Development of recommendations on partial transfer of land to gravity irrigation in zone of Bandyhan – I substandard pumping station with compensation of expenses from Tupolang reservoir

Ilkhom Begmatov*, *Shavkat* Botirov[1], *Hojadurdy* Hojadurdyyev[2], and *Yaran* Hudayberdiyev[2]

[1]"Tashkent Institute of Irrigation and Agricultural Mechanization Engineers" National Research University, Tashkent, 100000, Uzbekistan
[2]"Turkmen Agricultural University", Ashgabat, 744000, Turkmenistan

Abstract. Based on the analysis of the work of the Khazarbagh irrigation system, water use plans, the household regime of the Tupolang River, the operation mode of the pumping station–I, proposals have been developed for the partial transfer of machine irrigation lands to gravity for the zone, the Bandyhan–I subcommand pumping station. With a two–fold accumulation of water in the Tupolang reservoir up to 40-60 million m^3 and the use of this water for compensation through the end part of the Khazarbag canal, the distributor P – I in the Bandyhan canal, we recommend turning off the pumping station for the period from February to the first decade of June and from September to November. At the same time, the energy savings amount to 8.38 million kWh.

1 Introduction

On the territory of the Surkhandarya region of the Republic of Uzbekistan, we have completed the contractual work "Establishing the possibility of transferring part of the machine irrigation lands to gravity irrigation in an irrigation system subordinate to the Tupolang reservoir during its phased filling", in which the possibility of completely disconnecting the Bandyhan –II pumping station with compensation for expenses from the reservoir during its two-time filling was justified: in winter and in summer. Following these recommendations, the Bandyhan –II pumping station did not work in the year of the research. This year, 50 million m^3 of water was accumulated in the Tupolang reservoir for the first time, which allowed to increase in the irrigation area suspended from the Khazarbag-Tupolang canals by 4963 hectares compared to the previous year. This follows from the water use plans drawn up by the management of the Tupolang-Karatag Canal for the growing season. This work is a continuation of the previous one, the main content of which is the justification of the possibility of a partial or complete shutdown of the

*Corresponding author: ilkhommatbe@gmail.com

Bandykhan – I pumping station, with the passage of the missing expenses by gravity from the Tupolang reservoir to the end of the Khazarbag canal, from where it will flow through the distributor P – I to the Bandykhan canal.

2 Methods and Materials

The following materials were used in the calculation: linear scheme of irrigation system with hydraulic structures, general information of WUA (service area, main source of irrigation, rehabilitation, construction). Evaluate the condition and operation of hydraulic structures (water distribution unit, water measuring device). Methods for defining safety criteria of hydraulic structures, method of assessment of hydraulic structures safety level, development, and testing of hydraulic structures condition assessment system, analysis methods for research of experimental field methods were used.

The studies were conducted according to the methodology of inspection of hydraulic structures, methods for assessing hydraulic structures, methods for determining the criteria for the safe operation of hydraulic structures, calculation and evaluation of hydraulic structures (water distribution, water meter structures, etc.). and field observations [1 – 9].

In the course of the work, the following studies were carried out:

1. to study the condition of irrigation networks in the selected area.
2. to evaluate the hydraulic structures on the irrigation systems.
3. Determination of the order of repair of hydraulic structures.
4. Priority construction and repair of hydraulic structures.
5. Environmental impact assessment of hydraulic engineering works.
6. Comparison of conditions before and after construction, summarizing the results.
7. Making calculations based on regulatory documents.

The main objectives of the survey of hydrotechnical constructions on irrigation systems are:

assessment of the condition and safety of hydrotechnical constructions and their complexes, the forecast of their changes over time;

identification of deviations from project decisions, damage, defects, and changes in the physical and mechanical properties of materials;

cause of accident constructions;

identification of dangerous changes in the processes occurring in the construction system – the foundation (filtration, displacement, precipitation, stress level);

analysis and assessment of hydrotechnical constructions for emergency prevention measures;

assessment of compliance by the operating organization with the requirements of regulatory legal acts on the operation of hydrotechnical constructions;

development of recommendations to improve the safety of hydrotechnical structures.

The general issues of the construction, operation, and repair of hydrotechnical structures are the equitable distribution of water between water users (farmers) and between farmers and household plots [1].

3 Results and Discussion

Characteristics of the existing conditions for irrigation of land from the Bandyhan channels and the end part of Akkapchigai. The Bandyhan Canal starts from the Bandyhan – I pumping station, which is located on KP – 52 of the Sherabad Machine Main canal and has a lifting height of 40 m with a total flow rate of eight pumps NDN – 25 Q_s = 12 m^3/s. The length of the canal is 6.6 km, and the maximum throughput is 11 m^3/s; the canal is made in concrete cladding with a slope of i – 0.0001. According to the water use plan, the area suspended from the canal is 6,300 hectares. The main consumers are the state farms of Pakhtakor, Gulyam, and Tashkent, which take water from the Kyzyryksky canal, which departs from the Bandyhan canal on KP – 60. The linear scheme to the Bandyhan canal is the Bandyhan – II pumping station, with which the end part of the gravity Akkapchigai (Hazarbag) canal, which takes water from the river Tupolang, was replenished. In previous years, the maximum feed flow through the Bandyhan – II pumping station was 2.19 m^3/s. This year, due to the passage by gravity from the Tupolang reservoir of expenses compensating for the operation of the Bandyhan – II pumping station, the pumping station was disconnected at the end of Akkapchigai and the lands suspended from the end of the Akkapchigai canal were completely irrigated by gravity this year. At the end of the Akkapchigai canal on KP – 896+80, water enters the distributors P – 1 and P – 2, the existing capacity of which is 1.5 m^3/s and 4.0 m^3/s, respectively. Let's consider the possibility of the partial shutdown of the Bandykhan – I pumping station when the required expenses are passed into the Bandykhan canal by gravity due to the use of water accumulated in the Tupolang reservoir (with a capacity of 60 million m^3) through the end part of the Akkapchigai canal and the distributor P-1 [9]. This issue should be considered in conjunction with the maximum possible capacity of the terminal part of the Akkapchigai canal, distributor P-1, the Khazarbag canal, water use plans for the Bandyhan and Khazarbag canals, and the irrigation capacity of the river. Tupolang in the reservoir with the accumulation of water during the construction period up to 60 million m^3.

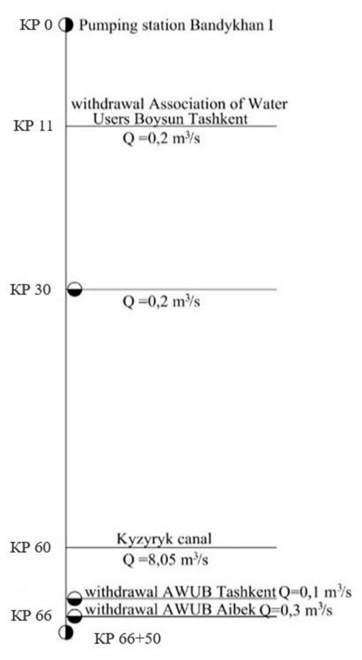


Fig. 1. Linear diagram of Bandyhan channel

This year, the Tupolang-Karatag Canal Operation Department has carried out work to increase the capacity of the terminal part of the Akkapchigai canal to 15 m^3/s, and work is underway to reconstruct the R-1 canal with an increase in capacity to 11-12 m^3/s and bringing its route to the Bandyhan canal [4]. The scheme of irrigation of land from the Bandyhan canal, partly by gravity and partly with the help of the Bandyhan –II pumping station, is shown in Figure 2. The existing operating mode of the Bandyhan – I pumping station. Let's analyze the operating mode of the pumping station according to the average decadal expenses in previous years, which are given in Appendix 1, the maximum and average long-term decadal expenses for the same period (Table 1). The above data shows that in December, January, and February, the station is practically not working. The maximum peak of expenses falls on two periods: from the 3rd decade of March to the 2nd decade of April and from June to August. The maximum flow rate of the pumping station supplied for all years of operation is 9.0 m^3/s.

Table 1. Values of maximum and average decadal expenses for previous years at Bandyhan – I pumping station.

Months	De ka des	$Q_{cf.}$ m^3/s	$Q_{max.}$ m^3/s	Months	De ka des	$Q_{cf.}$ m^3/s	$Q_{max.}$ m^3/s	Months	De ka des	$Q_{cf.}$ m^3/s	$Q_{max.}$ m^3/s
1	2	3	4	5	6	7	8	9	10	11	12
I	1	-	-	V	1	3.58	6.9	IX	1	3.48	7.2
	2	-	-		2	5.32	6.75		2	1.93	3.6
	3	-	-		3	5.92	6.59		3	1.73	3.6
II	1	-	-	VI	1	6.51	7.5	X	1	1.67	3.45
	2	-	-		2	7.06	8.1		2	2.16	3.15
	3	-	-		3	7.67	9.0		3	1.95	2.86
III	1	0.22	1.35	VII	1	8.27	9.0	XI	1	1.4	3.0
	2	2.18	3.75		2	8.47	9.0		2	0.83	3.8
	3	5.82	7.9		3	8.53	9.0		3	0.95	3.0
IV	1	8.03	8.55	VIII	1	7.83	8.25	XII	1	0.16	0.75
	2	6.6	7.95		2	6.16	7.9		2	0.36	1.5
	3	4.37	7.2		3	5.63			3	0.32	1.88

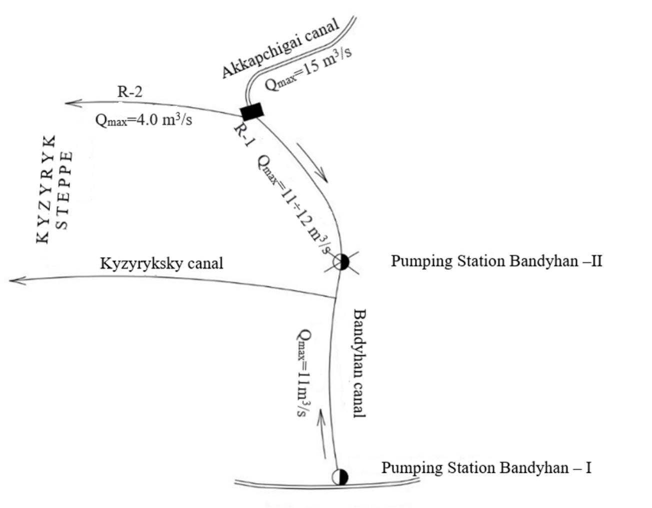


Fig. 2. Scheme of irrigation of lands from end part of Akkapchigai and Bandyhan canal for the current year.

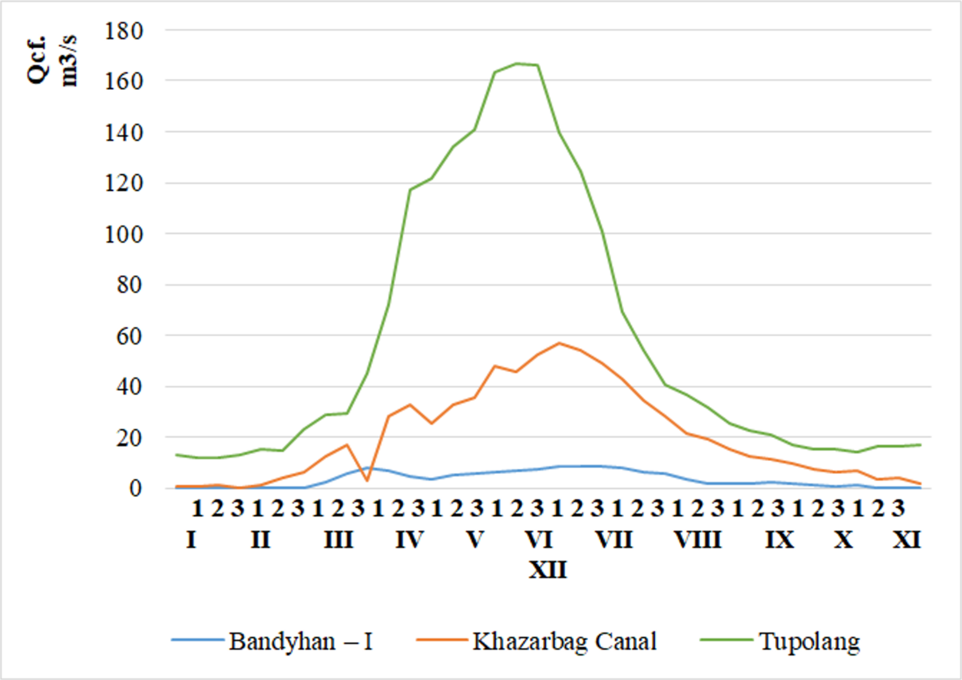


Fig. 3. Schedule of changes in average expenses for previous years on Tupolang River, Khazarbag Canal, and Bandyhan – I pumping station

Figure 3 combines curves characterizing the dynamics of average weekly expenditures for previous years by r. Tupolang (Harduri post), at the head of the Khazarbag and Tupolang-Karatag channels and the Bandyhan–I pumping station, the maximum flow rate that the Khazarbag-Tupolang-Karatag canal system can pass is 67 m^3/s, falls on the 3rd decade of June and July months. Therefore, in addition to the main consumption during this period, it is impossible to add expenses, about 9 m^3/s, fully compensating for the operation of the Bandyhan – I pumping station, according to the channel capacity. The rest of the time, expenses that compensate for the operation of the Bandyhan – I pumping station can pass through the channel. Linking the operation mode of the pumping station with the water resources of the Tupolang River and the reservoir under construction [10]. The maximum peak of expenditures on the Tupolang River runs from the 3rd decade of May to the 1st decade of July. The maximum water intake into the irrigation system compared with the expenses of the Tupolang river is how much shifted and falls in the 3rd decade of June and July. Let's compare the maximum expenses of the Tupolang river in previous years with the expenses of the irrigation system of the Tupolang river according to the water use plan for the current year in Figure 4. The expenses of the Tupolang river do not provide planned water intake in spring (March, the first two decades of April) and from the 3rd decade of July to November. The water deficit at this time is 16-30 m^3/s. With average long-term decadal expenses, water shortage begins in the 2nd decade of August, and water shortage reaches 22 m^3/s. Thus, the water resources of R.Tupolang provides the possibility of shutting down the pumping station from the second decade of April to the third decade of July. Still, starting from the 3rd decade of June, the capacity of the Khazarbag canal does not allow adding additional expenses to the planned expenses to compensate for the operation of the pumping station.

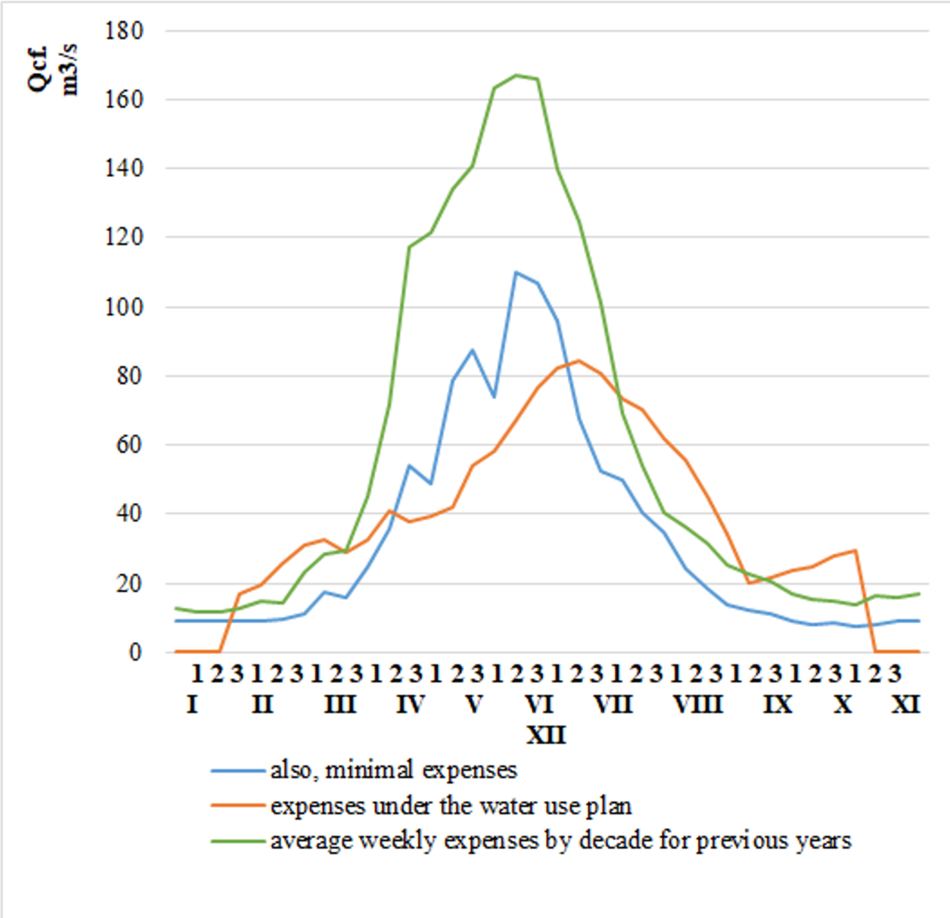


Fig. 4. Schedule of changes in average and minimum expenditures on Tupolang river and planned expenditures in irrigation system

Let's consider how the two-fold accumulation of water in the reservoir in winter and summer, up to 60 million m^3, will affect the size of the shortage of water resources along the Tupolang River and the possibility of disconnecting the pumping station in the periods from February to the 2nd decade of April and from September to November. Data on the water use plan for the non-vegetative period is needed to calculate the water shortage. Spring non-vegetative irrigation is provided for irrigation of alfalfa, orchards, grain, other crops, and household plots in the months of February-March. The water use plan for the non-vegetation period for the entire irrigation system of the Tupolang River has not been compiled for the current year. Still, data are available for irrigation areas and, in particular, for the Sary-Assy district [13]. Using these data, we performed approximate calculations of the required expenses for the Tupolang irrigation system and the Bandyhan canal in February, March, and the 1st decade of April. Table 2 shows data on the required total water intake of the irrigation system of the Tupolang river, the Bandyhan canal, the minimum and average annual runoff of the Tupolang river for the months of February-March, and the water shortage is calculated.

Table 2. Calculations of water shortage in irrigation system of Tupolang river and Bandyhan canal in spring non-vegetative period

Months	Name of indicators	Volume, million m^3
February	Required water intake to the system along the Tupolang river The same in the Bandyhan channel Total water intake Minimum runoff by Tupolang Water shortage with minimal runoff The same, with an average annual runoff	49.57 7.3/0 56.87/49.57 22.6 34.23 34.27/26.07 22.64/15.84
March	Required water intake to the system along the Tupolang river The same in the Bandyhan channel Total water intake Minimum runoff by Tupolang Water shortage with minimal runoff The same, with an average annual runoff Total spring deficit with minimal runoff The same, with an average annual runoff	73.27 12.16/7.6 85.43/80.87 39.56 72.55 45.87/41.31 12.88/8.27 80.14/68.28 35.47/23.61

Note: The denominator contains data considering the actual average weekly expenses of the Bandyhan – I pumping station.

The deficit, taking into account the 1st decade of April, for minimum expenses – 86.27, the same from the pumping station – 92.88, for average weekly expenses – 35.47, from the pumping station – 23.61 million m^3. A comparison of the required water intake into the Tupolang irrigation system and the Bandyhan canal with the minimum and average runoff of the Tupolang river for February and March shows (Table. 2) that with a minimum flow of the Tupolang River, the water shortage in the irrigation network is 80 million m^3, and with an average flow – 35 million m^3. Thus, the winter filling of the reservoir is up to 60 million m^3, and the average water content of the years completely covers the existing water shortage and in the lowest water year, when the deficit is about 20 million m^3 – by 75%. This means that in February and partly in March, the Bandyhan – I pumping station may not work. Let's take the share of water shortage attributable to the Bandyhan canal in proportion to the planned water intake into the Bandyhan canal. This will amount to 13.6% or 2.75 million m^3 of water [11]. Such a volume of water will require the operation of a pumping station only in the last decade of March, with an average flow rate of Q = 2.89 m^3/s. Calculations of water scarcity in the 1st decade of April are given in Table 3.

Table 3. Calculations of water shortage in irrigation system of Tupolang river and Bandyhan canal for 1st decade of April of growing season

Name of indicators	Volume, million m^3
The required water intake into the system Tupolang	28.43
The same in the Bandyhan channel	2.33
Total water intake	30.76
Minimum runoff by Tupolang	21.6
Water shortage with minimal runoff	39.23
The same, with an average annual runoff	9.16
The percentage of water intake of the Bandyhan canal from the total water intake	7.57
The shortage of water only through the Bandyhan canal is proportional to the water intake	0.69
Required water consumption in the 1st decade of April at the Bandyhan-I pumping station with minimal runoff	0.8

With a minimum flow of the Tupolang river, the total water deficit in the 1st decade of April is 9.16 million m^3, and with an average decadal flow, it is absent. In percentage terms, the deficit attributable to the Bandyhan canal from the water intake to the irrigation network of the Tupolang river is 0.69 million m^3, which requires the average flow rate of the Bandyhan – I pumping station in the first decade of April Q = 0.8 m^3/s. Consequently, in spring, with a minimum flow of the Tupolang river, the pumping station is required only in the 3rd decade of March with Q = 2.89 m^3/s and in the 1st decade of April with Q = 0.80 m^3/s and with an average annual flow, the necessary water intake is provided by the resources of the Tupolang river. From an economic point of view, when filling a reservoir in winter, it is advantageous to increase the water availability of machine irrigation lands, especially since the pumping station should only be switched on for two decades. Therefore, during this period, we recommend feeding the necessary expenses to the Bandyhan canal by gravity from the reservoir to the end part of the Akkapchigai canal and the R-1 distributor. In April, May, and June, the minimum flow of the Tupolang river exceeds the total water intake into the irrigation system of the Tupolang river and the Bandyhan canal. But in the 2nd and 3rd decades of June, planned expenditures in the irrigation system are 67.3 and 76.6 m^3/s, and the maximum capacity of the Khazarbag canal is 67 m^3/s. The average decadal actual expenditures to the irrigation system over the past years in these decades were 45.4 and 52.6 m^3/s, and the maximum was 56.3 and 61.1 m^3/s. The required consumption according to the water use plan in the Bandyhan canal in the 2nd and 3rd decades of June is 4.9 and 5.5 m^3/s, and the average decadal consumption of the pumping station at this time is 7.1 and 7.7 m^3/s (Table 4), i.e., taking into account the planned expenses in the Khazarbag canal and its maximum capacity, it is impossible to skip the additional expenses of the Bandyhan canal during this period, and the pumping station on the 2nd and 3rd decades of June must submit expenses following the plans for the water use of the Bandyhan canal [12]. If we take as a basis the actual average weekly expenses passing through the channels at this time, then the pumping station may not work in the 2nd decade of June and in the 3rd decade of June - with a flow rate of 1.8 m^3/s. According to the water use plan, the end part of the Akkapchigai at this time allows you to skip the additional required flow into the Bandyhan channel. In July – August, the pumping station must be fully operational because in the 1st decade of July, additional flow cannot pass due to restrictions on the capacity of the Khazarbag canal, and starting from the 2nd decade of July - due to a shortage of water resources of the Tupolang river. Data for June – August on the expenses of the Tupolang river, the Khazarbag and Bandyhan channels, and the pumping station are given in Table 4.

Table 4. Planned and averaged weekly expenses for irrigation system of Khazarbag – Tupolang – Bandyhan canals and Bandyhan–I pumping station.

Indicators	June			July			August		
	1	2	3	1	2	3	1	2	3
1	2	3	4	5	6	7	8	9	10
Minimum expenses p. Tupolang m^3/s	74.1	110	107	95.9	67.6	52.5	49.9	40.6	34.7
Planned expenditures in the irrigation system of the Tupolang river, m^3/s	58.2	67.3	76.2	82.3	84.2	80.6	73.3	70.4	61.7
Planned expenses in the Hazarbag Tupolang canal, m^3/s	47.01	54.31	64.11	67.59	69.92	66.6	60.27	57.56	49.59
Planned expenses in the Bandyhan canal, m^3/s	4.46	4.88	5.51	6.49	7.73	6.94	5.45	5.23	4.17
Total planned consumption of the Khazarbag and Bandyhan channels.	51.47	59.19	69.62	74.08	77.65	73.54	65.72	62.79	53.76
Average decadal actual consumption of Hazarbag Tupolang channels over the past years.	47.8	45.42	52.59	56.69	54.22	49.06	42.71	34.59	28.08
Average decadal flow rate of the pumping station.	6.51	7.06	7.67	8.27	8.47	8.53	7.83	6.66	5.63
Total actual flow of channels and pumping station.	53.9	52.48	60.25	64.96	62.69	57.59	50.51	41.25	33.71

From the table, comparing the pan total flow rate, the maximum channel capacity of 67.0 m^3/s, and the availability of water resources of the Tupolang river, it follows that in the 3rd decade of June, the pumping station should work with a flow rate of 3.0 m^3/s (total 7.78 m^3/s) and fully with planned expenses - in July, August [5]. Taking into account the actual average decadal expenses of the canal and the pumping station (60/65 m^3/s), the minimum expenses of the Tupolang river, and the maximum capacity of the canal (67 m^3/s), the pumping station could not work for the 3rd decade of June and the 1st, 2nd decade of July. The total water deficit for three months with a minimum flow is 174 million m^3, with an average long–term - 100.1 million m^3, including 17.3 million m^3 and 49.9 million m^3, respectively, through the Bandyhan canal, i.e., the accumulation of water in the reservoir up to 60 million m^3 does not fully cover the existing water shortage. If the accumulated water is used only in October and November, then the shortage of water resources is reduced to 98.9 million m^3 with minimal runoff and to 56.45 million m^3 with average annual runoff, including through the Bandyhan canal, respectively, to 9.9 million m^3 and 7.2 million m^3. With water accumulation up to 60 million m^3 in low–water years, the deficit remains in the volume of 38.9 million m^3, and in average water years – it is fully covered. The average annual volume of water raised by the pumping station in September – November is 1.9 times less than the planned water intake into the Bandyhan canal, which further reduces the water shortage along the canal [3]. We consider it expedient to use the accumulated water in the reservoir first of all in September – November to cover the deficit along the Bandyhan canal, while we recommend turning off the Bandyhan – I pumping station and compensating for the missing costs by passing water from the reservoir to the end of the Akkapchigai canal and then to the Bandyhan canal. Recommendations on the mode of operation of the Bandyhan – I pumping station when transferring part of the machine irrigation lands to gravity in the zone subordinate to the Bandyhan canal by skipping the missing expenses by gravity from the Tupolang reservoir when it is filled twice during the construction period up to 60 million m^3: 1. February, March, 1st decade of April - the station does not work, water enters the Bandyhan canal by gravity from the Tupolang reservoir due to winter accumulation of up to 60 million m^3. Taking into account the average decade of the actual water supply of the pumping station over the past years, the reservoir accumulation up to 30 – 40 million m^3 is sufficient. 2. From the 2nd decade of April to the 1st decade of June, the pumping station does not work because the water resources of the Tupolang river are sufficient to compensate for the costs of the pumping station and planned water intake into the irrigation system of the Tupolang river, the total costs are less than the maximum capacity at the beginning of the Hazarbag canal and in the end part of the Akkapchigai. 3. In the 2nd and 3rd decades of June, in compliance with water use plans, the operation of a pumping station will be required, respectively, with an expenditure of 4.9 and 5.5 m^3/s. Considering the average annual sub-decadal expenses passing at this time at the beginning and end of the Khazarbag canal (45.4 m^3/s; 52.6 m^3/s and 4.4; 4.8 m^3/s), the pumping station could not work. 4. In July, August the pumping station is operating, fully ensuring the planned water intake into the Bandyhan canal because, during this period, the missing flow rates cannot pass due to the limited capacity of the Khazarbag canal and the limited water resources of the Tupolang river. 5. In September, October, and November – we recommend turning off the pumping station when using water filled in summer (up to 60 million m^3) partially to compensate for the costs supplied by the Bandyhan – I pumping station. The throughput capacity at the beginning and end of the Khazarbag canal allows this time to skip the additional planned expenses of the Bandyhan canal, amounting to 1.1 – 3.4 m^3/s. Activities on the Bandyhan channel when using it as a gravity. With the recommended operation of the pumping station in the period from the 2nd decade of June to August, the rest of the time it will be necessary to pass water flows compensating for the operation of the Bandyhan - I pumping station by gravity through the Khazarbag channel and its end part – the Akkapchigai channel, the distributor P–1 and the Bandyhan channel [7]. Currently, the management of the operation of the Tupolang – Karatag irrigation system has implemented measures to increase the capacity of the terminal part of the Akkapchigai canal to 15 m^3/s. This is enough to skip the total planned expenses at the end of Akkapchigai and the Bandyhan Canal. Work is also underway on reconstructing the R-1 spreader bringing its capacity to 11-12 m^3/s. The linear scheme along the Bandykhan canal is shown in Figure 1. Most of the expenses from the Bandykhan canal on the PC – 60 go to the Kyzyryk canal; the main consumers of water are the farms "Pakhtakor", "Gulyam", and "Tashkent". The linear scheme of the Kyzyryksky canal is shown in Figure 5. The maximum intake into the Kyzyryk canal following the linear scheme is 8.05 m^3/s. From the Kyzyryk Canal to the Bandyhan – I pumping station, water is taken to PC – 30 and PC – 11 with a total flow rate of only 0.4 m^3/s. The area suspended from the Bandyhan Canal this year was 6,300 hectares. It follows from the water use plan that the maximum expenditures in the head of the canal fall on the 3rd decade of June and the 1st and 2nd decades of July and range from 7.8 to 8.3 m^3/s. The peak of the maximum expenses occurs at the end of March – mid–April, and in July, the value of expenses at this time is 7.2 - 7.7 m^3/s. Let's consider whether the Bandyhan canal can work in two directions: with gravity irrigation, water enters the end of the Bandyhan canal, and with a reverse slope of the bottom, but with a direct slope along the water level it goes to the Kyzyryksky canal; with machine irrigation, water from the Bandyhan – I pumping station from KP – 0 moves with a direct slope to the Kyzyryksky canal [2]. Parameters of the Bandyhan channel: Flow rate Q = 11 m^3/s; Slope i = 0.0001; Roughness coefficient n = 0.017; Slope laying m = 2.0; Bottom width b = 2 m; Construction height N_{str} = 2.75 m; Reserve in the dam above normal water level Δh = 0.6 m; The thickness of the concrete lining t_b = 15 cm. We will make a hydraulic calculation of the channel for expenses: 1. The average decadal in the head of the Kyzyryk canal for the 2nd decade of July (the maximum expenditure among the average decadal expenditure over the past years) Q_{sr} = 6.2 m^3/s; 2. The maximum consumption according to the water use plan for the Kyzyryk canal Q_{max}^{pl} = 6.9 m^3/s; 3. The actual maximum flow rate in the head of the Kyzyryk canal over the past years Q_{max}^{f} = 7.7 m^3/s; 4. The maximum consumption according to the water use plan at the the head of the Bandyhan canal Q_{max}^{pl} = 8.3 m^3/s; 5. The maximum flow rate of the Bandyhan pumping station is I $Q_{p.s.}$ = 9 m^3/s. Depending on the resulting filling in the channel, its construction height, and taking into account the creation of a reverse water flow from the end of the Bandyhan Canal to the Kyzyryk Canal (from KP-66 to KP-60), we will find the remaining stock in the dam [8].

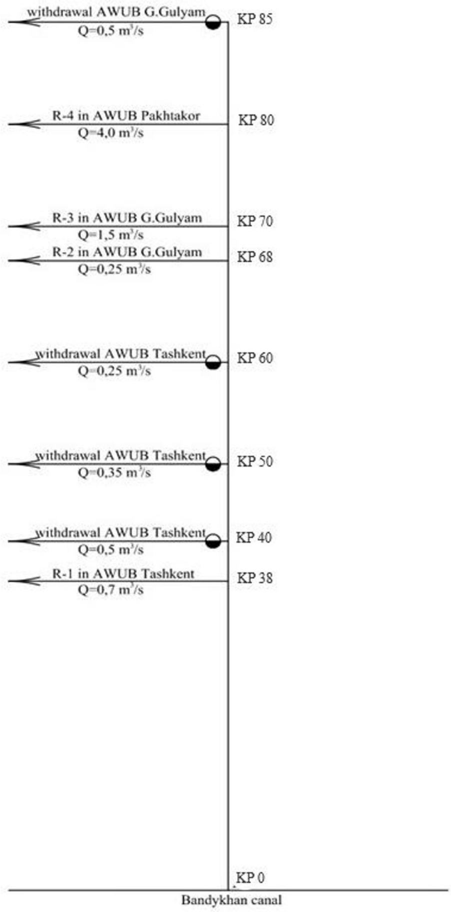


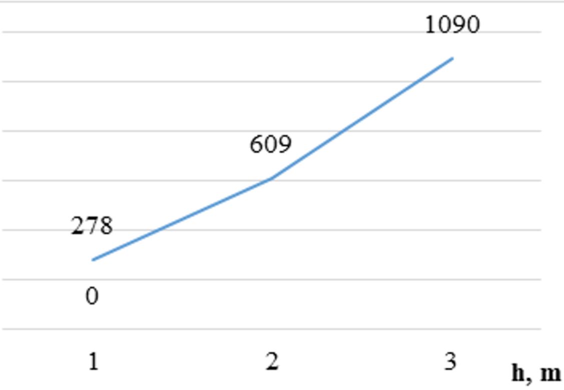
Fig. 5. Linear diagram of Kyzyryk canal

The calculation results are given in Table 5. The graph in Figure 7 was used to find the channel filling.

Table 5. Results of hydraulic calculation and reserves in dam at KP-66 of Bandyhan channel.

Name of expenses	Q, m^3/s	h, m	Δh, m
The average decadal maximum flow rate at the head of the Kyzyryk canal.	6.2	1.52	0.96
The maximum planned consumption in the head of the Kyzyryk canal.	6.9	1.6	0.88
The actual maximum flow in the head of the Kyzyryk canal over the past years.	7.7	1.66	0.82
The maximum planned consumption in the head of the Bandyhan channel.	8.3	1.74	0.74
The maximum flow rate of the Bandyhan pumping station is 1.	9.0	1.8	0.68
The maximum percentage consumption of the Bandyhan channel.	11.0	2.0	0.48

As follows from Table 6 and the longitudinal profile along the Bandyhan channel from KP-60 to KP-66 (figure 5.) with the actual maximum flow rate, which the pumping station $Q_{p.s.} = 9\ m^3/s$ has supplied over the years, the reserve in the dam at KP-66 remains quite sufficient Δh = 0.68 m. Even if the maximum design flow rate is missed, it will not be necessary to build up the dam because the reserve in the dam is at the same time Δh = 0.48 m. KP-66 to KP-60 on the Bandyhan channel, it is necessary to provide a blocking structure. At the same time, the channel will work in two directions: when the pumping station is operating and when gravity supplies water from the Akkapchigai channel to the end of the Bandyhan channel [6]. After water intake into the Kyzyryk canal on the Bandyhan canal from KP-60 to KP-0 (Bandyhan – I pumping station), there are only two outlets with a total flow rate of 0.4 m^3/s. Skipping such a flow in the opposite direction will not require the construction of dams on the Bandyhan canal.



h, m	k, m³/s
1	278
1,5	609
2	1090

Fig. 6. Graph $K = f(h)$

4 Conclusions

1. The Bandyhan – I pumping station should operate fully following the water use plan for the Bandyhan Canal from the 2nd decade of June to August;

2. In the period from March to the 1st decade of April, the expenses of the pumping station are compensated by the water accumulated in the Tupolang reservoir in winter in the amount of 30 – 40 million $m^{3,}$ and the expenses of the Tupolang river in domestic mode. This water flows by gravity from the Tupolang reservoir into the Bandyhan canal through the channels Hazarbag, Akkapchigai, distributor R – 1;

3. From the 2nd decade of April to the 1st decade of June, the costs of the pumping station are compensated at the expense of the water resources of the Tupolang river in the household mode. The capacity of the Khazarbag channels and its terminal part (Akkapchigai) allows you to skip these additional costs at this time;

4. From September to November – the costs of the pumping station are compensated by water from the Tupolang reservoir, accumulated in the summer in the amount of up to 60 million m^3;

5. When the Bandyhan – I pumping station is turned off, and water flows by gravity into the Bandyhan channel from the end part of the Akkapchigai, it will not be necessary to

build dams even with a maximum flow rate of Q = 11 m^3/s. But it is necessary to put a blocking structure on the Bandyhan canal after the diversion to the Kyzyryk Canal to create a direct slope along the water level from KP-66 to KP-60 of the Bandyhan canal;

6. The proposed mode of operation of the Bandyhan – I pumping station and the partial transfer of land suspended from the Bandyhan canal from machine irrigation to gravity irrigation when using Tupolang water and filling the reservoir twice in winter up to 40 million m^3 in summer – up to 60 million m^3, provide savings by reducing electricity consumption.

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References

1. O.A. Muratov. *Evaluation of the operational reliability of open spillway structures of reservoir hydroelectric facilities*//Abstract of PhD thesis, Tashkent, Uzbekistan (2019)
2. T.Z. Sultanov, I.A. Begmatov. *History of development of irrigation systems in Uzbekistan*, Irrigation and Meliration, **№01(3)**, Tashkent, Uzbekistan (2016).
3. B. Matyakubov, I.A. Begmatov, A. Mamataliev, S. Botirov, M. Khayitova. *Condition of irrigation and drainage systems in the Khorezm region and recommendations for their improvement* // Journal of Critical Reviews, ISSN- 2394-5125, **7**, Issue 5 (2020)
4. A. Rau, I.A. Begmatov, Z. Kadasheva, G. Rau, *Water resources management in rice irrigation systems and improvement of ecological situation in rice growing river basins*, in Proceedings of the IOP Conference Series: Earth and Environmental Science (**614**, No.1, p. 012151), IOP Publishing (2020, December)
5. A. Rau, I.A. Begmatov, G. Rau, *Study on the influence of rice paddies' water layer temperature on rice yield*, In Proceedings of the IOP Conference Series: Earth and Environmental Science (**939**, No.1, p. 012089), IOP Publishing (2021, December)
6. A. G. Rau, Z. K. Kadasheva, G.A. Rau, R. Meranzova, *Natural features and rational use of water resources in rice irrigation systems of Kazakhstan*, In Proceedings of the IOP Conference Series: Earth and Environmental Science (**548**, No. 2, p. 022061), IOP Publishing, (2020, August)
7. B. Matyakubov, D. Nurov, M. Radjabova, S. Fozilov, *Application of drip irrigation technology for growing cotton in Bukhara region*, In Proceedings of the AIP Conference (**2432**, No.1, p. 040014), AIP Publishing LLC (2022, June)
8. Z. Nie, X. Yang, Q. Tu, *Resource scarcity and cooperation: Evidence from a gravity irrigation system in China*, World Development, **135**, 105035 (2020)
9. O. Dengiz, *Comparison of different irrigation methods based on the parametric evaluation approach*, Turkish Journal of Agriculture and Forestry, **30**(1), 21-29 (2006)
10. M. Rahmatov, B. Matyakubov, M. Berdiev, *Maintainability of a self-pressurized closed irrigation network*, In Proceedings of the IOP Conference Series: Materials Science and Engineering (**1030**, No.1, p. 012170), IOP Publishing. (2021)
11. D. Masseroni, S. Ricart, F.R. De Cartagena, J. Monserrat, J. M. Gonçalves, I. De Lima, C. Gandolfi, *Prospects for improving gravity-fed surface irrigation systems in Mediterranean European contexts*, Water, **9(1)**, 20 (2017)

12. I.A. Begmatov, Sh. Botirov, A.Mamataliev, O.Durdiev, *Establishment of possibility of transferring part of machine irrigation land to gravity irrigation*, In Proceedings of the CONMECHYDRO – 2022, **365** 03032, Tashkent, Uzbekistan (2023)
13. S. Usmanov, M. Yakubov, Z. Mirkhasilova, L. Irmukhomedova, L. Babakulova, *The ways of using collector drainage waters for irrigation,* In Proceedings of the CONMECHYDRO – 2022, **365**, 01018//AIP Conference Proceedings, 2022, 2432, 030097 (2023)