2014, 2016; Cameron 2017; Waterhouse et al, 2016). Risks exists to transport salts and nitrates to groundwater in the short-term due to existing nitrates and salts in the vadose zone (Waterhouse et al, 2016). However, bringing in high quality surface water, over time, should improve groundwater quality through dilution (Bachand et al, 2016; Ariyama et al, 2017).

Previous efforts have laid the foundation for full-scale implementation. The McMullin Project, awarded through California's FloodSafe program (KRCD 2012) Are key collaborating organizations for this project. They include the Kings River Conservation District (KRCD), which has administered the awarded grant contract, led the permitting and all regulatory needs of the project as well as contributed to the design of the project; Terranova Ranch which has provided leadership, agricultural practices guidance, and matching funds; Bachand & Associates which has led conceptual design and provides technical leadership regarding implementation; and Provost & Pritchard serving as the project engineer.

Many elements have been considered in the system layout and design for conveying water effectively onto participating farmland and developing effective infiltration and farming strategies for participating farmers. The project design includes determining infiltration rates, crop selection to be flooded, duration of applied water, placement of the major canal system, and location of pump stations. Concurrent with the project is research by Bachand and Associates, Terranova Ranch, and partnering organizations (e.g. UC Davis, Sustainable Conservation) regarding crop, water quality, agronomic and logistical considerations, opportunities and constraints.

DESCRIPTION OF THE PROJECT AREA

Kings River Flow-James Bypass (Fresno Slough)

Historic flows passing through the James Bypass are highly variable in magnitude, frequency, and duration. Flows in excess of 500 cfs have occurred 20 times over a 50-year period from 1954 to 2006. On average, flood flows have occurred about every two years, and wet years typically occur consecutively (meaning three consecutive wet years) (Bachand et al 2017). Flows through the Fresno Slough on average occur over about 3 months (25^{th} percentile = 2 months; 75^{th} percentile = 4 months) with 1983 having flows the entire year. The capacity of the Fresno Slough is approximately 4,750 cfs.

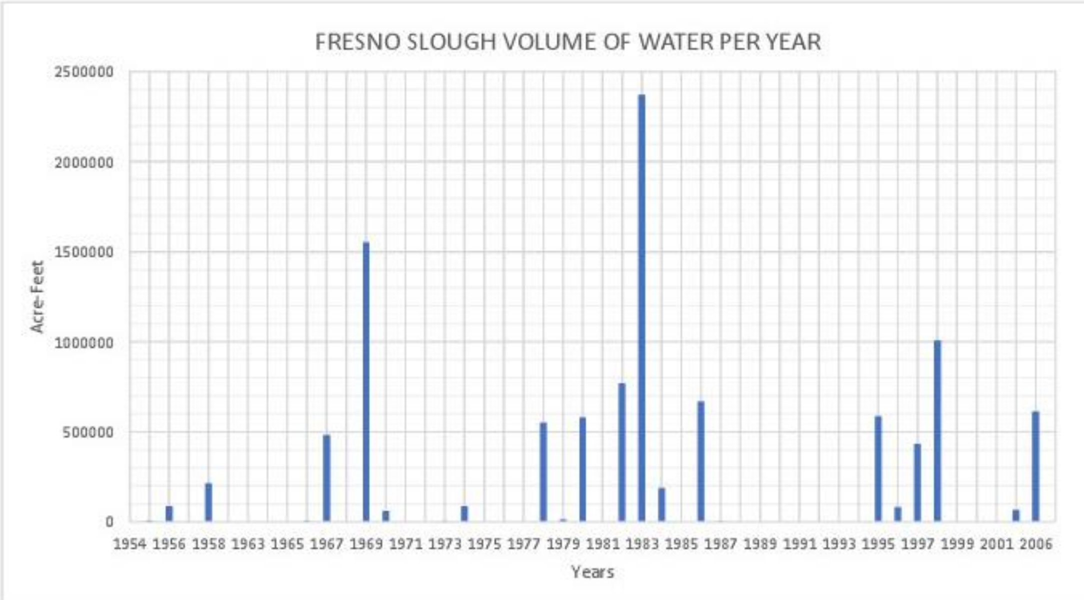


Figure 3. Yearly Water Volume through Fresno Slough (Kings River Water Master Reports). Note: Flows are highly variable in magnitude, duration and frequency. Flows can range from 100s of cfs to over 4,500 cfs and can occur for several years consecutively (e.g. 1978 – 1980; 1982 – 1984; 1995 – 1998) or not at all for many years (e.g. 1987 – 1994). Flows can also occur for a few weeks to several months (e.g. 2017) or even for over a year (e.g. 1983).

The highly variable flood flows require an expandable and flexible approach for flood capture if recharge is to be a viable solution for helping overcome chronic and severe overdraft plaguing much of the Central Valley, which is designated as critically over-drafted under SGMA.

The diversion point for this project is just upstream of the James Weir along the southern end of the James Bypass where SR 145 crosses the Kings River and a few miles north of Helm. Disadvantaged Communities (DACs) that have been threatened by flooding along the Kings River downstream of this location, including San Joaquin and Tranquility. Flood damages along the San Joaquin and Kings River add up to$1.4 billion (2013 dollars) since 1983 (Bachand et al 2016). This year, the levee system was in danger of failure. The Fresno Bee reported on March 12, 2017 that “Fresno County sheriff’s deputies left notices on the doors of 80 homes located south of West Jefferson Avenue, preparing residents for a possible levee break that could send thigh-high water into their homes.”

Infiltration Areas

Infiltration tests were conducted by Bachand & Associates and Terranova Ranch and found to be the highest during the initial period of inundation (Bachand et al, 2012, 2014). During the first day of inundation, infiltration rates were often above 5 in/d (35 in/d max). After about 2 days of inundation, infiltration rates were in the 2 to 3 in/d range, and these rates declined only slightly for longer periods of duration. The longest continuous duration measured during this period was 20 days at which time infiltration rates were at about 2 to 2.5 in/d (Bachand et al, 2012).

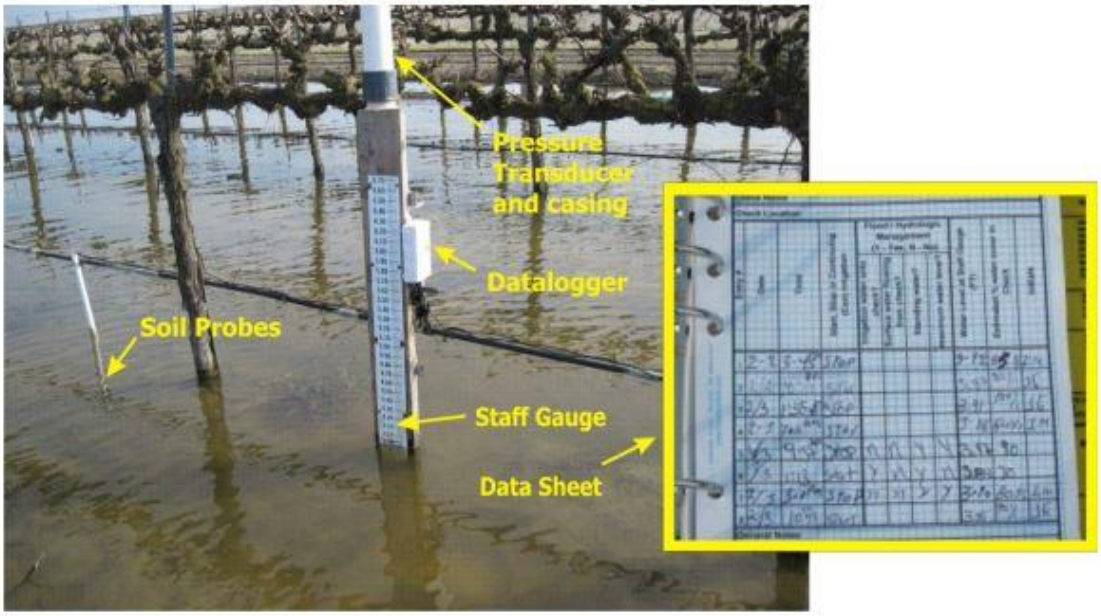


Figure 4. Infiltration Test Performed by Bachand & Associates (Bachand et al 2012)

There will be two types of flooding of farmed fields, one being a field that is considered a permanent flooded field and the other a temporary flooded field. Permanent flood fields will be fields that can take water any time of the year and most likely be all non-permanent cropped fields. Temporary flood fields can be on permanent cropped fields as well as non-permanent cropped fields. Temporary flood fields would be expected to take flood flows during periods in which crops can tolerate flooding. Permanent crops shown to be suitable for temporary flooding include grapes, almonds, and pistachios (Bachand et al 2012; 2014; Cameron, 2017).

DESIGN

The design includes the main conveyance system, which provides the hydraulic backbone for diverting flood flows from the Kings River and for conveying to participating farm fields, and an OFFCR system for capturing and infiltrating flood flows.

Several components make up the **Main Conveyance System** (Figure 5) and include a turnout, canal modifications and construction, crossings over highways and canals, and a pumping station as detailed below:

- Reinforced concrete turnout with a concrete deck to divert 500 cfs from the Fresno Slough with flow measurement (flow meter). The structure will be designed to operate at a water elevation of 177.5 feet (NAVD 88) providing a depth of water of approximately 8 feet through the turnout. At lower, more manageable flows in the James Bypass, the James Weir will be operated to maintain a higher water level, which is estimated to be 180.5 feet (NAVD 88). The structure will include four 6 foot by 8 foot double leaf slide gates. The deck has been designed to meet Caltrans HL-93 for truck traffic loading. Wing walls are designed to prevent soil creep along the bottom and the lower sides of the structure and based on a worst-case scenario of 11 feet of head when the gates are closed, isolating main canal.

- Modification of the existing Terranova Canal (main canal) will occur along McMullin Grade (SR 145) and be designed to convey 500 cfs. The existing canal will be modified to reduce the amount of excavation during construction. The bottom of the main canal will be constructed with minimal compaction. The infiltration that occurs will be included in the total infiltration.

- A reinforced concrete pump structure will ultimately have a capacity of 500 cfs. The structure will be at the end of the main canal and pump water to the north and east legs of the main conveyance system. The initial concrete structure to be constructed in Phase 1 will supply 150 cfs. The structure will be placed and designed for expansion to a capacity of 500 cfs in phases 2 and 3.

- A crossing at McMullin Grade (SR 145) and Floral Avenue will be installed using a bore and jack method of construction and will convey 400 cfs. This process will be considered a tunneling project. There will be multiple pipes crossing SR 145, and close attention to spacing between each pipe will be considered. The material used will be rubber gasketed reinforced concrete pipe designed for jacking.

- The north leg along the Siskiyou Avenue alignment from Floral Avenue to Springfield Avenue will convey 300 cfs. This design will consist of a canal with elevated banks and an inverted siphon crossing at the James Irrigation District's (JID) existing concrete lined canal (Coalinga Canal), and one equipment crossing (inverted siphon) further to the north. The east leg along Floral Avenue from State Route 145 (SR 145) to Madera Avenue will be designed to convey 400 cfs and consist of a canal with elevated banks and one equipment crossing (inverted siphon).

The bottom of both the north and east canals will be constructed with minimal compaction. The infiltration that occurs will be monitored and included in the total infiltration. The north and east legs will be designed with minimal longitudinal slopes to minimize the amount of material excavated. Due to the positive gradient in the direction of flow of both canals, half-mile sections of the canal will be designed to balance the cut and fill along the banks.

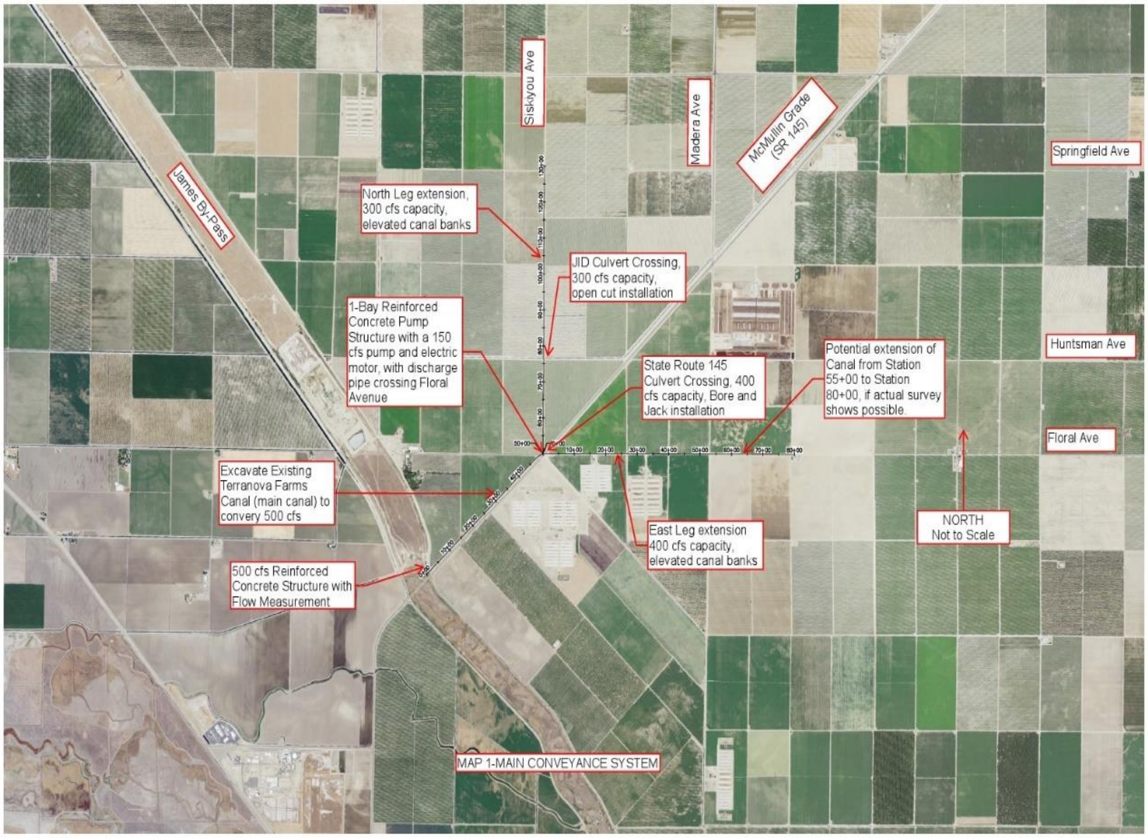


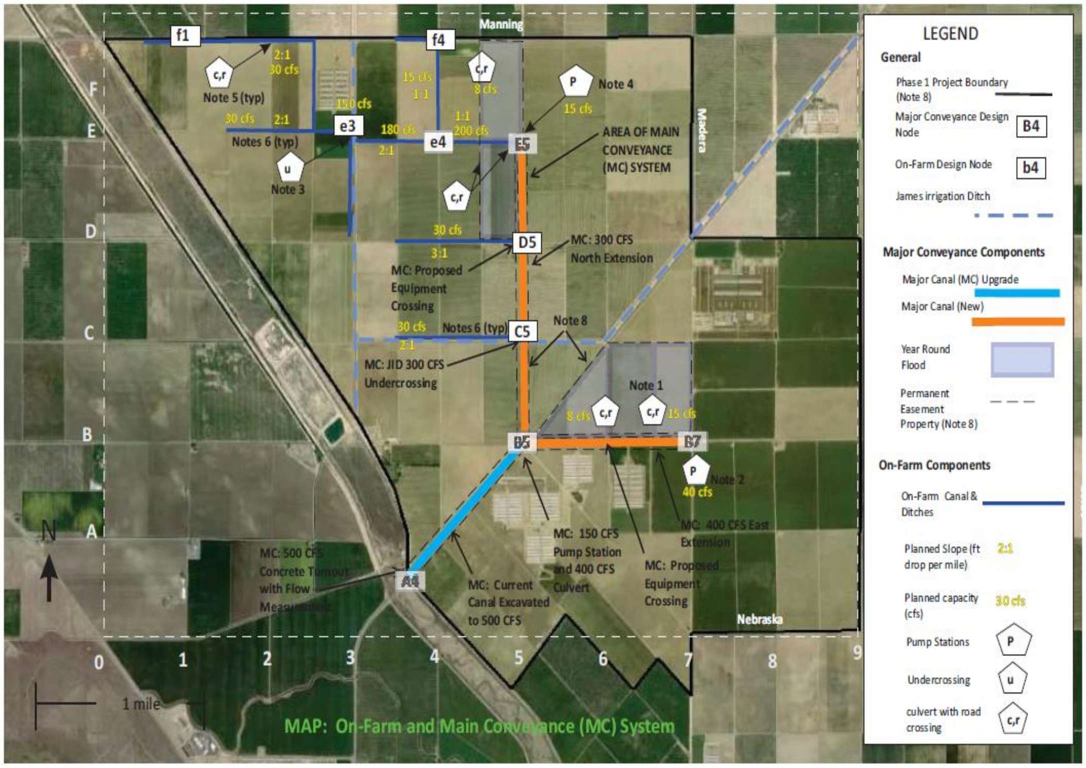
Figure 5. Main Conveyance System Alignment

The **On-Farm System** (Figure 6) is planned to include farm-scale conveyance systems (Bachand 2014):

- Flexible distribution-conveyance canals will enable movement of water throughout the project area for Phases 1-3. The canal system is being designed to enable flexible distribution, which consists of providing flows within one-half mile of all farm fields and feeding water into the legacy flood irrigation system using temporary or permanent pump stations. Where applicable the canal banks will be elevated to gravity feed farm fields.

- Management of head loss in pipes, including legacy flood Irrigation systems will transfer water from the canal system to targeted flood capture fields. Velocities will be designed to limit head loss so that standard irrigation pumps can be used to provide sufficient flows to meet direct recharge requirements.

This on-farm system is likely to evolve over time to meet flexibility, cost, and capacity needs for farmers and their participating fields.



Philip Bachand
Bachand & Associates
04-18-2017

Notes
1. Buried culverts to allow flow flood flows westward from eastern most permanent flood easement field.
2. Planned 40 CFS electric pump will flood most eastern flood easement field in field set and also have capacity to pump into legacy flood irrigation piping for flooding nearby fields. Pump on steel and concrete platform as appropriate. Pump will provide hookup for adjacent land owner access.
3. James Irrigation Ditch undercrossings are constructed through cutting the ditch, burying pipe and rebuilding ditch.
4. Planned 15 CFS electric pump will moves water from canal into flood fields. Culvert and gate on western side of fields allows gravity flow into adjacent fields from flood easement field.
5. Culverts with raised crossings are expected to be needed at every crossing for canals under 100 CFS.
6. Pumps will be needed to either move water from main conveyance canals into on-farm canals or to move water from on-farm canals onto farm fields. Gravity flow will be used whenever possible. Pumps may be permanent or temporary, depending upon expected use and location. Final decisions on pumps will occur under further design.
7. Not to scale.
8. **Permanent (Year Round) Easement Property** shows the area for permanent, year round facilities which includes the Major Conveyance Components (e.g. upgraded Major Canals, new Major Canals, Year Round Flood Fields). **Temporary (Seasonal) Easement Properties** include all temporary or seasonal facilities within the Phase 1 properties which include on-farm canals, ditches, pumps, and

Figure 6. Main and On-Farm Conveyance System (Bachand and Bachand, 2014). Note: the On-Farm Conveyance System will be designed to minimize head loss, be cost effective and easily constructed, and flexible. The conveyance system is planned to provide water within ½ mile of all participating acreage.

PERMITTING, REGULATORY COMPLIANCE, AND AGREEMENTS

The project has required state and federal regulatory compliance (Table 1), local and regional permitting (Table 2), and operational agreements and easements (Table 3). Some of these permits have been to develop the foundational infrastructure for Phase 1 as well as for expansion into Phases 2 and 3.

Many of the key efforts have been related to federal and state regulatory efforts. An Initial Survey/Mitigated Negative Declaration was required under the **California Environmental Quality Act (CEQA)** to identify all potential environmental impacts (Tetra Tech, 2016a). A Mitigation, Monitoring, and Reporting Program (MMRP) was completed to ensure that all measures are implemented and completed (Tetra Tech

2016b). CEQA was conducted concurrently with the 30% design efforts.
Other key efforts were needed due to the encroachment on Waters of the United States. **US Army Corps of Engineers Individual Permit for Section 404** compliance with the Clean Water Act (for fill or dredging in a Waters of the US) (Table 1). The permit is necessary because the proposed turnout will impact a small area of Waters of the US in Fresno Slough. The permit addresses and complies with requirements of the Harbors Act and the Clean Water Act. There are a number of regulatory efforts required under the 404 permits:

- Additional surveys will be conducted to prepare the Aquatic Resources Delineation Reports which includes the ordinary high-water mark survey.
- Compliance with the Endangered Species Act, and the proposed protocol surveys for the kangaroo rat will assist in Corps decisions in this area.
- Compliance with Section 106 of the National Historic Preservation Act which requires consultation with the California State Historic Preservation Officer (SHPO) to determine if the activities may have the potential to cause effects to any historic properties listed on, determined to be eligible for listing on, or potentially eligible for listing on the National Register of Historic Places.
- A cultural resources report will be needed to comply with these requirements.

Both the CEQA document and the 404 permit may take 12 to 24 months for completion, and working on these efforts concurrently, where possible, helps expedite the process.

Additional federal and state requirements require considerable time and effort and include:

- **A Notification of Lake or Streambed Alteration application for a Streambed Alteration Agreement (1602 agreement)** needs to be obtained from the California Department of Fish and Wildlife for work in the Fresno Slough prior to construction activities (Table 1).
- **A Water Quality Certification pursuant to Section 401** of the Clean Water Act shall be obtained from the California Regional Water Quality Control Board to cover State requirements for impacts to waters.
- **Caltrans Encroachment Permit for State Route 145 (McMullin Grade)** crossing is required across McMullin Grade. Tunneling is proposed because the pipe sizes are greater than 30” in diameter.

A number of local and regional regulatory efforts (Table 2) and cooperation agreements and easements (Table 3) are required as well. For instance, a Central Valley Flood Protection Board Encroachment Permit is required in conjunction with Reclamation District (RD) 1606 to allow the turnout to be constructed and operated with the boundary of the RD 1606.

In general, local and regional permits are less time consuming than State or federal permits and regulatory compliance. However, this project will require cooperation between KRCD, James Irrigation District, RD 1606, Terranova Ranch, and others. This cooperation has required the writing and implementation of agreements between the various cooperating parties to implement and operate the project (Table 3). These agreements include easements, facilities and operational agreements, which have required over 2-years to implement. Future phases for this project may be operated or owned by other agencies or organizations and for the expansions additional agreements will be required.

Table 1. Regulatory compliance and legal agreements required for McMullin Project

Permit	Focus	When Required	Reason for Permit	For Public or Private Project	Months Required
CEQA					
IS/MND	Identify measures to mitigate environmenal impacts (e.g. air, habitat, cultural, water) to less than significant levels	Implementation of infrastructure projects	Mitigation required for habitat, emissions, water and cultural resources	Both	18 - 24
MMRP	Ensure all required mitigation measures identified in the IS/MND are implemented and completedprojec	Monitoring of mitigation measures required by IS/MND	See IS/MND	Both	18 - 24
USACE 404 Permit	Compliance with Clean Water Act	Encroachment into Waters of the US	Turnout construction disturbs James Bypass	Both	8 - 12
Biological Reconnaissance Survey and Report				Both	12 - 18
Aquatic Resources Delineation Report				Both	12 - 18
Letter of Permission for Nationwide Permit				Both	12 - 18
Compliance with ESA (Endangered Species Act)				Both	12 - 24
NHPA Section 106	Compliance with National Historic Preservation Act	Determine if activities will impact historic properties listed on the National Register of Historic Places	Phase 1 conveyance and recharge facilities, entire operation.	Public	12 - 24
RWQCB, 401 Permit	Water quality state requirements for impacts to Water of the US under the Clean Water Act	Encroachment into Waters of the US	Turnout construction disturbs James Bypass	Both	8 - 12
CDFA, Streambed Alteratio	Fish and wildlife impacts from streambed alteration	Alteration of streambeds of Waters of the US	Construction in James Bypass	Both	12 - 24
Alteration application (1602 agreement)					
Biological Reconnaissance Survey and Report	See USACE 404 Permit				
Ordinary High Water Mark Survey					
Environmental Site Assessment, Phase 1	Identifies contaminant liabilities	Initial due diligence step	No contamination was identified	Both	3 - 6
Caltrans Encroachment Permit	State road system encroachment	Permit for construction and encroachment of a CA state road	SR 145 (McMullin Grade) crossing	Both	6 - 12
CA Water Code, Plan to Minimize	Minimize impacts of implementing project on neighbors		Impacts of operations (e.g. floodwaters, groundwater, resources)	Public (DWR)	3 - 6
DWR, H&H Study	Cost and benefits from flood mitigation	Assess costs and benefits for justifying receivig public funds.	Project costs and benefits from flood mitigation	Public (DWR)	6 - 18
SWRCB, SWPPP	Stormwater runoff management and control during construction	Protect areas from stormwater runoff debris, flows and erosion during construction period	Required for all Main Conveyance infrastructure	Both	1 - 2

Table 2. Local and Regional Regulatory Compliance

Permit	Focus	When Required	Reason for Permit	For Public or Private Project	Months Required
CVFPB Encroachment Permit		Encroachment into jurisdiction of other local agencies	The levee is in the boundary of Reclamation District 1606	Both	6 - 12
RD 1606 Encroachment					1 - 2
PG&E Connection Application	Power for pump station	Electrical hookups	Pump Station at Floral Ave and SR 145	Both	12 - 24
Fresno Co, Bldg Permit	Electrical connections for pump station	Electrical hookups	Pump Station at Floral Ave and SR 145	Both	4 - 6

Table 3. Legal agreements developed for Phase 1 McMullin Project

Permit	Focus	When Required	Reason for Permit	For Public or Private Project	Months Required
State and Federal Permits and Regulatory Requirements					
CEQA					
IS/MND	Identify measures to mitigate environmenal impacts (e.g. air, habitat, cultural, water) to less than significant levels	Implementation of infrastructure projects	Mitigation required for habitat, emissions, water and cultural resources	Both	18 - 24
MMRP	Ensure all required mitigation measures identified in the IS/MND are implemented and completed project	Monitoring of mitigation measures required by IS/MND	See IS/MND	Both	18 - 24
USACE 404 Permit	Compliance with Clean Water Act	Encroachment into Waters of the US	Turnout construction disturbs James Bypass	Both	8 - 12
Biological Reconnaissance Survey and Report				Both	12 - 18
Aquatic Resources Delineation Report				Both	12 - 18
Letter of Permission for Nationwide Permit				Both	12 - 18
Compliance with ESA (Endangered Species Act)				Both	12 - 24
NHPA Section 106	Compliance with National Historic Preservation Act	Determine if activities will impact historic properties listed on the National Register of Historic Places	Phase 1 conveyance and recharge facilities, entire operation.	Public	12 - 24
RWQCB, 401 Permit	Water quality state requirements for impacts to Water of the US under the Clean Water Act	Encroachment into Waters of the US	Turnout construction disturbs James Bypass	Both	8 - 12
CDFA, Streambed Alteratio	Fish and wildlife impacts from streambed alteration	Alteration of streambeds of Waters of the US	Construction in James Bypass	Both	12 - 24
Alteration application (1602 agreement)					
Biological Reconnaissance Survey and Report	See USACE 404 Permit				
Ordinary High Water Mark Survey					
Environmental Site Assessment, Phase 1	Identifies contaminant liabilities	Initial due diligence step	No contamination was identified	Both	3 - 6

Table 3-Continued. Legal agreements developed for Phase 1 McMullin Project

Caltrans Encroachment Permit	State road system encroachment	Permit for construction and encroachment of a CA state road	SR 145 (McMullin Grade) crossing	Both	6 - 12
CA Water Code, Plan to Minimize	Minimize impacts of implementing project on neighbors		Impacts of operations (e.g. floodwaters, groundwater, resources)	Public (DWR)	3 - 6
DWR, H&H Study	Cost and benefits from flood mitigation	Assess costs and benefits for justifying receivig public funds.	Project costs and benefits from flood mitigation	Public (DWR)	6 - 18
SWRCB, SWPPP	Stormwater runoff management and control during construction	Protect areas from stormwater runoff debris, flows and erosion during construction period	Required for all Main Conveyance infrastructure	Both	1 - 2
Local and Regional Permits					
CVFPB Encroachment Permit		Encroachment into jurisdiction of other local agencies	The levee is in the boundary of Reclamation District 1606	Both	6 - 12
RD 1606 Encroachment					1 - 2
PG&E Connection Application	Power for pump station	Electrical hookups	Pump Station at Floral Ave and SR 145	Both	12 - 24
Fresno Co, Bldg Permit	Electrical connections for pump station	Electrical hookups	Pump Station at Floral Ave and SR 145	Both	4 - 6
Legal Agreements and Easements					
KRWA, Flood Water Agreement	Water Rights for diversion	Temporary or permanent water rights required for flood recharge diversions. Water rights may be project specific or under established water rights of larger organization	Water rights for flood flow diversions from the Kings River at the James Bypass	Both	4 - 8
Coordination Agreements					
Facilities Easement Agreement	Management of turnout at James Bypass	Implementation of project on lands owned by other agencies or organizations	Agreement with RD 1606	Both	12 - 24
Common Use Agreement	Identify areas of common use by different participating agencies	Actions required on current easements held by other agencies or organizations	Crossing of James Irrigation Canal	Both	12 - 24
James Weir Operation Agreement	To coordinate diversions from Kings Rivers	Project depends upon operation of facilities held by other agencies or organizations	Operation of James Weir to enable diversions to the project.	Both	12 - 24
Master Project Agreement	Coordination on project implementation	Multiple organizations involved	Partnering by KRCD and Terranova Ranch, Inc.	Both	12 - 24
Project Easement Agreement	Legally identifies easements for lands required for project	Easements required for project	Facilities and Flood Easements	Both	12 - 24

CONSTRUCTION

This project will be designed and constructed following United States Bureau of Reclamation guidelines as well as California Department of Transportation (Caltrans) guidelines. In doing so licensed contractors will be familiar with the standard practices and will have the needed reference material such as, Caltrans Standard Specifications readily available.

Phase 1 construction is anticipated to start in 2018. The construction is estimated to take between 160 to 200 working days, with the construction of the turnout structure within the Fresno Slough being the most critical. In wet years like 2017, the window to construct in Fresno Slough will be small. Construction of the turnout and the pump structures is a critical path item and must be constructed simultaneously to attain high construction efficiency.

Construction of the canals can be done independent of each other with the tie in to the structures happening after the completion and curing of the concrete structures.

The crossing at SR 145 can be done independent of the other tasks as well. This process will be completed by jack and bore. This task will be considered a tunneling project. Caltrans guidelines will be followed.

CONCLUSION

The project is located in an ideal location; it is upstream of a check structure, the James Weir, which can control the level in the pool from which the water will be diverted. The layout of the main conveyance system will allow the project to expand further north and east. The on-farm conveyance system will provide water within one-half mile of flooded fields at a rate that will match the infiltration rate of the soil. Designating multiple farm fields with different crops will provide flexibility and allow rotation of fields to be flooded.

The McMullin On-Farm Flood Capture and Recharge Project will provide a substantial benefit in reducing impacts due to high flows along the Fresno Slough, as well as reducing groundwater overdraft through groundwater recharge and in lieu recharge by percolating high quality surface water to the groundwater aquifer, thus increasing the ground water quality. This project will have the potential to infiltrate up to 90,000 acre-feet at a rate of 1,000 acre-feet per day over an average of 90 days. This project will have a large area available to rotate and vary durations of applied water. Reduction of flows downstream is a method to reduce the impacts to DACs along the James Bypass. This project will demonstrate the cooperation between agencies and local farmers to find solutions for the groundwater overdraft in the area and to provide opportunities for increasing the use of flood flows as the area works to comply with SGMA. Local out-reach will give other agencies a platform to follow.

Important steps in planning for these projects is to anticipate legal and regulatory requirements. Meeting these requirements have required several years of effort under this project, and those challenges are likely common to other similar efforts. Each area will have its challenges, but overall, this project and others like it will benefit groundwater and the farming community for years to come. Given the need to comply with SGMA, the institutional and planning framework required by SGMA may facilitate similar projects.

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A PRACTICAL APPROACH TO WATER BUDGETS

Owen E. Kubit, PE, PG, CFM[1]

ABSTRACT

California's Sustainable Groundwater Management Act requires a water budget that evaluates historical, current and projected groundwater conditions. Annual reporting will also be required, but minimum reporting requirements only include groundwater levels, groundwater pumping, surface water use and change in groundwater storage. Several methods are available for these analyses including numerical groundwater models, spreadsheet-based water budgets, and other simple spreadsheet analyses. Numerical models are likely to be required for most areas, but spreadsheet analysis can also play an important role, especially in annual reporting, as a supplement to numerical models, or in place of a numerical model for a small or simple analysis. Performing a spreadsheet analysis can provide a quick initial assessment, and can be a 'no-regret' action, since the data collected and insights gathered can be applied in a numerical model. A comparison of the pros and cons of numerical models versus spreadsheet tools is provided. Spreadsheets can be flexible, transparent, easily audited, and do not require a modeling expert to modify. Numerical models have advantages when working with large amounts of data, and can be more accurate since they can more efficiently process interactions between parameters. Water budget and modeling frequency should consider how often major management decisions, such as adjustment of safe yield, are made. A simplified method for estimating change in groundwater storage is also presented that is transparent and generally not subject to significant interpretation. A combined approach to water budgets using numerical models and spreadsheet analysis may be the most efficient and practical approach.

INTRODUCTION

Water budgets are important tools for water managers to track water uses and losses, estimate groundwater overdraft, and evaluate the success of water conservation programs. California's Sustainable Groundwater Management Act (SGMA) will require many water areas to develop detailed water budgets. As a result, many California water agencies are evaluating different approaches to developing water budgets. In general, there are two types of water budget models: analytical models and numerical models. Analytical models include spreadsheets or other simple analysis tools. From here on, discussions on analytical models will be limited to spreadsheets. Numerical models, also called dynamic models, include more complex modeling programs, such as the United States Geologic Survey's MODFLOW or the California Department of Water Resources' Integrated Water Flow Model (IWFM). Each type of model has pros and cons, which are discussed below.

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SUSTAINABLE GROUNDWATER MANAGEMENT ACT

In 2014, California enacted landmark legislation known as the Sustainable Groundwater Management Act (SGMA) in response to years of groundwater overdraft throughout much of the State. The act requires that Medium- and High-Priority Groundwater Basins achieve groundwater sustainability by 2040. In these areas, the act requires the formation of local Groundwater Sustainability Agencies that must assess local groundwater conditions and develop Groundwater Sustainability Plans. These responsibilities are left in the hands of local authorities, but State intervention is possible if local authorities fail to meet the regulations.

Despite the importance of groundwater to the State, California lacked a statewide framework for regulating groundwater until the passage of SGMA in 2014. Prior to SGMA, groundwater was largely managed on a voluntary basis, and sustainable groundwater use was only required in a limited number of adjudicated basins. As a result, many agencies never saw the need, or took the effort, to develop a groundwater model or detailed water budget. Therefore, many agencies will need to develop new water budgets or enhance their current water budgets.

SGMA WATER BUDGET REQUIREMENTS

SGMA will require a water budget that evaluates historical, current and projected groundwater conditions. The water budget will need to be re-evaluated every five years. Annual reporting will also be required, but minimum reporting requirements only include the following:

- Groundwater levels
- Groundwater pumping
- Surface water use
- Total water use
- Change in groundwater storage.

The California Department of Water Resources (DWR) does not mandate use of a numerical model for the water budgets and states the following:

> "*If a numerical groundwater and surface water model is not used to quantify and evaluate the projected water budget conditions and the potential impacts to beneficial uses and users of groundwater, the Plan shall identify and describe an equally effective method, tool, or analytical model to evaluate projected water budget conditions*." (State of California, 2016)

Published regulations and personal communication with the California Department of Water Resources clearly show that analytical models are permitted, but numerical models may be necessary to meet SGMA requirements. During a 2016 meeting with DWR staff on SGMA modeling requirements they emphasized two key points: 1) selection of a model approach is up to the local agency; and 2) numerical models are considered by DWR to generally be more accurate than analytical models. However, they also suggested that a combined approach using both analytical and numerical models may be the best alternative.

COMPARISON OF SPREADSHEET MODELS AND NUMERICAL MODELS

Spreadsheet and numerical models each have advantages and disadvantages. In general, spreadsheets are flexible, easily audited, do not require a modeling expert to modify, and may be appropriate for simple analyses. Numerical models can evaluate more complex situations, and therefore may be more accurate and suitable for modeling large areas.

The California Department of Water Resources provides a good summary of the pros and cons of both types of models below:

> *"Similar to the question of whether models should be used during GSP development is the question of the appropriate level of model complexity. Simple models require fewer data, less complex software, and are, therefore, often less expensive, and have much shorter run times. These characteristics are advantageous when focusing on a single undesirable result. However, simple models may overlook important system components and the interconnectedness of undesirable results, and may be difficult to calibrate to historical data. Complex models can incorporate more data and professional judgment. Therefore, they often result in a more accurate representation of the groundwater system. However, complex models are more expensive and difficult to build, require more data and more technical expertise, and the complexity can lead to a false impression of accuracy; a complex model may in fact be less accurate."* (DWR, December 2016a)

Figure 1 illustrates several primary characteristics of water budget models. These characteristics are discussed below as they relate to spreadsheet and numerical models. The discussions are based on common knowledge of the two types of models, as well as the author's professional experience.

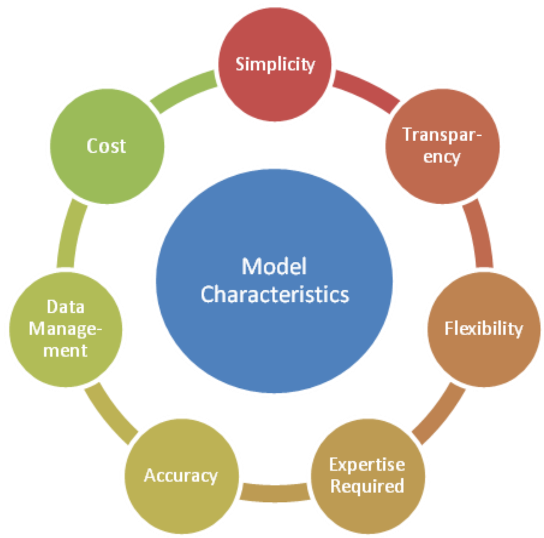

Figure 1. Water Budget Model Characteristics

Simplicity

Spreadsheets. Spreadsheets are generally simpler than numerical models. They have streamlined input, output and graphing capabilities. Spreadsheet models typically have simpler programming. They are also simpler since they are not as prone to extensive elaboration; in other words, spreadsheet formats limit the size and complexity of a usable model.

Numerical Models. Numerical Models are generally considered complex and require special software and modeling experts to compile or update. Numerical models can also accommodate large amounts of data and model complex processes.

Transparency

Spreadsheets. Spreadsheet models are valued for their transparency. In comparison, they are easier to follow and understand, easier to audit, and may be easier for government agencies to review too. The data and results can be easily communicated to water managers and the general public. Spreadsheets can also show the different stages in the development of the data so the results are easier to check and understand.

Numerical Models. Numerical models are less transparent due to their complexity and the nature of the software used. In the author's experience, these models are transparent to the modeler, yet that is because they have spent significant time collecting data, building the model and running simulations. That level of understanding is difficult to transfer to other parties that are interested in the model, but were not involved in the model development. This can result in a perception that the model is a 'black box', with little to no understanding on how the model works. The black box perception can be addressed through education, involving the model sponsor in the model development, adequate model documentation, and post-processing of data. A common problem arises when the model sponsor chooses not to stay engaged in the model development since they hired a consultant to perform the work, yet they must have significant involvement if they are to understand a complex model.

Flexibility

Spreadsheets. Spreadsheets are very flexible and can be easily modified by anyone familiar with basic spreadsheet operations. They are easily customized and tailored to fit specific projects.

Numerical models. Numerical models are not as flexible as spreadsheets, however, with some effort they can be quite versatile. Each modeling program has its limitations that must be worked around. Some flexibility is also lost because modeling experts are required to operate them.

Expertise Required

Knowledge of water budgets is a required whether one uses a spreadsheet or numerical model. Water budgets require both hydrogeologists and water resources engineers with expertise in groundwater, surface water, water management, urban water use and agricultural water use.

Spreadsheets. Virtually all engineers and geologists use and understand spreadsheets. The spreadsheet functions needed to develop a water budget are common and simple. This simplicity can allow water agencies to create or update their own water budget models. Advanced spreadsheet functions, such as Visual Basic programming, can be used, but are not required for a water budget spreadsheet.

Numerical Models. Numerical models require specialized training and a fair amount of experience to be proficient. This can limit who can create and perform regular updates to the models. In most cases specialized consultants perform this work. These consultants commonly work full time on hydrologic models as a specialty.

Accuracy

Spreadsheets. Spreadsheet models can be limited in their accuracy since they are usually based on simple equations, a simplified framework, and limited dataset. In fact, if only limited data is available then a numerical model may have little to no advantages over a spreadsheet model.

Spreadsheet models that consider interactions between different parameters are difficult to develop. DWR addresses this issue as follows:

> "*Often only one component of a groundwater system is evaluated at a time, and this approach omits the evaluation of potential interactions with other*

> *components. For example, a spreadsheet could use a simple equation to estimate the aquifer drawdown in one location based on pumping at another location, without considering the potential influence of nearby streams*." (DWR, December 2016a)

Stanford University (November, 2016)) also states that "*The assumptions required to model groundwater systems using analytical solutions limit their application to relatively simple systems*."

Lastly, most spreadsheet models are based on an annual time-step, while numerical models often use a monthly time step, which helps to better simulate actual conditions and improve accuracy. Spreadsheets models use annual time-steps since monthly simulations become overwhelming with the spreadsheet's data management capabilities.

<u>Numerical Models.</u> Numerical models can be more accurate than analytical models since they can: 1) better accommodate large data sets; 2) better accommodate a more frequent time-step; and 3) more efficiently process interactions between parameters. In other words, numerical models can perform large, complex analyses. However, numerical models, while typically more accurate than spreadsheet models, are still an approximation at best. A common problem results from unrealistic expectations. Model sponsors often expect very accurate results after having invested considerable time and money into a numerical model.

<u>Cost</u>

Much of the cost for preparing a water budget model involves collecting, reviewing and organizing the large amount of data needed. This effort is required for any type of model.

<u>Spreadsheets.</u> Development costs for spreadsheet models are often less than numerical models simply because spreadsheet models are less complicated, and their data management capabilities can limit how large or complicated the model is. They also use software that is readily available and that most water mangers already have. The model sponsor can often create the model themselves, and reduce the need for outside consultant costs.

<u>Numerical models.</u> Numerical models typically require a specialty consultant to prepare and regularly update. If the model is needed to simulate a project or proposed scenario then more consultant costs will be incurred. They may also require commercial software programs, or at least commercial programs that interface with public software.

<u>Summary</u>

Table 1 provides a summary of the strengths of different characteristics for spreadsheet and numerical models. They both have clears pros and cons. Spreadsheets are favorable for their simplicity and transparency, while numerical models are superior in accuracy and data management.

Table 1. Strength of Model Characteristics: Spreadsheet Models versus Numerical Models

Characteristic	Spreadsheet Models	Numerical Models
Simplicity	●	○
Transparency	●	◉
Flexibility	●	◉
Expertise Required	◉	○
Accuracy	◉	●
Data Management	○	●
Cost	◉	○

● - Excellent
◉ - Good/Fair
○ - Poor

SPECIAL USES FOR SPREADSHEET MODELS

Numerical models have superior modeling capabilities compared to spreadsheets. In fact, many guidelines on water budget models fail to even discuss analytical models, and treat numerical models as the only viable option. Numerical models are generally preferred for large complex water budgets, due to inherent limitations with spreadsheet programming. However, due to their simplicity, transparency, and lower costs, spreadsheet models offer advantages in several situations. Following are several scenarios when spreadsheet models may be suitable, either as a replacement for, or as a supplement to, a numerical model.

Initial Assessment

Engineering projects are usually designed in phases (reconnaissance-level design, feasibility-level design, preliminary design, then final design). The benefits of a phased approach include the ability to solicit input at different stages, and modify the approach before going too far. Likewise, water budgets can be performed in phases. A spreadsheet model can be an excellent first iteration in complex water budget. They can offer the opportunity for a quick, inexpensive, initial assessment, and provide a strong conceptual understanding of the water budget. They can also help with identifying initial parameters and data gap analysis. DWR (2016a) stated that analytical models are "*most suited to initial scoping studies*", but also states that analytical models "*may be limited when used as the only modeling tool*".

Simple Analysis

Water budgets are sometimes prepared for small areas (less than a few square miles) or idealized basins. In some cases, these water budgets only include a few parameters. For instance, if the area has no surface water supply or natural water bodies, then numerous parameters related to surface water usage, surface water seepage, and seepage impacts to groundwater flows can be ignored. In addition, in small areas some simplifying assumptions can sometimes be made, such as groundwater inflow being equal to groundwater outflow. In these cases, a spreadsheet model may be sufficient due to the simplicity of the analysis, and there may be few benefits from using a numerical model. In a well-known paper on modeling, Box (1976) stated: "*Since all models are wrong the scientist cannot obtain a "correct" one by excessive elaboration…….Just as the ability to devise simple but evocative models is the signature of the great scientist so overelaboration and overparameterization is often the mark of mediocrity*." In fact, a spreadsheet can inhibit excessive elaboration since it has limited abilities to manage and organize large amounts of data, and generally uses simplified equations.

Interim Analysis/Annual Reporting

Numerical models are often expensive to develop and update. Periodic model updates, such as every five years, are reasonable. Annual updates to a numerical model may or may not be warranted. For instance, if a model is developed and calibrated with fifty years of data the model sponsor may not want to take the time and cost to update and calibrate it with 51 years of data. Water budget and modeling frequency should consider how often major management decisions, such as adjustment of safe yield, are made. SGMA requires that models be reviewed every five years, however, on an annual basis only groundwater levels, groundwater storage, surface water deliveries, and groundwater pumping need to be reported. Spreadsheets can offer a practical tool for these annual reports. A simple spreadsheet analysis for estimating change in groundwater storage is presented in later in this paper.

Check Numerical Model

A spreadsheet model can be an effective way to provide a general check on the results of a numerical model. This can provide greater assurance to the model sponsor, especially if they feel the numerical model is a 'black box', and they do not sufficiently understand the data used in the model or how the model works. Spreadsheets and numerical models use different approaches, so it should be expected that results will differ, but spreadsheets can be used for a general comparison. If the comparisons are reasonably similar, then it can provide greater comfort to the model sponsor. If the results differ significantly, it could potentially identify parameters that require double checking, or the need for additional analyses.

CASE STUDIES

Two case studies involving the use of spreadsheet water budget models are described below. These both involve water agencies in the San Joaquin Valley of California.

Case Study No.1. In this case study, a water district wanted to begin efforts to comply with SGMA, and, in particular, was interested in a detailed accounting of their water budget. The water budget could help them assess their current conditions, and the magnitude of new funding, policy changes and project development needed. The local groundwater basin includes numerous water agencies, and they had not yet decided on their overall approach for a water budget model (software package, local versus regional model, etc.). Rather than wait, the water district prepared a conceptual water budget using MS Excel. They considered this a 'no-regret' task, since the work they performed in identifying parameters, collecting data, and performing a data gap analysis would ultimately be needed, regardless of the direction the region ultimately selected. The water budget was prepared for under $20,000. Their water budget proved very useful in identifying major water budget parameters and data gaps. The results will also be useful for comparison to future numerical or regional models.

Case Study No. 2. In the second case study, an Irrigation District desired a transparent water budget model that staff could update annually. The area was already covered by a regional numerical model prepared by the USGS that covered numerous agencies. However, the regional model covered a large area and was not focused on their district. They were also not involved in the model development, had no ability to rerun the model, and had limited documentation on model inputs and results. A local spreadsheet model was developed that was more practical for agency staff, who eventually became familiar with the assumptions and basis for all the model inputs. However, the regional model was still useful since it included several assumptions and data sets that filled in data gaps in the spreadsheet model.

GROUNDWATER STORAGE CHANGE CALCULATIONS

A simplified method for estimating change in groundwater storage is presented below that is transparent and does not require a full water budget. This method uses changes in groundwater levels and regional specific yield values developed by the USGS.

USGS has developed specific yield values for the entire Central Valley of California in several USGS publications (USGS 1959 and USGS 1989). In these publications, standard specific yield values were identified for soil descriptions commonly used by drillers (i.e. sand, fine sand, silt, clay, etc.). Regional specific yield values were then developed by summarizing the stratigraphy in hundreds of well completion reports, and using the estimated specific yield values for soil textural classes. Specific yields are reported for three intervals: 0 to 50 feet, 50 to 100 feet and 100 to 200 feet below ground surface.

The process for calculating change in groundwater storage includes the following steps:

1. Calculate average depth to groundwater for each Township based groundwater level measurements.
2. Multiply the height of water within each depth zone by the specific yield for that depth zone and by the area of that Township within the study area.
3. Sum the total storage change for all Townships.
4. Compare the storage change from one year to the next.

This methodology is illustrated in the table below:

Table 1. Groundwater Storage Change Calculation

			Specific Yield (%)			Depth to Water (ft)		
Township	**Range**	**Area (acres)**	**0'-50'**	**50'-100'**	**100'-200'**	**Avg. Depth**	**Annual Change**	**Change in Storage (AF)**
32	21	23,040	10.6	12.2	10.9	134	-1.7	-4,270
32	20	10,400	12.2	11.1	9.6	88	-0.9	-1,040

Many water budgets focus on estimating groundwater overdraft, especially water budgets prepared for SGMA. Groundwater levels are a straightforward indicator of overdraft, and they are the net result of all the parameters found in a water budget (i.e. groundwater pumping, groundwater flow, recharge, seepage). Hence, the method described above can estimate overdraft without the numerous assumptions and complex analyses found in a water budget. This method is also a practical for annual reporting. Water budgets can be useful for illustrating why overdraft is occurring (i.e. sources of recharge and groundwater withdrawals), but may not be needed on an annual basis.

CONCLUSIONS

Spreadsheet models and numerical models have pros and cons for water budget analyses. Spreadsheets are favored for their simplicity, transparency and low cost. Numerical models can be more accurate and can better simulate interactions between different hydrologic processes. However, numerical models are more complex, costlier and require a modeling specialist. The California Sustainable Groundwater Management Act will require many groundwater basins to prepare or update water budgets. Spreadsheets may be more practical for a small or simple water budget. They can also supplement a numerical model if they are used as an initial assessment to gain a general understanding of the water budget, and as a general check on the results of a numerical model. Spreadsheets can also be used to estimate overdraft using groundwater level and specific yield data, and avoid the need for a water budget model update every year. Therefore, a combined approach to water budgets using numerical models and spreadsheet analysis may be the most efficient and practical approach.

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DIAMOND FORK STREAM FLOW STUDY, UTAH

W. Russ Findlay[1]
Melissa Stamp[2]

ABSTRACT

One of the first projects pursued under the Reclamation Act of 1902 was the Strawberry Valley Project (SVP) in Utah. After development of the SVP, irrigation flows were released from Strawberry Reservoir via the Strawberry Tunnel into the Diamond Fork Drainage. These augmented flows scoured stream beds and damaged riparian habitats for decades. In 1992, congress enacted the Central Utah Project Completion Act (CUPCA) which stipulated that high flows from Strawberry Reservoir be removed from the streams and carried in pipelines through the system, and that damaged streams be restored through establishment of appropriate, seasonally adjusted, minimum stream flows. To provide the minimum stream flows, water can potentially be released at Strawberry Tunnel, Sixth Water Flow Control Structure, and Monks Hollow Overflow Structure.

The valves at the Sixth Water Flow Control Structure have been used to provide low level releases associated with winter minimum stream flow requirements. However, they were designed prior to enactment of CUPCA before low level releases were envisioned. These releases have caused damage to the sleeve valves due to cavitation. In 2012, the Central Utah Water Conservancy District (District) and the Department of the Interior (Interior) redesigned and repaired the valves at great expense. Subsequently, the same cavitation problems occurred. A similar set of sleeve valves, located at the Upper Diamond Fork Flow Control Structure, control flows to the Monks Hollow Overflow Structure which releases water to Diamond Fork River. These valves are similar in design and would likely sustain similar damage if low level flows were released form them. Therefore, they have never been used during winter low flow release periods. At present, winter steam flows can only be released safely from the Strawberry Tunnel.

Also, it is generally accepted by the agencies involved that the currently stipulated flows are too large for the upper stream reaches, resulting in continuous rather than seasonal sediment transport. Accordingly, the District, Utah Reclamation Mitigation and Conservation Commission (Commission), and Interior’s CUPCA Office, as Joint Lead Agencies, have initiated a study to determine optimum flow regimes and release locations that would reduce sedimentation and improve stream and fishery health. These studies are anticipated to occur over a minimum of three years. Winter instream flows will be released from Strawberry Tunnel until other options have been identified, developed, and studied.

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INTRODUCTION

Settlers began irrigating the lower part of Utah Valley on the south side of the Spanish Fork River and the area adjacent to Utah Lake on the north side of the river prior to 1860 (Figure 1). The low summer flow of the river limited development of the irrigable land, and the need for supplemental storage was evident. Planning for the SVP was begun in 1903. This project provided the first large scale transmountain diversion from the Colorado River Basin to the Bonneville Basin. It was also one of the earliest Bureau of Reclamation projects to develop hydroelectric power.

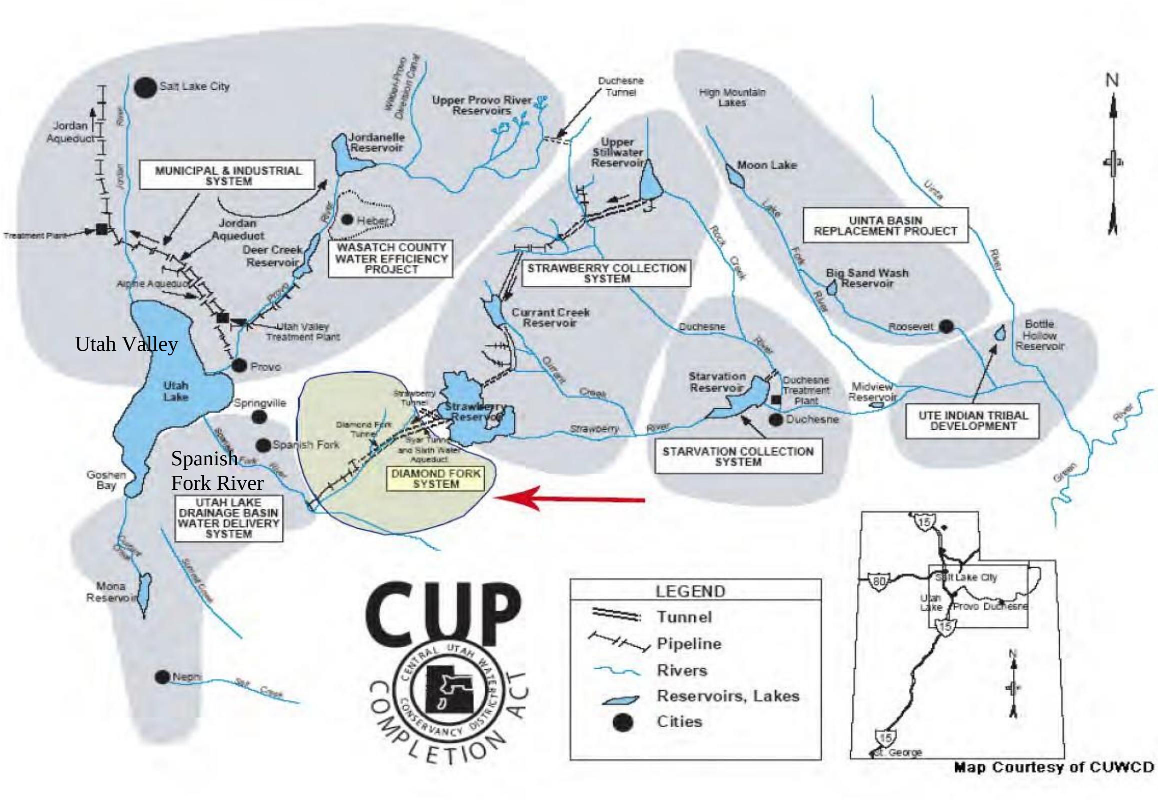

Figure 1. Central Utah Project – Bonneville Unit – Diamond Fork System

After the authorization of the SVP and construction of the Strawberry Tunnel in 1912, project irrigation flows were released from Strawberry Reservoir via the Strawberry Tunnel. These augmented flows scoured stream beds and damaged riparian habitats in Sixth Water Creek, Diamond Fork River and Spanish Fork River for decades.

Prior to construction of the Diamond Fork System, high summer flows releases from the Strawberry Tunnel within the Diamond Fork River regularly reached 500 cfs which damaged roads, campgrounds and lands as well as riverine habitats. Significant damage within the drainages occurred during the 1983 and 1984 spring runoff seasons. The highest peaks of record for the Diamond Fork River occurred in the spring of 1952 at 1,610 cfs, 1983 at 1,600 cfs, and 1984 at 2,000 cfs. These flows are considerably higher than what natural snowmelt runoff-driven peak flows would be, reflecting the effect of the imported water released via Strawberry Tunnel. The highest flow released from the Strawberry Tunnel outlet was 595 cfs in 1923. Flow releases usually ranged between 300-500 cfs during the irrigation season. These high flows also presented a significant safety hazard to recreational and other uses in the area.

The Central Utah Project (CUP) is a more recent project that, like the SVP, also transfers water from the Colorado River Basin to the Bonneville Basin. The Diamond Fork System of the CUP now conveys both CUP water and SVP water from Strawberry Reservoir to Utah Valley (Figure 2). With the completion of the Syar Tunnel and the Sixth Water Aqueduct in 1996 and the remaining Diamond Fork System pipeline components in 2004, the majority of project water deliveries are now made via pipelines rather than the natural stream channels. Strawberry Tunnel releases are now limited to meet minimum instream base flow requirements, and peak flows have essentially returned to natural snowmelt-driven levels. Since 2002, annual instantaneous peak flows have averaged about 360 cfs, with a maximum of 887 cfs in 2011.

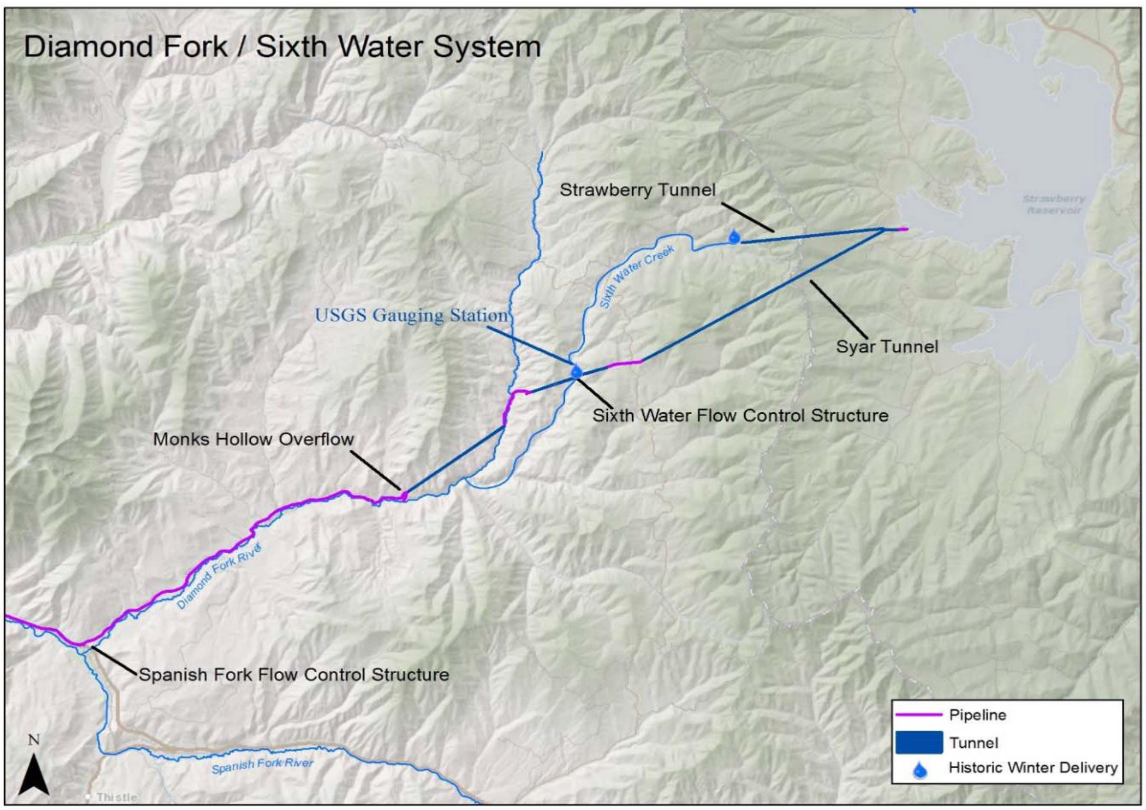

Figure 2. Diamond Fork - Sixth Water System

With completion of Syar Tunnel and the Sixth Water Aqueduct, Tunnel and Outlet in 1996, releases from Strawberry Tunnel provide instream minimum flows on Sixth Water Creek of 25 cfs (Nov-Apr) and 32 cfs (May-Oct). Since completion of the balance of the Diamond Fork System in 2004, base flows on lower Diamond Fork River have been managed to meet instream minimum flows of 60 cfs (Nov-Apr) and 80 cfs (May-Oct). These minimum instream flows were mandated in 1992 with enactment of the CUPCA and formalized in 1999 within a supplement to the Diamond Fork System Environmental Impact Statement. This return to more natural flow regimes has been accompanied by corresponding geomorphic adjustments on lower Diamond Fork River, including a return to a single-thread channel form and re-establishment of floodplain vegetation. The upper portion of Sixth Water Creek (above Sixth Water Outlet) has been adjusting to reduced flow for 21 years. The balance of Sixth Water Creek and the Diamond Fork River below their confluence has been adjusting to reduced flow for 13 years.

Although springtime peak flows have returned to more natural levels, minimum base flows remain 4 and 10 times greater than natural on lower Diamond Fork River and upper Sixth Water Creek, respectively. These supplemented base flows have resulted in higher than normal sediment transport through Sixth Water Creek and Diamond Fork River. Fine sediment transport now occurs year-round rather than only during the spring snowmelt period when flows are naturally high. Monitoring has documented high levels of cobble embeddedness and sedimentation in lower Diamond Fork River, raising concerns about the quality of pool and spawning gravel habitats.

Central Utah Project Completion Act (CUPCA)

CUPCA, PL 102-575, transferred the responsibility of the CUP from the Bureau of Reclamation to the District. This legislation authorized and directed the District to plan, construct and operate the CUP. CUPCA also established the Commission in order to coordinate the implementation of the mitigation and conservation provisions of the Act

Section 303(c)(1) of CUPCA (Figure 1) stipulated that high flows from Strawberry Reservoir be removed from the streams and carried in pipelines through the system, and that damaged streams (i.e. Diamond Fork River and Sixth Water Creek) be restored through establishment of minimum stream flows (Table 1).

Table 1. Diamond Fork and Sixth Water Minimum Instream Flows stipulated in CUPCA

	Winter Flows	**Summer Flows**
Diamond Fork River (near Monk's Hollow)	60 cfs October-April	80 cfs May-September
Sixth Water Creek (at Strawberry Tunnel)	25 cfs November-April	32 cfs May-October

To provide these minimum stream flows, water can potentially be released at three locations: Strawberry Tunnel; Sixth Water Flow Control Structure; and Monks Hollow Overflow Structure (Figure 2). However, the sleeve valves at the Sixth Water Flow Control Structure and Monks Hollow Overflow Structure were designed prior to enactment of CUPCA and were not designed to provide the low level releases associated with the winter minimum stream flow requirements. They were designed for high water pressure releases at high volumes.

As a result, the release of winter instream flows through the Sixth Water Flow Control Structure has resulted in damage to its sleeve valves. The damage includes erosion of the valve seats (Figure 3) and 'pitting' on the valve body (Figure 4). If left unchecked, this would have caused the valves to fail.

Figure 3. Erosion of Valve Seat

Figure 4. Pitting of Valve Body

In the fall of 2012, the District and CUPCA Office redesigned and repaired the sleeve valves at the Sixth Water Flow Control Structure in hopes that they would better handle the extreme range of flow deliveries at the Sixth Water Flow Control Structure (Figure 5 and 6). The cost of these repairs was approximately $1.5 million. However, in the year after this repair the newly redesigned and reconstructed sleeve valves experienced the same problems as mentioned above. Therefore, the Joint Lead Agencies determined that the valves could no longer be used to deliver the stipulated winter minimum instream flows at the Sixth Water Flow Control Structure. A similar set of sleeve valves located at the Upper Diamond Fork Flow Control Structure control flows to the Monks Hollow Overflow Structure which releases water to Diamond Fork River. These valves are similar in design and would likely sustain similar damage if low level flows were released from them. Therefore, they have never been used during winter release periods. At present, winter steam flows can only be released safely and efficiently from the Strawberry Tunnel.

Figure 5. Removal of Sleeve Valve

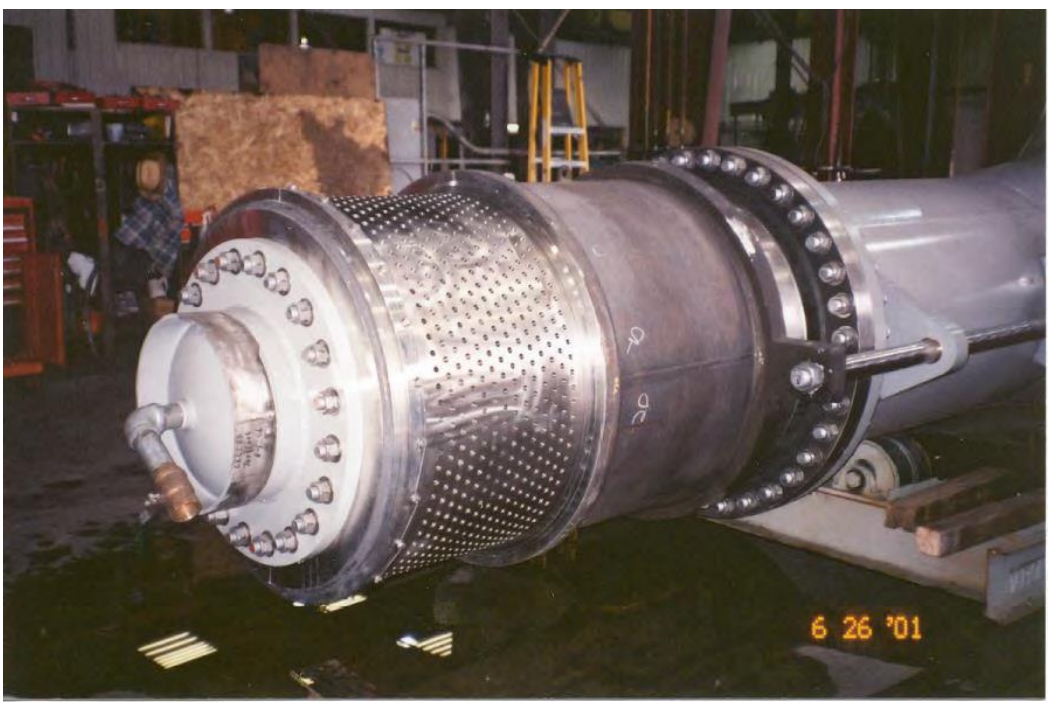

Figure 6. Sleeve Valve Being Repaired

Summer releases occur when the pipeline is fully charged and delivering large volumes of irrigation water. Therefore, summer releases are within the design specifications of the sleeve valves and do not pose a threat to their integrity. Therefore, summer flows are augmented through releases from the sleeve valves at Sixth Water Flow Control Structure and Monks Hollow overflow Structure.

ISSUES

Since it has been determined that use of these valves to deliver winter instream flows is no longer sustainable, these releases will be made through the Strawberry Tunnel pending development of a more workable alternative. Also, it is generally accepted by the agencies involved that the currently stipulated flows (both summer and winter) are too large for the upper stream reaches, resulting in continuous rather than seasonal sediment transport.

The Diamond Fork Drainage currently supports an important trout fishery of both native cutthroat and introduced brown and rainbow trout. Natural flows in upper Sixth Water Creek would be ten times lower than the mandated minimums and would not support this fishery. Therefore, it is necessary to continue to augment these base flows to some level. However, as previously stated, the CUPCA legislated flows may be too high to sustain a properly functioning riverine system and may cause adverse impacts to other ecological conditions. This is understandable considering the minimum instream flow requirements were defined over 25 years ago based on plans and predicted hydrologic operations for a very different system of water storage and delivery features that were to be constructed in the drainage.

Selenium levels in Sixth Water Creek have also been a concern. Since 1997, the Commission has partnered with the District to monitor water quality within the Diamond Fork Drainage in order to meet environmental commitments of the 1999 Diamond Fork System Final Environmental Impact Statement and Record of Decision. Selenium is naturally occurring in the system, the source being ground water that seeps into the Strawberry Tunnel and flows through the Strawberry Tunnel Outlet into Sixth Water Creek. The tunnel make is approximately 5-7 cubic feet per second (cfs). Strawberry Reservoir water deliveries made through the tunnel typically provide an additional 20-25 cfs, and dilute the naturally occurring selenium to levels that do not exceed water quality standards. It is very rare for these flow releases to drop below 18 cfs.

The threatened Ute-ladies' tresses exists along the Diamond Fork River. It was historically found in recently disturbed habitat such as isolated meander cutoffs or flood channels. Augmented flows have likely negatively affected suitable habitat for this orchid. More natural flow regimes would foster healthy sediment transport and deposition within the system which would be beneficial to this orchid. Revised flow recommendations must consider impacts to this orchid and its habitat needs.

STREAM FLOW STUDY

Due to the above mentioned issues, the Joint Lead Agencies have developed and are now implementing a study to evaluate the potential impacts of the CUPCA legislated augmentation of instream flows. The study will also determine optimum flow regimes and release locations that would reduce sedimentation, support and sustain functional riverine and riparian processes and resources, and improve the health of the fishery, while accounting for current infrastructure and contractual constraints. The study also involves collaboratively identifying the desired future conditions of Sixth Water Creek and the Diamond Fork River.

This study is specifically investigating sediment sources and transport, river morphology, fish population dynamics, stream and riparian habitat health and other specific parameters (e.g. substrate composition, channel morphological change, instream organic matter, primary production, stream metabolism, macroinvertebrate composition and drift, fish species composition and density, diet, and age structure, and water temperature and dissolved oxygen data).

To comply with the National Environmental Policy Act (NEPA), a categorical exclusion checklist was signed on October 1, 2015, to allow for flows to be experimentally altered from the legislated minimums during the anticipated minimum three year study period. The Joint Lead Agencies have entered into an agreement with Utah State University (USU) to complete these scientific studies which are currently in the second year of investigation.

The study is intended to measure the ecosystem’s health and identify the linkages between ecosystem resources and the flow regime. One challenge the study faces is the fact that the river channel and floodplain continue to adjust to the flow modifications that occurred with completion of the Diamond Fork pipeline system, and that the system will continue to adjust and respond to any future changes in flow regime. Because the channel system will be different in the future, the linkages between flow and the physical and biological aspects of the ecosystem must be understood thoroughly enough to predict future conditions.

Although natural flows can be estimated for the Diamond Fork Drainage, ensuring an approximation of these flows may not produce the ecosystem response desired by the Joint Lead Agencies. The system has been altered from its pristine conditions. Completely natural flows would not likely sustain a functional riverine and riparian system, improve the health of the fishery, and achieve a desired condition defined by the project stakeholders.

PRELIMINARY FINDINGS

The USU research team has collected extensive field data at nine sample sites throughout the watershed. Results remain highly preliminary, but initial findings include the following.

In 2016 base flows were sustained at lower-than-mandated levels. During this time, at the upstream-most sample sites on Sixth Water Creek, Bonneville cutthroat trout recruitment exceeded historical levels. Preliminary analyses suggest that recruitment may be maximized at summer flows well below the mandated minimum of 32 cfs. Also, the lower-than-mandated base flows in 2016, within lower Diamond Fork River, did not appear to adversely affect the brown trout population, as the measured size structure of brown trout was not found to be significantly different from observations made during the 2002-2011 time period. Unnaturally high base flows, as mandated by CUPCA, may increase the downstream transport of macroinvertebrates and juvenile fish.

Based on macroinvertebrate data collected in June 2016, nearly all sample sites had high (>25%) proportions of mayfly, stonefly, and caddisfly taxa. These population levels were found in conjunction with the lower-than-mandated base flows provided in 2016. Diet analyses indicate these species constitute an important food source for trout on Sixth Water Creek and Diamond Fork River.

It was also found that lower-than-mandated 2016 summer base flows did not cause dissolved oxygen levels to drop to harmful levels at any of the study sites. Also, during these lower flow releases, summer water temperatures on the downstream-most reaches of lower Diamond Fork River possibly exceeded the thermal tolerance of Bonneville cutthroat trout, but generally remained within the acceptable range for brown trout which dominate this area currently.

Dilution of Selenium discharge from Strawberry Tunnel may determine the minimum appropriate release of water from this structure. Analysis of the existing water quality information suggests that flows below 20 cfs may have Se levels of concern. Releases from this tunnel are generally higher, and would likely remain higher under any future proposed flow regime.

The study found that negligible sediment transport was observed at flows of 45 cfs or lower on Diamond Fork River and at flows of 33 cfs or lower on Sixth Water Creek. Minimum base flows would need to be established below these levels to ensure that proper and healthy sediment transport and deposition occurs within the system.

It will be important to determine flow thresholds that do not increase the entrainment of organic matter, invertebrates, or juvenile fish above healthy levels while maintaining a properly functioning riverine and riparian system. Flow recommendations will need to consider both maximum and minimum flow levels, as well as the seasonality and duration of these flows.

Scientific data collection continued in 2017 and instream flow recommendations will likely be provided by the end of 2018.

CONCLUSION

Winter Instream flows will be released only from Strawberry Tunnel until other options, if determined to be needed, have been identified, developed, and studied. CUWCD is currently investigating the possibility of alternative water release mechanisms at the Sixth Water Flow Control Structure to accommodate release of the minimum flows. This may include installation of a small power generator through exercise of a Lease of Power Privilege option. Other options may include modification of the existing valves, addition of valves able to release lower flows, or alternative release locations. Once optimum instream flow guidelines have been developed, a NEPA decision process will be formally initiated. A decision document would then be finalized and congressional action would be needed to adopt these flows under CUPCA.

ACKNOWLEDGEMENTS

We thank the joint lead agencies for their continued efforts to provide instream flows within the Diamond Fork Drainage. We are also appreciative of other federal and state agencies that have graciously provided consultation services during the development of this study. Their help and guidance have been invaluable in developing the current study aimed at providing recommendations best suited to meet the needs of the public while addressing conservation goals.

HONOLULU BAR FLOODPLAIN ENHANCEMENT PROJECT STANISALUS RIVER

Steven R. Knell, P.E.[1]

ABSTRACT

Honolulu Bar Floodplain Enhancement Project is a joint venture among the United States Fish and Wildlife Service (USFWS) Anadromous Fish Restoration Project (AFRP), United States Army Corps of Engineers (Corps), FISHBIO, Inc. and the Oakdale Irrigation District (OID).

The project is located at Honolulu Bar Recreation Area, a park in the Stanislaus River Parks system, California and is owned and maintained by the Corps. As mitigation for loss of white water recreation due to the construction of New Melones Dam, the Corps constructed a series of parks below Goodwin Dam to provide recreation areas for the public. Honolulu Bar is an island in the lower Stanislaus River that has been subjected to various human activities in the past including gold mining during the California Gold Rush. Because of the construction of New Melones Dam, flooding rarely occurs along the lower Stanislaus River and this has left many parts of the island unusable to salmon and steelhead except during high flows and allowed a side channel to silt up. Adult salmon have been left stranded in the side channel when flows are reduced.

OID was in need of a project to mitigate for the loss of 0.6 acres (0.24 ha) of vernal pool creation credits at a 4:1 ratio. No mitigation bank within the project's hydrologic unit code had 2.4 acres (1.0 ha) of creation credits available for purchase and the Corps Regulatory requirements would not accept in-lieu fees for this mitigation.

Fortunately for OID, its fisheries consultant FISHBIO, Inc. had obtained a grant from USFWS AFRP and was in the process of designing a habitat restoration project. The project planned to restore rearing habitat for federally listed and threatened Central Valley steelhead and species of concern fall-run Chinook salmon. The lower Stanislaus River is listed as critical habitat for steelhead and essential habitat for the Chinook salmon. The majority of salmonid spawning and juvenile rearing in the lower Stanislaus takes place in the 10-mile stretch of river below Goodwin Dam, in which the project is located. Honolulu Bar was accepted as an out-of–kind mitigation for OID's North Side Regulating Reservoir which was completed in 2009. The Project itself was competed on September 6, 2012 and has been operational since that time and has proven itself to be a beneficial and productive success.

This paper will provide an overview of the Honolulu Bar Project, its development, construction and a summary of monitoring results after it became operational in 2012.

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INTRODUCTION

The purpose of the Honolulu Bar Project seeks to increase and improve the quality and quantity of available salmonid habitat in the lower Stanislaus River through enhancement of floodplain, spawning, and side-channel habitat along approximately 1.5 miles of river within and adjacent to Honolulu Bar Recreation Area (RM 49 to RM 50.5)(Figure 1). The Stanislaus River is a tributary to the San Joaquin River, in Stanislaus County, California and the lower river is defined as the stretch of river between Goodwin Dam (RM 58.4) and the river's confluence with the San Joaquin River (RM 0).

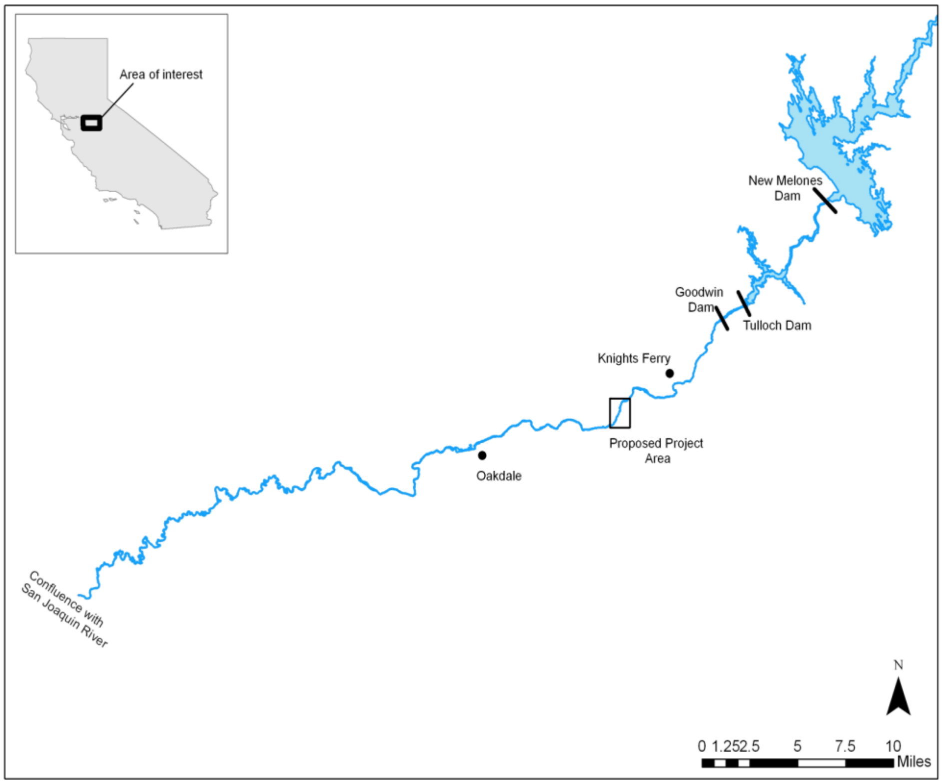

Figure 1. Honolulu Bar Floodplain Enhancement Project located on Stanislaus River (RM 49-50.5), Stanislaus County, CA

As with all projects built with federal cost share, an Environmental Assessment and Initial Study (EA/IS) were conducted to evaluate the potential impacts from construction and maintenance associated with the following activities:

- Creating seasonally inundated floodplain habitat
- Restoring year-round side channel rearing habitat
- Restoring self-sustaining native riparian vegetation
- Augmenting gravel into the main-stem

BACKGROUND

The lower Stanislaus River between Goodwin Dam (RM 58.4) and the confluence with the San Joaquin River has been designated as essential fish habitat for species of concern fall-run Chinook salmon (*Oncorhynchus tshawytscha)* and critical habitat for federally threatened Central Valley steelhead (*O. mykiss*). Spawning may occur from Goodwin Dam to Orange Blossom Bridge (RM 46.9) for steelhead and to Riverbank (RM 33) for salmon. However, the majority of salmonid spawning and juvenile rearing takes place in the ten-mile stretch below Goodwin Dam (RM 58.3 to RM 48), which encompasses the Project area.

Studies suggest that loss of rearing and spawning habitat may limit juvenile Chinook salmon production in the lower Stanislaus River (SRFG 2004) and restoration of instream and riparian habitat are priority actions (AFRP 2001). The Project site (Figure 2) currently has a limited amount of floodplain habitat and is fully inundated only under rare flood level events (i.e., > 5,000 cfs (142 cm/s)); therefore, it provides little functional salmon rearing habitat under the current flow regime. The current side-channel provides rearing habitat for salmon and steelhead under higher flow conditions, but is dewatered at flows under 250 cfs (7.1 cm/s)and connectivity between habitats within the side channel is reduced at flows under 350 cfs (9.9 cm/s). The side-channel is also a known area for stranding of adult salmon that attempt to utilize the side-channel for spawning. Therefore, there is a need to create seasonally inundated floodplain habitat and restore side-channel habitat, which will increase opportunities for steelhead and salmon to access quality rearing habitat and to reduce the potential for adult stranding.

The purpose of the Project is to create or restore several aquatic and riparian habitat elements in the Stanislaus River 2.4 acres (1 ha) of floodplain habitat on the inside edge of a mid-channel island, 0.7 acres (0.28 ha) of floodplain bench in the south side of the river upstream of the mid-channel island, 0.4 acres (0.16 ha) of spawning riffle in the river adjacent to the mid-channel island, 3.85+ acres (1.6+ ha)of native vegetation, and increased frequency and duration of flow connectivity in one mile of side channel habitat. Objectives of the Project include: (1) restoring seasonally inundated floodplain habitat, (2) restoring year-round rearing habitat, (3) addressing an existing adult stranding issue, (4) increasing usable spawning habitat area, (5) increasing hiding cover, velocity refugia, habitat complexity, and instream habitat types, and (6) restoring native vegetation.

Stanislaus River aquatic and riparian habitat improvement actions are deemed an important component to contribute to the USFWS AFRP's salmonid restoration efforts. These would contribute toward the implementation goals of several existing Central Valley fish and wildlife restoration plans to create a healthier, more-natural functioning ecosystem; enhance and restore aquatic and riparian habitats; protect and/or recover threatened and endangered species; and augment cumulative efforts to increase populations of anadromous fish in Central Valley streams.

In addition, the 2.4 (1 ha) acre floodplain and native vegetation restoration components will serve as a mitigation project to compensate for 0.6 acres (0.25 ha) (at a ratio of 4:1) of seasonal wetlands/vernal pools that has been adversely impacted by the construction of OID's North Side Regulating Reservoir Project, which is located approximately 0.5 mile (0.8 km) east of 28-Mile Road and 0.5 mile (0.8 km) south of Frankenheimer Road, northeast of the City of Oakdale, California. OID was unable to obtain in-kind mitigation of 2.4 acres (1 ha) of vernal pool creation credits for the reservoir project to the satisfaction of the Corps; therefore, out-of-kind mitigation for a floodplain habitat restoration project in the lower Stanislaus River at Honolulu Bar Recreation Area (RM 49 to RM 50) was proposed and accepted.

Figure 2. Honolulu Bar Floodplain Enhancement Project general footprints.

CONSTRUCTION

Construction was performed by OID crews with FISHBIO providing the necessary oversight to avoid any unnecessary impacts to the environment. OID crews received special environmental training to be in compliance with all of the permits that were required for the project. Work began on June 18th, 2012 with the construction of a road and temporary diversion of the side channel of the river. Once access was established, invasive and non-native plants such as Himalayan blackberry, tree of heaven and giant grass (arundo) that have overtaken the island were removed from the project area.

Parts of the island were dozed down and material generated on-site was put through a mobile gravel sorting plant. In total 12,500 cubic yards (9,557 cubic meters) of material was processed into 3 different sizes. Material larger than 5 inches (127 mm), material less than 5 inches (127 mm) in size but greater than ¼ inch in size and material smaller than ¼ inch (6.3 mm) in size.

The gravel size preferred by salmon and steelhead (<5 inch and > than ¼ inch) (<127 mm and > 6.3 mm) was put back into the main river channel upstream of the island to construct an instream bench and to fill deep pools inhabited by non-native fish that eat juvenile salmon. Fine material was transported across the river to an area above the designated floodway. The excavated areas were then contoured and graded into 3 large interconnected floodplain areas.

Larger material was scattered back into the finished areas that had been excavated and graded to add some complexity to the landscape for the juvenile salmon. Work on the island was completed on September 6, 2012 and the side channel diversion removed on September 17, 2012. Work on their newly remodeled habitat was be completed by September 30, 2012 in time for the arrival of adult salmon in the Stanislaus River. Native vegetation will be planted on the project site that will become self-sustaining over time. A specialized vegetation plan was prepared by River Partners, Inc. to create a habitat with a long flower blooming sequence to provide habitat and food source benefits to a suite of songbirds, native pollinators, and other wildlife. Restoration of native vegetation will promote shade and support invertebrate food supply for juvenile salmonid rearing. Juvenile rearing opportunities within the side-channel and main river will be improved by increasing the amount of quality habitat available over a wider range of river flows.

PERMITTING AND MONITORING

The Project included removal of non-native vegetation, grading a floodplain terrace in the mid-channel island (Honolulu Bar) to an elevation to provide for a more seasonally inundated floodplain at lower flows, sorting removed material into gravel larger than 1/4-inch (6.3 mm) size and used to create 1,200 feet (1,931 km) of instream bench and to add gravel to existing spawning riffles, grading approximately 1,000 linear feet (1,609 km) of side channel, reconnection of the side channel to the main-stem of the river, revegetation of the disturbed areas, and monitoring the project area for a minimum of 10 years.

The Corps issued an Individual 404 Permit (SPK #2009-00013) to OID for the construction of the North Side Regulating Reservoir. This permit required that mitigation and monitoring plan be developed for the associated out-of-kind mitigation project. The Corps subsequently issued a Nationwide 27 Permit (SPK #2009-01474) for the Project that included a Mitigation and Monitoring Plan for the 2.4-acre (1 ha) riparian habitat restoration area. The mitigation project area is required to meet specified success criteria for physical design and re-vegetation. Monitoring is required for a minimum of 10 years, with reports submitted annually to the Corps for the first 4 years, then bi-annually for years 6, 8, and 10 for a minimum of 10 years, the last 3 years without human intervention or until the success criteria for the project is met. The following content comes from the Year 4 Monitoring Report covering the period from September 2015 – August 2016).

PHYSICAL DESIGN

As-built surveys completed in 2012 by the USFWS showed that the post project elevations generally matched the design specifications, with some minor variations due to field fitting of project site conditions.

Flow Connectivity/Inundation

Continuous water level loggers were deployed and operated at the project site during the entire monitoring period. These loggers record water levels every 15-minutes at five locations in and around the Honolulu Bar project site (Upper, Lower, Floodplain, and Side channel). Water level data were correlated with Goodwin Dam releases to determine the frequency, depth, and duration of inundation in the side channel and floodplain. Water level data from the side channel site confirmed that the side channel remained connected throughout the Year 4 monitoring period.

The Honolulu Bar floodplain area begins to inundate at a flow of ~400 cfs (11.3 cm/s), and is fully inundated at a flow of ~1,000 cfs (28.3 cm/s) (Table 1). Juvenile Chinook salmon are expected to be present in the area during the spring period. Between February 1, and May 31, 2016, the floodplain area was partially inundated 19.8% (400 cfs -1,000 cfs) of the days and fully inundated 25.6% (>1000 cfs) of the days, for a total of 45.5% of the spring period. Although conditions improved during the latter part of 2015, this data is reflective of ongoing drought conditions, and this inundation rate is the second lowest observed in the four years of post-project monitoring, with previous years ranging from 22.5% to 68.3% of the spring period (Table 2).

Table 1. Summary of modeled inundation area and avg. depth at four flow levels based on 2012 as-built surveys

Flow (cfs)(cm/s)	Inundated Area (acres)(ha)	Avg. Depth (ft.)(m)
500 (14)	0.35 (0.14)	0.28 (0.08)
1000 (28)	1.02 (0.41)	0.93 (0.28)
1500 (46)	1.19 (0.48)	2.29 (0.68)
3000 (85)	1.39 (0.56)	3.65 (1.11)

Table 2. Annual floodplain inundation rates while juvenile Chinook salmon are expected to be present (Feb. 1 – Mar. 31) during post-restoration monitoring

Monitoring Year	Percent of Days Partially Inundated	Percent of Days fully Inundated	Total Percent of Days Inundated
2015-2016	19.8%	25.6%	45.5%
2014-2015	13.3%	9.2%	22.5%
2013-2014	32.5%	26.7%	59.2%
2012-2013	22.5%	45.8%	68.3%

Channel Stability

During September 1, 2015 to August 31, 2016, the maximum daily average flow at Goodwin Dam was 3,476 cfs (98 cm/s). There were no additional channel profile or sediment characterization surveys conducted during this monitoring period.

Revegetation Success

River Partners conducted the revegetation success monitoring for the Project. Data from the October 2016 census showed overall plant survivorship (58%), which is below the project success criteria of 70%. Low survivorship was witnessed in black willow, box elder, and valley oak. Only cottonwood (88%) and brickelbush (89%) exceeded the project goal of 70% survivorship. Natural recruitment was significant for both cottonwood and sandbar willow. Maintenance and irrigation will continue at the site in 2017 in order to address the low survivorship from the 2016 monitoring season.

Fish Monitoring

Spawning surveys were conducted October-December, 2015 to document locations of Chinook salmon redds in the Stanislaus River, including spawning activity in the Project area. Adult Chinook salmon were observed spawning in the side channel and in main channel riffles where gravel had been placed as part of the restoration project. A total of 92 redds were identified in the side channel, and an additional 90 redds were identified in restored riffles in the main channel during the 2015 survey period (Table 3). This represents the highest number of redds identified in the Project area since construction was completed in 2012, and corresponds with the high adult escapement in the fall of 2015.

Table 3. Annual red counts in the Honolulu Bar Floodplain Enhancement Project area.

Monitoring Year	Total Redds Honolulu Bar	Total Redds Stanislaus River	Percent Composition Honolulu Bar	Net Upstream Chinook Passage
2015	182	1568	11.6%	12703
2014	52	1302	4.9%	5422
2013	76	1944	3.9%	5437
2012	43	1847	2.3%	7132

PROJECT COSTS

Funding for the 2.4 acre Project was provided through 50% cost-share between OID and the USFWS AFRP. At Project completion, the itemized costs for the Project ended up being;

Phase I Permitting	$ 53,040
Phase II Construction	
OID Labor and Equipment	$ 223,210
FishBio Labor	$ 50,085
Phase III Monitoring/Reporting	
Period 2013-2016	$ 71,525
Period 2017-2022	$ 147,000
Total Project Cost	**$ 544,860**

CONCLUSION

OID was more than pleased to be able to participate in the habitat restoration project on the Stanislaus River which serves as the main source of irrigation water for its customers. It wasn't an easy process. Obtaining and working out all of the necessary permits took nearly 3 years to complete. The project was originally planned to encompass more than 20 acres (8.1 ha) until elderberry bushes, which host the federally listed and threatened Valley Elderberry Longhorn beetle were found on the island although the beetles themselves were not. The floodplain habitat restoration was downsized to the minimum size of 2.4 acres (1 ha) to avoid impacts to these bushes. One elderberry bush did have to be relocated.

While permitting was difficult, the reward via fisheries utilization of the site, has been quite gratifying. With little flood plain habitat available in the river, the data is showing strong utilization of the new Honolulu Bar habitat, making this a productive Project.

REFERENCES

FISHBIO - Draft Environmental Assessment/FONSI Initial Study/Mitigated Negative Declaration, Honolulu Bar Floodplain Enhancement Project, March 2010

FISHBIO - Honolulu Bar Floodplain Enhancement Project, Year 4 Monitoring Report (September 1, 2015 – August 31, 2016), October 2016

CASE STUDY: MODERNIZATION OF THE WALKER RIVER IRRIGATION DISTRICT

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ABSTRACT

The Irrigation Training and Research Center (ITRC) and Walker River Irrigation District (WRID) collaborated on the modernization of WRID with support from the Bureau of Reclamation, U.S. Department of Interior in Carson City, Nevada. This paper presents an update to the USCID case study that was presented in 2014 on the initial proposed plan for improving water gauges throughout WRID. There has been phased implementation of the initial proposed plan as well as modification and expansion of that plan. The initial scope of work for system improvements was developed by ITRC in 2009 following field investigations and engineering analyses of existing WRID infrastructure and operational procedures. The initial plan identified twenty primary sites for water gauge improvement and provided strategic engineering recommendations for new hardware, control equipment, and flow measurement devices for the sites, as well as water management strategies and integration of a new SCADA system for the entire district. Additionally, the plan prioritized the order of engineering implementation and automation recommendations and provided planning-level cost estimates. Over the following eight years, ITRC has assisted WRID in organizing implementation, including site-specific designs as well as updating hardware and control equipment recommendations to align with current technology. To date, twelve of the original twenty sites have been implemented. Twenty additional sites have been identified, fourteen of which have already been implemented. Additionally, up to six buffer reservoir sites located throughout the district are currently being developed.

INTRODUCTION

The recommendations in this paper are guided by successful experiences with many other irrigation districts in the western US in the transformation of old, manually-operated canal systems into modern projects operated with high levels of water delivery service and a clear accounting of water diversions. A successful irrigation modernization program must maintain an appropriate balance of technical upgrades and management sustainability. In the case of WRID, the motivation for irrigation modernization is the need for robust and cost-effective measurement and control of flows diverted from the Walker River. These flows are measured and automatically maintained locally. They are

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monitored and can be managed remotely by a Supervisory Control and Data Acquisition (SCADA) system.

Figure 1 shows a location map of completed and proposed system upgrades as well as proposed reservoir sites in the Walker River Basin.

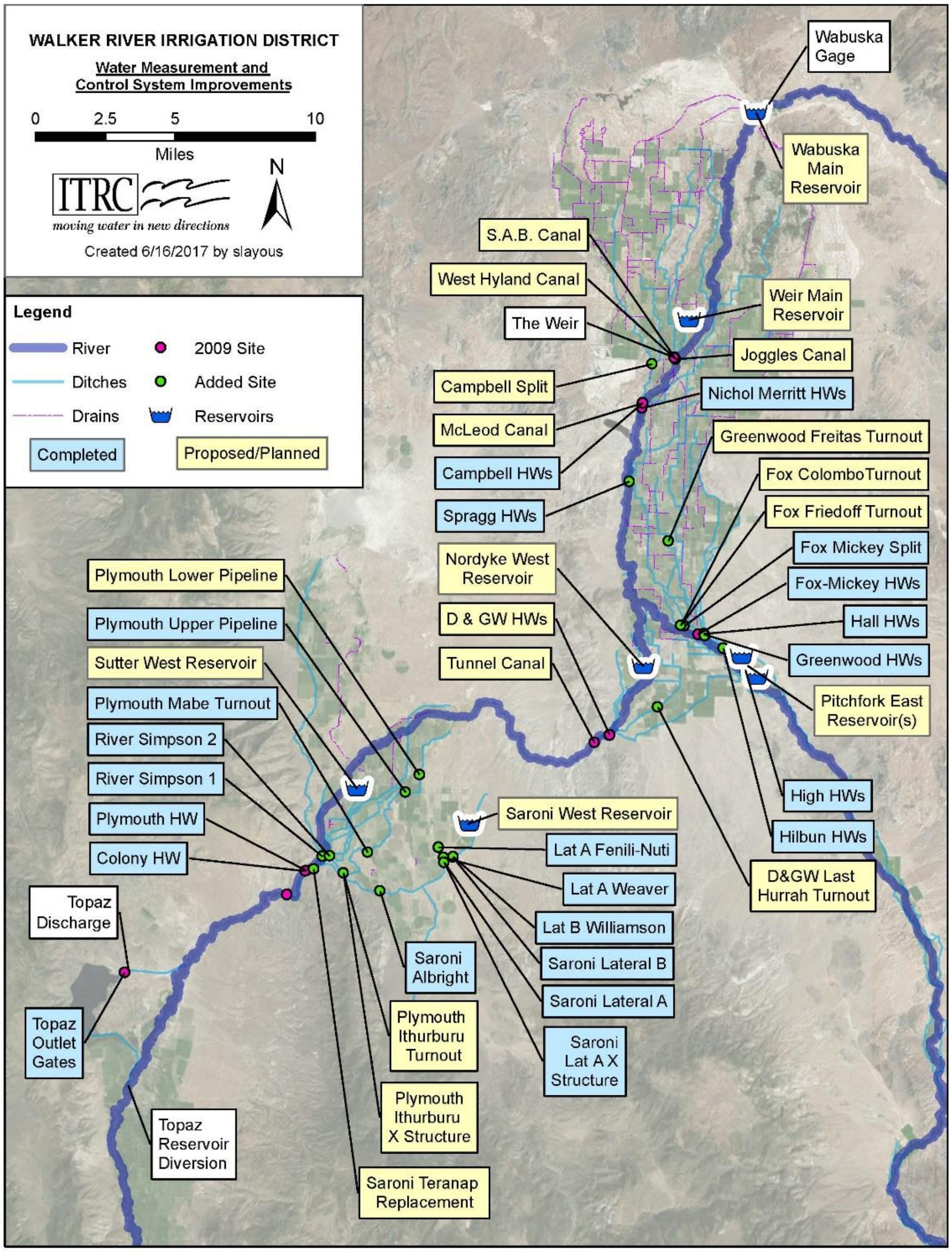

Figure 1. Irrigation facilities and USGS hydrologic monitoring stations in the Walker River Basin

Project Objectives

The initial project was designed to implement automated flow control to produce better flow rate and volume measurement of water deliveries as well as provide remote monitoring and control of the water deliveries.

In addition, the district-wide automation and SCADA system established in the initial project formed the backbone for subsequent monitoring and automation sites. The project also included upgrading check structures in the Saroni Canal with improved water level control structures to keep turnout deliveries constant.

The initial project has been expanded to include:

- Additional automated flow control sites
- Flow measurement sites
- Additional water level control structures in the canals to allow more constant turnout deliveries
- Sediment control structures to reduce movement of sand and sediments from river into canal systems
- Conversion to pipelines for reduced seepage, maintenance, liability, etc.
- Reservoirs throughout the district to increase flexibility, reduce spills out of the district, provide short-term storage, reduce peak flows, and improve groundwater recharge (currently in planning phase)

Review of Original (pre-Modernization) Water Operations

WRID operates five divisions covering approximately 80,000 acres in Nevada and California. There are approximately 50 sub-systems using irrigation water supplied in part by WRID including community ditch systems.

WRID pre-modernization system operations were characterized as follows:

- The headworks of a typical canal usually consists of one or two wooden slide gates with manually-operated steel lifting mechanisms (with hand wheels). One or two separate sets of slide gates were installed in some sites – with the downstream one (if it existed) operating as flow control. The canals had various types of spill structures; if located upstream of a Parshall flume, the structures maintained a desired flow rate in the canal through manual adjustments to the spill settings.
- Push-up diversion dams were built across the Walker River with large native rocks and streambed materials at the diversion points. This maintained a minimum hydraulic head across the canal headworks when river levels were low.
- The diversion channels at a canal headworks typically had a continuous return flow structure (of various designs) that served somewhat to keep water levels constant at the flow control gates by returning a portion of the diverted flow. Some sites used Danaidean gates (shown in Figure 2) for upstream water level control.
- The main conveyance canals had flashboard check structures of varying designs for maintaining canal water levels for turnouts.

Figure 2. Danaidean gate in WRID

Water orders are filled as follows:

1. Ditchtenders take water orders from customers. Some water orders come straight to the WRID office.
2. Ditchtenders turn in water cards every day at 11 a.m. The summary reports of daily allocations (same as the delivered volume) are based on the compiled information from all the water cards.
3. A daily water schedule is allocated to all canal systems and direct turnouts according to the <u>determined natural base flow by the water master</u>. A scheduling meeting is held every afternoon (at 1:00 p.m.) with the water master and ditchtenders to analyze the next day's customers' water requests that are made to ditchtenders compared to the determined natural flow.

PROJECT SUMMARY

Initial Project Components

A total of twenty sites were included in the 2009 plan for WRID. The recommendations were intended to provide benefits for WRID and its customers by improving the accuracy of measured diversions from Walker River and enhancing the real-time control capabilities of water managers. The recommended system improvements would also provide a foundation for future modernization programs and improved transparency of water management in the District. Completion of final designs required some additional information such as local survey data and the preparation of drawings, in addition to an evaluation and field testing of communications options. To date, twelve of the twenty sites have been completed.

Initial Project Cost Summary

The initial Water Gauge Improvement Project cost estimate was $3.5 million (refer to Table 1). Annual additional O&M costs were estimated to be about $131,000, most of which would be for maintenance of the automation and SCADA system. It was expected that the district would enter into a service agreement with an appropriate integration firm for periodic, semi-annual and annual checkups of the automation and SCADA system.

Table 1. WRID system improvements cost estimate summary overview

Component	Sub-Total Cost†	Annualized Capital Costs	Annual O&M Costs
Project Design, Engineering and Administration	$568,000	$49,000	-
Site Preparation, Surveying, and Civil Works	$313,000	$22,000	-
Canal Measurement and Control Upgrades (17 Automated Site With SCADA and Base Station)	$2,475,000	$233,000	$129,000
Canal Water Level Control Upgrades with Long-Crested Weirs (3 New Structures)	$96,000	$6,000	$2,000
Total	**$3,452,000**	**$310,000**	**$131,000**

† Includes Mobilization (5%) and Engineering & Project Management (15%), plus Contingency (25%)

Expanded Project Components

As the initial plan has been implemented, updates have been made to the original designs to reflect updated knowledge and additional requirements. Approximately twenty additional sites and projects have also been added to the original twenty sites, with fourteen of the twenty completed to date. A summary of the sites is given in Table 2.

Additionally, six reservoir sites for buffer storage are currently under development for the district. These sites will provide many benefits, including:

- Buffer storage to the district during the irrigation season
- A more constant flow rate to meet downstream legal flow requirements in the river (legal requirement shown as red dotted line in Figure 3)
- Short-term storage during storms to reduce peak flows and silt loads in the water (see Figure 4)
- Recharge to the groundwater basins (see Figure 5)

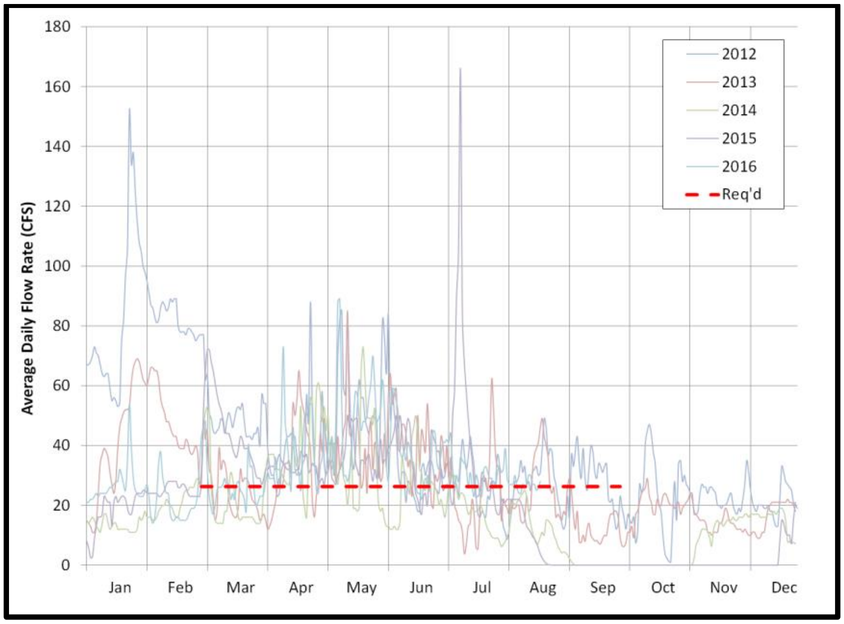

Figure 3. Average daily flow data from the Wabuska Gage for 2012 to 8/2016 (data from USGS)

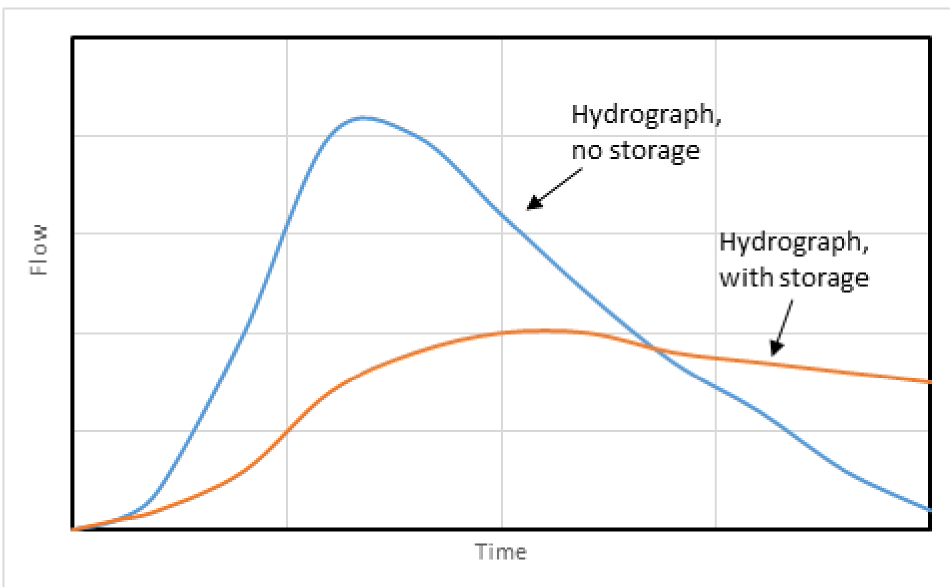

Figure 4. Conceptual comparison of district outflow without storage versus with storage

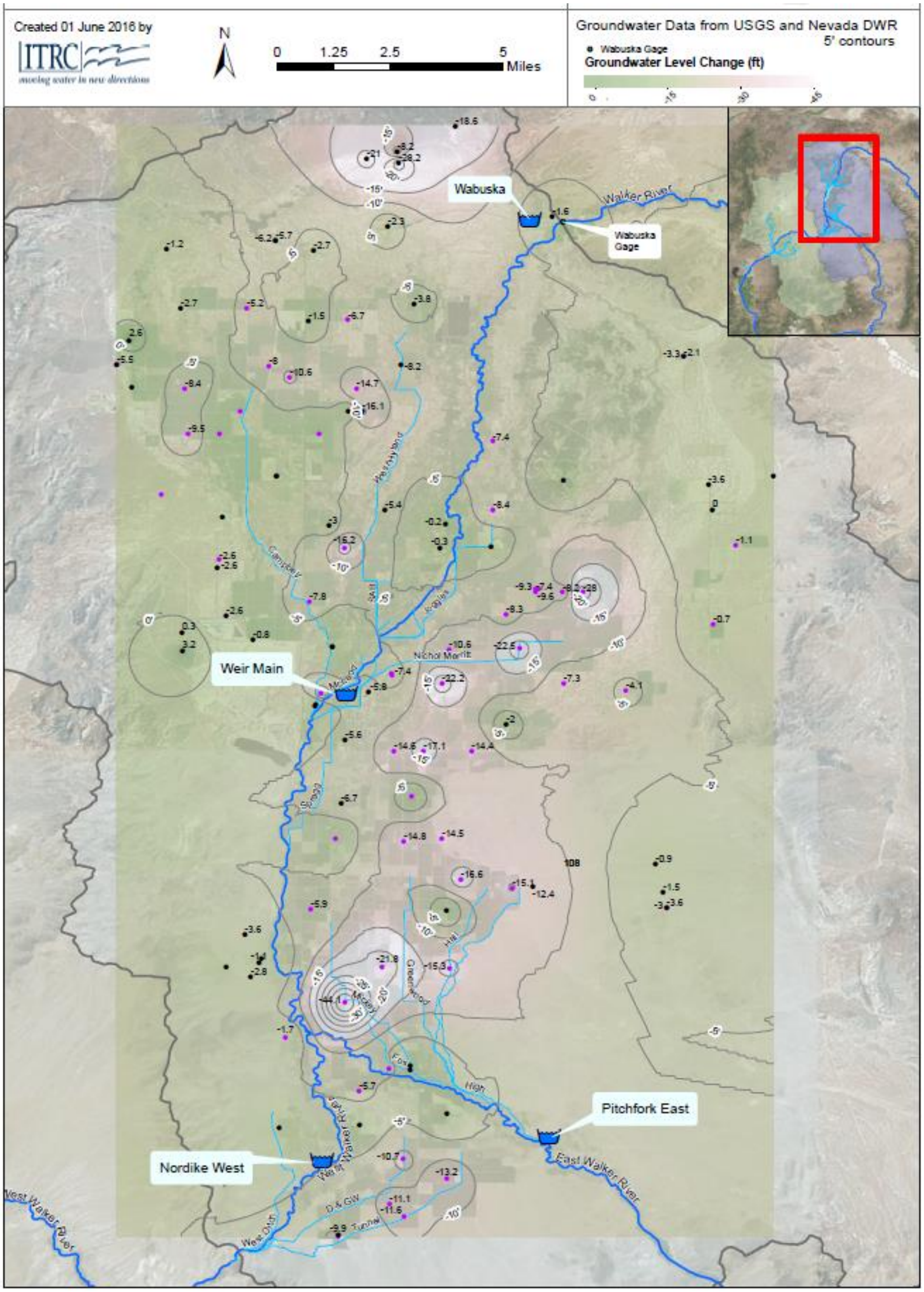

Figure 5. Change in groundwater level between spring 2012 and spring 2014

Table 2. Summary of WRID's improvement structures

	NAME	Complete	Max Flow (CFS)	Typ Flow (CFS)	Flume	Flap Gate	Gate(s)	LCW	Cross Regulator	Sediment Wall	Settling Basin	Pipeline
1	Saroni HW	√	110	45	√	√	2					
2	Colony HW	√	140	60	√		2					
3	Plymouth HW	√	55	30	√	√	1					
4	Tunnel HWs		75		√	√	1					
5	D&GW HWs		25		√	√	1					
6	Fox-Mickey HWs	√	140	75	√	√	2			√	√	
7	High HWs	√	25	18	√	√	1					
	G&H		130	75		√				√	√	
8	Greenwood HWs	√	70	40	√		2					
9	Hall HWs	√	60	35	√		2					
10	Campbell HWs	√	110	60	√		2					
11	McLeod HWs		10		√		1					
12	Nichol Merritt HWs	√	100	60	√		2					
13	Joggles HWs		65		√		1					
14	SAB HWs		40		√		1					
15	W Hyland HWs		50		√		1					
16	Topaz Outlet Gates	√					8					
17	Bridgeport Reservoir						6					
18	Saroni Albright	√		40				45′				
19	Saroni Wellington			50				60′				
20	Saroni @ Lateral A	√							√			
21	Spragg HWs	√	35	15	√	√	1			√	√	
22	Lateral A Weaver	√	5	3	√							
23	Lateral A Fenili	√	10	4	√							
24	Lateral A Nuti	√	10	7	√							
25	Saroni Lateral B Williamson	√	10	4			1					
26	Saroni Lateral A	√	25	15	√							
27	Saroni Lateral B	√	25	18	√		1					
28	River Simpson 1	√	60	34	√	√	2					
	River Simpson 2	√	45	25				50′				
29	Upper Fulstone Ditch	√	12	7	√		1					
30	FIM Turnout	√	5	2	√		1					
	Fox Mickey Split											
31	Mickey Turnout	√	45	28	√		1					
32	Fox Turnout	√	90	45	√			110′				
33	Campbell Split		110				2					
34	Plymouth Ithurburu Turnout		3.5		√							
35	Plymouth @ Ithurburu TO		-	-					√			
36	Plymouth Upper Pipeline	√	35		√							√
37	Plymouth Lower Pipeline		35		√							√
38	Saroni Teranap Replacement		110									√
39	D&GW Last Hurrah		8	6	√							
40	Fox Friedoff Turnout		8	4	√							

TECHNICAL SCOPE OF WORK

Headworks Package

The following section specifies an example "package" of the components that were part of the upgrades for each canal headworks. Two examples are shown in Figures 6 and 7. These major components included:

1. Self-contained motorized slide gate(s) in a district-standard configuration
2. Replogle flume (built from concrete) to replace the existing Parshall flume(s)
3. SCADA Remote Terminal Unit (RTU) for automatic control of the slide gate(s) and communication with the office base station in Yerington
4. Various modifications to the existing spill structures (depending on site conditions)

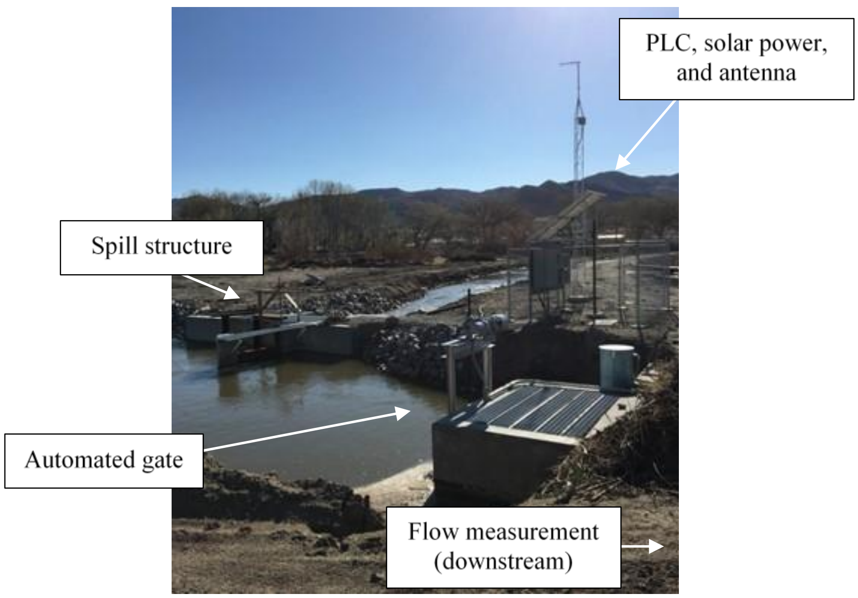

Figure 6. Example package site (automated gate, flow measurement weir, SCADA, and spill structure) on Spragg Canal

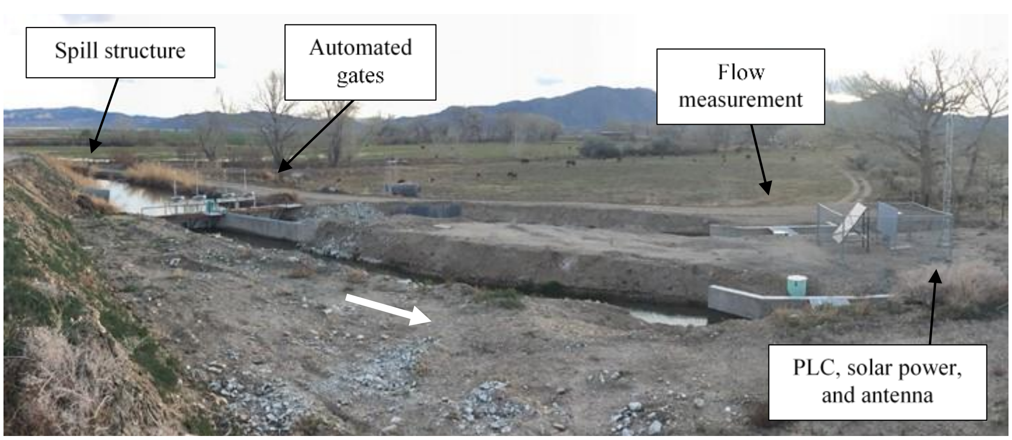

Figure 7. Example package site (automated gate, flow measurement weir, SCADA, and spill structure) on Greenwood and Hall Canals. This site is one canal that splits into two canals at this location.

<u>Overview of Water Management Strategies</u>

Implementation of the water gauge improvement projects created new management capabilities for water managers in WRID. The key strategies include the following:

- Control of diversions based on maintaining a constant target flow rate from canal headworks along the Walker River to match ordered demand for each canal system. Each canal headworks is equipped with new automated flow control gates and control systems for this purpose.
- One person in the office can observe flows at key points throughout the service area; eventually, information from storage reservoirs will also be available. This central water manager makes decisions on a more frequent basis as part of a real-time and coordinated approach to water distribution throughout WRID's points This involves the new automated hardware at the canal headworks, but also more significantly, active, real-time management of the system.
- Existing flashboard check structures were evaluated and prioritized for upgrading with long-crested weirs. The improved canal water level control at turnouts means that large changes in canal flow no longer affect the system's capability to provide steady and measureable water deliveries. Operators have the ability to run lower or higher canal flows in order to meet irrigation demands while keeping more constant turnout flow rates.
- The start of each canal is equipped with an upgraded water measurement device to be used in the new automated control system. Accurate measurement of canal diversions is important for proper management of scarce water resources. Knowing the actual amount of water delivered to the canals allows for a more complete understanding of the water demands in the system, and makes water records for individual accounts more precise. The flow rates and volumes of water delivered to the different canal systems is also critical information for water users in assessing and upgrading their own on-farm water management.
- New SCADA capabilities facilitate real-time remote monitoring of conditions throughout the Walker River Basin. Changes to canal flows can be made at specified times with accurate measurement of the current and historical *CFS*, as well as the delivered volume in *Acre-Feet*. The water operations and record-keeping practices have been simplified.

<u>Automated Flow Control Gate Package</u>. A major element in planned upgrades is the introduction of automated flow control gates at the headings of the selected canal systems. As part of this process, the existing slide gates were removed and replaced with a new headgate automation package that includes:

1. Fabricated aluminum slide gate(s) containing:
    a. Gate frame with guide rails, seals, and cross bars (self-contained)
    b. Reinforced rectangular gate leaf
    c. Stainless steel threaded shaft
2. Electric motor gate actuator (several standard sizes based on site conditions) with:
    a. Local control switches/pushbuttons
    b. Top mounting (on top of gate frame)

   c. Hand wheel for manual operation
   d. Internal gate position sensor
   e. Internal end-of-stroke limit switches
   f. Solar power
3. SCADA controller and communications

The objective was to have a **district-standard** slide gate and actuator package in WRID at all district canal headings.

The slide gate(s) require the following specifications:

- Series 8200 Fabricated Slide Gate (by Fresno Valves and Casting Inc., Selma, California) or approved equivalent
- Gate material (frame, slide and reinforcing): aluminum
- Stem material: stainless steel
- Flat back mount (secured to either a concrete headwall or angle iron)
- 3-sided J-seals (sides and top)
- Flush bottom seal

The electric motor actuator requires the following specifications:

- Rotork IQ Series or approved equivalent
- Series IQD10, multi-turn [Direct current, 24 VDC]
- Local controls (local/stop/remote)
- Internal position sensor with 4-20 mA AO or Modbus Interface Card (2-wire RS485)
- Torque switch protection and over-temperature protection
- Side-mounted hand wheel

The automation and SCADA Integrator is responsible for all the connections from the actuator to the control system and for the design and installation of the solar power system.

In order to fabricate the gates, the manufacturer requires information such as the opening width and frame height. The self-contained frame design can be mounted in place of the existing tandem wooden headgates using either anchor bolts into the existing concrete walls or anchoring to new pieces of angle iron that are mounted to the concrete walls.

Flow Measurement Upgrades with Replogle Flumes

Properly designed, constructed and maintained water measurement devices are a key component of the proposed irrigation modernization improvements in WRID. In addition, accurate flow measurement structures were required for integration with the new automated flow control gates. These structures were installed at the headworks of each canal system identified in the plan.

Before a final design decision could be made about the suitability of Replogle flumes at each of the identified locations, however, topographic survey data needed to be collected and analyzed to determine if there was enough hydraulic head available. The Replogle flume was determined to be the best device for applications in WRID (for open channel flow measurement) based on the following characteristics:

- Accurate over the entire range of flows
- Simple, easy-to-understand readings that are easily verifiable in the field
- No required manual adjustments, on-going calibration checks, or excessive maintenance
- Vandalism resistant
- SCADA compatible

Figure 8 show examples of the measurement structures installed in the district.

Figure 8. Concrete Replogle flume built in a rectangular cross-section on High Canal

The Replogle flume (e.g., broad-crested weir, ramp flume or long-throated flume) is a flow measurement device with a proven track record and thousands of successful installations in irrigation districts.

An advantage of installing new Replogle flumes in the WRID canals is that they will require minimal maintenance except for periodically checking the site to clean moss off the concrete ramp. It would also be easy to integrate these new flumes into the proposed automation and SCADA system.

The Replogle flume will provide an accurate measurement of flow rate. As with the Parshall flumes, the Replogle flume allows for rapid stabilization of flows when the gates are changed and rapid feedback to the RTU controlling the radial gates. The operator is able to monitor the flow rate from the district office and change the target flow rate, in addition to having the option of overriding the automatic function and manually controlling the gates.

ITRC Flap Gates for Automatic Spills. Spill structures were updated at a number of canal headworks sites (see Figure 9). In many of these sites there were several feet of drop in the water surface between the canal and the river where the spill was returned. In these places, the recommendation was to install an ITRC flap gate to provide a constant water level (within ±0.05 ft) while serving as an automatic continuous spill.

Figure 9. Flap gate installed in the Saroni Canal

The justification for upgrading the existing flashboard spill structures was that at the same size (i.e., the same width), the ITRC flap gate can pass significantly more water while maintaining better water level control. For example, a 4-ft wide flashboard spill would pass about 10 CFS with a depth of about 1 ft (head) on the weir, and the same weir could pass about 30 CFS, but the water depth would have to increase to 2 ft. A 4-ft wide ITRC flap gate can pass from 0 CFS to about 50 CFS with only minimal changes in the upstream water level.

There are important operational justifications for having continuous spills upstream of the automated flow control gates. The automated flow gates do not have to move as frequently if operators can always divert more water than is required for irrigation demands. Due to the short distance, it has no effect on the overall amount of water diverted from the river because the 'excess' water is immediately returned to the same reach of river. In addition, the continuous spills provide an inherent safety feature in the event there are any problems with the gate automation.

A spreadsheet design program allows users to customize the gate size and weight for the desired location. The updated design spreadsheets are available at http://www.itrc.org/reports/flapgate.htm.[4]

[4] The design spreadsheet provides no analysis of the structural soundness or integrity of a gate or of the supporting structure.

WRID AUTOMATION AND SCADA SYSTEM

Automation and SCADA are valuable tools for enhancing water management. The automation and SCADA component of this project involved the design, deployment, calibration, documentation, and verification of industrially-hardened hardware and software for new canal control and measurement. This system can be remotely accessed in real-time from a base station computer and mobile laptops running specialized human-machine interface (HMI) software.

The new WRID automation and SCADA system has improved the reliability and flexibility of water deliveries throughout the service area. Other benefits of automation and SCADA include real-time water accounting, upgraded record-keeping capabilities for historical analysis and forecasting, and faster response times to user inputs and alarms. Future web-based reporting for water use or water quality datasets will also be facilitated by this well-designed automation and SCADA system.

The implementation of the WRID automation and SCADA system involved a series of steps:

1. Radio testing and evaluation of practical, cost-effective communication options
2. Presentation to district staff and board members of the Water Gauge Improvement Project and decisions about the scope, schedule, and budget for implementation
3. Meetings and field visits to selected sites to finalize details of the hardware requirements, along with any structural modifications involved
4. Preparation of the final Request for Proposals (RFP)
5. Hardware installation, implementation, calibration, testing, etc.
6. Field verification
7. Training and on-site service support

The use of robust equipment and software conforming to standardized specifications, along with following some basic rules and practical techniques, ensure the implementation of a properly engineered automation and SCADA system. This type of system is reliable and can be expanded into the future. The following requirements were used to design the new WRID automation and SCADA system:

- Open system architecture
- A robust high-speed data radio network
- Industry-standard hardware components with Windows-based software
- System scalability
- High system reliability with redundancy of critical systems

Figure 10 shows a screenshot from the current SCADA system. The screen shows some details on the monitoring and control on the sites.

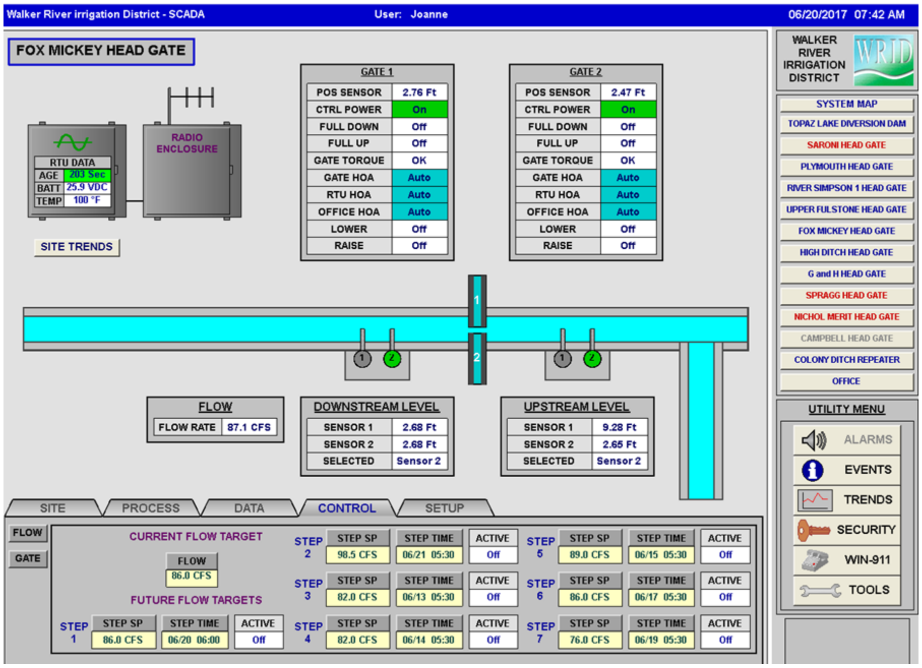

Figure 10. Example screenshot of WRID's SCADA system

Example Site at Fox Mickey Canal Headworks

The location of the Fox Mickey Headworks SCADA project at the diversion from the East Fork of Walker River is shown in Figure 11. This diversion is downstream from the G&H and Hilbun Canal Diversions. The design capacity of the canal headworks is approximately 140 CFS, with an average capacity of 75 CFS.

The layout of the old existing water control and measurement infrastructure at the headworks of the Fox Mickey Canal is also shown in Figure 11. The configuration and function of the old existing structures consisted of:

1. One (1×) 40-ft (est.) diversion weir across the East Walker River
2. Two (2×) 8-ft wooden slide gates (manually operated)
3. One (1×) spill structure with a 4-ft flashboard bay and a 48-inch slide gate
4. Two (2×) 7.5-ft slide gates (left gate is wooden and right gate is steel) (manually operated)
5. One (1×) spill structure with an 18-inch slide gate
6. Two (2×) 6-ft Parshall flumes

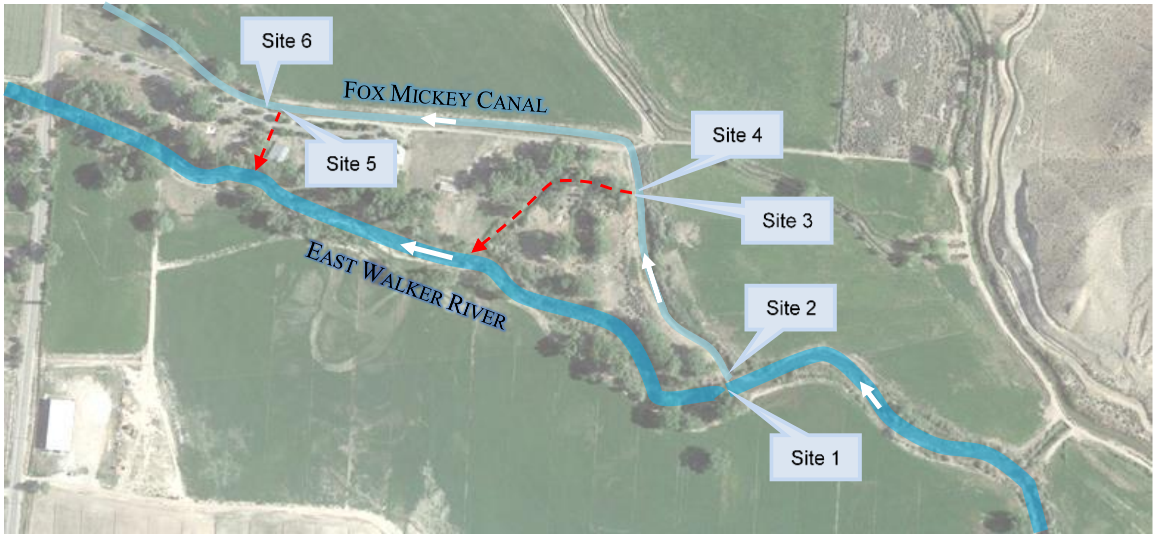

Figure 11. Layout of the existing Fox Mickey Canal diversion from the East Walker River

The modernization improvements at the Fox Mickey Headworks involved the following features, with site numbers corresponding to those shown in Figures 11 and 15:

1. Adding a new 180’ long × 35’ wide settling basin and 50’ long sediment wall between Site 2 and Site 3 (Figure 12, “Site 2a” in Figure 15). This basin reduces the sand and silt load that enters the canal system from the river. While the sediment basin reduces sediment load throughout the canal system, it increases maintenance requirements at the sediment basin site. The Fox Mickey sediment basin filled in 2016 (the first year it was functional), requiring the district to remove the sediment to prevent the sediment from affecting upstream water levels.

Figure 12. Settling basin and sediment wall on Fox Mickey Canal

2. Installation of one ITRC flap gate in the existing open spill channel at Site 3. The flap gate was designed with a capacity for continuous spill up to approximately 25 CFS (approx. 4-ft wide and 2-ft deep).

3. Installation of one 40’ long sediment wall directly downstream of Site 3 to reduce sediment load down the canal.
4. Replacement of slide gates at Site 4 with two new automated flow control gates (72 × 48 Series 8200 Fabricated Slide Gates by Fresno Valves and Casting, shown in Figure 13) installed in a new reinforced concrete headwall structure, as well as an RTU, solar panel, and newly established communication with the district’s headquarters in Yerington, Nevada for distributed control.

Figure 13. Automated gates on Fox Mickey Canal

5. Removal of the Parshall flumes at Site 6.
6. Installation of one new Replogle flume with automated flow rate measurement that is connected to the slide gates system for automatic flow control (Figure 14). The new flow measurement structure was installed approximately 1,000’ upstream of the existing Parshall flume (“Site 6b” in Figure 15).

Figure 14. Replogle flume on Fox Mickey Canal

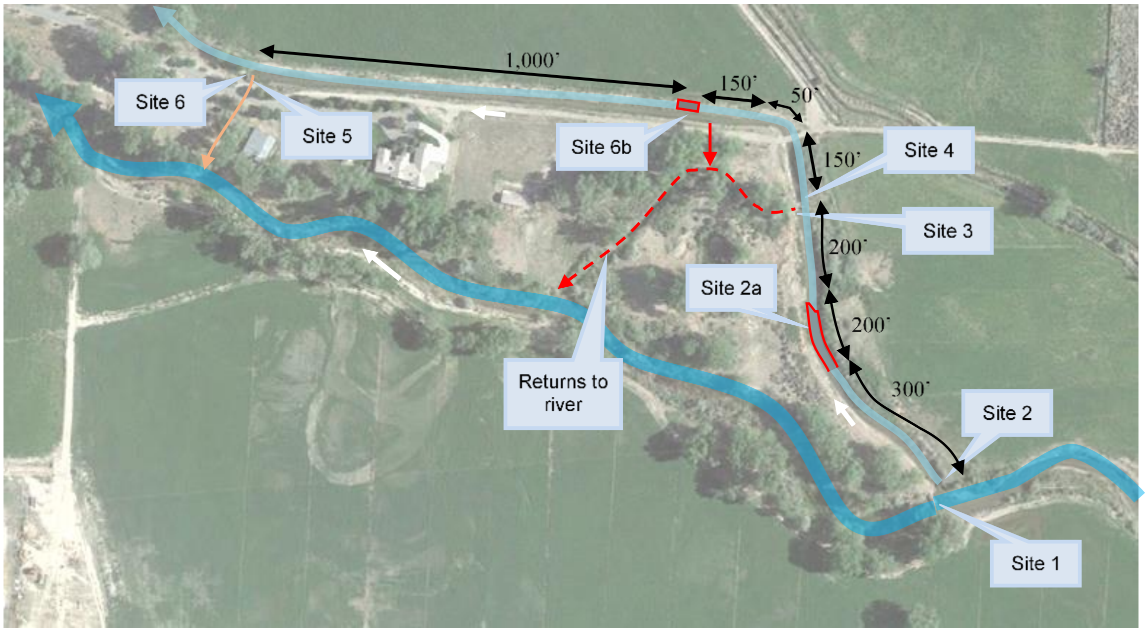

Figure 15. Layout of the proposed upgrades to the Fox Mickey Canal

7. Grading the canal from Site 6b to Site 6.
8. Flow rate target that is re-settable from the ClearSCADA HMI workstation at the headquarters office and from SCADA-equipped laptops
9. Solar-powered gates, automated control, and SCADA system (12/24 VDC)
10. Implementation by a team including:
    a. WRID: installation of the gate hardware, conduit, stilling wells, staff gauges, and concrete work
    b. Fresno Valves and Casting: provide gate hardware and electric motor drive system
    c. Integrator: automation and SCADA integration, RTU, wiring, redundant gate and water level sensors, HMI programming, radio communications
11. District-standard hardware/software
12. Flow rate (CFS) and water level data (Feet) transmitted to the base station at the WRID headquarters office every 1 minute via radio
13. On-site display of flow rate (CFS) and upstream water level (Feet), and other control parameters, in addition to local data logging and storage

Automation and SCADA System Operations. An overview of the new automation and SCADA system components at the Fox Mickey Canal Headworks is shown in Figure 16.

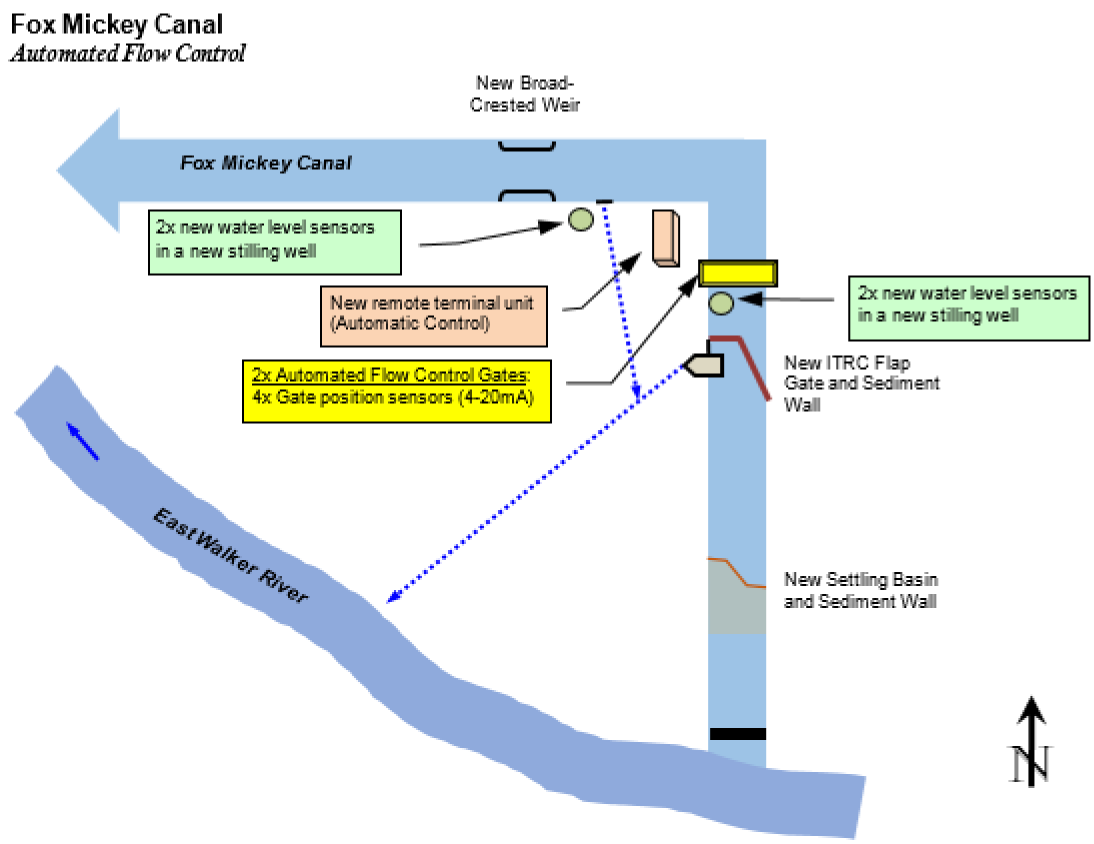

Figure 16. Schematic overview of the automation and SCADA improvements at Fox Mickey Canal

The main Remote Terminal Unit (RTU) was pre-assembled, bench-tested, and made ready for operation by the Integrator prior to delivery to WRID. Alteration, logic functions, metering, alarm, and all other control components used in the monitoring system are performed by the automation system. The "district standard" RTU consists of a stand-alone distributed control center with self-contained electronics and sensor systems including a graphical operator interface terminal. The control system consists of a SCADAPack 32/350 PLC or approved equivalent to control the timing of operation, gate alteration, control, and alarm functions, in addition to other specified equipment. A single PLC was used to control the gate.

Other components of the system included water level sensors; gate position sensors; an autodialer for emergency notification of alarm conditions (via the office HMI software); a battery backup system; and hand/off/auto selector switches and misc. electrical wiring. The water levels sensors upstream and downstream of the check structure (a total of four sensors) were provided and installed by the Integrator.

The automation and SCADA system for the Fox Mickey Headworks automated gates performs the following functions:

1. Automatically control flow based on a user-defined target flow rate
2. Remotely change the target flow rate
3. Allow remote manual control of the slide gate(s) to move to a target gate opening(s)
4. Remotely monitor system status (positions, alarms, gate status)
5. Remotely monitor water levels in the pool upstream of the slide gates in the river diversion channel
6. Remotely monitor the canal flow rate(s) measured at the Replogle flume
7. Remotely change the operation from automatic to manual (if necessary)
8. Remotely (but via a secure mode) change key controller set points
9. Remotely select which of the two redundant sensors (for every measurement) should be considered the “primary” sensor for control purposes

All construction and implementation has been completed at the Fox Mickey Canal site with all components operating accurately and efficiently.

CONCLUSION

WRID’s system of remote monitoring and control has improved water delivery for growers within the district. ITRC and the district have implemented numerous new flow measurement, flow control and sediment control devices; new hardware and control equipment; as well as discussed water management strategies. There has been no compromise on quality of the engineering design, electronics, and SCADA systems, because in the long run using high-quality, off-the-shelf technology is more economical based on the published experience of ITRC. ITRC has approached the modernization strategy by using the simplest device when possible, such as long-crested weirs. Costs on some items can vary widely depending upon challenges with communications, decisions about who does the construction and gate installation work, un-anticipated structural problems, prevailing wages, etc. The district plans on continuing the modernization based on the success of the program to date.

DESIGN FACTORS THAT IMPROVE CANAL DOWNSTREAM PI CONTROLLER PERFORMANCE AND ELIMINATE INSTABILITY PROBLEMS

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ABSTRACT

Various researchers have determined that the proportional integral (PI) controller is an effective method for performing canal downstream control. When designed properly, this controller can bring the downstream water level of a canal reach back to setpoint in a stable and timely manner. This paper examines techniques that can be used to make the PI controller more effective when operating a canal reach under downstream control conditions. Some of the factors reviewed in this paper are selecting proportional and integral gains that provide a more optimal response. These gains are the basis of a PI controller and proper selection means that the canal system response is timely. Control interval or cycle time is also an important factor that determines the speed of canal response and stability. Matching the cycle time to the PI gains is essential for stable operation as well as achieving the desired control response. Cycle time must also be tailored to the physical capabilities of the canal. Using flowrate as the controller input is also an important factor that will determine system stability. If a single canal reach is being controlled, this is not an issue, however when multiple reaches are in series, flowrate provides isolation between reaches. If gate position is used as the control input, reach isolation is lost. An issue that is often overlooked is integral error windup. If this is overlooked when designing a PI controller, the canal can be driven into an oscillatory behavior that is difficult to eliminate. However, a simple error nullification method eliminates the oscillatory behavior. When these factors are addressed in PI controller design and programming, the canal downstream controller is more effective and stable. This paper addresses these various techniques and provides easily used methods for controller design.

INTRODUCTION

One of the earliest examples of feedback control was demonstrated with the flyball governor in 1788 (Phillips and Harbor, 2000). This mechanism was developed by James Watt to control steam engine speed. Many feedback control methods have been developed and one of the most prevalent is the proportional integral derivative controller (PID). This type of controller is commonly used for feedback control on many industrial processes. Control designers prefer this type of control method because it has robust behavior and it is somewhat simple to implement in a control process. As with all control methods, the PID controller operates on the difference or error between a desired set

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point and the observed output from the system that is being controlled. To push the system back to the setpoint value, the controller positions an actuator (motor, hydraulic cylinder, etc.) in proportion to the error. The proportionality constant is called the proportional gain (K_p). However, the K_p value usually cannot move the system fully back to the desired setpoint. For this reason an integral gain (K_i) is needed to complete the task. The K_i component sums up the system errors over a period of time and multiplies this sum by the K_i gain. A third derivative gain is applied to the error rate change, but this can often cause instabilities in a system that has large time delays or low ratios of error change to noise such as a canal reach. For this reason, the derivative gain is often deleted from a canal downstream control design.

Sperry (1911) is believed to be the first person to design and use a PID controller. This devise was used to control the steering mechanism of a ship. Theoretical analysis of PID controllers was reported by Minorsky (1922). This work also focused on developing a controller that operated the automatic steering mechanism for a ship.

One of the most popular and well known methods of PI controller tuning is the Ziegler-Nichols methods of tuning. The Ziegler-Nichols methods were developed in 1942 (Ziegler, Nichols, 1942), and various modifications of this method are still popular today. The method is simple and easy to understand. The drawback to the Ziegler-Nichols tuning methods is that controller performance can be poor. Thus, the Ziegler-Nichols tuning methods are often considered only to be able to give "ballpark" estimates of the controller parameters. The first Ziegler-Nichols method is called the step-response method. The open-loop system is subjected to a unit step response. Based on the open-loop response, the proportional gain and integral time of the controller can be determined using empirical equations. The second Ziegler-Nichols method of tuning is called the frequency response method. In this method, the controller gain is increased until the process starts to oscillate. The controller gain that causes these oscillations is called the ultimate gain and the time period of the oscillations is called the ultimate period. The proportional gain and integral gain are then determined from the ultimate gain and ultimate period through empirical equations.

Tuning maps can be utilized to improve the performance of Ziegler-Nichols tuned controllers. Tuning maps are simply an array of controller responses (with varying tuning parameters) organized in a systematic way. In a way it is an organized trial and error method.

Various control schemes have been developed and tested to automate canal systems. Litrico and Fromion (2003) presented a multivariable design method using $H\infty$ optimization, in order to give a solution to the compromise between performance and resource management. Controller performance was tested on a canal in Portugal.

Van Overloop et al. (2005) present an optimization technique that can be used to tune PI controllers that accounts for interactions between the pools and changing flow conditions in the canal.

Clemmens and Schuurmans (2004) also present a method for tuning PI controllers using optimization techniques (i.e., a Linear Quadratic Regulator). Clemmens and Wahlin (2004) examined the performance of these controllers on the ASCE test canals. Baume et al. (1999) also discusses optimization techniques for tuning PI controllers. Litrico et al. (2007) present a method to automatically tune decentralized PI controllers for an irrigation canal pool. Their method, called Auto Tune Variation (ATV), generates small amplitude oscillations of the canal pool to determine the canal pool properties. These properties are then used in the Ziegler-Nichols equations to tune the controller. This method was evaluated using simulation techniques and on a real irrigation canal in France.

Reddy (1990) compared controllers designed using optimization techniques as well as using Ziegler-Nichols techniques.

Burt and Piao (2002) discussed the difficulty of tuning PI controllers for irrigation canals using trial-and-error techniques. Essentially, even when this process is done in a systematic manner, the process can take a long time. Because of interactions between the pools, tuning of all the controllers must be down simultaneously.

Skertchly and Miles (1994) discuss a method for tuning PID controllers for irrigation canals using trial-and-error techniques as well.

Malaterre and Rodellar (1996) present a methodology for both optimal controllers and predictive controllers. The predictive controller discussed in this paper is tuned via trial-and-error techniques.

Wahlin and Clemmens (2002) also used a PI controller to operate a series of canal reaches. The PI controller is tuned by using trial-and-error techniques for one reach, then an additional reach is added to the system. At this point, the controllers had to be adjusted so that they did not interfere with the operation of each other. This process continues as each additional reach is added. The task is time consuming and less-than-optimal gain constants usually result.

Irrigation canals are characterized by large amounts of inertia and lengthy delay times that can make them difficult to control. Delay occurs when there is significant distance between the site at which control is exerted (e.g., gated check structure) and the location of the control objective (e.g., water level at the downstream end of a pool). Because waves travel in the canal at a finite rate, a control action may not lead to any change in the objective for a significant time. Patience must be exercised to avoid making successive changes before feedback is felt from an initial change. The large inertia of a canal systems means that even when there is little physical separation between control elements and measured value locations, the effect of a change may be so small that it cannot be perceived above the natural noise of the system. This fact often makes the derivative term in a PID controller ineffective, since perceived changes in error due to noise may overshadow the actual error changes that would be noticeable if noise were not present. Thus, typically only PI controllers are used on irrigation canals. A PI controller uses two parameters (the proportional gain K_p and the integral time K_i). Determination of these two parameters for a PI controller is accomplished through a process called tuning. There are a wide variety of tuning methods and they differ with respect to the amount of information about the process dynamics that are required. Note that sometimes this process is also called controller design. One must consider that there are limitations that are dictated by the system and this limits the gains that can be implemented.

PI control is based on the following equation. The control designer needs to determine the gain values for the proportional and integral gains.

$$u(t) = K_p e(t) + K_i \int e(t)dt \qquad (1)$$

Where u(t) is the controller input, K_p is the proportional gain, e(t) is the error between the setpoint value and the observed variable that is being controlled and K_i is the integral gain.

Regardless of the method that is used to develop PI controllers there are some factors that will help to improve the performance of the controller. As the control designer determines the PI gains, properly dealing with these factors will determine the speed at which the controller can push the system back to setpoint, limit system interactions that can slow system response, and reduce system instabilities.

There are numerous methods that have been developed to design PI controllers. A simple internet search will provide multiple examples of design methods. Some of the methods are relatively easy to understand and implement. However, there are key traits that have to be remembered and understood when developing a PI controller. This paper will focus on some basic control features and describe some subtle features that help to design a PI controller.

The proportional (K_p) gain provides the largest contribution to the controller algorithm. In most cases when the K_p is increased the speed that the system is driven to setpoint value is increased. However, larger K_p values tend to extend setpoint overshoot (Figure 1) as well as increase system oscillations or ringing (Figure 2) for the observed variable as the system is being driven back to the desired value. Excessive values for K_p tend to increase oscillations and lengthen the time it takes for a system to reach a steady state operation (Figure 2). If the K_p value is excessive the system will be unstable.

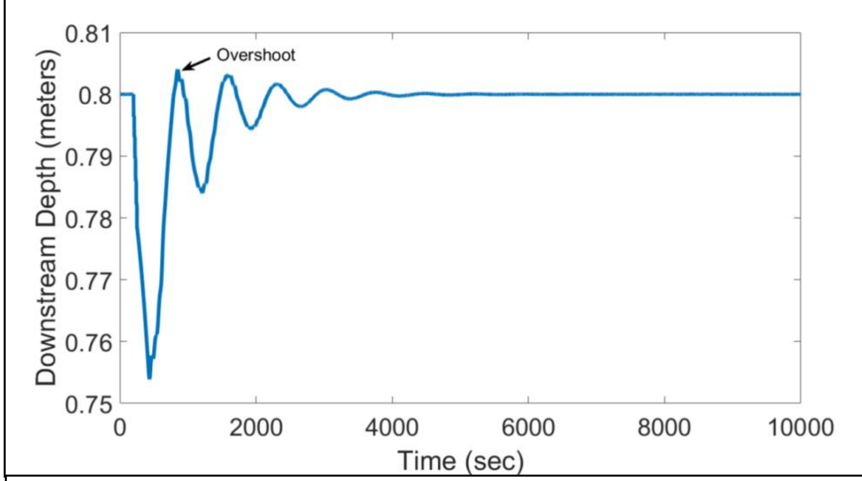

Figure 1. Typical PI response for a downstream water depth where the K_p and K_i gains need to be adjusted.

As mentioned earlier, the K_p value cannot pull the system all of the way back to setpoint so a K_i component is usually needed in the controller design. A properly selected K_i value tends to reduce system oscillations and pull the system closer to setpoint. If the K_i value is small it takes longer for the system to reach setpoint (Figure 3). However, if there are no additional disturbances, the system will eventually be pulled back to setpoint. If the K_i value is excessively large, the system will be unstable.

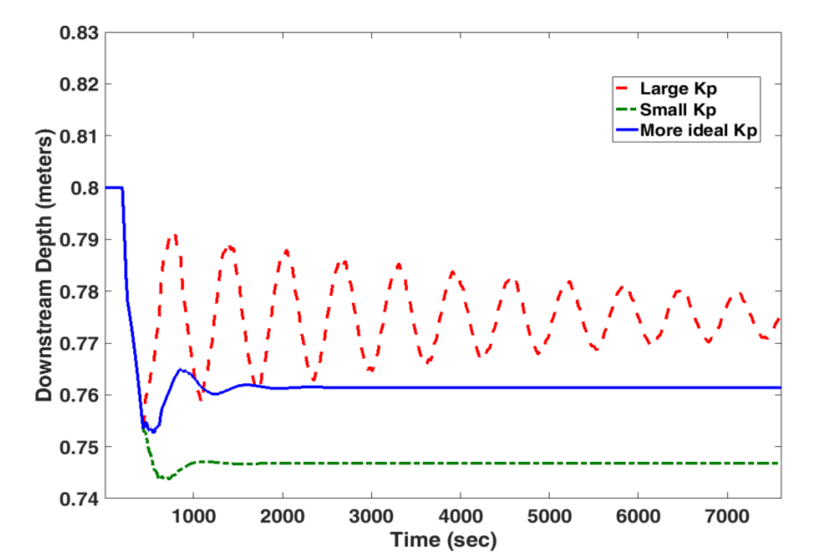

Figure 2. Graph of a downstream control system response for a canal reach. The proportional gain is only being used for the controller.

If the K_p and K_i gains are properly selected, then when a system experiences a disturbance, the controller can pull the system back to the desired operation point in a relatively timely manner with little oscillations. In addition to properly selecting the K_p and K_i gains, the control input and the control interval or cycle time will significantly affect the control response time.

Integrator Windup Error

Control system integrator windup error is a typical problem that often occurs for inexperienced control engineers (Cooper, 2006). If the system is not far from the setpoint, the windup error is usually not a problem. However, if the system error is large, windup error can create system oscillations and instabilities. The reason for this is the K_i error will start building when the system is far from its setpoint. As the K_i error builds it pushes the system toward setpoint. Nevertheless when the system is pushed back to setpoint the K_i error has become so large that the system is pushed past setpoint in opposite direction from the desired value. The K_i error term must then start building an error value that cancels out the original value to push the system back to the setpoint.

The error term builds in the opposite direction and the system is then pushed back past the setpoint and the cycle repeats. Usually, the oscillatory behavior deteriorates over time, but the system behavior is unacceptable. The control engineer needs to find a way to neutralize this behavior. It turns out that a simple effective way to deal with this problem is to simply zero the K_i error term when the system is driven far away from the setpoint. The K_p component can be used to pull the system back toward setpoint and then as the system gets close to setpoint the K_i function is turned on to allow the controller to pull the system back to the setpoint value.

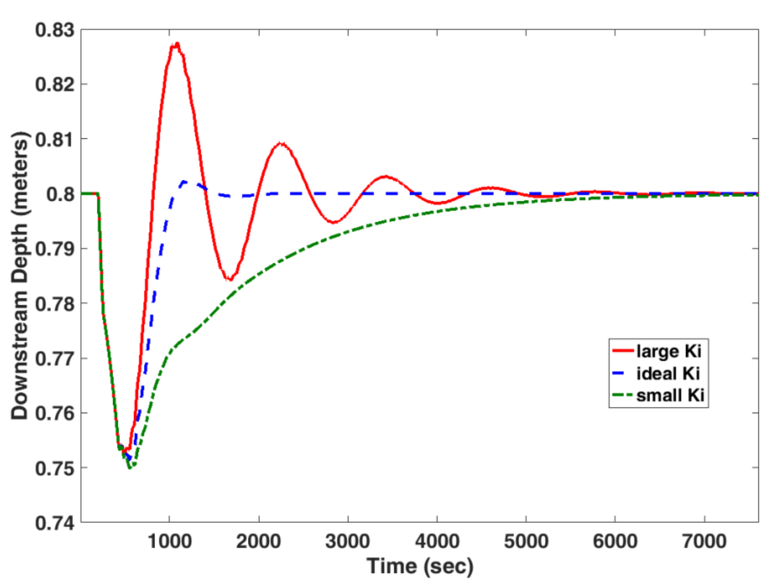

Figure 3. Graph of a downstream control system response for a canal reach. For different integral gains. Excessive Ki gains create instabilities while smaller Ki gains increase response time.

Cycle Time or Scan Interval

Cycle time or scan interval are also important factors when designing a PI controller. The cycle time will determine the size of the K_p and K_i gains. For example, these gains can usually be increased when the cycle time is reduced. If the gains are excessive for the large scan intervals, the system overshoot will also be large or the system may be driven to instability. If the gains can be increased, the controller has the potential for pulling the system back to setpoint faster. However, the system limitations should be considered before shortening the cycle time.

For example, the control gains may determine that an irrigation gate needs to move faster than the gate motor can move the gate. It does not make sense to use a cycle time that has the control routine trying to initiate a gate movement when the previous movement has not finished. It should be noted that the solid state electronics that are in SCADA systems allow for quick reliable communication. In many cases the limitations to the control system are the motors and structures.

If K_p and K_i gains are determined for a longer control interval and a shorter interval is used, the system control response will not be optimal for the selected gains. However the system will be stable and the response will have less drastic changes. The system performance will be smoother for disturbance compensation (Figure 4). This is especially evident when local downstream controllers are installed on canal reaches in series. It is not likely that a control designer will be willing to sacrifice system response time for a slower, smoother system reaction.

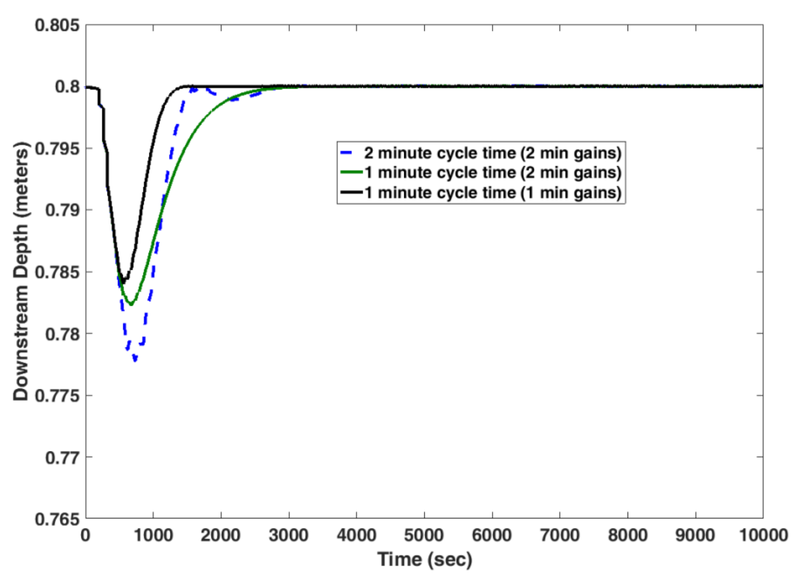

Figure 4. Comparing canal system response for 2 minute scan time K_p and K_i gains and for 1 minute gains.

Control Input Variable

The control input variable can also affect system stability. For example if the flowrate to a reach is used as the input variable instead of gate position, there will be less oscillations in the system response when two or more canal reaches are in series. The reason for this is that flowrate control provides a degree of isolation of the canal reach from the rest of the canal system. This happens because the control routine is continuously looking at the upstream and downstream water levels and computing a gate position based on the required flowrate.

On the other hand a control routine that just focuses on gate position adjusts the gate without considering if the position will provide the needed compensating flowrate. For instance, if a change is detected and the controller responds with a compensating gate adjustment, there will also be a corresponding change in upstream and downstream water levels. When the controller computes a gate change, it will initially look at the water levels, but it will not make gate adjustments to maintain a flowrate as the water levels change. This reduces the effectiveness of the gate change over time. In addition, initial changes in one reach will cause corresponding disturbances in connecting reaches. As the connecting reach controllers respond, they will interfere with the initial control changes that were made. Using flowrate control helps to isolate the changes.

It should be noted that if one reach is being controlled there is very little difference between a controller that focuses on gate movement verses a controller that looks at flowrate. This happens because the controller does not have to compete with other reaches for compensating flows (Figures 5 and 6).

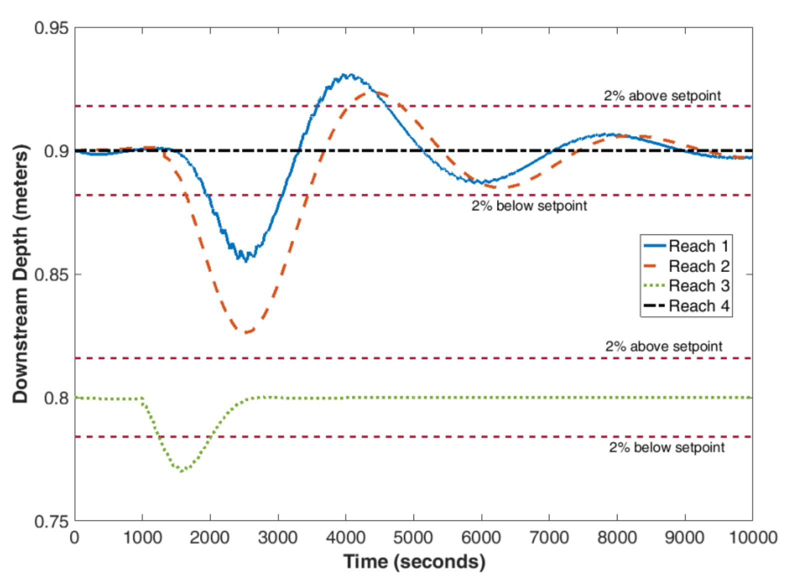

Figure 5. Graph of downstream water levels for 4 reaches in series. The controllers are designed to manipulate flowrate to maintain downstream water levels. An additional amount of water is taken from the downstream end of Reach 3.

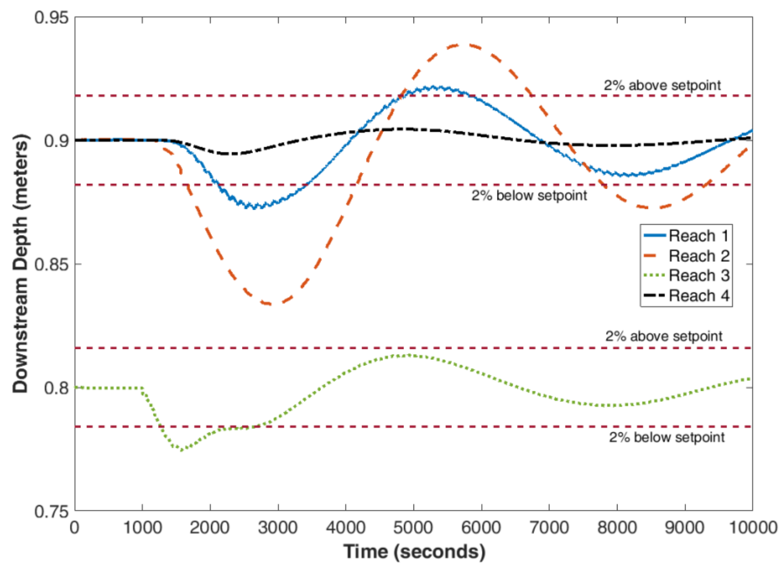

Figure 6. Graph of downstream water levels for 4 reaches in series. The controllers are designed to manipulate gate position to maintain downstream water levels. An additional amount of water is taken from the downstream end of Reach 3.

<u>Gain scheduling</u>

When a PI controller is designed to operate a canal system, it is designed for a particular operation point. If the operation point is changed significantly from the initial conditions, the controller will not provide optimal responses for other operation conditions. For example, if a PI downstream controller is designed for a specific flowrate and downstream depth, the controller will not operate the canal as optimally for other flowrates and depths. If other factors change during the irrigation season such as canal sedimentation or significant weed growth, this also affects system response for a PI controller.

Figure 7 shows the difference in response when PI gains are determined for operating a canal reach for a lower flow rate. If the canal base flowrate is increased, figure 7 indicates that the gains are not as optimal. Even when the setpoint water level is the same the response is less ideal for a different base flow rate. In order to provide a more optimal response for the different operating conditions, separate PI gains are required.

Using a different set of gains for different operating conditions is called gain scheduling. This method is implemented by creating a decision algorithm in the control routine that selects the best set of gains for the conditions that the canal is operating under. It should be noted that gain scheduling can be difficult to apply. As a control program transitions from one set of control gains to a different set of gains, there may be code conflicts if the programmer has not been careful with how the code is configured. It is sometimes better/easier to select a single set of gains that work reasonably well through the entire operation range and simplify the control algorithm.

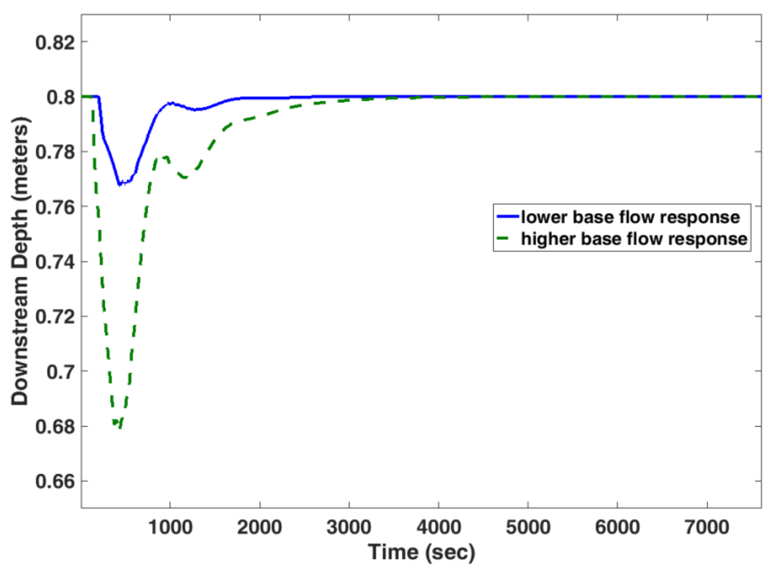

Figure 7. Operating a canal reach under downstream control. The K_p and K_i values are the same for both tests.

Incorrect Discharge Coefficient

It was mentioned earlier, that a PI control routine is robust. This means that despite inaccuracies (and there will definitely be inaccuracies in a canal system) a properly designed controller will provide the desired system response. An example of this is using an upstream control gate to maintain a downstream water level. If there is an error in the upstream flow measurement, the PI controller does not understand this. If the PI controller is properly tuned, the water level will be pulled back to the desired setpoint after a flow disturbance (Figure 8). A properly tuned PI controller doesn't necessarily care if it is driving the system back to and accurate setpoint. The controller only cares about driving the system back to what it thinks is an accurate setpoint.

Notice in Figure 8 that the control response is virtually the same despite the fact that a different discharge coefficient is used for the control gate. The controller is going to pull the canal water level back to setpoint. It should also be noted that the water level may also be in error. The controller will drive the system back to setpoint and that setpoint will be verified by whatever the sensor is transmitting back to the control unit.

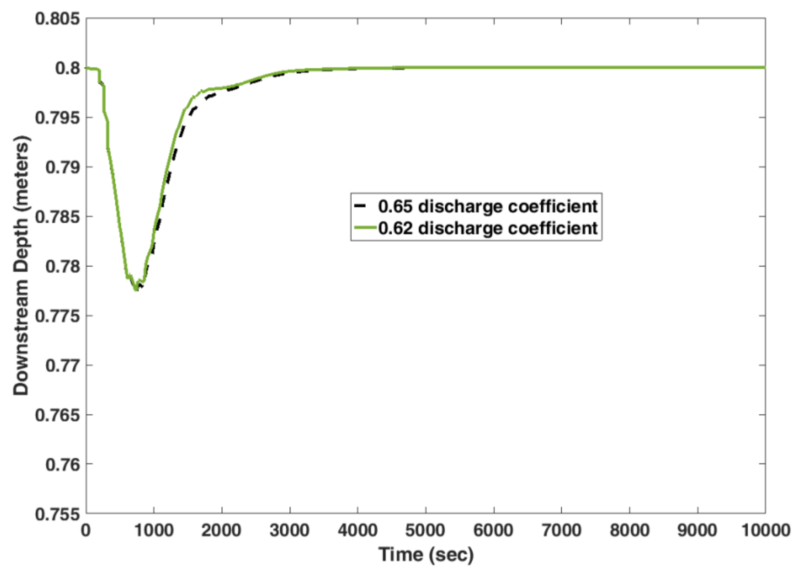

Figure 8. Graph of a downstream control system response with different control gate discharge coefficients.

CONCLUSION

A number of factors have been mentioned here that help to provide for a stable operating PI canal downstream controller. Selecting proper PI gains for the feedback controller is relatively easy for an experienced control designer. Nevertheless a control engineer needs to be aware of other factors that are mentioned in this paper such as cycle or scan time, integrator windup, and proper selection of the control input variable. Paying attention to these additional details will provide for a better operating control system.

It should be illustrated that each canal is unique and often presents specific challenges. An experienced control engineer should be able to deal with the uniqueness of each canal system. When the control system does not respond as expected, the control engineer has to break down the various system components including the electronic architecture to diagnose the particular problem that arises. In many cases, the solution to a non-characteristic control problem is simple, but it takes time to determine the solution.

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UTE INDIAN RIGHTS SETTLEMENT
TITLE V OF THE CENTRAL UTAH PROJECT COMPLETION ACT

Lee Baxter[1]
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ABSTRACT

Increasing pressure on water supplies motivated by rising population and associated development needs, coupled with recent emphasis on Native American self-determination, has resulted in increasing attention on Tribal Water Rights settlements. On September 20, 1965, the Ute Tribe (Tribe) and the US Bureau of Reclamation entered into the "1965 Deferral Agreement" wherein the Tribe agreed to defer, for 40 years, development of a substantial portion of its Federal Reserve water rights in order to facilitate construction of the Initial Phase the Central Utah Project (CUP). The Tribe occupies the second largest Indian Reservation in the United States, covering over 4 million acres, located within a three-county area in northeastern Utah known as the "Uintah Basin".

The CUP is a federal water development project, authorized under the Colorado River Storage Project Act of 1956 for the purpose of developing a portion of Utah's Colorado River Compact allotment. The 1965 Deferral Agreement recognized the need for the Tribe to defer use of irrigation water rights on over 15,000 acres of land in order for the Secretary of the Interior to certify to Congress that an unchallenged water right existed in order for construction to proceed on the CUP. In return, certain commitments were made to the Tribe, including inclusion of the deferred lands in the project plan for the Ultimate Phase of the CUP.

Twenty years later, although significant progress had been made on construction of the CUP, many of the commitments to the Tribe remained unfulfilled, and the Ultimate Phase of the CUP remained unauthorized.

Title V of P.L. 102-575, the Ute Indian Rights Settlement, was enacted by Congress in 1992 as a comprehensive settlement to deal with all unresolved Tribal claims arising out of the 1965 Deferral Agreement. The various sections of Title V included significant annual cash payments the Ute Tribe, authorized appropriations for Tribal and individual farming assistance, and improvements to the existing Uinta Indian Irrigation Project. Also authorized were appropriations for reservoir, stream, habitat, and road improvements, and a significant Tribal Development Fund.

Title V is administered by the Central Utah Project Completion Acts Office of the Secretary of the Interior, located in Provo, Utah.

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INTRODUCTION

This paper is intended to provide a brief background of the Ute Tribe in Utah and subsequent Tribal involvement with the Central Utah Project, followed by a discussion of implementation of the Ute Indian Rights Settlement.

BACKGROUND[3]

The Ute Indians, for whom the State of Utah is named, ranged across the Colorado Plateau for thousands of years prior to the arrival of Euro-American settlers. The name Ute means ‘land of the Sun’. The reservation is located within a three-county area known as the "Uintah Basin".

There were originally seven Ute clans or bands located in and around the Rocky Mountains. These clans were scattered over an area comprising some 150,000 square miles. The Utes encompass both forest dwellers as well as the more nomadic desert inhabitants. The forest dwelling Utes subsisted on wild game and fish, whereas the desert Utes would travel to find their food and resources.

Beginning in 1847, Utes experienced the full impact of Euro-American contact with the arrival of Mormon settlers. The initial Mormon settlement in the Salt Lake Valley occurred in a joint occupancy zone between Utes and Shoshones, and therefore caused little immediate disruption. But as settlers moved south along the Wasatch Front, they began competing with Utes for the scarce resources of these valuable oasis environments.

THE NORTHERN UTES[3]

Four of the seven above mentioned clans now comprise the Northern Utes on the Uintah-Ouray Reservation. In 1861, President Abraham Lincoln set aside the two-million-acre Uintah Valley Reservation for the Ute bands. This was the beginning of the present Northern Ute Tribe.

Utes found an inhospitable environment and little prepared for them in the Uintah Basin. Throughout the 1870s these Uintah Utes continued to hunt and gather in the surrounding country while Government Indian agents cultivated fields in an effort to convince them to settle down.

Things became more difficult in 1881 when the federal government forcibly removed the Yamparka and Parianuc (White River) Utes from Colorado to the Uintah Reservation. The following year the government moved the peaceful Taviwac (Uncompahgre) Utes to the adjoining two-million-acre Ouray Reservation.

[3] Davis, Robin. “Ute Indians”. September 10, 2010. http://uteindians.blogspot.com/

Today, the Uintah and Ouray Utes are comprised of three bands: the Uintah, the White River, and the Uncompaghre, with a tribal membership of about 3,150 members. The Tribal governing body consists of a six member Business Committee, two members from each band. The tribal headquarters are located at Fort Duchesne, approximately 130 miles southeast of Salt Lake City.

HISTORY OF THE UINTAH AND OURAY RESERVATION[4]

The Uinta Basin drew little interest during the initial phase of Euro-American settlement of the Great Basin. Early in the 1860's, Mormon Church leader, Brigham Young, ordered a small expedition to the Uinta Basin to determine the suitability for locating settlements there. Upon the expedition's return, the *Deseret News* reported that the expedition had found little there and that the basin was a "vast contiguity of waste...valueless excepting for nomadic purposes, hunting grounds for Indians and to hold the world together."

On October 3, 1861, by executive order, President Abraham Lincoln set aside the Uintah Valley in the territory of Utah for the use and occupancy of Indian tribes, thereby establishing the Uintah Reservation. The first agency on the reservation was established in 1865 at the head of Daniels Canyon, but was relocated several times over the next several years.

On January 5, 1882, President Chester A. Arthur issued an executive order creating the Ouray Reservation on adjacent lands for the resettlement of the Colorado Uncompahgre Utes. In 1886, the Uintah and Ouray agencies were consolidated to serve the Uintah and Ouray Reservation and were located at Fort Duchesne, not long after the construction of a military post there.

In 1897, Congress enacted the Dawes Act and began allotment of various reservations, and in 1904, approved 80-acre individual allotments for the Uintah and White River Utes of the Uintah Reservation. Individual Indians were given title to their allotments. Subsequently, lands on the Ouray Reservation were allotted to the Uncompahgre Utes.

On August 28, 1905, a total of 1,004,285 un-allotted acres were opened to (non-Indian) homestead entry. Prior to being confined to a reservation, the various bands of the Ute Tribe led a nomadic lifestyle, and were adept at hunting and gathering. Being confined to a reservation and adjusting to a farmer/rancher lifestyle was difficult for the Utes. Within a relatively short period of time, many of the Indians sold their allotments to non-Indian homesteaders. This, combined with opening the un-allotted lands to homesteading, created a checker board of Indian/non-Indian ownership on much of the reservation. This checker board ownership exists today and adds to the complexity of administering water rights on the reservation.

Following the Indian Reorganization Act of 1934, the Ute Tribe of the Uintah and Ouray Reservation began repurchasing alienated reservation lands, and in 1948 the federal

[4] Chapter 2 - Water Rights of the Ute Indian Tribe – Uintah and Ouray Reservation – an Overview, by Lynn Hansen, May 2014

government returned some 726,000 acres to the Tribe in what is called the Hill Creek Extension.
Today the Uintah and Ouray Reservation consists of approximately 1.3 million acres of trust land. The Reservation is the second largest Indian Reservation in the United States and originally covered over four million acres.

THE CENTRAL UTAH PROJECT AND THE 1965 DEFERRAL AGREEMENT

On September 20, 1965, the Ute Tribe, the Central Utah Water Conservancy District (District) and the United States entered in an agreement commonly referred to as the Deferral Agreement. In the Deferral Agreement, the Ute Tribe, at the request of the United States, deferred the use of its water on 15,242 acres of irrigable 1and in order to allow for the development of the Bonneville Unit of the Central Utah Project, a large Federal water development project in Utah.

The importance of the Deferral Agreement is twofold. First, the United States and the District recognized the necessity for the Tribe to defer the use of water in order for the Secretary of the Interior to certify to the Congress that an unchallenged water right existed so that construction could proceed on the Bonneville Unit of the Central Utah Project. Second, certain and definite covenants in consideration thereof were made to the Tribe, binding upon the United States and the District.

Following are excerpts from the agreed upon covenants in the Deferral Agreement (numbering remains consistent with Deferral Agreement) :

1. Construction of the Bonneville Unit of the Central Utah Project, initial phase, as authorized by the Congress of the United States, and as planned by the Bureau of Reclamation, may proceed without objection, interference or claim adverse to the water requirements for such unit.

2. Use of water on 21,208 acres of Indian water right land in the Uintah Basin portion of the Bonneville Unit, with the priority date of October 3, 1861, described as groups (2), (3), and (4) is recognized and confirmed.

3. That use of water for the 15,242 acres of Indian owned land, described as Group (5) be deferred at this time upon the condition that said lands be included in the ultimate phase of the Central Utah Project.

4. That deferment of the development of said Group (5) lands for irrigation purposes is granted by said Ute Indian Tribe conditioned upon the full and complete recognition of the water rights of said tribe, with a priority date of 1861 in Groups (1), (2), (3), (4) and (5) described in the book of claims filed with the state Engineer, State of Utah, by the Ute Indian Tribe, without resort to litigation.

5. That said deferment shall neither constitute an abandonment by said tribe, nor be construed as consent to any further deferment of the right to the use of water for the

15,242 acres referred to in paragraph 3 above. If the ultimate phase of the Central Utah Project is not completed sufficiently to supply said Indian water rights by the 1st day of January 2005, equitable adjustment will be made in accordance with said reserved and perfected water rights of the tribe to permit the immediate Indian use of the water so reserved.

9. That facilities will be provided under the Colorado River Storage Act to mitigate for losses to fish, wildlife and recreation upon the lands of the Ute Indian Tribe of the Uintah and Ouray Reservation or of its members caused by the construction and/or operation of the Central Utah project. This provision shall not be construed as any limitation upon the acceptance or use of any benefits as may become available under enhancement provisions of said act.

10. That development of the Uintah Unit of the ultimate phase of the Central Utah Project to provide storage of the runoff waters of the Uintah River and its tributaries, be programed for early authorization and construction.
12. That the exchange of Duchesne River water under the existing Duchesne Feeder Canal and Midview Reservoir for Lake Fork River water in order to free Lake Fork River water for use upstream on lands in the Moon Lake Project shall not impair the 1861 priority of the Ute Indian Tribe or its members either in flow or storage right, and such exchange shall not be construed as an exchange of water rights.

13. Nothing herein contained shall be construed as preventing the construction and use of facilities by the Ute Indian Tribe, the Uintah Indian Irrigation Project, or the United States for storage and use of water upon all Uintah Indian Irrigation Project lands not supplied from facilities constructed under the Central Utah Project.

The Deferral Agreement is a significant piece of the complex Ute water right puzzle, and it continues to be intertwined in almost every discussion regarding the Tribe's water rights.

Initial and Ultimate Phases of CUP

Because of its size and complexity, to facilitate planning and construction, Reclamation divided the Central Utah Project into six units to be built in two phases. The Initial Phase, which was authorized by the 1956 Colorado River Storage Project Act, was divided into four units: Jensen, Vernal, Upalco, and Bonneville. The Ultimate Phase included the Uintah and Ute Indian Units.

In 1965 when the Deferral Agreement was executed, the initial phase of CUP had already been authorized by Congress, but the ultimate phase was still awaiting Congressional authorization. In 1968 Congress amended the Colorado River Basin Project Act, to include the Uintah Unit in the initial phase, conditionally authorizing construction of the Uintah Unit, and feasibility investigations for the Ute Indian Unit. Additional authorizations occurred in 1972, and 1988.

The proposed Upalco Unit would have provided an average water supply of 21,800 acre-feet annually, 19,800 for irrigation and 2,000 for M&I use. The principal feature of the Upalco Unit would have been the Taskeech Dam, located on the Lake Fork River approximately six miles downstream from Moon Lake Reservoir. In addition to capturing water from Lake Fork River, the Taskeech Dam would also intercept surplus flows of the Yellowstone River and convey it to the reservoir through the Taskeech Feeder Canal.

Most of the irrigation water developed by the proposed Upalco Unit, about 17,500 acre-feet, would have been used to supply supplement irrigation water for about 34,110 acres of non-Indian land. Only about 2,300 acre-feet would be used to supplement the supply to about 8,500 acres of Indian trust lands.[5]

The Uintah Unit anticipated the construction of two reservoirs, one on the Uintah River and one on the Whiterocks River. It would have provided an average annual project water supply of 47,800 acre-feet, with 46,800 for irrigation and 1,000 for M&I use. The proposed Uintah Unit would have developed a water supply of 30,700 acre-feet of water annually for irrigation of 28,420 acres of Indian lands within the Uintah and Ouray Indian Reservation. Of this total, about 25,000 acre-feet would be used for full service irrigation of 7,818 acres, and 5,700 acre-feet would be used for supplemental irrigation on 20,602 acres.[6]

The Deferral Agreement proposed the Bottle Hollow Reservoir be investigated at an early date with a view of including the same as a storage facility of the Uintah Unit. However, the Bottle Hollow Reservoir including the Bottle Hollow Complex, was constructed in the early 1970’s as a mitigation feature, and is therefore not part of the Uintah Unit.

The Proposed Ute Indian Unit was an ambitious plan that contemplated diverting water from the Flaming Gorge Reservoir on the Green River and developing a collection system on various drainages for conveyance and distribution to the Uintah Basin and beyond. The Ute Indian Unit, when completed, was to constitute the "backbone” of an overall State water plan. By direct diversions and water exchange, it would have a significant impact on water supplies in most of Utah. Basically, the unit would provide for water resource development in the Uintah Basin and for exportation of additional water to the Bonneville Basin. The Ute Indian Unit, beyond a feasibility study, was never authorized for construction. In May of 1980, the Water and Power Resources Service (previously the Bureau of Reclamation) issued a Concluding Report on the Ute Indian Unit. The report stated: “A concluding report rather than a feasibility report has been written because many of the key factors which influence development of Utah’s remaining share of Colorado River water are in a state of flux thereby inhibiting formulation of a viable plan at the present time.”[7]

No feasibility study was completed and no further appropriations were authorized regarding the Ute Indian Unit.

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[5] Upalco Unit, Central Utah Project, Definite Plan Report, March 1980, Chapter VI, Page 79

[6] Uintah Unit, Central Utah Project, Definite Plan Report, August 1978, Chapter VI, Page 81

[7] Ute Indian Unit, Central Utah Project, Concluding Report, May 1980

Reclamation put a lot of effort into the investigation and planning of the Bonneville, Upalco and Uintah units. Unfortunately, progress was slow and congressional funding was limited and sporadic. Environmental requirements created by the passage of the National Environmental Policy Act of 1969 (NEPA) and the Endangered Species Act of 1973 had a huge impact on Reclamation's construction program, as they required federal agencies to assess the impacts to the environment and to endangered species of any proposed project before construction could begin.

High inflation during the 1970's and 80's, and the new environmental requirements, which could also affect project water supply, dramatically increased construction costs, therefore necessitating reformulation of project plans. Much to the disappointment of the Ute Tribe and the Uintah Basin water users, this ultimately led to the demise of the Ute Indian Unit and put the Uintah and Upalco Units in jeopardy.

As discussed earlier, the Deferral Agreement allowed the Bonneville Unit to proceed. As stated in covenant number 5 of the agreement; "If the ultimate phase of the Central Utah Project is not completed sufficiently to supply said Indian water rights by the 1st day of January 2005, equitable adjustment will be made in accordance with said reserved and perfected water rights of the tribe to permit the immediate Indian use of the water so reserved." Simply stated, if the CUP projects contemplated in the agreement that would benefit the Tribe are not completed by 2005, then equitable compensation was due the Tribe.

With the seemingly endless delays and perceived little progress being made on the Bonneville Unit by Reclamation, the Central Utah Water Conservancy District lobbied Congress to designate them as the entity responsible for the completion of CUP. That, and the glaring reminder of the clock ticking towards the January 2005 maximum date of deferment by the Tribe, prompted Congress to enact Public Law 102-575, Reclamation Projects Authorization and Adjustment Act of 1992.

Titles II through VI of this act are known as the Central Utah Completion Act (CUPCA), with Title V being the Ute Indian Rights Settlement.

Title II of CUPCAhad the effect of revitalizing the Uintah and Upalco Units. Section 201(c) (*Termination of Authorization of Appropriations)* referred to the various appropriation authorizations of the Upalco and Uintah Units and said those authorizations shall terminate five years after the date of the 1992 enactment unless: (1) the Secretary executes a cost-sharing agreement with the District for construction of such project, and; (2) the Secretary has requested, or the Congress has appropriated, construction funds for such project.

This language essentially established a five year time frame to complete the two requirements outlined in 201(c), or authorization for those units would automatically terminate. It did, however, leave the door open for a final attempt to construct the Uintah and Upalco Units.

With a new sense of urgency, a significant effort was undertaken by the Department of the Interior (Interior) and the Central Utah Water Conservancy District (District) to fulfill the provisions in Section 201(c) of CUPCA; provisions separate and apart from those in Title V. Although any obligation to provide storage for the Tribe was satisfied by Title V, the Department made it very clear that if constructed, the Uintah and Upalco Units would provide benefits to the Tribe along with the non-Indian Uintah Basin water users. Section 502(a) provided an annual payment to the Tribe for compensation in lieu of water from the proposed Uintah and Upalco Units, so this would be an added benefit to the Tribe over and above the Title V settlement.
The District and the Department were diligent in performing the tasks outlined in Section 201(c) of the legislation and were able to meet the requirements to prevent the loss of appropriation authorizations.

The District and the Department included the State, other federal agencies, the basin water users, and the Tribe, in a planning process that would hopefully lead to the construction of the Uintah and Upalco Units. As part of this process, the Uintah Basin Replacement Project as authorized in Section 203 of CUPCA was reconfigured to include the Uintah and Upalco Units.

Through a multi-year effort of coordinating, planning, and negotiating, it appeared in 1999 that the Uintah and Upalco Units would finally become a reality and would provide much anticipated storage to the Tribe and the Uintah Basin water users. The reconfigured Uintah and Upalco Units, although scaled down from the original proposals, would have provided the Tribe with 27,070 acre-feet of water for use on Tribal lands.[8] The Tribal benefit being about 44% of the total water developed by the two units.

Much to the disappointment of all the participants on the planning team, the Tribe ultimately decided to reject the additional benefits and not participate in the Uintah Unit Replacement Project. On April 29, 1999, the Tribe sent a letter to the Department of the Interior stating: "After extensive debate and consideration of the interests of the Tribe as a whole, the Business committee has decided that the Tribe will not proceed with the Uintah Unit Replacement Project."

Because of the Tribe's decision not to participate, the Uintah and Upalco Units were subsequently de-authorized and the Uintah Basin Replacement Project was completed in accordance with Section 203 without including the Uintah and Upalco Units.

TITLE V OF CUPCA[9]

In years prior to 1992, several attempts were made to introduce legislation that would ratify a water compact and settle the Ute Tribes' water rights. On July 13, 1988 Utah

[8] Draft Environmental Impact Statements, Upalco Unit - December 1996, Uintah Unit - February 1997.

[9] Chapter 12 - Water Rights of the Ute Indian Tribe – Uintah and Ouray Reservation – an Overview, by Lynn Hansen, May 2014

Congressman Howard Nielson filed a bill that he titled the Ute Indian Water Settlement Act. Later in 1988 Congressmen Wayne Owens introduced a separate bill, H. R. 5307, titled the Ute Indian Water Rights Settlement of 1988.[10] Although the language in the bills differed on the amount of monetary compensation, both bills provided for Congressional ratification of the 1980 (version of the) Compact. Ultimately, neither of these bills became law, but the political climate was such that similar bills in support of an Indian rights settlement were forthcoming.

Soon after the 1988 bills failed to become law, the Tribe hired Daniel H. Israel as their water attorney, and engaged a new strategy in resolving their water right claims. The strategy shifted to pursuing a financial settlement in lieu of CUP facilities to settle the commitments of the 1965 deferral agreement. A revised version of the 1980 Compact (1990) was negotiated with the State of Utah, and at the same time, new settlement language was crafted by Mr. Israel and the Tribe. This language would eventually be included as part of the Central Utah Project Completion Act. The United States was not invited to participate in this process and was left out of any discussions involving the drafting of the 1990 Compact and proposed Settlement language.

On October 30, 1992, Congress enacted Public Law 102-575, an omnibus bill entitled "The Reclamation Projects Authorization and Adjustment Act of 1992". Titles II through VI of this act are known as the Central Utah Completion Act (CUPCA). This includes Title V which is the Ute Indian Rights Settlement.

Title V was enacted by Congress as a comprehensive settlement to deal with the issues of un-quantified federal reserved water rights of the Ute Indian Tribe being subject to existing claims and prospective lawsuits and other unresolved tribal claims arising out the 1965 Deferral Agreement.

The Central Utah Project Completion Act Office (CUPCA Office) was established to implement and provide oversight of CUPCA, including Title V. An Implementation Team was established by the Secretary to oversee the implementation of Title V. The Team prepares an annual report and meets periodically to review progress and address issues relating to the implementation of Title V.

In the Deferral Agreement the Tribe deferred, for forty years, the development of a portion of its reserved water rights in order to facilitate the construction of the Bonneville Unit of the Central Utah Project. Certain features contemplated in the Deferral Agreement that would benefit the Tribe were never constructed. Title V provides financial benefits to the Tribe in lieu of the commitments made in the Deferral Agreement.

The following is a detailed overview of Title V:

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[10] Ute Indian Water Rights Settlement, Hearing, Before the Committee on Interior and Insular Affairs, House of Representatives, One Hundredth Congress, Second Session, on H.R. 5307, UTE INDIAN WATER SETTLEMENT ACT OF 1988, Hearing Held in Washington, DC, October 4, 1988.

Purpose – This Act and the proposed Revised Ute Indian Compact of 1990 are intended to:

(1) Quantify the Tribe's reserved water rights;
(2) Allow increased beneficial use of such water; and
(3) Put the Tribe in the same economic position it would have enjoyed had the features contemplated by the September 20, 1965 agreement been constructed.

In order to achieve the stated purposes in Title V:

- Section 502 provided for an annual payment to the Tribe, in lieu of storage from the Uintah and Upalco Units;
- Section 503 ratified the 1990 water compact (subject to re-ratification by the State of Utah and the Tribe);
- Section 504 authorized appropriations for Tribal farming operations, individual farming assistance and improvements to the Uintah Indian Irrigation Project that would reduce the Tribe's O&M costs;
- Section 505 authorized appropriations for reservoir, stream, habitat and road improvements; and
- Section 506 authorized appropriations for a Tribal development fund.

All of the authorized amounts in sections 504, 505, and 506 have been appropriated by Congress, making Title V fully funded as of Fiscal Year 2004.

Each section of Title V is discussed in more detail below.

Section 501 – Findings

Section 501(a) discusses four findings, the findings are as follows:

(1) The unquantified Federal reserved water rights of the Ute Indian Tribe are the subject of existing claims and prospective lawsuits involving the United States, the State, and the District and numerous other water users in the Uintah Basin. The State and the Tribe negotiated, but did not implement, a compact to quantify the Tribe's reserved water rights.

(2) There are other unresolved tribal claims arising out of an agreement dated September 20, 1965, where the Tribe deferred development of a portion of its reserved water rights for 15,242 acres of the Tribe's Group 5 Lands in order to facilitate the construction of the Bonneville Unit of the Central Utah Project. In exchange the United States undertook to develop substitute water for the benefit of the Tribe.

(3) It was intended that the Central Utah Project, through construction of the Upalco and Uintah units (Initial Phase) and the Ute Indian Unit (Ultimate Phase) would provide water for growth in the Uintah Basin and for late season irrigation for both the Indian and non-Indian water users. However,

construction of the Upalco and Uintah Units has not been undertaken, in part because the Bureau was unable to find adequate and economically feasible reservoir sites. The Ute Indian unit has not been authorized by Congress, and there is no present intent to proceed with Ultimate Phase construction.

(4) Without the implementation of the plans to construct additional storage in the Uintah Basin, the water users (both Indian and non-Indian) continue to suffer water shortages and resulting economic decline.

Section 501(b) states the purpose of the Act is to:

(1) Quantify the Tribe's reserved water rights;
(2) Allow increased beneficial use of such water; and
(3) Put the Tribe in the same economic position it would have enjoyed had the features contemplated by the September 20, 1965 Agreement been constructed.

Section 502 - Provisions for Payment to the Ute Indian Tribe

Section 502(a) provides for an annual payment to the Tribe in lieu of 35,500 acre-feet of water that would have been supplied to the Tribe by storage from the Central Utah Project had the Upalco and Uintah units been constructed.

The language in Section 502, in addition to the revisions to the 1980 Compact as reflected in the 1990 Compact, is a clear indication that the CUP facilities promised under the 1965 Deferral Agreement were no longer being considered. Rather the Tribe elected to receive a monetary settlement in lieu of storage facilities.

Section 502(b) authorizes the Secretary to make any unused capacity in the Bonneville Unit Strawberry Aqueduct and Collection System diversion facilities available for use by the Tribe.
The Tribe is currently in discussions with Interior to take advantage of this provision in Section 502(b) regarding the unused capacity in the above mentioned facilities.

Section 503 – Tribal Use of Water

In Section 503(a) Congress ratified the Revised Ute Indian Compact of 1990 subject to re-ratification by the Tribe and the State of Utah. The Secretary is authorized to take all actions necessary to implement the Compact. In 2011 the Ute Indian Tribe changed legal counsel regarding water issues and is now proposing to begin new negotiations on the Ute Compact. The State has indicated that it will take no action in ratifying the Compact until the Tribe has done so.

Section 504 – Tribal Farming Operations

Section 504 authorizes $45,000,000 in funding for the Tribe to:

(1) Develop a seven thousand five hundred acre farming/feed lot operation equipped with satisfactory off-farm and on-farm water facilities out of Tribally-owned lands and adjoining non-Indian lands now served by the Uintah Indian Irrigation Project;

(2) Develop a plan to reduce the Tribe's expense on the remaining sixteen thousand acres of Tribal land now served by the Uintah Indian Irrigation Project; and

(3) Develop a fund to permit Tribal members to upgrade their individual farming operations.

All appropriated Title V funds were deposited into interest bearing trust accounts managed by the Office of the Special Trustee for American Indians (OST).

Since 1996 the Tribe has used section 504 funding to improve the Tribe's farming and cattle operation. Two pipeline projects, the Four Corners and the Farm Creek pipelines, to improve the Uintah Indian Irrigation Project, have been completed. Funding is being used to assist Tribal members in upgrading their individual farming operations using policies and guidelines developed by the Tribe and approved by the CUPCA Office. This is an on-going program as the Tribe accomplishes the objectives outlined in Section 504. Expenditures are about $2 million per year.

Section 505 – Reservoir, Stream, Habitat and Road Improvements with respect to the Ute Indian Reservation

Section 505 authorizes funding for Reservoir, Stream, and Habitat improvements on the Ute Indian Reservation as described below.

Section 505(a) Repair of Cedarview Reservoir:

A total of $5,000,000 was appropriated and made available to the Secretary, in cooperation with the Tribe to repair Cedarview Reservoir.

Cedarview Reservoir was drained in 2008 and the Tribe entered into a contract with the Bureau of Reclamation to identify and treat areas of possible leakage within the reservoir and to design and implement a repair of Cedarview Dam. Design was completed in early 2009 and construction began in May of 2009. Work continued through the summers of 2009, 2010, 2011, and was completed in 2011. Now that the work is completed Cedarview Reservoir should be a much improved recreation area with a viable fishery for Tribal members.

Section 505(b) Reservation Stream Improvements:

A total of $10,000,000 was appropriated and made available to the Secretary, in cooperation with the Tribe and in consultation with the Utah Reclamation Mitigation and Conservation Commission (Commission) to improve stream habitat on 53 linear miles on Pole Creek, Rock Creek, Yellowstone River, Lake Fork River, Uinta River, and Whiterocks River.

In 2009 the Tribe utilized $1.7 million of Section 505(b) funds, as a cost share with the Commission, to build a fish hatchery. Construction on the Big Springs Fish Hatchery was initiated in June 2009 and completed November 2010. The Commission was responsible for providing 75% of the construction cost. Funds were provided through the American Recovery and Reinvestment Act of 2009. The first stocking was made in May 2012 to Midview Reservoir.

The Tribe is currently in the planning and design phase on stream improvement projects.

505(c) Bottle Hollow Reservoir:

A total of $500,000 was appropriated and made available to permit the Secretary[11] to:

(1) Clean the Bottle Hollow Reservoir of debris and trash resulting from a submerged sanitary landfill,

(2) Remove all non-game fish and,

(3) Secure a minimum flow of water to the reservoir to make it a suitable habitat for a cold water fishery.

Bottle Hollow Dam was constructed in the late 1960's early 70's as a mitigation measure to replace the loss of fisheries incurred on the reservation as a result of water lost through Bonneville Unit diversions from Rock Creek. Reclamation planned to provide a permanent water supply for the reservoir from the Uintah Unit.

Since its construction the Bottle Hollow Reservoir has suffered from an inadequate water supply, which likely contributes to its failure to support a cold water fishery. In fact, since the Uintah Unit was not constructed, Bottle Hollow has no water supply except what BIA is able to provide from excess flows from the Uintah River during periods of high run-off, and as pass through flows that are released back into the Uintah River and re-diverted into the Henry Jim Canal.

505(d) Minimum Stream Flows

This section directs the Secretary to endeavor to maintain continuous releases into Rock Creek to maintain flows of 29 cubic feet per second during the summer and 23 cubic feet per second during the winter measured at the reservation boundary.

[11] Section 505(c) differs from other sections in 505, in that it does not require consultation with the Tribe.

Shortly after the passage of Title V, the Tribe and their attorney Dan Israel, who drafted the Title V legislation, expressed their concern over the language in the legislation and contended that the flows in Rock Creek should have been measured at Stillwater Dam rather than at the reservation boundary. There are several small tributaries that add water to Rock Creek between Stillwater Dam and the reservation boundary. In H.R. 5307, as proposed by Congressman Owens in 1988, minimum flows in Rock Creek would have been measured at Stillwater Dam. That language changed in the 1990 version of H.R. 3960 and remained the same in the final version of H.R. 429 which became the enacted legislation.

The requirement of the legislation stands. However, based on the 1980 Stream Flow Agreement as amended in 1993, the Interagency Biological Assessment Team (IBAT) was established to recommend flow regimes for various streams affected by the Central Utah Project. The IBAT's recommendation for Rock Creek closely matches the flows of the earlier proposed legislation and with the Tribe's position. The IBAT's recommended winter regimen flows in Rock Creek are 19 cfs from the dam and 4 cfs from the South Fork of Rock Creek, which is released at Docs Diversion into Rock Creek just downstream from Stillwater Dam. The summer regimen of 29 cfs, has 21 cfs coming from the dam and 8 cfs coming from South Fork.

By following IBAT's recommendations the CUWCD essentially accomplishes what the Tribe had asked for, of 29 cubic feet per second during the summer and 23 cubic feet per second during the winter measured at Stillwater Dam. Records indicate that flows have met or exceeded the requirement each day since monitoring began in 1994.[12]

505(e) Land Transfer

The Bureau shall transfer 315 acres of land to the Forest Service, located at the proposed site of the Lower Stillwater Reservoir as a wildlife mitigation measure. The earlier 1988 versions had the land being transferred to the Tribe, but the final enacted legislation transferred the 315 acres to the Forest Service.

505(f) Recreation Enhancement

A total of $10,000,000 was appropriated to develop big game hunting, fisheries, campgrounds and fish and wildlife management facilities on the reservation.

This fund is heavily used by the Tribe on an annual basis to develop and enhance hunting, fishing, and recreation on the reservation. Notable accomplishments include the construction of a fish and wildlife administration building, a bison management facility, and various new or improved camping and recreation facilities within the reservation.

505(g) Municipal Water Conveyance System

[12] Central Utah Water Conservancy District, SCADA records.

A total of $3,000,000 was appropriated for participation by the Tribe in the construction of pipelines associated with the Duchesne County Municipal Water Conveyance System.

Section 506 – Tribal Development Fund

Section 506 authorized funding for the Secretary to establish a Tribal Development Fund.

In 2005, the Tribe withdrew the Section 506 funds from OST management under the provisions of the Indian Trust Fund Reform Act of 1994. The Secretary no longer supervises the Section 506 funds. Notable projects completed by the Tribe prior to 2005 include; the Ute Plaza grocery store, two gas station\convenience stores, a water bottling facility, a water hauling business and the purchase of a strip mall complex located off the reservation in Cheyenne, Wyoming.

Section 507. Waiver of Claims

(a) Authorizes the Tribe to waive and release claims concerning or related to water rights as described below.

(b) The Tribe shall waive, upon receipt of the section 504, 505, and 506 moneys, any and all claims relating to its water rights covered under the agreement of September 20, 1965, including claims by the Tribe that it retains the right to develop lands as set forth in the Ute Indian Compact and deferred in such agreement. Nothing in this waiver of claims shall prevent the Tribe from enforcing rights granted to it under this Act or under the Compact. To the extent necessary to effect a complete release of the claims, the United States concurs in such release.

(c) In the event the Tribe does not receive on a timely basis the moneys described in section 502, the Tribe is authorized to bring an action for an accounting against the United States, if applicable, in the United States Claims Court for moneys owed plus interest at 10 percent, and against the District, if applicable, in the United States District Court for the District of Utah for moneys owed plus interest at 10 percent. The United States and the District waive any defense based upon sovereign immunity in such proceedings.

In 1993, the Regional Solicitor in Salt Lake City issued a memorandum addressing whether the Tribe would need to execute a waiver of claims once the Secretary secured the necessary appropriations for sections 504 through 506. The memorandum concluded that the Settlement did not require further action by the Tribe to waive its claims once the Secretary received and deposited these funds into appropriate U.S. Treasury accounts.

CURRENT STATUS OF TITLE V IMPLEMENTATION

There is still much debate as to whether Title V fully satisfied or settled the Tribes water right claims. In 2011 the Tribe changed their legal counsel and hired a new law firm to advise them concerning water issues. At the advice of their attorneys, the Tribe has proposed a revised compact which differs from the previous versions. Both the Department of the Interior and the State of Utah have advised the Tribe that they do not support the new proposed compact.

Although not everyone agrees on the current version of the Compact, all parties agree that for Title V to be fully implemented, the 1990 Compact, or an acceptable revised version, must be ratified by the Tribe and the State. If the Tribe and the State ratify a version that differs significantly from the 1990 Compact, it will likely need further action from Congress.

Indian water rights are complex and those of the Ute Tribe are no exception. Although over the last forty years significant progress has been made in quantifying and settling the Ute water rights, there is still much to be accomplished.

The Department of the Interior through the CUPCA Office continues to oversee the implementation of the settlement as outlined in Title V. The Tribe and its legal team continue to push for revisions to a compact and what they believe is a fair and comprehensive settlement.

WATER RIGHT INTERFERENCE CONTRACTS AND RECLAMATION PROJECTS

Justin J. Record[1]
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ABSTRACT

Water right interference contracts are an essential component of many of the Bureau of Reclamation Projects in Utah. The first, and most notable, of these contracts is a 1938 Power Interference Contract between the United States Bureau of Reclamation, the Provo Water Users Association, the Weber River Water Users Association, and Utah Power and Light Company, now owned by PacifiCorp. In 2013, after consecutive years of drought and several Weber River Commissioner changes, significant concerns arose concerning the legitimacy and proper administration of the water rights affected by this interference contract. These concerns led to delays in the administration and distribution of the waters of the Weber River, which resulted in Deer Creek Reservoir losing 13,000 acre-feet of water during a drought year. During the subsequent year the United States Bureau of Reclamation, the Utah State Engineer, and a consortium of large water users initiated an intense review of how this interference contract should operate within the water right administration framework. This paper provides an outline the legal framework for water rights interference contracts and provides a summary of the findings from the 1938 Power Contract review.

INTRODUCTION

The United States Bureau of Reclamation (Reclamation) was established in July 1902 by the Secretary of the Interior Ethan Allen Hitchcock in accordance with the newly passed Reclamation Act. The Reclamation Act required that: "Nothing in this act shall be construed as affecting or intending to affect or in any way interfere with the laws of any State or Territory relating to the control, appropriation, use, or distribution of water...or any vested right acquired thereunder, and the Secretary of the Interior...shall proceed in conformity with such laws…" (43 U.S.C. § 383.) This translated to Reclamation acquiring water rights pursuant to the water laws of the individual states where Reclamation Projects are located. In general, the water laws of the seventeen western states where Reclamation operates are based on the Prior Appropriation Doctrine, which distributes water based on the date when the water right was first established.

Most of the Reclamation projects in Utah were authorized between 1930's and 1960's and the water rights associated with these projects bear similar priority dates. In Utah the majority of the base summer river flows were appropriated for irrigation prior to the 1900's. Consequently, many of Reclamation's water rights are junior in time to irrigation water rights in every Utah river basin. As a result, Reclamation's water rights typically have first priority only during the winter season when irrigation water rights are dormant

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or during the spring peak runoff period when stream flows exceed those needed for irrigation water rights. In total, eight of the fourteen Reclamation projects in the State of Utah hold junior project water rights that are insufficient by themselves to consistently fill project reservoirs and meet the intended project water uses. For these eight projects to be determined feasible, and before they were constructed, additional supplies of water were required. Reclamation addressed this need by entering into water right interference contracts with senior water right holders in the system to modify the distribution of water in the affected river systems.

The earliest of the Utah water right interference contracts is a 1938 Power Interference Contract ("1938 Power Contract") between Reclamation, the Provo Water Users Association, the Weber River Water Users Association, and Utah Power and Light Company, now owned by PacifiCorp. This contract is unique because benefits two Reclamation Projects, outlines key project operations, and sets up a complex series of trades involving power, reservoir storage, and money. Notwithstanding, in 2013, the Utah Division of Water Rights raised serious questions regarding the validity of the 1938 Power Contract and the contract's ability to modify project operations and state water rights. These questions led to an intense year-long review that examined the legitimacy and proper administration of the 1938 Power Contract by project operators and the Utah State Engineer. Below is a summary of the legal theory underlying water right interference contracts and a summary of the findings of the 2013 review of the 1938 Power Contract.

LEGAL HISTORY OF WATER RIGHT INTERFERENCE CONTRACTS

<u>The Prior Appropriation Doctrine Generally</u>

A water right interference contract operates primarily by modifying the distribution of water within a river basin by allowing water users to contract around established priority dates. Accordingly, to understand these contracts, it is helpful to understand the priority based system of water rights and how these contracts factor into this system. Since the early 1900's water resources throughout the Western United States have largely been allocated pursuant to a priority based system. This system, typically referred to as the Prior Appropriation Doctrine, arose both out of necessity and as a response to the conditions that existed in the West. In order to make these arid landscapes productive, would-be farmers and miners had to divert water from the streams and carry it considerable distances in ditches and canals to the place of need. The construction of the necessary diversion and conveyance facilities was an arduous and costly undertaking and the work was rarely accomplished during a single irrigation season. In order to protect their investments, early settlers established a priority based custom to provide assurance that claims to water would be preserved while the appropriator completed his diversion works, cleared his land and was able to put the water to beneficial use. This custom became the foundation for the Prior Appropriation Doctrine, which was ultimately codified, in different forms, by the various western states.

First-in-time, First-in-right

Prior Appropriation operates primarily upon the basis that those appropriators that are first-in-time are protected as against subsequent appropriators. R. DEWSNUP & D. JENSEN, A SUMMARY –DIGEST OF STATE WATER LAWS, 475, 719 (1973). Each water right within a relevant drainage basin carries a priority date, which is determined by the date the water right was established (either through diligence or permit). Under this system, water rights are ranked in the order that the right was acquired (its priority), and this priority schedule is used to distribute available water in times of shortage. A. DAN TARLOCK, LAW OF WATER RIGHTS AND RESOURCES § 5.30, Priority – Attributes and justification (2015).

A water right's priority date is of such importance that it becomes a key attribute of an appropriative property right to the use of water. San Carlos Apache Tribe v. Superior Court ex. rel. County of Maricopa, 972 P.2d 179 (Ariz. 1999). As applied, water masters, or State Engineers, utilize priority dates to determine who is entitled to receive water, when and in what quantity. Utah law provides that "each appropriator is entitled to receive the appropriators' entire supply before any subsequent appropriator has any right." *See e.g.* UTAH CODE ANN. § 73-3-21.1(2)(a). This concept has been applied so far as to allow an appropriator to divert 2/3rds of a drought-stressed flow, essentially allowing the dewatering of a stream. Baker Ditch Co. v. District Court of Eighteenth Judicial Dist., In and For County of Gallatin, 824 P.2d 260 (1992). Notably, because the priority date is a key attribute of ownership, due process does not require a hearing prior to the enforcement of priorities as amongst water rights. Keating v. Nebraska Public Power Dist., 660 F.3r 1014 (8th Cir. 2011). Rather, a senior appropriator need only make a "call" for more water, which initiates the administrative process for regulation or curtailment of the rights of junior appropriators in order of priority. To enforce a call for regulation, the water master will close (or cause to be closed) the diversion works of all junior appropriators as necessary to ensure the rights of the senior are satisfied.

An important corollary of this priority based system is the prohibition on junior water right holders from interfering with the rights of senior appropriators. Under Prior Appropriation, a valid appropriation (i.e. a water right) becomes a property interest that is entitled to protection as against unreasonable interference from other water users. *See* COLO. REV. STAT. ANN. § 37-92-301; N.M. STAT. ANN. § 72-5-23 to -24; UTAH CODE ANN. § 73-3-3; East Bench Irrigation Co. v. Deseret Irrigation Co., 271 P.2d 449 (Utah 1954). Further, downstream water users acquire a vested right against all upstream water users to have stream conditions remain substantially as they were when they made their appropriations. *See* Orr v. Arapahoe Water & Sanitation Dist., 753 P.2d 1217 (Colo. 1988); Piute Reservoir & Irrigation Co. v. W. Panguitch Irrigation & Reservoir Co., 367 P.2d 855 (Utah 1962); E. Bench Irrigation Co. v. Deseret Irrigation Co., 271 P.2d 449 (Utah 1954).

The Utah Supreme Court has "stated that no impairment is acceptable." Wayment v. Howard, 2006 UT 56, ¶ 13, FN 11, *citing* Piute Reservoir & Irrigation Co. v. W. Panguitch Irrigation & Reservoir Co., 367 P.2d 855, 858 (1962). However, while that standard may be true for impairment, this standard has not yet been applied to a de minimus standard to interference. *Id.* Interference is commonly construed to mean the denial of water and, as such, can manifest itself in many different ways, including an appropriator taking water out of priority, out of season or by diverting in excess of their right. Additionally, if an appropriator seeks to modify their water right by adding a new point of diversion or place of use, such change cannot interfere with existing rights (regardless of priority). However, in some states interference can be excused if the damages can be mitigated or upon just compensation paid to the impacted appropriator. *See e.g.* UTAH CODE ANN. § 73-3-3(3)(a)(ii).

Priority, and thus interference with water rights, reaches to both the direct source of water and also to any tributaries that contribute to that source. Granite Ditch Co. v. Anderson, 662 P.2d 1312 (Mont. 1983); *see also* Salt Lake City Corp. v. Silver Fork Pipeline Corp., 5 P.3d 1206 (Utah 2000) (holding that Salt Lake City had a vested right in the percolating flows into the surface source). Thus, in order to protect senior appropriators, regulations and curtailments may reach very far upstream. *See e.g.* Little Cottonwood Water Co. v. Sandy City, 258 P.2d 440 (1953) (holding that "No one can interfere with the fully appropriated source of supply in a manner that diminishes the quantity or injuriously affect the quality of the water of established rights, no matter how far it may be from the place of use.").

Nevertheless, priority does not attach to particular or specific waters. So long as there is no injury to water right holders, water from another source may be substituted for the original source. TARLOCK, supra at § 5.30, *citing* Reno v. Richards, 178 P. 81 (Idaho 1918). This empowerment is of particular importance when dealing with large municipal or federal water rights and projects. For example, Salt Lake City has entered into agreements to deliver water from the Jordan River, which is suitable for irrigation, in exchange for potable water from the mountain streams. *See e.g.* Salt Lake City Corp. v. Big Ditch Irr. Co., 258 P.3d 539 (Utah 2011) (noting that "an exchange agreement may consist of the transfer of title to senior rights in return for a contractual commitment to supply the exchanger."). Such exchanges are valid and acceptable, provided that the exchanger has sufficient and acceptable substitute water, such as a reservoir release, to protect downstream priorities and make the affected appropriator whole. TARLOCK, supra at § 5.30, *citing* City and County of Denver By and Through Bd. of Water Com'rs v. City of Englewood, 826 P.2d 1266 (Colo. 1992); *see also* City of Englewood v. Burlington Ditch, Reservoir and Land Co., 235 P.3d 1061 (Colo. 2010).

In the context of priority, interference is generally associated with taking water out of turn or otherwise denying a senior appropriator their right to a full allocation. If a senior appropriator can prove that a junior's actions resulted in less water being made available to satisfy his needs, he may enjoin the offending junior user and recover reasonable costs incurred to mitigate the injury. *Id*; *see also* R.T. Hahas Co. v. Hulet, 752 P.2d. 625 (Idaho Ct. App. 1998). Notably, this also applies in the opposite direction and a senior appropriator may be enjoined from interfering with a junior appropriator if there has been no interference by the junior with the senior's rights. *Id, citing* Fuller v. Sharp, 94 P.813 (Utah 1908).

Futile Call

One element of the prior appropriation doctrine that is absolutely essential for interference contracts to function property is the concept of futile call. Because Prior Appropriation abhors waste, a senior appropriator is not entitled to make a call for regulation if the water diverted by junior appropriators, had it been allowed to pass down the stream, would not reach the senior appropriators diversion works. West Point Irr. Co. v. Moroni & Met. Pleasant Irr. Ditch Co., 61 P. 16, 18 (Utah 1900). Under such circumstances, an upper or junior appropriator will not be enjoined from diverting water and the downstream or senior users' call for regulation will be deemed futile. The underlying idea behind the futile call doctrine is that the primary purpose of water appropriation is to put water to beneficial use and prevent the waste of water. *Id*, *citing* Power v. Switzer, 21 Mont. 523, 529, 55 P. 32, 35 (1898).

Thus, the futile call concept will excuse a junior appropriator from responding to a call for water if he or she shows that the outcome of that call would result in no beneficial use by the senior but only in the waste of water. *Id*. Futile call is essentially an affirmative defense a junior appropriator may make in the face of a call for regulation. Kelly v. Teton Prairie LLC, 376 P.3d 143, 147 (Mont. 2016); *see also* City of Aurora v. Simpson (In re Water Rights of Park Cty. Sportsmen's Ranch), 105 P.3d 595, 603 n.4 (Colo. 2005) (the futile call doctrine authorizes the state engineer to lift a curtailment order originally issued for the protection of decreed water rights under priority administration if the person whose diversion is curtailed proves that discontinuance of that diversion will not cause water to become available to senior priorities under a call for administration.").

The principle of the futile call is essential to water right interference contracts as it prevents outside parties from making a call on the water made available under an interference contract. Generally in an interference contract, a senior water right holder agrees to forebear using his water rights, thereby freeing up water for specific junior water rights that are held by a party of the contract. Without the futile call, the water forborne by the senior water right holder would go to the next water right in priority and not necessarily to the water rights contemplated in the contract. Consequently, most interference contracts include language allowing the senior water right holder to resume his water use if the forborne water does not go to the intended junior water right. This eliminates the ability of intermediary third party junior water right holders to make a call upon the water freed by up interference contracts. Essentially, under no situation can the intermediary water right holders receive the forborne water, because it must go to the intended junior water right or it will be called back to the senior water right.

KEY ELEMENTS OF WATER RIGHT INTERFERENCE CONTRACTS.

The elements that make a water right interference contract successful are rooted in the foundational principles of the Prior Appropriation Doctrine. The pattern of development in the West inevitably resulted with large Reclamation projects holding water rights that are junior in priority to the rights of early settlers. This situation results in the quixotic outcome that large municipal and domestic rights are regulated off during times of shortage in favor of irrigation uses. Reclamation utilizes interference contracts as a means to reverse these positions.

In their simplest form, interference contracts grant permission to a junior water right to take water ahead of a senior right usually on condition of some form of compensation. These contracts usually define when and how much water can be diverted by the junior water right holders and detail the compensation to be paid to the senior for the interference. For example the 1938 Power Contract, which is discussed in depth below, has a complex arrangements for compensation that includes payment for power interference, trading for power from Reclamation hydropower facilities, granting temporary storage in Reclamation reservoirs, and routing Reclamation water deliveries through private hydropower facilities. Compensation in other interference contracts are often much simpler with compensation often just being the ability of senior water right holders to subscribe to stored project water.

There are several conditions that must be present in order for an interference contract to be successful. These include both the terms of the contract and the administration of those terms by the water administrator. The terms of the contract must provide for adequate compensation for the interference. Likewise, the parties to the contract must define how and when the interference should take place. Finally, for the contract to be of peak effectiveness, the contract must include the ability of the senior water right to make a call for water, only if the junior water right is not receiving the water as intended. However, just as critical as the terms of the contract is how the contract is administered by the water master or State Engineer along with other water rights within the water basin. The administration needs to protect third party water right interests against impairment, properly accounting for the increased diversion of junior water rights involved in the interference contract, and protection for the interfered senior water rights against forfeiture claims.

CASE STUDY – 1938 POWER CONTRACT

Provo River and Weber River Projects Background

The Provo River Project (PRP) provides a supplemental water supply for irrigation of 48,156 acres of highly developed farmland in Salt Lake and Wasatch Counties, as well as an assumed domestic water supply for Salt Lake City, Provo, Orem, Pleasant Grove, Lindon, American Fork, and Lehi, Utah. The key structure of this project is Deer Creek Dam and Reservoir, which has a capacity of 152,700 acre-feet and is located on the Provo River 16 miles east of Provo City. The Deer Creek Reservoir stores Provo River floodwater, surplus water of the Weber River diverted by the enlarged Weber-Provo Diversion Canal, and surplus water from the headwaters of the Duchesne River diverted by the 6-mile Duchesne Tunnel.

The Weber River Project (WRP), formerly designated as the Salt Lake Basin Project, has its first division in the vicinity of Ogden, Utah. It was developed primarily to supply supplemental irrigation water to about 109,000 acres of land east of the Great Salt Lake, lying between the lake and the Wasatch Mountains. Its principal engineering feature is Echo Dam and Reservoir, which has a capacity of 74,000 acre-feet and is located 42 miles southeast of Ogden, on the Weber River. A secondary feature is the construction of the original Weber-Provo Diversion Canal ("WPC") which is located upstream of Echo Reservoir. This canal delivers Echo Storage Water via an upstream exchange to water users in the Provo River drainage. This canal was subsequently enlarged as part of the PRP.

Prior to constructing Deer Creek Reservoir for the PRP, the United States entered into a contract with the Provo River Water Users Association (PRWUA), Weber River Water Users Association (WRWUA), Utah Power and Light, and Utah Light and Traction Company (the "Power Company"). This contract (the 1938 Power Contract) allows diversions under the WRP and PRP to interfere with senior water rights located at four hydropower plants located downstream of project reservoirs near the mouths of the Provo River Canyon and Weber River Canyon. Under the 1938 Power Contract, the Power Company agreed not to operate its hydropower plants during the Winter Period ("Approximately October 15 to April 15"), in exchange for compensation for power generation losses either in the form of replacement power from the hydropower plant on Deer Creek Reservoir, or by power interference payments from PRWUA. Additionally, the 1938 Power Contract allows the Power Company to generate power from PRP and WRP water deliveries during the summer months and allows the Power Company a limited use of Echo and Deer Creek Reservoir storage for its power operations. In practice, the 1938 Power Contract allows a significant portion of the water historically used for hydropower generation to be stored in Echo and Deer Creek Reservoirs. In 2015 and 2016 the Weber River Commissioner estimated that the 1938 Power contract increased the Reclamation Reservoir storage by 46,848 acre-feet and 38,370 acre-feet respectively.

See Figure 1 for map of the PRP, WRP, and Power Plant locations.

Figure 1. Weber and Provo River System

THE 1938 POWER CONTRACT AND THE PERFECT STORM

Operations under the 1938 Power Contract were relatively quietly for over 70 years with the Weber and Provo Commissioners administering this contract along with other state water rights until 2013 when the "Perfect Storm" of events led to a thorough questioning and review of this interference contract. This "Perfect Storm" was created by the culmination of three factors.

The first factor was a nearly complete lack of historical knowledge of Weber River System by the incoming Weber River Commissioner. For 47 years (1962 to 2008) the Weber River water rights had been managed by a single river commissioner. While this longevity is rare for a river commission it is nearly matched by the Provo River Commissioner who has served for 46 years (1972 till 2017). However, because of the length of service of both these commissioners, their water distribution decisions were rarely questioned and consequently were not well documented. Unfortunately, this lack of documentation led to a transfer of limited institutional knowledge when the Weber River Commissioner retired in 2008 and later passed away. Further compounding this lack of knowledge transfer was the fact that the subsequent Weber River Commissioner, who served from 2008 - 2013, did not pass his limited institutional knowledge to a newly appointed commissioner in 2013.

The second factor of the "Perfect Storm" was several years of consecutive drought where Weber River reservoirs were not able to be filled, while because of the 1938 Power Contract there continued to be significant trans-basin diversions from Weber River to the Provo River to fill Deer Creek Reservoir. This led to increased scrutiny of the 1938 Power Contract and also the contracts surrounding the Weber-Provo Canal. Ultimately, this manifested with intense questioning by Weber River water users about the validity of the 1938 Power Contract.

The final factor that created the "Perfect Storm" was a limited understanding of the 1938 Power Contract by Water Project Operators, Reclamation, River Commissioners, and the State of Utah. The drafters of the 1938 Power Contract were long gone and there was almost no information about this interference contract outside the four corners of the document. Because everyone had simply trusted the veteran river commissioners to manage this interference contract, few parties had spent the necessary time to understand the finer details of this contract.

These factors came to a head during the middle of the 2013 spring runoff, with the newly appointed Weber River Commissioner refusing to make the water deliveries according to the 1938 Power Contract. He believed that since the 1938 Power Contract was not a Water Right Appropriation or Change Application he had no authority to administer water in the system according to this contract. The results of this position caused Provo-Weber Canal to end its diversions earlier than normal and shorted Deer Creek Reservoir and its water users 13,000 acre-feet of water.

This questioning of the 1938 Power Contract led to an intensive one-year review of contracts, project planning documents, and water right histories to understand the proper administration and accounting of the interference contracts and the relationship of these contracts to the basin's water rights as a whole. Additionally, Reclamation held monthly meetings with key interested parties to the operations of the Weber River including the State of Utah, Project Operators for the Weber River, Weber Basin, Provo River, the Central Utah Projects, the River Commissioners for the Weber and Provo Rivers, and major water users and municipalities in both drainages.

WATER RIGHT ADMINISTRATION UNDER THE 1938 POWER CONTRACT

This year-long intensive review identified three important questions about how water right interference contracts should be administered in the local river systems. These questions were answered in a letter from Reclamation drafted in August 25, 2013 to the Utah State Engineer documenting the findings of the intensive group review of the 1938 Power Contract. These questions and their answers (as found in the Reclamation letter) are outlined below.

1) Under What Water Rights Is the Power Water Being Stored?

This question revolves around which water rights the junior water right holder uses in an interference contract. Specifically, the question is whether the power water should be accounted for under the hydropower water rights or under the federal project storage rights. Ultimately, the parties determined that the 1938 Power Contract didn't convert any of the non-consumptive hydropower water right into a consumptive use storage right, because that would not have been allowed under Utah water law. Instead, the 1938 Power Contract simply places the junior PRP and WRP water right in a better position, by priority, to capture water and the power water should be accounted for under the parameters of those junior water rights. Therefore, the amount of power water that may be diverted by the junior water rights is limited by the parameters of the WRP and PRP water rights. Stated another way, the PRP and WRP waters rights cannot be enlarged by the 1938 Power Contract.

2) What Priority Date Should Be Assigned to the Reclamation Project Storage Made Possible by the 1938 Power Contract?

The senior hydropower water rights that are being interfered with in the 1938 Power Contract are represented by Water Right No. 35-8061 with a 1903 priority date. The parties to the 1938 Power Contract are compensating the Power Company, through payments or replacement power, in order to interfere this 1903 water right. Therefore, to the extent possible, Reclamation has stepped into the Power Company's position (1903) and the water made available through the 1938 Power Contract should bear a 1903 priority date. Therefore, Reclamation believes that non-project water rights, which would not have received water when the power plants are operating, should not be entitled to take water when the power plants are turned off through the contract. There are three important water right priority groups to consider when the 1938 Power Contract is being exercised:

> **Water Rights Prior to 1903** are senior to the power water rights and senior to all Reclamation PRP and WRP water rights. These water rights should continue to be given water ahead of Reclamation project rights whether or not the 1938 Power Contract is being exercised.
>
> **Intervening Water Rights** are junior to the power water (1903) rights but senior to Reclamation Project water rights (August 25, 1924). Intervening winter water rights downstream of the Weber Power Plant would have received water if the plant was operating and should continue to receive water. Intervening winter water rights upstream of the Weber Power Plant would not have received water if the power plant was operating and should be treated as junior to the power water, as quantified at Echo Dam and stored in Echo Reservoir or diverted via the WPC.
>
> One reason these intervening water rights cannot divert the power water is due to the principle of futile call. If these intervening water rights were able to successfully call for the power water, the 1938 Power Contract would be turned off and the power water would be moved back to the associated hydropower plants. Essentially Reclamation can use the water above these intervening rights or the power water can bypass these intervening users.
>
> **Water Rights Junior to 1924** are junior to both the power plant rights and Reclamation's PRP and WRP rights, and would only be entitled to water after Echo Reservoir and WPC water rights are fully satisfied.

3) Are Water Right Change Applications Necessaryto Support the 1938 Power Contract?

No water right change applications were necessary in Utah to effectuate the 1938 Power Contract because neither the characteristics of the senior, nor those of the junior water rights were altered by the 1938 Power Contract. Rather, the 1938 Power Contract simply turned off the senior water rights for the benefit of the specifically identified junior water rights. These junior water rights likewise remain within their parameters, but simply have more water available to them to satisfy their rights. While it is true that the 1938 Power Contract allows a junior water right to take water ahead of its priority date, Utah water law contains no mechanism to change the priority dates of a water right. Additionally, so long as the priority dates are managed consistent with the previous question, then no third party water user will be impaired by this shift of priority.

OTHER PROVISIONS OF THE 1938 POWER CONTRACT

In addition to the above described water rights interference provisions, the 1938 Power Contract clarified the operations of the PRP and WRP as they related to this contract and outline various water, power, storage, and monetary trade compensate for the interference.

PRP's Temporary Use of Echo Reservoir

One unique aspect of the 1938 Power Contract is that it provided the PRP with the ability to temporarily storage power water in Echo Reservoir. This storage allows PRP additional time to exchange their portion of the power water to the upstream WPC in the runoff season. This temporary storage and exchange is necessary because limited upper Weber River winter water availability and icy conditions generally do not allow for a full diversion of PRP's portion of the power water. There are two ways PRP's temporary storage water can be exchanged upstream from Echo Reservoir to WPC; either by a conventional exchange, where water is released from Echo Reservoir to satisfy downstream senior water rights while a like amount is taken at the WPC; or if Echo Reservoir is still storing water at the time of the exchange, then the temporary PRP storage can be converted to WRP water (under water right 35-9739), and the upper Weber River water that would have been stored in Echo Reservoir can be diverted to PRP at the WPC.

Further, temporary (sometimes called third party) storage in Reclamation's reservoirs is a common practice in the State of Utah. This temporary storage can occur formally under federal contracts such as the Deer Creek Reservoir/Jordanelle Reservoir Operating or informally under the direction of the River Commissioner, usually to facilitate more efficient water deliveries. A good example of informal temporary water storage is Starvation Reservoir. This reservoir is used to temporarily store downstream direct flow water rights, when irrigators need to cut, dry, and bale their fields. In every case where temporary/space-available storage is made available on Reclamation's reservoirs in Utah, the temporary storage is not counted against the reservoir's water rights. Rather, the reservoir is allowed to fill under its primary storage rights the same way it did before the temporary storage occurred. Therefore, if the reservoir fills with its base water rights, then the temporary storage water always spills first. Often, temporary storage has specific time limitations where the water cannot be held over at the end of the year or storage season.

To prevent impairment to the WRP, this temporary storage is not counted as diversions under Echo Reservoir storage water rights, which have a maximum annual storage of 74,000 acre-feet. As further protection to the WRP, this temporary storage is made only upon a "space available basis" and can only occur when the storage space is not required for WRP water rights or operations. Lastly, the temporary water spills out of Echo Reservoir before any WRP water, and any temporary water not exchanged out of the reservoir by July 1st is given to the WRP for use under Echo Reservoir storage water rights.

Divisions Of Power Water Between The Provo River And Weber River Projects

The 1938 Power Contract divides the power water available at Echo Dam equally between the PRP and WRP. To ensure an equal division, the Weber River Commissioner quantifies the power water available, and tracks the amount of this water stored at Echo Reservoir and the amount diverted through the WPC. If at the end of the year, too much power water was diverted across the WPC, the extra water will be held in Deer Creek Reservoir for WRP shareholders on the Provo River system. This extra water is considered part of Echo Reservoir storage. If more water is stored in Echo Reservoir than is diverted across the WPC, then the extra water becomes temporary storage for the PRP until July 1st when it is converted to WRP storage.

Today's Accounting for Power Water

It is important to note, that since the 1938 Power Contract, additional reservoirs have been built on both the Weber and Provo Rivers. The Weber River Commissioner often stores Echo Reservoir water rights in Rockport Reservoir, near Wanship, Utah, and other upstream reservoirs to increase operational flexibility later in the runoff season. For water operations under the 1938 Power Contract, Echo Reservoir spills when the sum of the water credited to Echo Reservoir storage in all the basin's upstream reservoirs exceeds the physical capacity of Echo Reservoir. The Weber River Commissioner carefully tracks paper and physical spills of Echo Reservoir and reduces the temporary PRP storage in Echo Reservoir accordingly. Likewise, on the Provo River side the Deer Creek Reservoir/Jordanelle Reservoir Operating Agreement allows water under Deer Creek Reservoir water rights to be stored in Jordanelle Reservoir and vice versa. The Provo River Commissioner keeps detailed records of how much water is credited to each reservoir and considers Deer Creek Reservoir full when the PRP water stored in both reservoirs reaches the storage capacity of Deer Creek Reservoir.

Power Company's Use of Reclamation's Reservoirs

The 1938 Power Contract allows the Power Company to generate power from all Echo Reservoir storage deliveries to WRP during the summer period. Additionally, the Power Company is allowed to temporarily store water in Echo Reservoir for future power generation. This storage right is separate from the power interference storage provisions in the 1938 Power Contract for the benefit the PRP and the WRP, and cannot affect power water previously stored and for which compensation has been made to the Power Company. To further protect the WRP, this storage:

- Is made on a space available basis and cannot interfere with WRP Project water rights or the temporary storage of PRP water.
- Is the first water to spill from Echo Reservoir even before the temporary PRP water storage.

- One half of this water can be "claimed" by WRP and stored under its Echo Reservoir Storage water right.
- WRWUA can release this water as needed for emergency operations.

OTHER INTERFERENCE CONTRACTS IN RECLAMATION

The 1938 Power Contract is the first and one of the largest water right interference contracts for Reclamation Project in Utah. It has been very successful in increasing the annual storage of the WRP and PRP and has significantly contributed to the long term viability of these projects. This success has led to the crafting of very similar hydropower interference contracts for the Central Utah Project, Ogden River Project, and Weber Basin Project. The Central Utah Project (CUP) expanded upon the 1938 Power Contract by condemning the Olmsted Power Plant at the mouth of Provo Canyon. This allowed the CUP to increase the level of interference at this power plant to allow Jordanelle Reservoir to capture a significant portion of the natural flows of the Provo River. Given the immense spread in priority dates between the 1903 decreed Olmsted hydropower rights and the 1974 Jordanelle Storage water rights, the futile call principle is essential to prevent a third party water call for the power interference water. To protect the futile call concept, the CUP is now reconstructing the Olmsted power plant at a cost of $42 million even though it may not be able recover these costs through power generation.

Another common type of non-hydropower water interference contracts are often called Exchange and Adjustment Contract. These types of interference contracts do not involve annual compensation like a power interference contract. Instead they were a prerequisite before Reclamation would construct the storage project. Essentially, in order for the Reclamation project to be feasible the project needed to capture runoff flows ahead of the existing direct flow water rights in the system. Therefore, as a condition of receiving project water the downstream water users agreed to limit the early season diversion of their senior direct flow water rights. For example with the Emery Project in Central Utah, the entire Cottonwood Creek Consolidated Irrigation Company agreed to cap their direct flow diversions to 4% in April, 15% in May, 21% in June and no limit from July to October. Similarly, in order to receive water from the Farson Project, in Wyoming, the subscribing water users agreed in their project storage subscription contracts to limited the use of their direct flow water rights to after May 15th of each years.

CONCLUSION AND LESSONS LEARNED FROM THE 1938 POWER CONTRACT REVIEW

The 1938 Power Contract was (and is) a novel approach to resolving a familiar problem in the West: the fact that major water storage infrastructure is dependent on very junior water rights. This simple fact could have severely inhibited the ability of Reclamation to accomplish its goals of providing stable irrigation and municipal supplies of water in the western states. The 1938 Power Contract, while ultimately a very complex contract, has modified the way diversions occur in the Weber and Provo River Basins through a simple contracting process. Reclamation contracted to allow the interference with a senior hydropower water right in exchange for additional power at alternative times and/or financial compensation. Ultimately, however, the 1938 Power Contract is a successful solution because of the willingness of the interested parties to work through the accounting, transfer and diversion of water within these two river systems.

The success of the 1938 Power Contract has led to additional hydropower and non-hydropower water right interference contracts in Utah. These contracts have been used to shore up the water supplies of over eight Reclamation projects in Utah alone. Interference contracts cause less impact to the hydrologic system than simply purchasing senior water rights, because the interference is limited to only what is needed to support the Reclamation project. This has the effect of preserving some of the senior water uses. Consequently they are a valuable tool for large scale investments in water infrastructure within the prior appropriation system.

RAPID ASSESSMENT OF FLOOD RISK FROM CANAL EMBANKMENT FAILURES

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ABSTRACT

Flood wave propagation from canal failures can damage infrastructure and lead to loss of life. Like dam breaches, being able to predict the velocities and depths of these flood waves is critical for emergency planning, operations and maintenance prioritization, and insurance applications. And while the extensive literature on dam breaches can be utilized for canal embankment failures as well, doing so is somewhat limited because, unlike many dams, canal breach flood waves are highly dependent upon both the location of the breach and the planar expansion of the wave into the floodplain. Of course, two-dimensional (2D) hydraulic modeling can be used for canal embankment breach modeling, but doing so is typically expensive and time consuming, particularly if multiple locations are considered – an unavoidable requirement for a comprehensive investigation. To address this challenge, a method is presented here to rapidly assess flood risk from canal embankment failures. The method includes a new simplified quasi-2D unsteady flood wave propagation model that conservatively predicts flood wave velocities for dynamic break conditions. Since the model requires only a few inputs and utilizes closed-form equations, computation speed is fast enough to allow multiple breach locations to be considered. As a result, breach scenarios can be applied over specific intervals along a canal. From these scenarios, worst-case conditions maps can be developed for points of interest along the canal. These maps can then be used to guide emergency operations, identify potential breach locations that warrant more sophisticated modeling, and prioritize operations and maintenance activities. As an example, an application of the model is developed and the results compared with 2D hydraulic model executed within HEC-RAS. As expected, the simplified methodology provides conservative predictions as compared with HEC-RAS model in terms of both flood wave propagation speed and extent.

INTRODUCTION

Flood wave propagation from canal embankment failures can damage infrastructure and lead to loss of life. Like dam breaches, being able to predict the velocities and depths of these flood waves is critical for emergency planning, operations and maintenance prioritization, and insurance applications. And while the extensive literature on dam breaches can be utilized for canal failures as well, doing so is somewhat limited because,

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unlike many dams, canal breach flood waves are highly dependent upon both the location of the breach and the planar expansion of the wave into the floodplain. Of course, two-dimensional (2D) hydraulic modeling can be used for canal breach modeling, but doing so is typically expensive and time consuming, particularly if multiple locations are considered – an unavoidable requirement for a comprehensive investigation.

To address this challenge, a method is presented in this paper to rapidly assess flood risk from canal failures. The method includes a new simplified quasi-2D unsteady flood wave propagation model that conservatively predicts flood wave velocities for dynamic break conditions. Since the model requires only a few inputs and utilizes closed-form equations, computation speed is fast enough to allow multiple breach locations to be considered. As a result, breach scenarios can be applied over specific intervals along a canal. From these scenarios, worst-case conditions maps can be developed for points of interest along the canal. These maps can then be used to guide emergency operations, identify potential breach locations that warrant more sophisticated modeling, and prioritize operations and maintenance activities. As an example, an application of the model is developed and the results compared with 2D hydraulic model executed within HEC-RAS. As expected, the simplified methodology provides conservative predictions as compared with HEC-RAS model in terms of both flood wave propagation speed and extent.

BACKGROUND

Generally speaking, flows from a canal or levee break are expected to transition from flow perpendicular to the break into radial flow (Figure 1 below). A reasonable expectation for this transition radius r_0 (ft) is $r_0 \approx \frac{1}{2}w$, where w (ft) is the levee failure width. Flow through both the breach and the radial transition is assumed to be governed by the broad-crested weir flow, and hence expressed as:

$$q_0 = c_d c_v \sqrt{\tfrac{4}{27}}\sqrt{2g}\,h_0^{3/2} \tag{1}$$

where q_0 (cfs / ft) is the flow rate per unit width into the flooded region, g (ft/sec^2) is the acceleration due to gravity (typically assumed to be 32.2 ft/sec^2), c_d (dimensionless) is the distance coefficient, and c_v (dimensionless) the velocity approach coefficient.

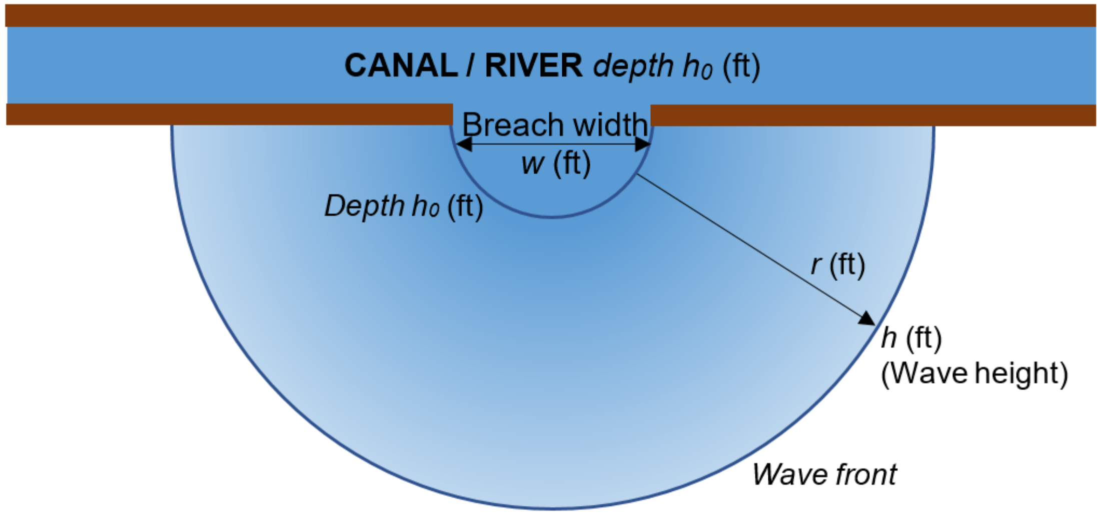

Figure 1. Simplified Levee or Canal Break Flood-Wave Geometry (Plan View)

Given Equation (1), q_0 may be written in the slightly simpler form:

$$q_0 = C\sqrt{2gh_0^3} \tag{2}$$

where an overall discharge coefficient $C = c_d c_v \sqrt{\frac{4}{27}}$ (dimensionless) has been introduced. Outside of the transition region, flow is assumed to proceed outward more or less radially; that is, equally along radial distances r (ft). The energy equation taken from the depth at the canal break h_0 (ft) (corresponding to $r_0 = w/2$), to a depth h (ft) at r as follows:

$$\left(1+C^2\right)h_0 + s_0 r = s_0 r_0 + h(r) + \frac{v(r)^2}{2g} + \int_{r_0}^{r} f \frac{1}{h(x)} \frac{v(x)^2}{2g} dx \tag{3}$$

where s_0 (ft/ft) is the radial slope from r_0 to r, and v (ft/sec) the depth averaged velocity, x (ft) is the distance coordinate aligned with r used within the friction loss integral, and f (dimensionless) the friction coefficient.

Both numerical studies and physical tests on radial flow indicate that, in general, both $v(r)$ and $h(r)$ both decrease as r increases (Townson and Al-Salihi, 1989; Roger et al., 2009). The exceptions are caused by the presence of a hydraulic jump, which is sometimes predicted for divergent flow conditions (e.g., Abbott and Lindeyer, 1969; Mungkasi, 2014) and yet other times are not (e.g. Zoppou and Roberts, 2000). However, the general trend of decreasing flood-wave velocity and depth is supported by all of the referenced literature. Further, since human life is in danger from flood waves, it is imperative that flood wave velocity estimates be greater than or equal to the actual flood wave velocity. To achieve that objective, it is reasonable to assume $h(x) = h_0$ and

$v(x)=v(r)$ so as to minimize friction loss in the friction loss integral on the right-hand side of Equation (3) while still capturing the nonlinearity of the governing equations. The result is:

$$\left(1+C^2\right)h_0+s_0r\approx s_0r_0+h+\frac{v^2}{2g}+f\frac{r-r_0}{h_0}\frac{v^2}{2g} \tag{4}$$

where the explicit dependence on r in the function notation has been removed for brevity. In terms of v, this equation is:

$$v=\sqrt{2g}\sqrt{\frac{\left(1+C^2\right)h_0^2-h_0h+s_0h_0\left(r-r_0\right)}{h_0+f\left(r-r_0\right)}} \tag{5}$$

In terms of the flow per unit width q (cfs/ft), Equation (5) may be written:

$$q=\sqrt{2g}\sqrt{\frac{\left(1+C^2\right)h_0^2-h_0h+s_0h_0\left(r-r_0\right)}{h_0+f\left(r-r_0\right)}}h \tag{6}$$

Conservation of mass is expressed by the Saint-Venant equations, which in polar coordinates can be written:

$$\frac{\partial h}{\partial t}+\frac{\partial q}{\partial r}=-\frac{q}{r} \tag{7}$$

where t (sec) is time elapsed since the break began. Together, Equations (6) and (7) provide a complete description of the flood wave propagation.

Going forward to solution, it is easier to work with non-dimensional variables, defined as follows:

$$H\equiv\frac{h}{h_0};\ R\equiv\frac{r}{r_0};\ Q\equiv\frac{q}{q_0};\ T\equiv\frac{C}{r_0}\sqrt{2gh_0}t;\ S_0\equiv\frac{r_0}{h_0}s_0;\ F_0\equiv\frac{r_0}{h_0}f \tag{8}$$

The energy and continuity equations become:

$$Q=\frac{1}{C}\sqrt{\frac{1+C^2-H+S_0\left(R-1\right)}{1+F_0\left(R-1\right)}}H \tag{9}$$

$$\frac{\partial H}{\partial T}+\frac{\partial Q}{\partial R}=-\frac{Q}{R} \tag{10}$$

Equation (9) shows that Q is an explicit function of H and R only. As such, it can be substituted into Equation (10) to obtain:

$$\frac{\partial H}{\partial T}+\frac{\partial Q}{\partial H}\frac{\partial H}{\partial R}=-\frac{\partial Q}{\partial R}-\frac{Q}{R} \tag{11}$$

Subsequent calculations are simplified by dividing Equation (11) by the partial derivative of Q with respect to H, thereby obtaining the equivalent formulation:

$$\frac{\partial H}{\partial Q}\frac{\partial H}{\partial T}+\frac{\partial H}{\partial R}=-\frac{\partial H}{\partial Q}\left(\frac{\partial Q}{\partial R}+\frac{Q}{R}\right) \tag{12}$$

Equation (12) can be solved using the method of characteristics. The method of characteristics simply assumes that both R and T are functions of a single combined variable S (dimensionless – not to be confused with the longitudinal slope term S_0). That is, $R\equiv R(S)$ and $T\equiv T(S)$, and hence H is a function of S only [i.e., $H=H\left(R(S),T(S)\right)$]. The total derivative of H with respect to S is therefore:

$$\frac{dH}{dS}=\frac{dT}{dS}\frac{\partial H}{\partial T}+\frac{dR}{dS}\frac{\partial H}{\partial R} \tag{13}$$

Equation (13) is the same as Equation (12) provided the following three equalities are met:

$$\frac{dR}{dS}=1 \tag{14}$$

$$\frac{dT}{dS}=\frac{\partial H}{\partial Q} \tag{15}$$

$$\frac{dH}{dS}=-\frac{\partial H}{\partial Q}\left(\frac{\partial Q}{\partial R}+\frac{Q}{R}\right) \tag{16}$$

Equation (14) implies that:

$$R=S+K \tag{17}$$

where K (unitless) is the integration constant. Accordingly, Equation (16) becomes:

$$\frac{dH}{dR}=-\frac{\partial H}{\partial Q}\left(\frac{\partial Q}{\partial R}+\frac{Q}{R}\right) \tag{18}$$

which has the simple solution:

$$Q=R^{-1} \tag{19}$$

where the boundary condition $Q=1$ at $R=1$ has been applied. Equation (15) provides the following integral solution for T as a function of R:

$$T = \int \frac{\partial H}{\partial Q} dR + J \tag{20}$$

where J is the integration constant determined by the boundary condition $T = 0$ at $R = 1$.

FLAT PLANE SOLUTION

Despite the relatively simple forms of the governing equations, the solutions can be quite complicated. That said, for mild slopes where S_0 is approximately zero, Equation (9) can be approximated as:

$$Q = \frac{1}{C}\sqrt{\frac{1 + C^2 - H}{1 + F_0\left(R - 1\right)}}H \tag{21}$$

Note that this assumption of $S_0 = 0$ is conservative in terms of flood wave propagation speed for adverse slopes, but non-conservative for floodplains that slope away from the break. Hence, engineering judgment must be applied for individual applications. Further simplification of Equation (21) is achieved by noting that the H term within the radical of Equation (21) is of only secondary importance as compared with the H term outside of the radical. Hence, it introduces minimal error to assume it equal to 1, an assumption that still allows Q to comply with the boundary condition $Q = 1$ at $R = 1$ and $H = 1$, is conservative in terms of overall flow, yet helpfully linearizes the relationship between Q and H. The simplified result is:

$$Q \approx \frac{H}{\sqrt{1 + F_0\left(R - 1\right)}} \tag{22}$$

The solutions are thus:

$$H = \frac{\sqrt{1 + F_0\left(R - 1\right)}}{R} \tag{23}$$

$$\frac{dR}{dT} = \frac{1}{\sqrt[3]{1 + \frac{3}{2}F_0 T}} \tag{24}$$

$$R = 1 + F_0^{-1}\left[\left(1 + \tfrac{3}{2}F_0 T\right)^{2/3} - 1\right] \tag{25}$$

AGREEMENT WITH 2D MODELING

To compare the simplified equations with a full implementation of the 2D equations, a breach simulation was developed in HEC-RAS 2D. This model assumed a 20-foot depth and a breach propagation rate of 0.2 ft/sec to a maximum 360-foot breach width. The

breach sides were modeled as vertical and a broad-crested weir coefficient of 2.6 was assumed. The HEC-RAS modeled floodplain used 20-foot by 20-foot cell sizes with a zero slope (e.g., $s_0 = 0$). A total map size of just under 1 square mile was applied (approximately 5,000 feet by 5,000 feet). A Manning's roughness coefficient of 0.06 was assumed. In order to maintain a depth of 20 feet at the breach, a total rainfall hyetograph equal to the outflow from the breach was applied to reservoir area behind the breach.
To compare the HEC-RAS simulation and the derived simplified model predictions, both the equivalent C-coefficient and Darcy-Weisbach friction factor needed to be determined for the selected HEC-RAS parameters. The equivalent C-coefficient is simply $C = 2.6/\sqrt{2g} = 0.32$, and the equivalent friction factor is found from equating the friction slopes given Manning's and Darcy-Weisbach at the breach. This well-known conversion for English units is:

$$f = 8g\left(\frac{n}{1.49h_0^{1/6}}\right)^2 \tag{26}$$

from which it is readily determined that $f = 0.15$ for the selected parameters. Note that the model assumes the breach width of 360' occurred instantaneously.

The results of the HEC-RAS simulation with the derived simplified model are shown in Figure 2 and Figure 3 below. As expected, the simplified model predicts higher flood-wave speeds as compared with the HEC-RAS simulation, particularly during shorter times during which the breach width is still forming but the simplified model assumes it has already developed. However, this discrepancy steadily decreases as the model time increases until flood wave propagation speeds between both the simulation and the simplified model are in near perfect agreement. Hence, the simplified equations appear to be well-suited for conservative prediction of flood-wave arrival times.

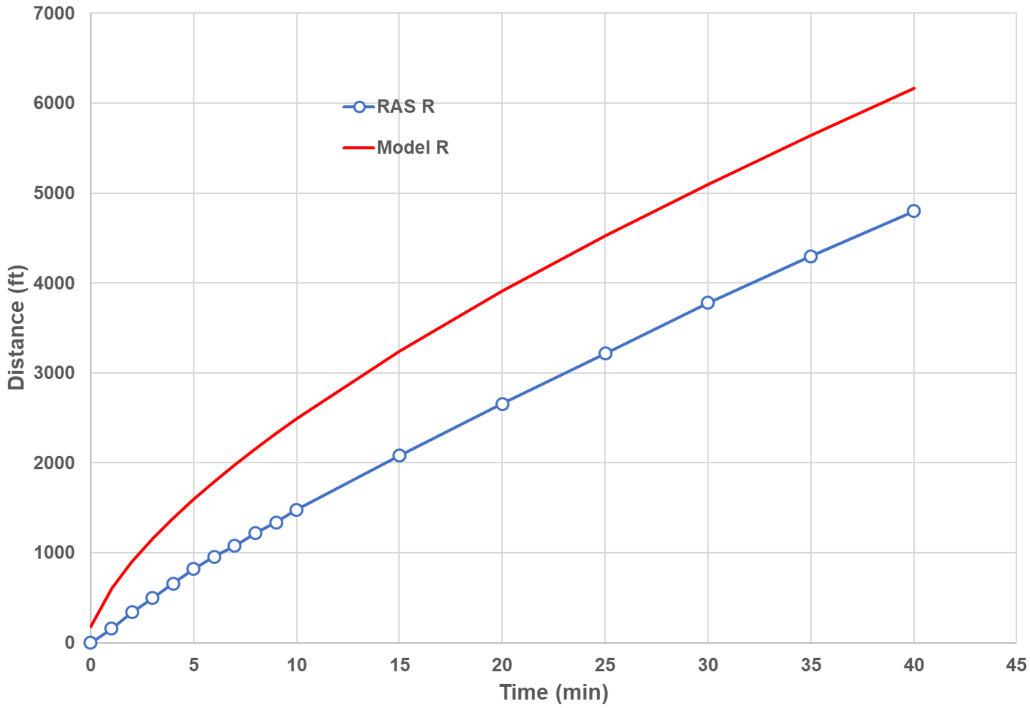

Figure 2. Flood-Wave Distance Versus Time

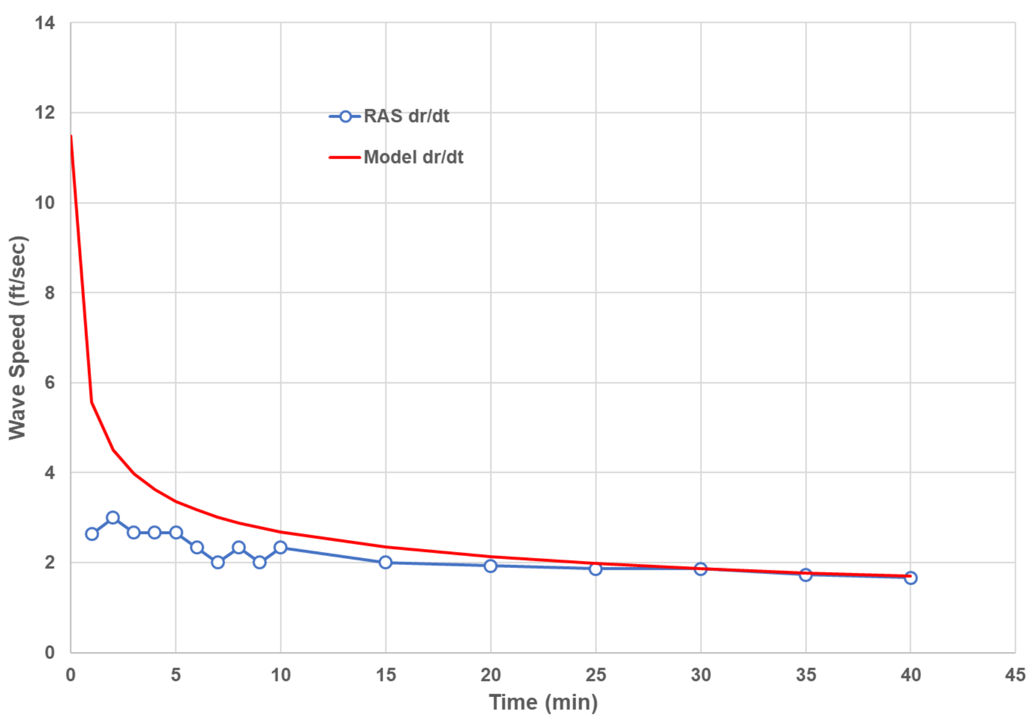

Figure 3. Flood-Wave Speed Versus Time

NEXT STEPS / CONCLUSIONS

The method of characteristics used here for solution is useful for flood-wave prediction but is not a full dynamic solution to the governing equations. Work is currently underway to develop full explicit equations that describe not only flooding depths and velocities within the entire floodplain, but will do so for sloped floodplains and during breach formation times as well.

It must be noted that, given the assumptions used for their development, the simplified equations presented here should never be used to replace a full 2D hydraulic model. However, by capturing the key aspects of the flood-wave mechanics, the equations can be used to support 2D modeling by helping to prioritize 2D model application projects, check developed 2D model results, and guide development and improvements near levees or canals at the planning stage.

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MAINTENANCE OF ANCIENT IRRIGATION SYSTEMS IN SOUTHERN INDIA

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Ian Hogg[4]

ABSTRACT

The irrigation and drainage systems of the Cauvery Delta in Southern India developed over 1800 years and evolved using bifurcation and spill channels from the principal river as main irrigation delivery channels. A unique feature of the systems is that the same channels are used for both the distribution of irrigation water and for the drainage of floodwater. The systems irrigate about 1.4 million hectares and the area is intensively farmed with paddy rice being the main crop. The most recent major adjustments to the systems were made about 90 years ago and in the modern era the systems have been subject to deferred maintenance for many years. However, the Tamil Nadu government is planning to improve the efficiency of the systems, using real-time weather data to determine crop water requirements and engineering interventions to rehabilitate the main channels, and mitigate the impact of climate change on flooding, water availability and cropping. To assist the government, the Asian Development Bank funded Technical Assistance to India for Climate Adaptation through Sub-basin Development Program (ADB 2012). The Program was developed by Mott MacDonald, Consultants, United Kingdom. The main channels and appurtenant structures were surveyed and mapped and geo-referenced, inventories prepared of the systems' assets, and hydraulic models prepared for six main channels. Challenges included determining actual water use and distribution, considering the contribution of groundwater, ensuring sufficient drainage capacity to pass floodwater through low lying coastal areas, and assessing the impact of sea level rise and changing coastal processes.

INTRODUCTION

The configuration of irrigation and drainage systems reflect the technologies and design available at the time of their construction. These configurations become the legacy of the implementers and successor scheme managers develop ways to operate and maintain this

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legacy over subsequent decades and centuries. In California, many irrigation and drainage systems were planned, designed and constructed during the first part of the 20th century. In India, irrigation and drainage systems can be much older dating back millennia or more and the basic layout of the oldest systems can leave a challenging legacy for today's managers. One such system that dates from the 2nd century is located in the Cauvery Delta in the state of Tamil Nadu, Southern India.

The basin of Cauvery river covers a major part of peninsular India, spreading over the states of Tamil Nadu, Karnataka, Kerala and Union Territory of Puducherry (Figure 1). The catchment covers an area of 85,626.23 km^2.. It is bounded by the Western Ghats on the west, by the Eastern Ghats on the east and the south and by ridges separating it from Krishna basin and Pennar basin on the north. The basin comprises of three administrative sub-basins namely Cauvery Upper, Cauvery Middle and Cauvery Lower sub-basin. The main channel of the Cauvery River rises at an elevation of about 1341 m and flows for about 800 km before its outfall into the Bay of Bengal.

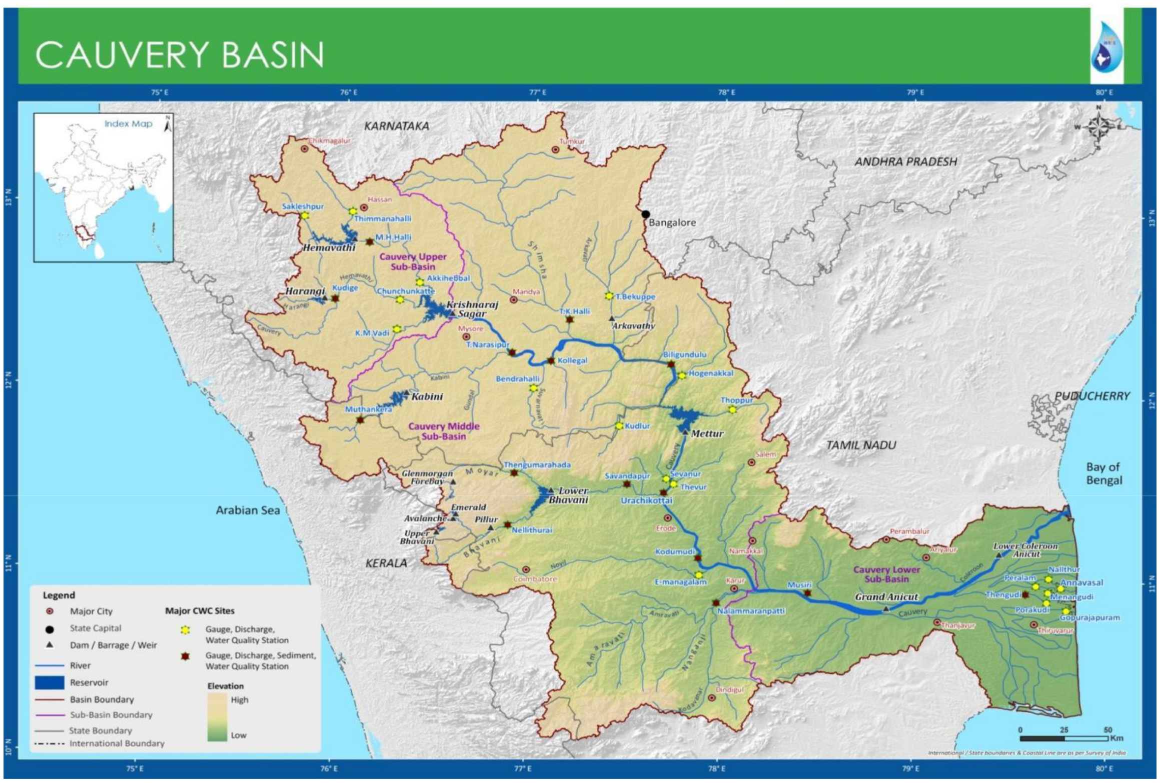

Figure 1. Cauvery Basin, Southern India (Source: CWC and NESC 2014)

The Cauvery delta starts at the Grand Anicut (barrage) `at approximately 75 m elevation and slopes gently towards the Bay of Bengal over a distance of 160 km (Figure 2). The delta consists of three sub basins: the Cauvery sub basin, the Vennar sub basin and the Grand Anicut Canal sub basin. It lies in a marginally semi-arid region. The annual rainfall is variable, ranging between 1774 mm and 653 mm with an average of 1192 mm. The north-east monsoon (November to December) produces between 1331mm and 316 mm with an average of 782mm, contributing most of the annual total in many years.

Normally the south-west monsoon (June to August) delivers only light rains because of the shadowing effect of the Western Ghats Mountains to the west in Kerala state. Potential evapotranspiration is about 1599 mm/year near the coast and 2227 mm/year further inland and irrigation is required to meet crop water requirements.

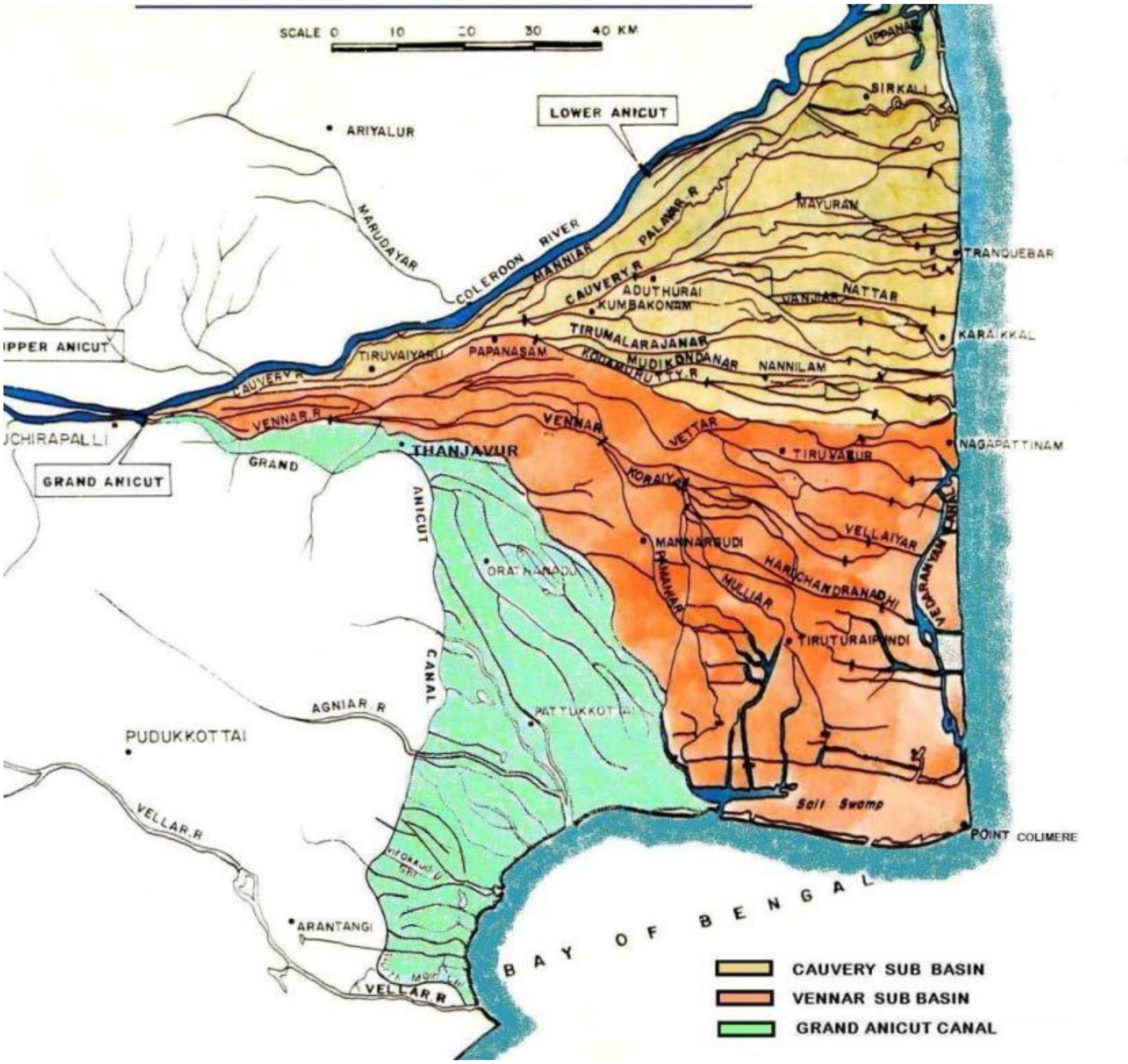

Figure 2. Layout of the Cauvery Delta (Source: ADB 2014)

The Grand Anicut or '*Kallanai*' as it is locally called in Tamil, was constructed by King Karikala Chola in the 2nd century AD, marks the first step in taming the Cauvery River and bringing irrigation facilities to the delta. The construction of the barrage was mainly a closing exercise but also provided necessary head to draw the irrigation supply required for the Delta and pass flood surpluses back to the main river channel below the Grand Anicut. The British remodeled the Anicut in the 19th century mainly to improve irrigation flows to the delta.

The Cauvery delta has a geographical area of 6,900 km^2 and a gross irrigated area of 5,220 km^2 of which about 1,900 km^2 is in the Vennar sub basin. Irrigation water is supplied to the delta from the Cauvery River at the Grand Anicut (barrage) via the Cauvery and Vennar rivers and the Grand Anicut Canal (Figure 2). The irrigation systems comprise natural deltaic ephemeral distributary rivers that are used, when there is inflow from the Grand Anicut, to irrigate command areas by distributing irrigation water through 36 natural branches and a network of 29,881 distribution canals with a total length in excess of 22,400 km. Some of the rivers also serve as drains which distribute already-used water to downstream command areas and also drain excess water to the sea.

Prior the 1930s, farms were irrigated from run-of-river flows generated mainly during the south-west monsoon (June to August). After each southwest monsoon ended, river flows diminished naturally and irrigated crops became dependent on rainfall from the north-east monsoon (October to December) during the latter part of the growing season. As both monsoons are unreliable and river flows are consequently also unreliable, agriculture was highly vulnerable to water scarcity. After construction of two major dams in the 1920's and 1930's, it became possible to regulate flows so that surface water supply for irrigation was more reliable and agricultural was more sustainable.

As surface water supplies are uncertain due to highly variable monsoon rains and a shortage of in-stream and off-stream storage sites, groundwater is a vital supplementary source of water without which agricultural output and rural incomes would be significantly lower. However in the Cauvery delta there are many areas with limited fresh groundwater availability or, towards the coast plain, with saline groundwater. In areas with suitable groundwater, there are an estimated 135,000 hand dug wells and 90,000 borewells constructed in the Vennar System (CGWB, 2008a, 2008b and 2009). Hand dug wells are predominantly for household water supply, while the borewells are for irrigation.

Damaging floods and droughts are endemic due to erratic monsoon conditions. There have been three major floods and one major drought in the delta since 2000 causing $240 million of damage in three administrative districts covering the Vennar sub basin (ADB 2014). There was a major drought from 2003 to 2004. Climate change studies indicate increases in rainfall during the monsoon months (June to December) but drier conditions from January to May (Srinivasan, 2013). Mean annual temperature is expected to rise by 1.5^{O}C by 2050. The climate projections also show 19% increases in storm rainfall volumes. Therefore more frequent and serious flooding can be expected. In coastal areas flooding will be gradually exacerbated by rising sea levels of between 0.29m (low scenario) and 0.87m (high scenario) by 2100.

In many parts of the delta the rivers are used not only to irrigate and drain the command areas but also to discharge floodwater from local storm runoff and from the Cauvery River. Being natural watercourses, the rivers are generally oversized for irrigation purposes. Being ephemeral, they are prone to congestion from vegetation and sediment and consequently, without adequate maintenance, they have limited capacity to drain floods from local watersheds and command areas following heavy rainfall. Consequently the irrigation systems are prone to flooding due to overtopping and breaching of river embankments and drainage congestion in the command areas.

Two crops of paddy are grown where sufficient water is available: *Kuruvai* paddy over 110-115 days from June to October, followed by *Thaladi* paddy over 135 days from October to January/February. Only one crop, *Samba* paddy which takes 155-160 days from August to January/February is grown because farmers are solely reliant on surface water and there is no fresh groundwater availability due to salinity or low yielding aquifers. In some upstream areas where surface water or groundwater is plentiful, three crops may be grown.

In India, the central government regulates the use of water in interstate rivers basins such as the Cauvery and management of surface water resources within each state is primarily the responsibility of the state government. Tamil Nadu's Water Resources Department (WRD) has a central role in the provision of surface water for irrigation throughout the state including the Cauvery delta. It is responsible for the design, implementation, management, operation and maintenance of public irrigation schemes. In its proposals and programmes WRD is committed to the modernisation of irrigation systems and improvement of water resources management in the Cauvery delta .

To assist WRD in improving the efficiency of the Cauvery delta including issues arising from climate change, the Asian Development Bank funded the Climate Adaptation and Sub-Basin Development Program-CASDP (ADB 2012). The Program produced a feasibility study which focused on the requirements of Vennar sub basin (ADB 2014) and was prepared by Mott MacDonald, Cambridge, United Kingdom. The information provided in this paper comes from the Consultant's Report.

IRRIGATION INFRASTRUCTURE

The layout of the main channels and drains of the Vennar Sub Basin is shown schematically in Figure 3. Ten main river channels convey both irrigation and drainage water while ten other channels are primarily drainage channels (for example, the Valavanar and Nallar Drains). The physical characteristics of the channels are variable. Some reaches have uniform cross sections and straight alignments while other reaches have varying cross sections and winding alignments. Some reaches are overgrown with vegetation and clogged with water hyacinth while other reaches are quite open.

Water levels and flows in the main channels are managed with head regulators, cross regulators and fixed weirs (bed dams or grade walls). In addition, at the lower end of the channels, tail-end regulators manage outflows and prevent the inflow of seawater. Discharges through the regulators are calculated by WRD from measured upstream water levels, areas of gate openings and numbers of open gates. Typical inflows into the Vennar system (See Figure 4) show pronounced 6-day cycles of 5000-7000 cusecs in September and October, prior to the onset of the north-east monsoon, followed by smaller more-erratic inflows during the north-east monsoon in November and December 6. Water levels are not measured at intermediate points along the river channels or in the Vedharanyam Canal or in the outlets to the sea.

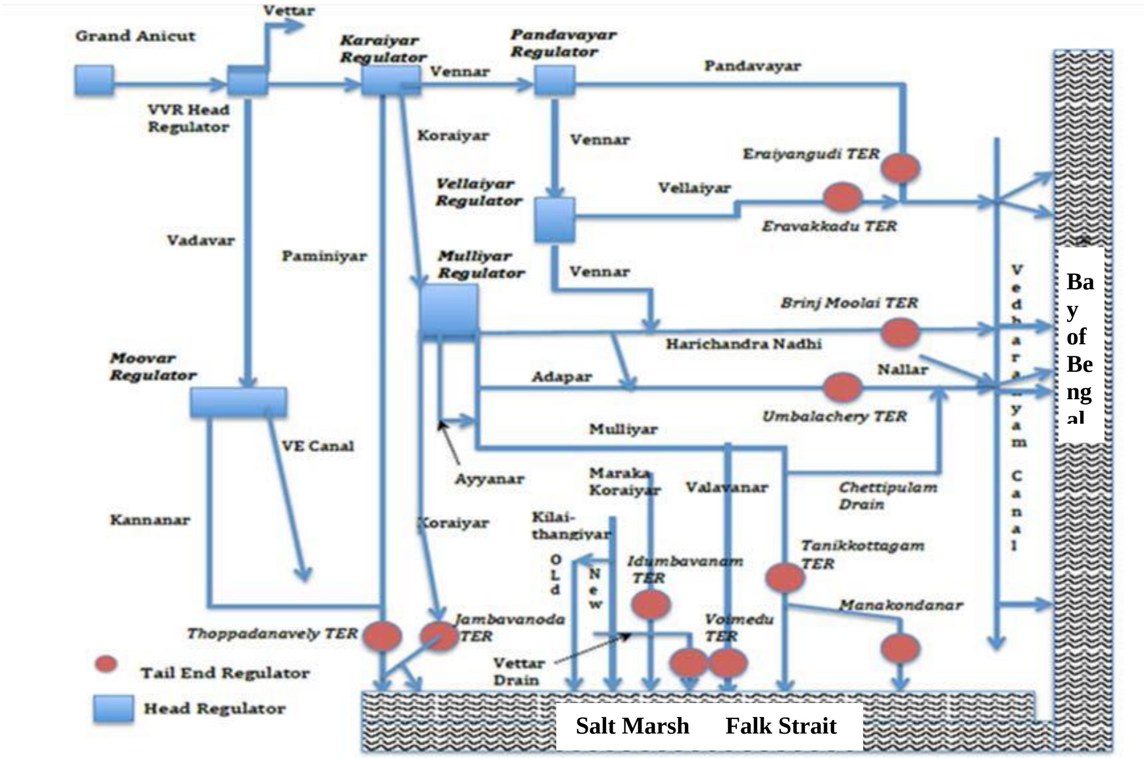

Figure 3. Layout of the Vennar System (Source: ADB 2014)

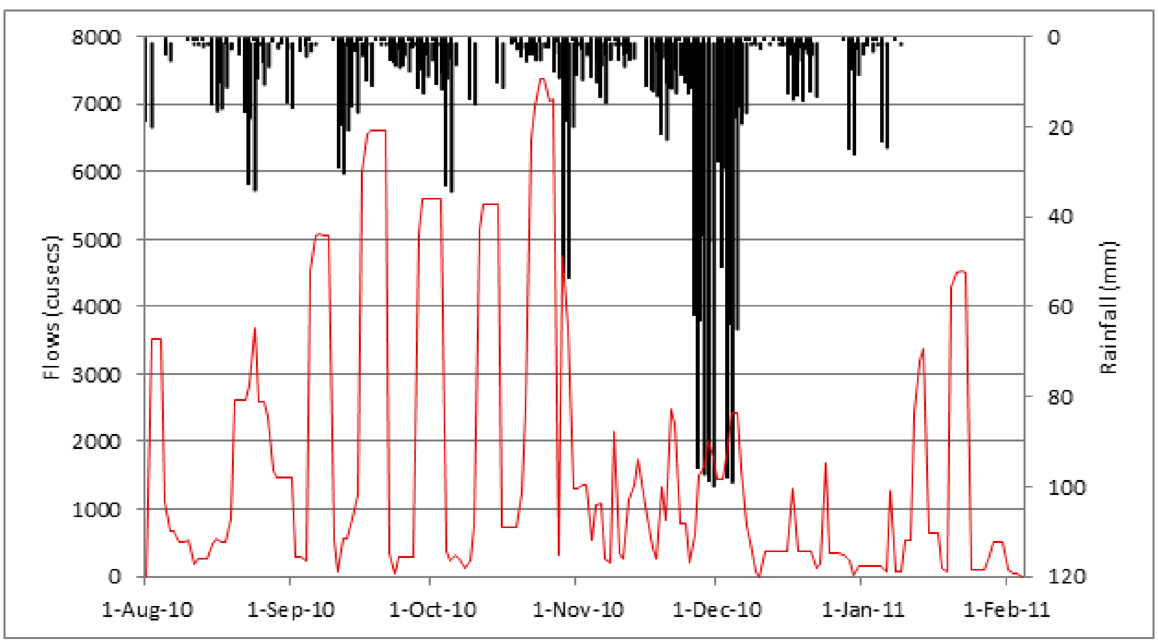

Figure 4. Irrigation inflows and Rainfall in the Vennar System (Source: ADB 2014)

In the Vennar system there are seven head regulators at major river bifurcation points, 188 intermediate regulators and 11 tail-end regulators (See Figure 3). The tail-end regulators serve the dual purpose of increasing water levels to serve low lying command areas near the coast and preventing seawater ingress to the system. When heavy rainfall occurs and drainage congestion takes place the tail-end regulators are kept open to accelerate outflows to the sea, but the balancing effect of the Vedharanyam Canal and adjacent lagoons, combined with high tides and the storm surges that tend to accompany cyclonic rainfall, slow outflows causing drainage congestion and flooding in coastal areas.

Irrigation water is distributed from the main channels through head sluices located on the banks of the main channels. The head sluices are mostly located sufficiently close to cross regulators or fixed weirs that water levels are adequate, but some head sluices are too far upstream and are therefore sometimes subject to inadequate water levels. It is necessary therefore to run some main rivers at discharges in excess of normal irrigation supply order to ensure adequate water levels at those sluices

From the irrigation head sluices, water is distributed through networks of canals and field channels. Maintenance of these networks has been minimal in recent times and consequently water distribution is inefficient due to seepage, congestion due to vegetation and sediment, and broken sluices. In the worst cases, distant farmers do not receive any surface water at all. In some locations in the lower reaches, pump stations are provided to lift water to land that is out of command.

The surface water distribution system has not kept pace with the changing distribution of landholdings in the command areas. Land tenure has become progressively fragmented through the traditional inheritance system. The average size of a land holding in the delta is now 0.75 ha (WRO, 2008) whereas the canal network was designed for 20 ha blocks. Therefore, in many locations, small scale distribution infrastructure does not exist, and field-to-field spillage is necessary in order to water distant farms.

Drainage is provided by a network of field and collector drains connected to the main channels. Flows from some drains to the main channels are managed by drainage infall sluices but most drains have open infalls. During floods, water levels in the main channels are often higher than water levels in the drains thus preventing the drainage of surface runoff from the command areas. The main channels are also used to carry flood flows from the Grand Anicut as well as excess floodwaters arising from within sub basin. Flood flows through the main river channels during the November 2008 Flood are shown in Table 1 along with typical irrigation flows. The flood flows can be more than 3 to 5 times larger than typical irrigation flows. The increase in flood flows along the channels is due to the inflow of flood waters from within the sub basin and diversion of flood waters from one channel to another.

Table 1. Irrigation Flows and Flood Flows in the Main Channels (Source ADB 2014)

River Channel	Head Regulator	Typical Irrigation Flow (m^3/s)	2008 Flood Flow Upstream (m^3/s)	2008 Flood Flow Downstream (m^3/s)
Vennar	VVR Head	153	479	521
	Koraiyar Head	49	311	331
Koraiyar	Koraiyar Head	57	200	276
	Mulliyar Head	21	276	324
Harichandra	Mulliyar Head	10	closed	59

The anicuts and principal regulators have been operated and maintained by government departments since the 19th century. In the modern era, WRD operates the infrastructure. Most of the infrastructure is physically old and, within the Vennar system, manually operated. Many structures are in need of repair.

Originally the minor canals, many of which are natural streams, were maintained by the farmers through the self-help (*kudimaramath*) system. However, in the 1930s, most of the distribution canals and their structures were adopted by the government, but, in the modern era, the government has had to concentrate maintenance on critical primary infrastructure such as head, cross and tail-end regulators and arterial canals, because of limited resources. It has not been possible to maintain secondary structures and the canal network to the same standard. Minor canals and structures are nominally in the care of the farmers, but gradually the self-help system has broken down, particularly since the advent of electrical pumps for groundwater abstraction and the provision of free electricity by the state government. Consequently, the physical condition of the minor infrastructure has deteriorated. Many of the smaller canals and watercourses are now silted-up, weedy and leaky and some are no longer maintained or used.

OBJECTIVES OF IMPROVING SYSTEM PERFORMANCE

The objective of CASDP was to design an investment plan for climate adaptation in the Cauvery delta and deliver initial improvements to the Vennar sub-basin initially. The climate change projections indicate only a marginal decrease in vulnerability to water scarcity during the monsoon periods and greater vulnerability during the dry season. They also indicate a significant increase in vulnerability to floods. The plan has therefore been designed to address two major climate change risks (i) water scarcity and (ii) floods.

The scope for improving the performance of the Vennar sub-basin and addressing climate change issues are constrained by several factors including:

- No land readily available to store irrigation or flood water
- No scope of re-aligning channels due to intensive agricultural land use and urbanisation adjacent to the main channels.
- Low hydraulic gradients in channel reaches in coastal areas
- Saline groundwater under about 50% of the sub basin.

- Need to carry flood flows and irrigation flows in the same channel

Hence the options for improving conveyance efficiency of the main channels were to re-section channels and increase embankment heights and improve the performance and reliability of structures by replacement or repair.

PLANNING AND DESIGN

Due diligence carried out during the preparation of CASDP included assessments of the water sector institutions and policies; the financial management and procurement capacity of the Executing Agency (the Tamil Nadu Water Resources Department); the vulnerability of the project area to floods; drought and climate change; economic and financial feasibility of the project; social and gender issues; environmental issues; water resources availability; existing agriculture and aquaculture systems and opportunities.

The design of CASDP is framed by of the following specific safeguards, strategies and plans: (i) poverty reduction and social strategy; (ii) resettlement framework and resettlement plan; (iii)
gender action plan; (iv) environmental assessment and review framework; (v) initial environmental examination; (vi) water resources management road map; (vii) communication plan and (viii) risk assessment and risk management plan. A land entitlement matrix was developed to address the requirements of ADB's social themes and the 2013 Land Acquisition and Resettlement and Rehabilitation Law of India.

The planning process is shown in Figure 5, and involved undertaking physical surveys of the main channels and tail and cross regulators. An asset survey was carried out to update the WRD Component Registers, some of which dated from the 1920's, and determine the condition of appurtenant structures including drainage outlets and head sluices. As-constructed drawings were not available. Climate data was collected and analysed as input to the hydrologic modelling.

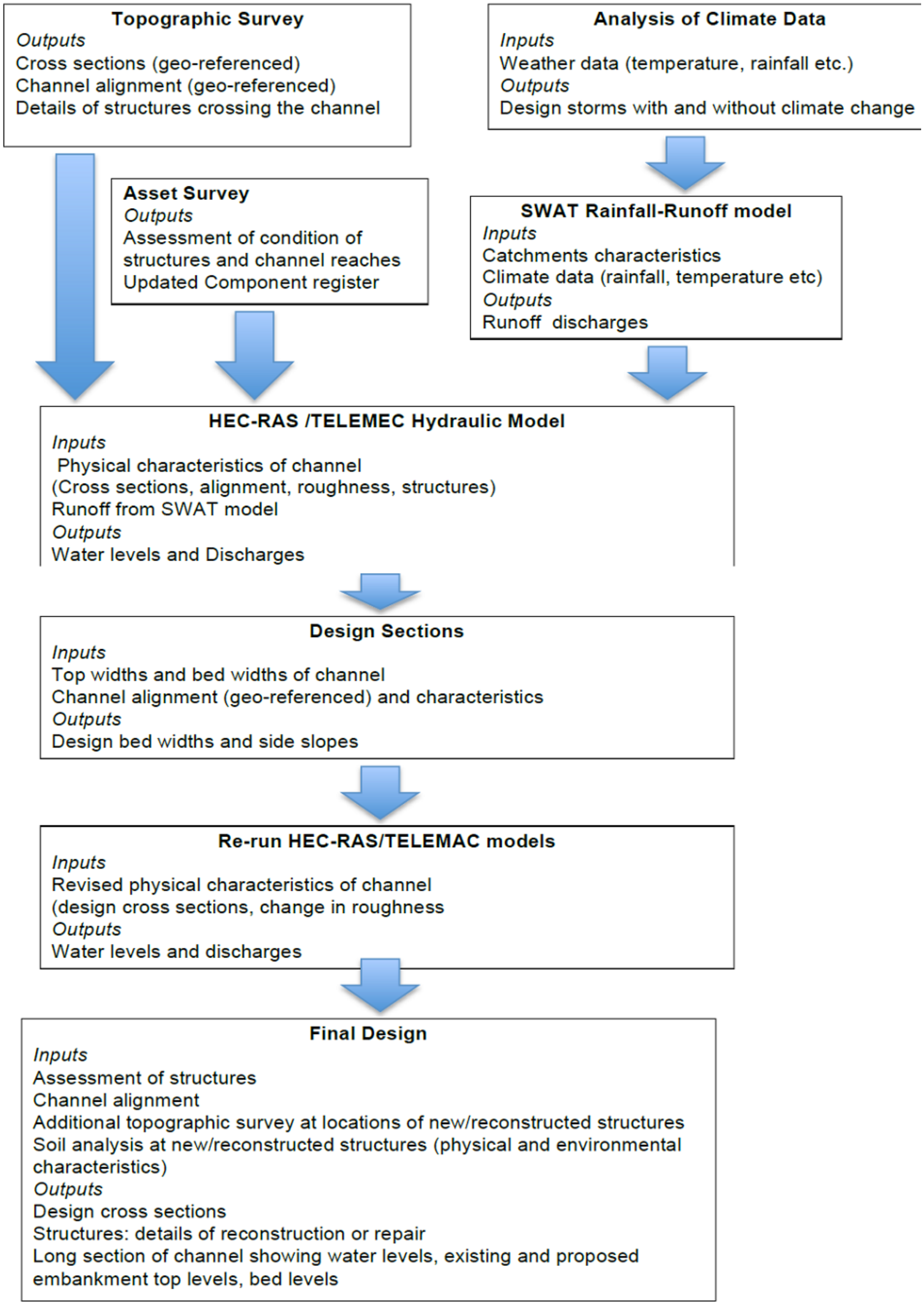

Figure 5. CASDP Planning and Design Process (Source: ADB 2014)

HYDROLOGY AND MODELLING

Hydrologic and hydraulic models were prepared for the Vennar system including the Vellaiyar, Pandavanar, Harichandra and Adappar Rivers, the Valavanar Drain and the Vedharanyam Canal and associated straight cuts to the sea (ADB 2014). MWSWAT hydrologic models were used to simulate rainfall and runoff for a period of 12 years from 2001 to 2012. In the absence of high resolution topographic maps or DEMs, rainfall-runoff catchments were delineated from low resolution public domain DEMs (SRTM). A total of 112 catchments were identified. HEC-RAS 1D hydraulic models were developed and calibrated for the period 2001 to 2012 for the Vellaiyar, Pandavanar, Harichandra and Adappar Rivers and the Valavanar Drain. A TELEMAC 2D hydraulic model was developed to simulate two dimensional tidal flows in the lower reaches of the rivers, downstream of their tail-end regulators and in the Vedharanyam Canal and the straight cuts.

The hydraulic modelling was a considerable challenge due to the dense network of rivers, canals and drains, numerous inter-linkages and structures, low hydraulic gradients, tidal influences, merged flood plains and limited availability of detailed topographic and tidal data. A further challenge was the lack of river level and flow data from cross regulators and head sluices and uncertainties in the river level and flow data from the head and tail regulators, especially during severe floods when these regulators may have been drowned or bypassed. The HEC-RAS model for the Harichandra River is shown in Figure 6.

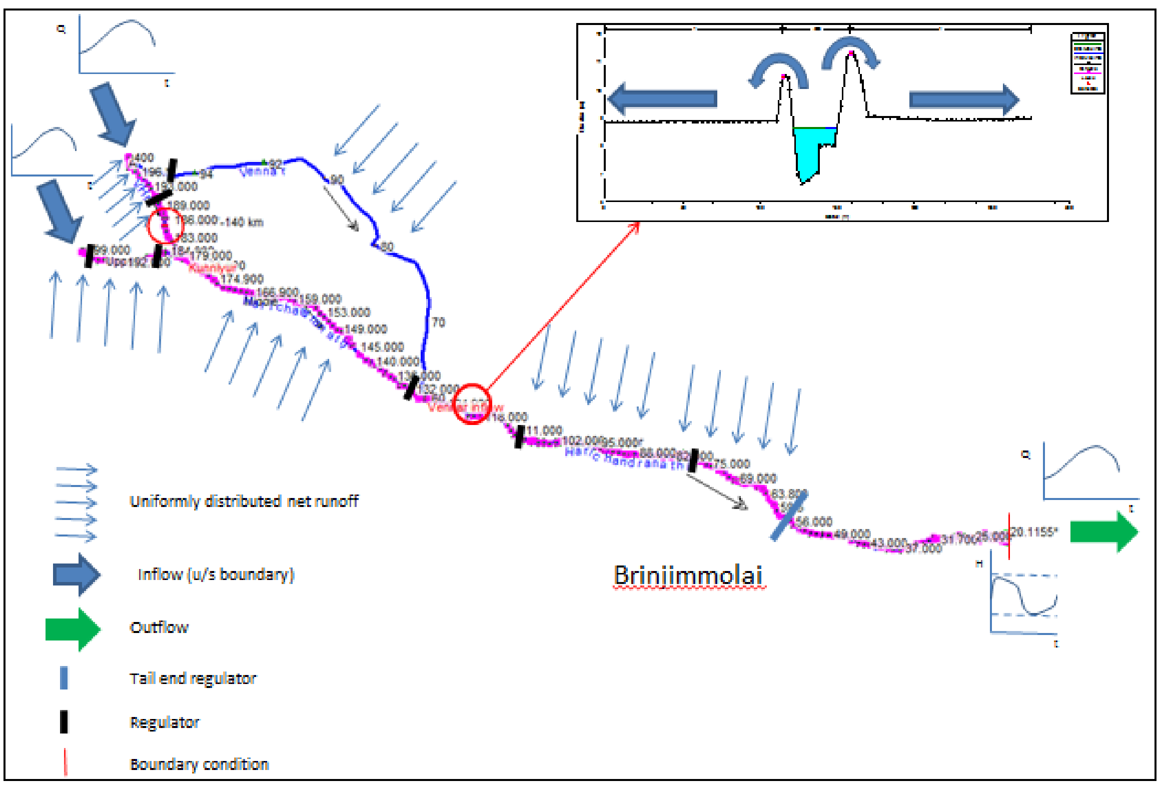

Figure 6. HEC-RAS Model, Harichandra River with Uniform Lateral Inflow (Source:ADB 2014)

For design purposes, the models were calibrated for the November 2008 flood event which had an estimated return period of about 1:50 years. A long profile of peak water levels during the 2008 flood is illustrated in Figure 7 and indicates that they over-topped the bank levels at several locations, mainly in the lower reaches where the bed slope flattens as the river enters the coastal plain. These locations broadly correspond to the flooded areas indicated on the satellite image of flood extents provided by the National Remote Sensing Centre. Figure 7 indicates that none of the regulators were drowned or over-topped during the 2008 event which is consistent with the observations of WRD and information gathered during field visits.

The first option considered for reducing flood impacts was to model improved the conveyance efficiency of the river channel by re-sectioning the channel and standardizing the embankment heights (where required) to contain the design flood flow (Q25) with 1.5 m freeboard. The geometry of the model cross sections was adjusted to accommodate these changes and the model re-run to determine the impact on flows and water levels. After consideration, WRD determined that this option was not practical as government land was not available to widen the channel plus it would cause too much disruption to irrigation flows. Therefore a second option of re-grading the bed and standardizing the banks was modeled for Q25, Q25 with climate change (CC), Q50 and Q50 CC, and Q100 and Q100 CC and the respective water levels for the existing and post-project channel geometry. The results of this second option (Figure 7) and were acceptable to WRD. The Q25 discharges increase by about 20% with climate change and Q25 with climate change are greater than the Q50 without climate change. Water levels increase by about 15 % with climate change. These show that the proposed flood mitigation measures will substantially reduce the extent of the 25-year flood except where surface runoff is prevented from draining into the river by high river levels and low ground levels relative to the river bed. In the upper Harichandra catchment, some linear flooding and scattered flooding is shown to persist. There will also be a substantial reduction of the impact of the 50 and 100-year floods which, in the without-project, without-climate change scenario inundate the entire lower half of the catchment.

The model hydrographs at the Brinjimoolai tail end regulator on the Harichandra River compare reasonably well with the observed flood hydrographs (Figure 8), particularly the Option 2 (Phase 1) model hydrograph which shows a better simulation of the observed recession than the calibration model (simulated with flood plain) . This is to be expected as the overbank flows from the channel to the flood plain in the calibration model do not return to the channel.

There were several sources of uncertainty in the modeling including:

- Possible errors in observed peak discharge data through the regulators caused by non-modular flow conditions and/or by-passing of the regulators;
- Possible errors in SWAT inflows due to uncertain sub-catchment boundaries in flat terrain;
- Lack of regulator gate opening data;
- Uncertainty in historical channel roughness parameters due to mobile channel beds and ephemeral flow regimes;
- Imprecise topographic data in the upper catchments.

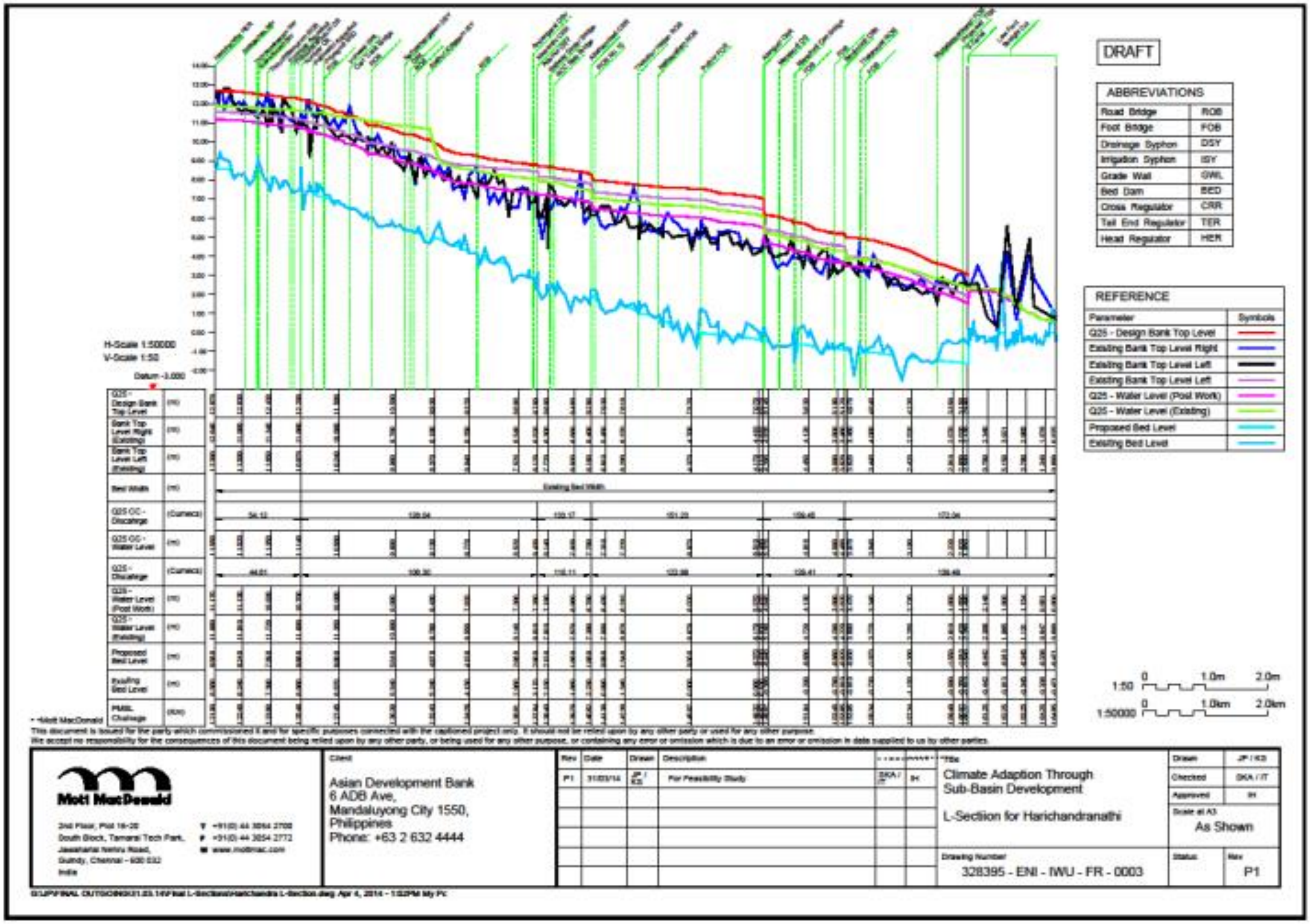

Figure 7. Long Section of the Harichandra Channel (Source: ADB 2014)

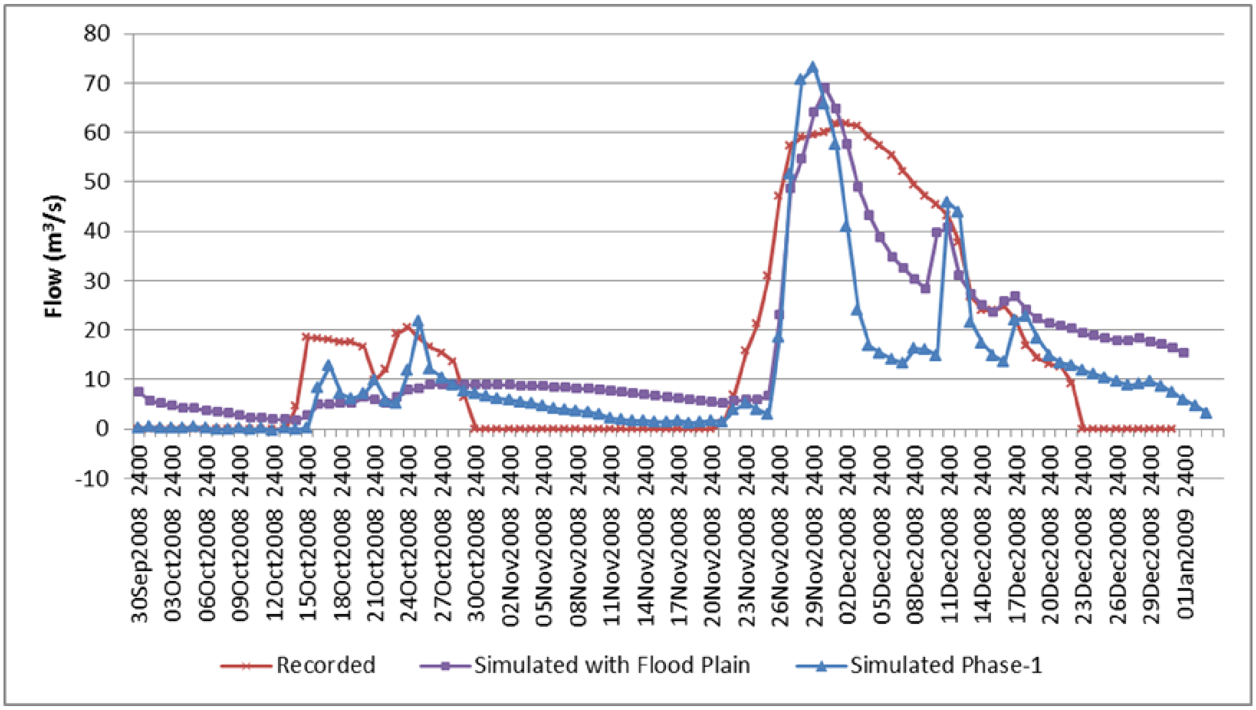

Figure 8. Modelled and Observed Flows, Brinjimoolai TER, Harichandra River (Source: ADB 2014)

CONCLUSIONS

The scope for addressing some underlying inefficiencies of the Vennar irrigation and drainage system was constrained by the legacy of the initial layout of the system and its subsequent evolution. However, there are possibilities for greater efficiency, starting by improving the hydraulic performance of the main channels.

Subsequently, based on the Consultant's report (ADB 2014), the $144 million Climate Adaptation in Vennar Subbasin in the Cauvery Delta Project was developed by the Tamil Nadu government and the ADB and the Report and Recommendation of the President (ADB 2016) for the Project was approved by the Board of ADB in May 2016.

The impacts of the Project will be (i) coastal districts are better protected from cyclones and flooding exacerbated by climate change; and (ii) innovative and inclusive economic growth, including agricultural growth, is accelerated in Tamil Nadu. The outcome will be that climate-resilient water management in the Vennar system is improved.

The outputs of the project will be:
Output 1: Flood risk management and irrigation infrastructure upgraded. Structures will be improved according to new design guidelines that consider climate change impacts. More-resilient flood management structures will reduce the frequency and impact of flooding. The civil works involve (i) re-sectioning and strengthening the embankments of six main channels totaling 235 kilometers to improve their resilience and flood

conveyance capacity; (ii) improving conveyance of three straight cuts between the Vedharanyam canal and the sea; (iii) constructing 4 new regulators, reconstructing 10 dysfunctional regulators, and repairing 13 damaged regulators; (iv) doing work (new, upgrades, and repairs) on 133 irrigation head sluices offtaking from the main channels; (v) upgrading 20 bed dams and grade walls within the main channels; (vi) upgrading 136 other minor irrigation and drainage structures; and (vii) upgrading 13 pump stations through new pumps and electrical systems and repairs to pump houses.

Output 2: Improved water and flood risk management systems established. This output will deliver nonstructural interventions designed to (i) improve decision-making on water resources, and (ii) manage flood risks and flood events. Initiatives to be developed under (i) are: (a) greater participation by stakeholders in the planning and delivery of water services through the formation of channel stakeholder groups; (b) better assessment of water resources through the installation of additional equipment to monitor and measure rainfall, surface water, groundwater, and tide levels and flows; (c) development of a decision support system that would provide system status information and enable more accurate water allocation planning and more effective asset management; and (d) training for WRD officers on more effective management of water resources. Flood risks and flood events will be managed by (i) installing flood forecasting and warning systems, and (ii) mapping flood risks. The output also includes provision for a feasibility study, and the detailed design of similar improvements in the remainder of the Vennar and Cauvery systems that may be financed under a subsequent project.

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ISOLATING LIVESTOCK WATERING FROM IRRIGATION CANALS: THE DUCK VALLEY IRRIGATION PROJECT

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ABSTRACT

In many areas throughout the western US, livestock are permitted to walk through irrigation canals and utilize the irrigation water for drinking. This paper provides a case study of an irrigation project that is in the process of separating the livestock from the irrigation facilities. The Duck Valley Irrigation Project has explored options for irrigation modernization, paired with new techniques for bringing drinking water to livestock. Project difficulties, recommendations, and cost estimates are discussed.

INTRODUCTION

Throughout the intermountain west, many irrigation projects have a mix of ranchers and farmers. Historically, livestock ranchers have allowed their cattle and horses to walk into canals for drinking, to walk through canals from a field on one side to fields on the other side of the canal. In some projects, water is delivered year-round for livestock drinking.

The problems with this specific mix, from an irrigation perspective, can include the following:

1. Ranchers typically construct barbed wire gates across canal access roads. There may be several per mile. Sometimes ranchers lock the gates. This makes operator access problematic, to say the least.
2. The livestock damage the banks.
3. Ranchers install barbed wire fences across the canals, which restrict access for canal bank maintenance and catch weeds.
4. The year-round water in the canals makes good canal and structure maintenance very difficult, and also causes freeze-thaw damage to structures in many areas.

Livestock ranchers often do not perceive any problems with livestock in canals. Therefore, when the irrigation project managers attempt to isolate irrigation facilities from livestock – changing traditional practices – conflict and differences of opinion between ranchers and irrigation managers are inevitable.

This paper provides a case study of an irrigation project that is in the process of separating the livestock from the irrigation facilities, for which the Irrigation Training & Research Center (ITRC) at Cal Poly State University, San Luis Obispo, was contracted to provide modernization recommendations.

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DUCK VALLEY IRRIGATION PROJECT (DVIP)

The Duck Valley Irrigation Project (DVIP) is in the Duck Valley Indian Reservation of the Shoshone-Paiute tribes on the border of Idaho and Nevada. The reservation was established by Executive Order on April 16, 1977, in the valley that was selected by Captain Sam, a Shoshone leader. Today about 2,300 Shoshone-Paiute hold membership at Duck Valley with about 12,000 livestock that need water during the winter months. The irrigation project is fairly unique in the fact that while it is on an Indian Reservation and was originally operated by the US Bureau of Indian Affairs, it is now operated by the tribes.

The irrigation project is supplied by gravity through unlined canals from the Owyhee River, which runs through the reservation. DVIP has about 12,000 irrigated acres.

Figure 1. Location of DVIP on the Border of Nevada and Idaho

Modernization of DVIP

As part of a federal settlement agreement, the DVIP received about $35 million to upgrade its irrigation project, which has fallen into disarray since its original construction. Some additional funds are available from USDA/NRCS for on-farm improvements.

There are many interesting aspects to the proposed modernization. These include the details of replacing almost all canal laterals with pipelines, new control structures on main canals, improved flow measurement and control, recirculation of return flows, remote control of the headworks of the supply dam, and buffer reservoir design and management. Furthermore, important design details will impact the user-friendliness of the project, minimize conflicts between water users, and improve flexibility and reliability of water supplies.

An important aspect of the plan involves drying up all the canals during the winter to facilitate maintenance and to reduce damage to structures – especially concrete damage due to freeze/thaw conditions. The proposed lateral pipelines are a key to the modernization efforts, and if they are not drained in the winter the risers would break due to the extreme freezing conditions in DVIP.

For about six winter months, the ranchers bring their cattle and horses in from the range and rotate them on fields throughout the irrigation project. Historically, cattle and horses have had unlimited access to the canals for drinking. It is their only water supply. Because the vast majority of the ranchers focus on their cattle rather than on irrigated farming, the possibility of losing access to livestock drinking water alarmed ranchers.

Public Relations

The DVIP has a manager, a secretary, and three ditchriders. The manager receives direction from volunteer tribal members who have been appointed by the tribal council to a Water Board. All contracts, important policies, irrigation modernization plans, etc. must be approved by the tribal council. There are also three organized groups of livestock ranchers in the valley, organized geographically and with different concerns and conditions. The irrigation season is very short, and incomes are low.

Irrigation modernization projects can become very "personal" for individuals when the projects involve construction and changes on their property – as opposed to rather sterile off-farm improvements such as modifying dams and reservoirs or lining major canals. Farmers want to feel personally assured that the modernization will not harm them; it is interesting that they typically focus on possible negative impacts rather than on benefits – possibly because they are not familiar with the new hardware/practices. Larger irrigation districts have staff who develop web pages and provide newsletters to inform farmers of ideas and proposals. Larger irrigation districts may hire outside firms to work on the public relations aspects of modernization. DVIP's small staff is over-worked with the day-to-day operation of the project, and has no experience with more advanced strategies of public relations.

The tribe hired ITRC to develop an irrigation modernization plan. The contract was technical in nature, and only envisioned a few meetings to present the plan to the Water Board and to the tribal council and to solicit input. It did not envision an awareness program to keep ranchers and farmers informed at every step along the way. It also did not include the development of a livestock watering program because that was supposed to be a separate issue. Furthermore, the modernization plan was developed over a relatively short time frame – about six months. This made effective communication with the community more challenging.

It could have been possible that all of the ranchers and farmers would have attended all the Water Board and tribal council meetings, and therefore would have been well informed. However, DVIP is similar to other irrigation projects, in that such meetings tend to have sparse attendance. Most of the communication tended to be word-of-mouth among neighbors, a mode in which a single statement can have many interpretations and extrapolations of impact.

<u>Putting the Livestock First</u>. The concern of the ranchers about how the livestock would be watered was legitimate. The tribes began investigating "nose pumps" (described later) for livestock in early 2016 and approved the hiring of a livestock water program person,

followed by the purchase and installation of about a dozen such pumps in the summer of 2016. However, as of February 2017, only three nose pumps had been installed. The ranchers did not see a lot of movement to address their concerns. Meanwhile, the ranchers heard that an irrigation modernization plan was being developed, and feared that livestock needs would be ignored.

The rumors and speculations in the community ramped up quickly. Some ranchers concluded that their water was going to be completely shut off and their livestock would die of thirst. People became emotional. It was clear that there could be no discussion of irrigation modernization until the livestock watering issues were first resolved. Regardless of the contract wording, ITRC had to become involved in the livestock watering program if there was to be any chance for the irrigation modernization plan to be accepted.

Therefore, the following strategy was developed and then articulated/discussed in a number of public meetings:

1. The livestock and irrigation challenges needed to be addressed simultaneously in the planning stage.
2. An irrigation modernization plan was first needed, because it would shape a decision as to whether the irrigation system could be dual purpose for both irrigation and livestock water. The irrigation modernization plan development required an understanding of both groundwater and surface water resources, the capacity of electrical service throughout the project, elevations, maps of parcels, etc. That same information was needed to visualize options for livestock water.
3. A robust plan was needed to provide livestock water. There could be more than one option. The solution(s) needed to supply sufficient flow, be very simple, have redundancy, and must be able to withstand the extreme winter freezing conditions.
4. Even if irrigation canals were replaced by pipelines, the small flows in the original irrigation canals would not be shut off during the winter until all fields supplied by a canal were equipped with a new independent livestock watering system.
5. Modernization of irrigation facilities could begin with “off-farm” improvements that had no impact on livestock watering.
6. A series of meetings were needed right away with the three livestock groups, the tribal council, and the overall community to address concerns and explain the options, process, etc.

<u>The Case That Was Made for Improved Livestock Watering</u>. It is important to separate the livestock watering from the irrigation water for the following reasons:

1. Good irrigation management and service can only be provided by the irrigation system operators if they have easy and good access to project irrigation features. This means, in part, that they should not be restricted by having to open and close barbed wire gates on canal access roads.
2. During the winter maintenance season, it is highly desirable to be able to dry out canals for repairs, cleaning, and new construction.
3. Canal banks are damaged, and water quality is degraded, if animals can walk into canals.

There are also benefits to the livestock from having a separate water supply, as follows:

1. Cattle gain more weight if the water is warmer.
2. Clean drinking water is better for the cattle.
3. Diseases and flukes that can be spread between fields with canal or drain water are decreased.
4. Under the current system, some fields occasionally do not get enough livestock drinking water or have no access to winter water. A new system can supply water to these fields.

Canal Fencing and Animal Crossings. All canals should have roads on both sides for operators and maintenance vehicles to access structures and turnouts quickly and safely. To prevent livestock from entering canals through canal roads, barbed wire fencing is needed on both sides of the canal.

The 40 acre parcels of DVIP that are split by a main canal require a specifically designed canal crossing to prevent cattle from entering the canal. Figure 2 shows a profile and top view of the proposed canal crossings.

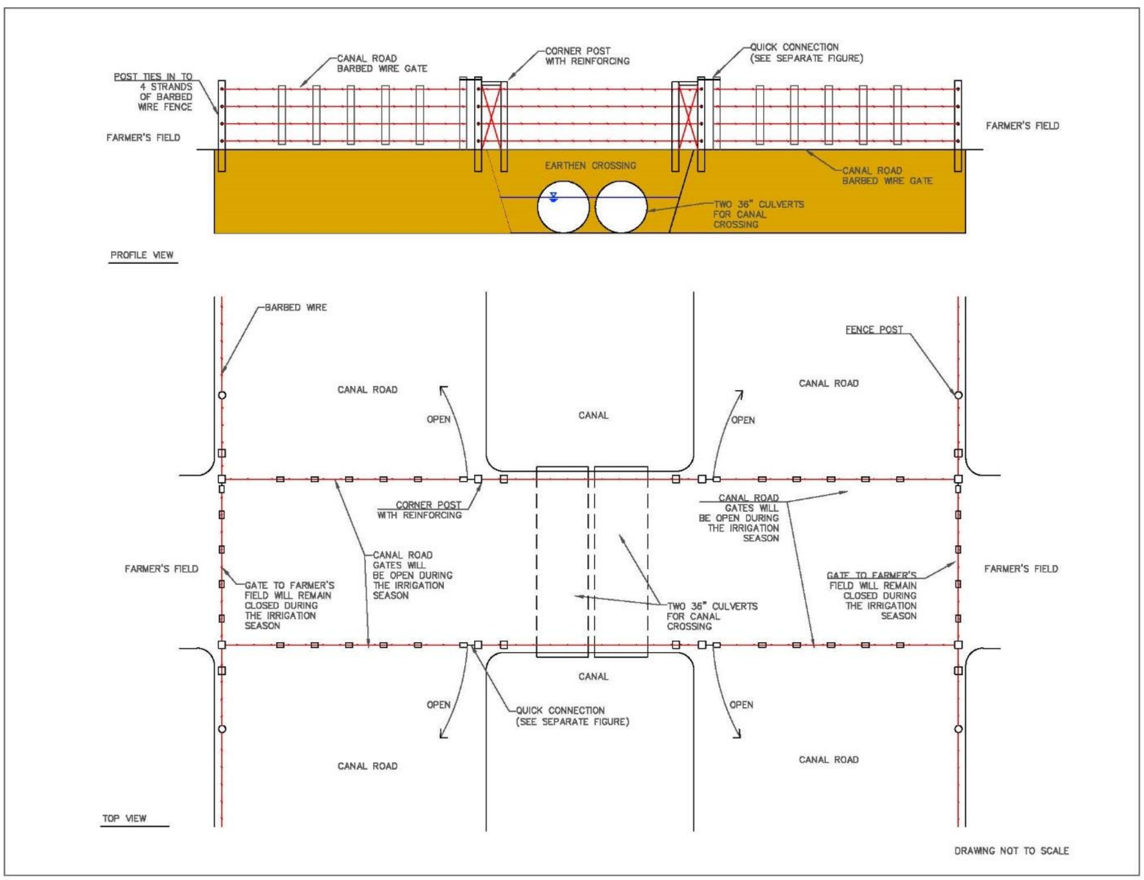

Figure 2. Barbed wire fence and gate configuration at main canal crossings

Basic Design Assumptions and Considerations for Livestock Watering. In examining livestock watering options, the following basic assumptions were used:

1. About 12,000 animals need water during the winter.
2. The daily water requirement may be as high as 25 gallons/head.
3. During the winter, perhaps 20 gallons of that will be used within 6 hours during the day.
4. Based on the flow of 20 gallons/head, in 6 hours, the total flow rate needed by the animals is 670 GPM.

Other items considered for a new livestock water system were:
1. If any small valves are used, the water needs to be very clean to prevent plugging.
2. Only very special equipment will function during freezing conditions.
3. Livestock are healthier if the water is of "medium" temperature, as opposed to almost freezing.
4. A system that passes the same small flow through one trough and into another trough may transmit parasites and diseases to downstream animals.

Livestock Watering Options

The following options can be considered for providing livestock water.

1. **Nose pumps.** The animals actually pump the water from a well, which requires training of the animals. *This is the only option that does not require pressurized water*. Information on one brand can be found at Frostfree Nosepumps (info@frostfreenosepumps.com). Some sketches from the website can be seen in Figure 3. The list price for materials (not including installation or digging of the well), is about $2500. Installation, coordination, and logistics can triple the total cost. This option is only applicable to areas of shallow water tables.

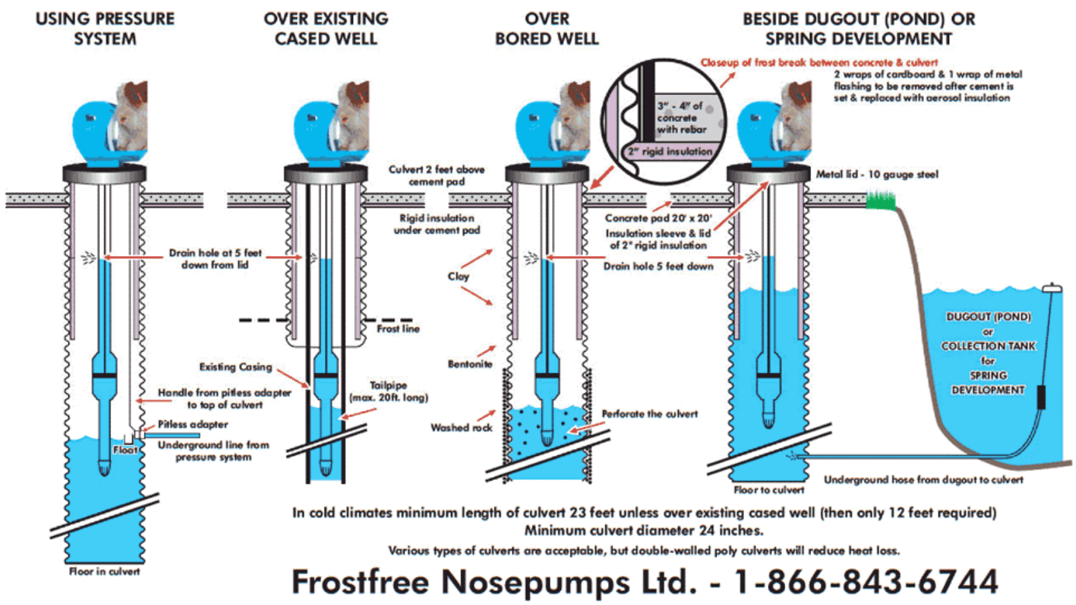

Figure 3. Nose pumps by Frostfree

2. **Nose valves.** The animals push a paddle and pressurized water flows out of a valve.

   One variation of this is the Bar-Bar-A Horse and Livestock Drinker. It works like a frost-free hydrant (with a buried on/off valve) but it is designed for animals. By pushing on the paddle, the animal receives and drinks water. After finishing drinking, the remaining water drains back into the ground – leaving an empty bowl and riser pipe. The following is from their website (https://www.horsedrinker.com/how-to/automatic-waterers-work/). An approximate cost for the "drinker" alone is $520.

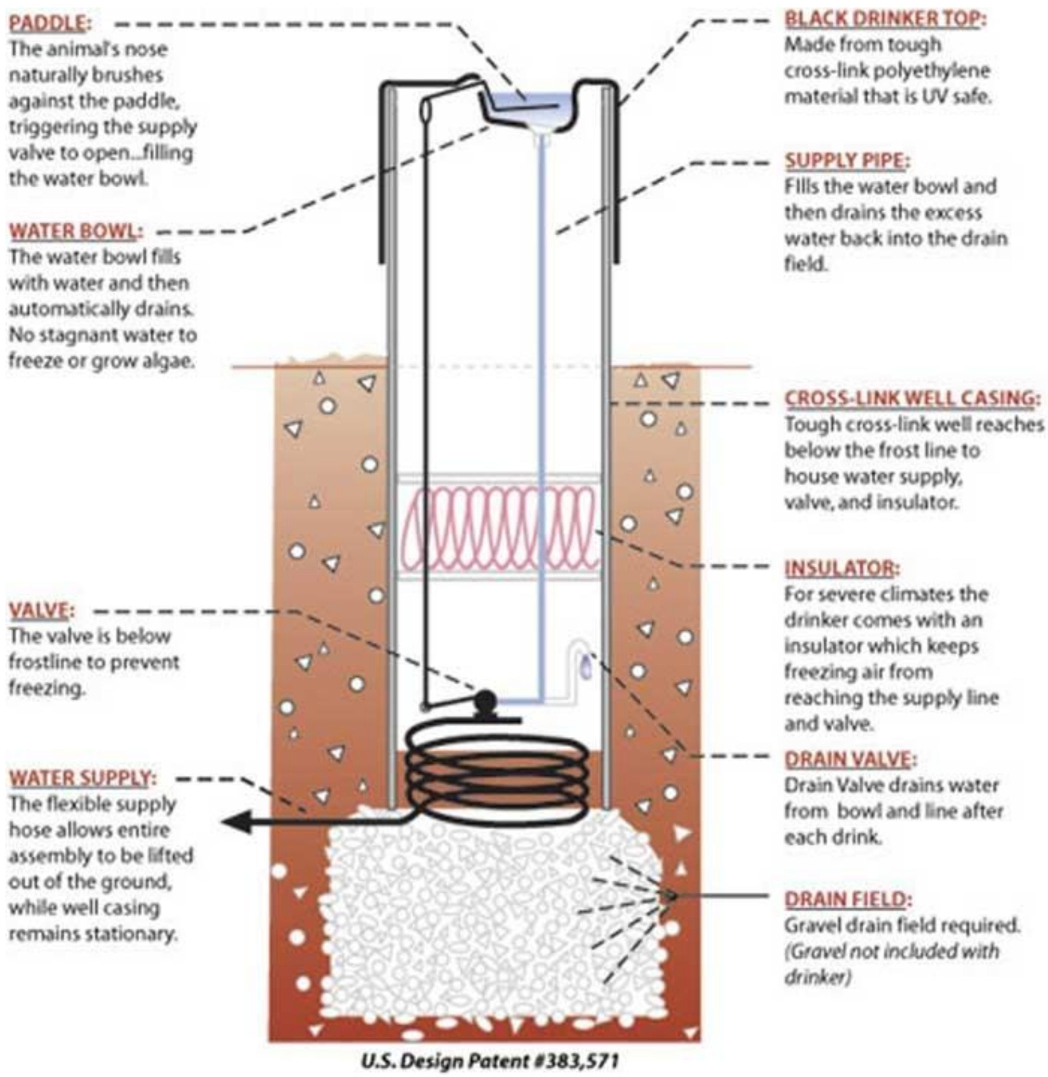

Figure 4. Nose valve by Bar-Bar-A

   A similar option is sold by Thermosink (thermosink@gmail.com). An approximate cost for the double unit (shown below) is $1800, not including installation. The vendor recommends pouring about 1 gallon of mineral oil into the center float container to prevent it from freezing. An advertised advantage of this unit, as compared to the previous Bar-Bar-A unit, is that this does not require drainage.

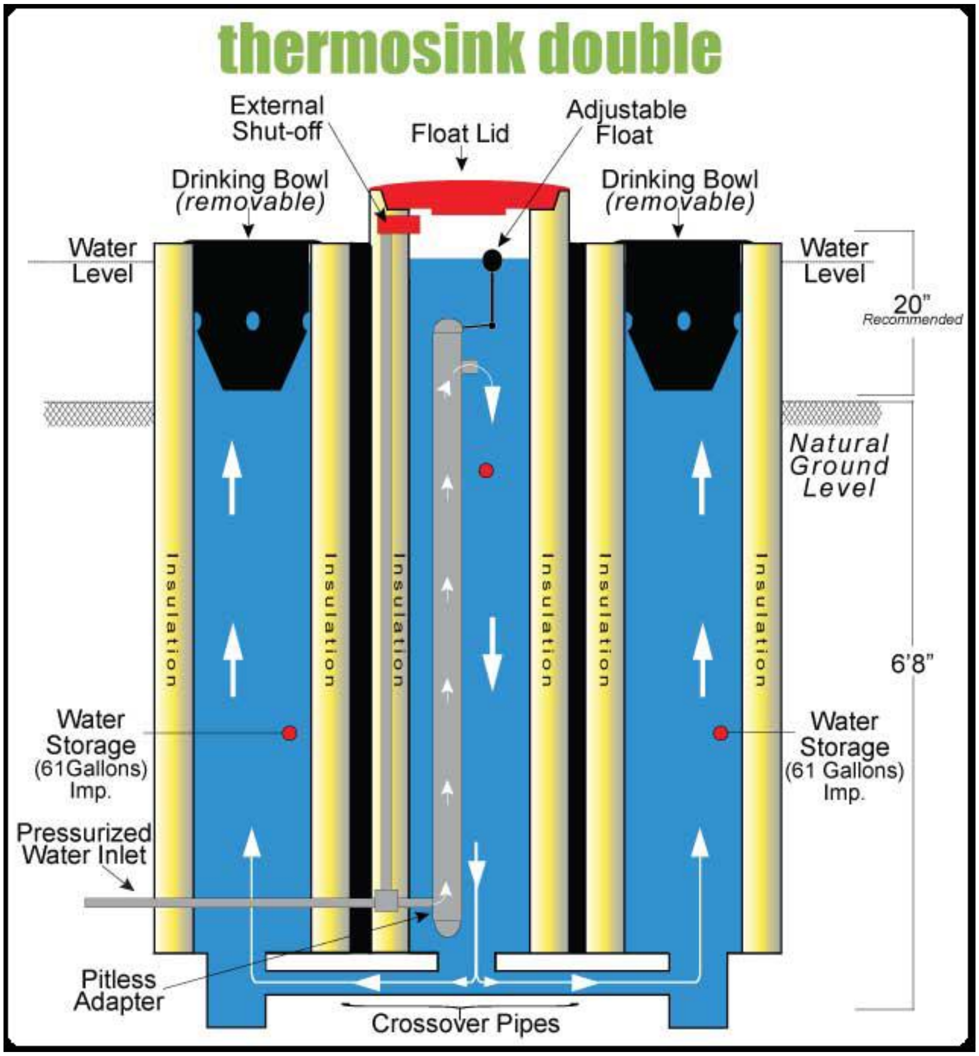

Figure 5. Nose valve by Thermosink

3. **Conventional troughs with constant overflow**. This option requires a fairly large amount of power at the water supply because of the constant overflow. In addition, the overflow needs to go somewhere, which can cause slippery conditions for livestock in the winter and drainage problems in the summer.

4. **Conventional troughs with a float valve, plus some type of heater.** The biggest problem with this setup is getting the electric power to the heater. Solar power is an option for this, but it may be problematic in the winter. Any solar power heating would also need batteries for night-time and cloudy days, which brings up maintenance issues. Extending the electric grid in the valley to all the troughs would be expensive.

Figure 6. Solar unit used to power a trough heater

5. **A special frost-free trough that is supplied with a float valve, but with no heater or electricity**. These have been recommended by university livestock extension specialists in other states. The key factor in these troughs is that they are partially buried. Figure 7 is from a presentation by Terry Bidwell of Oklahoma State University, and shows an example of an installed trough in which the water has not frozen over.

Figure 7. Example of an installed frost proof stock tank

An example of a commercially available trough of this design is the "Super Tanker" manufactured by The Concrete Works, LLC (www.theconcreteworks.com/stocktanks/supertanker.html). The "Super Tanker" is advertised to handle over 70 head of cattle per side with sufficient pressure. It has a float valve with a very large opening.

The entire body of the tank is fabricated out of concrete. Figure 8 shows what the tank looks like. The two concrete flaps are always “up” and are used to hold the soil in place.

Figure 8. “Super Tanker” frost free tank unit from Concrete Works, LLC

Figure 9 shows an installed Super Tanker. At least ¾ of the tank has to be set below grade for insulation. The center portion of the tank is covered with soil for additional insulation.

Figure 9. “Super Tanker” frost free tank from Concrete Works, LLC installed in another location.

Preferred Option. The preferred option was the "super tanker" configuration because of its simplicity, apparent robustness, low pressure requirement (about 5 feet of pressure), and large valve opening.

A minimum of 4 ft of cover will be required above all valves and pipes due to the freezing conditions. This deep burial will also help to keep the water at a reasonable temperature for drinking.

The approximate cost for the double trough and valve is about $800 in large volumes, not including installation. It is envisioned that a double trough would be installed along a fence line, with two double troughs per 80 acres (resulting in two drinking openings per 40 acres).

Water Supply Options. Two different pipeline systems were examined as options to supply livestock water throughout Duck Valley.

1. One option is to have an extensive network of wells and pumps throughout the valley, with each well supplying just a few troughs. However, drilling so many wells is expensive, and an extensive network of electric power lines would be necessary. Plus, very small pumps are much less efficient than larger pumps – meaning that it costs more per acre-foot for power with small pumps than for larger pumps.

   Therefore, the recommended option for pressurized water is to use eight wells, each with about 175 GPM, to supply inter-connected branching pipeline systems. The 175 GPM would only be the maximum flow rate for a few hours per day, and the combined well flows of 1400 GPM has a substantial safety margin in it to account for the fact that cattle will not be spread uniformly throughout the valley.

   The operation of the recommended option is as follows:
   a. This is a demand system. The wells will pressurize water, to supply mainlines and sub-laterals that are piped directly to each trough.
   b. Each 40 acre parcel will have two troughs. The maximum flow rate to each trough will be approximately 2 GPM.
   c. Isolation valves will be used in the event of well maintenance or well pump failure.
   d. If a trough is not used, the water supply to that trough should be shut off, and the trough must be drained to prevent freezing damage.

2. A second option used river water to supply the livestock water pipelines instead of wells. This second option was not recommended because:
   a. Flood flows in the river can cause large debris and ice to show up at the diversion point.
   b. Filters in the river required for the pumps might be susceptible to damage.
   c. The water would be colder, which is not ideal for the cattle.
   d. There would be no redundancy; if the main water source should fail, there would be no other way to quickly shift to another water source.

Cost Estimate

The estimated cost for 10 wells, pumps, PVC pipeline grid, 430 double stock troughs, fittings, installation and a solar system near the DVIP shops to offset power costs was $5 million. The estimated cost for fences and road crossings (to exclude livestock from the main canals) was $381,000. Contingencies, permits, and project management and engineering would be additional costs.

WATER TRANSFERS STRUCTURED TO FUND ON-FARM CONSERVATION IMPROVEMENTS

Steven R. Knell, P.E.[1]

ABSTRACT

The State of California passed legislation in 2009 entitled Senate Bill (SBx) 7-7. That legislation has since been incorporated in the California Water Code as §10608.48. The purpose of the code section is three-fold; (1) To require irrigation districts to accurately measure water to each farm gate; (2) To require irrigation districts to charge volumetrically for each acre foot delivered; (3) To require irrigation districts to implement a wide array of conservation programs and measures that improve on-farm water use efficiency by its water users. This paper will focus on the latter aspect regarding funding of conservation.

Funding in every irrigation district is challenging. It is likely the most challenging aspect of a district's total operation. Water rates for years have been held at a level that met operation and maintenance expenses and hopefully generated enough revenue to do "capital replacement" projects that kept up with the life-cycle needs of a district's infrastructure. Now irrigation districts are being asked to do all that they have done in the past plus advance their modernization efforts to improve water use efficiency, both system wide and on-farm.

Oakdale Irrigation District (OID) developed a Water Resources Plan (adopted 2006) that identified the annual life-cycle replacement costs of its infrastructure at $3.5 million (current dollars). Its modernization costs were pegged at the same, $3.5 million annual expense. None of these costs were, at the time, anticipatory of the requirements of SBx 7-7 and the unfunded cost growers and farmers may have to absorb in meeting on-farm modernization costs.

OID has been successful in using water transfers/sales with willing buyers to fund its infrastructure improvements since 1999. OID's investment in infrastructure have totaled over $55 million during that period. This paper will discuss the benefits and challenges of this business plan and provide new thought on how irrigation water can assist district farmers in meeting their costs of modernization and improved water use efficiency on-farm.

AGRICULTURAL WATER MANAGEMENT PLAN (AWMP) VS. WATER RESOURCES PLAN (WRP)

To address confusion to the reader who may not be from California, there are two types of planning documents that OID has prepared which are discussed in this paper.

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Agricultural Water Management Plan (AWMP)

Agricultural Water Management Plans (AWMP) are a requirements of the Water Conservation Act of 2009 (SBx7-7) and the Governor's Executive Order B-29-15. Prior to 2009, AWMP were voluntary compliance requirements under the Agricultural Water Suppliers Efficient Water Management Practices Act of 1990 (AB3616).

Under the recent 2009 Act, SBx7-7 modified Division 6 of the California Water Code (CWC or Code) and in particular, now requires all agricultural water suppliers to prepare and adopt an AWMP as set forth in the CWC and the California Code of Regulations (CCR) on or before December 31, 2012. AWMPs must be updated by December 31, 2015 and then every 5 years thereafter (CWC §10820 (a)).

Additionally, the CWC requires suppliers to implement certain efficient water management practices (EWMPs). Executive Order B-29-15, issued April 1, 2015 further requires 2015 AWMP updates for agricultural water suppliers serving more than 25,000 acres to include in their Plan a detailed drought management plan describing actions and measures to manage water demand during drought, along with quantification of water supplies and demands for 2013, 2014, and 2015 (to the extent available).

In simple terms, AWMPs in California have turned into an accountability and reporting requirement for agricultural water suppliers to the State. AWMP reporting includes a detailed water balance and accounting of water supply, addressment of climate change impacts, and an addressment of how efficient water management practices, as outlined in the CWC §10608.48, are being accomplished by the water suppliers.

Water Management Plan (WRP)

In 2004, OID embarked on the development of a Water Resources Plan (WRP) which was adopted by the Board in 2006. The purpose of the WRP were set out in four stated goals;

- Provide long-term protection of OID's water rights.
- Address federal, state and local challenges.
- Rebuild and modernize an out-of-date system to meet changing customer needs.
- Develop affordable ways to finance improvements.

The WRP was an introspective look by OID's Board of Directors at where OID was at; how to move forward with a proactive strategy to meet regulatory challenges; evaluate the state of its water delivery system and develop an affordable financial plan to pay for those necessary improvements

In this paper, the reader will see references to changes in water balances from different AWMPs and also associated statements to WRP activities in accomplishing the financing of various aspects of improvements in the OID system.

BACKGROUND

History of OID

In 1909 OID was organized under the California Irrigation District Act by a majority of landowners within the district in order to legally acquire and construct irrigation facilities and distribute irrigation water from the Stanislaus River (ref. Figure 1). In 1910 OID and the neighboring South San Joaquin Irrigation District (SSJID) purchased Stanislaus River water rights and some existing conveyance facilities from previous water companies. Both districts continued to expand their operations over the ensuing decades.

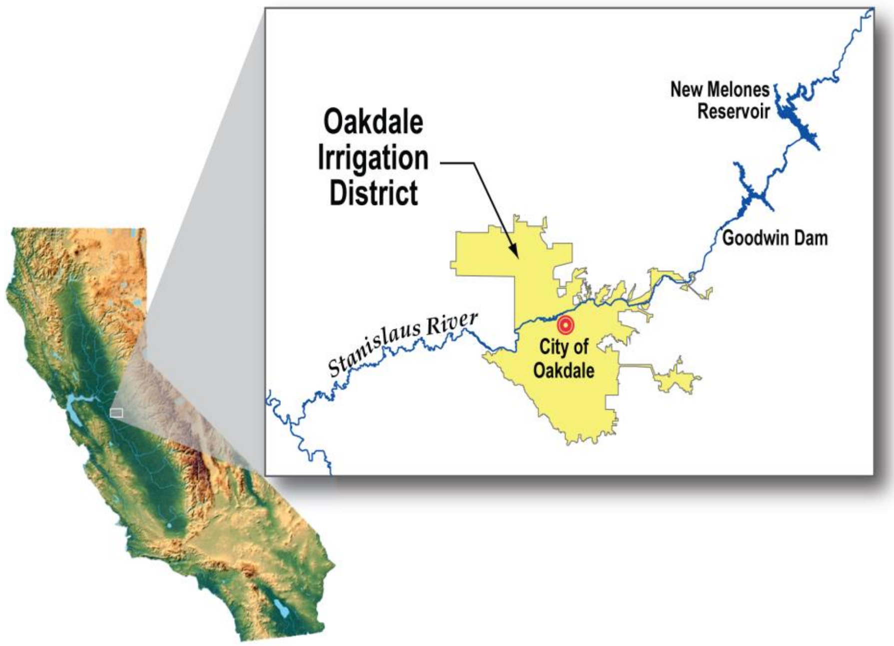

Figure 1. Location of Oakdale Irrigation District

Since their creation, OID and SSJID have constructed dams and reservoirs to regulate surface water storage and deliveries. Most dams were constructed in the 1910s and 1920s, including Goodwin Dam (1913), Rodden Dam (1915), and Melones Dam (1926), which provided 112,500 acre-feet (ac-ft) of shared capacity. To provide supplemental water storage for OID and the SSJID, the Tri-Dam Project was created in the 1940s. Sites were approved in 1948 for Donnells Dam and Beardsley Dam on the Middle Fork of the Stanislaus River, and for Tulloch Dam above Goodwin on the main stem of the Stanislaus River. The two districts entered a joint agreement to carry out the proposed project and now jointly own and operate the three storage reservoirs for a combined storage capacity of 230,400 ac-ft.

In the early 1970s the Bureau of Reclamation (Reclamation or Bureau) replaced the Melones Dam with the larger New Melones Dam and Reservoir. The districts have an operations agreement with Reclamation to utilize the federally owned New Melones Reservoir for the delivery of its senior water rights.

These historical capital investment has led to a stable, plentiful water supply for the district. Over the last 50 years, the district has focused its financial resources principally on paying off these capital investments; as a result, the district has invested little in replacement, modernization, automation or rehabilitation of its existing system over the years. That focus changed in 2004.

The District Today

Currently, the district maintains over 330 miles of laterals, pipelines, and tunnels, 29 production wells, and 43 reclamation pumps to serve local customers. Refer to Figure 2 for more details about OID.

OAKDALE IRRIGATION DISTRICT FACTS

Year OID was organized: 1909

Total district acreage: 80,900

Total irrigated acres: 65,000

Annual diversion right: 300,000 acre feet

Diversion point: Goodwin Dam

Maximum diversion rate from Goodwin Dam: 910 cfs

Total distance of water delivery system: 330 miles of canals (open, lined, and buried pipelines)

Number of agricultural wells: 24

Number of agricultural water accounts: 2,900

Percent of OID agricultural customers who farm parcels of 10 acres or less: 60 percent, constituting 12 percent of OID land

Percent of OID agricultural customers who farm parcels of 40 acres or more: 4 percent, constituting 60 percent of OID land

The combined storage capacity for Tulloch, Beardsley, and Donnells Reservoirs: 230,400 ac-ft

Combined power generation of hydro-electric facilities: 100,000 KVA

Figure 2. OID Facts

In general, the district's facilities, system operations, political organization, and administration have not changed significantly over the last several decades. Nearly all water supply canals were constructed more than 100 years ago. In recent years however, the district's customers, land use, and financial resources have developed in a direction that is influencing the way OID provides services and conducts business.

Oakdale Irrigation District (OID) provides pre-1914 water rights to over 65,000 acres of irrigated farmland located within the northern San Joaquin Valley of California. Initiated in November 2004 and completed in June 2007, OID developed a Water Resources Plan (WRP) as a strategic roadmap for addressing its future infrastructure and modernization needs. Since Plan development the district has been moving forward with the implementation of a $170 million capital improvement program to meet the multifaceted needs of the district. Those needs as outlined in the WRP include the protection of the

District's water rights; an increase in agricultural water supply reliability during droughts; protection for the local area's surface and groundwater supplies; along with a roadmap to modernize and rebuild a century old system to meet the needs of its changing customer base. Regional water transfers have been used as the basic funding mechanism to make this all happen.

OVERVIEW OF WATER TRANSFERS

History of Water Transfers at OID

OID began transferring water in 1999 through two separate contracts. One to Stockton East Water District (SEWD) for their treatment and delivery to the City of Stockton and one contract to the United States Department of Interior, Bureau of Reclamation. A portion of water under the Bureau contract was for use in a fish study called VAMP (Vernalis Adaptive Management Plan) and the second portion of that contract was for ancillary water to meet dissolved oxygen and salinity objectives at Vernalis as required under Reclamation's operating permit from the State of California for New Melones Dam and also for miscellaneous fish flow needs.

These two contracts at inception in 1999 had 10 year terms with renewal clauses that effectuated their ending dates in the fall of 2010 for SEWD and in 2011 for the Bureau. In 2009 OID made a water sale to the San Luis & Delta Mendota Water Authority (SLDMWA) and in each year from 2013-2016 OID made a water sale to the SLDMWA and the California Department of Water Resources (State Water Contractors).

Over the course of these transfer years OID moved 639,650 acre feet of water and generated a revenue stream totaling $69 million dollars. On average the aggregate price of water marketed was just over $108 per acre foot on these contracts. The cost of water to purchasers ranged from $60 to $400 dollars depending on circumstances, hydrology and "market."

Water Markets Available to OID

There are three types of water markets OID has been involved with over the years. Each market has a different ability to pay and comes with a different set of politics.

High End Metropolitan Areas: These markets come with a high capacity to pay but in-district politics for completing such transactions can be difficult. Water kept locally serving local needs is a common public response to these types of contracts and is not without merit. However, the benefit in marketing to high-end metropolitan areas is the potential for high returns with the least amount of water being transferred. Despite the desire to keep water local, water agency budgets still have to be met and water transfer revenues are a significant part of the OID's budget. With that perspective though, balancing the financial needs of the district and the needs of the local community is the driver of discussions at the local level.

Local / Regional / Municipal Areas: These markets are only now developing. For many years, the local and regional areas have relied on a seemingly abundant availability of both surface and groundwater supplies that has now become less than reliable in the San Joaquin Valley. With the implementation of the Groundwater Sustainability Act (2014), Senate Bill x7-7 (2009), changes to the arsenic rule, rising nitrate contamination, salt water intrusion and groundwater degradation from years of overdraft, etc. local and regional markets are now beginning to seek both diversification and reliability in their future water supplies.

Agricultural Market Areas: This local agricultural market's capacity to pay is simply defined and premised on what makes business sense. This market compares the cost OID is seeking and compares that against the cost of pumping groundwater. In the area east of Oakdale, where agricultural is expanding solely on the reliance of groundwater, that current cost is approximately $60-$80 per acre foot, depending on depth to groundwater. While the market is easy to define, the cost conscientious farmers in the area, despite long term sustainability questions, still have little interest in paying more for surface water if the cost to pump groundwater is less.

Markets on the westside of the San Joaquin Valley, which rely on Central Valley Project (CVP) water or groundwater, if insufficient CVP water available, have a different perspective. Groundwater on the westside can be as deep as 200-400 feet and is costly to pump compared to CVP water if and when it's available. This market and the capacity to seek transfers or water sales to reduce groundwater pumping has grown in recent years. That value has increased substantially during the 2012-2016 drought.

Environmental Market Areas: Purchase of water to meet environmental needs was a premise for the original Bureau of Reclamation contracts mentioned previously. In two of the latest OID water transactions to the SLDMWA/DWR, water was released on a fish friendly schedule as part of a pulse flow. While not a direct payer for the benefit, the ability be have both water moved downstream to agricultural buyers on a fish-friendly schedule is an opportunity that needs greater consideration.

The Water Market End Game: The end game in water transfers/sales is always to provide the maximum protection to the district's water rights and to insure reliable, adequate water deliveries to the farming community of the district before any water is marketed outside. Meeting that goal may best be met by having equal participation of water sales in a mix of market areas. Again, meeting the district's financial goals for revenues and funding of its required and legislatively mandated CIP programs being on the forefront of those decisions.

IMPROVEMENTS IN WATER USE EFFICIENCY

As outlined in OID's Water Resources Plan (WRP), revenues derived from water transfers were directed at making infrastructure and modernization changes in OID's water delivery system. Those changes significantly improved OID's capacity to deliver water more efficiently and with better control, thereby enhancing customer service.

As an indicator of the change in OID water use we turn to comparisons of OID's 2001 Agricultural Water Management Plan and its 2016 update, both submitted to the Department of Water Resources in compliance with the Agricultural Water Suppliers Efficient Water Management Practices Act of 1990 (AB3616). Figure 3 below represents the "demand water" required in 2001 versus the change in that demand water in Figure 4, which represent the aggregate of data from 2005 – 2014 water years, as was used in the 2016 updated plan.

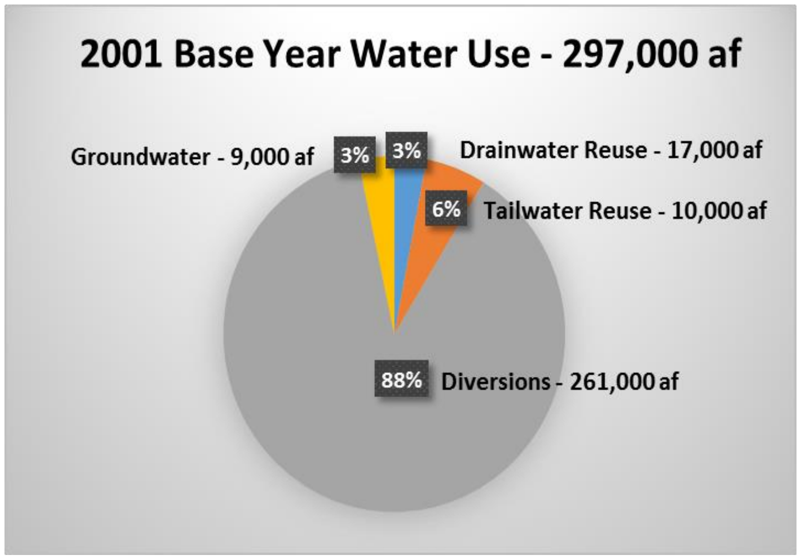

Figure 3. Data from OID's 2001 Ag Water Management Plan

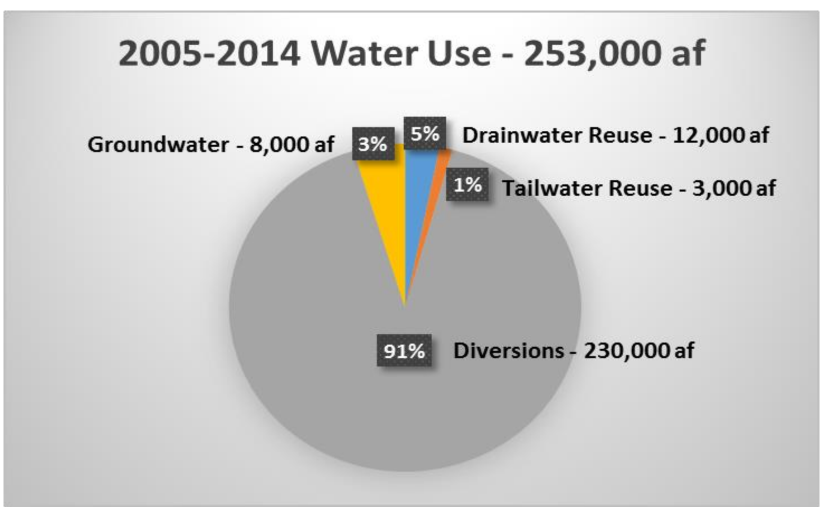

Figure 4. Data from OID's 2016 Ag Water Management Plan

Over the periods of time covered by the Ag Water Management Plans OID has been able to reduce its annual water demand by 44,000 acre feet. As one drills down into the details of that change in usage you find the following caveats that make up that number:

- A change in Consumptive Use: OID, like many Central Valley irrigation districts, has seen a significant conversion to permanent crops. Conversions of pastureland to tree crops has been a part of the OID land use changes. Estimates in 2001 were that ET of applied water was about 147,000 acre feet. In the 2016 updated Ag Water Management Plan that number moved down to 124,000 acre feet.

- A reduction of farm runoff: This is a result of two factors. One being the conversion of pastureland to trees. With that conversion comes the installation of drip/micro systems being installed in much of these orchards, reducing or eliminating runoff. The other factor is the ability by OID to provide better water service to the farm-gate due to the enhanced control provided by the modernization of its delivery systems.

  It is difficult to achieve high water use efficiency on-farm if water deliveries from the irrigation district lack flexibility in the frequency, rate and duration of those deliveries. The more efficiently an irrigation district can deliver water to the farm the more efficient the farm can be in the application of that water.

- A reduction in Operation Spills: Likely the biggest benefit to reducing system losses can be seen in the reduction of operation spills in OID's delivery system. The enhanced water control afforded by automation reduced spills from 50,000 acre feet in the 2001 Base Year to just over 15,000 acre feet in the 2016 update.

  The addition of two regulating reservoirs during that period was also instrumental in providing the necessary main canal control of diverted water.

WHERE THE MONEY WAS SPENT

Between 2006 and 2014, the study period for the 2016 Ag Water Management Plan, OID completed more than 510 individual capital improvement projects, including 175 projects since 2012. Total costs by improvement category between 2006 and 2014 are summarized in Table 1. Total expenditures during that period were more than $46 million, with more than $7.1 million in improvements completed since 2012.

While no two irrigation districts are alike, a telling note to OID's infrastructure and modernization needs can be seem from where OID spent the revenues derived from water transfers/sales. Table 1 below is an itemization of those expenditures as accounted for between 2006 through 2014.

Table 1. Itemization of Expenditures of Water Transfer/Sale Revenues

Expenditure Category	Expenditure (Millions)
Canal Rehabilitation	$ 5.71
Flow Control and Measurement	$ 8.43
Deep Well Replacement/Rehabilitation	$ 0.97
Pipeline Replacement	$ 6.77
Turnout Replacement	$ 1.48
Outflow Management	$ 0.29
Reclamation System Rehabilitation	$ 1.41
Main Canal and Tunnel Rehabilitation	$14.86
Northside Regulation Reservoir	$ 6.32
Misc.	$ 1.25
Total	$46.49

Projects within any given improvement category may include components of other improvement categories. For example, canal and lateral rehabilitation project costs and pipeline replacement project costs often included turnout replacement. For purposes of this paper, those project costs have not been separated out, hence some of these costs do include component parts of other categories.

These goals include rebuilding and modernizing the OID distribution system to improve water supply reliability while also improving operability and operation of the system. Improved operation is expected to result in reduced losses primarily to spillage. Additionally, the quality of delivery service to customers continues to improve, including increased delivery steadiness, improved delivery measurement, and increased flexibility in water ordering and delivery to customers.

While not constructed during the 2006 to 2014 period, a significant benefit to water delivery improvements on the south side of OID's service area, was the construction of the Robert Van Lier Regulating Reservoir in 2001-2002 at a cost of $5.5 million.

CONCLUSIONS

OID is developing plans for the next phases of projects that will further advance conservation in its service area. OID is evaluating the feasibility of and pursuing funding opportunities for recycling tertiary treated M&I discharge from the City of Oakdale into its delivery systems and the total automation of various aspects of its canal system using Rubicon™ Total Channel Control (TCC) technology.

As has been the case since 2006, when OID's Water Resources Plan (WRP) was adopted, projects to be implemented will be based on the specific needs of OID and its customers to maximize cost-effectiveness and to achieve supply reliability and operational benefits within available budgets. As part of the WRP, OID has pursued opportunities for water transfers across multiple potential water markets. These markets include agricultural markets (e.g., existing, adjacent agricultural groundwater users), local and regional areas (e.g., nearby municipal and industrial water users), and metropolitan areas. By evaluating and implementing transfer opportunities across a range of markets, OID has thus far been able to meet the financial requirements of implementing the WRP while also maximizing the local beneficial use of available surface water supplies.

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OPERATION, MAINTENANCE, AND REPLACEMENT RESERVES ON THE BONNEVILLE UNIT, CENTRAL UTAH PROJECT

Reed R. Murray[1]
Rich Tullis[2]

ABSTRACT

The Central Utah Project (CUP) located in the central part of Utah is the largest water resources development effort ever undertaken in the State. The project provides Utah with the opportunity to beneficially use a portion of its allotted share of the Colorado River water through a transbasin diversion. The CUP was originally divided into several units, of which the Bonneville Unit was the largest and last to be completed. The Central Utah Water Conservancy District (CUWCD) is the project sponsor and is responsible for the construction, operation, maintenance and replacement (OM&R), and repayment of the Bonneville Unit. The CUWCD incurs direct and indirect costs required for OM&R of the Bonneville Unit. These costs are reimbursed by CUWCD customers including the United States which is obligated to pay for the cost of Bonneville Unit OM&R allocated to Fish and Wildlife and Flood Control purposes. In addition to regular OM&R the CUWCD also addresses replacement of aging infrastructure with reserve accounts established in 1965 specifically for replacement. In 2005, the CUWCD began Asset Management Program to evaluate future replacement needs of all its facilities. Several groups began to call for all water costs including future development to be paid for through water user fees. In 2013, The Utah State Legislature, feeling pressure from these groups, enacted the "Water Conservancy District Capital Assets Bill." This Bill requires certain water organizations, including the CUWCD, to implement a capital asset plan and establish a reserve account to fund the future replacement of facilities. The necessity for addressing facility needs comes at a time when all levels of funding, federal, state, and local are facing severe budget restrictions. The CUWCD's evaluation has led to a prioritization and ten-year schedule of facility repair, rehabilitation, and replacement. Costs associated with the new schedule have substantially increased the reserves bill to CUWCD customers. The CUWCD's Asset Management Program and Reserve Account illustrates one approach to address the problem of aging infrastructure.

INTRODUCTION

The first known development in Central Utah by non-Native Americans occurred in 1822, when a group of fur traders established a trading post at Utah Lake, known as Fort Ashley.

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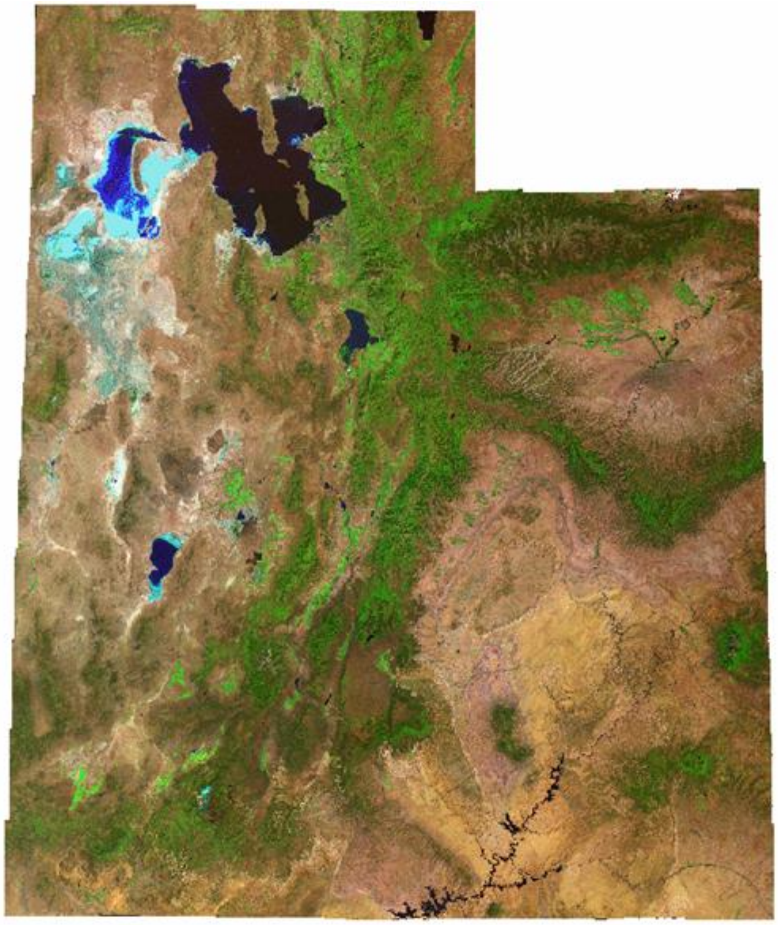


Figure 1. State of Utah

Non-native American settlement of Utah's Salt Lake Valley began in 1847 by Brigham Young and the Mormon[i] pioneers. See Figure 1. Under Brigham's leadership, the pioneers began the first large-scale irrigation system in the United States, they learned however, that streams entering the Salt Lake Valley from the Wasatch Mountains did not maintain sufficient flow to support large-scale irrigation. Eventually they looked to the Uinta Mountains where the larger Weber, Bear, and Provo Rivers originated.

During the 1880's, as the nation's population increased, leaders thought of the western United States as a tremendous opportunity for expansion and immigration. Congressional actions followed with bills such as the Reclamation Act of 1902 which established a fund from the sale of Western Lands to be used in the "examination and survey for and the construction and maintenance of irrigation works for the storage, diversion, and development of water for the reclamation of arid and semiarid lands in the said States and Territories, and for the payment of all other expenditures provided in this act."[ii] At the time, the nation was strongly in favor of development of western water resource development.

Congressional authorization followed the 1902 Act for Bureau of Reclamation. These included the Strawberry Valley Project, Uintah Indian Irrigation Project, Provo River Project, and Moon Lake Project. Then in 1956 the Colorado River Storage Project Act (CRSPA) was enacted which authorized construction of Dams on the Upper Colorado River including Flaming Gorge and Lake Powell. CRSPA also authorized participating projects including the CUP. The CUP was divided into six units with the Bonneville Unit as the largest and most comprehensive. See figure 2.

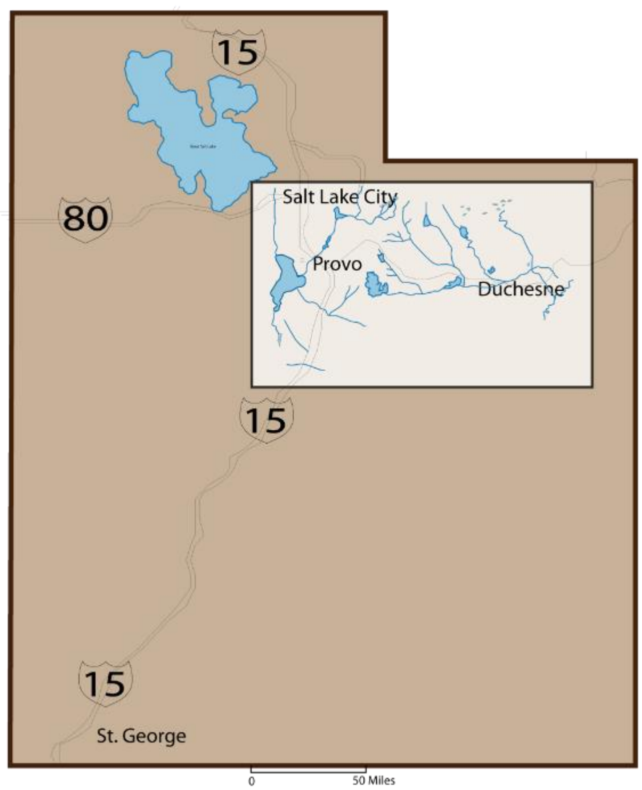


Figure 2. Bonneville Unit Location

As planning for the CUP was being refined by Reclamation, local support for the project was clearly evident. The Governor, Legislature and the Utah Water and Power Board were instrumental in creating the CUWCD.[iii] A report entitled the Bonneville Unit Definite Plan Report (DPR) was published and submitted to Congress in August 1964. The DPR provided details regarding planning and development of the Bonneville Unit. Congress appropriated funds and construction began soon thereafter.

OPPOSITION TO WATER DEVELOPMENT

Not everyone was enthusiastic about water development in Utah. Beginning in the mid-1960s, environmental concerns about the CUP began to appear from local outdoor groups. Environmental awareness was also growing around the nation, which resulted in enactment of the National Environmental Policy Act of 1969 (NEPA) and the

Endangered Species Act (ESA). The Utah issues eventually caught the attention of national organizations such as the Sierra Club. Their main concerns centered on the proposed diversions from streams in the Uinta Basin in eastern Utah.

In 1973, Reclamation released the Bonneville Unit Final Environmental Impact Statement. The document was a programmatic environmental impact statement for the entire Bonneville Unit. Concerns were raised over the programmatic approach of the document. In 1974 the United States District Court ruled that the Bonneville Unit Final EIS was in compliance with NEPA, and this decision was upheld by the United States Tenth Circuit Court of Appeals. However, Reclamation committed to prepare a site-specific EIS for each of the remaining Bonneville Unit Systems before initiating construction.

During the 1980's the authorized ceiling for the central Utah Project was nearing its limit. This required local leaders to seek additional federal spending authority of the Central Utah Project. On October 30, 1992, the Central Utah Project was re-authorized under the Central Utah Project Completion Act (CUPCA). Among other things, CUPCA increased the authorized spending limit for the CUP and gave responsibility to the CUWCD to complete the project.

The primary purpose of CUPCA is to provide for the orderly completion of the CUP by increasing the appropriations ceiling, by authorizing certain water conservation and wildlife mitigation projects, and by providing funding for construction of certain project features for delivery of water for irrigation, municipal and industrial use, and instream flows for fisheries to specified areas

FUNDING OPERATION, MAINTEANCE AND REPLACEMENT

For decades' water managers throughout the country focused on the original capital investments of water projects. As facilities came online, water managers began to realize that they were facing a substantial financial burden to sustain the infrastructure that had been constructed. In 2004 the American Water Works Association (AWWA) commissioned two reports through their Water Utility Council: *"Dawn of the Replacement Era: Reinvesting in Drinking Water Infrastructure"* and *"Avoiding Rate Shock: Making the Case for Water Rates."* These reports were a call to action for water managers to take inventory and assess the future needs of aging infrastructure.

"Ultimately, the rate-paying public will have to finance the replacement of the nation's drinking water infrastructure either through rates or taxes. AWWA expects local funds to cover the great majority of the nation's water infrastructure needs and remains committed to the principle of full-cost recovery through rates."[iv]

As water managers attempted to address aging infrastructure, they found it was not a simple matter to gain political and public support to fund the replacement of facilities. Increasing water charges for any reason is a difficult step to take.

Advisory Team. As part of Utah's effort to address these issues, Utah's Governor appointed a Water Resource Advisory Team in 2013 to bring all parties together to create a strategic water planning roadman. In July 2017, the state released its "Recommended Water Strategy" report which was prepared by the Advisory Team after four years of effort. The report offers 93 recommendations regarding the future of water in Utah. One of the topics discusses assessing, replacement, and funding aging infrastructure.

Legislative Action. An audit of the CUWCD by the State Legislature was conducted in 1989 and again in July 1999. The audits were critical of the use of property tax payments for water development and instead encouraged that users bear the cost through increased water rates.

The legislature focused on the four largest districts in the state; Jordan Valley Water Conservancy District (JVWCD), Weber Basin Water Conservancy District, Washington County Water Conservancy District, and the CUWCD. In 2013, Senate Bill 276 was enacted titled the "Capital Asset Assessment, Maintenance, and Replacement Policy" which requires water conservancy districts with annual operating budgets greater than $5 million to adopt a policy for and prepare reports on the district's qualified capital assets. It also requires the districts to allocate sufficient funds in a multi-year capital asset plan for repair and replacement of capital assets.

Early drafts of the bill required water districts to report to the State Legislature every five years regarding asset management and replacement funding. After discussion with the water districts, the final bill instead requires water districts to report to the Division of Water Resources. The first plans are well underway and will be delivered to the Division before the end of 2017.

Another audit was launched in 2015 by the State Legislature. This audit questioned the accuracy of the Projections of Utah's water needs. It was critical of the States planning for water and recommended a new focus on the reliability of water use data, conservation goals, and growth in future planning.

The state Legislature responded to the audit during the 2016 General Session with 14 water related bills and joint resolutions. Eight of these were passed and signed by the Governor. These bills cover a variety of topics, including water rights and law, infrastructure funding, pricing, accuracy of water data, metering, and quality.

Division of Water Resources. In 2010, the Utah Division of Water Resources published a report "The Cost of Water In Utah – Why are our water costs so low?" The report discussed the success of water managers and suppliers in keeping the municipal and industrial water charges affordable. The report acknowledged that water development in Utah has been successful due to the availability of high quality water, available agricultural water that could be converted to M&I use, and available funding from state and federal sources. Speaking on water charges the report states:

"With the steady increase of population and the need to meet the water requirements of its future population, Utah's relatively inexpensive water sources will need to be supplemented with more expensive sources. This will cause the cost of water to steadily increase. However, even with proposed expensive water projects, because of Utah's unique climate, geography and other factors discussed in this report, average water bills are likely to remain below those of other areas of the west and the nation."[v]

In 2014, a statewide water infrastructure plan was developed by the Utah Division of Water Resources, and water conservancy districts that showed that a large amount of funding would be needed for the development and management of water resource projects. The plan indicated that $33 billion was needed statewide for water resources. The establishment of a fund was meant to be seed money to be added to by other resources. The fund would include $15 billion for new development and $18 billion for repair and replacement. This plan was meant to be updated periodically with the next update due in 2017 in time for the legislative session.

Environmental groups, who were long opponents of water development were critical of the report and found an opportunity to use the costs of water and taxing authority to pressure the state legislature and local governments to oppose water development. Despite the fact that the infrastructure plan was released to the public for review and comment, an environmental media campaign included an opinion article which stated:

"These four government agencies are the Jordan Valley, Central Utah, Weber Basin and Washington County Water Districts. They collect your property taxes and water bills, but ignore your calls for lower taxes and less spending. Because these agencies have virtually no democratic oversight, they don't care what you think."[vi]

In response, David Eckhoff, of the American Society of Civil Engineers said:

"…our conservancy districts operate on honesty and open book policies. Future major water projects will require investments beyond the capabilities of current funding mechanisms. The creation of a special fund to accommodate these projects is a necessary and transparent means to accomplish them."[vii]

Prepare 60. By 2016, the Division of Water Resources together with the largest water conservancy districts released a Statewide Water Infrastructure Plan and established a center called "Prepare 60".[viii]

The Prepare 60 Center states "Our Mission is to Ensure that Utah Has a Sustainable Water Supply into the Future." The Center's objectives is:

- Protect What we Have: Repair and Replacement of Aging Infrastructure
- Use it Wisely: Water Conservation Initiatives, state goal, 25% by the year 2025
- Provide for the future: New water supplies are vital

The statewide plan lays out a detailed, decade by decade schedule of tasks that includes a combination of repair and replacement of aging water infrastructure and the development of new infrastructure and water supplies throughout the state. The plan estimates the cost to be $33 billion. Nearly half of the funds would be allocated for new development. But $18 million would be used to replace aging infrastructure, such as dams, treatment plants, power plants, and thousands of miles of canals, pipelines and tunnels.

The plan calls for the $33 billion fund to be covered by the water conservancy districts, who would provide for roughly 50 percent, with the remaining 50 percent divided among municipalities, cities, a new state revolving loan fund, and existing Department of Water Resources funds. The investment would be repaid with interest by water users.

CUWCD RESERVES

In 1965, a Repayment Contract was executed between the CUWCD and United States to provide for the repayment of the facilities constructed under the Central Utah Project. The contract also addressed OM&R responsibilities and required the CUWCD to maintain a Replacement Reserve Fund for replacement of the facilities constructed under the Central Utah Project. A separate account, an Emergency Reserve Fund, was also required to be established and to maintain $325,000 in the fund at all times.[ix] The funds were to be established by assessing water users a minimum of 10 cents per fund for each acre-foot of water. CUWCD realized that the reserve charges required in the 1965 Repayment Contract funds may have been adequate in the 1960's but would be insufficient to provide replacement of facilities in the future. CUWCD incrementally increased the funds reserve charges up to $3.00/acre-foot by the year 2016.

Development of the CUP provided much needed water for irrigation, M&I, and other purposes. At the same time, year after year the project added new assets to be maintained. CUWCD has maintained records regarding exiting assets and replacement needs. These records were based on institutional knowledge and regular OM&R reviews of facilities. With the CUP under construction since 1964, major facilities were now approaching the end of their life cycle creating an even larger concern for replacement needs.

Over many years, CUWCD investigated aging infrastructure, inventory of assets, and establishment of adequate reserve funds for infrastructure replacement. There are $3.4 billion in assets managed by CUWCD. This includes federal and non-federal assets.

CUWCD Staff and Board of Trustees discussed the options for increasing reserve charges to pay for replacement of aging infrastructure. Although the CUWCD asset management program will show the need for increasing water fees, the Board was concerned about impacts to the water users. The AWWA refer to water rate impacts as the Rate Shock Index[x] to illustrate the point at which increased charges would be detrimental to the water users as shown in Figure 3.

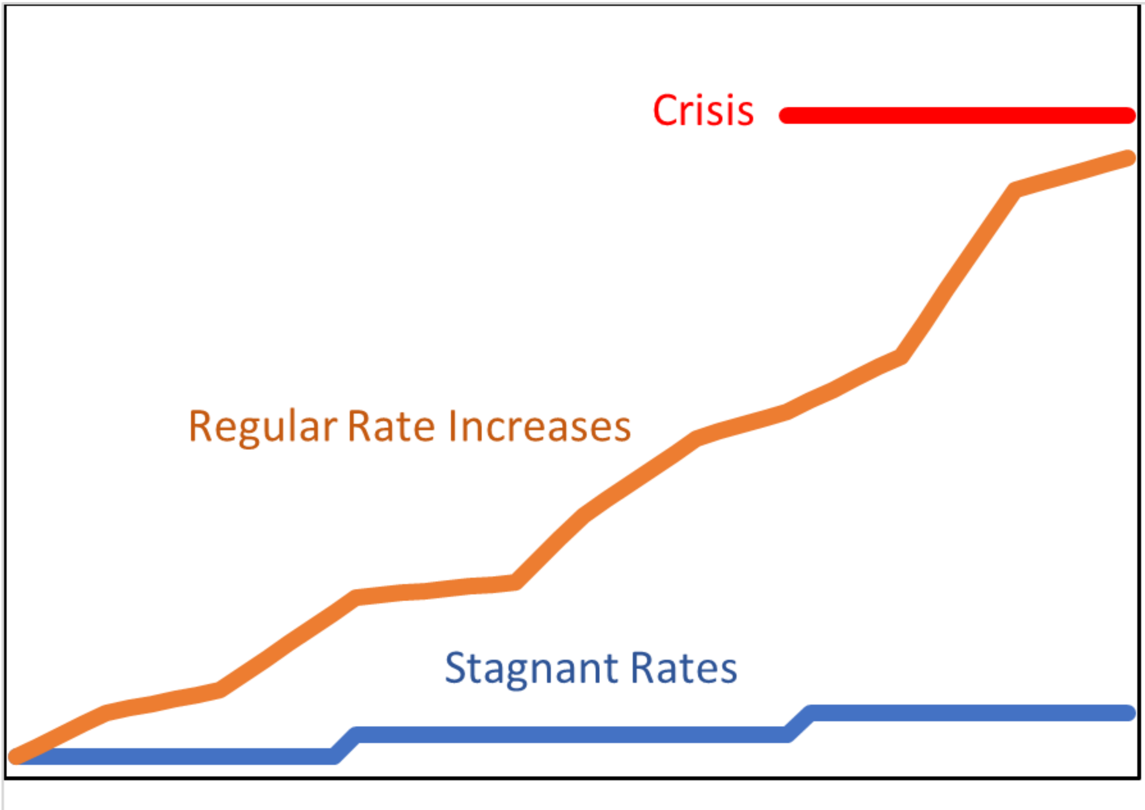


Figure 3. Rate Shock Index

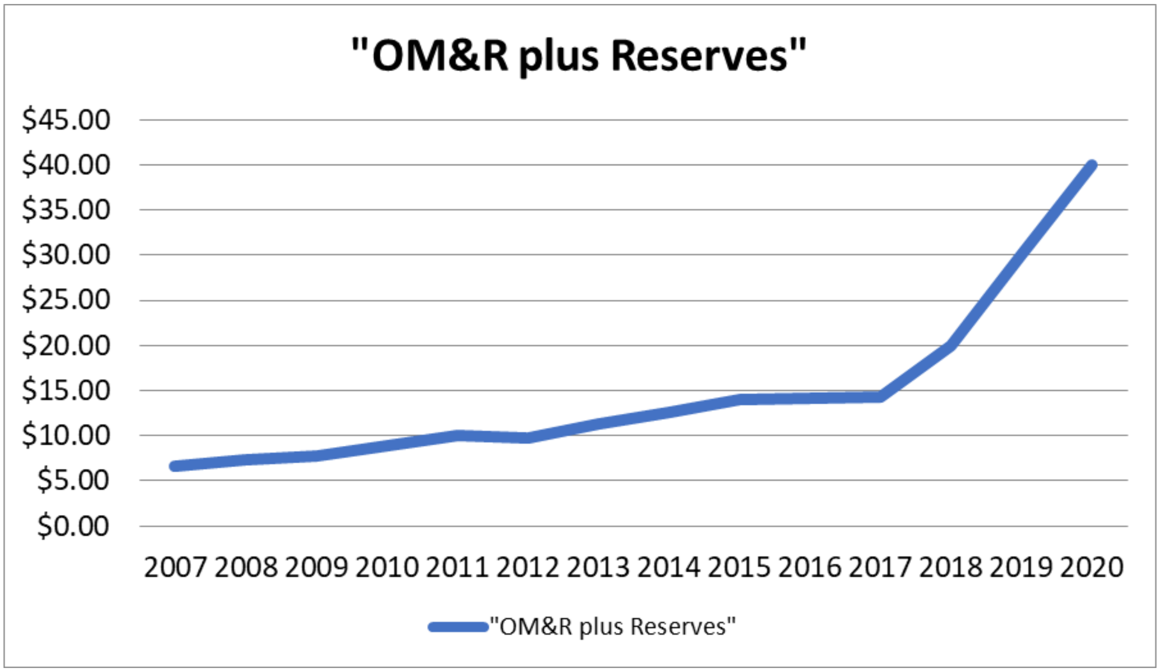
One of the issues the Board struggled with was how to drastically increase charges while not stockpiling millions in reserves without having a clear schedule of needs. At the May 2017 Board Meeting, the CUWCD Board of Trustees passed Resolution 2016-05-10 establishing a policy for increasing the reserve charges as part of the pricing structure on project and non-project water supplies. This policy set a new reserve charge for the period of 2017 through 2020 with the understanding that the Board, with staff recommendations, would evaluate and adopt an updated policy by the end of 2019. The policy placed a cap of the maximum allowable reserve charge plus OM&R of $50/acre-foot. These charges would have an immediate impact on municipal water users as the OM&R Rates combined with the newly increased reserve fee would be incrementally increased to $50 by the year 2020. See Table 1.

IMPACT TO FEDERAL PARTNERS

Payment for development the Central Utah Project is the responsibility of CUWCD based on an allocation of project purposes. CUWCD is required to repay the costs of irrigation, municipal, and industrial allocations. The remaining fish and wildlife and flood control purposes are considered con-reimbursable. Payment for OM&R follow the same allocation with CUWCD responsible to cover the reimbursable portion and the United States to pay for the non-reimbursable portion.

In addition to the impacts from the charge increase to municipalities, the increase would have significant impacts to the three federal agencies associated with the Central Utah Project: Department of the Interior CUPCA Office, Bureau of Reclamation, and the Mitigation Commission. The three agencies agreed to pay the non-reimbursable portion of OM&R in accordance with the 2004 Bonneville Unit Definite Plan Report for the Bonneville Unit.

Table 1. OM&R Plus Reserves

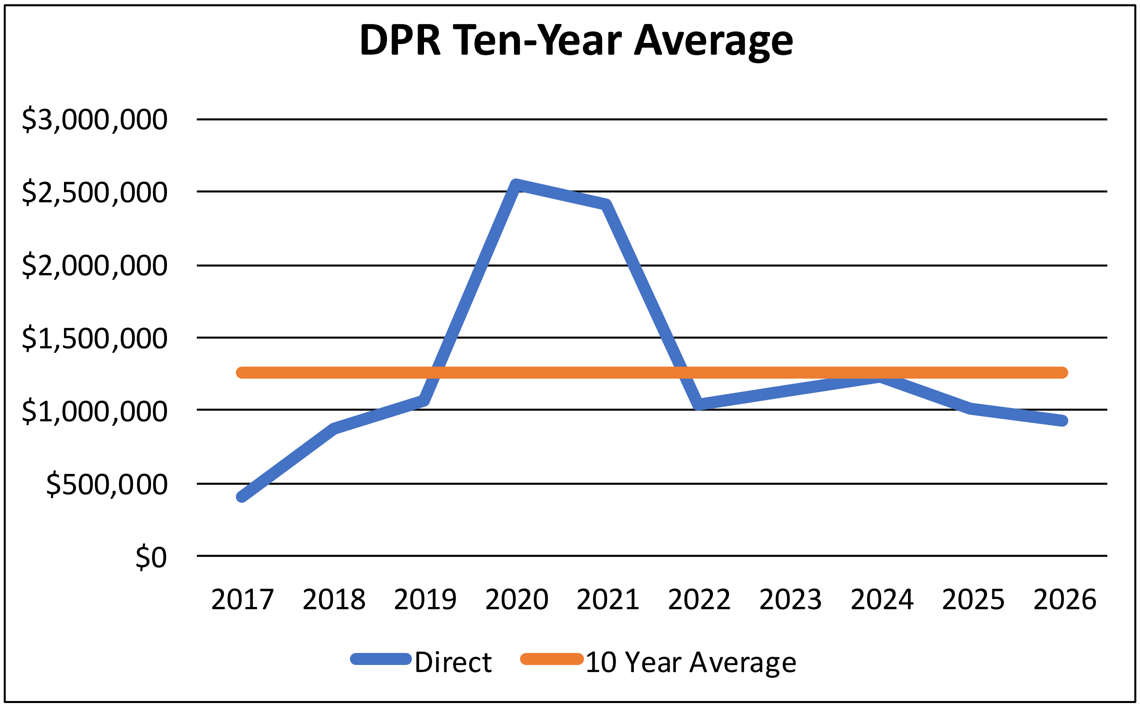


From 1903 – 2015, federal appropriations were a big part of the development of water resource projects. Now financing for water projects from the federal government is dwindling. CUWCD as with other water organizations must find was to continue development and replace aging infrastructure with little or no federal contribution.

Although the OM&R generally increase incrementally over time, the reserve charges are based on a multi-year projection of the cost of replacing facilities. If a major replacement is needed in the near future, the Reserve charges could spike requiring the three federal agencies to bear a cost that has not been planned for in their budget cycles. With this concern in mind, CUWCD and the agencies discussed options to cover they increased Reserve Costs.

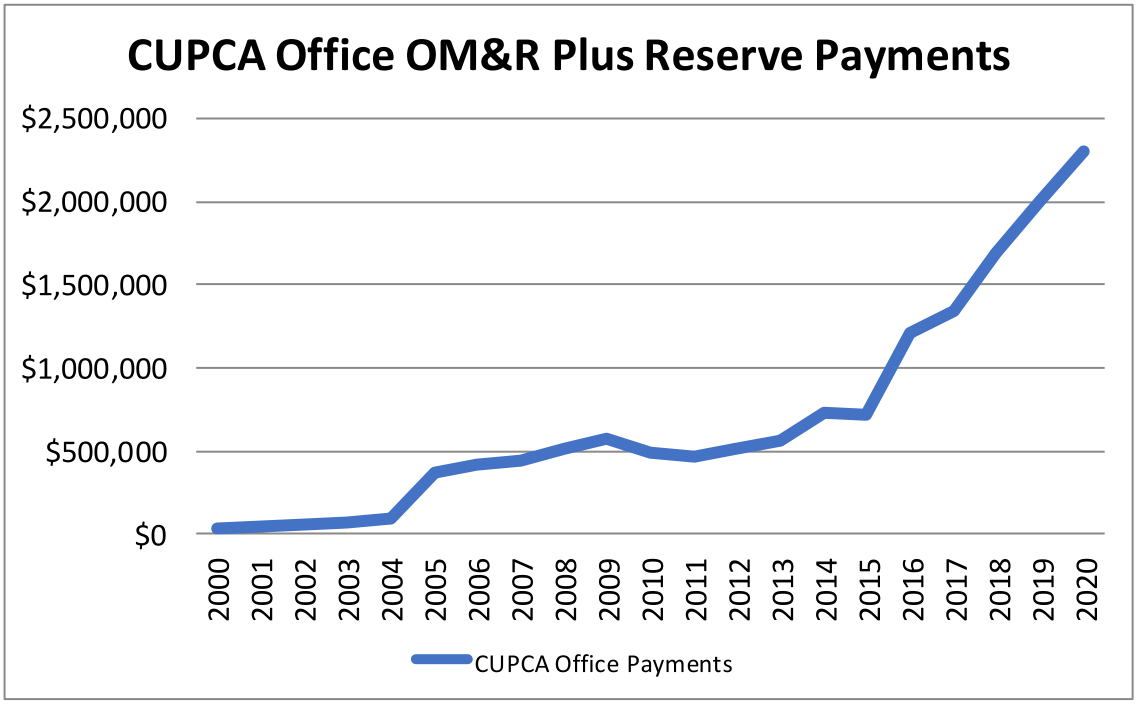
On April 18, 2017, three federal agencies signed a memorandum of understanding with CUWCD regarding the payment of OM&R Reserves to CUWCD. This agreement acknowledges that the federal agencies had previously agreed to pay OM&R to CUWCD in accordance with the 2004 Definite Plan Report and other contracts and agreements. In the agreement the federal agencies agree to pay reserves in accordance with the OM&R allocation. To dampen the effects of potential large increases in Reserve charges, the agreements provides a method to pay an annual ten-year moving average of Reserves costs. See Table 2.

Table 2. Ten Year Average



Although the agreement to average the DPR reserve Costs provided some relief to the three agencies, there are additional Reserve charges not covered by the DPR. The CUPCA Office is responsible to pay for OM&R costs related to water delivered for instream flow purposes. As water is acquired for endangered species or other fish and wildlife purposes, the annual OM&R is paid by the CUPCA Office. The increase in reserve charges also impacts these costs as well. Annual CUPCA Office payments for OM&R plus reserves has increased from $50,000 in the year 2000 to $1.2 million in the year 2016. This significant increase is due to additional water acquisition but more to the increase in reserve charges. See Table 3.

Table 3. CUPCA Office Payments



FUTURE OF ASSET MANAGEMENT

Looking toward the future, CUWCD is developing an Asset Management Program (AMP) which is an overriding comprehensive plan to extend life, minimize risk, and financial impacts over the life of its assets. The AMP has been under development over the past 8 years with a consultant on board for the past 5 years assisting in the development of asset replacement cost and industry standard lifespans. The AMP collects and analyzes asset level information. Eventually, it will provide valuable information on assets such as the cost of replacing infrastructure and how to maintain the infrastructure in a fiscally responsible manner.

The AMP includes an inventory of new infrastructure currently under development. This includes facilities such as the federal Utah Lake System and the non-federal Central Water Project. Data acquisition is an important part of the program. Data includes asset information during construction, warranty, location, performance, cost to replace, photos, and links to OM&R manuals.

The AMP is also comprised of existing major facilities. A current example is the North Fork Siphon which is a facility under the federal Central Utah Project. The Siphon is a 72-inch diameter steel pipeline, 4,712 feet in length that traverses a canyon descending 700 feet from the east to the valley floor under the North Fork of the Duchesne River and then rises on the west side of the canyon. The North Fork Siphon is nearing the end of its life cycle and is in need of replacement.

The AMP is estimated to have 50 to 70 thousand assets not including real property. Developing replacement cost and lifespan information on such a large number of assets would be a very difficult process, therefore, the District has developed organizational units within each facility called 'Asset Management Units'. Currently over 1,000 AMU's have been created (representing less than half of the projected total) which have been further broken down into nearly 8,000 line items where unit cost and lifespan information can be stored. The District plans to link the larger Asset database and its 50-70,000 items to the AMU line items at a later date to enhance the data analysis potential of the dataset.

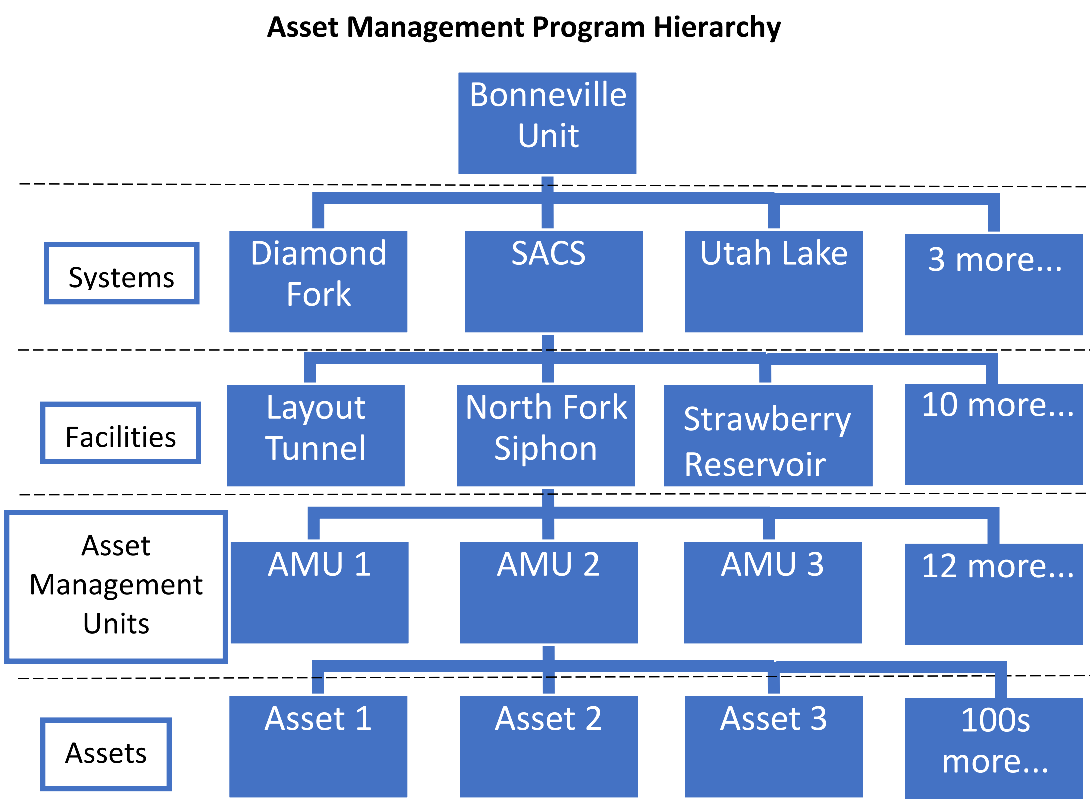


Figure 4. Asset Management Program Hierarchy

In the example of the North Fork Siphon, the Strawberry Aqueduct and Collection System (SACS) is comprised of reservoirs, pipelines, and tunnels including the North Fork Siphon. The Siphon is divided into 15 AMUs and each AMU may contain as many as 500 assets each. See Figure 4. The AMP will be a valuable tool to identify assets and provide information regarding asset status and scheduled replacement.

CONCLUSION

Water users in Utah have become accustomed to low water bills due to the availability of high quality water. This availability is possible through 100 years of water development. Now, CUWCD and other water resource managers are faced with 100 years of aging infrastructure including dams, pipelines, and valves. CUWCD has identified approximately $3.4 billion in assets that need to be operated, maintained and eventually replaced. Funding from federal and other funds have been greatly reduced. There is a reluctance from the state legislature and other groups to use taxing authority to finance water resource projects. The replacement of facilities through increased water charges is a necessary but difficult step to take.

REFERENCES

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