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IRRIGATION DISTRICT SERVICE IN THE WESTERN U.S.

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ABSTRACT: Data were obtained from 61 agricultural districts within the Mid-Pacific Region of the USBR regarding the level of water delivery service provided to users, water pricing, associated characteristics, and plans for modernization. A Flexibility Index (FI) was developed to characterize the degree of water delivery flexibility provided by each district. Based on results, a program for technical assistance to irrigation districts was developed and implemented.

INTRODUCTION

Many irrigation districts throughout the western U.S. have been actively engaged in modernization efforts. In some cases "modernization" refers to the simple replacement of wooden structures with steel and concrete structures. Ideally, modernization will result in an improvement of the level of water delivery service (flexibility and reliability) provided to farmers while at the same time fulfilling goals related to improving economics, the environment, or other aspects of irrigation projects (Plusquellec, et al 1994). In many cases, the impetus and/or funding for irrigation district modernization efforts has come from sources which are outside of the irrigation districts. These external sources include persistent droughts, an opportunity to sell water which is conserved and transferred, the need to increase in-stream flow rates by reducing diversions from rivers, and the need to improve downstream water quality (either suspended or dissolved solids) by decreasing or better managing the drainage outflows.

The Irrigation Training and Research Center (ITRC), located within the BioResource and Agricultural Engineering Department at California Polytechnic State University in San Luis Obispo, has an active technical assistance program for irrigation districts. This assistance has taken many forms. One has been the offering of numerous short courses for district personnel on topics such as SCADA (Supervisory Control and Data Acquisition), flow measurement, canal automation, and canal modeling. These courses have typically been funded by organizations such as the US Bureau of Reclamation (USBR), the California Energy Commission, California Dept. of Water Resources, or individual districts. ITRC also provides troubleshooting and brainstorming services to many irrigation districts. Regardless of the initial motivation for modernization which a district may have, ITRC works with the districts to achieve better water delivery service to farmers while also meeting or exceeding the original goals.

Implicit in the term "modernization" is the concept that something in the district, whether it be management or hardware, will be improved. Before any modernization program begins, the present status of the water delivery system and management should be determined. This provides information on the present level of service, and the hardware and management

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which is used to provide that service. Based on this information, a systematic and targeted program of improvement or modernization can begin. On a regional basis, it is helpful to have a baseline knowledge of the degree of water delivery service, so that the impact of modernization programs can be assessed in the future.

PROCEDURES

In 1995, ITRC, under contract with the Mid-Pacific Region of the US Bureau of Reclamation (USBR) gathered data from 61 agricultural irrigation districts within the Mid-Pacific Region of the USBR by interviewing irrigation district personnel and studying their Water Conservation Plans to complete a "Status and Needs Survey" (Burt et al., 1996). The purpose of the Status and Needs Survey was to define the present status of irrigation districts, with the goal of defining a meaningful technical assistance program for the districts by ITRC, on behalf of the Mid-Pacific Region of the USBR.

These 61 districts cover 902,000 hectares, comprising about 90% of the irrigated acreage in Mid-Pacific Region irrigation districts. The interviews were conducted in person during a visit to each districts. Visits typically required 3-4 hours of interview time, and were conducted with high level district personnel such as the district manager or watermaster. Data were then analyzed to determine general demographic information, the degree of water delivery flexibility provided to farmers, and the extent of existing and planned district modernization.

FLEXIBILITY OF WATER DELIVERY

Urban homeowners are accustomed to receiving water from the tap “on demand”; they do not need to provide advance notice to the water purveyor. Homeowners are provided unlimited flexibility in frequency (when they receive the water) and duration (how long they use it). They are provided with a limited flow rate flexibility - they can vary the flow rate from a few drops per minute, but with a maximum capacity which is limited by the size of the service connection. In the Mid-Pacific Region, agricultural water users (i.e., farmers) receive water with a high degree of equity (not measured in this study) and with much more flexibility than most irrigators in other areas of the world. Nevertheless, the flexibility of water deliveries in the Mid-Pacific Region does not compare with the “on demand” flexibility which is provided to homeowners.

Frequency Flexibility

835,500 hectares within the 61 irrigation districts have policies which allow farmers to receive water on an unlimited frequency schedule (Table 1), as long as the farmers order water in advance of receiving it. For farmers who have an unlimited frequency schedule, the mean advance notice time was 26 hours, and the mean number of times a farmer cannot get water on his requested day is once per season.

63,800 ha (7% of the total area) use a form of rotation schedule. Of these, 56,100 ha use a fixed rotation with trading turns between farmers, and 7700 ha use a modified rotation schedule. None of the districts surveyed use a strict fixed rotation (no trading turns) or a fixed rotation during peak water use periods.

Table 1. Analysis of Districts with Various Frequency Policies* (n=61).

Type of Schedule	Total Hectares	% Total	Number of Districts
Fixed Rotation (with trading turns)	56,100	6	1
Modified Rotation	7,700	1	1**
Unlimited Frequency	835,510	93	60

*"Frequency" pertains to a farmer choosing the day he receives water.
**One district had unlimited frequency on most of the district area, but had a modified rotation on other areas.

Flow Rate Flexibility

Only one district responded that farmers could not receive different flow rates for each irrigation - although this district allows farmers to receive several different flow rates throughout the season. The remaining districts have policies allowing farmers to receive different flow rates at each irrigation.

Similarly, 56 districts have no restrictions on changing a flow rate *during* an irrigation event; the average advance notice before changing flow rates during an irrigation is 13 hours. Three districts do not allow any flow rate changes during an irrigation. Seventeen districts have a policy of no advance notice required before a flow rate change.

Duration Flexibility

Thirty-four districts have policies allowing farmers to receive water for any arranged duration. The remaining districts allow delivery durations of 12 hours, 24 hours, or other fixed increments. The advance notice required before farmers can shut off the water ranged from 0 to 24 hours, and averaged 6 hours; seven districts do not require advance notice to shut off.

On average, district personnel must be present to open and close farm turnouts nearly 50% of the time. On average, district personnel operate gates within one hour of the prescribed time. When there is not enough flow to match a water order, 22 districts pro-rate the order and 27 districts postpone the water.

Flexibility Discussion

Duration flexibility is important for all forms of on-farm irrigation, but it is very difficult for irrigation districts to allow farmers to shut water off unannounced or at odd times - canals and pipelines with conventional control hardware can overflow if this happens. Farmers would like more duration flexibility to reduce over-irrigation, and avoid unnecessarily high bills and deep percolation of water and nutrients. Drip and microirrigation systems are easily automated to provide the correct amount of water to replace evapotranspiration (ET) plus losses due to non-uniformity, so they are ideally suited for management with unlimited duration flexibility. Since soil infiltration rates change through the season with surface (furrow, basin, border strip) irrigation, farmers rarely know exactly when they will complete a surface irrigation of a field.

Since a surface irrigation could be finished at any hour of the day or night, farmers can prevent overirrigation if they can shut off their water with no advance notice.

Farmers want a high degree of flexibility in irrigation delivery duration; ideally farmers would operate their own turnouts. If the district requires that a district employee operate the turnouts, the farmerís ability to automate an on-farm irrigation system disappears.

Many water conveyance systems, delivery canals and pipelines are not designed with adequate control systems to permit farmers to operate turnouts. Often, when one farmer makes a flow rate change, the ditchrider must move along the complete length of the supply canal or pipe to readjust the flows of other open turnouts.

Most irrigation districts have areas of their distribution system with limited capacity. When farmers request water, district personnel must check the pipeline/canal capacity to ensure there is enough capacity to supply that order without adversely affecting other users.

The districts with rotation schedules in California are typically those with extensive systems of monolithic concrete pipeline laterals. Those pipelined systems operate at very low pressures (typically less than 2 m). They were typically designed so that only one farmer at a time took a large flow rate for a relatively short duration. The flow rates and durations vary depending upon the size of the field, but are usually based on the request of the farmer for that particular event. Turnout flow rates of 1 cubic meter/sec for a 5-10 ha field are common. Water measurement is done at only one location - at the head of the lateral.

As farmers convert to drip/micro irrigation the district with the monolithic concrete pipe laterals are unable to provide water to these farmers because those farmers need relatively small flow rates for long durations. If the drip/micro irrigators put flow meters on their individual turnouts, the volumes delivered can be computed. However, the outflow to the drip/micro fields lowers the flow rates which a surface irrigator would receive simultaneously - increasing the surface irrigation labor and often decreasing efficiency. Because the surface irrigators would suffer, drip/micro irrigation systems are not connected to the lateral pipelines. As a result, most of the drip/micro irrigation systems in these districts are supplied by well pumps. The complete reliance on well water not only overdrafts the groundwater aquifer because of the withdrawals; it also reduces the recharge from deep percolation which formerly occurred with surface water irrigation.

Flexibility Index (District Level)

The above mentioned aspects of district delivery policies regarding frequency, flow rate and duration were indexed to quantify the level of water delivery flexibility provided by each district. Each of three sub-indices (frequency, flow rate and duration) has a rating from 1 - 5, with 5 as the most flexible score. The sum of these sub-indices gives the Flexibility Index. A Flexibility Index of 15 is the highest score possible.

The Flexibility Index defined in Table 2 was developed as a performance index that can be used in future studies. The average indices for frequency, flow rate, and duration were 3.3, 4.3, and 4.0. The average total flexibility index (i.e., the sum of the frequency, flow rate, and duration indices) was 11.6 out of a possible 15. Overall, the flexibility indices were high - all

districts had flexibility ratings greater than 10. The overwhelming majority of districts (54) had flexibility ratings less than 13; one district received a perfect score of "15".

Table 2. Definition of the Flexibility Index.

Points	Condition
	FREQUENCY
1	Always a fixed rotation
2	Fixed rotation with trading, or limited frequency, or fixed rotation during peak season only
3	24 hours or more advance notice required before delivery is made
4	Less than 24 hours advance notice required before delivery
5	Farmer does not need to notify district before delivery
	FLOW RATE
1	Same flow rate must always be delivered
2	Several flow rates are allowed during the season
3	A different flow rate is available each irrigation, with up to 2 changes per irrigation allowed
4	Flow rate can be changed any time, provided advance notice is given to the district
5	Flow rates can be different and changed by the farmer without giving advance notice to the district
	DURATION
1	District assigns a fixed duration of irrigation
2	District assigns a fixed duration, but allows some flexibility
3	Farmers must select a duration with a 24 hour increment
4	Farmers can choose any duration, but must give notice before changing
5	Farmers can have any duration, with no advance notice required before changing

Level of Interest in Flexibility

On a scale of 0 to 9 (9 being "very important), district managers gave an average rating of 4.0 when asked if there is a need to improve the flexibility of water delivery service. The managers applied the same average rating to their impression of farmers' desire for better flexibility.

District management was asked how many times during the last 5 years the subject of improving water delivery flexibility had been addressed at board meetings. Of 57 districts answering the question, 35 districts listed 0-5 times; 14 listed 6-10 times; and 8 listed 10-15 times.

OTHER FINDINGS

On-Farm Irrigation Methods

Recognizing the types and acreages using different irrigation methods helps in understanding the degrees of supply flexibility required by farmers. Farmers vary in their need for technical and educational support depending on their irrigation method; drip systems require frequent, flexible water deliveries. Over half (53%) the total acreage represented by the Survey used surface irrigation methods (i.e., furrow, border strip, or basin). Sprinkler and drip irrigation represented 19% and 13% of the total irrigated acreage, and is expected to increase.

The remaining acreage was irrigated rice (6%) or used combination irrigation methods (i.e., hand-move sprinkler and drip on row-crops) (Table 3).

Table 3. On-farm Irrigation Methods Used Within District Service Areas (n=61).

Irrigation Method	Hectares	Percent of Total
Furrow	325,700	38
Border Strip or Basin	130,300	15
Hand Move or Side Roll Sprinklers	89,900	11
Center Pivot or Linear Move	1,200	<1
Permanent Sprinklers (trees or vines)	24,000	3
Rice	49,200	6
Drip on Row Crops	7,500	1
Microspray or Drip (trees or vines)	98,600	12
Solid Set Sprinklers on Row/Field Crops	34,800	4
Combination	82,900	10
TOTAL	844,100	100

Water Pricing

The majority of interviewed districts (45 districts representing 666,100 ha) charge for water on a volumetric basis. The mean price is $398/ha-m ($47.80/AF). Twelve districts representing 225,100 ha use a fixed pricing structure; seven districts charge different prices depending on the crop type.

Delivered Water

The water supply allotted to the districts is highly variable, by both district and by year. Districts that experience wide fluctuations in water supply almost always see ground-water recharge as a major concern, and their policies may emphasize recharge during wet years rather than flexible deliveries during average or dry years. Districts had .76 m average gross water available for deliveries the last ten years, including both surface and groundwater supplies.

Conjunctive Use

Within the Mid-Pacific Region conjunctive use is widespread. 54 districts reported 484,000 ha which is partially supplied by wells. The estimated average pumping depth (weighted by acreage) was 67 m. In 11 of the districts, representing 235,000 ha, 100% of the farmers have dual surface/groundwater supplies. The number of actively used wells is increasing as more farmers convert to drip/micro irrigation.

Reservoirs

Reservoirs are often recommended for providing flexibility. Approximately 3 percent of the service area has farmer turnouts with privately owned reservoirs. 181 regulating reservoirs were identified on the district canal networks of 24 districts, and more regulating reservoirs are planned.

Automation of Canals

Only a few of the districts utilized comprehensive canal automation schemes. The majority of automation was of single gates at bifurcation points, usually to obtain a known and constant flow at the head of a canal or lateral. 96% of all cross regulators noted were manually operated. The vast majority were either flashboards, vertical undershot non-motorized gates, or combination gates (undershot plus side weirs).

SCADA Systems

By far the largest interest of the districts was the selective implementation of Supervisory Control and Data Acquisition (SCADA) systems. Districts are very interested in automating more canal headings, and are interested in remote monitoring/control of those points, plus the water levels or flows at the ends of canals and in reservoirs.

TECHNICAL ASSISTANCE PROGRAM

The Status and Needs Assessment determined what types of structures, communication systems, flow measurement devices, conveyance facilities, etc. were in use at the present, and what the districts plan to invest in for future improvements. As a result of those findings, ITRC and USBR embarked on an aggressive program of technical assistance to districts. This program is offered to districts on a cost sharing basis, and is available upon request by the individual districts.

Key components of this assistance include:

- Rapid appraisals of the district modernization needs. A 1-2 day survey is conducted with district personnel, and recommendations are then given.
- Improvement of flow measurement and flow control techniques. This includes assistance with the selection and design of structures, as well as training.
- Development of RFQs (Request for Qualifications) and RFPs (Request for Proposals) for SCADA systems. These documents provide detail of the required hardware and software for the district. The development of these documents is an important learning opportunity for district personnel, as they must develop a master plan for modernization in order to properly specify the SCADA needs.
- Design of improvements for drainage or irrigation water recirculation and storage facilities, to reduce surface discharges and to increase delivery flexibility.
- Technical assistance in selecting proper structures for flow control and water level control (upstream or downstream), or for improvements in delivery through pipelines.
- Short courses for farmers on pertinent topics related to on-farm irrigation, such as drip irrigation filtration, simple irrigation scheduling, and improvement of furrow irrigation.
- Development of improved PI (Proportional Integral) algorithms for upstream

control, and demonstration of the Begemann gate for upstream water level control. The response by the districts to this technical assistance has been strongly enthusiastic.

Appendix I. References

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