IRRIGATION DISTRICT SERVICE IN THE WESTERN UNITED STATES

By C. M. Burt and S. W. Styles

ABSTRACT: Data were obtained from 61 agricultural districts within the Mid-Pacific Region of the U.S. Bureau of Reclamation, regarding the level of water delivery service provided to users, water pricing, associated characteristics, and plans for modernization. A flexibility index was developed and used by the writers to characterize the degree of water delivery flexibility provided by each district. The flexibility index provides a rating of 3-15 (15 being the highest value) based upon the frequency, rate, and duration of irrigation water delivery service to farmers. The data show that 42% of the districts received a flexibility score of 12 or greater, with two of the districts receiving almost perfect scores. Based on these results, a program for technical assistance to irrigation districts was developed and implemented. A high priority item was supervisory control and data acquisition systems.

INTRODUCTION

Many irrigation districts throughout the western United States have been actively engaged in modernization efforts. Modernization is not to be confused with rehabilitation – 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 user benefits, improving economics, the environment, or other aspects of irrigation projects (Plus-quellec et al. 1994). In many cases, the impetus and/or funding for irrigation district modernization efforts has come from sources outside of the irrigation districts. These external pressures include persistent droughts, an opportunity to sell water that 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.

Implicit in the term "modernization" is the concept that something in the district, whether it be management (operation) or hardware (physical features providing better control capabilities), will be changed to improve water delivery service. Before any modernization program begins, the present status of the water delivery system and management should be assessed and documented. Information is needed regarding the present level of service, and the hardware and management that is used to provide that service. Based on this information, a systematic and targeted program of improvement or modernization can be defined. On a regional basis, it is helpful to have baseline knowledge of the degree of water delivery service, so that the impact of modernization programs can be assessed in the future.

In 1995, the Irrigation Training and Research Center (ITRC) was contracted by the Mid-Pacific Region of the U.S. Bureau of Reclamation (USBR), Sacramento, Calif., to provide technical assistance to irrigation districts in the region. As one of the steps to properly focus the regional technical assistance program, a Status and Needs Assessment (Burt et al. 1996) was designed to gather data from 61 agricultural irrigation districts.

ITRC, located within the BioResource and Agricultural Engineering Department at California Polytechnic State University in San Luis Obispo, Calif., has had an active technical assistance program for irrigation districts for over 20 years. That experience was useful as background for developing a proper survey. Historically, ITRC assistance has taken many forms, including 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 USBR, the California Energy Commission, California Department of Water Resources, or individual districts. ITRC had developed rapid appraisal procedures to evaluate modernization needs of irrigation districts in different circumstances, including special procedures for international projects (Burt and Styles 1999).

This paper emphasizes the "flexibility" aspect of water delivery service because equity is not typically an issue within any single Mid-Pacific Region irrigation district. The paper ends with a description of some other important issues with respect to water delivery service, including on-farm irrigation system requirements, water pricing, and plans of districts for modernization.

PROCEDURES

Data for the Status and Needs Assessment was collected through interviews with irrigation district personnel and by studying district water conservation plans. The data pertinent to this paper helped define the level of water delivery service provided by the districts.

These 61 districts cover 902,000 ha, comprising about 90% of the irrigated acreage in the Mid-Pacific Region irrigation districts. The interviews were conducted in person during a visit to each district. Visits typically required 3-4 h of interview time and were conducted with senior 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 efforts. Many districts have had ongoing modernization programs that are now being accelerated.

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 (i.e., "when" they receive the water) and duration (how long they use it). Homeowners have a limited flow rate flexibility – they can vary the flow rate from a few drops per minute–but the maximum capacity is limited by the size of the service connection. In the Mid-Pacific Region, agricultural water users (i.e., farmers) receive water with much more flexibility than irrigators in most other areas of the world. Nevertheless, the flexibility of water delivery service in the Mid-Pacific Region is typically not equivalent with the on demand flexibility that is provided to homeowners.

Frequency Flexibility

Within the 61 irrigation districts, 835,500 ha (93% of the surveyed area) have policies that 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 h, and the mean number of times a farmer cannot get water on his requested day is once per season.

A form of rotation schedule is used for 63,800 ha (7% of the total area). Of these, 56,100 ha use a fixed rotation with trading turns between farmers, and 7,700 ha use a modified rotation schedule. None of the districts surveyed use a strict fixed rotation (no trading of turns) or a fixed rotation during peak water use periods.

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 for 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 h. 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, 24 h, or other fixed increments. The advance notice required before farmers can shut off the water ranged from 0 to 24 h, and averaged 6 h; 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 1 h of the prescribed time. When there is not enough flow to match a water order, 22 districts prorate the order, and 27 districts postpone the water.

Flexibility Discussion

Duration flexibility is important for all forms of on-farm irrigation, but it can be very difficult for irrigation districts to allow farmers to shut water off unannounced or at odd times. Upstream controlled canals and open pipelines will overflow when this happens. Furthermore, if all farmers only take water for a portion of the time, there can be capacity problems in meeting the demands. Five of the districts reported having some capacity problems for over 50% of the time, and 46 of the 61 districts reported some capacity problems at some times.

Farmers would like more duration flexibility to reduce overirrigation and to avoid high water/power bills and the associated deep percolation of water and nutrients. Drip and microirrigation systems are easily automated to provide the correct amount of water to replace evapotranspiration plus losses due to non-uniformity; thus they are ideally suited for management with unlimited duration flexibility. Because 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. Because a surface irrigation might be completed at any hour of the day or night, surface irrigation farmers need the option of shutting the water off at these unpredictable times with no advance notice.

TABLE 1. Analysis of Districts with Various Frequency Policies[a] (*n* = 61)

Type of schedule (1)	Total area (ha) (2)	Percent total (3)	Number of districts (4)
Fixed rotation (with trading turns)	56,100	6	1
Modified rotation	7,700	1	1[b]
Unlimited frequency	835,510	93	60

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

Farmers prefer to operate their own turnouts. If the district requires that a district employee operate the turnouts, the farmer's ability to automate an on-farm irrigation system disappears completely unless the farmer builds an on-farm reservoir.

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 requests 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.

As mentioned above, 75% of the irrigation districts indicated they have some zones of their distribution system with limited flow rate capacity under their current mode of operation. When farmers request water, district operators must check the pipeline/canal capacity to ensure there is enough capacity to supply that order without adversely affecting other users. This limited capacity restricts the ability of the district to provide unlimited flexibility in frequency, rate, and duration.

In the Mid-Pacific Region, only two districts had rotation schedules. However, they have similar characteristics as several other large, non-USBR districts on the eastern side of the San Joaquin Valley. Those districts typically have extensive systems of monolithic concrete pipeline laterals. Such pipelined systems operate at very low pressures (typically <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 m3/s for a 5-1O-ha field are common. Water measurement is done at only one location-at the head of the lateral.

As farmers convert to drip/microirrigation, the districts with the monolithic concrete pipe laterals are unable to provide the required flexibility to these modernizing farmers because the farmers need relatively small flow rates for long durations. If the drip/microirrigators put flow meters on their individual turnouts, the volumes delivered can be computed. However, the outflow to the drip/microfields lowers the flow rates that a surface irrigator would receive simultaneously. This can increase the surface irrigation total labor and decrease application efficiency. Because the surface irrigators would suffer, in many cases the districts have not been able to connect the drip/ microirrigation systems to the lateral pipelines. As a result of this lack of service, most of the drip/microirrigation systems in these districts are supplied by well pumps. The increasing reliance on well water not only overdrafts the ground-water aquifer because of the withdrawals, it also reduces the recharge from deep percolation that formerly occurred with surface water irrigation. These irrigation districts are looking for new hardware solutions to provide better water delivery service to the increasing number of drip/microirrigators.

Flexibility Index (District Level)

The above mentioned aspects of district delivery policies and system capacities regarding frequency, flow rate, and duration were indexed to allow a comparison of the level of water delivery flexibility provided by each district. Each of the three factors of frequency, flow rate, and duration was subdivided into ratings from 1 to 5, with 5 being the most flexible score. Each of the three factors was given the same importance to flexibility. The sum of the ratings judged for the three factors was termed the flexibility index. A flexibility index of 15 is the highest possible.

The flexibility factors as defined in Table 2 were developed to provide a performance index that can be used in future studies. The average indices for the 61 districts 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>10. However, 54 districts (88% of the total) had flexibility ratings <13; one district received a perfect score of 15.

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 how important is the need to improve the flexibility of their 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. Compared to other items of business such as securing or protecting their water supply, water pricing, and new environmental regulations, the specific topic of improving water delivery flexibility is an infrequent issue at board meetings.

TABLE 2. Definition of the Flexibility Index

Point (1)	Condition (2)
	(a) Frequency
1	Always a fixed rotation
2	Fixed rotation with trading, or limited frequency, or fixed rotation during peak season only
3	24 h or more advance notice required before delivery is made
4	<24 h advance notice required before delivery
5	Farmer does not need to notify district before delivery
	(b) Flow Rate
1	Same flow rate must always be delivered
2	Several flow rates are allowed during the season
3	Different flow rate is available each irrigation, with up to two 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
	(c) 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-h segment
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

OTHER FINDINGS

On-Farm Irrigation Methods

Recognizing the different irrigation methods used helps in understanding the degrees of supply flexibility required by farmers to obtain high irrigation efficiencies. It has been the experience of the writers that this does not necessarily translate to what the farmers understand as a need.

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%) of the total irrigated acreage within the 61 districts used nonrice surface irrigation methods (i.e., furrow, border strip, or basin). Sprinkler and drip irrigation represented 19 and 13% of the total irrigated acreage, respectively, and are expected to increase. The remaining acreage was irrigated rice (6%) or used a combination of irrigation methods (i.e., hand-move sprinkler and drip on row-crops) (Table 3).

Water Pricing

The majority of interviewed districts (45 districts representing 666,100 ha) charge for water on a volumetric basis, with a mean price of $398/ha-m ($47.80/AF). Twelve districts representing 225,100 ha use a fixed pricing structure (i.e., a specific fee per hectare); seven districts charge different prices depending on the crop type. It is typical of the districts with volumetric charges to include a fixed per-hectare fee in their charges to cover loan payments and fixed costs.

Water prices have increased dramatically by double or more in most districts over the last decade. The increases are due to higher costs for water (i.e., what they pay to the USBR for water supplies and their own pumping costs) as well as increased costs for modernization, legal fees, and other expenses.

Delivered Water

The water supply allotted to the districts is highly variable, by district and by year. Districts had 0.76-m average gross water available for deliveries the last 10 years, including surface and ground-water supplies. This is insufficient for many crops (there is no summer rainfall) and as a result, many farms have fallow lands during dry years.

Districts are increasingly aware that their water supplies are at risk. The Central Valley Improvement Act transferred 98,700 ha-m of water to the environment in 1992. Many districts have recently begun taking proactive roles in modernization programs to minimize spills and to improve on-farm irrigation efficiencies, because they fear that, if they cannot prove that their water use is reasonable and beneficial, they will lose more of their water supply.

TABLE 3. On-Farm Irrigation Methods Used within District Service Areas (*n* = 61)

Irrigation method (1)	Area (ha) (2)	Percent total (3)
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
Continuous flooded 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

Conjunctive Use

Within the Mid-Pacific Region conjunctive use is widespread. Fifty-four districts reported that 484,000 ha is partially supplied by pumping from 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/ground-water supplies. The number of actively used wells is increasing as more farmers convert to drip/microirrigation.

Districts that experience wide fluctuations in water supply almost always see ground-water recharge as a major element in their water management. Their policies have historically emphasized recharge during wet years rather than providing flexible deliveries during average or dry years, as most farmers have wells in those districts. However, even these districts are now seeing modernization as important in minimizing spills and in supporting high-tech on-farm irrigation methods (drip/ micro) when water supplies are available. In some districts the surface water is more expensive than well water (farmers

only pay the pumping cost for well water), and the surface water is provided with less flexibility. Many short-sighted farmers therefore will not use surface water unless the districts have a policy that every farmer will be charged for a minimum usage, whether the water is accepted or not. The districts must have such a policy to reduce ground-water overdraft and to obtain revenues to pay for modernization and other programs.

Reservoirs

Reservoirs are physical facilities that can provide significant additional flexibility. Approximately 3% of the service area has farmer turnouts with privately owned reservoirs. There were 181 regulating reservoirs (owned by the districts themselves) identified on the district canal networks of 24 districts, and more regulating reservoirs are planned under future modernization.

Automation of Canals

Only a few of the districts utilized comprehensive canal automation schemes. The majority of automation consisted of single gates at bifurcation points, usually to obtain a known and constant flow at the head of a canal or lateral. Ninety-six percent of all cross regulators noted were manually operated. The vast majority of canal cross regulators were either f1ashboards, vertical undershot nonmotorized gates, or combination gates (undershot plus side weirs). District operators can sometimes still provide a high degree of flexibility because of excellent access to sites, high mobility, very good communications, and the use of pumpback or regulating reservoir systems.

SCADA Systems

By far the largest interest of the districts for modernization was the selective implementation of SCADA systems. Districts are very interested in automating more canal head gates and pumps and in remotely monitoring/controlling those points. The second highest SCADA priority is monitoring the water levels or flows at the ends of canals and in reservoirs.

CONCLUSIONS

The Status and Needs Assessment determined the type of water delivery service currently offered by irrigation districts, with particular emphasis on flexibility. In addition, the assessment helped better understand outside pressures on each district. The types of structures, communication systems, flow measurement devices, and conveyance facilities in use at the present time were identified as well as the districts' plans for future investments. As a result of those findings, ITRC and USBR embarked on a program of providing technical assistance to districts. This program was offered (and continues to be offered) to districts on a cost-sharing basis and was available upon request by the individual districts. The response by the districts was excellent, with almost all of the major districts participating in at least one significant program. Almost all of the program components have resulted in improvements in water delivery service, while simultaneously helping the districts meet other objectives such as reducing spill, reducing labor, preventing equipment damage, and protecting water rights.

Key components of this assistance included

- Rapid appraisals of the district modernization needs - A 1-4-day visit of the district was conducted with district personnel. Recommendations were then provided to the district and often served as the blueprint for future modernization plans.
- Improvement of flow measurement and flow control techniques-This included assistance with the selection and design of structures, as well as training.
- Development of request for qualifications and request for proposals for SCADA systems-These documents provided details 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 proportional integral algorithms for upstream control and development of a design program for a simple automatic hydraulic Flap Gate (the ITRC flap gate) for upstream water level control.

The survey showed that California's Mid-Pacific Region (USBR) irrigation districts currently have relatively high levels of water delivery service. It also showed that there is room for improvement. The enthusiastic acceptance of the subsequent technical assistance program for modernization has demonstrated that these irrigation districts are indeed interested in maximizing their water delivery service through management and hardware, within their economic and physical limitations.

APPENDIX. REFERENCES

Burt, C. M., O'Connor, K., Styles, S. w., Lehmkuhl, M., Tienken, C., and Walker, R. (1996). "Status and Needs Assessment: Survey of irrigation districts-USBR Mid-Pacific Region." Irrigation Training and Research Center, California Polytechnic State University, San Luis Obispo, Calif.

Burt, C. M., and Styles, S. W. (1999). "Modern water control and management practices in irrigation-Impact on performance." Ajoint FAa, IPTRID, and World Bank publication, Food and Agriculture Organization ofthe United Nations (FAD) Water Rep. No. 19, FAa, Rome.

Plusquellec, H., Burt, C. M., and Wolter, H. W. (1994). "Modern water control in irrigation-Concepts, issues, and applications." World Bank Technical Paper Number 246, Irrigation and Drainage Series, Washington, D.C.