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Project "Integrated Water Resources Management in the Fergana Valley" (IWRM-FV Project)

MANUAL
ON THE IMPLEMENTATION OF INTEGRATED WATER RESOURCES MANAGEMENT

VOLUME 3. WATER MANAGEMENT IN WATER USERS' ASSOCIATIONS
(WUA specialist manual)

Edited by Horst, M.G.

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This Manual is prepared by the team of the following experts: Alimdjanov, A.A., Masumov, R.R., Pinkhasov, M.A., Rasulov, R.A., Horst, M.G., and Yakubov, Sh.Kh.

Under the general editorship of Horst, M.G.

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http://iwrm.icwc-aral.uz

Please send your comments and suggestions to the following address:
horst_mg@icwc-aral.uz

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FOREWORD

Under the reorganization of irrigated agriculture of the Central Asian Region (CAR), when former large state-run farms have been transformed into a number of small individual farm units, the irrigation network management level has considerably declined. Low-water years of recent years became often aggravated because of anthropogenic water deficits caused by lack of coordination between crop irrigation demands and irrigation network operation mode.

The split-up of former large farm units into small ones along with the changing former large farms' on-farm irrigation networks for inter-farm networks caused the need for the creation of intermediate self- government link – water users' association (WUA) – as the intermediary that represents the interests of local water users in governmental water authorities and, with the involvement of local water users, operate and maintain irrigation systems beginning from the water delivery points within the WUA contour to farm lands.

The lower and the most large-scale section of the water management system in irrigated agriculture is composed of individual farms. The water use efficiency and effectiveness at the farm level as well as the economic feasibility of water consumed for the crop grown by farmers in the final analysis influences the effectiveness of the water management system in irrigated agriculture.

Designed for practical use by WUA specialists, this Manual has covered basic recommendations worked out by the IWRM-FV Project experts and tested at facilities of the Project and oriented to efficient and effective use of water resources.

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ABBREVIATIONS

BISA	Basin Irrigation System Administration
CDN	Collector and Drainage Network
CMO	Canal Management Organization
CW	Cipolletti weir
CWC	Canal Water Committee
DWDP	Daily water distribution planning
DWDS	Daily water distribution schedule
EF	Efficiency factor
FC	Fixed channel (of trapezoidal, rectangular, triangular, parabolic profile)
F&L	Fuels and lubricants
GS	Gauging station
HMZ	Hydromodule zone
IDS	Irrigation and drainage system
IF	(Individual) farm
IS	Irrigation system
ISA	Irrigation Systems Administration
IWRM	Integrated Water Resources Management
PF	Parshall flume
PHGRE	Provincial Hydrogeological Reclamation Expedition
PTN	Production and technical needs
RRO	Repair-and-renewal operations
R&S	Regulations and Specifications
SFMC	SANIIRI flow-measurement crest
SFMF	SANIIRI flow-measurement flume
SFMP	SANIIRI flow-measuring probes (of circular or rectangular cross-section)
TW	Thomson weir
UCWU	Union of Canal Water Users
VF	Venturi flume
WA	Water availability
FMD	Flow-measuring device
WMO	Water Management Organization
WR	Water rotation
WSA	Water supply availability
WU	Water user
WUA	Water Users' Association
WUG	Water Users' Group
WUM	Water Users' Module
WUP	Water Use Plan

TERMS AND DEFINITIONS

Application days are the days of filing water applications by water users for certain water volume for certain periods.

Canal efficiency (factor) implies the ratio of the discharge at which water is supplied through the canal less the water losses from it (this discharge is called Q_{net}) to the flow rate at the canal head (so-called Q_{gross}).

Concentrated flow rate means water supply to water users for a short-time period in comparison with crop irrigation regime.

Continuous-flow diversion is water diversion from a main canal (secondary canal) to the WUA contour with a discharge being kept constant during each ten-day period. In the case when several offtakes supply water (from one source) to WUA, the discharge uniformity condition can be set for several (or all) offtakes.

Continuous flow is the water supply regime at which fixed-rate, uniform within each ten-day period, flow is supplied to a water management facility. As a rule, large water users (100 ha and more) are irrigated at a fixed rate.

Farm's irrigation contour is an area within the farm (or the whole farms territory) irrigated from one offtake. A farm may include several irrigation contours.

Fixed flow rate implies continuous-flow water supply to water users during a certain period in conformity with average ten-day period rates provided for in the water use plan.

Gauging station (site) is a station at the watercourse where flow rate and other flow parameters are measured and which is equipped with appropriate gauges.

Hydromodule (water allowance) is the design (standard) discharge of irrigation water in terms of liter per second (l/s), which, depending on water demand of a crop, should be supplied per one hectare of the area under this crop.

Individual farm is an agricultural enterprise with the right of a legal entity based on the cooperative activities of farm members, which has agricultural production with using a land parcel allotted to it for a long-term lease.

Inter-irrigation period is the time after a regular water application to a particular field (plot) till the beginning of the next water application to this field (plot).

Irrigation network (system) efficiency implies the ratio of water volume supplied to entities-water users to the water volume withdrawn from a water source to this effect and transported through a irrigation canal system to water delivery points, i.e. to the places where water is supplied to water users.

Irrigation regime implies the aggregate of rates, time of performance and number of water application for a particular crop.

Irrigation system is the complex of interconnected offtakes that have a single water withdrawal source. For example, main canal, collector, groundwater well, pumping station.

Limited water use implies the situation when a water user receives water from a public water management body in the quantity and regime that are not in compliance with the water application filed by the former and is respectively less and tougher in accordance with limit set in a water supply plan by the WUA with which the water users concluded a contract.

Non-vegetation period is the period from October 1 through March 31 of the following year during which because of drop in climate temperature the crop growth and development almost cease. During this period, non-vegetation irrigation (leaching, pre-tillage, water-charging, pre-planting) is carried out.

Operational planning is carried out every ten days and serves for drawing up ten-day operating water use and water distribution plans. At operational planning, they allow for the ten-day limit, so-called TAKSYM, set by water management organization proceeding from current water resources availability.

Seasonal planning implies making a water use plan in linkage with cropping pattern on the assumption that all irrigated blocks will be irrigated with constant hydromodule for every crop. Seasonal planning is drawn up before the vegetation period after farmers filed water applications for crop cultivation. Seasonal planning takes into account seasonal limit. The results of seasonal planning serve as the basis for making a main canal operation plan.

Secondary canal means the canal that takes water from a main canal to supply water to two ore more water users.

Ten-day water distribution schedule implies water distribution to water users for ten days with specifying concrete water discharge time and value.

Vegetation period is the period when crop growth and development (vegetation) can take place (in crop production, this is the period from sowing till harvesting). From the standpoint of water management organizations, this period covers from April 1 through September 30 of the current calendar year, viz. the period of the carrying out of vegetation irrigation.

Water application rate is the design quantity of water supply per hectare of crop area for one water application (m^3/ha).

Water application site is the area in a particular farm where water application simultaneously starts and simultaneously ends after the lapse of the water application time (after supply of rated water application).

Water delivery point refers to the place where water is delivered to a water user.

Water distribution plan is the document that is drawn up by irrigation systems administration which reflects the volume and regime (broken down by months and ten-day periods) of the distribution of design water resources volume available in this water management systems to certain irrigation systems.

Water distribution uniformity is the degree of ensuring the uniformity of water distribution between water users against water needs.

Water requirement (water requirement rate) water volume, measured in cubic meters (m^3), required to be supplied during a hydrologic year per hectare allotted for a particular crop to meet its need for moisture and provide optimum water and salt regime for root habitable layer to gain planned yield.

Water rotation is alternate water supply to irrigated plots within an irrigated contour.

Water source is a water body (river or another watercourse, reservoir, groundwater deposit, irrigation channel, collector) from which water is withdrawn.

Water supply availability is the ratio of actual water withdrawal to the planned one.

Water supply is delivery of water from a higher-order canal to a lower-order canal.

Water supply plan is the document that is drawn up by a WUA according to the water applications received from water users and allowing for real abilities to satisfy these applications; it states water supply (to water users) volumes and regime broken down by ten-day periods in linkage with certain WUA's water delivery points.

Water supply stability is the degree of the stability of water supply to WUAs by a water management organization during a day, ten-day period, month, and during a vegetation (inter-vegetation) period.

Water use (consumption) means use of water to meet one or another need; in other words, use of consumption of water resources by entities for production (manufacture) purpose or for the provision of services.

Water user/consumer is an entity that needs certain quantity of water and actually uses (consumes) this water.

Water Users' Association is an organization established on a voluntary and self-governance basis; it unites entities that need water and has the status of legal person incorporating individual farms, organizations and enterprises – water users that usually take water from a common water source.

Water withdrawal is diversion of water from a river or another water body for irrigation, watering, water supply, use of water power, etc.

Water withdrawal limit is the limit to water volume fixed by a water management body on the water withdrawal from a water source or irrigation system and designed for supplying to water users.

Water withdrawal place is the place equipped with appropriate facility and designed for taking water from a water source or irrigation system.

1. OPERATING HYDROMETRY IN WUA

1.1. Selection of a construction site and water gauge type

As the IWRM-FV Project implementation experience has shown, selection of the water gauge construction type and place presents a certain difficulty for hydrometric specialists and farmers because of the lack of professional knowledge and practical skills in hydraulic engineering construction. This section gives certain recommendations on practical application of required knowledge when constructing the simplest water gauges.

A preliminary selection of a water gauge type is made depending on the relief, flow rate, water velocity, and other conditions according to the recommendations given in Table 1.1.

Table 1.1

Recommendations for the selection of a water gauge type

Flow grade and regime	**Water composition characteristics**	**Maximum flow rate Q, m^3/s**	
		below 0.5	**0.5-1.0**
High and medium gradients, steady-state flow: V = (0.5 – 1.5) m/s	Concentration of suspended sediments of up to 1.0 kg/m^3	TW, CW, SFMF, PF, VF, SFMC, FC	SFMF, PF, VF, SFMC, FC
	Concentration of sediments of over 1.0 kg/m^3, presence of driftwood and garbage	SFMF, PF, VF, SFMC, FC	SFMF, PF, VF, SFMC, FC
Medium and low gradients, unsteady-state flow: V = (0.01 – 0.5) m/s	Concentration of suspended sediments of up to 1.0 kg/m^3	SFMP, FC	SFMP, FC
	Concentration of sediments of over 1.0 kg/m^3, presence of driftwood and garbage	FC	FC

Notation conventions:

TW – Thomson weir; CW – Cipolletti weir;

PF – Parshall flume; VF – Venturi flume;

SFMF – SANIIRI[1] flow-measurement flume; SFMC – SANIIRI flow-measurement crest;

SFMP – SANIIRI flow-measuring probes (of round or rectangular cross-section);

FC – fixed channel (trapezoidal, rectangular, triangular, parabolic) profile.

[1] SANIIRI is the Central Asian Research Institute of Irrigation named after V.D. Zhurin.

It is known that canal bottom slope is designed depending on the relief and its value influences water flow regime value.

With ***steady-state*** flow in the earth channel, water surface is relatively calm and smooth. There are no highly silted or eroded sections in the channel, water level hardly changes, and nothing obstructs water flow.

With ***unsteady-state*** flow, its elements (velocity, depth, flow rate, etc.) change in terms of both time and length. Such a flow nature is characteristic of highly silted canals with little bottom slopes and overgrown with aquatic vegetation.

On the basis of those characteristics, a hydrometric specialist or water user will on the spot preliminarily determine the flow regime. The concentration of sediments in irrigation water is of no small importance. If the content of suspended sediments is more than 1 kg/m3 or if the flow transports great deal of floating garbage, the crest (weirs) will always become silted or the orifices of water gauges (probes) will become clogged up, and, as a result, the gauging station will stop functioning properly. Therefore, one should perform a series of consecutive actions to ensure correct selection of a gauging station construction site.

1.1.1. Procedure of the water gauge construction site and type selection.

Selection of the canal section and site for a gauging station being designed.

The canal section where the construction of a gauging station is planned should be straight, with a length of not less than L = (6-10) * b, where *b* is the canal bed width (Fig. 1.1). The gauging station's site should be divided in the middle or a little downstream of the straight-line section's middle at a distance of l = 0.5-0.7 * L. One should visually make sure that there is no bottom bed load and that canal banks and sides are not damaged.

Visual identification of the flow regime, definition of the load presence in irrigation water.

The canal section's surface and bottom is inspected at both its upstream and downstream parts. The flow regime at the planned gauging station installation place is determined and irrigation water quality (load presence) is visually assessed.

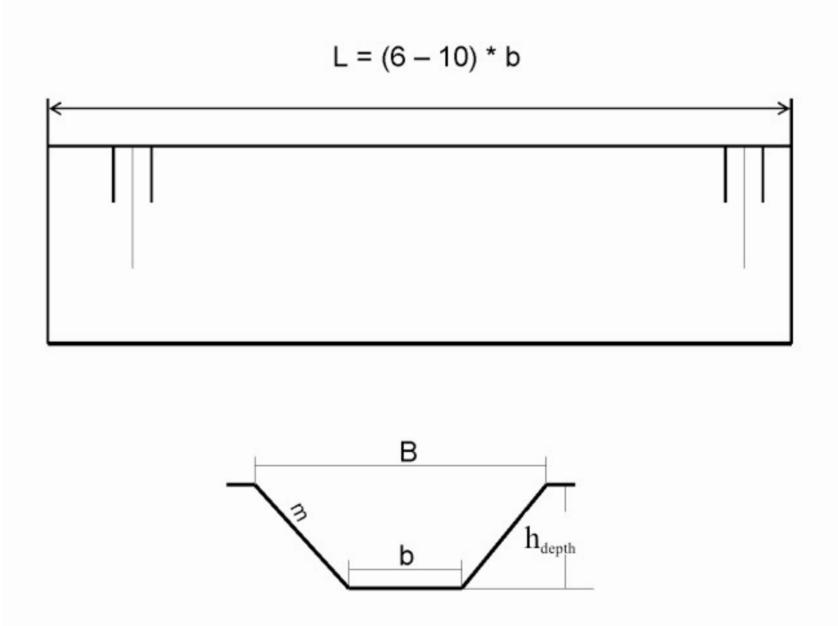


Figure 1.1 Longitudinal and transverse profiles of the selected canal section.

Measurement of the average width at the canal bed (b), upper part (B), and constructional depth of the canal (h) and determination of the rectilinear section length.

Depending on the results of the inspection of the planned gauging station installation places, appropriate water gauge types suitable for water accounting at the planned gauging site are selected based on the recommendations given in Table 1.

Depending on the financial possibilities, availability of local building materials and other factors, an appropriate water gauge type should be finally selected.

Selection of an appropriate water gauge type

As a rule, the following types of water gauges are used as typical flow measuring facilities:

- Thin-plate weirs of different profiles;
- SANIIRI flumes (by Yartsev).
- SANIIRI flow-measurement crests;
- Venturi flumes;
- Parshall flumes;

All the above-listed water gauges meet the requirements of relevant standards and rules, owing to which it becomes possible to make and apply such gauges without individual calibration.

Flumes (Parshall, Venturi) are not recommended to be built in WUAs (see the Standard RDP 99-77 "Rules for flow measurement by using standard weirs"), because those are difficult to make.

1.1.2. Thomson (TW) and Cipolletti (CW) weirs

TW-50 weir is designed for measuring water flow of up to 50 l/s. TW is made of both portable and fixed design (Fig. 1.2). Its structure is composed of a triangular weir with edges convergent at the angle of 90°, made of 3-mm thick steel sheet, stiffening angle, and level gauge fixed on the weir wall aslant (45°) or vertically (90°). The TW top edge facing the headrace flume must be sharp with a facet (45°).

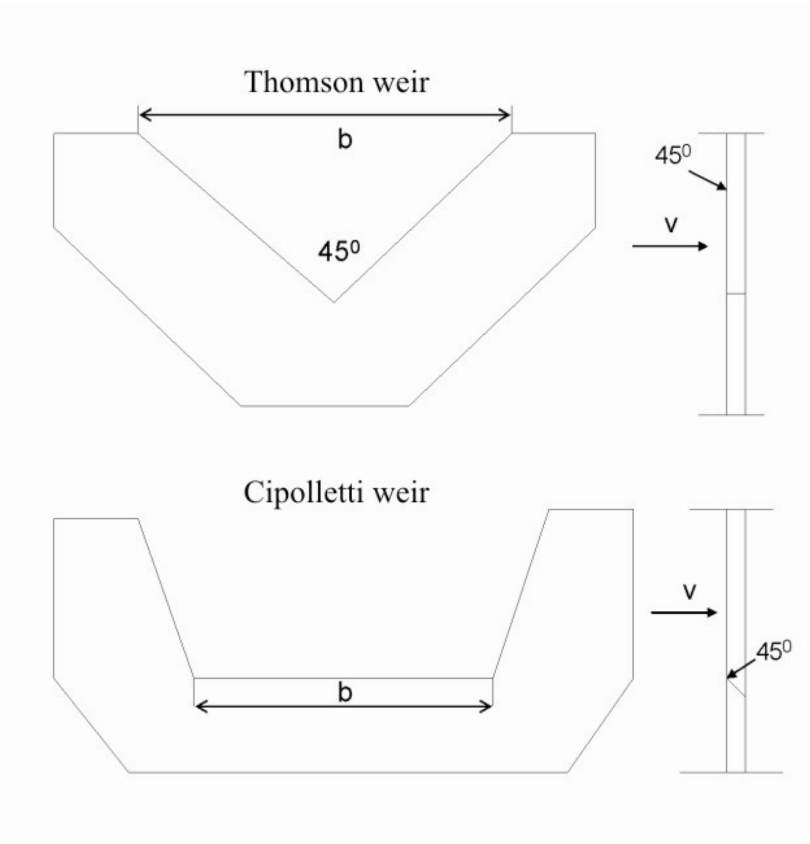


Figure 1.2. Weirs.

CW-50 weir (Fig. 2) is designed for irrigation ditches with the effective range of flow rate from 5 to 80 l/s; CW-75 for irrigation ditches with the effective range of flow rate from 15 to 230 l/s.

CW-50 weir is classified as a trapezoidal weir with thin plates with side slopes 1:4. It is made of 3-4 mm thick steel sheets and angle bars to ensure the rigidity of the construction. The weir crest width (b = 50 cm) is made with a tolerance of ± 2–3 mm, the rest dimensions with a tolerance of ± 5–10 mm; the weir sluice edge must be smooth, clean, with no jag and ledge.

The CW-75 weir is made of 4 mm thick steel sheet; the weir sluice must be smooth with no jag and ledge. The basic size of the crest b = 75 cm, made with a tolerance of ±5 mm, the rest dimensions are with a tolerance of ±10 mm.

The TW and CW weir crest width is made with a tolerance of ±2–3 mm, the rest dimensions are with a tolerance of ±5–10 mm; the weir sluice edge must be smooth, clean, with no jag and ledge.

The TW and CW weir crest edge must be sharp with a facet of 45^o facing the flow.

The level gauge must be made of metal covered with water-resistant paint at a specialized plant. The graduations and figures are not to become obliterated and the rod's zero points are to be in line with the weir crest mark. The whole metal construction is to be painted by three-coat anticorrosive paint.

1.1.2.1. TW and CW weir installation requirements

- the earth section of the canal designed for the installation of a weir must be straight and its length should be L = 10 * b with symmetrical cross section;
- the earth section of the canal (bed and sides) must be cleaned from the silt, aquatic vegetation, and garbage with keeping symmetry;
- a weir has to be installed strictly upright and perpendicularly to the canal centerline by fitting it into the earth channel bed and sides in the middle of the section prepared;
- the weir crest must be strictly horizontal; its vertical wall has to be perpendicular to the base; the weir centerline must match with the canal centerline;
- the weir crest *P* height should be greater than the maximum depth h_{max} of the canal (Fig. 1.3) after the weir;
- the beginning of the headrace section and end of the tailrace sections of the canal must be made in the form of hydraulic key wall, i.e. by pouring concrete of the width and thickness twice as much as the thickness (t) of the concrete lining of canal bed;
- in order to decelerate flow velocity, which is over 0.5 m^3/s, the headrace section of the canal before the weir should be widened and depth should be deepened.

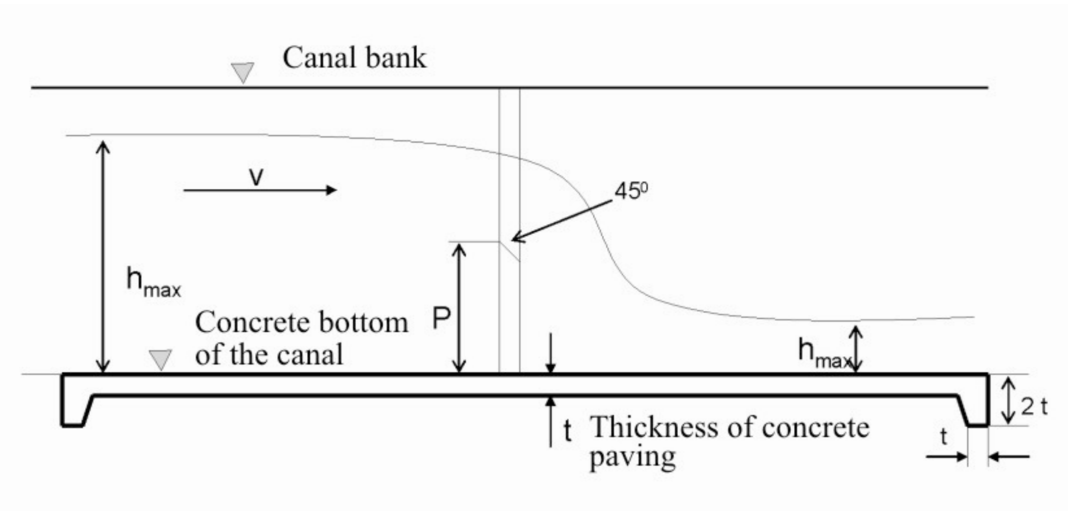


Figure 1.3 Gauging station with a Cipolletti weir.

Note: *To set the weir crest in strictly horizontal position and correlate its crest mark with the zero position of the hydrotechnical rod, it is suggested to use a leveling instrument or hydrolevel, using a transparent small-diameter hose filled with water.*

1.1.2.2. Flow rate measurement by means of weirs.

Flow rate is determined according to working equations:

for TW triangular weirs:

$$Q = 1.4 * H^2 \sqrt{H} \text{ , m}^3\text{/s} \tag{1.1}$$

for CW trapezoidal weirs:

$$Q = 1.9 * b * H\sqrt{H} \text{ , m}^3\text{/s} \tag{1.2}$$

where:

b is weir crest width, (m);

H is water head above the weir crest, (m).

For easy determination of water flow through a gauge level, the flow rate values for all types of weirs are given in Table 1.2.

Table 1. 2

Flow rate values (Q, l/s) subject to water level (H, cm) for weirs CW-50, CW-75, TW-50.

Pole level, H (cm)	CW-50 flow rate Q (l/s)	CW-75 flow rate Q (l/s)	TW-50 flow rate Q (l/s)	Pole level, H (cm)	CW-50 flow rate Q (l/s)	CW-75 flow rate Q (l/s)	TW-50 flow rate Q (l/s)
3.0	5.0	-	-	16.5	64.0	94.0	15.0
3.5	6.0	-	-	17.0	61.0	98.0	17.0
4.0	7.0	-	-	17.5	70.0	103.0	18.0
4.5	9.0	-	-	18.0	73.0	108.0	19.0
5.0	10.0	16.0	0.8	18.5	76.0	114.0	20.0
5.5	12.0	18.0	0.9	19.0	79.0	120.0	22.0
6.0	14.0	21.0	1.3	19.5	82.0	124.0	23.0
6.5	16.0	23.0	1.5	20.0		128.0	25.0
7.0	18.0	26.0	1.8	20.5		132.0	26.0
7.5	20.0	30.0	2.1	21.0		136.0	28.0
8.0	22.0	33.0	2.5	21.5		140.0	30.0
8.5	24.0	36.0	2.9	22.0		145.0	32.0
9.0	26.0	39.0	3.3	22.5		150.0	33.0
9.5	28.0	42.0	3.9	23.0		154.0	36.0
10.0	30.0	46.0	4.5	23.5		160.0	38.0
10.5	32.0	49.0	5.0	24.0		166.0	40.0
11.0	35.0	52.0	5.6	24.5		170.0	42.0
11.5	37.0	55.0	6.2	25.0		175.0	44.0
12.0	40.0	59.0	7.0	25.5		180.0	
12.5	42.0	63.0	7.7	26.0		186.0	
13.0	44.0	66.0	8.5	26.5		191.0	
13.5	47.0	70.0	9.3	27.0		197.0	
14.0	50.0	74.0	10.0	27.5		202.0	
14.5	52.0	78.0	11.0	28.0		208.0	
15.0	55.0	82.0	12.0	28.5		214.0	
15.5	58.0	86.0	13.0	29.0		220.0	
16.0	61.0	90.0	14.0	29.5		225.0	

1.1.2.3. Operation of weirs (TW, CW).

To ensure normal, within feasible accuracy ($\sigma = \pm 5$ %), water accounting, the following rules have to be observed:

- check the crest horizontality and wall verticality on a regular basis; control that the gauge zero matches with the crest level;
- clean the headrace section of the canal if it is silted (crest P should be higher than the canal bed at the upstream); the weir crest must not be flooded at the downstream part (Fig. 1);

* the weir must be maintained at least once a year (cleaning from sediments, correction of faults, painting, placement of rods, etc.).

1.1.3. Flow measuring flume of SANIIRI (SFMF).

For small canals in WUAs, it is recommended to construct SANIIRI flumes. The SANIIRI flow-measuring flume (SFMF) is a short flume with vertical walls converging towards the downstream and with the horizontal bottom. The flume is connected with the canal at its downstream and upstream parts by means of wing walls; at that, a well is made at its water impact part. The crest P is not necessary to become higher than the canal bed. The level gauge is to be fixed to the front wall of the flume; the gauge zero is to match with the mark of the flume bottom (Fig. 1.4).

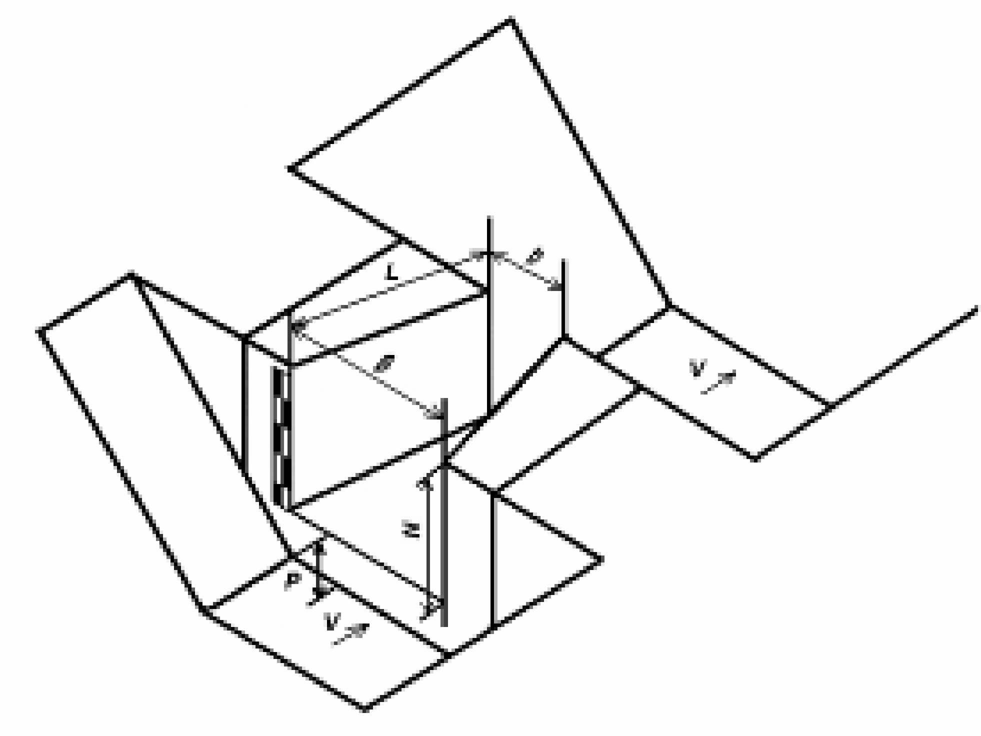


Figure 1.4 SANIIRI flow-measuring flume (SFMF)

The flume dimensions and their discharge capacities subject to the outlet width are shown in Table 1.3.

Table 1.3

SFMF dimensions and their discharge capacities subject to the outlet width

Flume dimensions	Flume outlet width, b_f *(m)*							
	0.2	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**1.0**
Flume outlet width $B_f=1.76\ b_f$	0.34	0.51	0.68	0.85	1.02	1.19	1.36	1.76
Flume length $l=2b_f$	0.4	0.6	0.8	1.0	1.2	1.4	1.6	2.0
Height of flume's vertical walls $H_l=(1.5\text{-}2)b_f$	0.4	0.65	0.7	0.8	0.9	1.0	1.2	1.5
Crest height $P \geq 0.5\ H_{max} (H_{max} \leq 0.8 H_l)$	0.16	0.26	0.28	0.32	0.40	0.40	0.40	0.50
Flow rate, m^3/s	0.051	0.157	0.286	0.555	0.916	1.064	1.217	2.140
Water depth, H_{max}, m	0.25	0.40	0.50	0.65	0.80	0.80	0.80	1.0

Flow rate equation for SFMF at free discharge $\left(h/H < 0.2 \right)$ is given by:

$$Q = C * b * H * \sqrt{2gH}\ , \text{m}^3/\text{s} \qquad (1.3)$$

where: $C = 0.5 - \dfrac{0.109}{6.26 * H + 1}$ is discharge coefficient;

b is the flume throat outlet width (m);

H is the water depth above the flume crest at the upstream part (m).

He working equation is given by:

$$\text{Q} = 1.72 * b * H^{1.55}\ , \text{l/s} \qquad (1.4)$$

The SANIIRI flume is designed for measuring flow rates at free-flow discharge (Fig. 1.5). Free-flow discharge for SFMF is provided at $h \leq 0$.

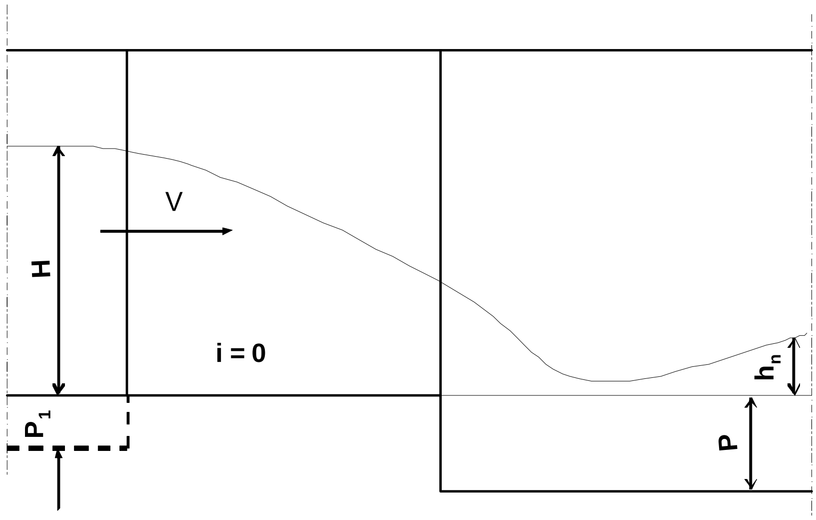


Figure 1.5. SANIIRI flume profile.

For easy calculation, flow rate values subject to water level are given in Table 1.4.

Table 1.4

Flow rate values (Q, l/s) subject to water level (H, cm) for SFMF.

Water depth H, cm	**Flume outlet width, b_f, cm**						
	20	**30**	**40**	**50**	**60**	**70**	**80**
1	0.3	0.5	0.7	0.9	1.0	1.2	1.4
2	1.0	1.5	2.0	2.3	3.0	3.5	4.0
3	1.9	2.8	3.8	4.7	5.7	6.6	7.6
4	2.9	4.4	5.9	7.4	8.8	10.3	11.8
5	4.2	6.3	8.3	10.4	12.5	14.6	16.7
6	5.5	8.3	11.1	13.8	16.6	19.4	22.1
7	7.0	10.5	14.0	17.6	21.1	24.6	28.1
8	8.6	13.0	17.3	21.6	25.9	30.2	34.5
9	10.4	15.5	20.7	25.9	31.1	36.3	41.5
10	12.2	18.3	24.4	30.5	36.6	42.7	48.8
11	14.1	21.2	28.3	35.4	42.4	49.5	56.6
12	16.2	24.3	32.4	40.5	48.6	56.7	64.8
13	18.3	27.5	36.7	45.8	55.0	64.2	73.3
14	20.0	30.8	41.1	51.4	61.7	72.0	82.2
15	22.9	34.3	45.8	57.2	68.6	80.1	91.5
16	25.3	37.9	50.6	63.2	75.9	88.5	101.2
17	27.8	41.7	55.6	69.5	83.3	97.2	111.1
18	30.4	45.5	60.7	75.9	91.1	106.2	121.4
19	33.0	49.5	66.0	82.5	99.0	115.5	132.0
20	35.7	53.6	71.5	89.4	107.2	125.1	143.0

Water depth H, cm	Flume outlet width, b_f, cm						
	20	**30**	**40**	**50**	**60**	**70**	**80**
21	38.5	57.8	77.1	96.4	115.6	134.9	154.2
22	41.4	62.1	82.9	103.6	124.3	145.0	165.7
23	44.4	66.6	88.8	111.0	133.2	155.3	177.5
24	47.4	71.4	94.8	118.5	142.2	165.9	189.6
25	50.5	75.8	101.0	126.3	151.5	176.8	202.0
26		80.5	107.3	134.2	161.0	187.9	214.7
27		85.4	113.8	142.3	170.7	199.2	227.6
28		90.3	120.4	150.5	180.6	210.7	240.8
29		95.4	127.4	158.9	190.7	222.5	254.3
30		100.5	134.0	167.5	201.0	234.5	268.0
31		105.7	141.0	176.2	211.5	246.7	282.0
32		111.1	148.1	185.1	222.2	259.2	296.2
33		116.5	155.3	194.2	233.0	271.8	310.7
34		122.0	162.7	203.4	244.0	284.7	325.4
35		127.6	170.2	212.7	255.3	297.8	340.3
36		133.3	177.8	222.2	266.7	311.1	355.5
37		139.1	185.5	231.9	278.2	324.6	371.0
38		145.0	193.3	241.6	290.0	338.3	386.6
39		150.9	201.3	251.6	301.9	352.2	402.5
40		157.0	209.3	261.6	314.0	366.3	418.6
41			217.5	271.8	326.2	380.6	434.9
42			225.7	282.2	238.6	395.1	451.5
43			234.1	292.7	351.2	409.7	468.3
44			242.6	303.3	363.9	424.6	485.3
45			251.2	314.0	376.8	439.6	502.5
46			259.9	324.9	389.9	454.9	519.9
47			268.7	335.9	403.1	470.3	537.5
48			277.7	347.1	416.5	485.9	555.3
49			286.7	358.3	430.0	501.7	573.4
50			295.8	369.7	443.7	517.6	591.6
51				381.3	457.5	533.8	610.0
52				392.9	471.5	550.1	628.7
53				404.7	485.6	566.6	647.5
54				416.6	499.9	583.2	666.5
55				428.6	514.3	600.1	685.8
56				440.7	528.9	617.0	705.2
57				453.0	543.6	634.2	724.8
58				456.4	558.5	651.5	744.6
59				477.9	573.5	669.0	764.6
60				490.5	588.6	686.7	784.8
61				503.2	603.9	704.5	805.2
62				516.1	619.3	722.5	825.7
63				529.0	634.8	740.6	846.4
64				542.1	650.5	758.9	867.4

Water depth H, cm	Flume outlet width, b_f, cm						
	20	30	40	50	60	70	80
65				555.3	666.3	777.4	888.5
66					682.3	796.0	909.7
67					698.4	814.8	931.2
68					714.6	833.7	952.8
69					731.0	852.8	974.6
70					747.4	872.0	996.6
71					764.1	891.4	1018.8
72					780.8	910.9	1041.1
73					797.7	930.6	1063.6
74					814.7	950.5	1086.2
75					831.8	970.4	1109.1
76					849.1	990.6	1132.1
77					866.4	1010.9	1155.3
78					883.9	1031.3	1178.6
79					901.6	1051.8	1202.1
80					919.3	1072.5	1225.8

1.1.3.1. SFMF making and operation requirement.

- The shift of the flume plane or orifice relative to the axial plane of the intake channel must not be greater than 5 mm with the intake channel width of $B_к$ < 500 mm. At $B_к$ = (500–1500 mm) is 10 mm. And, finally, at $B_к$ > 1500 mm is 15 mm;
- Vertical deviation of flume throat sidewalls must not be more than 2 mm per 1 m of the wall height.
- The flume throat bottom and mouth be strictly horizontal. Deviation within 1 mm per 1 m of the throat length (or width) is permitted.
- Downstream submergence of the flume bottom is not permitted.

With properly constructed SFMF, water flow inflows to the stilling pool of the gauging station's outlet without submergence (Fig. 1.6), i.e. the condition $h \leq 0$ holds.

Figure 1.6. Gauging station with SFMF, downstream view.

1.1.3.2. Preparatory works and technology of SFMF gauging station construction

There is a preparatory work procedure which is required to be observed when constructing gauging stations. The preparatory works include the following operations:

- Cleaning a selected canal bed section from bed load and vegetation; its length should be not less than **L = (6-10) *b**, where *b* is the average canal bed width, (Fig. 1.7);
- Smoothing the canal section slopes to achieve maximum straightness and symmetry;
- At the beginning of the straight canal section, building a earth dike cofferdam to prevent water ingress;
- Setting surveying rods at the beginning and end of the straight section as well as in the middle of the cross-section of the canal;
- In the water-gauging device installation site, **l = 0.5-0.7*L,** cleaning the foundation and putting stone paving, at least 15–20 cm thick, beneath the foundation of the water-gauging device (Fig. 1.8);
- Installing metal form of the water-gauging device along the canal centerline; guiding oneself by the surveying rods, drawing a transverse, perpendicular axis for proper installation and orientation of the water-gauging device’s form mouth relative to the canal centerline (Fig. 1.9);

Figure 1.7. Cleaning the canal bed from silts and aquatic vegetation.

Figure 1.8. Placing riprap beneath the foundation of a water-measuring device.

Figure 1.9. Putting metal form for a SANIIRI flume along the canal section centerline.

Figure 1.10 Part of the concrete lining of the intake channel of a gauging station with a SANIIRI flume.

- Install a level gauge (RUG-0.5) at the interior side of the metal form's head with a measuring at the front and place concrete against the form. To save concrete, it is recommended to use big stones and pebbles;
- Pour 5-cm-thick concrete on the slopes and bed of the canal headrace and tailrace sections (Fig. 1.10);

- After 24 hours, take out the SANIIRI flow-measuring flume's forms and pour concrete to the SANIIRI flume crest up to the zero level of the rod;
- Seal all construction joints and concrete slopes of the gauging station with cement grout.

Preparation of concrete and cement grout

In the hydraulic engineering construction, very strong and durable material – concrete – that represents the mix of cement, water, and crushed stone or gravel. For concrete, it is best to use washed clean sand of mean particle size. Another concrete aggregate – gravel – represents the mix of natural stones of 5 to 8 cm. Water, cement, and gravel are taken in a certain ratio and well mixed to get concrete mixture (Table 1.5). The concrete laid in the form stiffens in 30-40 minutes; therefore concrete mixture must be prepared just as much as it can be laid for an hour. Concrete water resistance, strength, and durability depend chiefly on accurate ratio of cement and water quantities. Excess water is detrimental, because this reduces concrete strength and durability. For construction works, concrete constituent elements are recommended to be mixed in the following proportion: per one part of 200-250 grade cement, they take (in terms of volume) 2 parts of sand and 3 parts of gravel. 50 kg of cement requires 20 l of water or, in terms of volume, 6-7 parts of water per 10 parts of cement. The quality of a prepared mixture can be checked by trying with a spade: one should a few times tap the concrete mix by the flat part of the spade. *If open cavity pockets are seen between the stones, this means that the concrete is too thick; when tapping with a spade on a good mix, hollows are quickly filled with the mortar. If the spade when tapped is plunged into the mix leaving a hollow, this means that the concrete is too liquid.*

Mixed concrete has to be laid in previously prepared forms for an hour. For easier taking out the form after the concrete mixture is dried out, it will be helpful if one spreads used machine oil on the inner walls. One should concrete only on strong base, otherwise it will crack. With thick concrete layer (over 300 cm) and deep form, the mix has to be rammed and poked with a spade or long stake in order to better fill the corners of the form. In a few hours after the concrete is placed, its surface has to be smoothed with a wooden plasterer's float or metal trowel. One should bear in mind that with quick dryout concrete loses strength. To slow down the dryout process, concrete surface must be watered from time to time and covered with cellophane film.

Table 1.5

Recommended concrete grades subject to use environment

Use environment	Concrete grade	Approximate cement consumption, kg/m^3
Variable level	M-200; V-8; Mrz -250	270
	M-300; V-8; Mrz-300	290

Notations: *V-8* stands for waterproofing of concrete; *Mrz* stands for freeze resistance, alternate freezing and thawing cycles.

Preparation of cement mortar

To protect hydraulic facilities from the impact of water environment and to smooth the concrete surface, it is plastered by cement mortar of the ratio of 1_{cement} **:** 3_{sand} with adding a small amount of lime paste or clay (up to 10 % of its volume). Cement mortar should be made by little slugs, since it stiffens in 40-50 minutes and it becomes hard to work with as well as its quality goes down.

Tools required for work:

- Round-pointed shovels for smoothing the earth slopes and bed of the canal – 2 pcs.
- Square-faced shovels for throwing ground over and preparation of concrete mix – 2 pcs.
- Buckets for water delivery when making concrete mix – 1 pce.
- Metric tape measure with a length of at least 2 m – 1 pce.
- Stakes 0.6 long for aligning along the canal centerline – 2 pcs.
- Rope for siting formwork installation place and alignment – 10 m.
- Wooden pole (gauge) for positioning slopes and edges of the canal’s lined section, 1.5-2 m long – 1 pce.
- Builder’s level gauge for horizontal alignment of the form and crest of a water-measuring device – 1 pce.
- Wood floating rule for plastering and smoothing concrete surface – 1 pcs.
- Builder’s trowel for smoothing concrete surface – 1 pce.
- Auxiliary tools: hammer, hand saw, knife.

In the w ... ecorded or
when fl ... ith a level
gauge is ...

To obta ... ibration of
FC. Fix ... least 5 cm
thick in ... water flow
(Fig. 1.1

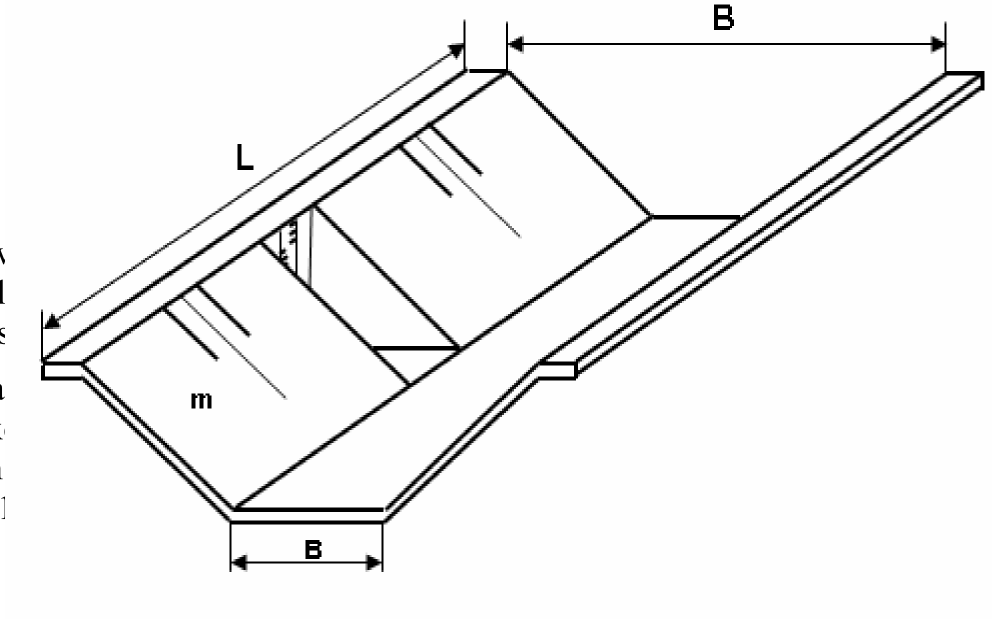


Figure 1.11. Fixed channel.

1.2.1. FC-type gauging station equipping requirements.

- The FC-type gauging station should be installed at a straight section of the canal with uniform flow regime;
- At a straight section of the canal, there should be no obstacles (bridge footing, closeness of river bend) that would influence the flow regime at the gauging station's site;
- To maintain constant cross-section in an earth channel at the gauging station's site, it is recommended to make lining on canal slopes and bed (concrete belt);
- The FC canal section must be straight, with constant form of rectangular, trapezoidal, or parabolic cross-section, with allowed deviations from average dimensions (width, channel overall height, rate of slope values) of not more than ±2 % of the cross-section, with constant bed slope.
- The beginning of the FC upstream section and end of the FC downstream section must be made in the form of hydrotechnical key wall, viz. by pouring concrete with a width and thickness that are twice as much as the canal bed concrete lining thickness;
- The level gauge must be installed in a special well or niche; the gauge zero mark must coincide with that of the canal bed at the gauging station's site;
- The gauging station must always be clean and free from sediments and trash;
- With headwater/variable flow behavior at FC-type gauging stations, it is necessary to make check measurement of water discharge after every change in the water level;
- At a canal flow velocity below 2 m/s, an admissible length of the section, where specified conditions have to be maintained, must be within L = (6 - 10)*b depending on the canal downstream width (b).

1.2.2. Calibration of FC-type gauging station.

The FC-type gauging station is calibrated with the purpose of plotting calibration dependence *Q = f (H)* and calculating, by using it, the table of discharges, errors of flow measurement by the gauging station.

Construction and calibration of the FC-type gauging station is carried out in accordance with the requirements of the Guidelines on the Calibration and Checking of the Gauges of Flow Measurement in Open Canals by the "Velocity-Area" Method, VTR-M-1-80. To obtain reliable dependence, one should measure at least 5-7 values of the flow at the levels uniformly distributed over the flow variation range at this gauging station (Fig. 1.12). Based on the results of the flow variation at this gauging station, a discharge characteristic diagram is plotted and a discharge table is calculated (*detailed recommendations are given in Section 3*).

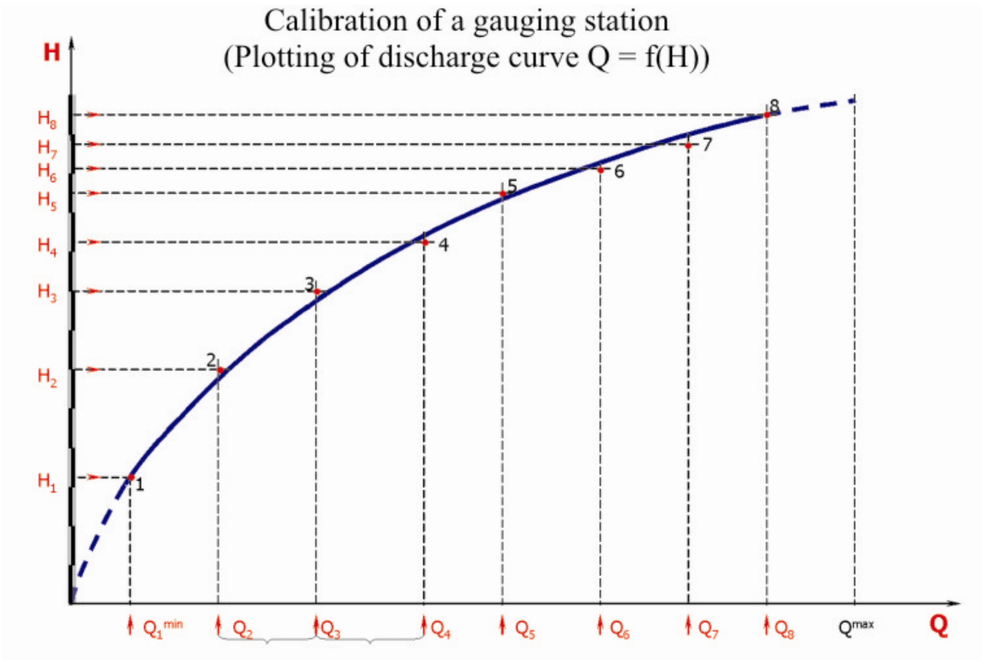


Figure 1.12. Water discharge-level diagram Q = f (H).

Taking into consideration that there are no propeller flowmeters in WUAs, FC is recommended to be calibrated by means of transportable weirs CW-25 and CW-50 (*detailed recommendations are given in Subsection 1.3*).

1.3. Calibration of small gauging stations.

1.3.1. Calibration of small fixed-channel type gauging stations.

As is known, there is no method for the calibration of fixed-channel (FC) type gauging stations (GS) for low discharges (about Q = 100 l/s). The well-known "velocity-area" flow-measurement method applied for open canals with high and average discharges is not suitable for measuring low discharges, and consequently for the calibration of GSs. The point is that at small flow, canal (watercourse) size is also small. Hence, the error of flow measurement (and gauging station construction) in terms of absolute unit will be higher, while the relative errors will be similar.

For example, with the linear dimension of 2 m and the relative error of its measurement equal to ± 1 %, the absolute error will come to ± 2 cm, which can be kept under normal construction and measurement conditions.

However, with the linear dimension of 0.2 and the relative error of its measurement also equal to ± 1 %, the absolute error will come to only ± 2 mm. Under normal conditions, it is impossible to keep such an accuracy when measuring (and when building) watercourse flows. Therefore, to calibrate a FC-type GS with low discharges, another calibration method is required which would secure sufficient accuracy (that meets the requirements of normative documents).

To calibrate a FC-type GS, it is necessary to determine the relationship between water discharges and levels within the operating range of discharge variation. This, first, requires measuring, by another method or means, a series of water discharge values within the operating range of GS discharge variation. At that, the accuracy of the flow measurement method or means must be a few times (at least three times as per the normative documents) higher than the required accuracy of the gauging station being calibrated.

Thin-plate weirs are the most suitable for this purpose.

First, they are highly accurate (the most accurate among flow measuring tools for open watercourses). Second, they are simple in terms of design and hence are user-friendly.

To calibrate small GSs, it is expedient to make and use portable models of thin-plate weirs. .

1.3.1.1. Preparatory works

For carrying out calibration, a portable thin-plate weir version is made, which is meant for maximum design discharge values of the GS being calibrated. Thin-plate weirs with the trapezoidal cross-section (Cipolletti-weir type) with crest sizes of 25 and 50 cm (CW–25 and CW–50) designed for maximum discharges of up to respectively 40 and 80 l/s are the most suitable for this.

When making a portable weir version (Fig. 1.13), it is necessary to meet the main requirements of the regulations and specifications (R&S) for making thin-plate weirs («Method of flow measurement by constriction flow meters for use for land reclamation*», MVI 06-90*), especially as those pertain to making their crests – the main dimension that determines its discharge.

R&S recommend following this requirement with a tolerance of, for example, not more than ± 2 for CW-50 (consequently, for CW-25 it should be more than ± 1 mm), as well as full coincidence of the zero of the gauge with the crest line mark of the weir when being installed, etc. Reinforcement rods and an angle are welded on directly and fully to the weir wall.

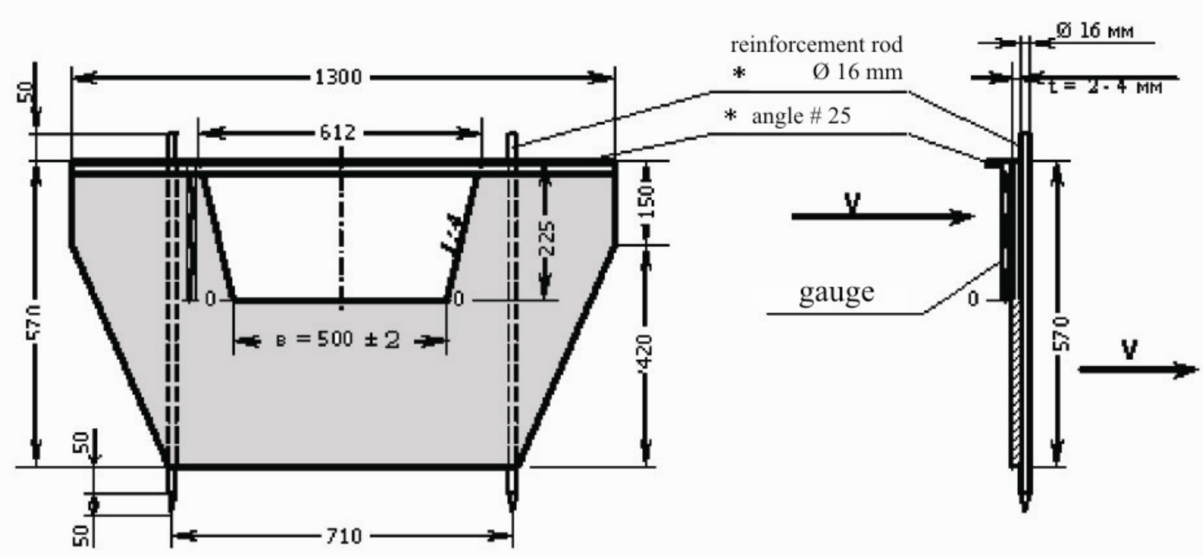


Figure 1.13. Cipolletti weir CW-50 (portable version, Q≤ 80 l/s).

The following works are carried out at the gauging station:

- Checking the completeness, integrity, state of health, and operability of the sluice water outlet and check dam of the feeder; at that, integration and operating conditions of all structures (canal upstream and downstream sections, FC-type gauging station, sluices, etc.) must be good enough, without deformations and disturbance of the canal cross-section, cleaned from bed load and vegetation, and so forth.
- The cross profile of the fixed (concrete) part of FC must fit in with the average grade line of the watercourse so that the fixed part of the cross-section does not cause additional resistance to the stream breaking water flow pattern at a certain watercourses section, and it should have sufficient length.
- FC GS must be equipped with a hydraulic rod (gauge) in accordance with the R&S requirements. At that, it is necessary to ensure full coincidence of the rod zero with the FC bed mark.
- To install a portable weir at downstream, a place for gauging site is selected taking into account main R&S requirements for the installation of it; at that, one should take notice of the sufficiency of the straight section length, cross-section symmetry, absence of objects that may cause flow disturbance and break its pattern at the weir approach, etc.
- The watercourse section banks are leveled with the purpose of obtaining highest possible straightness and symmetry.

With insufficient slope of the downstream, space-limited environment, etc., they prepare in advance the options of possible temporary (for the calibration time) direction of flow course bypassing this watercourse section or direction of water to depression of sufficient capacity, or field of a relatively low elevation, so on (Fig. 1.14).

1.3.1.2. Weir installation.

After having carried out preparatory works at the gauging station:

- weir is installed at the selected gauging site of the downstream canal in compliance with the general requirements for its installation (Figs. 1.15 and 1.16);
- the weir should be installed strictly upward cutting it into the watercourse bed and banks so that there is no water leakage from under the weir and its sides.
- the weir crest must be strictly horizontal; the weir wall must be perpendicular to the base; the weir centerline must coincide with the watercourse center line.
- the weir crest mark must be higher by at least 4-5 cm than the mark of the maximum normal water stage in the watercourse downstream of the weir.
- with the velocity of approach to the weir higher than 0.5 m/s, the downstream section of the watercourse should be widened and the bottom should be deepened in order to decelerate the flow rate.

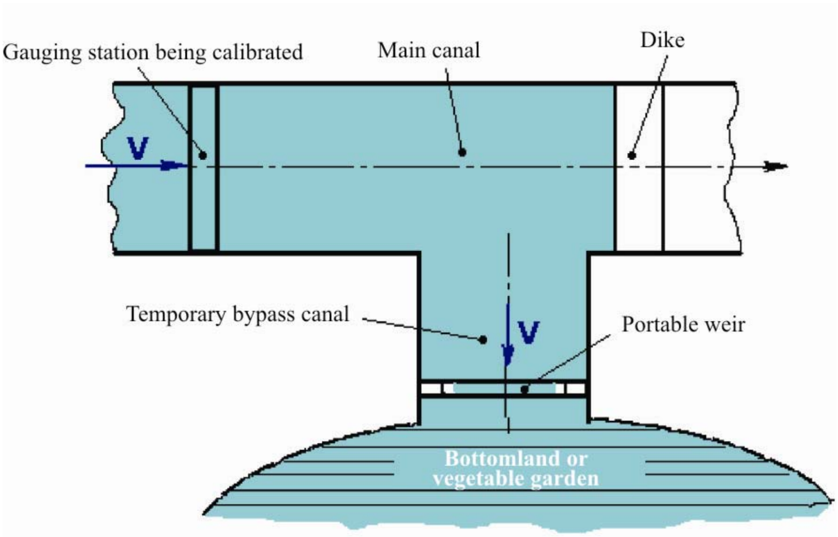


Figure 1.14. Scheme of one of portable weir location options when making calibration.

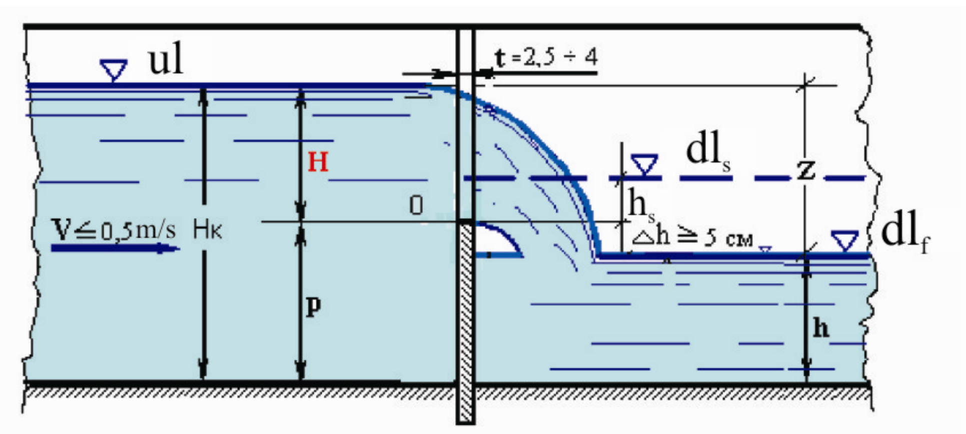


Figure 1.15. Longitudinal profile of the canal section with a thin-plate weir under submerged (dashed line) and free-flow regimes.

Notation conventions:

$H_к$ – upstream water depth;

h – downstream water depth;

h_s – submergence height (value);

ul – upstream water level;

dl_f – downstream water level under free-flow regime;

dl_s – downstream water level under submerged regime;

z – difference between upstream and downstream water levels;

O – weir crest mark;

p – weir crest height.

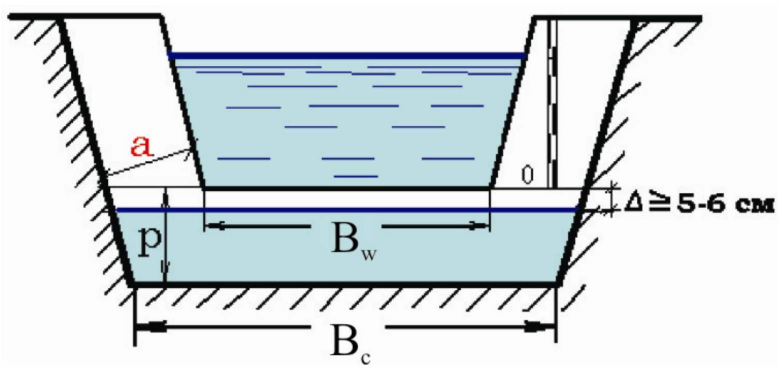


Figure 1.16. Thin-plate weir in the canal (downstream view under free-flow regime).

1.3.1.3. Flow measurement by portable weirs.

Measurement of flow by means of portable Cipolletti weir under **free discharge (*free-flow weir*)** is carried out by a working equation (1.2).

For easy determination of the water discharge through the weir, the water discharge table can be used (Table 1.6).

Table 1. 6

Dependence of discharge on water level for free-flow weirs CW-25 and CW-50

Level reading on the rod *H* (cm)	**Water discharge *Q* (l/s)**	
	CW-50	**CW-25**
3.5	6.0	3.0
4.0	7.0	3.5
4.5	9.0	4.5
5.0	10.0	5.0
5.5	12.0	6.0
6.0	14.0	7.0
6.5	16.0	8.0
7.0	18.0	9.0
7.5	20.0	10.0
8.0	22.0	11.0
8.5	24.0	12.0
9.0	26.0	13.0
9.5	28.0	14.0
10.0	30.0	15.0
10.5	32.0	16.0
11.0	35.0	17.5
11.5	37.0	18.5
12.0	40.0	20.0
12.5	42.0	21.0
13.0	44.0	22.0
13.5	47.0	23.5
14.0	50.0	25.0
14.5	52.0	26.0
15.0	55.0	27.0

15.5	58.0	29.0
16.0	61.0	30.5

1.3.1.4. FC-type gauging station calibration method.

As well known, the purpose of the calibration is to determine the relation between water discharge and water level. FC-type gauging station calibration by using a portable weir is carried out in accordance with the requirements of *Guidelines on the Calibration and Checking of the Gauges of Flow Measurement in Open Canals*. The only difference is that in this case water discharge is measured not through the "velocity-area" method but by using a portable weir installed at the selected gauging site.

Calibration is performed as follows:

- If the canal operation regime allows carrying out calibration for the full effective range of flow variation without causing damage to the production process, calibration is made without interruption (at a heat). Otherwise, it is allowed to calibrate during the vegetation period as the canal flow rate changes.
- Before starting and upon completion of flow measurement, water level at the unit being calibrated, i.e. fixed channel, and calibrating instrument, i.e. weir, is recorded. At that, the water level measurement by rods in terms of absolute value must be within ± 1 cm.
- A flow rate is set within the canal operating range and its value is determined by means of the weir. For that, one should read out the water level from the weir gauge. Having had the water level value and by using a ready flow rate table for this weir type and size, one can determine the flow rate value.
- At a given flow rate value, water level is read out from the FC gauge.
- Then another canal flow rate value is set. At this flow rate value, the measurement procedure similar to that with the previous flow rate value is followed.
- In order to get a reliable calibration relationship, one should take at least 5 flow rate values for 5 levels evenly distributed over the effective range of flow variation at a given GS. All water level and measured flow rate value reading procedures are repeated after setting a new flow rate value. Flow rate and water level measurement is carried out after transient processes in the canal (as well as in the weir) are completely over, which can be verified by the stability of the current water level readings.

When executing calibration works, one has to make sure the upstream water head caused by the weir does not influence the FC operation regime. If does, it would be necessary to change the location of weir installation site (e.g., relocate it downstream).

When fixing canal flow rates with which the calibration results are harmonized, it is necessary to allow for the following conditions:

- the top discharge curve point must match with the value that is of no more than 85 % of the maximum water discharge in the canal;

- the bottom point must match with the value that is of no more than 15 % of the maximum water discharge in the canal.

To acquire sufficient number of water discharge points for calibration, they proceed to plotting up GS discharge curves, i.e. discharge dependence on water level **Q = f (H)**, which can be made through traditional means, viz. on graph paper, but it would be more efficient to do that by computer. In this case, owing to wide functionalities of computers working hours will be sharply reduced, and the quality and accuracy of results will be high enough.

General view of discharge curves is shown in Figure 1.12.

To plot a discharge curve by a traditional way, two mutually perpendicular intersecting coordinates are to be drawn on a graph paper: vertically for water level ***(H)*** and horizontally for discharge ***(Q)***. From the water level (***H***) points a straight line (dashed lines towards the directions of arrows) is to be drawn rightward, and from the water discharge values (obtained from the results of the measurements by using calibrating means) straight lines (solid lines) are to be drawn upward until intersect the water level lines. The point of the intersection of the two lines is to be dotted. As was mentioned, the number of such points should be not less than five. Then these points are joined with a smooth line. This yields a fragment of a curved line. The lower (left) part of this curve is to be smoothly joined with the zero point of the axes (point *O* in the graph). As a result, you will get a discharge curve **Q = f (H)**.

By means of a discharge curve one can determine water discharge by using only water level (solid lines). However, a discharge line **Q = f (H)** is not sufficiently easy to use in practice. Therefore, based on it a discharge table is made (Table 1.7).

In the discharge table, the first left column shows water level values with a 10-cm step. Unit values of water level (figures from 0 to 9), with a step of 1 cm, are given in the top row of the table. The cells on the rest table rows show the numerical values of water discharge. Thus, for every water level value with a step of 1 cm, they determine water discharge values and enter in appropriate cells of the discharge table. After having been filled out, it is ready for usage, i.e. determination of GS water levels ***Q*** through measured water levels ***H***.

Table 1.7

Discharge table

H	**Discharge (Q, l/s)**									
cm	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0.0										
10.0										
20.0										
etc.										

1.3.1.5. Influence of weir downstream submergence on discharge.

In practice, there happen to be cases where a weir downstream is submerged, i.e. the downstream water level takes up a position higher than weir crest mark (Fig. 1.15, *dashed line is the regime of water outflow at downstream weir submergence*) because of flat slope of watercourse, downstream silting, etc. *Such a regime is extremely undesirable: under this regime, discharge from the weir can be determined only **roughly**.*

At downstream weir submergence, the design discharge equation (1.5) and Tables 1 and 6 for the determination of water discharge become void, since at that discharge measurement errors sharply increase (by 5-7 % and over). To account the submergence impact, it is needed to introduce the submergence factor $\boldsymbol{\sigma_s}$ into formula (1.5):

$$Q = 1.9 * b * H\sqrt{H} \times \sigma_s \qquad m^3/s \qquad \textbf{(1.5)}$$

The numerical values of the submergence factor $\boldsymbol{\sigma_s}$ depend on the extent of submergence, viz. ***Z/p*** and $\boldsymbol{h_s/p}$ values (designations are given in Fig. 1.15). For easy determination of water discharge from **the submerged weir**, it is recommended to use the following (correction) table (Table 1.8).

As follows from Table 1.8, the submergence factor $\boldsymbol{\sigma_s}$ is determined depending on the values ***Z/p*** and $\boldsymbol{h_s/p}$. Hence, in each specific case the numerical values of ***Z/p*** and $\boldsymbol{h_s/p}$ are determined and by using Table 1.8 the numerical values of $\boldsymbol{\sigma_s}$ are specified**.** To obtain the water discharge values under submerged regime, the free-flow water discharge value is determined by using Table 1.6 and is multiplied by the value of the submergence factor $\boldsymbol{\sigma_s}$ defined from Table 1.8.

Table 1.8

Submergence factor σ_s dependence on Z/p and h_s/p values (Fig. 1.15)

Z/p	h_s/p																	
	0	**0.1**	**0.1**	**0.2**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
0.05	1.05	0.84	0.74	0.68	0.64	0.58	0.54	0.52	0.50	0.48	0.47	0.46	0.45	0.45	0.44	0.44	0.44	0.43
0.1	1.05	0.93	0.85	0.80	0.76	0.70	0.66	0.64	0.61	0.60	0.58	0.57	0.57	0.56	0.55	0.55	0.54	0.54
0.2	1.05	0.98	0.94	0.90	0.87	0.82	0.79	0.76	0.74	0.72	0.71	0.70	0.69	0.69	0.68	0.68	0.67	0.67
0.3	1.05	1.01	0.97	0.94	0.92	0.88	0.85	0.83	0.81	0.80	0.79	0.78	0.77	0.77	0.76	0.76	0.75	0.75
0.4	1.05	1.02	0.99	0.97	0.95	0.92	0.90	0.88	0.87	0.85	0.84	0.84	0.83	0.82	0.82	0.82	0.81	0.81
0.5	1.05	1.03	1.01	0.99	0.98	0.95	0.93	0.92	0.90	0.89	0.89	0.88	0.87	0.87	0.87	0.86	0.86	0.86
0.6	1.05	1.03	1.02	1.00	0.99	0.98	0.96	0.94	0.93	0.92	0.92	0.91	0.91	0.90	0.90	0.90	0.90	0.89
0.7	1.05	1.04	1.02	1.01	1.00	0.99	0.98	0.96	0.96	0.95	0.95	0.94	0.94	0.93	0.93	0.93	0.93	0.92

1.3.2. Calibration of small gauging stations on parabolic flumes.

As is known, standard reinforced concrete parabolic flumes of LR[2] type are in fact perfect fixed channels, but of curvilinear shape. On the other hand, their geometric shape and sizes are known and accurate enough, and the workmanship is good, because they are factory-built. Therefore, those can be successfully used as fixed channels, and the LR flume calibration process can be simplified by using existing nomograms for hydraulic designing of LR flumes (Fig. 1.17 and 1.18).

1.3.2.1. Calibration of flumes by using nomograms.

These nomograms for LR flumes are drawn up depending on the parabola parameter *P*: P = 0.2 m (these are the flumes of the sizes: LR-40; LR-60; LR-80) (Fig. 1.17); P = 0.35 m (these are the flumes of the sizes: LR-100; LR-120) (Fig. 1.18).

LR flumes calibration by using nomograms is performed as follows:

- By means of a levelling instrument, station rod, and measuring tape, they determine the value of the actual longitudinal slope of the flume (*by the measuring tape measure 4-5 sections of the flume within the straight-line portion where the gauging station site is located; by using the levelling instrument and, station rod, the flume bed marks at the beginning and end of the portion are identified; and proceeding from the ratio of difference between these marks to the portion length, the slope I* is *determined*).
- The water depth (***H***) on the axial gauge point of the current is metered when the flow is running through.
- On the nomogram, these two points are marked on their scales and a straight line is drawn so that it intersect all the four (***Q, H, I, V***) scale lines as shown on the nomogram (Figs. 1.17 and 1.18).

[2] Type of flumes installed on piles, poles, and slabs.

- In the point of the intersection of the straight line and discharge scale line, the water discharge value appropriate for a given water flow depth is specified.
- The other discharge values for the calibration of that flume are also determined by the same way, measuring water flow depth every time at different discharges.

Example: procedure of plotting the dependence Q=f(H) for parabolic flume LR-100.

Measured flume slope: **I = 0.001 m/m**.

Measured water flow depth: **H = 82 cm**.

The flow velocity measured on the axial gauge point at a depth of **0.6H:** $\mathbf{V_{0.6H} = 1.21}$ **m/s.**

By these two measured values (***H*** and ***I***) they mark two points at appropriate scales (***H*** and ***I***) of the nomogram (Fig. 1.18).

By joining these two points by a straight line, the numerical value of the flume slope is determined on the discharge ***Q*** scale:

By the water discharge values obtained for different measured flow depths, they plot (on graph paper or on computer) the discharge (calibration) curve Q = f (H) for this gauging station.

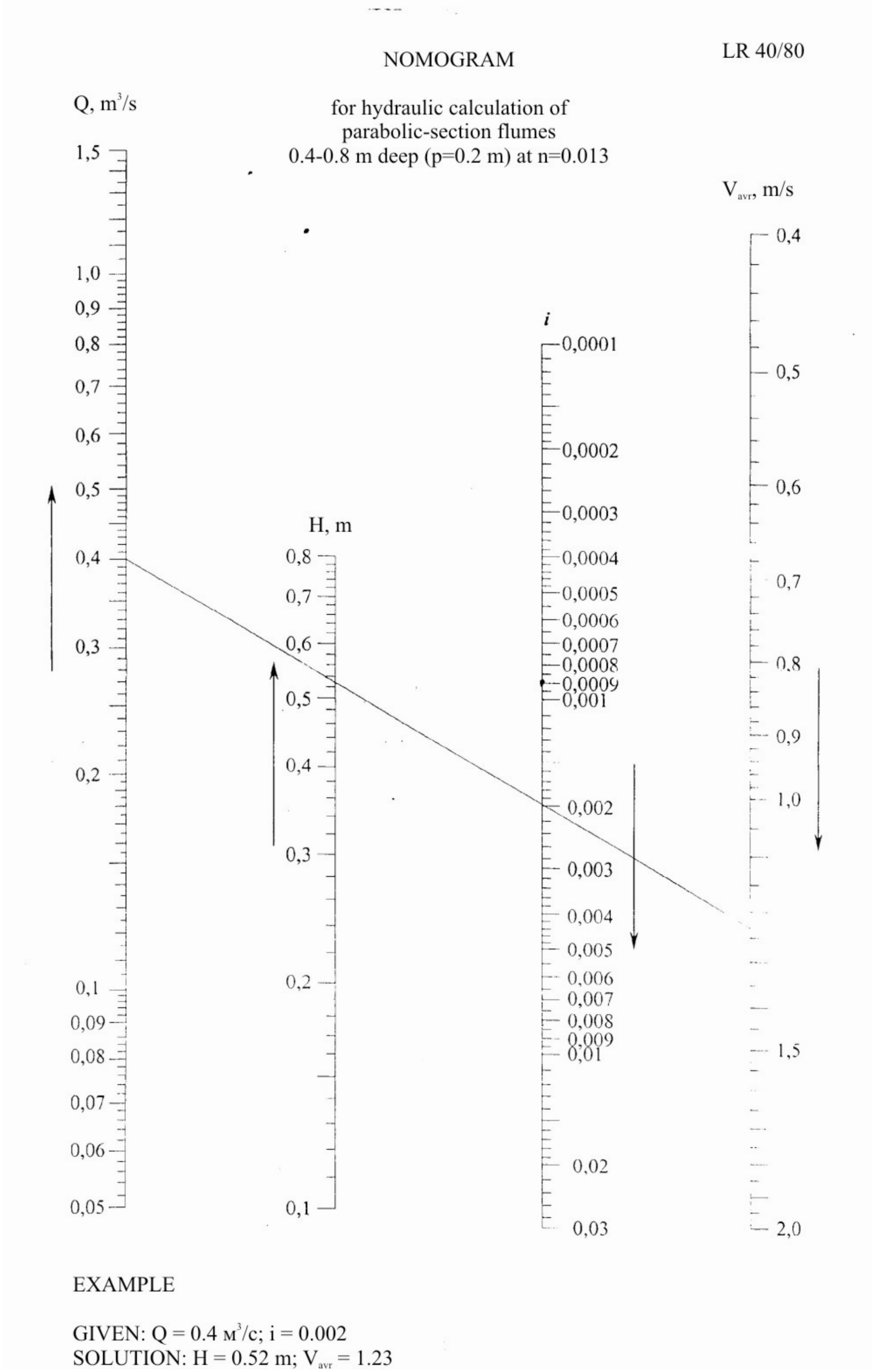


Figure 1.17. Nomogram for hydraulic calculation of parabolic flumes LR-60 and LR-80.

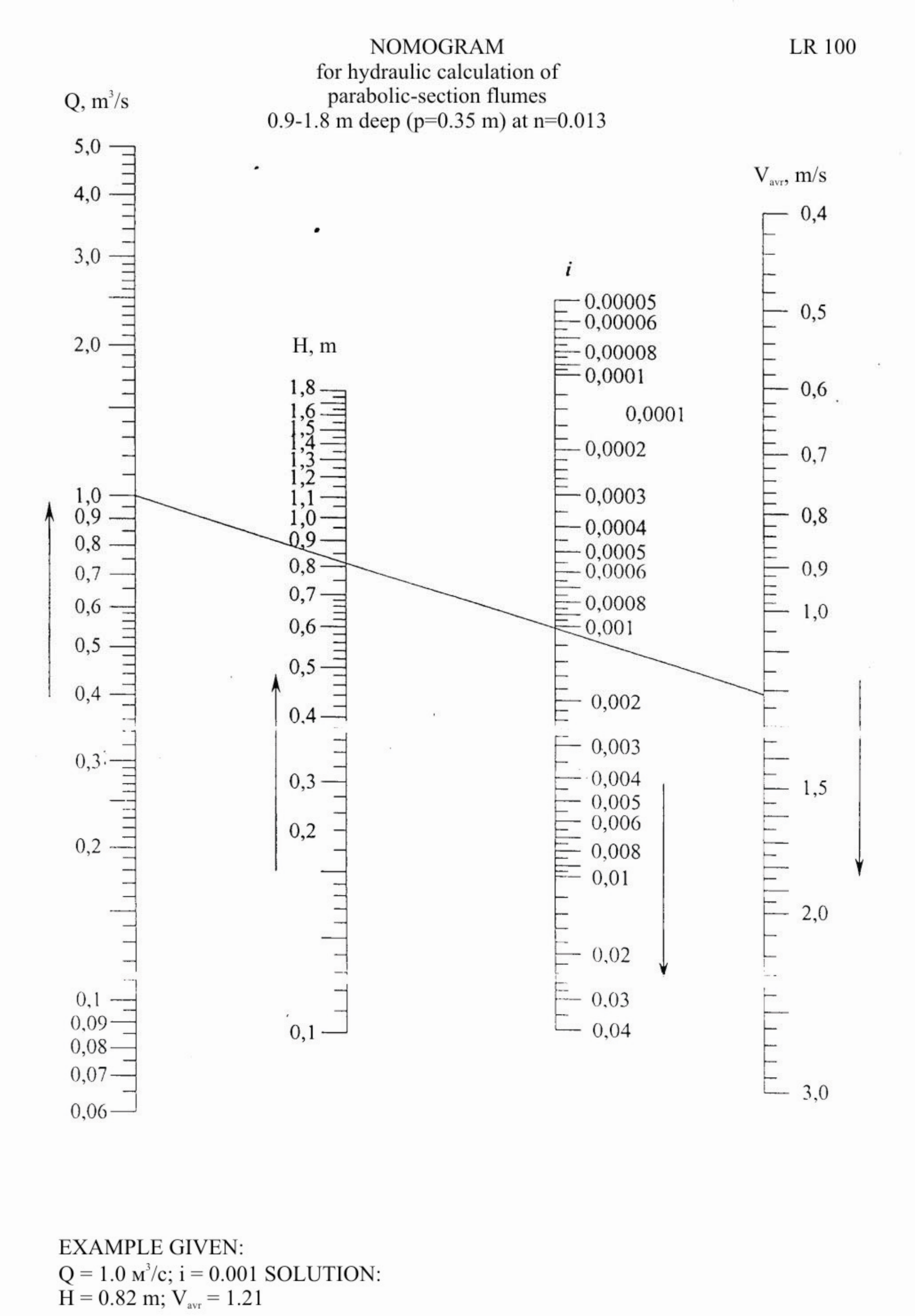


Figure 1.18. Nomogram for hydraulic calculation of parabolic flume LR-100.

1.4. List of the documents required to accept finished gauging stations for putting into operation.

To accept a finished gauging station for putting into operation and evaluate it, WUA hydrometer specialists have to prepare a set of the following documents:

- Water discharge gauging list (Form 1 – Appendix 1.1) for FC-type gauging stations;
- Statement of calibration (Form 2 – Appendix 1.2) for FC-type gauging stations;
- Technical certificate of water discharge measurement instrument (Form 3 – Appendix 1.3).

Before commissioning and carrying out evaluation or calibration, the gauging station must be cleaned from sediments, the hydraulic rod and FMD must be thoroughly cleaned and be accessible for inspection. Headrace and tailrace channels must be cleaned from bush. Metrological certification is to be carried out by specialists of metrological centers who have permission from national standardization agencies to perform such works, or local water management organization specialists who have special authorization and permissions for carrying out such works.

Gauging station calibration periodicity:

- For simple gauges: once every three years;
- For thin-plate weirs (triangular, rectangular, and trapezoidal): once every two years;
- For water-measuring flumes and fixed channels: once every three years.

1.5. Water accounting in WUA.

1.5.1. Determination of the water volume supplied to the water user in the farm.

As well known, settlement payment for the water volume supplied to water users is done not for water discharge (**m^3/s** or **l/s**) per unit time (per second), but for total volume in terms of cubic meters (**m^3**) during the water supply period. Therefore, to get the value of the total volume ***W*** for the period duration, the water discharge ***Q*** gained by the readings from the gauging station should be multiplied by the number ***T*** of seconds in this period:

$$\mathbf{W(m^3) = Q(m^3/s) \times T(s)} \qquad \mathbf{(1.6)}$$

For instance, if the irrigation period duration is one hour, to obtain the total volume (runoff) it is necessary to multiply the gauging station discharge by 3600, since one hour equals 3600 seconds. Accordingly, if the irrigation period comes to one day, then to get the water volume one has to multiply the gauging station discharge by 86 400 (one day has 3600 × 24 = 86 400 seconds) etc.

To control the quality of the water supplied to the water users, analyze water consumption and water supply level, water discharge and irrigation duration (in terms of hours) need to be recorded on a regular basis in order to determine the total water volume in terms of cubic meters. In the practice of water management organizations, they have worked out a special daily water discharge log and water accounting instruction.

1.5.2. Logging of water accounting

1. Water discharge measurement can be made in the morning at 8:00, in the daytime at 13:00, and in the evening at 20:00, as well as at any abnormal change in the water level at the gauging station site on the canal and its offtakes.
2. Water discharge at the offtakes to farms equipped with elementary types of water meters is measured by the readings of the level gauge and discharge tables.
3. The measured water discharge values must be put down in a special log which is the basic document when making mutual settlement between water users and suppliers.
4. The log must be filled in by the persons who per se executed water discharge measurements (WUA hydrometer specialists) and coordinated with water users (farmers).
5. The log must be bound and its pages be numbered. Making corrections in the log is not allowed. When correcting water discharge values, the reasons and justifications for such changes must be stated therein.
6. In case of wrong filling in or correction of water discharge and volume values in the log, the reasons for and persons in charge who committed errors in the records must be indicated. If the reasons for the corrections and regular wrong filling in the log are ill-founded, the management must address the matter of the responsibility of these persons.

An example of a water (intake and delivery) accounting log is shown in Appendix 4.

List of references used for Section 1

1. Rules of liquid discharge measurement by means of standard weirs and flumes RDP 99-77. Publishing House of Standards, Moscow, 1977.
2. Reinforced concrete parabolic irrigation and drainage canals. Procedure of flow measurement by the velocity-area method MVI 33-4755559-09-91.
3. Kazachek, G.A., Builder's manual. Publishing House, Minsk, 1998.
4. Masumov, R.R., Water accounting manual for hydrometer specialists in WUAs. 2005.
5. Rasulov, U.R., Method of the calibration of small gauging stations and water accounting in WUA. 2009.

Appendix 1.1

Form 1

Site__________ Canal_________ Gauging station__________ №_____ Picket_____

LIST OF WATER DISCHARGE MEASUREMENT №_____

Instrument__________ Type__________ №_____ Blade__________

Turbidity ___________ Bed load_________ Garbage__________

H_1 = Q = m^3/s F = m^2

H_2 = V_{aver} = m/s B = m

H_3 =

No of gauge point	Distance between the gauge points	Water depth on the gage point, m	Area of the water section between the gauge points, m^2	Distance from measurement point, m	Impeller blade revolutions per intake	Duration of the measurements for intake from the beginning of the work, s					Impeller blade revolutions during the whole period	Impeller blade revolutions per second	Flow rate at the point, m/s	Flow rate at the gauge point, m/s	Average flow rate at the gauge point, m/s	Average flow rate between the gauge points, m/s	Water discharge between the gauge points, m^3/s
						1	2	3	4	5							

Appendix 1.2

Form 2

CONCURRED BY: APPROVED BY:

________________ _______________

«_____»_________20 «_____»__________20

CERTIFICATE

of calibration of the FMD № ____- located at the

Picket_____________ of the canal ____

____________________________of the irrigation system____________________

_________________________MAWR_____________________________________

We the undersigned______________________________________

____

carried out during __________________________20

calibration of the FMD ____

including the following components: __________________________________

____

information of the design and dimensions of the control station, equipment configuration

The calibration has been carried out when measuring_________________

of water discharge values________ by the way appropriate to____________

____________________________________ measurement range __________

For the calibration of FMD, _____________________ has been used

________________gauging section located at a distance of

_____________ from FMD.

Characteristics of the gauging station: _______________________

____

Water discharge was measured by means of propellers________________

____

installed _____________________________________

in ________ points of each gauge point

Calibration conditions:____

____

Calibration results:___________________________________

____

Water discharge measurement results by the method ________________

given on recording cards_____ are enclosed.

Based on the calibration results, Q=f(H) dependence has been plotted, then by the least-square method the root-mean-square deviation of the calibration results from the faired curve has been calculated according to the Q=f(H) plot; it does not exceed________%

Root-mean-square error____________________________________

____

9. Conclusion ____

____

«______» __________________20

SIGNATURES:

Verification Officer of the Metrological Service________________

Hydraulic Engineer of ISA ________________

Appendix 1.3

Form 3

Ministry of Agriculture and Water Resources ____________________________

TECHNICAL CERTIFICATE

of

Name of the canal, picket _____________________________________

Name of FMD ____

FMD type, design features ____________________________

____

FMD location and operation characteristics, hydraulic regime

____

FMD was installed in the year ___________

Estimated and actual values of FMD _________________________

FMD layout chart ____

Technical feature of FMD:

FMD proper ____

test parameter measurement instrumentation _________________

(stream) crossing means ____

steadying device ___________________________________

reach fasteners ______________________________________

reference marks and leading beacons _____________________________________

automation and remote control devices _________________________

auxiliary equipment and implements ______________________

Hydraulic components:

Name of hydraulic components	Values of hydraulic parameters of		
	Canal	Water outlet from the canal	Control section of FMD
Water discharge, m^3/s			
Constructional depth, m			
Bottom width, m			
Surface width, m			
Slope ratio, m			
Area of water section, m^2			
Full admission, m			
Maximum flow velocity, m/s			
Maximum hydraulic radius, m			
Maximum water level difference, m			
Canal bed slope			

10. Reference marks of characteristic points:

Name of characteristic points	Measurement time, year			
	20__	20__	20__	20__
Reference mark				
Canal edge				
Canal bed				
Origin of the scale				

record of FMD overhaul _______

____

record of FMD calibration ________

____

dated «___» __________201__.

SIGNATURES: ___________________ _________________

WUA Manager, Hydraulic Engineer, Hydrometer Specialist

Appendix 1.4

Ministry of Agriculture and Water Resources of the Republic of Uzbekistan

Chief Water Management Department

_________________ Basin Irrigation System Administration

For _________________________ irrigation period

(autumn-winter or summer)

LOG

of

water intake and delivery

between

Water Users' Association __________________________

and water user (farm) ____

from the canal ____

Name of the canal that supplies water to

(farm) _____________________________________

Water withdrawal place (point) _________________________________

Type of flow measuring device _______________________________

Area commanded by a given water withdrawal point (ha) _____

Area of the farm commanded by a given water withdrawal point (ha) _____

This Log:

is registered ______________________

on "_____" ______________20__, № _____

Note: *This Log is executed in two copies for each water withdrawal point; a representative of WUA has one copy, a representative of the farm has another.*

Authorized persons who carry out water intake and delivery

Parties	Name	Title	Specimen signature

Water supplier			
Water user (consumer)			

Note: *The authorized persons who carry out water intake and delivery must performed in order.*

Updates made in the coordinate table

№	Measurement time	H (cm)	Q (l/s)	Adjustment +/- (cm)	Name of the person who made the update	Reason for adjustment	Signature
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							
31							

"_____" ______________20___

Day	Water opening time	Water level, cm			Water shutoff time	Average water level, cm	Average water discharge, l/s	Duration of water withdrawal period, hour	Volume of the water withdrawn for this period, m^3	Signatures	
		8:00	14:00	20:00						Water supplier	Water user
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
Total for the 1st ten-day period	According to the limited water use plan										
	In fact										
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
Total for the 2nd ten-day period	According to the limited water use plan										
	In fact										
21											
22											
23											
24											
25											
26											
27											

28	
29	
30	
31	
Total for the 3rd ten-day period	**According to the limited water use plan**
	In fact
Total for the month	**According to the limited water use plan**
	In fact

2. DRAWING UP AND CORRECTION OF WATER DISTRIBUTION PLANS AT THE WUA LEVEL BASED ON DAILY SCHEDULE

Breaking down of the former planned irrigated territory into a number of farms with relatively small irrigated plots (often of 1-4 ha) in recent years has considerably complicated water resources management at the so-called local (low) level given furrow irrigation from gravity irrigation systems which prevails in the region.

To coordinate the relationship between water users and water management organizations, Water Users' Associations, voluntary unification of water users, have been established. One of the main purposes of WUA is equitable distribution of water resources among water users and effective use of those.

Water users' water demands which are mainly due to crop irrigation needs can be met only with strict coordination of the schedules of water supply through WUA canals of all levels with the schedules of water supply through WUA offtakes from the main canal[3]. The seasonal water use plans, annually drawn up from the "bottom" (WUA management) and to which limits are set "from above" (Canal Management Organization), serve as the basis for achieving harmonized schedules of water distribution from the main canal with the schedules of water distribution through WUA irrigation network. Following considerations and agreements, a compromise plan is adopted allowing for forecasted dryness of the year; in the organization and management of water distribution within WUA, WUA should be guided by this plan.

The organizational and technological stages of WUA water use/distribution plans are shown in Table 2.1.

---

[3] In addition to the irrigation of field crops and homestead lands, the water use plan provides for continuous-flow water supply to meet so-called industrial and technical needs.

Table 2.1

Stages of water resources management and drawing up of WUA water use/distribution plans

Stage	Type of activity	Executor	Period of execution	Result (output)
1	Preparation of the IDS for the season (repair, cleaning, khashars, etc.)	WUA Council and Management, WUs	February-March	Certificates of repair-and-renewal operations in WUA IDS
2	Compilation of initial information for drawing up WUP along with the identification of farms' boundaries and areas, linear networks of the distribution network, arrangement of GSs and flow regulators in that.	WUA hydraulic engineer/WUA HS and WUs	1st ten-day period of March	Statement of cropping on the lands commanded by WU offtakes with HMZ-based identification. Linear schemes of the distribution networks with arrangement of GSs and flow regulators.
3	Collection of information on cropping broken down by WUA offtakes from the main canal	WUA Management	1st ten-day period of March	Summary statement of cropping broken down by WUA offtakes from the main canal with HMZ-based identification.
4	Drawing up of seasonal WUA WUP	WUA Management	1st ten-day period of March	WUA WUP
5	Submission of WUA WUP to CMO	WUA Management	2nd ten-day period of March	WUA WUP
6	Fixing limits of the water withdrawal to WUA offtakes from the main canal and other water sources for the coming vegetation period and adjustment of main canal water use plan taking into account the expenditure credit.	CMO and UCWU	2nd ten-day period of March	Approved main canal WUP adjusted in accordance with the limit of water withdrawal from the main canal and other sources which was allotted for the vegetation period.
7	Adjustment of WUA WUP in accordance with the water withdrawal limit set	WUA Management	2nd ten-day period of March	Adjusted WUA WUP
8	Preparation and conclusion of contracts between CMO and WUA on water supply to the WUA	CMO and WUA Management	2nd ten-day period of March	Contract between CMO and WUA on water supply to the WUA
10	Preparation of logs of water intake at CMO gauging stations and delivery to WUA offtakes and registration in the Water Inspectorate	CMO and WUA Management	2nd ten-day period of March	Log of water intake at CMO gauging stations and delivery to WUA offtakes
11	Preparation and coordination of	WUA	3rd ten-day	Approved seasonal WUP

Stage	Type of activity	Executor	Period of execution	Result (output)
	seasonal WUP broken down by water users' offtakes	Management and Council	period of March	broken down by water users' offtakes
12	Preparation and conclusion of contracts between WUA and WUs on water supply to WUs' offtakes	WUA Management and WUs	3rd ten-day period of March	Contracts between WUA and WUs on water supply to WUs' offtakes
13	Preparation of logs of water intake and delivery to WUA offtakes	WUA Management and WUs	3rd ten-day period of March	Log of water intake and delivery to WUA offtakes

2.1. Initial information for drawing up of the WUA water use plan

Water use/consumption plan is the document made by the water user, i.e. WUA, which serves as an application for requesting water from governmental water management authorities (with the requested discharges and volumes of water withdrawal from water sources to the WUA contour broken down by ten-day periods). The WUA water use plan is drawn up based on agricultural water users' applications and proceeding from the pattern of agricultural use of the lands allotted to them and planned by them, and soil-reclamation conditions and hydromodule zones to which cultivated lands refer as well as proceeding from the crop irrigation rates and regimes recommended for these conditions.

The initial information required to draw up a WUA water use plan includes the following materials and data:

- Map/linear network and technical characteristics of the WUA irrigation network;
- Identification of belonging of the irrigated lands to hydromodule zones (HMZ);
- Pattern of the crops irrigated by agricultural water users, including homestead lands and double crops;
- Crop irrigation regimes during the vegetation period in the HMZs of the WUA location area;
- Efficiency of the canals that distribute water within the WUA contour.

2.1.1. Map/linear network and technical characteristics of the WUA irrigation network

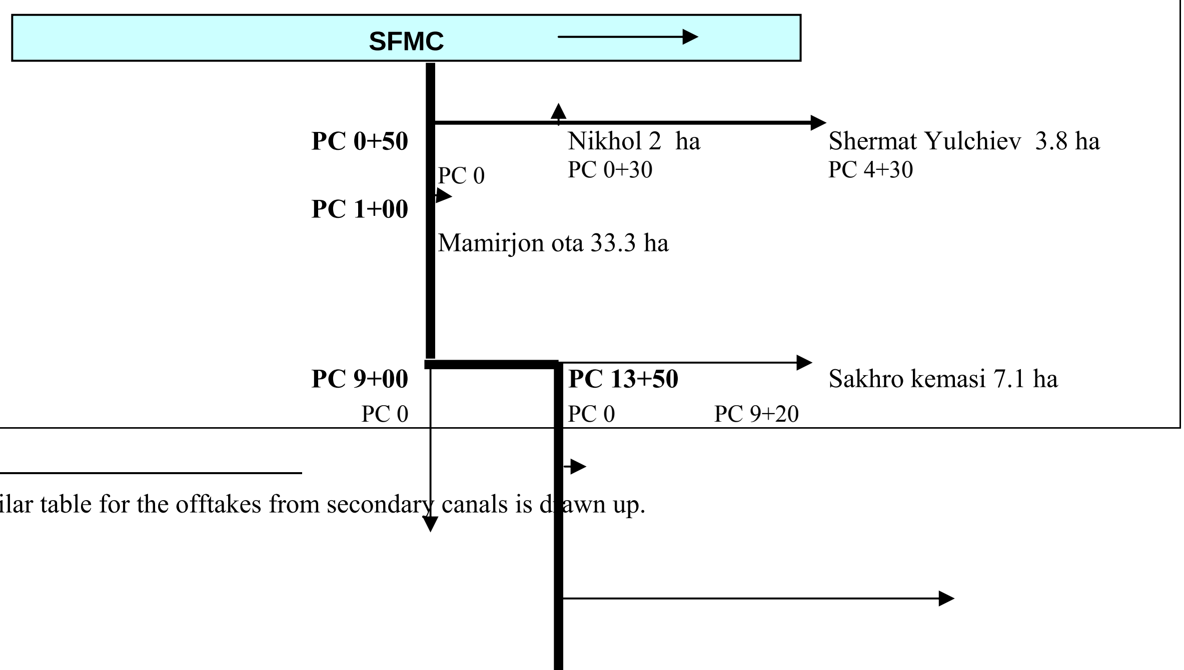
Based on the WUA map (M 1:10 000 – 1:25 000), linear networks of the offtakes (secondary canals) from the main canal and offtakes from the secondary canals are drawn up (Fig. 2.1). In addition to a linear network, the Technical Characteristics of WUA Irrigation Network Table[4] is made (Table 2.2).

On the linear networks of the offtakes from the main canal, the particular water users' offtakes from the main canal and gauging stations are specified. For further calculations and accounting losses along the canal it is necessary to indicate pickets where main water distribution points/nodes are located.

Table 2.2

Technical characteristics of WUA irrigation network
(*case study of the WUA "S. Kasymov"*)

№	Secondary canals (offtakes from the main canal)	Serviced area, ha	Offtake capacity, l/s	Length of distributors system, km	Efficiency
1	Shermatov (Kalinin)	234	800	11.8	0.75
2	Pipe (Sh.Yulduzi-1)	50	100	4.16	0.75
3	Saroy - 1	894	1200	16.6	0.85
4	Saroy - 2	39.1	800	3.4	0.80
5	Pipe (Sh.Yulduzi-2)	49.3	400	2.2	0.75
6	Pipe (Sh.Yulduzi-3)	55.3	300	1.8	0.75
7	Farm (Yangi otvod)	206	700	9.4	0.80
8	Krupskaya	303	1000	15.1	0.80
9	GES-1(pipe)	43.9	200	3.8	0.73
10	Orol	58.4	400	3.6	0.75
Total for the WUA		**1933**			



[4] A similar table for the offtakes from secondary canals is drawn up.

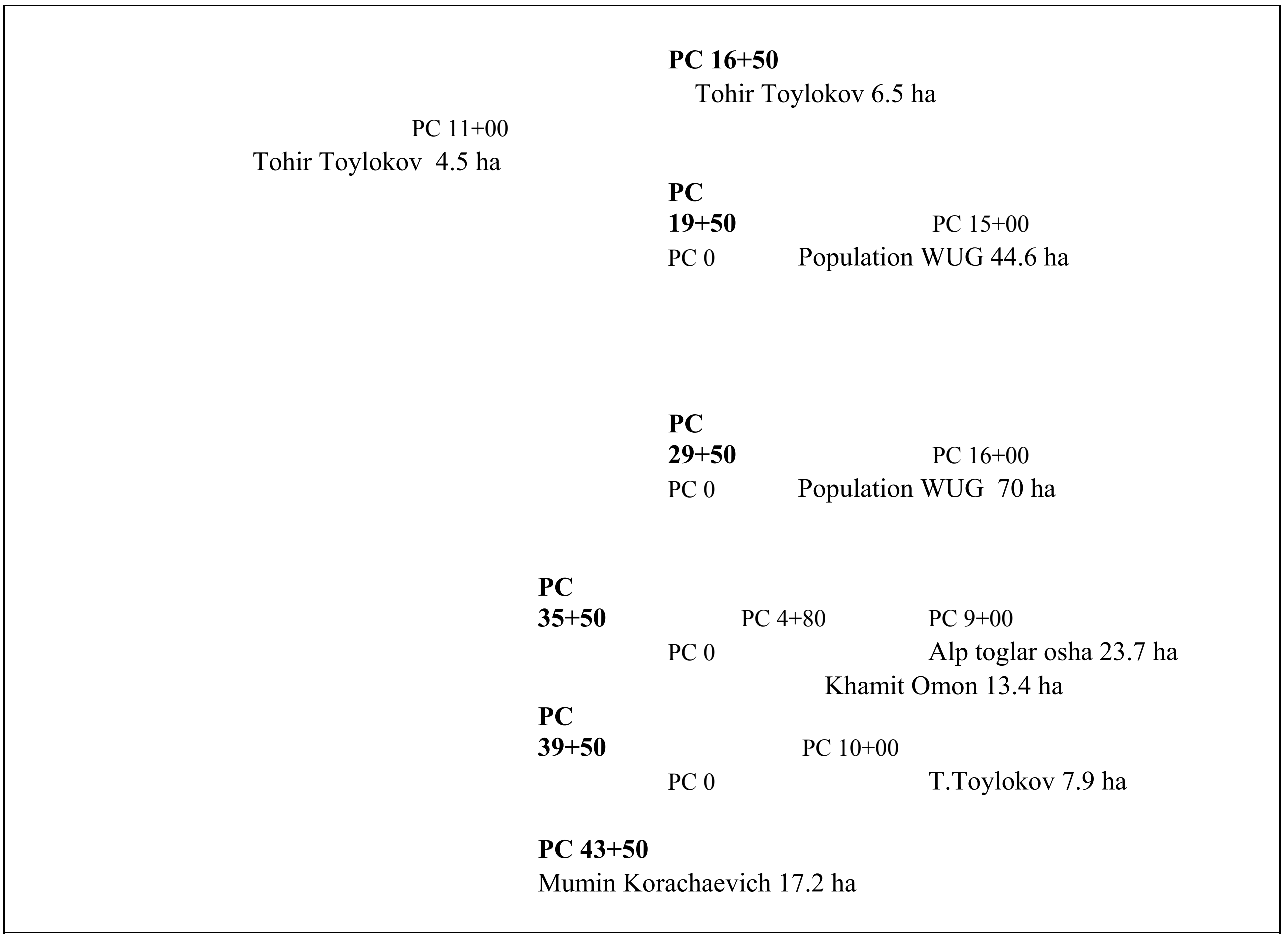


Figure 2.1 Linear network of the secondary canal "Shermatov".
(case study of the WUA "S. Kasymov" in the Bulakboshi district of the Andijan province)

2.1.2. Belonging of irrigated areas to hydromodule zones (HMZ)

In order that correctly estimate crop irrigation demands, first it needs to identify the belonging of the irrigated area to a particular *hydromodule zone* (HMZ). Under the conditions of Central Asia and Southern Kazakhstan, and the Unified HMZ Scale[5] (Table 2.3) is used, allowing for which HMZ areas are outlined based on soil-reclamation maps.

> ***Hydromodule zone** is a taxonomic unit the distinctive features of which consist in the combination of thickness of stone-free layer, grain-size composition, soil structure and composition, and occurrence depth of the groundwater that has influence on capillary moisture inflow to the root-inhabited zone and moisture reserves therein under (ultimate) field moisture capacity.*

[5] The Unified HMZ Scale was adopted at the regional coordination meeting in Dushanbe in 1991.

Table 2.3

Unified scale of hydromodule zones for the conditions of Central Asia and Southern Kazakhstan

HMZ	Soil characteristics
***Automorphic soils* (GWT > 3 m)**	
I[a]	Very shallow, highly stony, of different grading
I	Shallow (0.2-0.5 m), medium-stony, of different grading on sandy-pebble sediments and gypsums, as well as thick sandy
II	Medium-thick soft-stony of different grading on sandy-pebble sediments and gypsums; thick sandy-loam and light-loamy
III	Thick medium, heavy loamy and clayey
***Semi-hydromorphic soils* (GWT = 2-3 m)**	
IV	Thick sandy and sandy-loam, as well as shallow and medium-thick of different grading
V	Thick low and medium-loam homogeneous; heavy-loam, becoming thinner downwards
VI	Thick heavy-loam and clayey dense, homogeneous; of different grading, with stratified structure
***Hydromorphic soils* (GWT = 1-2 m)**	
VII	Thick sandy and sandy-loam, shallow and medium-thick of different grading
VIII	Thick
IX	Thick heavy-loam and clayey dense, homogeneous; of different grading, with stratified structure

Then the HMZ maps are combined with the maps of planning of WUA’s irrigated areas which indicate irrigation, collector & drainage network, and irrigation wells so that one could attribute a particular irrigation contour to the appropriate HMZ (Fig. 2.2).

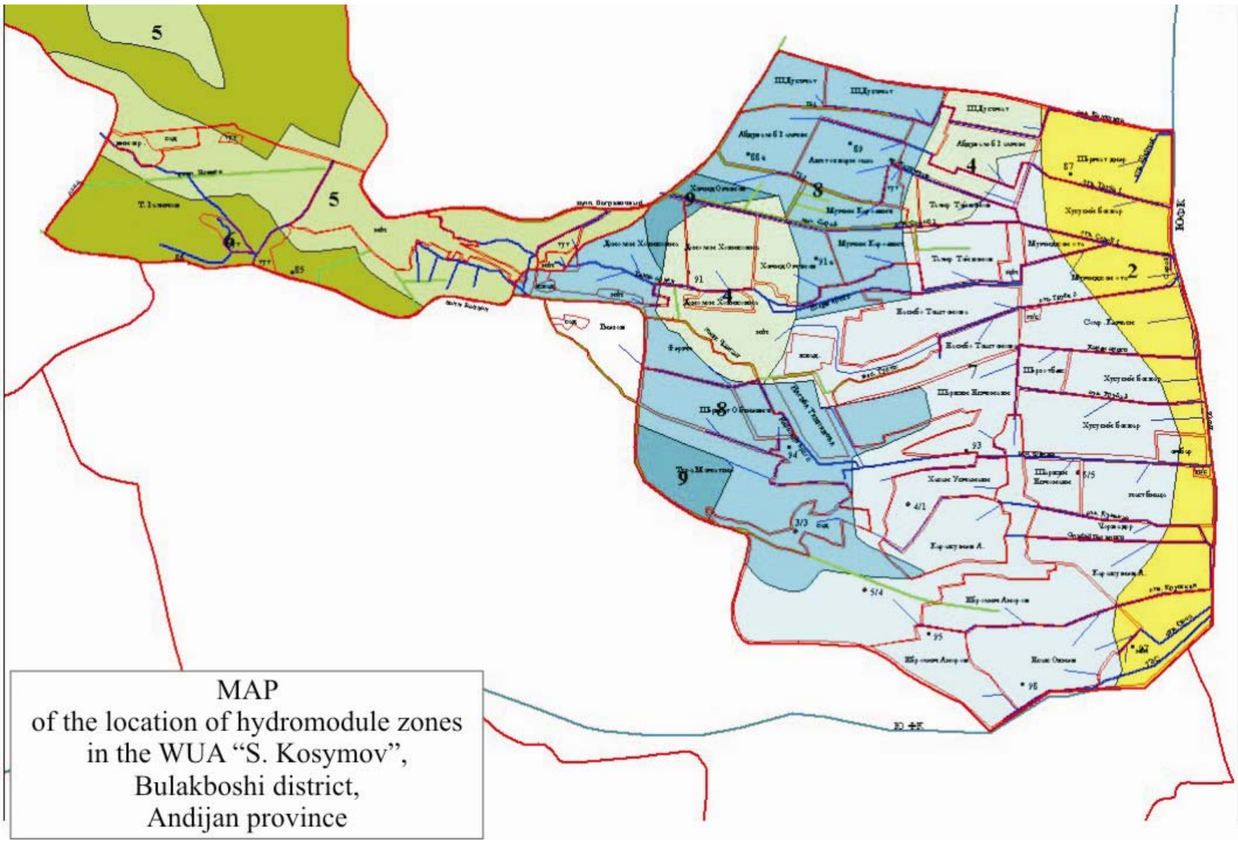


Figure 2.2. Map of hydromodule zones.
(case study of the WUA “S. Kasymov” in the Bulakboshi district of the Andijan province)

2.1.3. Irrigated cropping pattern

To define crop irrigation requirements/demands for the forthcoming vegetation period, every WUA water user should file an application in advance (usually before mid-March of the current year).

Fragment of a seasonal application of water users for cropping in irrigation contours

Republic	**Uzbekistan**
Province	**Andijan**
District	**Bulakboshi**
Canal	**SFC**
WUA	**S. Kasymov**
Offtakes from SFC	**Shermatov**

Seasonal applications of water users for the cropping during the vegetation period of 2010

Water users	№ contour according to State Land Cadastre	Crop	HMZ	Area, ha	Sowing date
Mumin Korachaevich	**41**	Cotton	V	3	08.04.10
		Winter wheat (Russia)	V	14.2	10.10.09
		Double crops	V	7.1	
Khamit Omon	**38**	Cotton	VI	13.4	12.04.10
Alp toglari osha	**36**	Cotton	V	14.8	14.04.10
		Winter wheat (Russia)	V	8.9	01.10.09
		Double crops	V	4.45	

Based on this, the WUA Management draws up the consolidated list of planned cropping within WUA contours in linkage to each offtake from the main canal, including the areas of the homestead lands located within the WUA contours in this list. Then the cropping plan within the contours and broken down by the offtakes that supply water to the WUA is given to water management organizations ISA-BISA[6] for summarization and Canal Water Committee (CWC) for approval.

2.1.4. Crop irrigation regimes

The rates and time of water application to crops are set in accordance with the irrigation regime adopted for a particular natural and climatic zone, which is based on average long-term climatic parameters (Table 2.4).

[6] In early July, after harvesting winter wheat, the cropping pattern is adjusted and the areas allotted for double crops are specified. This adjustment is made depending on the water content in sources during the vegetation period.

Table 2.4

Fragment of a record of crop irrigation regime (desert zone, C-2A)

HMZ	Crop	(Seasonal) irrigation rate, m^3/ha	№ of water application	Water application rate, m^3/ha	Water application time		Water application period, days	Hydromodule ordinate, l/s/ha
					start	end		
II	Winter wheat	5200	1	600	24 Sept	18 Oct	25	0.28
			2	600	19 Oct	12 Nov	25	0.28
			3	600	25 Mar	9 Apr	16	0.43
			4	600	10 Apr	22 Apr	13	0.534
			5	700	23 Apr	3 May	11	0.737
			6	700	4 May	13 May	10	0.810
			7	700	14 May	24 May	11	0.737
			8	700	25 May	6 Jun	13	0.623
V	Winter wheat	4600	1	600	26 Sept	15 Oct	20	0.35
			2	600	16 Oct	5 Nov	21	0.33
			3	800	28 Mar	13 Apr	17	0.54
			4	800	14 Apr	26 Apr	13	0.71
			5	800	27 Apr	7 May	11	0.84
			6	800	8 May	18 May	11	0.84
			7	800	19 May	1 Jun	14	0.66
II	Cotton	6200	1	800	13 May	5 Jun	24	0.39
			2	800	6 Jun	20 Jun	15	0.62
			3	800	21 Jun	3 Jul	13	0.71
			4	800	4 Jul	16 Jul	13	0.71
			5	900	17 Jul	29 Jul	13	0.80
			6	800	30 Jul	12 Aug	14	0.66
			7	800	13 Aug	31 Aug	19	0.49
			8	500	1 Sept	15 Sept	15	0.39
V	Cotton	4900	1	800	28 May	16 Jun	20	0.46
			2	800	17 Jun	5 Jul	19	0.49
			3	900	6 Jul	20 Jul	15	0.69
			4	900	21 Jul	5 Aug	16	0.65
			5	800	6 Aug	20 Aug	15	0.62
			6	700	21 Aug	4 Sept	15	0.54
VI	Orchards and vineyards	3900	1	800	1 May	25 May	25	0.37
			2	800	26 May	20 Jun	26	0.36

HMZ	Crop	(Seasonal) irrigation rate, m^3/ha	№ of water application	Water application rate, m^3/ha	Water application time		Water application period, days	Hydromodule ordinate, l/s/ha
					start	end		
			3	800	21 Jun	15 Jul	25	0.37
			4	800	16 Jul	10 Aug	26	0.36
			5	700	11 Aug	5 Sept	26	0.31
V	Double crops	5300	1	1100	27 Jun	12 Jul	16	0.80
			2	1400	13 Jul	2 Aug	21	0.77
			3	1400	3 Aug	26 Aug	24	0.68
			4	1400	27 Aug	12 Oct	48	0.34

Based on the crop water application rates and water application rates, **hydromodule ordinates** are calculated (right column in Table 2.4).

$$q_{iCrop} = m_i/(86.4 * t_i) \qquad (2.1)$$

q_{iCrop} - hydromodule ordinate/design (standard) consumption of irrigation water in terms of liter per second (l/s) which, in compliance with the water demand of a particular crop, should be supplied per one hectare of the area under this crop at the i^{th} water application, l/s/ha

m_i - water application rate according to the crop irrigation regime at the i^{th} water application in particular natural and climatic area and hydromodule zone, m3/ha

t_i - water application period at the i^{th} water application to the crop in a given natural and climatic area and hydromodule zone, days

When forming crop irrigation regimes, they proceed from a theoretical assumption that the design crop water application rate is evenly supplied to this crop over the irrigation/inter-irrigation period, i.e. with daily rate of water supply for the irrigation of it defined as:

$$Q_{iCrop} = (\omega_i * m_i)/(86.4 * t_i) \qquad (2.2)$$

Q_{iCrop} - required water supply rate during the water application period of i^{th} water application to the crop on the assumption of even release of daily portion of water application rate, l/s

ω_i - area under the crop irrigated at the i^{th} water application, ha

It is noteworthy that such a “theoretical” regime of water supply stretched out for the entire water application period of each water application with daily meeting crop water requirement can be provided only with drip irrigation method.

To achieve the consistency of the schedules of the water distribution from the main canal and WUA irrigation network and to reduce organizational losses of irrigation water, they use the ways of technologically practicable concentrated water supply implemented at daily planning of water distribution.

2.1.5. Ten-day hydromodule ordinates

Within a ten-day period, there may be a case when water application with the hydromodule designed for this water application is accomplished for several days, and during the rest days of the ten-day period another water application with the new hydromodule designed for the next water application. In this context, the ten-day hydromodule used in the calculation of a seasonal water use plan is determined by the formula:

$$\mathbf{q_{dn} = (q_i * t_{idn} + q_{(i+1)} * t_{(i+1)dn}) / T_{dn}} \qquad \textbf{(2.3)}$$

$\mathbf{q_{dn}}$ - ten-day hydromodule of water application to the crop for the **n**th ten-day period beginning from the vegetation period, l/s/ha

$\mathbf{q_i}$ - irrigation hydromodule of the **i**th water application to the crop, l/s/ha

$\mathbf{q_{(i+1)}}$ - irrigation hydromodule of the next water application, l/s/ha

$\mathbf{t_{idn}}$ - number of **i**th water application days in the **n**th ten-day period with a hydromodule of $\mathbf{q_i}$, days

$\mathbf{t_{(i+1)}}$ - number of next water application days in the **n**th ten-day period with a hydromodule of $\mathbf{q_{(i+1)}}$, days

$\mathbf{T_{dn}}$ - number of days in the **n**th ten-day period

Thus, when developing a seasonal water use plan, they previously, by using irrigation hydromodule ordinates (Table 2.4), determine **ten-day irrigation hydromodule** (l/s/ha) required to compensate water requirement of the crops in the cropping pattern of the lands commanded by secondary offtakes[7] (Table 2.5).

Table 2.5

Ten-day hydromodule ordinates (l/s/ha) in crop irrigation
(case study of the lands commanded by the Shermatov offtake in the WUA "S. Kosimov")

Crop	HMZ	Irrigated area, ha	April			May			June			July			August			September		
			I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Cotton	II	25.7					0.309	0.386	0.502	0.617	0.712	0.712	0.748	0.776	0.661	0.522	0.487	0.386	0.193	
	V	17.8						0.168	0.463	0.473	0.487	0.591	0.694	0.651	0.634	0.617	0.540	0.216		

[7] Hydromodule ordinates used for accounting water consumption by homestead lands are taken equal to 0.45 l/s/ha irrespective of HMZ and a vegetation month.

Crop	HMZ	Irrigated area, ha	April			May			June			July			August			September		
			I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
	VI	17.2						0.160	0.441	0.482	0.579	0.637	0.694	0.651	0.634	0.617	0.579	0.289		
Winter wheat	II	33.6	0.444	0.534	0.696	0.788	0.759	0.664	0.374											0.194
	V	23.1	0.545	0.662	0.764	0.842	0.806	0.661	0.066											0.174
Orchard	VI	2				0.370	0.370	0.363	0.356	0.356	0.370	0.370	0.363	0.356	0.356	0.312	0.312	0.156		
Intercrops	VI	1		0.161	0.322	0.322	0.322	0.515	0.676	0.781	0.703	0.766	0.360							
Double crops	II	16.8									0.827	0.903	0.953	0.905	0.874	0.772	0.698	0.367	0.367	0.367
	V	11.6									0.318	0.796	0.776	0.772	0.694	0.675	0.525	0.345	0.345	0.345
Homestead lands	all HMZs	114.6	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
PTN		234	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038

2.2. Organization of daily water distribution planning in WUA

2.2.1. Formation of water users' modules broken down by WUA canals

The module (group) of water users (WUM) is formed with the purpose of organizing alternate water distribution among water users in compliance with the quantities, rates, and terms of vegetation water application to the crops cultivated by WUM water users. WUM unites water users of one or several WUA canals.

Depending on an area commanded by the canal, there are the following WUA formation options:

Option 1. If the irrigated area commanded by a WUA canal is within the range of 160-300 ha, the WUA canal water users unite into one WUM regardless of cultivated cropping pattern and belonging of the irrigated areas to certain WUMs.

Option 2. If the area commanded by a WUA canal is more than 300 ha, two or more WUMs are established.

Option 3. If the area commanded by a WUA canal is less than 160 ha, WUM integrates areas commanded by a few canals. (*If the total irrigated area commanded by WUA canals is within the range from 160 to 200 ha, then WUM is set up* in accordance with the first Option*; if the total irrigated area commanded by several WUA canals is 500 ha and more, WUM is set up* in accordance with the second Option).

In Table 2.6, cropping on the irrigated area of 234 ha commanded by the Shermatov canal (WUA “S. Kosimov” in the Bulakboshi district).

Table 2.6

Shermatov canal cropping broken down by water users' offtakes for the vegetation period of 2010

№	Water user	HMZ	Irrigated area, ha	in particular:				
				cotton	wheat	double crops	mulberry	population
1.1.1	Nikhol WUG	VI	2				2	
1.1.2	Sh. Yulchiev	VI	3.8	3.8				
1.2	Mamirjon ota	II	33.3	19.6	13.7	6.85		
1.3	T. Toylokov	II	4.5		4.5	2.25		
1.4	Sakhro kemasi	II	7.1		7.1	3.55		
1.5	T. Toylokov	II	6.5		6.5	3.25		
1.6	Population WUG	VI	44.6					44.6
1.7	Population WUG	VI	70					70
1.8.1	Khamit Omon	VI	13.4	13.4				
1.8.2	Alp toglar osha	V	23.7	14.8	8.9	4.45		
1.9	T. Toylokov	II	7.9		7.9	3.95		
1.10	M. Koraevich	V	17.2	3	14.2	7.1		
Total on the Shermatov canal			**234.0**	**54.6**	**62.8**	**31.4**	**2.0**	**114.6**

In accordance with the above-stated criteria, a first-option WUM is established on the Shermatov canal (Table 2.7).

Table 2.7

Crop composition in the Shermatov WUM broken down by hydromodule zones

WUM	Crop	HMZ	Area under crop, ha
Shermatov	cotton	II	19.6
		V	17.8
		VI	17.2
	wheat	II	39.7
		V	23.1
	double crops	II	19.85
		V	11.55
	mulberry	VI	2
	homestead lands	VI	114.6
Total in the Shermatov WUM			**234**

2.2.2. Determination of average ten-day water consumption by WUM

The irrigation hydromodule employed in the irrigation regime calculation take into account only net direct water requirement, in other words those do not allow for the losses in water transport through the distribution network from the main canal offtake head. In order to take into account these losses, the net water transport discharge values obtained through calculations are divided by the efficiency factor. The efficiency factor value is taken from the certificates with the specifications of the offtakes (Table 2.2).

$$Q_{gross(offtake)} = (q_{dn(crop\ 1)} * \omega_{(crop\ 1)} + \ldots + q_{dn(crop\ N)} * \omega_{(crop\ N)}) / \eta_{irrig.\ network} \qquad (2.4)$$

where: ω_{crop} is the area under the irrigated crop, ha

$q_{dn.crop}$ ten-day crop irrigation hydromodule value, l/s/ha.

Thus, a water supply plan broken by ten days of the vegetation period is drawn up for the WUM areas irrigated from the canal (Table 2.8).

Table 2.8

Seasonal plan of water supply (l/s) for crop irrigation during the vegetation period (case study of the lands commanded by WUM/Shermatov canal, 2010)

Crop	HMZ	Irrigated area, ha	April			May			June			July			August			September		
			I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Cotton	II	25.7					8	10	13	16	18	18	19	20	17	13	13	10	5	
	V	17.8						3	8	8	9	11	12	12	11	11	10	4		
	VI	17.2						3	8	8	10	11	12	11	11	11	10	5		
Winter wheat	II	33.6	15	18	23	27	26	22	13											7
	V	23.1	13	15	18	19	19	15	2											4
Orchard	VI	2				1	1	1	1	1	1	1	1	1	1	1	1			
Intercrops	VI	1						1	1	1	1	1								
Double crops	II	17									14	15	16	15	15	13	12	6	6	6
	V	11.55									4	9	9	9	8	8	6	4	4	4
Homestead lands	all	114.6	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52
PTN			9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Net water transport discharge, l/s			88	94	102	108	114	115	105	95	117	126	130	128	123	117	111	90	76	81
Water withdrawal flow (EF=0.748)			118	126	136	144	152	154	140	127	156	169	174	171	165	156	148	120	101	109

2.2.3. Determination of daily water flow in WUM water users' offtakes

When planning daily water distribution for each of the vegetation crop irrigation on particular irrigated areas, net water supply $Q_{crop(1\ day)}$ is determined first on the assumption of supplying water application rate to the whole irrigated area for one day, i.e. by formula (2.2), but with t_i equal one day:

$$Q_{crop(1\ day)} = (\omega_i * m_i) / 86.4 \qquad (2.5)$$

$Q_{crop\ day}$ - required net water supply rate during the **i**th water application to a crop on the assumption of supplying the water application rate for one day, l/s

The required water supply rate for each crop irrigation during vegetation is executed in the form of a table (Table 2.9).

Table 2.9

Required water supply flow (on the assumption of supplying the water application rate to the whole irrigated area for one day by way of example of the Shermatov WUM (vegetation period of 2010)

№	Water users	HMZ	Total irrigated area, ha	Crop	Area under crop, ha	Water application							
						#1	#2	#3	#4	#5	#6	#7	#8
1.1.1	Nikhol	VI	2	mulberry	2	19	19	19	19	16			
1.1.2	Sh. Yulchiev	VI	3.8	cotton	3.8	35	40	40	40	35	35		
1.2	Mamirjon ota	II	33.3	cotton	19.6	181	181	181	181	204	181	181	113
				wheat	13.7	95	95	111	111	111	111		
				dbl. crop	6.85	79	111	111	111	103			
1.3	T. Toylokov	II	4.5	wheat	4.5	31	31	36	36	36	36		
				dbl. crop	2.25	26	36	36	36	34			
1.4	Sakhro kemasi	II	7.1	wheat	7.1	49	49	58	58	58	58		
				dbl. crop	3.55	41	58	58	58	53			
1.5	T. Toylokov	II	6.5	wheat	6.5	45	45	53	53	53	53		
				dbl. crop	3.25	38	53	53	53	49			
1.6	WUG-1 HL	VI	44.6	homestead	44.6	26	26	26	26	26	26	26	26
1.7	WUG-2 HL	VI	70	homestead	70	40	40	40	40	40	40	40	40
1.8.1	Khamit Omon	VI	13.4	cotton	13.4	124	140	140	140	124	124		
1.8.2	Alp toglar osha	V	23.7	cotton	14.8	137	137	154	154	137	120		
				wheat	8.9	82	82	82	82	82			
				dbl. crop	4.45	57	72	72	72				
1.9	T. Toylokov	II	7.9	wheat	7.9	55	55	64	64	64	64		
				dbl. crop	3.95	46	64	64	64	59			
1.10	M. Koraevich	V	17.2	cotton	3	28	28	31	31	28	24		
				wheat	14.2	131	131	131	131	131			
				dbl. crop	7.1	90	115	115	115				

2.3. Seasonal adjustment of the water use plan and on-line adjustment of daily water use schedules

2.3.1. Seasonal adjustment of the water use plan

Seasonal adjustment of the water use plan is made in March-April, after the Central Asian countries have approved limits on the water withdrawal to irrigation systems, which were set based on the forecasts of water content in main water sources. After Basin

Irrigation System Administrations inform district water management organizations about the water withdrawal limits, the latter fix the water withdrawal limits on WUA contours.

Having received limited water volume for the vegetation period, WUA defines the water supply coefficient:

$$K_{\text{water supply}} = \frac{\text{Volume of the water limit allocated to WUA}}{\text{Planned WUA water requirement}} \qquad \textbf{(2.6)}$$

Using the water supply coefficient, the schedule of daily water distribution to farms-water users is appropriately adjusted. However, since this schedule is based on average long-term climatic data, it needs to be adjusted during the vegetation period allowing for:

- existing water content in the irrigation source;
- variation of weather parameters;
- level of crop development, etc.

Given this the water relations between water users and WUA, WUAs and WMO are regulated based on water demand applications (Appendix).

2.3.2. On-line adjustment of water distribution

The process of on-line adjustment of water distribution and execution of the procedure of water resources management coordination between farmers and WUA and between WUAs and WMO consists of three stages:

Stage 1. Drawing up daily schedules of water distribution to WUA canals in accordance with the water applications from water users and order of the classification and registration of those.

When making daily water distribution schedules, first WUA hydraulic engineer enters the days and rates of water supply to homestead lands in the schedule.

If the area commanded by the homestead land offtakes is:

- 40 ha and over: ***continuous flow*** water supply is provided;
- below 40 ha: ***concentrated water supply*** is provided *(viz. water rotation between homestead lands)*[8]

The rest part of the water withdrawal to the WUM is distributed among other water users according tot heir water applications.

A WUA hydraulic engineer accepts applications from a water user for each crop being grown, examines the water distribution schedule for WUM irrigation in the presence of the water user and puts him/her on the queue with fixing the date, period, and flow of

[8] At concentrated water supply to homestead lands, the water supply schedule (in 3-5 days) must be coordinated with the makhalla committee and approved by the WUA Council.

water supply (an example is given in Inset II). The same data are written down on the water user's application and recorded in the ***WUA water users' water application log***[9]**.**

INSET II

To Director of the WUA "S. Kasymov"
Mr. M. Karimov

APPLICATION № 2
from Individual Farm (IF) *"Alp toglari osha"*
Date: 27 March 2010

Total irrigated area, ha	Crop	Irrigated area shown in the application form, ha	Net water application rate m^3/ha	Water supply period		Agreed water supply rate, l/s
				beginning	end	
23.7	wheat	8.9	800	04.04 at 7^{00}	05.04 at 7^{00}	9
				05.04 at 7^{00}	06.04 at 7^{00}	30
				06.04 at 7^{00}	07.04 at 7^{00}	30
				07.04 at 7^{00}	08.04 at 7^{00}	13

Head of IF "Alp toglari osha" Name: F. *Makhkamov* Sign: _______________
Actual water supply to IF: ____l/s "___" ___ 2010 Director of WUA: ____________

- to be filled by the water user

- to be filled by the WUA hydraulic engineer upon agreement with the water user

When distribution water according to the water users' applications, a particularly important thing is the organization of the first vegetation irrigation of the first cycle of the queue of water supply to water users. Ideally, water application begins from the tail sections of a secondary canal with step-by-step shift towards the head section[10]. With such an approach, one can remarkably reduce organizational losses of water owing to concentrated water supply.

To fulfill this condition, it is essential that crop sowing too begin from the irrigated areas commanded by the end sections of the secondary canal. However, in practice this cannot always be achieved, therefore the WUA Management adjusts the operating water distribution schedule proceeding from the water users' applications. A queue of water users is formed allowing for the earliness (*no less than three days before the next ten-day period*) and order of receiving of applications.

Similarly, the water applications are accepted and daily water distribution schedules are drawn up for other WUM water users.

At on-line planning and management of water distribution in WUA, it is recommended to adhere to the order of irrigation fixed in the seasonal plan of daily planning (Table 2.10).

Stage 2. WUA filing consolidated water application to CMO and receiving a CMO's notification-decision concerning the application for the quantity of water to be allocated to the WUA for the next ten days proceeding from the real water situation.

[9] The water user must sign in the log and take a copy of his water application. Another copy of the water user's application is filed in the **WUA water users' water applications file folder.**
[10] This can be due to using the scheme of planning crop irrigation beginning from the end sites of WUM.

The WUA Management records received applications and files to CMO (*no less than two days before the next ten-day period*) consolidated application for water withdrawal to the WUA broken down by secondary canals that take water from a main canal (an example is given in Inset III).

Table 2.10

Fragment of planned daily water distribution to water users' offtakes
(*case study of the Shermatov WUM*, 2010)

№	Water users	HMZ	Total irrigated area, ha	Crop	Area under crop, ha	April 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.1.1	Nikhol	VI	2	mulberry	2															
1.1.2	Sh. Yulchiev	VI	3.8	cotton	3.8															
1.2	Mamirjon ota	II	33.3	cotton	19.6															
				wheat	13.7	14	30	30	21											
				double crop	6.85															
1.3	T. Toylokov	II	4.5	wheat	4.5	16														7
				double crop	2.25															
1.4	Sakhro kemasi	II	7.1	wheat	7.1														20	29
				double crop	3.55															
1.5	T. Toylokov	II	6.5	wheat	6.5													29	16	
				double crop	3.25															
1.6	WUG-1 HL	VI	44.6	homestead	44.6	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26
1.7	WUG-2 HL	VI	70	homestead	70	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
1.8.1	Khamit Omon	VI	13.4	cotton	13.4															
1.8.2	Alp toglar osha	V	23.7	cotton	14.8															
				wheat	8.9				9	30	30	13								
				double crop	4.45															
1.9	T. Toylokov	II	7.9	wheat	7.9											12	36	7		
				double crop	3.95															
1.10	M. Koraevich	V	17.2	cotton	3															
				wheat	14.2							17	30	30	30	24				
				double crop	7.1															
PTN						9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Total for Shermatov WUM			234.0	water supply		105	105	105	105	105	105	105	105	105	105	111	111	111	111	111
				water withdrawal		140	140	140	140	140	140	140	140	140	140	148	148	148	148	148
Shermatov canal efficiency is 0.748																				

INSET III

To Head of the Markhamat Division of SFMC MO

WATER APPLICATION from WUA «S.Kasymov»
from April 1 to April 10, 2010

№	Secondary canal	Total irrigated area, ha	Average ten-day flow rate, m^3/s	Indicators	Daily water supply rate, l/s 1	2	3	4	5	6	7	8	9	10
1	Shermatov (Kalinin)	234	140	Planned	140	140	140	140	140	140	140	140	140	140
				Limit	119	119	119	119	119	119	119	119	119	119
				Requested	140	140	140	140	140	140	140	140	140	140

…	….	…	…	…	…	…	…	…	…	…	…	…	…	…
10	Orol	58.4		Planned	…	…	…	…	…	…	…	…	…	…
				Limit	…	…	…	…	…	…	…	…	…	…
				Requested	…	…	…	…	…	…	…	…	…	…
Total for WUA from SFC		**1933**		**Planned**	…	…	…	…	…	…	…	…	…	…
				Limit	…	…	…	…	…	…	…	…	…	…
				Requested	…	…	…	…	…	…	…	…	…	…

Director of WUA "S. Kasymov" **Karimov, M.**

29 March 2010

Taking into consideration the water content in the main water source, CMO sets the water supply coefficient (Formula 2.6) for coming ten days for WUA offtakes from the main canal (an example is given in Inset IV) and notifies (*no less than two days before the next ten days*) the WUA about the water discharge from the main canal to WUA offtakes which was fixed for the coming ten-day period.

INSET IV

To Director of the WUA "S. Kasymov"
Mr. M. Karimov

NOTIFICATION
of the water flow from SFMC to the WUA "S.Kasymov" offtakes
set for the period from April 1 to 10, 2010

№	Secondary canal	Total irrigated area, ha	Average ten-day flow rate, m^3/s	Daily water supply flow rate fixed for ten days, l/s									
				1	2	3	4	5	6	7	8	9	10
1	Shermatov (Kalinin)	234	113	113	113	113	113	113	113	113	113	113	113
…		…	…	…	…	…	…	…	…	…	…	…	…
10	Orol	58.4	…	…	…	…	…	…	…	…	…	…	…
Total for WUA		**1933**		…	…	…	…	…	…	…	…	…	…

Head of SFMC Water Use Department

29 March 2010

Stage 3. On-line adjustment of daily schedules of water distribution to WUA canals in compliance with the water content in the main water source for the forthcoming ten-day period.

The ways to adjust the daily schedules of water distribution to WUA canals depend on the ratio of the water volume allocated to the WUA to the planned water consumption for the forthcoming ten-day period.

If the water supply availability in WUA decreases:

by 30 %: the first method of daily water distribution schedule adjustment in accordance with the assigned *taksim*[11].

by more than 30 %: the second method of daily water distribution adjustment schedules with the application of water rotation.

[11] Water quantity allocated to WUA on a ten-day basis form the main canal; it is decided proceeding from the actual water availability in water sources.

2.3.2.1. Adjustment of the daily schedules of water distribution to WUM in accordance with the assigned taksim.

In line with the water supply coefficient set by CMO for the forthcoming ten-day period, the WUA Management adjusts the daily plan of water distribution to all offtakes from the main canal to the WUA (*no less than one day before the next ten days*), introduces adjustments to the earlier applications of water users on the waiting list and puts the schedule of water distribution to main canal offtakes for the coming ten-day period on a publicity board (*an example of flow distribution at water availability of 81% is given* in Inset V).

INSET V

NOTIFICATION

of water supply order and fixed water consumption of WUM/Shermatov canal water users from SFMC

(for the period from April 1 to 10, 2010)

№	Water users	HMZ	Total irrigated area, ha	Crop	Area under crop, ha	Indicators	April									
							1	2	3	4	5	6	7	8	9	10
1.1.1	Nikhol	VI	2	mulberry	2	*resuest*										
						taksim										
1.1.2	Sh. Yulchiev	VI	3.8	cotton	3.8	*resuest*										
						taksim										
1.2	Mamirjon ota	II	33.3	cotton	19.6	*resuest*										
						taksim										
				wheat	13.7	*resuest*	14	30	30	21						
						taksim	11	24	24	17						
				double crop	6.85	*resuest*										
						taksim										
1.3	T. Toylokov	II	4.5	wheat	4.5	*resuest*	16									
						taksim	13									
				double crop	2.25	*resuest*										
						taksim										
1.4	Sakhro kemasi	II	7.1	wheat	7.1	*resuest*										
						taksim										
				double crop	3.55	*resuest*										
						taksim										
1.5	T. Toylokov	II	6.5	wheat	6.5	*resuest*										
						taksim										
				double crop	3.25	*resuest*										
						taksim										
1.6	WUG-1 HL	VI	44.6	homestead	44.6	*resuest*	26	26	26	26	26	26	26	26	26	26
						taksim	21	21	21	21	21	21	21	21	21	21
1.7	WUG-2 HL	VI	70	homestead	70	*resuest*	40	40	40	40	40	40	40	40	40	40
						taksim	32	32	32	32	32	32	32	32	32	32
1.8.1	Khamit Omon	VI	13.4	cotton	13.4	*resuest*										
						taksim										
1.8.2	Alp toglar osha	V	23.7	cotton	14.8	*resuest*										
						taksim										
				wheat	8.9	*resuest*				9	30	30	13			
						taksim				7	24	24	11			
				double crop	4.45	*resuest*										
						taksim										
1.9	T. Toylokov	II	7.9	wheat	7.9	*resuest*										
						taksim										
				double crop	3.95	*resuest*										
						taksim										

1.10	M. Koraevich	V	17.2	cotton	3	*resuest*										
						taksim										
				wheat	14.2	*resuest*							**17**	**30**	**30**	**30**
						taksim							**14**	**24**	**24**	**24**
				double crop	7.1	*resuest*										
						taksim										
PTN						*resuest*	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**9**
						taksim	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**9**
Total for Shermatov WUM			**234.0**	**water supply**		*resuest*	**105**	**105**	**105**	**105**	**105**	**105**	**105**	**105**	**105**	**105**
						taksim	**87**	**87**	**87**	**87**	**87**	**87**	**87**	**87**	**87**	**87**
				water withdrawal		*resuest*	**140**	**140**	**140**	**140**	**140**	**140**	**140**	**140**	**140**	**148**
						taksim	**116**	**116**	**116**	**116**	**116**	**116**	**116**	**116**	**116**	**116**

Director of WUA "S. Kasymov" **Karimov, M.**

2.3.2.2. Organization of water distribution under the conditions of water rotation in WUA

In case of dramatic decrease of water availability in water withdrawal sources (*by more than 30% of the water withdrawal limit set in the plan*) it becomes necessary to introduce tougher water rotation between water users' irrigated sites/offtakes commanded by the secondary offtakes of the main canal or between secondary offtakes[12]. Daily water flow of WUM during the water rotation cycle is defined by:

$$Q_{WUM}^{WR} = \frac{Q_{WUM}^{appl} * T * K^{WUA}}{t} \qquad \textbf{(2.7)}$$

where

Q_{WUM}^{WR} is WUM daily water flow rate during a water rotation cycle, l/s;

Q_{WUM}^{appl} is WUM daily water flow rate according to an application, l/s;

T is water rotation period, days;

K^{WUA} is coefficient of water availability in WUA during the water rotation period;

t is duration of water rotation cycle, days.

An example of the Shermatov WUM water flow distribution during the water rotation application period at water availability of 65% is given in Inset VI.

[12] The water principles set do not apply to the water supply for PTN.

INSET VI

NOTIFICATION

of water supply order and fixed water consumption by WUM/Shermatov canal water users from SFMC during water rotation

(for the period from April 1 to 12, 2010)

№	Water users	HMZ	Total irrigated area, ha	Crop	Area under crop, ha	Indicators	April											
							1	2	3	4	5	6	7	8	9	10	11	12
1.1.1	Nikhol	VI	2	mulberry	2	*resuest*												
						WR												
1.1.2	Sh. Yulchiev	VI	3.8	cotton	3.8	*resuest*												
						WR												
1.2	Mamirjon ota	II	33.3	cotton	19.6	*resuest*												
						WR												
				wheat	13.7	*resuest*	14	30	30	21								
						WR	28	34										
				double crop	6.85	*resuest*												
						WR												
1.3	T. Toylokov	II	4.5	wheat	4.5	*resuest*	16											
						WR	10											
				double crop	2.25	*resuest*												
						WR												
1.4	Sakhro kemasi	II	7.1	wheat	7.1	*resuest*												
						WR												
				double crop	3.55	*resuest*												
						WR												
1.5	T. Toylokov	II	6.5	wheat	6.5	*resuest*												
						WR												
				double crop	3.25	*resuest*												
						WR												
1.6	WUG-1 HL	VI	44.6	homestead	44.6	*resuest*	26	26	26	26	26	26	26	26	26	26	26	26
						WR	34	34	34				34	34	34			
1.7	WUG-2 HL	VI	70	homestead	70	*resuest*	40	40	40	40	40	40	40	40	40	40	40	40
						WR	52	52	52				52	52	52			
1.8.1	Khamit Omon	VI	13.4	cotton	13.4	*resuest*												
						WR												
1.8.2	Alp toglar osha	V	23.7	cotton	14.8	*resuest*												
						WR												
				wheat	8.9	*resuest*				9	30	30	13					
						WR		4	38				11					
				double crop	4.45	*resuest*												
						WR												
1.9	T. Toylokov	II	7.9	wheat	7.9	*resuest*											12	36
						WR									18			
				double crop	3.95	*resuest*												
						WR												
1.10	M. Koraevich	V	17.2	cotton	3	*resuest*												
						WR												
				wheat	14.2	*resuest*							17	30	30	30	24	
						WR							27	38	20			
				double crop	7.1	*resuest*												
						WR												
Total for irrigation				**water supply**		*resuest*	96	96	96	96	96	96	96	96	96	96	96	96
				water withdrawal		*WR*	124	124	124				124	124	124			
PTN				**water withdrawal**		*resuest*	128	128	128	128	128	128	128	128	128	128	128	128
						WR	166	166	166				166	166	166			
Total for Shermatov WUM			**234.0**	**water supply**		*resuest*	12	12	12	12	12	12	12	12	12	12	12	12
						WR	12	12	12	12	12	12	12	12	12	12	12	12
				water withdrawal		*resuest*	140	140	140	140	140	140	140	140	140	140	148	148
						WR	178	178	178	12	12	12	178	178	178	12	12	12

Director of WUA "S. Kasymov" **Karimov, M.**

List of references used for Section 2

1. Alimdjanov, A. Method of drawing up a water use plan at the WUA level, presentation. 2009.

2. Alimdjanov, A. Adjustment of a water use plan under the conditions of applied water rotation. 2009.

3. Mirzaev, N.N., Tuchin, A.I., Alimdjanov, A. Planning water use at he WUA level: daily water distribution plan based on the crop irrigation regime. 2007.

4. Mirzaev, N.N., Saidov, R., Ergashev, I. Drawinh up and implementation of water distribution plans. 2008.

5. Stulina, G.V., Solodkiy, G.F., Zherelyeva, S.G. Recommendations on hydromodule zoning and crop irrigation regime, report. 2009.

6. Khasankhanova, G.M. Crop water consumption. 1999.

Appendix 2.1

Organizational and technological stages of operating water distribution in WUA

Stage	Type of activity	Executor	Time of execution	Result (output)
1	Accept and record of water applications, and drawing up daily schedules of water distribution (DWDS) to WUA offtakes from the main canal for the forthcoming ten-day period	WUA Hydraulic Engineer	3 days before the next ten days of the vegetation period	WUA canal DWDS for the forthcoming ten-day period (filing and logging of water users' water applications)
2	Analysis of DWDS for WUA offtakes and formation of a consolidated application for water withdrawal to WUA for the forthcoming ten-day period	WUA Director and WUA Hydraulic Engineer	3 days before the next ten days of the vegetation period	Consolidated water application by WUA for the forthcoming ten-day period
3	Filing of WUA's water application to CMO and receipt a notification from the CMO about the taksim (water distribution coefficient) for the forthcoming ten-day period	Director of WUA, CMO	2 days before the next ten days of the vegetation period	Flow and volume of water withdrawal to WUA approved by CMO for the forthcoming ten-day period
4	Distribution of the water withdrawal volume allocated for WUA from the main canal taking into account water formation in internal water sources of the WUA (CDW, DW, PS, etc.).	WUA Director and WUA Hydraulic Engineer	1 day before the next ten days of the vegetation period	Planned water distribution of the water withdrawal allocated for WUA for the forthcoming ten-day period among WUA offtakes from the main canal
5	Adjustment of DWDS for the forthcoming ten-day period for WU offtakes and presentation of the adjusted DWDS to WUA Council	WUA Council, WUA Director, and WUA Hydraulic Engineer	1 day before the next ten days of the vegetation period	Distribution of low and volume of water supply to WU offtakes approved by WUA Council
6	Informing WUs of the DWDS adopted for the forthcoming ten-day period	WUA Hydraulic Engineer, HS mirabs	1 day before the next ten days of the vegetation period	Putting DWDS on a publicity board
7	Monitoring of the fulfillment of the plan of ten-day water distribution to WUA offtakes from the main canal coordinated with CMO	Head of MC HS, WUA Director, and WUA Hydraulic Engineer	Every day within the ten-day period	Log of water intake from the main canal and delivery to WUA offtakes
8	Monitoring of DWDS fulfillment and online adjustment of DWDS during the ten-day period	HS Hydraulic Engineer and mirabs	Every day within the ten-day period	Log of water intake and delivery to WUA offtakes
9	Assessment and analysis of the DWDS fulfillment and	WUA Director, WUA Hydraulic	2 days after the	Results of the past-ten-day DWDS

Stage	Type of activity	Executor	Time of execution	Result (output)
	informing the WUA Council about the past-ten-day DWDS fulfillment results	Engineer, and WUA Council	ten-day period	fulfillment. Decisions on imposing (as appropriate) sanctions on WUs that violate the water use discipline
10	Preparation of the statements of water intake and delivery between WUA and WUs on a monthly basis	WUA Hydraulic Engineer, HS mirabs, WUs	3 days after the reporting month	Statements of water intake and delivery between WUA and WUs agreed upon by the parties
11	Preparation of monthly water use reports for each WUA offtake from the main canal and other sources, with assessments and indicators	WUA Director, WUA Hydraulic Engineer	3 days after the reporting month	Water use reports for each WUA offtake from the main canal and other sources, with assessments and indicators
12	Preparation of monthly statements of water intake and delivery between CMO and WUA	CMO, WUA Management	First week after the reporting month	Statement agreed upon by the parties

3. MONITORING OF WATER USE IN WUA

The major task of WMO and CMO is water delivery to the offtakes of water users to required quantity in a certain time and in accordance with the crop irrigation regime.

The water management activities of WMO and WUA are closely interrelated. For example, if a WMO organized its work at a high technical level, but a WUA failed to organize water use and uniform distribution of water among water users, all the efforts of the WMO aimed at technical improvement of the system were in vain and had little effect. A similar situation will emerge if a WUA draws up optimal water distribution schedules, but a WMO cannot stably provide it with water.

This non-coordination of WMO and WUA operation regimes causes suffers, first of all, to water users as well as causes considerable organizational losses of irrigation water.

The basic task of WUA in the use of water resources is as follows:

- ensuring of secured and equitable water supply and distribution of water among water users;
- reduction of non-productive water losses in the irrigation network of WUA;
- ensuring of free access for WUA water users to water apportioning related information.

Monitoring of the water use in WUA is supposed to solve the main problems of the WUA and enhance the performance of the WUA, enable water users controlling and assessing the water distribution organization activity of the WUA.

Based on the data of the monitoring and assessment of water distribution and use in the WUA, the WUA Council must ascertain whether the WUA Management has attained the results provided for in the WUA operation plans approved by the WUA General Meeting. Following the consideration of the WUA Management work, water users take decisions along with the evaluation of the Management activity.

WUA activity monitoring consists in continuous, regular collection and analysis of the information about the execution of the plan of water use and water distribution within WUA's irrigated contours as well as about water use by water users.

During monitoring, they compare actual water distribution with the planned distribution in order to introduce timely adjustments, as appropriate, in the WUA operation plans in the course of their implementation.

The WUA Council can evaluate the activity of the Management impartially provided that conclusions are based on correctly fitted indicators of the performance of the set tasks. Correctly fitted monitoring indicators allow proper keeping track of the dynamics of the water use in the WUA, assessing achievements and timely eliminating drawbacks.

3.1. Initial materials for the monitoring of the water use in WUA

For the monitoring of the water use in WUA, one has to have tables of the planned, applied for, taksims, and actual daily indicators of the water supply to WUA canals (Table 3.1) and schedules of daily water distribution among canal water users who cultivate crops (Table 3.7).

Table 3.1

Indicators of planned, applied for, taksims, and actual water supply to secondary canals to WUA during the vegetation period, l/s

№	Name of secondary canal	Irrigated area, ha	Water supply indicators	April											
				1	2	3	4	5	6	7	8	9	10	Total for ten-day period	11
1	1st canal (secondary) of WUA		plan												
			applied for												
			taksim												
			actual total for WUs' offtakes												
			actual for the secondary canal HS												
…	…	…	…	..	..	..	..	..	..	..	..	..	..	..	..
N	Nth canal (secondary) of WUA		plan												
			applied for												
			taksim												
			actual total for WUs' offtakes												
			actual for the secondary canal HS												
Total for WUA			plan												
			applied for												
			taksim												
			actual total for all offtakes												
			actual for all head HSs of the WUA's secondary canal												

Two actual indicators of the daily water supply to WUA secondary canal:

- Total daily water supply to WUA offtakes from the secondary canal;
- Daily water supply at the secondary canal head.

The daily water supply in WUA as a whole is estimated as follows:

- By summing up actual water supply to all water users' offtakes commanded by secondary canals;
- By summing up actual water supply from the main canal at the heads of WUA secondary canals.

Monitoring of the water use in WUA is carried out in two stages.

3.2. Stage 1. Analysis of the actual provision of WUA and its major canals with water by water management organizations

At this stage, the following problems are solved in the course of the monitoring:

- execution of the plan, limit (or taksim) of the water supply:
    - secondary canals;
    - to WUA as a whole.
- available water supply is ensured:
    - secondary canals;
    - to WUA as a whole.
- stability of the water supply to WUA is determined;
- uniformity of the water distribution to WUA canals is determined;
- operating efficiency of WUA canals for a certain period is determined;
- the water sources to cover the water volume required for WUA as a whole and for WUA canals separately are determined;
- adjustment to the daily volume of water distribution to water users is made.

Actual water supply to WUA by a water management organization is estimated for **daily** and **ten-day** periods**.**

3.2.1. Actual water availability in WUA canals

The daily water availability in WUA canals against the planned indicators is defined by the formula:

$$\alpha_{i\varepsilon} = \frac{Q^{f}_{i\varepsilon}}{Q^{p}_{i\varepsilon}} \qquad (3.1)$$

where

$Q^{p}_{i\phi}$ is the planned daily water flow rate at the canal head, l/s;

$Q^{f}_{i\varepsilon}$ is the actual daily water flow rate at the canal head, l/s.

The coefficient of daily water availability to a WUA canal is entered in column 7 of Table 3.2.

Table 3.2

Coefficient of daily water availability in a canal

№	Name of WUA canal	Irrigated area, ha	Ten-day period days	Planned water supply, l/s $Q^{p}_{i\phi\lambda}$	Actual water supply, l/s $Q^{f}_{i\varepsilon\lambda}$	Water availability coefficient $\alpha_{i\varepsilon\lambda}$
1	**2**	**3**	**4**	**5**	**6**	**7**
			1			
			2			
			3			
			…..			
			9			
			10			
Average ten-day value $\alpha_{id\lambda}$						

Initial data for the assessment of ten-day water availability in WUA canal are taken from Table 3.1.

The ten-day water availability in WUA canals against the planned indicators is defined by the formula:

$$\alpha_{id} = \frac{Q^{f}_{id}}{Q^{p}_{id}} \qquad (3.2)$$

where

Q^{p}_{id} is the planned average ten-day water flow rate at the canal head, l/s;

Q^{f}_{id} is the actual average ten-day water flow rate at the canal head, l/s.

The average ten-day water availability in WUA canals compared to the application for water or assigned taksim is determined in the same manner.

The coefficients of ten-day water availability in WUA canals are entered in Table 3.3.

Table 3.3

Water availability in WUA canals during the vegetation period

№	**Name of secondary canal**	**Irrigated area, ha**	**Water availability against**	**Months**						
				April			**…**	**September**		
				I	**II**	**III**	**…**	**I**	**II**	**III**
1	2	3	4	5	6	7		20	21	22
1	Canal 1		planned							
			applied for							
			taksim							
2	Canal 2		planned							
			applied for							
			taksim							

Provision of WUA canals with water by water management organizations within the range from 90 to 110 % of the planned for a certain period is considered permissible and not causing negative consequences for farms-water users[13].

Computation of progressive total water availability in WUA canals will substantially shorten the calculation time and give operational evaluation of the water availability in WUA canals from the beginning of the vegetation period as against to the planned indicator.

Coefficient of the progressive total water availability in WUA canals is defined by the formula:

$$\alpha_{v\,pt}^{f|p/WUAcanal} = \frac{W_{pt}^{f/WUAcanal}}{W_{pt}^{p/WUAcanal}} \quad (3.3)$$

where

$\alpha_{v\,pt}^{f|p/WUAcanal}$ is coefficient of the progressive total water availability in a WUA canal from the beginning of the vegetation period;

$W_{pt}^{f/WUAcanal}$ is the actual progressive total WUA canal runoff volume from the beginning of the vegetation period, ths m^3;

$W_{pt}^{p/WUAcanal}$ is the planned progressive total WUA canal runoff volume from the beginning of the vegetation period, ths m^3.

The indicators of the actual progressive total available water supply to water users are given in Table 3.4.

[13] Irrigation of Uzbekistan, Volume 4, page 45.

Table 3.4

Indicators of planned actual water supply and water availability in WUA canals for the vegetation period

№	Name of secondary canal	Irrigated area, ha	Indicators	Months						
				April			…	September		
				I	II	III	…	I	II	III
1	WUA canal-1		Planned flow rate, l/s							
			Planned runoff volume, ths m^3							
			PPTRV, ths m^3							
			Actual flow rate, l/s							
			Actual runoff volume, ths m^3							
			APTRV, ths m^3							
			Water availability, % of APTRV/PPTRV							

Note: APTRV stands for actual progressive total runoff volume
PPTRV stands for planned progressive total runoff volume

3.2.2. Determination of ten-day stability of water supply to WUA

Coefficient of ten-day stability of water supply to WUA canals (stability of water supply to WUA canals by WMO) is given by:

$$\mathbf{S}^{\kappa}_{\mathbf{id\lambda}} = 1 - \frac{\sqrt{\dfrac{\sum_{\varepsilon=1}^{n}(\alpha_{id\lambda} - \alpha_{i\lambda\varepsilon})^2}{\mathbf{n}-1}}}{\alpha_{id\lambda}} \qquad (3.4)$$

where

S^{κ}_{id} is coefficient of ten-day stability of water supply to a WUA canal;

α^{f}_{id} is average ten-day water availability in WUA canal;

$\alpha^{f}_{i\varepsilon}$ is daily water availability in WUA canal;

d is ten-day index;

ε is day index;

n is the number of days in the ten-day period concerned, n = 10 or 11 days;

λ is canal index.

The calculation is made in a tabular form. Initial daily indicators for the calculation are taken from Tables 3.1 and 3.2. The obtained water supply stability coefficients for the ten-day periods of the vegetation period for the WUA canal are entered in Table 3.5.

Table 3.5

Coefficients of stability of water supply to the WUA canal from MC during the vegetation period

№	WUA canal	Irrigated area, ha	April			May			June			July			August			September		
			I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1																				
2																				
3																				

3.3. Stage 2. Monitoring of the water distribution among WUA canal water users

3.3.1. Monitoring of WUA canal operating efficiency trends

One of the min purposes of WUA is to reduce of non-productive water losses in the irrigation network of WUA canals, i.e. deliver water volume taken from the main canal to water users with lowest possible losses. This requires having the information on the planned and actual operating efficiency of WUA canals.

The data on the planned operating efficiency of the WUA canals should be taken from technical certificates of the main canal and its offtakes.

The actual operating efficiency of a given WUA canal is defined from the ratio of the total daily water flows in this WUA canal offtakes to the water withdrawal flow at the head gauging station of this canal:

$$\eta_{WUAcanal}^{act\,op.eff.} = \frac{\Sigma \text{q offtakes from the WUA canal}}{\text{Q head GS of the WUA canal}} \tag{3.5}$$

The total daily water flows in water users' offtakes and water flow at the head gauging station of the WUA canal are taken from Table 3.1. The obtained results of the WUA canal's operating efficiency calculation are entered in Table 3.6.

Table 3.6

Trends of the WUA canal's operating efficiency during the vegetation period

№	WUA canal	Efficiency	May										Average for ten days
			1	2	3	4	5	6	7	8	9	10	
1	Canal-1	in certificate											
		actual											
2	Canal-2	in certificate											

		actual											
3	Canal-3	in certificate											
		actual											

3.3.2 Monitoring of the uniformity of the water distribution among WUA canal water users

In order to involve water users in the water distribution process and ensure openness and clearness of this process, the water distribution monitoring results are on specially prepared stands.

These stands present the schedules of daily planning of water distribution to water users' groups with indicating grown crops, daily flow values and order of water receipt by every water user (Table 3.7).

Every day a WUA hydraulic engineer records the actual water distribution results in daily water distribution schedules.

Table 3.7

Daily water distribution among WUs and WUGs cultivating Crop-1 on the lands commanded by the WUA canal (l/s)

WUs cultivating Crop-1	Irrigated area, ha	Indicators	April																	Water supply for one watering		
			6	7	8	9	10	11	12	13	14	…	…	22	23	24	25	26	planned	actual	WSA
WU-2		planned																x			
		actual																			
WUG-1		planned															x	x			
		actual																			
WU-3		planned														X	x				
		actual																			
WU-4		planned												X	X						
		actual																			
WU-5		planned																			
		actual																			
WUG-2		planned						x	X	X	X										
		actual																			
WU-6		planned	X	X	X	X	X	x													
		actual																			
WUG Crop-1		planned	X	X	X	X	X	X	X	X	X			X	X	X	X	X			
		actual																			

WUA hydraulic engineer and water users can:

- keep track of the execution of the plan, limit, taksim of the water supply to farms-water users that are WUA members;
- identify which water source (surface, irrigation wells, CDW) can provide the water volume required for water users or group of water users.

In case of a departure from the fixed water supply limit, a WUA hydraulic engineer adjusts the water distribution schedules.

3.3.3. Uniformity of the water distribution among water users through a WUA canal

Coefficient of the uniformity of the water distribution through a WUA canal is defined by the formula:

$$R_{\lambda}^{\beta} = 1 - \frac{\sqrt{\frac{\sum_{\varepsilon=1}^{n}(\alpha_{\lambda}^{\beta} - \alpha_{\varepsilon}^{\beta})^2}{n-1}}}{\alpha_{\lambda}^{\beta}} \qquad (3.6)$$

where

R_{λ}^{β} is the coefficient of the uniformity of the water distribution through the WUA canal ;

α_{λ}^{β} is water availability in the WUA canal as against the set limit;

$\alpha_{\varepsilon}^{\beta}$ is water availability in a water users' offtake from the WUA canal as against the limit set for this offtake;

β is water distribution uniformity index;

λ is canal index;

ε is water user index;

n is number of canal water users/offtakes;

The results of the calculation of the coefficient of water distribution uniformity among WUA canal water users are entered in Table 3.8.

Table 3.8

Coefficient of the uniformity of water distribution among water users and to the WUA canal

№	WU offtakes	Irrigated area, ha	Water supply indicators, ths m^3		Available water supply to WU as against the set limit	Water supply uniformity coefficient	
			limit	actual		to WUA canal	among canal sections*)
1	2	3	4	6	7	9	11
Total for WUA canal							

*) number of canal section water users is 25 % of the total number of WUA canal water users.

3.3.4 Uniformity of the water distribution among WUA canal sections

Coefficient of the uniformity of the water distribution among WUA canal sections (to assess the degree of water restriction to water users' offtakes at the end part of the WUA canal) is defined by the formula:

$$\mathbf{U}^{\tau}_{i\lambda} = \frac{\sum_{n \in I} \alpha_{i\nu}}{\sum_{n \in J} \alpha_{i\nu}} \tag{3.7}$$

where

$U^{r}_{i\lambda}$ is coefficient of the uniformity of the water distribution among WUA canal sections;

λ is WUA canal index;

τ is coefficient index allowing for the uniformity of the water distribution between the WUA canal end and head parts;

I is the number of the offtakes located at the end part of the WUA canal (25 % of the total number of WUA canal water users);

J is the number of the offtakes located at the head part of the WUA canal (25 % of the total number of WUA canal water users): ***I=J***

3.3.5 Coefficient of water use by water users

The ratio of water use by water users is assessed based on the ratio of "standard" water use volume (product of net field irrigation rate and actually irrigated area divided by the volume of the water withdrawal to a water user's offtake during the vegetation period):

$$WUR = \frac{r * F}{W} \times 100 \tag{3.8}$$

where

WUR	is water use ratio, %
r	is crop irrigation requirement, net irrigation requirement, m^3/ha
F	is actually irrigated area, ha
W	is the volume of the water withdrawal to a water user's offtake during the vegetation period, m^3

3.4. Assessment of WUA Management performance

The WUA Council must regularly carry out monitoring of the WUA Management activity.

It is necessary to compare the results gained with the targets and purposes and evaluate the importance and expedience of the works related to the improvement of WUA irrigation infrastructure.

Following the vegetation/inter-vegetation period, it is necessary to perform final evaluation of WUA performance. If the evaluation is positive, the WUA Council can take a decision of rewording the WUA Management for the organization of fair and equitable water distribution to WUAs. If the evaluation is negative, the WUA Council can impeach credibility of the WUA Management with appropriate recommendations on the replacement of managers. An intermediate and final evaluation of the WUA performance can be made based on the criteria given in Table 3.9.

Table 3.9

WUA Management performance evaluation criteria

№	Indicator	High	Satisfactory	Unsatisfactory
1	Stability of water supply to WUA from MC	0.9 – 1.0	0.8 – 0.9	below 0.8
2	Water availability			
	MC - WUA	0.9 – 1.1	0.8 – 1.2	below 0.8 over 1.2
	WUA – Water User	0.9 – 1.1	0.8 – 1.2	below 0.8 over 1.2
3	Operating efficiency of WUA canals	Equal and more than planned efficiency	0.95 of planned efficiency	below 0.95 of planned efficiency
4	Uniformity of water distribution among WUs	0.9 – 1.0	0.8 – 0.9	below 0.8

List of references used for Section 3

1. Alimdjanov, A. Organization of the monitoring of water use in WUA. Presentation, 20089.
2. Mirzaev, N.N., Ergashev, I. Water management in irrigation systems. 2009.

4. ORGANIZATION OF WATER USE IN HOMESTEAD LAND WATER USERS' GROUPS

In the present agricultural sector of the Central Asian countries along with large farms specializing in cotton and cereal crop cultivation, there are minor water users – owners of homestead lands the irrigated area of which vary from 0.04 to 0.30 ha. Homestead lands account for 25-40 % of the whole serviced area of WUA, and the number of homestead land owners comes to thousands. The main problem of WUA water use organization consists in the organization of water distribution among minor water users-homestead land owners.

With the purpose of enhancing the water use effectiveness and efficiency in water distribution management, homestead land owners unite in water users' groups (WUG).

4.1. Organizational arrangements for WUG establishment and operation

WUG organizes water distribution among a number of water users based on water distribution schedules worked out by WUA specialists and which stipulate the volumes, time, and duration of water supply to the WUG.

As a preliminary, WUA specialists together with makhalla committee representatives investigate the zones where WUGs are planned to be set up and establish:

- **WUG contours.** In practice, homestead lands have a lot of water withdrawal points and when establishing a WUG it is necessary to clearly identify the contours of the areas commanded by every point of water withdrawal from WUA irrigation network and build up a WUG according to the hydrographic principle, uniting these points of water withdrawal to homestead lands;
- Points of water withdrawal from WUA canal to WUG:
  - from one offtake of a WUA canal (the irrigated lands of homestead land owners are located around one offtake from the WUA canal stem)
  - or directly from the WUA canal stem (the irrigated lands of homestead land owners are located along one offtake from the WUA canal stem)
- **Characteristics of the irrigation network commanded by WUG offtake** (Table 4.1): length; irrigated area; discharge (conveyance) capacity; number of water users/homesteads that take water from each WUG canal/street channels; cropping pattern on WUG canal/street channels.

Table 4.1

Characteristics of the irrigation network commanded by WUG offtake

WUG	G st re	k e n	D is c	at e d ar	In particular broken down by crops, ha	n o m

					orchards	vegetables	vineyards	others	
Laylak WUG	1.								
	2.								
	3.								
	4.								
	5.								
Total for WUG									

Water distribution schedules for WUGs are coordinated with water users/makhalla committees and WUA Council.

WUG water users are represented by leaders of local self-government bodies, i.e. makhalla committees and kishlak councils, and WUA concludes contracts with them, where planned water supply indicators at the gate of each homestead land WUF are stipulated.

To implement the water distribution plan, homestead land water users elect the WUG leader.

The WUG leader **has the right to**:

- Take water in accordance with a fixed schedule along with recording, together with a WUA hydrometer specialist, the water flow and volume received in the water intake and delivery logs to be signed by the both.
- Take part in decision making in the WUA, represent and defend the interests of the WUG in the relationship with the WUA;

The WUG leader **is obliged to:**

- Control if the planned flow and volume of the water supply to the WUG are correctly stipulated in the contract between WUA and makhalla committees;
- Draw up schedules of alternate water distribution among water users;
- Carry out uniform water distribution among all the members of the Water Users' Group;
- Make efforts to settle the controversies arisen between water users of the Group when distribution water;
- Control over the technical condition of the WUG irrigation and collector & drainage networks;
- Collect money from WUG members for the services provided by WUA and CMO;

4.2. Organization of water distribution in WUG

Depending on the irrigated area of WUG homestead lands, they take a decision of continuous or discontinuous water supply:

- below 40 ha: ***discontinuous*** (***alternate) water supply*** is provided;
- 40 ha and over: ***continuous water supply*** is provided.

4.2.1. Organization of water distribution in WUGs with irrigated areas below 40 ha

A water management organization allocates water with a constant hydromodule of 0.45 l/s/h to the irrigated areas of homestead lands regardless of the crop types being grown.

Planned water requirements of WUGs are determined in a tabular form (Table 4.2).

Table 4.2

Example of the determination of flow rates to WUG offtakes

№	WUG	Commanded area, ha	Irrigation hydromodule, l/s/ha	Water withdrawal to makhalla offtakes, l/s	Flow rate at the water supply concentrated within one day, l/s
1	**2**	**3**	**4**	**5**	**6**
1	WUG-1	19.9	0.45	9	45
2	WUG-2	2.3	0.45	1	5
3	WUG-3	5	0.45	2.3	11

- WUG name is written in the second column.
- Irrigated area of WUG is entered in the third column.
- In the fourth column, irrigation hydromodule of homestead lands is 0.45 l/s/ha.
- In the fifth column, planned required daily consumption of WUG, which is defined as the product of the relevant irrigation hydromodule of the homestead lands and the WUA area: **19.9 ha x 0.45 l/s/ha = 9 l/s.**
- In the sixth column, the planned required flow of water supply to homestead land WUG during water rotation period, 5 ha, is entered; it is defined by multiplying the planned daily required consumption of the WUG by 5 days.

Table 4.3 gives an example of a schedule of water distribution among WUA homestead land WUGs that are in the regime of water rotation with other water users of the WUA.

Table 4.3

Daily schedule of water distribution to WUGs with irrigated areas below 40 ha

№	WUG	Irrigated area, ha	drawal to makhalla	supply concentra	May

					11	12	13	14	15	16	17	18	19	20
1	WUG-1	19.9	9	45		20	25				20	25		
2	WUG-2	2.3	1	5		5					5			
3	WUG-3	5	2.3	11		11					11			

Water supply to homestead lands according to water distribution schedules is of top priority for WUA. Therefore, WUA workers first provide homestead land WUGs with water and then the rest WUA water users.

4.2.2. Organization of water distribution in WUGs with irrigated areas of 40 ha and over

Based on the materials of WUG investigation on location, homestead lands are divided into several zones by major streets of the WUG[14].

Determination of the planned water requirements of WUG streets are made in a tabular form (Table 4.4).

Table 4.4

Water requirement of WUG street aryk[15] networks

№	WUG streets	Irrigated area, ha	Irrigation hydromodule, l/s/ha	Water supply to a makhalla offtake, l/s	Efficiency	Water withdrawal to a makhalla offtake, l/s	Flow rate at the water supply concentrated within one day, l/s
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	Street-1	16.7	0.45	7.5		**9.6**	48
2	Street-2	13.2	0.45	5.9		**7.6**	38
3	Street-3	11.7	0.45	5.3	**0.78**	**6.8**	34
4	Street-4	13.9	0.45	6.3		**8.0**	40
5	Street-5	**7.5**	0.45	3.4		**4.3**	22
TOTAL		**63**	0.45	28.4		**36.3**	

Table 4.4 columns 1 to 6 are filled the same as Table 4.2.

- In column 7, the planned water withdrawal flow rate of the WUG street is entered, which is determined as the ratio of the planned water supply flow rate to the street efficiency *(7.5 l/s / 0.78 = 9.6 l/s)*.

[14] In the offtakes of homestead lands with irrigated areas of over 25 ha, water losses in street aryk networks should be accounted.

[15] Street channel.

- Column 8 shows the planned required flow rate of water withdrawal to WUG streets on the assumption of releasing five-day water volume for one day, which is determined by multiplying the daily planned water withdrawal of streets by five days.

Water withdrawal to the other WUG streets is defined in the same fashion.

4.2.2.1. Water distribution among WUG streets

Water distribution among WUG streets can be performed in two manners:

- alternate;
- hourly.

Alternate water distribution among WUG streets

Daily water flow of WUG is distributed alternately among its streets. If the water requirement of a street is lower than the WUG water flow, the rest part of the flow will be distributed to another WUA street. Similarly, WUG flow is alternately distributed among WUG streets (Table 4.5).

Table 4.5

Schedule of the daily water distribution among Laylak WUG streets (Fig. 4.1)

№	Streets	Commanded area, ha	Flow rate during 5 days, l/s	April														
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Yangi chek	16.7	48				10	36				10	36				10	36
2	Laylak	13.2	38			12	26				12	26				12	26	
3	Damarik	11.7	34		10	24				10	24				10	24		
4	Tegirmonboshi-1	13.9	40	14	26				14	26				14	26			
5	Tegirmonboshi-2	7.5	22	22					22					22				
Total for WUG		**63**	**182**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**

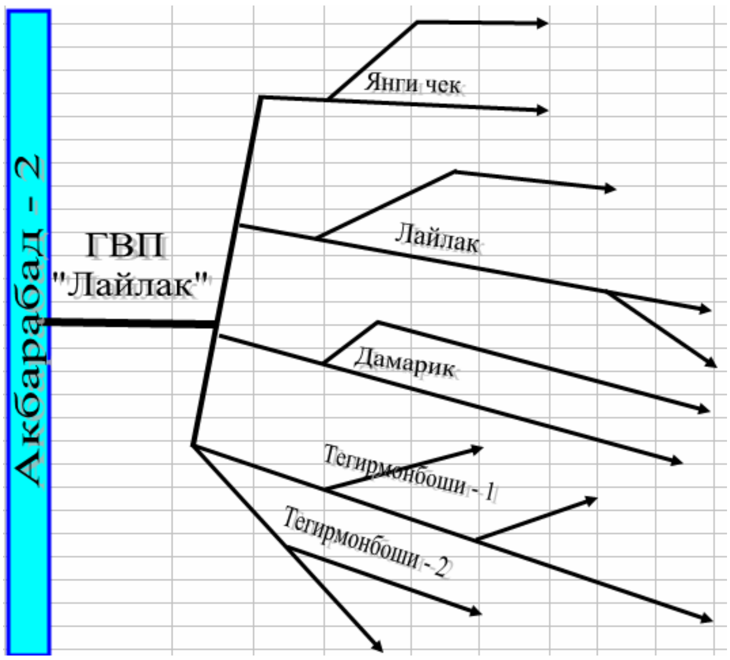


Figure 4.1 Layout of the Laylak WUG street irrigation network

Hourly water distribution among WUG streets

The time for hourly water supply to WUG streets is defined by the formula:

$$T_{street} = \frac{Q_{street}^{water\ withdrawal}}{Q_{Laylak\ WUG}^{water\ withdrawal}} * T_{5\ days}$$

where

T_{street} is the time of the WUG water supply to Street-1, hours;

$Q_{street}^{water\ withdrawal}$ is the required volume of the water withdrawal to Street-1 for 5 days, m^3;

$Q_{Laylak\ WUG}^{water\ withdrawal}$ is the required volume of the WUG water withdrawal for 5 days, m^3;

$T_{5\ days}$ is the total water supply time according to the schedule; $T_{5\ days}$ = 5 days * 24 hours = 120 hours.

In the same manner, duration of the water supply to the rest WUG streets is determined in terms of hour. The calculation results are entered in Table 4.6.

Table 4.6

Schedule of the hourly water distribution among Laylak WUG streets

№	Streets	Commanded area, ha	Flow rate during 5 days, l/s	hrs	April																			
					1	**2**	**2**	**3**	**3**	**4**	**4**	**5**	**5**	**6**	**6**	**7**	**7**	**8**	**8**	**9**	**9**	**10**	**10**	**11**
					7h	**15h**	**15h**	**16h**	**16h**	**14h**	**14h**	**16h**	**16h**	**7h**	**7h**	**15h**	**15h**	**16h**	**16h**	**14h**	**14h**	**16h**	**16h**	**7h**
1	Yangi chek	16.7	48	32	36	36									36	36								
2	Laylak	13.2	38	25			36	36									36	36						
3	Damarik	11.7	34	22					36	36									36	36				
4	Tegirmonboshi-1	13.9	40	26							36	36									36	36		
5	Tegirmonboshi-2	7.5	22	14									36	36									36	36
Total for WUG		**63**	**182**		**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	#

WUG street flow switching must be carried out in the daytime.

The daily and hourly schedules of water distribution among WUG streets are coordinated in the makhalla committee and WUA Management, and WUG Leader informs aksakals (elders) among WUG homestead land owners about the order of water distribution through aryks.

5. PLANNING OF FINANCIAL AND ECONOMIC ACTIVITIES AND SETTING THE RATES FOR THE SERVICES PROVIDED BY WATER USERS' ASSOCIATIONS

The wellbeing of farms to a large extent depends on sustainable functioning of WUA influences. Timely supplied and equitably distributed water, efficient irrigation network and the structures in it, good reclamation state of lands provide conditions for making good returns from irrigated lands. Most of the main components required to provide conditions for gaining worthy profit from crop irrigation depend on the quality of the services provided by WUA personnel.

Thus, the basis for successive operations and involvement of skilled specialists in this activity must be included into the planned budget of WUA. The WUA financial plan is nothing other than the basis of the agreement based on which water users employ WUA staff. Therefore, WUA budget formation have to proceed from not only farmers' readiness to pay for the services but also from necessary expenditures in order that the WUA may fulfill the water users' requirements of stable water supply to water users' offtakes and ensuring adequate condition of the irrigation & drainage network.

The WUA financial plan should be formed based on accurate planning of all types of works which water users wish to get in the form of WUA services: water use planning; equitable water distribution; maintenance of proper condition of irrigation & drainage networks and irrigated lands. Such planning should be made for short-term (1 year), mid-term (2-3 years), and long-term (5-10 years) periods. With such an approach, WUA can balance required expenditures for the maintenance of irrigation & drainage networks, ensuring of efficient water distribution and setting rates appropriate for these services.

5.1. Forming of the WUA budget estimate

The WUA budget for a planned period is made proceeding from the principal tasks of the activity, namely:

- provision of WUA members with irrigation water;
- maintenance and operation of the irrigation and collector & drainage network belonging to the WUA, including their improvement, restoration, and development;
- within the WUA, ensuring of ecological security, prevention of soil erosion on irrigated lands, land salinization and swamping, as well as protection of the irrigation and drainage network's facilities from damage;
- rendering any type of water disposal and effective use related services to water users.

5.1.1. Information necessary to form the WUA budget

When forming a budget, it is necessary to have the available the following information:

1. About WUA members that are within the Water Users' Association[16] (name of the water users, number of irrigated lands, cropping pattern, and plantings in farms);

2. About basic production assets of the WUA and their book values with appropriate breaking those down into irrigation and reclamation network, buildings, equipment, machinery, etc.;

3. About the operating personnel of the WUA (permanent and temporary) and their salaries;

4. About the interest charge on personnel's payroll associated with social insurance and pension fund in accordance with the existing legislation;

5. Target figure of the fund of material assistance to WUA personnel;

6. Target figure of the fund of WUA personnel incentive fund;

7. Expenses related to RROs on WUA facilities (facilities, scope of work, cost estimate with appropriate justification);

8. Transportation costs in the WUA;

9. Other expenses (electric power, rent, use of office equipment, etc.);

10. Rate of deprecation costs of basic assets existing in each country;

11. Crop and planting profitability in each farm-WUA member for previous years (it is desirable for the last three years);

12. Per cent of the reserve fund of all types of current costs (the reserve fund must be of not less than 15% of all types of current costs).

If WUA performs the functions of pumping water supply to farms, it is necessary to have relevant information about the parameters of the pumping station or unit, farms' areas (it is very important to know what type exactly) where water is supplied to, pumping unit operation mode, and costs of the pumping water supply works.

When forming WUA budget, it is required to take into consideration that certain amount of works can be executed by water users-WUA members themselves, which will reduce the budget being built and made up by the water users.

The WUA expense allocated over the area serviced by the WUA will give the cost per 1 ha of the serviced area.

As is known, WUA is a non-profit organization, and cannot have any profit. Therefore, all unspent WUA budget will remain in the WUA reserve, in other words it can be used in future in accordance with the Statute of WUA Reserve Fund which sets forth the reserve fund accumulation and use procedure (Appendix).

In case of the formation of considerable amount of WUA reserve fund or emergence of a new financing source (from foreign investors, government assistance, bank credits, etc.) in the WUA, questions will arise with regard to effective use of these funds, i.e. their channeling and expected effect from that. There may be many options to solve this problem. For example, if the option of using reserve or other funds for the construction and operation of fish hatchery, it is necessary to weigh lump-sum costs with current costs associated with this complex and with the effect that can be gained for a series of years owing to the profit made from a project implementation.

[16] There are also water users that are within the WUA but are non-members of the WUA.

There may be other channeling of funds, for instance the measures for land reclamation, development of “free” lands within the WUA contour, and so forth.

Any option of investment should be given a comprehensive analysis with their more effective use evaluation.

5.1.2. Cost items in the WUA budget

Estimate of WUA expenditures includes the following:

- WUA permanent and temporary personnel salary;
- planned incentive fund;
- planned fund of material assistance to the WUA personnel;
- charge on payroll (social insurance, pension fund);
- depreciation of basic assets;
- operating costs, total

in particular for:

- repair-and-renewal operations;
- cost of transportation;
- electric power;
- fuels and lubricants;
- administration and management costs (without salaries), total

including:

- stationery;
- miscellaneous costs (renting, use of office equipment, utilities expenses);
- purchase of furniture;
- reserve fund.

Each item of the Estimate of Costs must be properly justified.

For example, for the Item of WUA Permanent Personnel Salary must be substantiated in the WUA Management manning table, and the temporary personnel salary is corroborated by the information of the number of these employees, occupation, time of employment, rate of wages, etc.

Planned *incentive fund* is provided (with the consent of WUA members and WUA Council) to the amount of up to 50 % of the WUA permanent personnel salary budget and provides for the criteria according to which this its allocation to WUA employees is calculated.

The *material assistance fund* is planned in the same manner. Its size may be equal to one or more months of the salary budget (depending on a relevant decision of the general meeting or WUA Council).

The amount of basic assets depreciation is calculated in line with the Rates of Depreciation for Full Complete Restoration of Basic Assets existing in the country. Normally, for irrigation and reclamation networks they use the average rate of depreciation of the original value at the rate of about 5%.

When calculating RRO costs, one should allow for, first, top-priority RROs and, second, financial capabilities of the WUA.

The list of planned WUA RRO type and scope should include: name of canals, drains, collectors, type and scope of works, their costs and references to the justification of the calculations.

Proper justification must also be provided when calculating WUA administration and management costs.

If the WUA intends purchasing furniture, the cost justification should take into account the type of the furniture, number, value, and so on.

5.1.3. Reserve fund in the WUA budget

The reserve fund in the estimate of costs must account at least for 15 % of all types of expenditures.

Reserve fund is a financing source for:

- elimination of canal and structure accidents;
- carrying out immediate repair works on WUA facilities;
- purchase of equipment and machinery for WUA;
- carrying out of costly measures (rehabilitation of on-farm IDSs, land reclamation, restoration of DW systems, overhaul repair of irrigation and collector & drainage networks, construction of fish hatcheries, etc.).

The reserve fund is built and used in compliance with the *Statue of WUA Reserve Fund* (Appendix 5.1).

5.1.4. Annual WUA estimate of costs by the example of the WUA "Akbarabad" (Kuva district of the Fergana province, Republic of Uzbekistan)

To estimate WUA expenditures for a planned year, the expenditures borne by the WUA every year as well as planned measures associated with RROs, building of gauging stations on WUA canals and collectors, land reclamation, procurement of spare parts, fuels and lubricants, etc. have to be assumed as a basis.

The overal expenditures of a WUA exemplified by way of example of the WUA "Akbarabad" are shown in the Estimate of Costs for 2009 (Table 5.1).

Table 5.1

WUA "Akbarabad" Estimate of Costs for 2009

№	Type of expenditure	Amount, ths UZS
1	**Total expenditures for salary budget**	**48 380**
	in particular:	
	▪ payroll	31 440
	▪ bonuses (50 % of the permanent personnel salary)	14 520
	▪ material assistance	2 420
2	**Social insurance 24 % (31,440 + 14,520) * 0.24**	**11 030**
3	**Operating costs** (without salaries)	**7 852**
	in particular:	
	▪ fuels and lubricants costs	1 190
	▪ WUA IDS maintenance costs	6 662
4	**Administration and management costs**	**1 902**
	in particular:	
	▪ stationery	240
	▪ purchase of furniture	622
	▪ miscellaneous costs (renting, use of office equipment, telephone communication)	1 040
5	**Total amount of depreciation**	**2 907**
	Reserve fund (15 % of all expenditures) (68709 ths UZS x 0.15)	**10 306**
	TOTAL	**82 377**

Amount of depreciation is calculated as follows:

58 149 ths UZS x 0.05% = 2 907 ths UZS, where

58 149 ths UZS is 0.05 is the book value of basic assets, and 0.05 is an average depreciation rate (5 % of the book value).

The WUA "Akbarabad" personnel salary budget is based on the manning table (Table 5.2) with the amount of 31 440 ths UZS.

Table 5.2

WUA "Akbarabad" Management manning table for 2009 (draft)

№	Position	No of positions	Monthly salary of the total no of positions (UZS)	Annual salary budget (UZS)
I. WUA Office And Management Personnel				
1	Director	1	200 600	2 400 000
2	Chief engineer	1	140 000	2 280 000
3	Chief hydrometer specialist	1	170 000	2 040 000
4	Accountant	1	190 000	2 280 000
5	Dispatcher	1	170 000	2 040 000
6	Custodian	2	140 000	1 680 000
7	Charwoman	1	70 000	840 000
	Total for I	**8**	**1 130 000**	**13 560 000**
II. Technical personnel				
Site 1 (RP-1)				
1	Manager of the Site	1	130 000	1 560 000
2	Observer	4	400 000	4 800 000
3	Seasonal observer	2	200 000	1 200 000
	Total		**730 000**	**7 560 000**
Site 2 (Akbarabad-1, Akbarabad-2)				
1	Manager of the Site	1	130 000	1 560 000
2	Observer	3	300 000	3 600 000
3	Seasonal observer	2	200 000	1 200 000
	Total		**630 000**	**6 360 000**
Site 3 (RP-2)				
1	Manager of the Site	1	130 000	1 560 000
2	Observer	2	200 000	2 400 000
	Total		**330 000**	**3 960 000**
	Total for II	**16**	**1 690 000**	**17 880 000**
	Grand Total	**24**	**2 820 000**	**31 440 000**

This salary budget provides for 4 seasonal observer positions in all, each for 6 months of work with total salary budget of 2400 ths UZS.

In the Estimate, **bonus fund** is provided to the amount of 50 % of all salaries of the personnel, save seasonal observers. In the WUA in question, the total amount of annual salary comes to 31 440 ths UZS, of which the seasonal personnel salary is 2400 ths UZS (Table 5.2). Hence, the planned bonus fund will come to:

$$(31440 ths UZS - 2400 ths UZS) * 0.5 month = 14520 ths UZS$$

Material assistance is provided for to the amount equal to the one-month amount of the total salary budget, except the salary of seasonal observers:

$$\left(\frac{31440 ths UZS - 2400 ths UZS}{12 months}\right) = 2420 ths UZS$$

Social insurance is provided for in accordance with the existing laws as 24 % of the salary budget (salary and bonus)

$$(31440+14520)*0.24=11030 ths\,UZS$$

Operating costs are taken into account for fuels and lubricants and expenditures for repair-and-renewal operations.

F&L costs are provided for to the amount of 1190 ths UZS. Here, it is meant that the WUA, using the machinery of large farms, will spend F&L at its own expense.

In 2009, the WUA was planning to carry out RROs to the total amount of 6662 ths UZS for the installation of 40 control gates at head offtakes of WUA canal water users and additionally 20 gauging stations for newly established farms.

The list and cost of RROs in the WUA are given in Table 5.3.

Table 5.3

Recommended list of RRO types in the WUA "Akbarabad" for 2009

№	Name of canals and types of works	Unit	Scope of works	Unit cost, UZS	Total cost, ths UZS
1	Installation of control gates at the head offtakes of water users on canals:				
	Akbarabad-1	unit	10	92 894	928.9
	Akbarabad-2	unit	10	92 894	928.9
	RP-1	unit	10	92 894	928.9
	RP-2	unit	10	92 894	928.9
	Total	unit	40	92 894	3 715.6
2	Additional installation of gauging stations for newly established farms	unit	20	147 329	2 946.6
	TOTAL FOR WUA				**6 662.2**

Execution of planned RROs will result in the improvement of quality of accounting and distribution of the water resources used in WUA, decrease in the number of water use related controversies and conflicts between the WUA and water users.

Administration and management costs are provided for to the amount of 1902 ths UZS, of which expenditures for stationery, renting, electric power, and telephone communication amount to 1380 ths UZS.

Tool-based survey allowed determining the scope of cleaning works on 3 and 4-order canals connected with secondary canals (Table 5.4).

Table 5.4

Scope of cleaning works carried out manually on 3 and 4-order canals connected with secondary canals in the WUA "Akbarabad" in 2009

№	Name of canal	Volume of manual cleaning, m^3	Cleaning cost, ths UZS
1	Akbarabad-1	1 388	508.38
2	Akbarabad-2	6 554	2 377.1
3	RP-1	3 322	1 204.8

4	RP-2	6 152	2 231.2
	Total for WUA	**16 896**	**6 321.48**

It is obvious from Table 4 that the volume of cleaning per 1 ha comes to:

$16896\,m^3 : 3052\,ha = 5.5\,m^3 / ha$

or per-unit cost of cleaning works per 1 ha comes to:

$26991\ ths\ UZS : 3052\ ha = 2071\ UZS / ha$.

As follows from given showings, each water user performs cleaning works in accordance with the indicators of its irrigated lands.

Thus, total contribution of water users in the WUA work per 1 ha in 2009 comes to:

$26991\ UZS / ha + 2071\ UZS / ha = 29062\ UZS / ha$.

Budgeted costs by the WUA "Akbarabad" in 2009:

- Budgeted annual costs: 82 377 ths UZS.
- Scope of works executed by water users themselves (this includes mainly cleaning works carried out manually): 63 21 ths UZS.

6321 ths UZS : 3052 ha = 2071 UZS/ha

- Total planned annual costs of the WUA: **88 698 ths UZS.**

5.2. Procedure of charging WUA services

In the IWRM-FV Project zone, two principles of fixing rates for WUA services are followed.

According to the first principle, a uniform WUA service rate is imposed for all water users proceeding from the total WUA estimate of costs. This type of rate is set chiefly taking into account the financial capabilities of the water users growing so-called strategic crops (cotton and wheat) that have comparatively low profitability per unit irrigated area. Therefore, when fixing this rate, as a rule low rate is set and accordingly required activities are provided for in the work schedule.

The second principle of rating takes into account the profitability of each crop and planting in farms per 1 ha, as well as provides that 5-7 % of the profit gained will form an average weighted rate for WUA services.

The second principle of rating allows considering individual abilities of each water user and, accordingly, carrying out required large-scale measures aimed at the making and development of WUA.

5.2.1 WUA service rate determined according to WUA estimate of costs

WUA service rate for a specific year is determined by the following formula:

$$T = \frac{\sum C}{\omega}, \text{ national currency/ha} \qquad (5.1)$$

where

T is WUA services rate in the national currency per 1 ha;

$\sum C$ represents total costs according to annual WUA estimate, in the national currency;

ω is the WUA area serviced, ha.

Pursuant to budgeted annual costs of 82,377 ths UZS (Subsection 5.1.4), per-ha rate for rendering services to WUA members comes to 26,991 UZS/ha (82 377 ths UZS : 3052 ha). This rate is submitted to the general meeting for approval.

With WUA's budgeted total annual costs of **88,698 ths UZS** (Subsection 5.1.4), the contribution of WUA members composed of two parts comes to:

• rate set per 1 ha	- 2 6991 UZS/ha
• cleaning work carried out by a water user	- 2 071 UZS/ha
Total (total contribution of the water user)	**- 29 062 UZS/ha**

WUA service rates can be differentiated (if approved by the WUA general meeting) subject to the following factors:

- If WUA provides the irrigated lands of a WUA member with not river water, but with brackish collector & drainage water. In this case, the WUA service rate can be reduced by 50%;
- If WUA supplies irrigation water to irrigated lands located on high level and hence requiring pumping water supply. In this case, the pumping water supply costs are added to average service rates.

In the WUA "Akbarabad", the WUA service rate under the conditions of land irrigation with not river but collector & drainage water is set at the rate of 50 %, i.e. 13,496 UZS/ha.

5.2.2. WUA service rates fixed according to the profitability of the crops and plantings grown in the farms serviced by WUA

This type of rate is based on the WUA service rating of about 5-7 % of the profit gained in agricultural production; this rate is used in international practice.

Table 5.5 gives profit indices for particular crops and plantings obtained in farms-indicators of the IWRM-FV Project in the Fergana Valley in 2008.

The profitability of the key crop, cotton, is taken as the **basic margin of profit** in the Fergana Valley indicator farms, which allowed determining to what extent crop and planting profitability per 1 ha of the area in service is more or less than that of the key crop.

Having the information of cropping and plantation pattern in WUA and their profitability per 1 ha as well as taking into consideration that WUA service rate must be about 5 % of each crop and planting profit, one can define the average weighted rate per 1 ha of the farm's serviced area by the following formula:

$$T_{a,aver} = \frac{(\omega_1 \bullet P_1 + \omega_2 \bullet P_2 + \omega_3 \bullet P_3 + \ldots + \omega_n \bullet P_n) \bullet 0,05}{\omega_1 + \omega_2 + \omega_3 + \ldots + \omega_n} \quad (5.2),$$

where

$\omega_1, \omega_2, \omega_3 \ldots \omega_n$ are areas under crops and plantings, ha;

$P_1, P_2 \ldots P_n$ represent the crop and planting profitability per hectare in the national currency;

0.05 is the margin of crop and planting profit set at 5 % of the crop and planting profit per 1 ha.

Table 5.5

Specific crop and planting profit indices obtained in farms-indicators in the Fergana Valley provinces in 2008, $/ha*

Fergana Valley province	Specific profit per 1 ha				
	Cotton	Cereals	Orchards	Vineyards	Vegetables
Republic of Uzbekistan					
Andijan province	360	320	750	1475	470
margin of profit broken down by crops	1	0.9	2	4	1.3
Fergana province	317	305	690	1340	490
margin of profit broken down by crops	1	0.95	2.15	4.2	1.5
Kyrgyz Republic					
Osh province	450	392	780	1275	510
margin of profit broken down by crops	1	0.87	1.7	2.8	1.15
Republic of Tajikistan					
Sogd province	407	336	619	1341	530
margin of profit broken down by crops	1	0.82	1.52	3.29	1.3

* The table is drawn up based on the data from the Report on the IWRM-FV Project Position C1.2 “Development of the water user’s ability-to-pay principle at the farm level” (executive in charge is Nerozin, S.A.)

For example, the average weighted rate for the WUA “Akbarabad” services can be defined from the figures given in Table 5.6.

Table 5.6

Technical and economic performance of all farms and homestead lands in the WUA “Akbarabad” in 2008

№	Name of crops and plantings	Irrigated area, ha	Specific per-ha profit of farms, USD*
1	Cotton	1092	317
2	Cereals	766	305
3	Orchards	360	690
4	Vineyards	385	1340
5	Vegetables	449	490
	Total	**3052**	

* According to S.A. Nerozin’s Report on the IWRM-FV Project Position C1.2 “Development of the water user’s ability-to-pay principle at the farm level”.

Substituting table data into the formula (2), we will get the value of the average weighted rate for the WUA as a whole ($/ha):

$$T_{avw} = \frac{(1092.317 + 766.305 + 360 \cdot 690 + 385 \cdot 1340 + 449 \cdot 490) \cdot 0.05}{1092 + 766 + 360 + 385 + 449} = \frac{1564104 \cdot 0.05}{3052} = 25.62$$

25.62 · 1500 UZS[17] = 38 430 UZS/ha

The obtained figure of 25.62 $/ha is the average weighted rate in the WUA as a whole.

In some farms, one can obtain an individual average weighted rate having its cropping and plantation patterns showings but accepting specific profit average for the WUA as a constant.

In Table 5.7, a few farms with different cropping and plantation patterns in the WUA "Akbarabad" in 2008 are shown.

Table 5.7

Performance of some farms of the WUA "Akbarabad" for 2008.

№	Farm	Total farm area, ha	in particular			Profit per 1 ha of:		
			cotton	cereals	orchards	cotton	cereals	orchards
1	Zarnigol-Ikbol	11.8	5.8	6	–	317	305	–
2	Uzakov	35.6	21.6	14	–	317	305	–
3	Azimdjon	15.6	5.6	7	3	317	305	690

The average weighted rate for the farm "Zarnigol-Ikbol" comes to:

$$T_1 = \frac{(5.8 \cdot 317 + 6 \cdot 305) \cdot 0.05}{11.8} = 15.5 \ \$/\text{ha} \ \text{ or}$$

15.5 $/ha · 1500 UZS = 23 250 UZS/ha

The average weighted rate for the farm "Uzakov" comes to:

$$T_2 = \frac{(21.6 \cdot 317 + 14 \cdot 305) \cdot 0.05}{35.6} = 15.6 \ \$/\text{ha} \ \text{ or}$$

15.6 $/ha · 1500 UZS= 23 400 UZS/ha

The average weighted rate for the farm "Azimdjon" comes to:

$$T_3 = \frac{(15.6 \cdot 317 + 7 \cdot 305 + 3 \cdot 690) \cdot 0.05}{15.6} = 19.16 \ \$/\text{ha} \ \text{ or}$$

19.16 $/ha · 1500 UZS = 28 740 UZS/ha

As follows from the considered calculations for some farms of the WUA "Akbarabad", the rate values in the examples considered vary from 23,250 UZS/ha to 28,740 UZS/ha, although this is not the limit for these values. All depends on cropping pattern and accordingly on crop profitability.

To ensure objectivity in rating WUA services, it is necessary to allow for the cropping and plantation patterns in each farm and fix an individual rates for those proceeding from the proposed method.

[17] USD1 = UZS1500

Rate calculation for each farm in the WUA should be carried out taking into account objective information on the cropping and plantation patterns on the serviced lands.

Thus, the second principle of rating seems to be the most acceptable, because it:

- Considers the financial capabilities of each water user depending on the crops and plantings grown by it;
- Allows carry out full-scale measures aimed at water supply to water users, improvement of land reclamation condition, perform the works related to water saving, environmental safety, etc.;
- The calculations by way of the example of the WUA “Akbarabad” show than if the crop and planting profitability in WUA farms is not taken into account, one can set maximum rate of 26.9 ths UZS/ha, while when taking into account the profitability of cultivated crop an average weighted rate can be 38.4 ths UZS/ha.
- Fixing such a rate will allow enhancing the financial capabilities and accordingly carrying out required activities.

The both principles of rating WUA services are interrelated.

The first principle enables setting a rate to which the limit of needed financing to ensure sustainable WUA operation is in line with, namely the limit below which the quality of the services provided degrades.

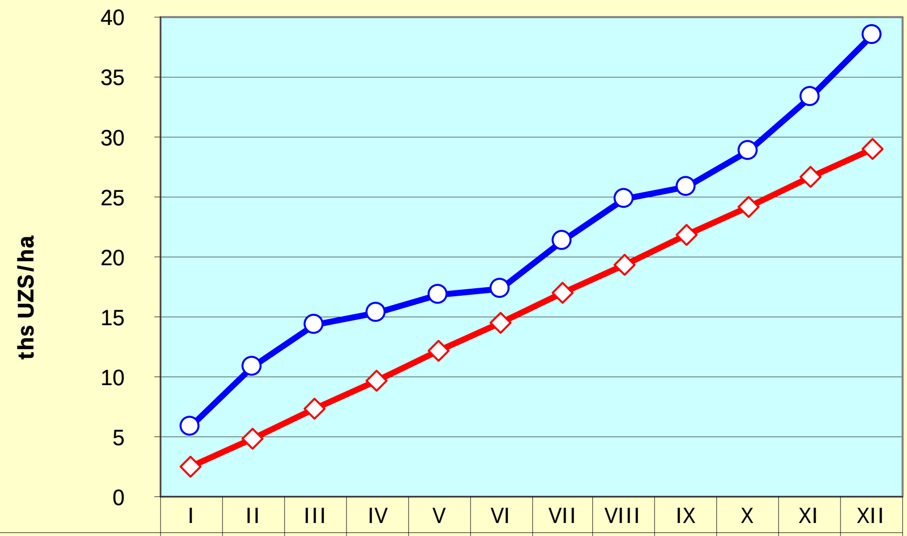
The second principle is based on the assessment of the ability to pay proceeding from the farms’ incomes and setting rates that correspond to the profitability of agricultural production.

Balancing of these two approaches is a tool that allows WUA specialists making decisions for achieving sustainable WUA operation.

As a rule, the rates set allowing for the second principle should be somewhat higher so that WUA service costs can be covered even if the WUA service fees collection rate is less than 100 %.

The difference obtained in the payment according to the second principle (with this payment exceeding actual expenditures of the WUA in a year under review) can be accumulated in the WUA reserve fund.

The interrelation between both approaches is illustrated in Fig. 5.1 drawn based on the considered examples of application of both principles.



	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Limit (progressive total) of required financing for sustainable WUA operation (ths UZS/ha)	2,4	4,8	7,3	9,7	12,1	14,5	17,0	19,4	21,8	24,2	26,6	29,1
Assessment of the ability to pay (progressive total) proceeding from farms' incomes (ths UZS/ha)	5,8	10,8	14,3	15,3	16,8	17,3	21,3	24,8	25,8	28,8	33,3	38,4

Figure 5.1. Comparison (progressive total) of the required financing of WUA services with the ability to pay allowing for the agricultural production profitability
(by the example of the WUA "Akbarabad")

List of references used for Section 5

1. Pinkhasov, M.A., Anarbekov, O. Concise manual on the development of business plan for Water Users' Associations (WUA). 2006.
2. Pinkhasov, M.A. Guidelines for rating the WUA services provided to water users. 2009.
3. Pinkhasov, M.A. Guidelines for rating the services of water supply to water users. 2009.

Appendix 5.1

APPROVED
at General Meeting of the WUA «____________»
«_____» ______________ 20__

STATUTE

of the Reserve Fund of WUA «________________»

1. The WUA reserve fund is formed from:

– contributions of WUA members;
– contributions of WUA cofounders;
– assignments from self-supporting structures established under WUA;
– other sources.

2. Formation of the reserve fund in WUA from WUA members' contributions, planned size for the budget year and its use must be coordinated with the representatives of WUA members at an Annual General Meeting of WUA.
The reserve fund size depends on the economic resources of fund-creation sources and is unlimited.

3. The size of the annual reserve fund should be provided for in the WUA budget on an annual basis.
Participation of WUA members and cofounders in the formation of the reserve fund depends proportionally on their shares in the WUA budget.

4. The reserve fund must be accumulated on an individual account in a bank for several years and used in compliance with Item 5 of this Statute.

5. Use of the reserve fund.
The reserve fund can serve as a financing source for the following measures:
– elimination of accidents on WUA canals and facilities;
– carrying out of immediate repair works at WUA facilities;
– purchase of equipment and machinery for the WUA;
– execution of costly measures (rehabilitation of on-farm IDN, land reclamation, restoration of failed VD, overhaul repair of irrigation and collector & drainage networks, construction of fish hatcheries, etc.).
The WUA reserve fund is administered by the WUA Management in accordance with a decision of the General Meeting regarding the target and amount to be used.
Use of the reserve fund for other purposes (bonuses, salary, operation of on-farm IDN) is prohibited.

6. The reserve fund may not be distributed among WUA members but in case of WUA liquidation.

6. METHODS OF WATER SAVING AND IRRIGATION ON WUA FIELDS

The concept of water saving in irrigated agriculture is much broader that mere reduction of the consumption of water withdrawn from sources. The water saving system involves a wide range of issues: optimization of reclamation regimes amid drainage and irrigation technology, agrotechnical ways that improve soil fertility, improvement of irrigation technology, etc.

The purpose of water saving on irrigated lands is such farm production that optimum level of crop yield and accordingly profit from agricultural production are ensured with rational consumption of irrigation water.

In this context, water saving ways guided by real economic situation and farmers' abilities to improve the irrigation characteristics by available means and without substantial investment to the irrigation network, viz. mainly owing to raising the level of water management and irrigation quality, balancing at that:

- The irrigation network capacity to convey required flow within required timeframe.
- Crop irrigation requirement with minimizing crop losses because of under-irrigation or over-irrigation.
- Irrigation technology elements that minimize losses to surface disposal and infiltration outside the root-inhabited zone with relatively high uniformity of moistening of the crop root inhabited zone.

6.1. Ways and measures that facilitate water saving

The main ways facilitating water saving with requiring no considerable investment and which are distributed to some extent in irrigated farming zones of the Central Asian region are given in Table 6.1.

Table 6.1

Ways and measures facilitating water saving

A. Technical	• putting antifiltration coating on irrigation canal network • leveling the surface of irrigated plots • equipping water delivery points with water accounting facilities • repair and re-equipping of gauging stations • repair-and-renewal operations in irrigation and collector & drainage networks • partial reconstruction of the irrigation and collector & drainage networks
B. Technological	• improvement of water accounting quality (calibration and certification of gauging stations, raising of water measurement frequency) • reuse of intra-contour surface disposal of irrigation water • improvement of tillage quality (raising of the cultivation number, deep plowing) • improvement of soil fertility (differentiated application of mineral and organic fertilizers, crop rotation) • use of mulch coating on furrow ridges • every-other furrow irrigation (alternation of irrigated and “dry” spaces between rows) • multitier irrigation by short furrows • discrete adjustment of water supply to furrows • discontinuous flow irrigation • counter-furrow irrigation • use of collector & drainage water
C. Organizational	• charged water use • change of cropping pattern (growing less hygrophilous as well as higher-value types of crops) • financial stimulation of mirabs and irrigators for water application quality • organization of contests among mirabs and irrigators • improvement of the water use discipline • organization of water rotation in the irrigation network • organization of water rotation on the field (concentrated water application)

	• organization of water application at night • training (capacity building) • workshops for exchange of experience • methodological assistance to farmers (consultations on practical and legal issues related to irrigated farming)

6.2. Basic water saving techniques

6.2.1. Technology of irrigation by alternating irrigated and dry spaces between rows

With irrigation technology of alternating irrigated and dry spaces between rows *(mainly during blossoming and fruitification periods)* (Fig. 6.1) depending on the spacing width of 60 cm or 90 cm, furrows are ploughed at every 120 cm or 180 cm, respectively.

The non-irrigated spacing is maintained by cultivation in loose state thus providing favorable air and gas exchange in the root habitable zone of crops. Introduction of fertilizers into the non-irrigated spacing prevents their washout beyond the root-inhabited zone thus ensuring the enhancement of their use efficiency.

Water saving effect becomes evident by the fact that unlike water application to every furrow, under which evaporation takes place virtually from the whole moistened field surface, with this technology beds with width of 1.3-1.4 m (at spacing of 0.9 m) and 0.9 m (at spacing of 0.6 m) get moistened (Figs. 6.2a and 6.2b) owing to lateral capillary moisture distribution to the sides of irrigated furrows.

0.4-0.5 m wide beds (at spacing of 0.9 m) and about 0.3 m (at spacing of 0.6 m) remain dry and loose, and the water losses due to nonproductive physical evaporation form these become almost zero. Because of reduced physical evaporation from soil surface by 20-25 %, total water consumption decreases. In consideration of this, irrigation water can be saved by 20-25 % as against the method of water supply to every furrow.

Figure 6.1. Irrigation by alternating irrigated and dry spaces between rows.

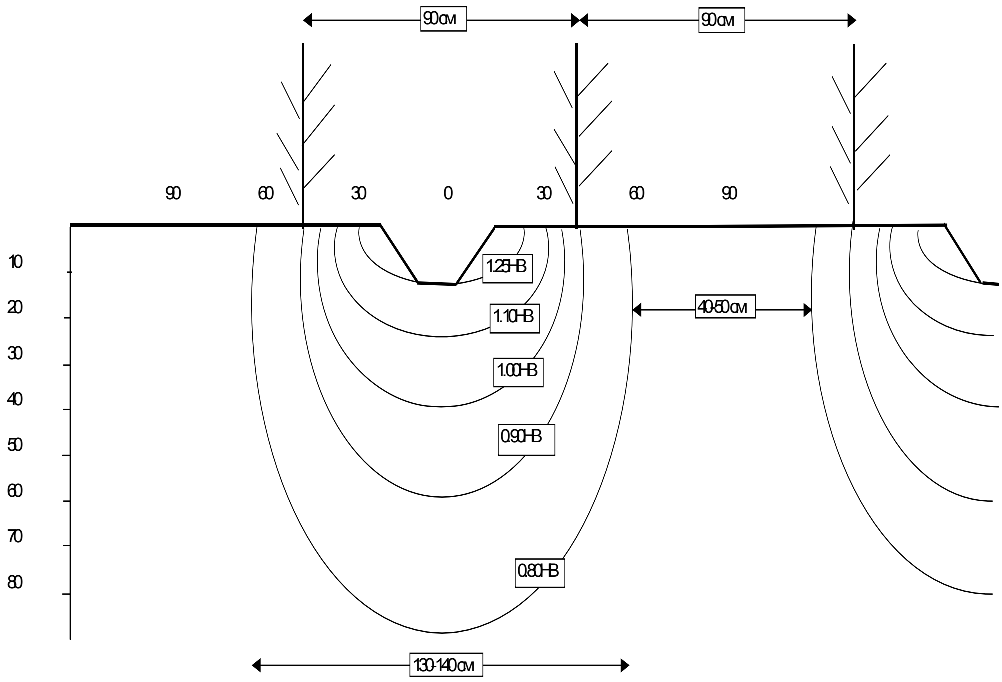


Figure 6.2a. Moisture distribution pattern with irrigation of every other space between rows.

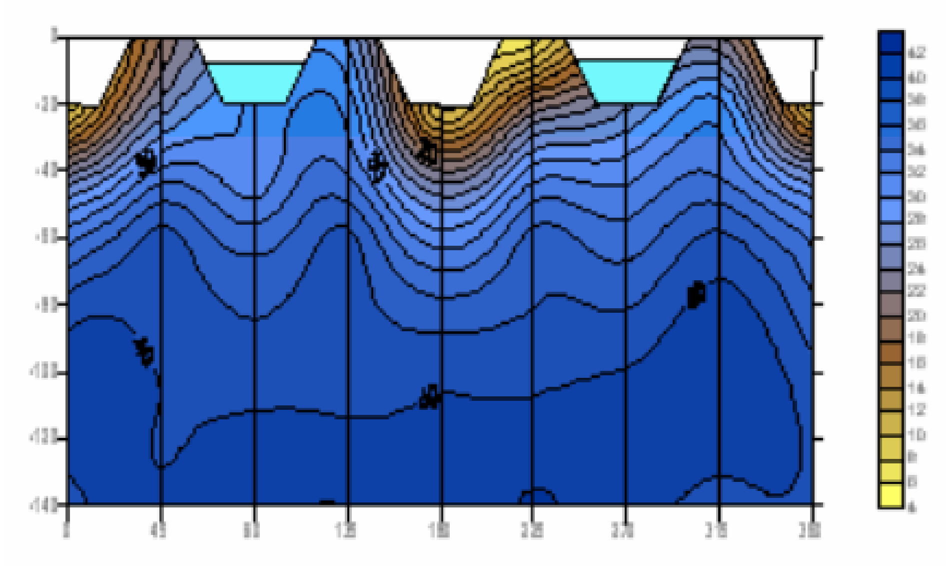


Figure 6.2b. Moisture distribution pattern with irrigation of every other space between rows.

The water supply volume required to meet the net water requirement with this technology has to be increased in comparison with the conventional technology by 1.5-1.6 times (Table 6.2). This can be achieved, provided that the field is well leveled and its furrows have a normal depth, by strengthening irrigating stream up to permissible limit in terms of erosion safety or extending the time of irrigation.

6.2.2. Multitier furrow irrigation with intra-contour use of formed outflow

Short-furrow irrigation can be improved through using multitier water application Fig. 6.3).

With multitier irrigation, an irrigated field is divided into 3-4 tiers the distance between which is subject to the furrow length. As a rule, the furrows are short, i.e. 60-100 m. There are a few layout of irrigation by tiers. The most popular layout is that when so-called *shokh-aryks*[18] are routed along the centerline of irrigated plots. Irrigation by 60-100 m short furrows is started from the first tier; at the next tier, the furrow heads are prepared. When irrigation streams reach the distribution ditch of the second tier, the formed outflow runs to the distribution ditch and adds to the flow taken from the *shokh-aryk*. Irrigation on next tiers is performed in the same succession. The tier-based irrigation allows achieving uniform moistening of irrigated plot of land and considerably reducing surface disposal, since disposal outside the field is made only from the furrows of the last tier.

Table 6.2

Basic indices of the irrigation by alternating irrigated and dry spaces between rows with spacing intervals of 0.9 m and 0.6 m (example)

[18] *Shokh-aryk* is a distribution ditch along an irrigated field.

Indices	Unit	Continuous moistening	Bed moistening	
Net water application rate at the bed moistened	m3/bed area	700	700	700
Width of the moistened bed	m	0.9	1.3	1.4
Furrow length	m	100	100	100
Area of the moistened bed	m^2	90	130	140
Number of beds per ha	unit/ha	111.1	55.6	55.6
Width of the dry bed	m	0.0	0.5	0.4
Area of the dry bed	m^2	0.0	50	40
Total area of dry beds per ha	m^2/ha	0.0	2728	2182
Water application rate reduction factor for the field		0.0	0.73	0.78
Net water application rate for the field	m^3/ha	700	509	547
Volume of net water supply to the furrow	m3	6.3	9.2	9.8
Design efficiency of the field	%	60	60	60
Volume of gross water supply to the furrow	m3	10.5	15.3	16.4
Gross water application rate for the field	m^3/ha	1167	848	912
Saving in comparison with water supply to every furrow	%		27.3	21.8

Indices	Unit	Continuous moistening	Bed moistening	
Net water application rate at the bed moistened	m3/bed area	700	700	700
Width of the moistened bed	m	0.6	0.87	0.93
Furrow length	m	100	100	100
Area of the moistened bed	m^2	60	87	93
Number of beds per ha	unit/ha	166.7	83.3	83.3
Width of the dry bed	m	0.0	0.3	0.3
Area of the dry bed	m^2	0.0	33	27
Total area of dry beds per ha	m^2/ha	0.0	2743	2195
Water application rate reduction factor for the field		0.0	0.73	0.78
Net water application rate for the field	m^3/ha	700	508	546
Volume of net water supply to the furrow	m3	4.2	6.1	6.6
Design efficiency of the field	%	0.6	0.6	0.6
Volume of gross water supply to the furrow	m3	7.0	10.2	10.9
Gross water application rate for the field	m^3/ha	1167	847	911
Saving in comparison with water supply to every furrow	%		27.4	21.9

Water saving effect becomes evident by 15-20 % (of water supply) decrease in the water losses due to surface disposal outside the irrigated field, since the surface disposal that is not used within this contour is formed only on the last tier. In a mean and steep slope area with tier-based layout of fields and irrigation ditches, surface disposal from upstream fields runs to downstream irrigation ditches. The ratio of irrigation water use with tier irrigation layout within the farms' contours approaches unity.

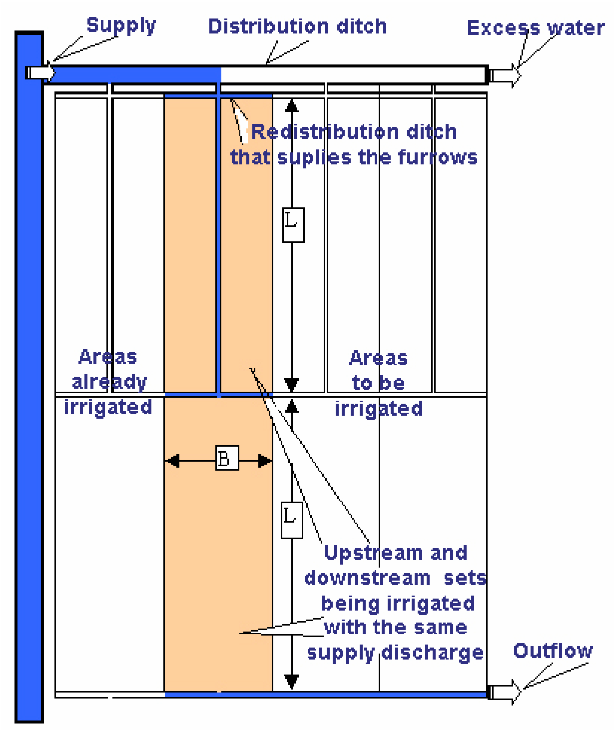


Figure 6.3. Layout of multitier irrigation with discharge water reuse for the irrigation of successive furrow groups.

6.2.3. Discrete adjustment of water supply to furrows

Discrete adjustment of water supply to furrows can allow reducing labour costs (irrigation of two furrows by a single flow switch), improving moistening uniformity (faster run), and decreasing surface disposal (additional moistening by lower flow rate after running).

For discrete adjustment of water supply, the water supplied from an irrigation ditch is alternately directed to the left and right branches of the distribution ditch through an earth dike cofferdam or T-pipe with a manually operated disk valve (Fig. 6.4).

Discrete irrigation is managed according to the quarter rule. The first impulse begins from water supply, for example, to the left leg (left group of furrows) and ends when the irrigating stream front reaches a quarter of the furrow length. Then water is supplied to the right leg until reaches a quarter of its length and then sequentially to the left and right legs until the travel of irrigation streams to furrow ends is fully completed (Fig. 6.5). When the run of the irrigation streams to the furrow end finishes in the left leg furrows, the valve or earth dike cofferdam is set up so that the left leg furrows take a half of the initial discharge and, after the time period equal to the duration of the fourth impulse, the discharge doubles and is divided to both legs which are simultaneously irrigated from this point in the additional moistening stage (Fig. 6.5).

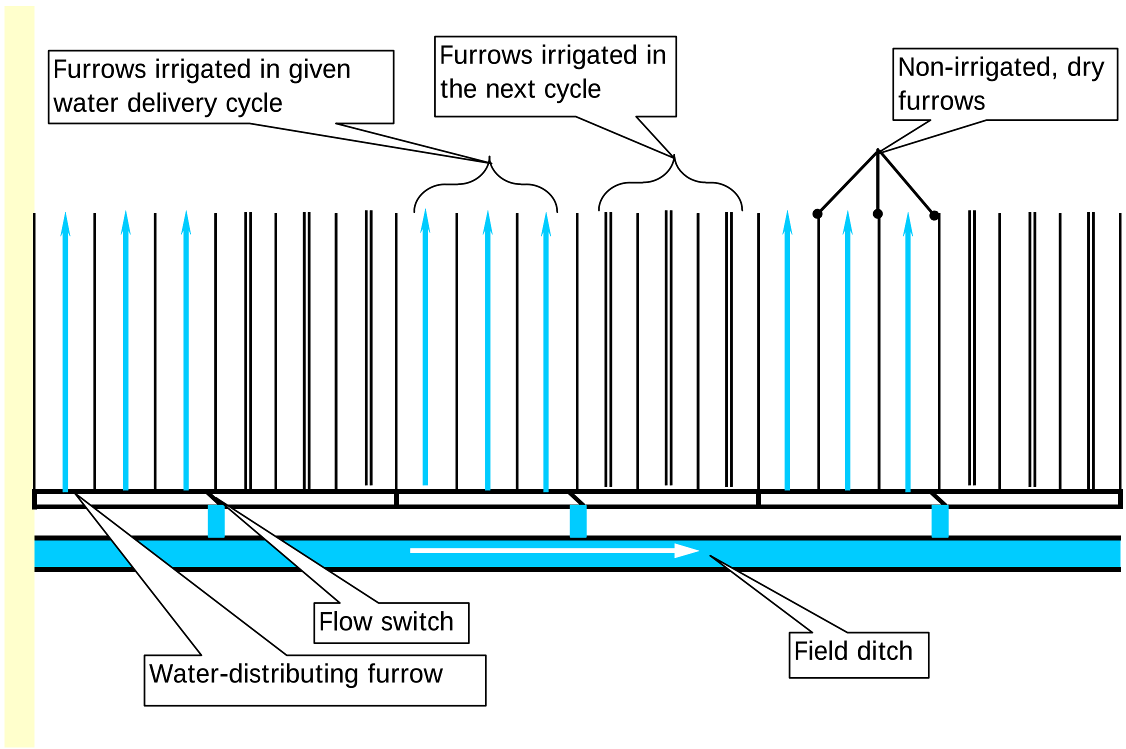


Figure 6.4. Scheme of discrete water supply under the irrigation with alternating irrigated and dry furrows.

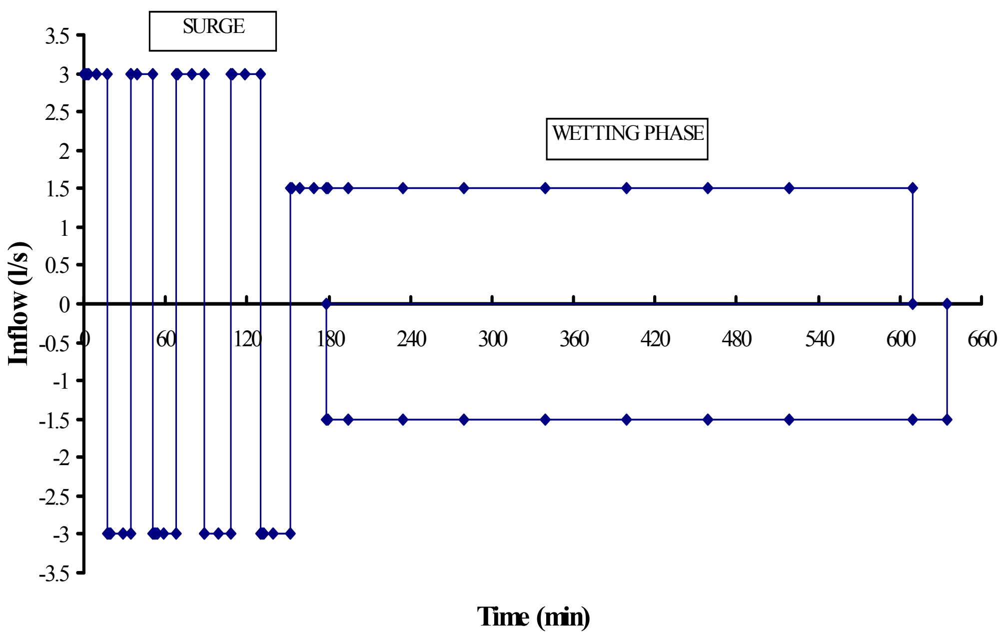


Figure 6.5. Discrete irrigation regime as an additional option (the positive values refer to the irrigation of the left leg, and the negative ones to the irrigation of the right leg).

6.3. Selection of irrigation technology elements depending on furrow slope and soil permeability

The systems of furrow irrigation from a gravity irrigation network are the most widespread in our region.

The factors that determine the combination of furrow irrigation technology elements ($T_{irrigation}$, q_{furrow}, L_{furrow}) optimum for specific conditions with known water application rates are the slope along the irrigation line and soil permeability.

It is quite difficult to achieve optimum (*simultaneous meeting of two criteria: high efficiency of water application rate use and acceptable (no less than 80 %) moistening uniformity*) in working environment.

In practice, the duration of water supply to furrows, $T_{water\ supply}$, and depending irrigation duration, $T_{irrigation}$, are determined first by the possibilities to organizer efficient irrigation. From this standpoint, organization of irrigation and accordingly water supply to furrows are adopted in practice adapting to the length of daylight. Under the conditions of non-automated irrigation, furrow filling with water and regulation of furrow streams along the irrigation width can be performed only in daylight, viz. accommodating the schedule of commencement and completion of water supply to furrows to daytime.

The length of furrows on a specific field is normally adopted proceeding from the field configuration, slopes along the line of irrigation and length of agricultural equipment pass (bout) during pre-irrigation and post-irrigation soil treatment. Thus, in practice they chiefly vary flow rate to the furrow conforming to soil infiltration characteristics. With steep slopes and gentle and mean slopes on light soils, discharges are limited to erosion-proof values of irrigation streams.

To reduce organizational losses of irrigation water in gravity irrigation systems caused by inconsistency between the irrigation of an individual field and irrigation of the group of fields on the irrigated land, it is advisable to standardize the duration of supply to irrigated plots conforming to the irrigation organization within contours of water use unit. This principle is implemented in the simulation model SIRSAN-II worked out by SIC ICWC.

Allowing for the principles and algorithm actualized in the SIRSAN-II model, preferred through furrow irrigation parameters of the main types of water permeability within a wide range of slopes with a typical hydraulic roughness coefficient of furrow bed $n = 0.025$ were calculated and preferred ranges of values were given. These values (Tables 6.3–6.7) can act as a reference for setting irrigation technology elements optimum for specific conditions, i.e. combinations: furrow length; distance between irrigated furrows; water application rates; standardized water supply durations and rate of water supply to furrows.

The recommended preferred ranges of through furrow irrigation technology parameters minimize surface and underground disposals.

Table 6.3

Low permeability soils (texture – clay)

Parameters		Unit	Slopes (m/m)		
			gentle	mean	steep
			0.0025>S>0.001	0.0075>S>0.0025	0.025>S>0.0075
Furrow length	L	m	200…400	100…400	100…200
Distance between irrigated furrows	d	m	0.9	0.6/0.9	0.6
Water application rate	m_{net}	m^3/ha	1000…1100	1000…1100	800…900
Water supply duration	T_{ws}	hour	48	48	36...48
Flow rate range	q	l/s	0.2…0.4	0.05…0.4	0.05…0.20

Table 6.4

Reduced water permeability soils (texture – loamy clay)

Parameters		Unit	Slopes (m/m)		
			gentle	mean	steep
			0.0025>S>0.001	0.0075>S>0.0025	0.025>S>0.0075
Furrow length	L	m	100...400	100...200	100
Distance between irrigated furrows	d	m	0.9	0.6/1.2*/0.9/1.8*	0.6/1.2*
Water application rate	m_{net}	m^3/ha	800...1100	700...900	800...900
Water supply duration	T_{ws}	hour	12…24	12...48	36...48
Flow rate range	q	l/s	0.2...1.2	0.1...0.6	0.05...0.20

Table 6.5

Medium water permeability soils (texture – paddy-field soil)

Parameters		Unit	Slopes (m/m)		
			gentle	mean	steep
			0.0025>S>0.001	0.0075>S>0.0025	0.025>S>0.0075
Furrow length	L	m	100...400	100...200	70...100
Distance between irrigated furrows	d	m	0.9/1.8*	0.6/1.2*/0.9/1.8*	0.6/1.2*
Water application rate	m_{net}	m^3/ha	800...1000	800...900	800...1000
Water supply duration	T_{ws}	hour	6…36	6…36	6…24
Flow rate range	q	l/s	0.5…1.9	0.2...1.2	0.10...0.25

Table 6.6

Higher water permeability soils (texture – light loam, loamy sand)

Parameters		Unit	Slopes (m/m)		
			gentle	mean	steep
			0.0025>S>0.001	0.0075>S>0.0025	0.025>S>0.0075
Furrow length	L	m	50…150	50…100	50...70
Distance between irrigated furrows	d	m	0.9	0.6/1.2**	0.6/1.2**
Water application rate	m_{net}	m^3/ha	800...900	800	700
Water supply duration	T_{ws}	hour	6…12	3…12	3…12
Flow rate range	q	l/s	0.4...1.0	0.2...0.4	0.05...0.20

Table 6.7

High water permeability soils (texture – loamy sand, sandy)

Parameters		Unit	Slopes (m/m)		
			gentle	mean	steep
			0.0025>S>0.001	0.0075>S>0.0025	0.025>S>0.0075
Furrow length	L	m	50…70	50	30...50
Distance between irrigated furrows	d	m	0.6/1.2**	0.6/1.2**	0.6/1.2**
Water application rate	m_{net}	m^3/ha	800...900	800	700
Water supply duration	T_{ws}	hour	6	3…6	3…6
Flow rate range	q	l/s	0.3…0.6	0.2...0.4	0.05...0.20

* irrigation of every other spacing

List of references used for Section 6

1. Mirzaev, N.N. Application of best water saving practice in the Aral Sea region. 2001.

2. Horst, M.G. Water saving memorandum. 2006.

3. Horst, M.G. Possible ways to raise the level of rational water use in the irrigated agriculture in the Aral Sea basin in connection with the climate change. In the collection "Dialogue about water and climate: case study of the Aral Sea basin". 2002.

4. Horst, M.G., Solodkiy, G.F. SIRSAN-II: simulation model for the calculation of the through furrow irrigation method elements. 2007.

5. Horst, M.G., Shamutalov, Sh.Sh., Gonçalves, J.M., Pereira, L.S. Assessment of the improvements in furrow irrigation and water saving in cotton irrigation. In the book "Irrigation management with the view of controlling the desertification processes in the Aral Sea basin. Assessment and tools.". 2005.

6. Horst, M.G., Shamutalov, Sh.Sh., Gonçalves, J.M., Pereira, L.S. Discrete irrigation as a water saving way. In the book "Irrigation management with the view of controlling the desertification processes in the Aral Sea basin. Assessment and tools.". 2005.

7. RECLAMATION IN WUA

7.1. WUA reclamation network and interaction with PHGRE

Horizontal drainage system within the irrigated contours of WUA represented by open and closed collectors and drains with hydraulic strictures is designed for timely diversion of excessive saline groundwater from irrigated areas.

CDN system components are as follows:

- primary (field) drainage ways;
- collecting canals (collectors) of different orders;
- hydraulic (control, grade-control, water check, etc.) structures;
- gauging stations;
- outfall structures;
- well chambers;
- drainage water pumping stations;
- automation and remote control instrumentation;
- structures built at the intersections of CDN with the irrigation, and railway networks;
- observation well network;
- road network.

The collectors (drains) that serve two and more WUAs fall into the category of inter-farm ones and are on the books of WMO's operating entities.

The collectors (drains) that serve one WUA fall into the category of on-farm ones.

The collectors (drains) that serve the lands of one individual (dekhkan) farm should be rated as farm collectors (drains).

Division of a collector & drainage network into intern-farm and on-farm networks and adjustment in the course of their technical maintenance caused by a change of the route layout in the plan or boundaries of farms-land users within administrative districts are carried out by a land management service in agreement with WMO's operating entities, and then is approved through an order by the district administration.

Technical management of CDN operation, irrespective of its type and importance, is executed by the reclamation service of WMO bodies represented by Provincial Hydrogeological Reclamation Expeditions.

Technical maintenance of CDN consists of the following operations:

- routine monitoring of technical condition of CDN and performance of organizational and technical measures aimed to maintain it in serviceable state;

- Creation of favorable conditions for the control of moisture, salt, temperature, nutrient, and air regimes of soils with the purpose of gaining high and sustainable crop yields with the most efficient use of water and land resources;
- Definition of technical and economic indicators of reclamation effectiveness of CDNs; development and carrying out of measures aimed at their improvement.

Misusage of the on-farm or inter-farm CDN is strictly prohibited. In exceptional cases, use of CDN for other purposes (surface water passage under storm rainfall, accidents in irrigation networks, etc.) as well as carrying out of construction works on it by other ministries and institutions, which impede its normal operation, can be allowed only with the permission only of WMO bodies.

The open CDN transferred to the WUA book is operated at the cost of land users (WUAs) or based on agreements with water management organizations.

WUA is obliged to:

- vest the on-farm open CDN in irrigators (ameliorator) and mirabs;
- when making WUA activity financing plans, make provision of funds for the operation and maintenance of the on-farm KDN that is on the WUA balance sheet;
- secure the safety of both inter-farm (passing through the WUA territory) and on-farm CDN;
- perform the works associated with the maintenance of the CDN that is within the WUA;
- provide the reclamation services of water management bodies with necessary information for the assessment of CDN operability as well as the report on the repair-and-renewal operations executed on it;
- together with land reclamation and water management agencies, work out plans to carry out a package of the measures related to technical maintenance and improvement of the on-farm CDN;
- commissioning of the rehabilitated (built) on-farm CDN and subsequently recognize it (built) on the balance sheet as a fixed asset.

CDN efficiency is determined according to the following indicators:

- Operation costs.
- Groundwater occurrence depth.
- Soil salinity degree;
- Groundwater salinity degree;
- Change in crop yield.

These indicators get compared with similar ones for the precedent years and their causes are analyzed.

Following the analysis of the reclamation condition of irrigated lands and their use for economic purposes, yield of the crops grown, technical state of the CDN and structures, the WUA Management together with water users plan measures aimed at the improvement of the technical state and drainage systems as well as identify priority objects to perform maintenance and reconstruction works on to be considered and approved by the WUA Council.

In the absence of design & estimate and executive documents of drainage systems, WUA must, by its own efforts or by involving design organizations (*if the budget allows*), draw up a CDN map with all existing structures on it as well as a layout of the irrigation, road, and operational observational networks linked to farms' boundaries and then estimate the technical state of collectors and drains according to the inventory materials (Appendix 7.1) and evaluation reports.

7.2. Monitoring of CDN operation by PHGRE

The CDN operation monitoring includes measurement of drainage flow discharge and water level, sampling of drainage and irrigation waters. It is executed by the reclamation services of water management bodies.

The scope of monitoring observations, number of the observations per unit area, and their location on the map depend on natural & economic as well as hydrogeological & reclamation conditions and are determined according to existing normative documents.

As for the operating draining systems where there are no monitoring facilities (gauging stations, observation wells, piezometers, etc.), their number and location are determined proceeding from the necessity to receive information from a territory serviced by the WUA.

When studying the drainage flow dynamics, the following are to be defined:

- number of the drainage water drained and salts in it;
- relation between water supply (water application, leaching) and the drainage flow;
- relation between the drainage flow and groundwater level;
- groundwater volume used for irrigation and leaching;
- CDN performance as compared to previous years and design indicators.

The flow rate in CDN is measured every five days during the vegetation period and every ten days during the non-vegetation period. Under steady drainage flow conditions, it is allowed to be measured more rarely but with a frequency multiple of five. With forced discharge of surface water to the CDN, one needs to account it by measuring CDN flow outside regular hours.

The hydrochemical regime of the drainage water is monitored by sampling for chemical analysis: once a month during the vegetation period and once a quarter in the rest period of the year. The drainage water is sampled at the gates of particular plots, farms, lands, or systems – normally at drain and collector outlets.

The chemical composition of irrigation water is determined by sampling once a year; with higher salinity, at least three times a year (in the beginning, middle, and end of the vegetation period) at the heads of inter-farm or on-farm canals. In chemical laboratories of water management bodies, they carry out comprehensive and short-cut analyses of the water sampled.

The chemical analysis results are processed and stored in PHGRE and are to be provided to WUA at its request along with explanations and recommendations of the PHGRE.

List of references used for Section 7

1. Yakubov, Kh.E., Umarov, P.D. Manual on solving reclamation problems in WUA. 2006.
2. Yakubov, Sh.A. Scope of reclamation measures in WUA and planning of those for short-term and long-term periods. Roadmaps. Presentation. 2008.
3. Yakubov, Sh.Kh. PHGRE role and tasks. Presentation. 2010.

Appendix 7.1

REPUBLIC ____________

PROVINCE ____________

DISTRICT ______________________

WUA ____________________

TECHNICAL CERTIFICATE №
of on-farm open drainage network

____

1. Year of drain commissioning .... year
2. Drainage length .... m
3. Area serviced by the drainage .... ha
4. Average flow velocity .... m/s
5. Type and number of gauging stations on the drainage ....
6. Number of small drains joining the drain ………. .... units
7. Water intake .... "____________" collector
8. Reserve along the stream:
On the right side .... m
On the left side .... m

9. Technical parameters of the drain

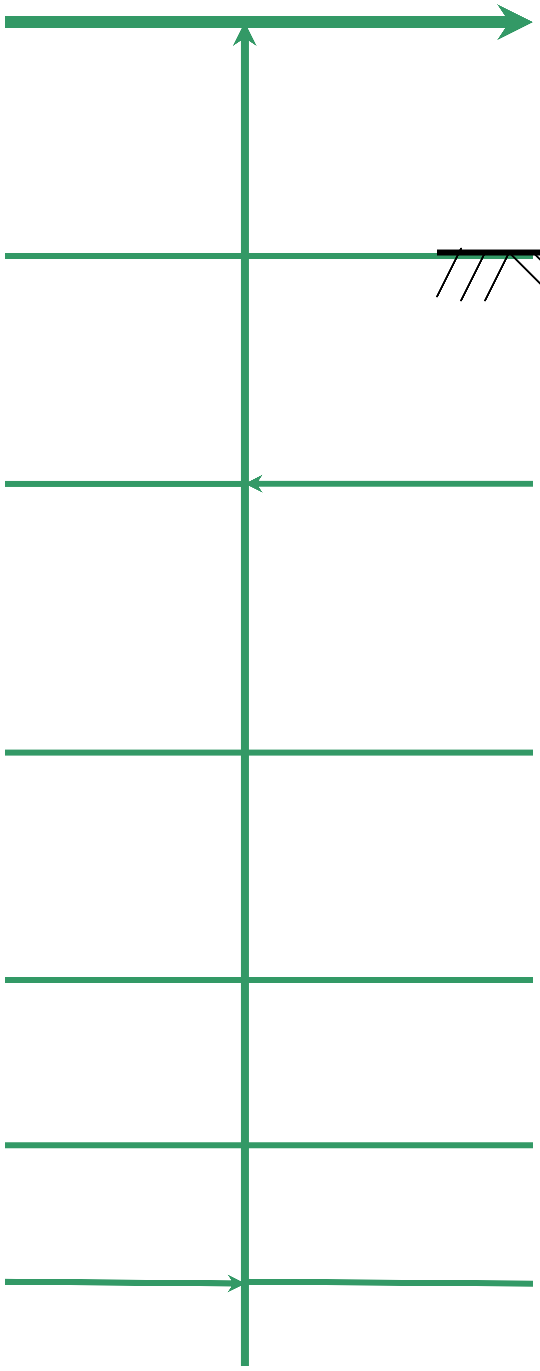
Measures	At the beginning of PC-0	At the middle	At the end
Maximum flow rate, m^3/s			
Minimum flow rate, m^3/s			
Average vegetation flow rate, m^3/s			
Depth (h), m			
Top width (B), m			
Bottom width (b), m			
Slope (m)			
Fall of drain (i)			

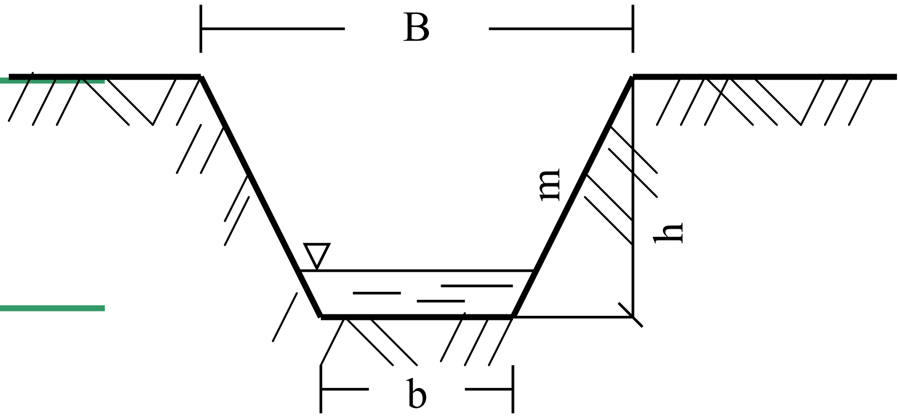
10. Repair-and-renewal operations

Years	Days and months	Technical cleaning		Total		Length	Note
		Volume, m^3	Cost, ths UZS	Volume, m^3	Cost, ths UZS		

11. Drain scheme and (longitudinal) profile

Water intake name. Collector "________________"





12. Additional information

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Certificate prepared by: ____

Title, signature (Name)

Certificate checked by: ____

Title, signature (Name)

Updated in year of 201 ____

Title, signature (Name)

Updated in year of 201 ____

Title, signature (Name)

WUA Guide to Completing Technical Certificate

Technical Certificate is to be filled by a WUA Hydraulic Engineer based on the drainage network inspection and maintenance results as well as obtained field records and approved by the WUA Director. If WUA workers cannot currently fill out some items, those can temporarily be left unfilled and done later at the first opportunity.

1. **Year of drain commissioning:** to be taken from design, archive, and accounting materials of former (before WUA establishment) farms or ISAs.
2. **Drainage length, m**: to be taken from design materials or can be measured by WUA technicians or mirabs.
3. **Area serviced by the drainage, ha**: proceeding from drainage parameters, to be taken the same as for similar drains in consultation with PHGRE experts.
4. **Average flow velocity, m/s**: to be taken from design materials or calculated based on measurements.
5. **Type and number of gauging stations on the drainage, units:** to be calculated by technicians or mirabs.
6. **Number of small drains joining the drain, units**: to be calculated by technicians or mirabs.
7. **Water intake:** the name of the collector (or depression) where water from a particular drain flows in is to be entered.
8. **Reserve along the water course:** proceeding from the relevant parameters, can be taken from Water Inspectorate or PHGRE experts.
9. **Technical parameters of the drain:** to be drawn from design materials; drain flow can be calculated by WUA hydrometer specialists in consultation with PHGRE experts; slope ratios and falls of the drain are to be drawn from design materials; if required materials are not available, the width and depth can be measured on one’s own.
10. **Repair-and-renewal operations:** records are to be made after every cleaning or maintenance work.
11. **Scheme:** is to be plotted by a hydrometer specialist based on the measurements made by WUA technicians or mirabs.
12. **Additional information:** a hydrometer specialist has to enter any information of the works carried out on the drain or an area commanded by the drain.

Edited in
Scientific Information Center
of Interstate Commission for Water Coordination

Republic of Uzbekistan, 100187,
Tashkent, Karasu-4, B. 11
Telephone: +(998 71) 265 92 95, 266 41 96
Fax: +(998 71) 265 27 97
E-mail: dukh@icwc-aral.uz; dukh@rol.uz

Makeup by: Beglov, I.F.