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ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ

Satbayev University

# ХАБАРЛАРЫ

# ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ
НАУК РЕСПУБЛИКИ
КАЗАХСТАН
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**M. Li*, T. Ibrayev, N. Balgabayev, M. Alimzhanov, A. Zhakashov**

Kazakh Research Institute of Water Economy, Taraz, Kazakhstan.
E-mail: limarina76@mail.ru

# WATER DISTRIBUTION IN CHANNELS OF THE MOUNTAINOUS AND PIEDMONT AREA

**Abstract.** In Kazakhstan, the most fertile and promising for irrigated agriculture are the lands of the mountain-foothill zone of the south and southeast of the country, composed mainly of sedimentary, effusive-sedimentary rocks. To a lesser extent, Ordovician and Upper Paleozoic intrusive complexes are common in the composition of bedrock. Neogene - Quaternary deposits of various genesis and lithological compositions are presented as cover deposits. Irrigation canals in this region are distinguished by large (over 0.02) bottom slopes and makeup approximately 30-40% of the length of all canals. And as we have seen from the best operating practices of bottom outlets, the main reason for lowering their capacity by 50-60% of the engineering costs is the helicoidally flow motion in receiving chamber. The purpose of scientific research is to the processes of water distribution of the bottom outlet on canals with a turbulent water flow regime. Scientific research was carried out in laboratory conditions at an experimental facility.

The scientific research was conducted in laboratory conditions at an experimental facility. The process of helicoidally flow motion was observed during the experiments in a square receiving chamber. Graphs of variations in discharge capacity of bottom outlets with a square receiving chamber are plotted depending on its dimensions and water level difference in the tray and discharge pipe. The capacity grows with an increase in the dimensions of the rectangular receiving chamber. The bottom outlet with a square receiving chamber does not provide a designed waterway flow due to the helicoidally water flow motion in it. An aeration cord is formed in the center of the discharge pipe flow, and the discharge pipe does not function with a full cross-section. It is required to upgrade the hydraulic conditions of the waterway intake chamber and discharge facility pipe to increase the throughput capacity of the bottom water outlet using receiving chamber. This can be achieved: either by increasing the dimensions of the receiving chamber; or by installing an oblique front wall with a dividing partition at the rear wall of the receiving chamber.

**Key words:** Water allocation, field surveys, bottom water outlet, receiving chamber, helicoidal motion, hydraulic operation, irrigation channels.

**М. Ли*, Т. Ибраев, Н. Балғабаев, М. Алимжанов, А. Жакашов**

«Қазақ су шаруашылығы ғылыми зерттеу институты», Тараз, Қазақстан.
E-mail: limarina76@mail.ru

# ТАУЛЫ ЖӘНЕ ТАУ ЕТЕГІНДЕГІ АЙМАҚТЫҢ КАНАЛДАРЫНДАҒЫ СУДЫҢ ТАРАЛУЫ

**Аннотация.** Қазақстанда суармалы егіншілік үшін ең құнарлы және перспективасы бар жерлерге еліміздің оңтүстік және оңтүстік-шығыс тау етегі аймақтары жатады, бұл аймақтар, негізінен шөгінді, эффузивті-шөгінді жыныстардан құралған. Тау жыныстарының құрамында аз дәрежеде ордовик және жоғарғы палеозой интрузивтік кешендер жиі кездеседі. Неоген – әртүрлі генезді және литологиялық құрамды төрттік шөгінділері жамылғылар ретінде берілген. Суармалы жүйелердегі суландыру каналдары түбінің еңістері (0,02-ден) жоғары болып есептелетіндері шамамен барлық каналдар ұзындығының 30-40% құрайды. Түптік суөткізгіштердің пайдалану тәжірибесі көрсеткендей жобалық көрсеткіштерден өткізу қабілетінің 50-60% төмендеуінің негізгі себебі, қабылдау камерасында ағынның бұрамалы қозғалысы болып табылады. Ғылыми зерттеудің мақсаты – ағыны қарқынды режимдегі каналдардың түптік суөткізгіштердегі су бөлу процесстерін зерттеу. Ғылыми зерттеулер зертханалық жағдайда эксперименталды арнада жүргізілді. Эксперимент өткізу кезінде тікбұрышты қабылдау камерасында ағынның бұрандалы қозғалыс процесі байқалады. Тікбұрышты қабылдау камерасы бар түптік суөткізгіштердің өткізу қабілеті өлшемдері мен арнадағы және шығару құбыры деңгейлерінің айырмасын ескере отырып мәліметтері бар графиктер тұрғызылды. Тікбұрышты қабылдау камерасы бар түптік суөткізгіштер ағын бұрандалы қозғалыста болғандықтан, есептік өтімділікті қамтамасыз ете алмайды. Қабылдау камерасы бар түптік суөткізгіштердің өткізу қабілетін арттыру үшін су қабылдау камерасы мен құрылымның су тастағыш құбырының кіру бөліктерінің гидравликалық талаптарын жақсарту қажет. Бұған не қабылдау камералары мөлшерін ұлғайтумен; не қабылдау камерасының артқы қабырғасы мен алдыңғы қабырғасын бөліп тұратын көлбеу қалқа орнату арқылы қол жеткізуге болады.

**Түйін сөздер:** су бөлу, табиғи зерттеулер, түптік суөткізгіш, қабылдау камерасы, бұрамалы қозғалыс, гидравликалық жұмыс, ирригациялық каналдар.

**М. Ли*, Т. Ибраев, Н. Балгабаев, М. Алимжанов, А. Жакашов**

Казахский научно- исследовательский институт водного хозяйства,
Тараз, Казахстан.
E-mail: limarina76@mail.ru

# ВОДОРАСПРЕДЕЛЕНИЕ НА КАНАЛАХ ГОРНО-ПРЕДГОРНОЙ ЗОНЫ

**Аннотация.** В Казахстане наиболее плодородными и перспективными для орошаемого земледелия представляются земли горно-предгорной зоны юга и юго-востока страны, сложенные преимущественно осадочными, эффузивно-осадочными породами. В меньшей степени в составе коренных пород распространены интрузивные комплексы ордовика и верхнего палеозоя. В качестве покровных отложений представлены неоген – четвертичные отложения различного генезиса и литологического состава. Ирригационные каналы в данном регионе отличаются большими (свыше 0,02) уклонами дна и составляют приблизительно 30-40% протяженности всех каналов. Опыт эксплуатации донных водовыпусков показал, что основной причиной снижения их пропускной способности на 50-60% от проектных расходов сооружения является винтовое движение потока в приемной камере. Целью научных исследований является процессы вододеления донного водовыпуска на каналах с бурным режимом течения воды. Научные исследования проводились в лабораторных условиях на экспериментальной установке. Построены графики изменения пропускной способности донных водовыпусков с прямоугольной приемной камерой в зависимости от ее размеров и перепада уровней воды в лотке и отводящей трубе. Донный водовыпуск с прямоугольной приемной камерой не обеспечивает пропуск расчетного расхода воды из-за винтового движения потока воды в нем. Для увеличения пропускной способности донного водовыпуска с приемной камерой необходимо улучшить гидравлические условия входа в водоприемнуй камеру и отводящую трубу сооружения. Это может быть достигнуто либо увеличением размеров приемной камеры, либо устройством наклонной передней стенки с разделительной перегородкой у задней стенки приемной камеры.

**Ключевые слова:** водораспределение, натурные исследования, донный водовыпуск, приемная камера, винтовое движение, гидравлическая работа, ирригационные каналы.

**Introduction.** As to research conducted in 2021-2023 under the scientific and technical program “Irrigation technologies and technical facilities to introduce new irrigation lands, reconstruction and modernization of irrigation systems”, lands of the south and south-east of the country are seen to be the most fertile and promising for irrigated agriculture in Kazakhstan. The total irrigation area in Almaty, Zhambyl, Turkestan and Kyzylorda regions is 1.5 million hectares, or 77% of all irrigated land in the country (Ustabaev T., 2022). About 25-30% of irrigation areas in these regions are

located in the mountainous and piedmont area. Irrigation channels with high (over 0.02) bottom slopes on irrigation systems make up about 30-40% of the length for all channels (Creation of water allocation management in irrigation systems based on hydrological information, using water resources formation in river basins: Research report, 2021).

A feature of the hydraulic operation of channels on lands with large bottom slopes, composed mainly of sedimentary, effusive-sedimentary rocks, to a lesser extent represented by intrusive complexes of the Ordovician and Upper Paleozoic, and as cover deposits of the Neogene - Quaternary deposits of various genesis and lithological composition is a turbulent flow regime at certain water flow. (Hernández-Dueñas, 2011; Saleh, 2005; Prous, 2020). (Hernández-Dueñas et al., 2011; Saleh, 2005; Prous et al., 2020). A turbulent water flow regime and wave phenomena leads to a reduced channel capacity and hydraulic facilities on it. The channels of the mountainous and piedmont area show changes in a high range of slopes i=0.01-0.3 water flow rates q=0.2-25.0 $m^3/s$.

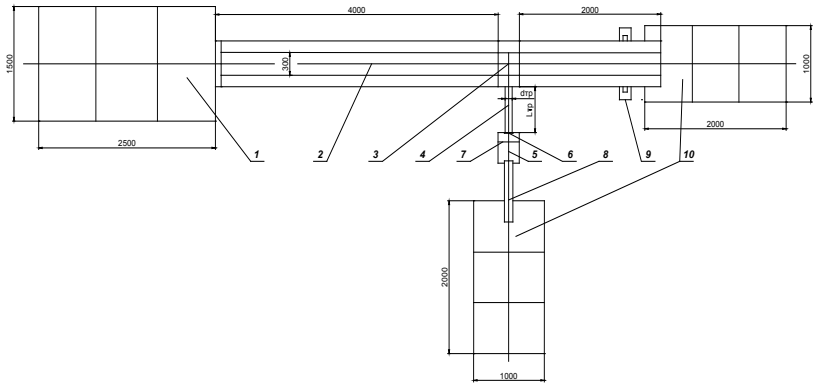
Field surveys of the water allocation process on channels with high slopes have shown that they do not function efficiently in a turbulent flow regime. Channels and hydraulic facilities often do not get design water flow rates, they are primed and their structural parts are distorted. So, there are important problems to study water apportioning processes in channels with a turbulent water flow regime (Brethouwer, 2022; Ding et al., 2021; Balakumar et al, 2007).

And as we have seen from the best operating practices of bottom outlets, the main reason for lowering their capacity by 50-60% of the engineering costs is the helicoidal flow motion in receiving chamber. Helicoidal motion and aeration cord in rotation center take up to 1/3 flow section of the discharge pipe. This results in further loss of the flow water strength (Shchev'ev, 1994).

Research objective is the water apportioning processes of bottom outlets on channels with turbulent water flow regime. Research guidelines to assess the effect of dimensions and design of a square receiving chamber, flow processes and vortex formation in the water intake, on a capacity of bottom water outlets (Jiang et al., 2020; Hunt et al., 1988; Kwak et al., 2020; Bhargava et al., 1984).

**Materials and Methods.** Experimental investigations were conducted in laboratory conditions.

The experimental facility was constructed to take laboratory tests of the bottom water divider during rapid stream flow and hydraulic processes following it (Figure 1). The receiving chamber of the water divider has a square cross form




The facility consists of: a receiving tank with a tranquilizer – 1, a metal tray – 2, a bottom water intake (8x12) – 3, a metal discharge pipe d 80 mm, 100 mm – 4, a water allocation (tranquilizer) well – 5, equipped with a sluice gate – 6 and a water wall – 7, a discharge tray – 8, screw elevators – 9, for vertical motion of the main tray, two water-measuring tanks equipped with triangular spillways – 10.
Figure 1. The experimental facility diagram

The receiving tank with a dimension of 1000x1500x2500 mm is installed at a height of 1000 mm and is equipped with a triangular Thomson spillway, with two stabilizing walls placed in front of it, and a grid in front of the tray access. Tray width along the bottom – 300 mm, length – 6000 mm, rate of slopes – 1.5 and consists of two sections with a length of 4000 mm and 2000 mm. Receiving water divider chamber of rectangular cross-section hxlxb = 80 x 240 x 300 mm, 100x300 mm is placed between them, which was moved in accordance with the diameter of the discharge pipe 80 mm, 100 mm.

The discharge pipe connects the receiving chamber with the water allocation well placed on a sliding support that allows you to up and down the well with the outlet under the modified slope of the main tray.

The water measuring tanks installed at the end of the main and outlet tray with a dimension of 700x1000x2000mm are equipped with Thompson spillways and two stilling walls. The change in the bottom slope of the main tray was made within i=0.00-0.06.

The water supply to experimental facility was made through a VK-12 centrifugal pump in a fixed pressure tank offering a drain valve to reduce level fluctuations. The water flow supplied to facility was regulated by valves and measured on the triangular spillway of the receiving tank.

Modeling was conducted according to the Froude criterion and the geometric model scale was taken to be λ=10 (Kisselyov, 1972; Nedrigi, 1983). The accepted dimensions of the experimental facility made it possible to conduct research in the following ranges of variation:

- Slope i=0.005, 0.01, 0.02;
- Water flow rate q1=2.0 $m^3/s$, 6 $m^3/s$, 10 $m^3/s$;
- Supply pipe diameters of 80 mm and 100 mm;
- Ratio of the receiving chamber dimensions h/b = 1, 0.7, 0.5, 0.3; where h is the depth of the receiving chamber, b is the width of the receiving chamber.

The following measurements were taken during the experiments:

- Supplied q1, diverting q2 and transit q3 water discharge flow rates;
- The contours of the free flow surface on the receiving chamber section;
- Flow depths in the main tray;
- Values of the static difference in water levels in the tray and outlet.

The level control of the free water surface and the depth were measured using a scale to define the maximum and minimum fluctuation values of the water surface levels.

Static pressure magnitude was defined from the difference of the water horizon marks above the ledge of the intake chamber and in the water allocation well. The water horizon plotting was conducted through leveling.

Control of the water flow rate in the receiving chamber was conducted through a Pitot tube, due to the significant aeration of the water flow.

**Result and discussion.** The process of helicoidal flow motion was observed during the experiments in a square receiving chamber.

Graphs of variations in discharge capacity of bottom outlets with a square receiving chamber are plotted depending on its dimensions (Figure 2) and water level difference in the tray and discharge pipe (Figure 3).

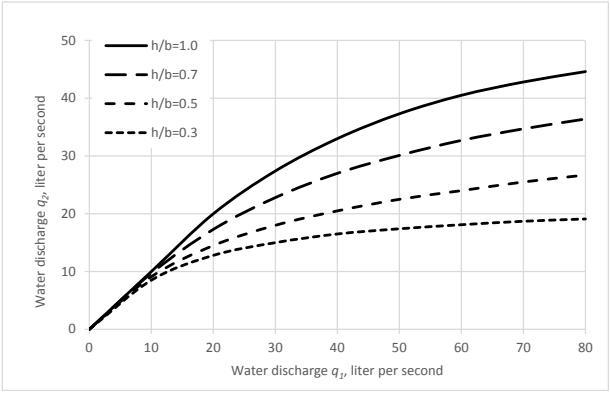



Figure 2. Dependence graph of the diverting water flow rate on the supplied water flow rate

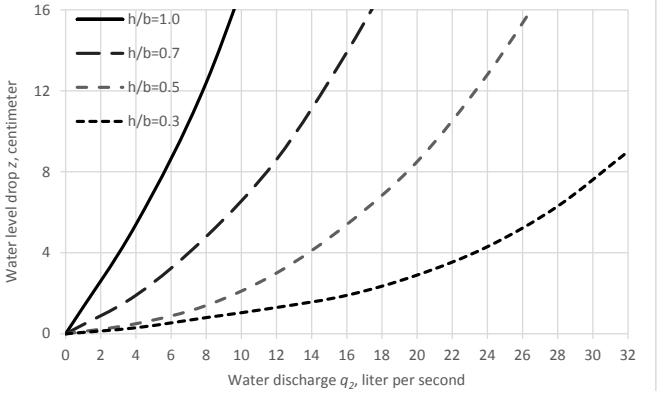



Figure 3. Dependence graph of the water level drop on the discharge water flow

The difference in water levels in the tray and the discharge pipe was resolved according to the following formula

$$z = (A - i \cdot l) - B_i \quad (1)$$

where A is the mark of the water horizon in the tray along the ledge of the receiving chamber;

i· - tray slope;

l - distance from the ledge to the discharge pipe;

B – water horizon mark in the tranquilizing tank of the discharge pipe.

z drop magnitude varied in the range from 4 cm to 15 cm.

Following the results shown in the graphs, it can be seen that facility capacity grows with an increase in the dimensions of the rectangular receiving chamber. This is due to high losses of water flow energy for helicoidal motion, the intensity of which grows with a decrease in the dimensions of the receiving chamber. Besides, water jet with small dimensions of the receiving chamber enters the discharge pipe tangentially, i.e. tangentially to side surface of the receiving chamber. At the same time, an aeration cord is formed in the center of the discharge pipe flow, and the discharge pipe does not function with a full cross-section.

Increasing the dimensions of the receiving chamber to h/b>3 results in the following:

- Main jet deflection is smoother;
- Helicoidal motion intensity behind the protrusion of the receiving chamber decreases sharply;
- There is no helicoidal motion in discharge pipe.

There is an improvement in the conditions for entering the water flow into the pipe, since the loss of water pressure in the receiving chamber is mostly due to the momentum transfer of the main water flow into the vortex area.

The hydraulic operation mode of the bottom water outlet can be improved by the following measures (Figure 4):

- Front wall is oblique at the entrance of the receiving chamber, for a smoother entry of the water flow;
- Separation wall mechanism on the rear wall of the receiving chamber, for damping helicoidal motion of the water flow.

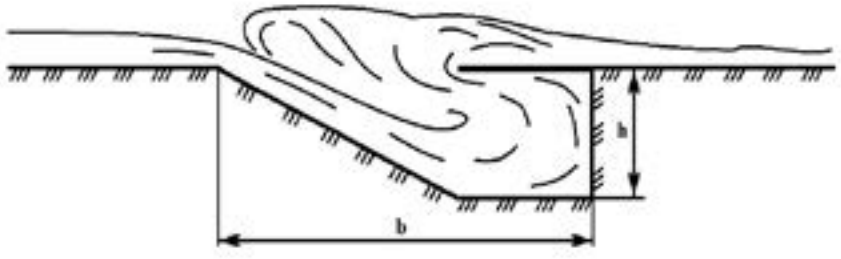



Figure 4. Receiving chamber diagram

Such a water outlet has a high capacity compared to water outlets with a rectangular receiving chamber, about 2 times. However, the mechanism of the oblique wall and the dividing side does not fully exclude the area of turbulent vortices formation. The dimensions of these areas are many times smaller compared to a rectangular receiving chamber.

Three modes of water flow were observed in the receiving chamber during the research:

1. The first mode of water flow is found with small tray fillings ($q1 < 40$ l/sec), a high water intake coefficient ($k = q2/q1 > 0.75$). As to this case, the flow merges along the lower oblique side of the receiving chamber without leaving the surface. Afterwards, the water flow broadens and a vortex area arises above it at the upper dividing wall.

2. The second mode of water flow is caused by a high filling of the tray ($q1 \approx 60$ l / sec), the average coefficient of water intake ($k = 0.5$). The water flow is totally trapped by the receiving chamber and breaks away from the oblique side. Two areas with vortex motion are formed in the receiving chamber – at the oblique side and the dividing wall. Since the discharge pipe cannot pass the entire water flow, an area of high water level arises above the dividing wall.

3. The third mode of water flow is seen with high tray fillings ($q1 \approx 60$ l/sec), low water intake coefficient ($k = 0.15$). Isolated section of the water flow is pressed against the separation wall, and a helicoidal area is formed at the oblique side of the receiving chamber. In this case, the water outlet does not guarantee the passage of the isolated water flow, as water flow is squeezed out by a helicoidal motion from the discharge pipe, and the thickness of the trapped water layer decreases.

Discharge outlet does not have a great impact on the structure of the transit water flow with high tray fillings while reducing the water intake coefficient.

**Conclusions.** Irrigation channels with high (over 0.02) bottom slopes on irrigation systems make up about 30-40% of the length for all channels. And as we have seen from the best operating practices of bottom outlets, the main reason for lowering their capacity by 50-60% of the engineering costs is the helicoidal flow motion in receiving chamber.

Experimental studies of the water apportioning processes of bottom outlets on channels with turbulent water flow regime were carried out. Graphs of variations in discharge capacity of bottom outlets with a square receiving chamber are plotted depending on its dimensions and water level difference in the tray and discharge pipe.

Three modes of water flow were observed in the receiving chamber during the research: the first mode of water flow is found with small tray fillings, a high water intake coefficient; the second mode of water flow is caused by a high filling of the tray, the average coefficient of water intake; the third mode of water flow is seen with high tray fillings, low water intake coefficient. All three modes of water flow have vortex area. Discharge outlet does not have a great impact on the structure of the transit water flow with high tray fillings while reducing the water intake coefficient.

The bottom water outlet with a rectangular receiving chamber does not allow the passage of design water flow due to the helicoidal motion of the water flow in it. It

is required to upgrade the hydraulic conditions of the waterway intake chamber and discharge facility pipe in order to increase throughput capacity of the bottom water outlet using receiving chamber. This can be achieved: either by increasing the dimensions of the receiving chamber; or by installing oblique front wall with a dividing partition at the rear wall of the receiving chamber.

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**Information about the authors:**

**Marina Li** – Candidate of Technical Sciences, leading researcher of The Kazakh Scientific Research Institute of Water Economy LLP, Taraz, Kazakhstan; limarina76@mail.ru; https://orcid.org/0000-0002-8880-5705;

**Tursun Ibrayev** – PhD, Deputy Director for Research of The Kazakh Scientific Research Institute of Water Economy LLP, Taraz, Kazakhstan; kiwr-t@mail.ru; https://orcid.org/0000-0002-1450-5275;

**Nurlan Balgabayev** – Doctor of Agricultural Sciences, Research Director of The Kazakh Scientific Research Institute of Water Economy LLP, Taraz, Kazakhstan; balgabayev@mail.kz; https://orcid.org/ 0000-0001-8127-7981.

**Mamirzhon Alimzhanov** – junior researcher of The Kazakh Scientific Research Institute of Water Economy LLP, Taraz, Kazakhstan; alimzhanov.mamur@bk.ru; https://orcid.org/ 0000-0003-0541-2779.

**Aidos Zhakashov** – junior researcher of The Kazakh Research Institute of Water Management LLP.; aidos.zhakashov.86@mail.ru; https://orcid.org/ 0000-0002-5471-5795.

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