RESEARCH REPORT

100

The Reliability Improvement in Irrigation Services: Application of Rotational Water Distribution to Tertiary Canals in Central Asia

Iskandar Abdullaev, Mehmood Ul Hassan, Herath Manthrithilake and Murat Yakubov

International Water Management Institute

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Cover photograph by Iskandar Abdullaev shows water users cleaning the Sokolok Canal, Kyrgyzstan.

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Acronyms

FSU	Former Soviet Union
IFPRI	International Food Policy Research Institute
IHE	International Institute for Hydraulic and Environment Engineering (UNESCO-IHE Institute for Water Education)
IIMI	International Irrigation Management Institute
ILRI	International Institute for Land Reclamation and Improvement
ISF	Irrigation Service Fee
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
O&M	Operation and Maintenance
OIP	On-Farm Irrigation Project
SIC ICWC	Scientific-Information Center of the Interstate Coordination Water Commission of the Central Asia
WMO	Water Management Organization
WUA	Water Users Association
WUG	Water Users Group

Summary

Land and agricultural reforms in Central Asian countries, following the collapse of the Former Soviet Union (FSU), have led to a big increase in the number of individual farm units along secondary and tertiary canals. Given the new setting, the methods for water distribution, as applied under the former large-scale collective farming system, have become irrelevant, leading to much chaos, inequity and unreliability in water supply to farmers. Thus, many farmers and water managers have had to resort, with variable success, to some alternative water distribution methods to meet these new challenges. Nevertheless, transparency and equity in local water use still remains an issue. With this in mind, an action research to study an arranged intermittent (rotational) water distribution was undertaken in a typical distributary canal in collaboration with a Water Users Association (WUA) in the Kyrgyz Republic during 2003 and 2004. The rotational water distribution method employed was performed in a truly participatory manner and allowed farmers involved to always be aware of their specific time schedules, including when to irrigate their fields and for how long. This alone has translated into huge time savings for farmers when waiting for their irrigation turns and more equitable water distribution between different canal reaches. This has also allowed those at the tail ends to increase crop yields and net incomes, resulting in better Irrigation Service Fee (ISF) collection. At the same time, there has also been a change in the nature and pattern of water disputes.

The work conducted on rotational water distribution suggests that it is the needs and concerns of the end users that provide a good entry point for collective action, to pragmatically understand and analyze the situation, from where appropriate remedial strategies and methods can be further devised and employed. This is also a good starting point to initiate farmer debates and discussions on public participation, which should ultimately lead to a truly farmer-owned process and action. Legal instruments alone, though being an important factor, *per se* are rarely sufficient to fully enable, sustain and institutionalize required change to local communities. Unfortunately, this has mostly been the case in Central Asian economies so far, and it is this that requires major change.

The reliability improvement in irrigation services: Application of rotational water distribution to tertiary canals in Central Asia

Iskandar Abdullaev, Mehmood Ul Hassan, Herath Manthrithilake and Murat Yakubov

Background

Central Asia has one of the oldest systems of irrigated agriculture in the world, with the history of irrigation dating back thousands of years. In the early twentieth century (pre-Soviet times), water distribution was based on the Islamic *Shar'ia* law. According to *Shar'ia,* water was regarded as a common good. The public owned all canals and ditches collectively with the main principle for water sharing being for a landowner to receive sufficient water to fill their field (Bartold 1970; Mukhamedjanov 1986).

During the Soviet era, Central Asia was covered with large irrigation schemes serving a total of about 8.0 million ha (hectares) of irrigated cropland. Massive irrigation and drainage systems were designed to accommodate the needs of large-scale farm units owned and controlled by the state. These large farms consisted of a number of production units called "brigades" with water allocated and distributed against "agro-technical operations plans." From the mid-1960s, water distribution in Central Asia was demand-based. In the mid-1980s, this was replaced by the "adjusted water demand principle" ("*limitirovannoye vodopol'zovazniye*" in Russian) or, simply, supply-based, requiring proportionate adjustments to the initially expressed water demands in situations of lower water availability.

After the collapse of the Soviet Union, the integrated large-scale irrigation systems had to be shared across the newly established independent Central Asian states. Each nation undertook its own agricultural, land and water reforms to subdivide state farms into smaller, farmer-owned or managed units. In some cases, farmers are free to plant whatever crops they like, but cotton and wheat are still mandated, for instance in Uzbekistan. In Central Asia, there are tertiary canals that supply water to only a few farmers in some areas, and to hundreds in others. Previously, these canals served big collective farms with the entire system designed to suit large-scale farming. However, such water allocation and distribution mechanisms had become unsuitable or even redundant in the post-Soviet Central Asia, thus resulting in chaos, inequity and unreliability at all levels of the irrigation system management. This has also led to a mismatch between water supply and actual cropping pattern needs, and an increase in the number of water-related disputes. So, this report addresses a specific context of massive inequity and unevenness in water allocation and distribution experienced presently by the water users in transitional Central Asian economies, as a result of broad-scale fragmentation of the previously large farms. The report describes action research aimed at making water distribution at the tertiary level more reliable, transparent and equitable.

Water distribution along irrigation schemes: Institutions and infrastructure

Main canals ("*magistralniy kanal*" in Russian) in Central Asia are normally lined and very well equipped to prevent seepage losses. Every major offtake along a main canal is equipped with flow regulation and water measurement structures. The gates at the main canal offtakes are regulated based on total water demand by water users. Water requests are collected every three days by the canal managers to prepare a schedule of water releases at all diversion points. At the same time, it is not uncommon for the manager to make sudden changes to such schedules, if so requested by higher-level authorities or in case of an emergency. If canal water has to be lifted by pump, the reliability of the water supply depends on the availability of electricity. The main canal is normally divided into reaches ("*gidrouchastok*" in Russian), which are supposed to be coordinated by their operations control units ("*dispecherskiy punkt*" in Russian). Since they are equipped with outdated and inefficient radio communication sets, those in charge of different canal sections lack real-time data and, to a large extent, now make uncoordinated water distribution decisions. This leads to quite frequent flow changes being made simultaneously in different reaches, resulting in unreliable and unequal water distribution throughout Central Asia.

The former on-farm water distribution system in Central Asia includes secondary and tertiary canals. Normally, they are poorly equipped with regulation structures (such as outlets, gates or measuring devices) due to some built-in features peculiar of the old system. One on-farm irrigation system in the FSU used to belong to one collective farm or a state farm ("kolkhoz" or "sovkhoz"). Since their funds were quite limited, such farms could only improve on-farm irrigation infrastructure when all other costs were fully met. Thus, farm level infrastructure is typically scanty and poorly maintained.

Currently, daily bulk water deliveries are arranged with individual tertiary canal water masters (*mirabs*), normally twice a day and based on (i) total water requested by water users for the day, or (ii) water available from the main canal for further deliveries down the secondary network.

Water delivery to the farm gate (field) is the full responsibility of a WUA's *mirab*, who is to collect all water requests from the water users and open the gates as per the irrigation schedule, prepared by the WUA committee. It should also be noted that *mirabs* always enjoy a high degree of freedom in supplying water to the farms. In most cases, *mirabs* are very rational and do their best to avert any water-related conflicts through discussions with water users and appropriate on-the-spot decisions. However, due to the large numbers of competing water requests, mirabs are unable to equally and reliably distribute water among numerous water users.

Problem Description

The centerpiece of water resources management is allocation of water to different purposes and users, complemented by distribution to those users (actual implementation of allocation decisions). Thus, the term "allocation" refers to the assignment of rights or allowance to use water (Uphoff 1986). A working definition for water allocation could be a combination of actions enabling water users and uses to obtain or receive water for beneficial purposes according to a recognized system of rights and priorities (Taylor 2001). The three water allocation mechanisms widely used in the world are: (i) administrative, (ii) user-managed, and (iii) applying

TABLE 1.
Irrigation scheduling and water delivery by allocation types.

Allocation type	Type of scheduling	Type of delivery at tertiary offtake	
Supply-based (water source)	Proportional scheduling	Traditional	Irregular changing flows
		Arranged	Intermittent full supply
Demand-based (crop water requirement)	Central scheduling (agency deciding)	On request	Variable flows - short periods
		Arranged	Variable flows - long periods
		Arranged Rotation	Intermittent full supply
	Responsive scheduling (farmer deciding)	Automatic	Stepwise changing flows

Source: Horst 1998.

of market instruments in water allocation (IFPRI 1994). In a broader sense, water allocation can be divided into two types: supply driven and demand driven. Table 1 presents the options for irrigation scheduling and water distribution emanating from these two water allocation types.

Until the 1980s, the water requirements of the irrigation in Central Asia was demand-based (against crop water requirements) with water deliveries scheduled and effected centrally (i.e., administrative mechanism) by state-run Water Management Organizations (WMOs). Irrigation water was delivered in variable flows in 10-day intervals (decade) based on crop type, sown area, soil characteristics, groundwater depth and other environmental factors of irrigated areas. To streamline water allocation for irrigated agriculture, a “zoning system” was developed by research institutes categorizing all irrigated areas. The zoning was based on the environmental characteristics of each particular zone, affecting in some way or other the consumption pattern of irrigation water. Thus, the areas with similar environmental indicators were grouped under one irrigation zone (or hydromodule), specifying predetermined irrigation regimes (date, amount, frequency) for all crops grown in such areas. This approach was meant to facilitate the water distribution process in irrigated agriculture.

By the mid-1980s, given the growing concerns over the drying Aral Sea, the water allocation principle in Central Asian agriculture shifted from being demand-based (against crop water requirements) to that driven rather by supply. According to the latter, initially expressed water demands for irrigation were later subject to proportionate adjustments considering actual water availability in a river basin. However, the way water was scheduled and delivered to users continued to be the same as it was earlier when crop water requirements were not restricted.

At present, scheduling and deliveries of irrigation water are centrally arranged by WMOs, based on cropping patterns. Central to the process is preparation of draft water-use plans based on statutory water requirements for all crops planned for a season. These are later subject to proportionate adjustments if overall water availability for the season is forecast at somewhat less than normally required. This system worked quite well under the large-scale farming system, when a much fewer number of water users had to be dealt with. However, key changes in the Central Asian economies following independence led to multiple fragmentations of huge state farms among numerous newly established individual farmers. Thus, WMOs find it almost impossible to (i) collect water requests from so many users, and (ii) to deliver water to them in an orderly and timely basis. Due to large numbers of overlapping water requests from the farmers, the WMOs are hard-pressed to prepare any workable water delivery schedules. Therefore, almost all canal outlets are left open instead, to let water continuously flow without much regulation. Consequently, the upper reach tertiary canals receive more water at the cost of the tail end canals, and within tertiary canals, small fields fill up quickly and surplus water is discharged to the drainage network, while bigger plots are never irrigated fully throughout the season (IWMI 2004). In addition, water deliveries become unreliable in the lower reaches due to discharge fluctuations, and simultaneous efforts of water withdrawal by canal mirabs, as well as the users. This situation, especially, puts those at the tail ends of canals (farms and households) at a great disadvantage due to unreliable and unequal water distribution.

Experience elsewhere suggests that effective water delivery in situations like these can only be achieved by fostering greater participation of users in the process of planning water use and distributing water (Abernethy 1988; Horst 1987; Horst 1990). Involving water users in the planning and distribution processes requires participatory approaches and methods that are user-oriented, as well as being simple enough to be understood by farmers. Given this context, IWMI, under the auspices of the IWRM-Fergana Project[1], experimented with a number of such alternative water distribution methods that would be effective and build on farmers' own initiative and capacity. One such method was successfully introduced and pilot-tested at a tertiary canal of a pilot WUA in Kyrgyzstan. The method in question is called *user-based rotational water distribution* and features proportional scheduling of full canal flow for rotational delivery to individual outlets with active participation of the water users. This was not something completely new to the local people. Some variation of it, locally called "avron", was practiced long before Russia conquered Central Asia in the second half of the nineteenth century (Thurman 1998).

Methods and Materials

User-based Rotational Water Distribution

One of the methods widely used for water distribution, based on timed allocation, is known as *warabandi.* The method has been widely practiced for over a century in most countries of South Asia, such as India, Pakistan, Bangladesh and Nepal. In Pakistan and northern India, it is applied over some 24 million hectares. According to many reports, there are a number of variants of warabandi, featuring a range of designs and management options. Water at a tertiary level is supplied to every landowner or field at a fixed rate, for a fixed duration and at a fixed time on fixed days. The irrigation variables are fixed either by the O&M (operation and maintenance) agency (*pucca warabandi*) or by the farmers (*kachaa warabandi*). The duration of the turn is proportional to the size of the farm. One advantage of this method is that it matches local management capacity and is intended to provide equitable access. However, some *warabandi* systems have increasingly been experiencing severe problems with sustainability (salinity) (see, for instance, Bandaragoda and Ur Rehman 1995; Chaudhry and Young 1989; Latif and Sarwar 1994; Lowdermilk et al. 1975; Makin 1987; Merrey 1990; Qureshi et al. 1994; Singh 1981; Vehmeyer 1992; Bastiaanssen and Bos 1999). Since the *warabandi* practice tends to breakdown when water supply is not limited, some experts both inside and outside Central Asia, have suggested that *warabandi* does not suit the specific Central Asian context where crop diversification and land fragmentation are important factors. There is

[1]IWRM Fergana-Integrated Water Resources Management in Fergana Valley, project funded by Swiss Agency for Development and Cooperation, implemented in the Fergana Valley of Kyrgyzstan, Tajikistan and Uzbekistan. The project is jointly implemented by IWMI and SIC ICWC since the year 2001.

ample evidence that no real water shortages are present in Central Asia (Mukhamedjanov et al. 2004; SIC ICWC 2003), with most problems in current water distribution being rather of a socio-institutional nature, than purely technical. We hypothesized, with proper adjustments and strong focus on the socio-institutional aspects of water distribution, *warabandi* could be adapted successfully in the emerging context of Central Asian irrigated agriculture.

The main hypothesis of this study holds that, when designed and applied in direct consultation with water users, w*arabandi* makes local water distribution more transparent and effective, thus, improving equity, reliability and timeliness of the water supply to farmers sharing one distributary canal, and reducing the number of water-related disputes among them.

The main feature of the proposed water distribution method is timing the duration of water delivery to each watercourse in the distributary in accordance with crop-specific water requirements. This is a major difference between classical *warabandi* as practiced in South Asia and the rotational methods pilot-tested in Central Asia. The latter, among other things, also provides the opportunity for water users to actively participate in water distribution.

The three major parameters that are considered when implementing rotational water distribution are as follows: (i) the 10-day water duty for each watercourse based on the statutory water requirements of each particular crop grown; (ii) the time required to release the required volumes, based on the discharge rate available in the head of the distributary canal and the size of the fixed outlet structure in the head of each watercourse; and (iii) the timing of opening and closing each outlet.

The existing planning procedures were followed to determine the 10-day water duty for each watercourse. Local water use plans are normally prepared annually, based on crop plans (crop type and area sown), canal characteristics (delivery efficiency) and weather forecast. In this research, an Excel spreadsheet-based program was used to calculate the water duty for each watercourse of the study canal.

The time required ($T_{irr\ (i,j)}$) to release the 10-day water duty for a watercourse is calculated as follows:

$$(T_{irr\ (i,j)}) = \frac{(V_{irdecade\ (i,j)})}{(Q_j \cdot 3.6)} \qquad (1)$$

Where: $Tirr_{(i,j)}$ duration of water supply to watercourse "*i*" in the *j*-*th* decade, in *hours*

$V_{irdecade\ (i,j)}$ water duty for the watercourse "*i*" in the *j*-*th* decade, crop water requirement, identified from water use plan in m^3 (cubic meters)

Q_j head discharge for the distributary canal in the "j" *decade*, in *l/s* (liters per second)

3.6 factor to convert *l/s* into m^3/h (cubic meters per hour)

In this regime, all flow is supposed to be supplied to only one watercourse at a time. This is practically feasible, because the offtakes have the same discharge rate as at the head of the distributary canal, and so diverting the entire distributary inflow to one offtake at a time does not create any problems.

The Site

To pilot-test this user–based rotational water distribution method, a tertiary canal was selected in one of the WUAs located in Osh Province of the Kyrgyz Republic. It is called Sokolok Canal under the WUA "Zhapalak". The selection was done in consultation with the WUA. The study canal is believed to be representative of a typical tertiary canal in Central Asia today. The WUA was founded in 1996 and has 2,112 ha in the total irrigated service area (figure 1). The command area of the Sokolok Canal is 290 ha and the canal is around 6 km (kilometers) long. This tertiary canal supplies water to 473 water users via 14 watercourses. The maximum capacity of Sokolok Canal at the offtake is 250 l/s. Its water source is the main Aravan-Akbura canal, which is one of the largest canals in Osh Province, South Kyrgyzstan.

Before the intervention, the study distributary was poorly maintained. It had no water regulation structures, so all its outlets were opened and closed manually, using spades, stones and mud. This made water distribution extremely difficult to manage, leading to frequent siltation and bank destruction. During 2003-2004, a part of the distributary was lined under the World Bank-sponsored On-Farm Irrigation Project (OIP).

The cropping pattern in the pilot area comprised of 43.4 percent corn, 11.5 percent winter wheat, 3.3 percent sunflower, 3.1 percent vegetables, including onions, tomatoes, and cucumbers, while 2.1 percent of the command area was occupied with fruit trees. The average landholding within the command area is 0.48 hectare per household. The sizes of individual land parcels across the watercourses were not uniform, with the following 3-land distribution patterns observed:

1. Commands with less then 0.50 ha per landholding on average (Watercourses 1, 2, 4, 6, 8, 13, and 14)
2. Commands with the landholding sizes between 0.50 to 1.0 ha (Watercourses 3, 9, 10, 11, and 12)
3. Commands with an average of more than 1.0 ha (Watercourses 5 and 7) per landholding

Data Collection

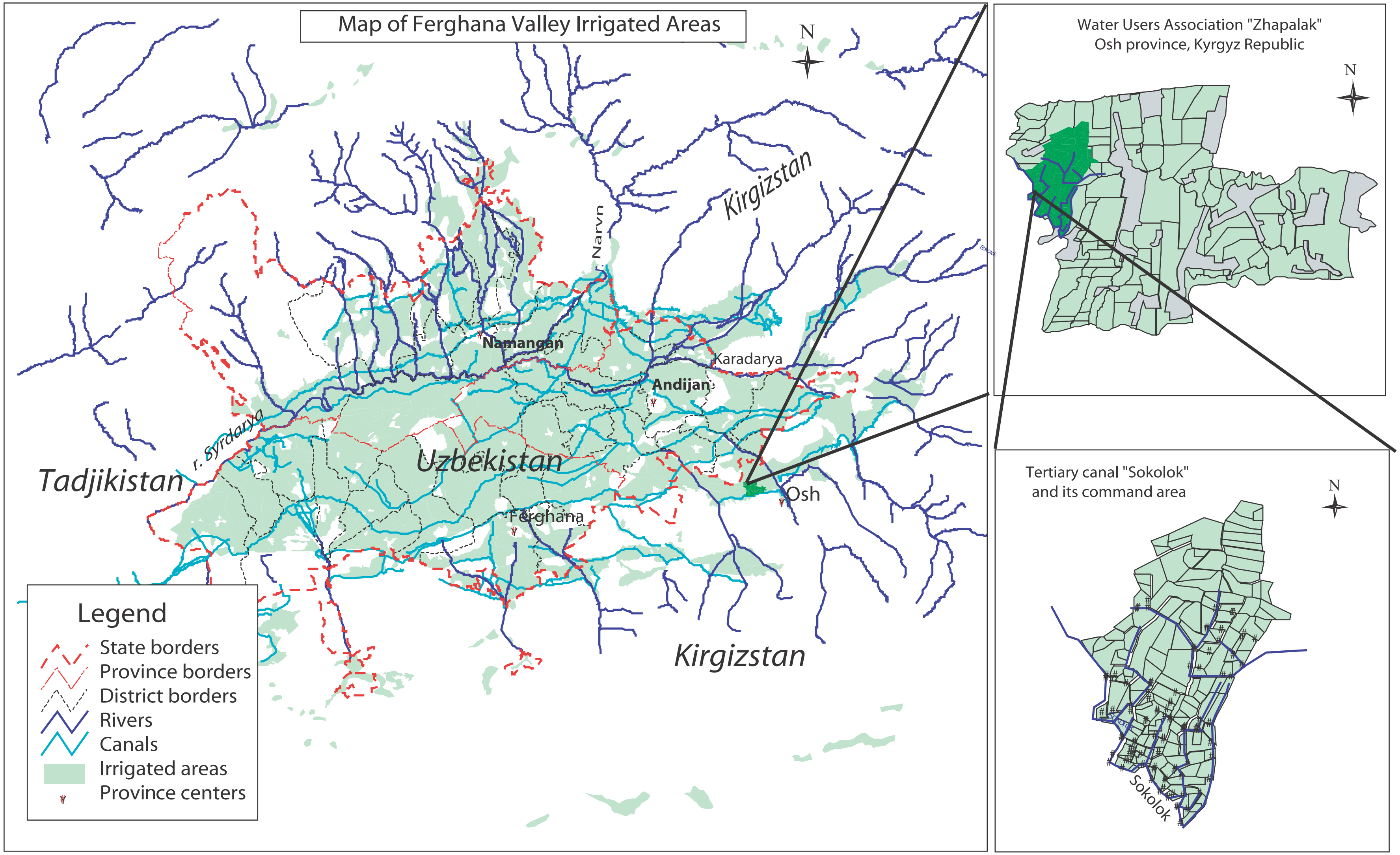
Most baseline and follow-up data required for this study were collected either from (i) primary sources such as farmer surveys, direct field measurements of maximum and minimum water discharges in the canal outlets (these were obtained using mobile weirs), process documentation by field observers (minutes of the meetings of Water User Groups (WUG) by watercourses), direct communication with WUA staff (technical data on Sokolok Canal and its offtakes, etc.); or from (ii) secondary sources such as WUA records (water, land and cropping information from staff reports and annual reports by the WUA Director to the WUA Council, and technical documentation). Data for 2002, that were not available from secondary sources, were obtained by interviewing the canal master and the water users. In addition to technical data, the existing water distribution practices, as well as farmers' perceptions and attitudes of them, were collected and analyzed because of rapid appraisal surveys.

Assessing the Irrigation Performance by Survey

A considerable amount of work in the world of research has been dedicated in the past 10 years to developing an irrigation performance assessment framework. Most irrigation performance indicators have traditionally measured adequacy, equity and reliability of water services (Wolters 1992; Murray–Rust and Snellen 1993; Bos et al. 1994). Overall, the methods for such evaluation have, particularly, undergone major changes in the last 20-25 years. Performance assessment began in the mid-70s in terms of classical irrigation efficiencies (Bos and Nugteren 1974; Jensen 1977). This was later translated into an assessment based on irrigation performance indicators (Levine 1982; Small and Svendsen 1990; Bos et al. 1994) with the most recent developments leading to the principles of water accounting at the basin scale (Molden 1997; Burt et al. 1997).

Bos et al. (1994), after a thorough analysis of all the previous work, came up with a list of indicators to measure the performance of (i) water delivery systems, and that for (ii) environment and economic aspects of the production system. This paper builds on the former - water delivery system performance indicators. Those are: (i) *Reliability:* actual water delivery schedules reflecting the planned or intended irrigation schedules; (ii) *Timeliness:* water delivery against specific time requested; and (iii) *Equity:* an extent to which each farm receives water according to irrigation requirements of the crops grown (Bos et al. 1994, 2005; Horst 1998).

FIGURE 1.
Pilot canal location.



Note: Map was created by Dr. Alexander Platonov, GIS/RS Specialist at IWMI, Tashkent, Uzbekistan.

The general consensus is that performance evaluations can only be made at the higher hierarchical levels in an irrigation system and where routine and accurate flow measurements are made. Therefore, in this study at the tertiary canal level, we have used water users' perceptions of irrigation services as a performance evaluation tool. The surveys were conducted in January and November of 2003 to analyze the situation before and after the intervention. Eighty water users were sampled (17 percent of total) in each survey. Five to six water users were randomly selected from each watercourse, using the WUA's Irrigation Service Fee (ISF) roster for the Sokolok Distributary. They were requested to evaluate water distribution performance based on the above three indicators before and after the intervention using a 1-to-5 scale from very bad (1) to excellent (5). The survey questions reflecting those indicators were simply designed to make it easy for farmers to give answers.

Assessment Criteria

The efficiency of rotational water distribution before and after the intervention was evaluated against five measurable indicators. All such indicators for the intervention period were compared with those for the previous crop season. The *first indicator,* ranked by the water users as the most important, was equity between the offtakes of the distributary canal. This was operationalized as the ratio of total or per hectare volume of water actually supplied for a watercourse, based on measured data, to the water duty for the watercourse in the water use plan of the Sokolok Canal. The *second most important indicator* ranked was the average wheat yield per watercourse during the intervention period compared to the previous crop season. Wheat yields were assessed by interviewing household heads and farm leaders, as well as from tax records at local government offices. The *third indicator* was the rate of ISF collection per watercourse. As no special efforts were made by the WUA Directorate to improve ISF collection during the intervention period, any improvement in fee collection was assumed to have resulted from better water distribution and users' satisfaction with the service. The ISF collection data for the two seasons in question were obtained from WUA accounts. The *fourth indicator* was time spent by water users to get their irrigation turn during the intervention compared to the preceding crop season. The *fifth indicator* was the number and nature of water-related disputes in the distributary canal compared to the previous year. In WUA "Zhapalak", conflicts and grievances had been regularly registered since 1999, so the field staff registered all such disputes during the intervention period as well.

Results and Discussions

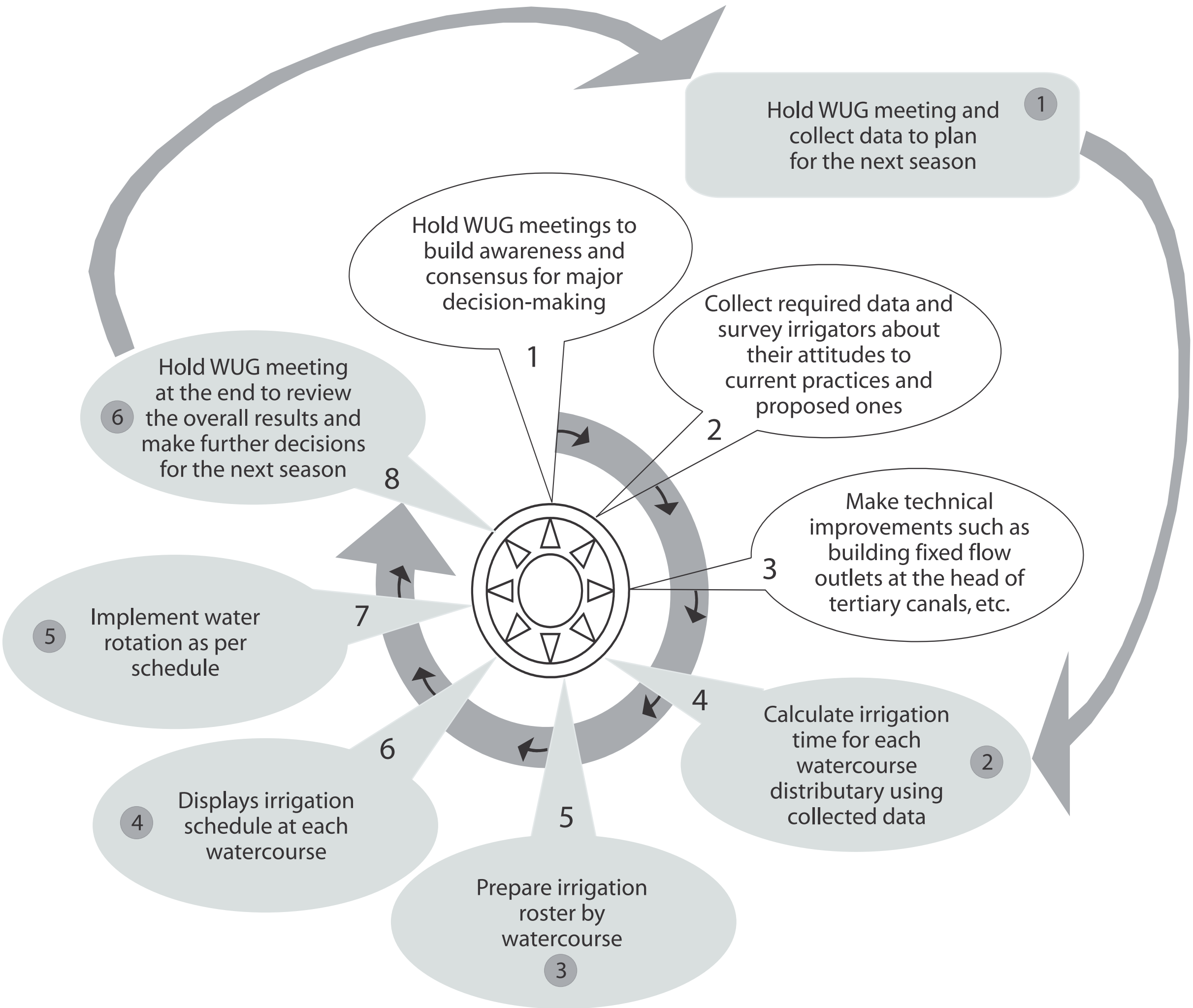
Monitoring the Rotational Water Distribution: Socio-technical Issues

The new, rotational water distribution was implemented in two phases. During the *first phase* in the growing season (April-October) of 2003, it was directly supervised by the project staff. Two field staff were hired in the first year of the trial to implement and monitor the whole process. They were first trained for two weeks in the rotational water distribution to facilitate farmers and WUA staff in the smooth implementation. The following data were collected by the staff: daily head discharges for the distributary and all its offtakes, annual cropping patterns for each offtake command, the number of hours each watercourse was scheduled to receive water, daily changes in water schedules and the number of disputes that occurred during the season.

During the *second phase* in 2004, water distribution was supervised directly by the WUA staff (water master) in cooperation with the WUGs at each offtake. The project staff only monitored the process.

Adopting and implementing the new methodology was not an easy technical task. It took quite an effort to plan and prepare it thoroughly in close cooperation with the WUA Directorate, water masters and water users. A survey conducted prior to the intervention indicated the need for farmers to be organized into Water User Groups (WUGs) along each watercourse. However, due to insufficient time left in the first year, the formation of WUGs was postponed to early 2004. The project staff met water users from each watercourse to discuss WUG issues. As a result, each watercourse nominated a volunteer to represent its users on all rotational water allocation issues. WUGs were finally formed in the second year at each watercourse using a thorough social mobilization approach, based on the following 8-step cycle (figure 2).

FIGURE 2.
Participatory cycle for rotational water distribution.



Note: Created from experimental observations and data from the Sokolok Canal.

In the *first phase,* it was the project staff who initiated meetings and surveys at each watercourse to perform diagnostic analysis of the problems faced, build awareness and consensus among the water users, who then elected their own representative to supervise water distribution.

In the *second phase,* project staff worked in close cooperation with the offtake representatives and canal masters to collect the required technical data on the distributary canal and all its offtakes. The data included information on the command and sub-command areas, canal lengths, hydraulic and flow control structures, the number of water users, temporal flow characteristics, cropping patterns for a particular growing season by each offtake, long-term averages for water discharges and water level in the head of the distributary, etc.

In the *third phase,* water users were mobilized to make technical improvements to their canals. A technical survey identified the major technical obstacles as being siltation, poor maintenance, unstable flows and unregulated offtake diversions (table 2).

The second meeting with farmers concentrated on technical problems that might hinder rotational operation. Users were willing to desilt their canals and also asked for support from the project in equipping their offtakes with gates. Three alternative gate structures were identified, with the majority favoring a pipe-based shut-off gate structure, given its cost and utility. While technical assistance to design and produce the required number of gates was provided by the project, labor contributions to install them were made by the water users with supervision from the project staff. Project staff calculated the required pipe diameter for each gated outlet based on the maximum discharge of an offtake diversion and contracted a local manufacturer to produce 14 units. Each unit cost US$35. The outlets were installed before the beginning of the growing season in March 2003. In addition, two flow regulation gates were installed in the middle and tail reaches of the canal to help sustain its water level so that the outlets could receive water without much damage to the canal banks. The gates are operated by the *mirab* (canal master), according to the agreed distribution schedules.

The *fourth phase* involved conversion of the water volumes planned for each watercourse into water turns. The duration of each water turn was calculated using formula (1). These calculations were facilitated by a special spreadsheet provided to the WUA. WUA staff and canal masters (*mirabs*) were trained to use it and then implement the schedule in the field.

Following this, (*the fifth phase*), the water turns were transformed into 10-day draft irrigation schedules. The draft schedules were discussed with WUGs every 10th day of each month throughout the growing season. Preliminary discussions held within the WUGs along the Sokolok Canal had revealed that the farmers preferred their irrigation turns to proceed from the head-end to the tail of canals. Following this

TABLE 2.
Major impediments to rotational distribution in Sokolok Canal.

Technical Problem	Description
Discharge in the canal is low due to siltation	Q_{max}= 200 l/s, $Q_{average}$= 120 l/s (multi-year); In the 2003 season $Q_{average}$ was only 80 l/s
Canal water losses are huge	73% of head discharge is lost to infiltration (as tested prior to the intervention)
Flows and water supply are very unstable	Head discharge fluctuates throughout the day
Offtake diversions are not regulated	None of the offtakes have any regulation structure and thus have to be manually closed or opened using mud and stones

Notes: Created from experimental observations and data from the Sokolok Canal.
l/s = liters per second.

pattern, irrigation schedules for the first 10 days were drafted and approved by WUG representatives from the beginning of April 2003. The format of the schedules was kept as simple and user-friendly as possible. It clearly set out the time for each irrigation to start and finish in each watercourse. Starting at midnight on the first day, an irrigation turn was scheduled to end at midnight of the 10th day following a 10-day rotation cycle.

In the *sixth phase*, after irrigation schedules were finally approved, they were widely communicated and publicized among all water users in the command area using metallic display boards placed at the head, middle and tail of the distributary canal. Such displays proved to be a good reminder to water users as to when and for how long they would receive water.

The *seventh phase* was the implementation of the water rotation as scheduled and jointly approved. In 2003, this was supervised by the project staff but in 2004, the canal's water master took charge. In both cases, those in charge were instructed to regularly note any interruptions or failures in the irrigation schedule as well as measure and record the flow rates at the head of the distributary and its offtakes three times a day.

Finally, in the *eighth phase* - upon completion of the crop season, both in 2003 and 2004, a series of wrap-up meetings were held by each WUG to (i) discuss the outcomes of the new methodology used, (ii) measure overall users' satisfaction, and (iii) refine any further arrangements for the next growing season. Following this, another survey was conducted to follow up users' perceptions.

Users' Responses Before and After Intervention

The survey (table 3, columns titled "before") clearly suggested that water users had been quite unhappy with existing water distribution practices, in terms of equity, reliability and timeliness, longing for better performance. The follow-up survey of the same respondents conducted in 2004 revealed that the share of those dissatisfied with various aspects of the irrigation service performance had considerably decreased, while those satisfied increased (table 3, columns titled "after"). Likewise, those sampled also reported that the time expended to get their irrigation turn had also decreased. Table 3 also shows that, overall, the water distribution rated as bad or very

TABLE 3.
Irrigation service performance as ranked by survey respondents.

Rankings by Respondents [% of total]	Reliability		Timeliness		Equity		Overall Performance	
	Before[1]	After[2]	Before	After	Before	After	Before	After
1 – Very bad	9%	4%	12%	5%	40%	14%	5%	10%
2 – Bad	44%	30%	48%	26%	56%	22%	32%	24%
3 - Moderate	31%	18%	40%	15%	4%	17%	38%	15%
4 - Good	12%	37%	0	51%	0	38%	19%	42%
5 - Excellent	4%	11%	0	3%	0	9%	6%	9%
Total No. of Respondents	100% N=80	100% N=80	100% N=80	100% N=80	100% N=80	100% N=80	100% N=80	100% N=80

Notes: Created from experimental observations and data from the Sokolok Canal.

[1] Before implementation of rotational distribution

[2] After implementation of rotational distribution

bad both before and after the intervention was similar. This can be partially explained by relatively poor services for some tailenders compared to those at the canal head.

Number and Nature of Water Disputes

Disputes between farmers over water distribution are direct indicators of the irrigation service efficiency. The number of disputes as well as their nature can help diagnose water-related problems. In many cases, water disputes between different offtakes of the distributary canal are prone not to be registered and handled internally by the water users. The WUA staff is normally approached only if parties in a dispute fail to settle their grievances on their own. Given this, registered water disputes represent only the tip of the iceberg. Nevertheless, patterns in the incidence of such disputes can be quite indicative of how water users react to any particular changes in water distribution practices. The disputes registered by and large belonged to the following two types: (i) over water volumes, normally occurring between WUA staff (canal master) and water users, when the latter complain that the volume of water supplied was not enough to grow their crops; and (ii) over irrigation turns, most prevalent between water users along the same watercourse (prior to the rotational water distribution, there were disputes over water rotation between the canal water users).

In the year preceding the intervention, there were 26 disputes registered with half of them (13) being over water volumes and another half over irrigation turns (table 4). Thus, water users were equally in dispute both with one another and with the WUA. In the first year after rotational water distribution was introduced, the total number of disputes declined to 18 or by a third. The second year of practicing with rotational water distribution witnessed further decline down to 14. Most disputes (83 percent) occurring in the first year were over water volumes, with those over irrigation turns amounting to only 17 percent. The same trend was also observed in 2004. Thus, water distribution improved due to clear water distribution schedules reducing the total number of disputes, especially those between water users.

Water Service Fee Collection

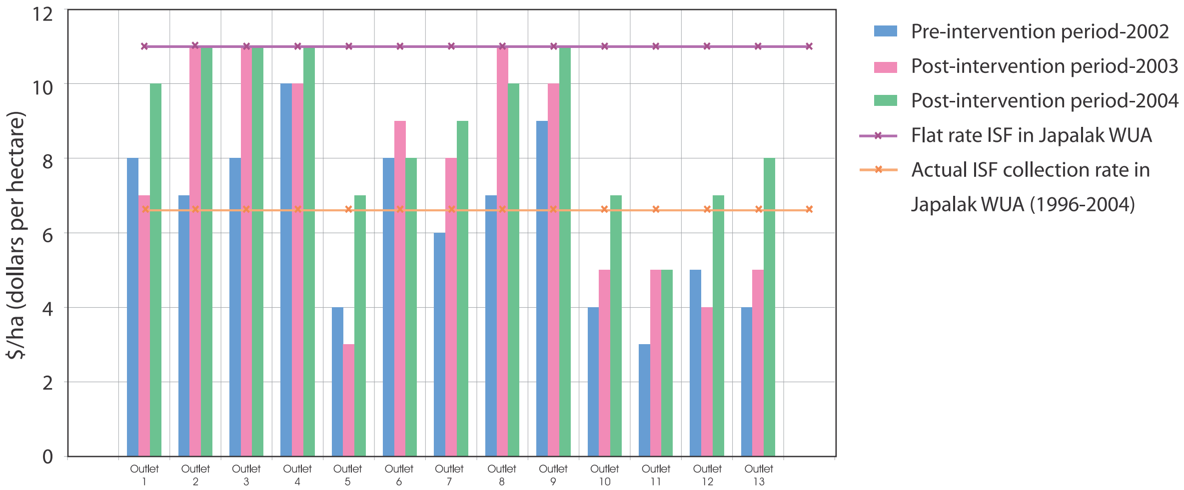
Since 1996, it has been mandatory to pay for irrigation water in Kyrgyzstan. The Kyrgyz WUAs are subject to two Irrigation Service Fee (ISF) tariffs as set by the Kyrgyz government - one for the summer crop season ("*vegetatsionniy period*" in Russian) set at $0.73 for each 1000 m^3 of water withdrawals, and one for the winter crop season ("*mezhvegetatsionniy period*" in Russian) set at $0.24. A markup to this amount is additionally charged by the WUAs to cover their operation and maintenance costs. Thus, the total water fee for the summer crop season in the study WUA "Zhapalak" in 2003-2004 was set at $0.98 per 1000 m^3 of water withdrawn. According to national water regulation, at least 70 percent of ISF should be paid in cash with the rest in kind. However, given high poverty and poorly developed local markets, the ISF is usually paid in kind. In

TABLE 4.
Type and number of water disputes in Sokolok Canal.

Time Period	Total No. of Disputes	Disputes over Water Volumes	Disputes over Irrigation Turns
Prior to intervention, 2002	26	13	13
After intervention, 2003	18	15	3
After intervention, 2004	14	10	4

Note: Created from experimental observations and data from the Sokolok Canal.

FIGURE 3.
Water service fee collection by outlets of Sokolok Canal.



Note: Created from experimental observations and data from the Sokolok Canal.

addition, the volumetric charges, although statutory, are hardly implemented by Kyrgyz WUAs due to the lack of accurate water measurement. So ISFs are normally charged on an area basis ($/ha). Thus, in WUA "Zhapalak" there was a flat rate of about $11 per hectare, regardless of the crop type or location. Fee collection for the selected Sokolok Canal was amongst the highest in this WUA even before rotational distribution was introduced. Total fees collected from half of its sub-commands were more than on average for the entire WUA - $6.6/ha, although farmers from the offtakes 5, 7, 10, 11, 12 and 13 paid on average less than $4/ha in water fees (figure 3). As for the offtake 14, the local water users were exempted from paying ISF due to the prevalence of kitchen gardens here and availability of alternative water sources.

It was also assumed that there was a direct relationship between ISF collection and the quality of irrigation service. Although, no other special measures were undertaken by the WUA management when first introducing the rotational water distribution, the ISF collection dramatically improved. During the first year of intervention (2003), the number of tertiary commands that had average or above average collection rates increased. However, no changes were found in the case of the downstream offtakes when compared to 2002. In 2004, when rotational water distribution was managed by water users themselves, 12 out of 13 offtakes along the Sokolok Canal had higher water fee collection rates than on average for the entire WUA.

Thus, improvements in revenue collection were mainly the result of the newly adopted water distribution method as well as the empowerment of the local WUGs to take local management decisions on their own and collectively manage the process. Following the second year of the rotational water distribution experiences, 12 out of 14 outlets along the Sokolok Canal increased ISF collections by 50 percent, having the highest ISF collection rates among other canals of WUA Zhapalak.

Among the main drivers for the farmers of Sokolok Canal to opt for rotational water distribution was high water losses coupled with large numbers of water users located along the canal, which made local water distribution a regular nightmare. Despite being an integral part of an irrigation system with quite a secure water supply, the farmers in this particular canal had not normally received their water on time. Therefore, once the method was applied, most of the farmers were quite happy to pay for even less water, provided it was distributed equitably and on time.

Wheat Yields

An accelerated process of land redistribution in Kyrgyzstan has brought about both positive and negative changes. The restructuring of agriculture has led to increased land and water productivity, adoption of innovative approaches and conservation of costly inputs by new farmers. At the same time, the reforms have resulted in the emergence of a predominantly subsistence farming system in Kyrgyzstan. Under this system, growing wheat and securing sufficient grain reserves have become one of the most important coping strategies for most subsistence farmers to survive through the winter. In the study area, those at the tail end of canals experienced much lower yields due to a lack of irrigation water. Therefore, it was much hoped that the rotational distribution of water would improve this situation. Prior to the intervention, the wheat yields in the study offtakes 4, 5, 7, 8, 9, 10, 11, 12 and 13 were 1.5-2 times lower than on average in the WUA, amounting to 1 t/ha (figure 4).

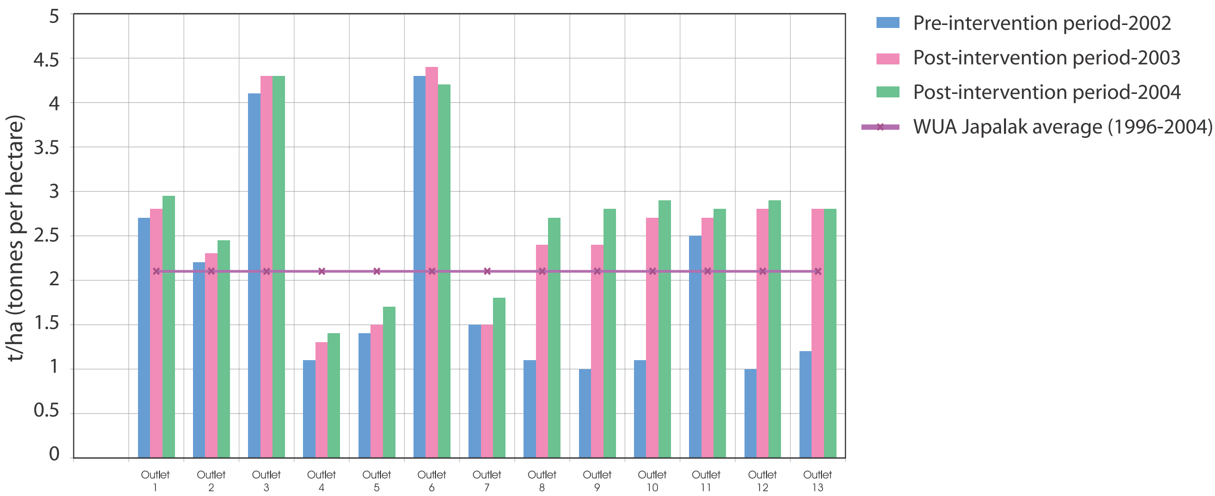
Improved water distribution had a positive impact on wheat yields at all study offtakes. The number of sub-commands that had yields higher than 2.1 t/ha (i.e., WUA average) increased from 4 in 2002 to 10 in 2003. This was especially the case with the downstream offtakes, where wheat yields in 2003 and 2004 doubled and tripled, respectively. Offtakes 4, 5 and 7, featuring one of the lowest yields in the WUA prior to the intervention were still yielding lower than on average in the WUA, suggesting that there might have been some other problems that were not water-related. Such other problems could well be poor seed quality, under-application of fertilizer as well as poor insect and pest control.

Assessing Rotational Water Distribution: Equity, Reliability and Sensitivity

Equity of water distribution

The equity of water distribution along the Sokolok Distributary was assessed by comparing actual water withdrawals against the initially planned targets. WUA data for 2002, the year preceding the intervention, were cross-checked with those from the canal master's water records. In 2001, the ratio of actual-to-planned water withdrawals for the Sokolok Canal was 200.5 percent, which is higher than on average for the entire WUA "Zhapalak" (123 percent). This suggests that water withdrawals by both the study canal and the entire WUA

FIGURE 4.
Wheat yields by outlets of Sokolok Canal



Note: Created from experimental observations and data from the Sokolok Canal.

were higher than planned. However, in no way did it mean that all the offtakes along the study canal received water equally or in excess of what was planned. Thus, the first four upstream sub-commands were extremely water-abundant, while those in the downstream (offtakes 9 through 13) had far less water than planned (table 5). This can be clearly seen from the huge difference between the maximum (705.9 percent) and minimum (34.5 percent) values for the ratio of actual-to-planned water withdrawals by the study offtakes. To show the overall water equity in the study canal, the sums of the actual-to-planned ratios for two groups of watercourses were compared. The first group comprised of the four most upstream watercourses while the second represents the four most downstream offtakes. In the year preceding the adoption of the new method, the difference between these two groups amounted to an incredible 1304.1 percent, i.e., the four most upstream offtakes were collectively received by 1304.1 percent more water than the four further downstream! At the same time, water withdrawals by the tail-most offtake (no. 14) amounted to 228.0 percent of what was initially planned due to the continuous flow status it enjoyed for serving the needs of residential kitchen gardens. In 2003, the year when the new rotational distribution method was first introduced the gap between the maximum (225 percent) and minimum values (24 percent) of actual-to-planned ratios for water withdrawals decreased. It should also be noted that, in 2003, the entire water use situation both in the whole WUA and in the study canal dramatically changed. Only 46.2 percent of the initially planned water was actually withdrawn by the canal, and 43 percent, in overall, by the WUA. This can be explained by the low quality of the water planning and high precipitation (almost double of the long-term average) rates that occurred in the year 2003.

In 2003, the difference between the sum of actual-to-planned ratios for water withdrawals by the four most upstream offtakes and that for the four most downstream sub-commands along the

TABLE 5.
Ratio of actual-to-planned water withdrawals by the offtakes of the Sokolok Distributary (% of planned withdrawals).

Distributary Offtakes	Year 2002	Year 2003	Year 2004
No. 1	112.0	67.5	53.2
No. 2	705.9	51.7	60.7
No. 3	468.8	72.0	59.3
No. 4	210.5	62.0	63.3
No. 5	37.0	225.0	54.0
No. 6	71.4	30.0	52.5
No. 7	62.5	28.0	64.0
No. 8	381.8	72.5	66.0
No. 9	91.2	72.5	68.0
No. 10	34.5	26.0	58.0
No. 11	71.4	32.9	56.0
No. 12	41.7	34.0	60.0
No. 13	45.5	24.0	44.0
No. 14	228.0	62.0	87.5
Average, Sokolok Canal	200.5	46.2	60.3
Average, WUA “Zhapalak”	123.0	43.0	47.5
Difference between the sums of ratios for 4 most upstream and 4 most downstream offtakes	1,304.1	136.3	18.5

Note: Created from experimental observations and data from the Sokolok Canal.

Sokolok Distributary amounted to only 136.3 percent, resulting in far more equitable water distribution among the offtakes. In 2004 with water withdrawals, in overall, for the WUA being 47.5 percent of what was planned, diversions made by the Sokolok Canal stood at 60.3 percent of the initially planned water. The difference between the maximum (87.5 percent) and minimum (44 percent) values of actual-to-planned ratios for water withdrawals in 2004 further decreased, thus suggesting that water distribution was more equitable.

The reason for far lesser actual water withdrawals against the initially planned targets in 2003 and 2004 was not that there was little water in the main canal. In 2003 and 2004, water availability in the Aravan-Akbura Main Canal that supplies water to the study WUA was 85-90 percent. This suggests that the main reasons for such, much lower actual water withdrawals should be sought inside the WUA and the study canal. It can, rather, be explained by well-above average rainfalls in those two years (precipitation in 2003 and 2004 was 145 and 140 percent, respectively, of the long-term average).

Reliability of water distribution

The overall reliability is the indicator, which reflects both adequacy and timeliness of water distribution for the irrigated area. Bos et al. (1994) have suggested the following formula for calculating the overall reliability of the irrigation system:

Overall Reliability (OR) = *(Actual Volume Delivered /Planned Volume) x (Actual supply duration/ Target supply duration)* (2)

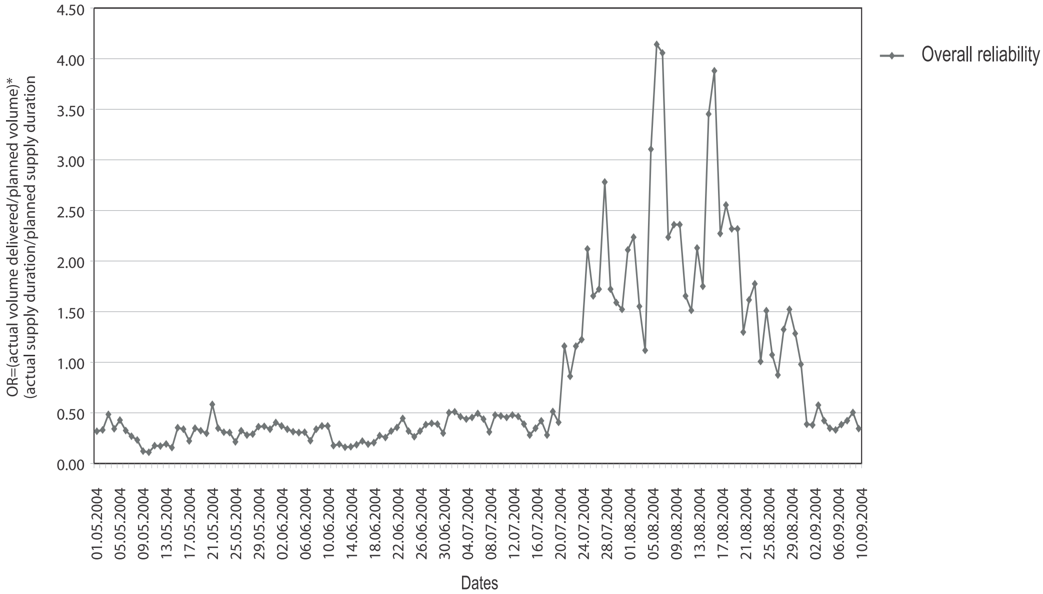
The optimal value of overall reliability of the canal (system) is one, when the irrigation canal (system) delivers planned volumes of the irrigation water for the planned durations. *OR* could be measured for each outlet of the tertiary canal. However, under rotational water distribution only one outlet receives water at a time. Therefore, *OR* of the entire canal (Sokolok) does reflect the reliability situation for each outlet. On the other hand, *OR* is a function of the operations of higher level canals (secondary and primary), while the interventions in the study area involved only a tertiary canal. Nevertheless, the OR analysis helps realizing that even with good water management practices, well applied at the lowest levels, the problems will still persist due to malfunctions at the higher levels. Fully acceptable water service reliability can only be achieved through water management improvements at all hierarchical levels.

Overall reliability for Sokolok Canal was determined by comparing the expected (planned) discharge values, and irrigation supply duration against the actual ones. The overall reliability of water distribution was assessed only for 2004. For this, water discharges and duration of the water supply in the Sokolok Canal were measured by the field staff on a daily basis, using calibrated standard flumes starting from May 01, 2004 through September 10, 2004.

The overall reliability of the Sokolok Canal being very low (0.1-0.50) for the period of April through mid-July (figure 5), then drastically increasing to 4.00 suggests that water was delivered in excess of what was demanded and for longer periods than planned.

The *OR* once again declines at the end of the crop season (September) down to 0.5-0.6, due to the season ending. The *OR* analysis for water services in the pilot canal clearly suggests that it was not optimal or high enough to be fully acceptable. As noted above, the *OR* of the tertiary canal depends, among other things, on the higher-level canals, suggesting that there is need to improve water management at higher levels, such as secondary canals (WUA-managed) and primary canals (managed by Water Management Organizations). Interventions targeting only tertiary canals will not result in dramatic improvements in irrigation water reliability.

FIGURE 5.
Overall reliability of Sokolok Tertiary Canal for vegetation season of year 2004.



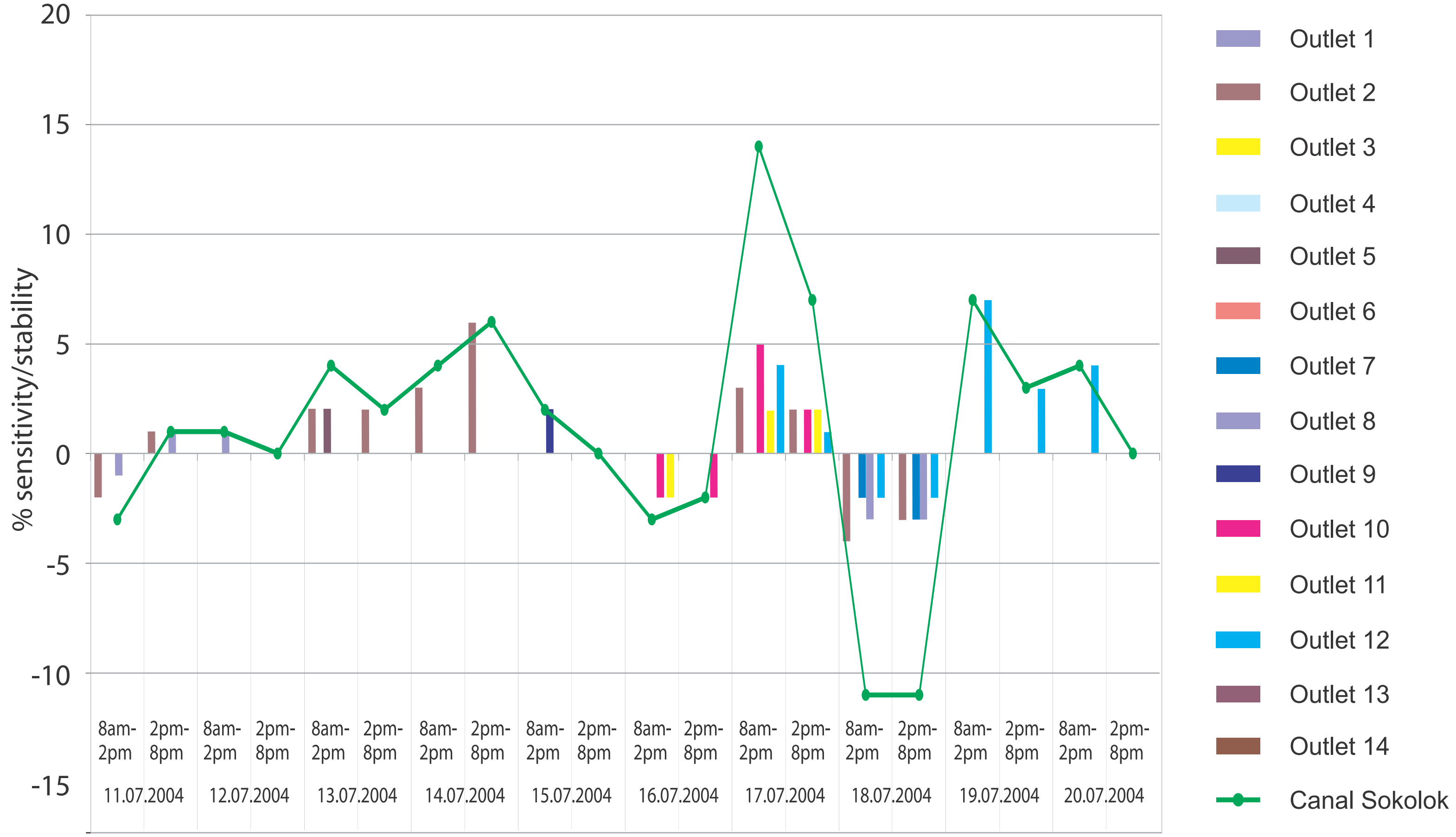
Note: Created from experimental observations and data from the Sokolok Canal.

Flow stability during water distribution in the Sokolok Canal

Stability analysis indicates how changes in the higher-level canal are reflected on water distribution in the lower level. For example, 100 percent stability means that discharge fluctuations in a canal are equally distributed among all its offtakes. This was assessed by comparing changes in the discharge rate of the study distributary canal with variations in that of the offtakes, within two time intervals in a day from 8 am to 2 pm and from 2 pm to 8 pm. Ideally, for the rotational water distribution to be properly implemented the flow stability should be 100 percent. This would occur if the entire flow is diverted to only one watercourse at a time. However, in 2004, when farmers managed their water distribution, water was at times delivered to 3-4 offtakes simultaneously. As a result, the flow stability during rotational water distribution decreased.

To perform sensitivity analysis, data on the head discharges of the study distributary canal and those of its offtakes for the second 10-day period in July 2004 were compared. The results of this analysis are presented in figure 6. Throughout the monitoring period, all the offtakes showed very good daily stability against changes in the head of the distributary canal. For example, on July 11, 2004 the head discharge in the Sokolok Canal at 8 am was 55 l/s, at 2 pm 58 l/s and at 8 pm 57 l/s, which translates into a 3 l/s or 5 percent increase between 8 am and 2 pm and a one l/s or 2 percent decrease between 2 pm and 8 pm. At the same time the offtakes 2, 7 and 8 that were simultaneously opened during that day showed the following changes in their discharges: in the offtake no. 2 the discharge from 8 am to 2 pm changed from 24 l/s to 26 l/s (8 percent increase) and from 2 pm to 8 pm changed from 26 l/s to 25 l/s (4 percent decrease). The discharge rate at offtake no. 7 throughout the day remained unchanged (12 l/s) while discharges in the offtake no. 8 changed from 10 l/s to 11 l/s (8 am – 2 pm) and from 11 l/s back to 10 l/s (2 pm – 8 pm). These patterns remained consistent throughout the entire monitoring period. Most of the time, the flow stability during rotational water distribution was very high for the offtakes with high discharge rates, and lower for those with low discharges. To address this issue, the water user representatives made the decision not to discriminate against the offtakes with lower

FIGURE 6.
Assessing sensitivity of water distribution in Sokolok Canal (11/07/2004 - 20/07/2004).



Note: Created from experimental observations and data from the Sokolok Canal.

discharges. Thus, any changes in the head discharge of the distributary canal were distributed among the offtakes with higher discharges. Overall, the observed flow stability in the study canal was quite good. For the first five days of the period (July 11, 2004 – July 15, 2004) when the discharge rate in the distributary canal was mainly declining, three of the five operational offtakes followed suit while the remaining two had the opposite trends. Later, on July 15, 2004 through July 17, 2004, the discharge trend in the distributary canal was increasing. However, no reaction was observed in the discharge rates of the then operational offtakes, suggesting very low sensitivity. From July 17, 2004 to July 18, 2004 with the distributary canal flow declined, the two offtakes showed very high stability. From July 18, 2004 to July 19, 2004, the discharge trend in the distributary canal was again on the rise, with the offtakes 3 and 14 perfectly following the pattern, thus showing very good stability. Overall, during the 10 days of monitoring the distributary, the canal discharge trend changed five times. Out of 13 offtakes that rotated water turns during this period, four offtakes were quite sensitive to any fluctuations in the flow of the distributary canal while the remaining nine were quite good.

Despite relatively high water withdrawals from the main canal (13,000 m^3/ha), water deliveries to the field level, in most cases, amounted to less than 300 mm (millimeters), representing a fraction of the crop water demand. However, this amount might seem fairly high in comparison with other irrigated regions, such as in Australia. The major reason for such a low water supply to the fields is water losses amounting to 70 percent of the total water withdrawals. Most of these losses, around 70 percent of them, occur due to seepage in the delivery system at all levels, while the remaining 30 percent is lost to leakages in the canals. Overall, most water deliveries occur during the crop season and no soil leaching or winter irrigation are practiced in the area of study.

Conclusion and Recommendations

The preceding discussion clearly suggests that rotational distribution results in greater equity and transparency in water supply to farmers and most likely results in: reduced number of water-related disputes; time savings for farmers when irrigating; and improved ISF collection from a rising number of individual farmers. Besides, there is evidence that crop yields also improved. These results indicate that rotational water distribution could be usefully applied in a large part of post-Soviet Central Asia, where most of the secondary and tertiary irrigation systems lack flow regulation structures and are poorly maintained. While these are the explicit benefits of the proposed method, there are also some that are implicit.

The intervention employing rotational water distribution allowed improving the overall water situation in the study Sokolok Canal. For instance, the difference between the sum of actual-to-planned ratios for water withdrawals by the four most upstream offtakes and that for the four most downstream sub-commands along the Sokolok Distributary dramatically decreased from 1304 percent in the year preceding the intervention to only 136 percent in the year after, resulting in far more equitable water distribution among the offtakes. Throughout the monitoring period, all the offtakes showed very good daily stability against changes in the head of the distributary canal. The water users located at the tail of the Sokolok Canal enjoyed more equitable water distribution which allowed them to grow relatively more water-intensive crops, such as wheat. The number of those who were fully or almost satisfied with their water distribution under the rotational method more than doubled compared to the previous management regime.

This was largely due to across-the-board improvements in the quality of water deliveries (reliability, timeliness and equity), especially, for those at the tail ends of the canals. Such improvements come from a mixture of positive changes that occurred in the study area, as better communication between the farmers, better scheduling of the water deliveries, improved canal condition (due to regular cleaning and simple technical solutions) as well as transparency and compliance with agreed water delivery schedules. However, analysis of Overall Reliability (*OR*) of the irrigation services clearly indicated that it was not optimal or high enough to be fully acceptable. As noted above, the *OR* of the tertiary canal depends among other things on the higher-level canals, suggesting that there is the need to improve water management at higher levels, such as secondary canals (WUA-managed) and primary canals (managed by Water Management Organizations). Interventions targeting only tertiary canals will not result in dramatic improvements in irrigation water reliability.

Rooted deeply in the legacy of the FSU top-down management paradigm, it is public participation that is the weakest element of irrigation management in the post-Soviet transition economies, especially, in Central Asia (Ul Hassan et al. 2004). This results in a poor sense of ownership, poor cost and revenue recovery and overall poor sustainability of local irrigation systems. Decisions are normally made and imposed on communities using technocratic approaches with no regard to the socio-technical nature of irrigation systems. The findings of this action research suggest that water distribution can be efficiently improved through concerted efforts and methods that put "people first." In an irrigation management context, such efforts and methods are most effective when they address issues not only technically (equity, reliability, sensitivity, timeliness, crop yields, etc.) but also employ equally important social and other sometimes intangible dimensions, such as providing effective mechanisms for building sustainable community-based institutions, nurturing local initiative, collaboration and collective action, while effectively minimizing and managing conflict. Two years of experience have shown that once the farmers have realized all the benefits from an intervention, they tend to further refine it more to suit their conditions. As has been evident from the experience elsewhere in South Asia, as soon as the users come to grips with the rotational distribution, there is potential for it to be gradually converted from being a purely technical solution to a localized and sustainable institution, which not only ensures effective water distribution among community members, but also improves the maintenance of their common property irrigation infrastructure due to a more responsible and coordinated collective behavior.

This clearly suggests that it is the needs and concerns of the end users that provide a good entry point to pragmatically understand and analyze the situation, from where appropriate remedial strategies and methods can be further devised and employed. This is also a good starting point to initiate farmers' debates and discussions on public participation, which should ultimately lead to and end up in a truly farmer-owned process and action.

In summary, the experiment has demonstrated that interventions aiming to improve water distribution at the tertiary level can succeed, if carefully planned and implemented in close consultation with and full participation of the beneficiaries themselves from the very beginning, by addressing their real needs and problems and nurturing their own initiative, collective action and institutions.

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