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Operation damless intake of the Amudarya river (Central Asia)

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Abstract. The article describes the nature of the ongoing channel processes occurring in large damless water intakes from the Amudarya-Karakum, Karshi, and Amu – Bukhara channels located in its middle course. The characteristic features of the ongoing channel processes in the area of water intake are given. Based on the analysis of the current state of damless water intake, a method for improving its operation is recommended. To solve the problems of ensuring high-quality water intake and water supply, experimental studies were carried out to determine the angle of the bottom threshold in the inlet section of the head structure in the ABMCh. The analysis of the studies showed that for the threshold angles to the shore $\beta = 30^\circ, 45^\circ, 60^\circ$, an increase in the angle β from 30° to 60° increases the intensity of the artificial transverse circulation formed in the flow. It is proved that this circumstance is also true for a constant angle of threshold β with an increase in the relative threshold height H_{rth} . The bottom threshold ensures the entry of bottom sediments into the head structure of the damless water intake. The threshold height is set to 1.44 m, which is determined in comparison with the height of the beds of sediments. To prevent the entry of a large amount of bottom sediment into the head structure of a damless intake, it is recommended that the device be used especially in the inlet section of the channel. It is shown that a Karakum channel is intensively exposed to deigish. Moreover, in this process a certain sequence is traced. First, one deigish is formed, the erosion products of which create favorable conditions for the occurrence of the next deigish. So the chain of deigish “walks” along the shore. The distance between deigish, also a “step,” varies widely: from 3-7 to 15-40 m or more. Then, the remaining protrusions between the deigish are washed out, which leads to a general expansion of the channel. It has been established that deigish appears and develops in both straight and curved sections of the channel. In the latter case, they are formed mainly on the concave bank, although there are cases of their location on the convex. This means that there are corresponding conditions for its formation in both straight and curved sections of the channel. It is substantiated that the formation and intensive development of deigish are associated with the intense channel-forming activity of the flow, which manifests itself both in the process of developing channel forms and in active sediment transport. It is recommended that in order to prevent the deigish process, it is necessary to carry out water management measures aimed at strengthening the channel of the channel. The implementation of concrete cladding using modern materials to reduce losses on filtering the channel in addition to



preventing deigish channel and also helps to increase the efficiency of the irrigation channel.

1. Introduction

The Amudarya river is characterized by the intensity of its course, due to the high flow rates, steep slope of the channel bed and free surface, significant transporting capacity of the stream. All this together with the easily moving channel along which the Amudarya flows, creates conditions for the wandering of the stream, eroding the right and left banks, washing out the developed lands, resolving dams, complicating the operating conditions of such a large ' into the Karakum Channel. Obtaining a guaranteed volume of water with the least amount of sediment and the effect on flow dynamics becomes a problem for hydraulics with damless water intake. The solution to this important problem is the main factor in the normal operation of damless water intakes, which justifies the relevance of the presented work [1]. Based on the relevance of solving the problem of operation, damless water intakes to the Karakum, Karshi Main, and Amu-Bukhara machine channels were taken as the object of study.

To solve these problems, large-scale studies were conducted by such foreign scientists as F.Virgilio, K.Elpidio, A.V. Klovsky, D.V. Kozlov V.A. Shaumyan, and others [2,3,4,5,6,7]. To date, on the basis of the well-known theoretical studies of these authors with the use of extensive experimental and field studies S.T. Altunin, N.F. Danelia, R.J. Julaev, E.A. Zamarin, A.S. Obrazovskiy, M. V. Potapov, and their students proposed and introduced into the practice of channel hydraulics [8,9,10,11,12].

S.K. Abalyants, A.M. Mukhamedov, K.F. Artamonov, D.A. Atashev, D.S. Saryev, H.A. Irmukhamedov, H.A. Ismagilov, I. A. Buzunov, R. Urkinbaev, J. Kuchkarov and many others[11,12,13,14,15].

Despite the fact that extensive research has been carried out to solve the above problem, due to the complexity and multifactorial nature of the reasons for the ongoing processes in the area of damless water intakes, called channel processes, and also due to the lack of a rigorous theoretical solution, its logical completion has not yet been achieved[16,17,18].

A comparative analysis of large damless water intakes and give recommendations on improving the operating conditions of damless water intakes determining the optimal mode of their operation is the main goal of this work [19–20].

2. Methods

Consideration of the current state of large damless water intake, determining the features of the ongoing riverbed processes in the area of damless water intakes, and choosing the optimal operation option is the main method for studying this work.

3. Results and Discussion

The construction of large damless water intakes in the Karakum Channel, Karshi Main Channel, Amu – Bukhara Machine Channel caused disturbances in the everyday mode of the middle course of the river. Amudarya, changing its channel process since water is discharged from the river disproportionately to the amount of sediment, i.e. water entering the regulator being preliminarily purified from certain fractions of sediment that is discharged into the floodplain of the river.

Having lost part of the water flow rate and increasing its turbidity due to discharged sediment, the river's transporting ability gets reduced. Therefore, sediment deposition occurs below the water intake point, and sedimentation occurs along the coast where the water intake point is located. Here, the marks on the bottom of the river begin to grow and there is a double effect on the channel: firstly, the stream pushing the channel away with deposited sediments in the direction opposite to the water

intake of the coast; secondly, a transverse slope is formed in the river also in the direction of the opposite bank.

According to the foregoing, it can be stated that the conditions for guaranteed water withdrawal are worsening in the water intake area. The river channel is constantly moving away from the water intake point, which requires huge costs for the construction of an additional section of the drainage channel. Similar situations are observed at the intakes of the Karakum Channel, the Karshi Main Channel-KMCh, and the Amu-Bukhara Machine Channel-ABMCh.

Changes in flow rates and water levels for the medium flow of the river. The Amudarya river, where the damless water intake to the Amu-Bukhara Machine Channel (ABMCh) is located, was studied on the basis of water flow measurement materials made at the section of Kerki and Chardzhou Railways Bridge. In addition to them, field observation materials from the operational service of the ABMCh and Uzhydromet channels were also used [24].

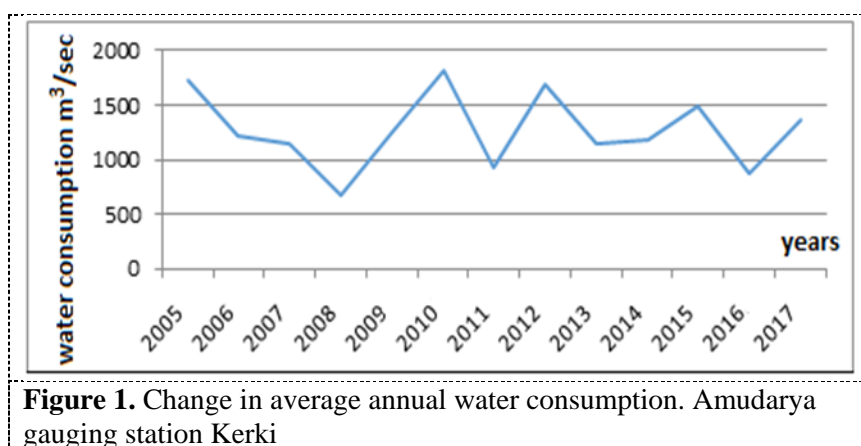


Figure 1. Change in average annual water consumption. Amudarya gauging station Kerki

The highest average annual water discharge was observed in the following years: in 2005 - 1722 m³/s; in 2010 - 1822 m³/s; in 2012 - 1691 m³/s. In the period from 1980 to 2003, the lowest average annual water discharge was observed: in 2008 - 671 m³/s; in 2011 - 929 m³/s; in 2016 - 866 m³/s.

Now we will consider the flow of water from the river to the inlet sections of the ABMCh. Based on daily water discharges passing through ABMCh, monthly mean values were determined at the entrance to the water intake channels. For clarity, incoming expenses were grouped by month, i.e. The range of flow rate is shown. Calculations showed that the amplitude of the monthly flow rate changes in large ranges.

Such sharp fluctuations in water consumption included in the ABMCh are associated with unregulated inlet gauges and water consumption schedules during the washing of fields from salt and their recharging before sowing and irrigation of various types of crops throughout the growing season.

Sharp fluctuations in water flow during one month in 1999-2018 very often lead to complications, when water is supplied through channel № 1, excess water often flows out, through channels № 2 and № 3, there were cases of water returning to the river - up to 450 m³/s.

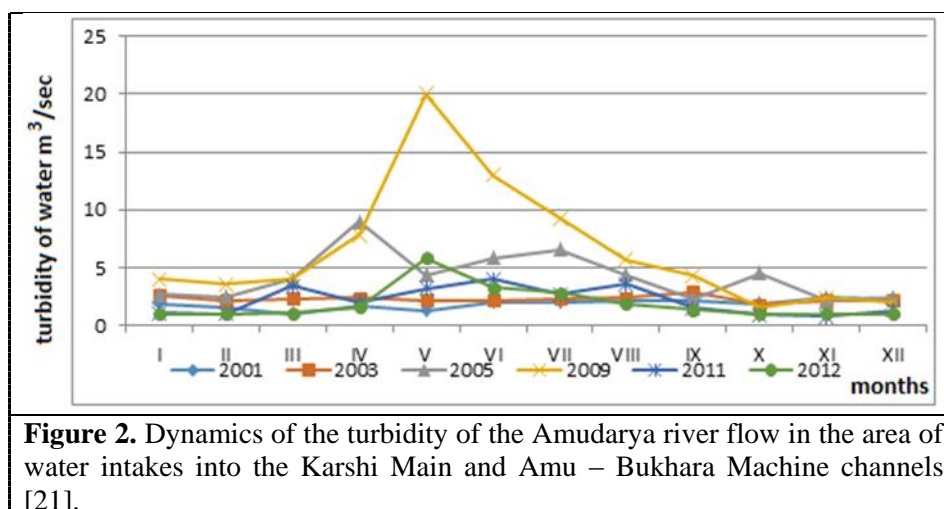
Thus, due to the unregulated input, the total water flow during the flood reaches up to 800 m³/s and more. Together with water, a large amount of sediment enters the channel. In high-water years of passing costs, it is accompanied by high water levels, the best conditions for water intake to the Amu-Bukhara Channel arise, and significant difficulties in organizing water supply are not observed. The greatest difficulties in the implementation of water supply arise during the low water period, and especially in dry years.

In low water low costs are accompanied by low water levels, which leads to low levels in front of the regulator of the head office of the ABMCh. There were cases of a complete opening of the regulator gates, then the level differences between the upper and lower pools decreased to 0.2 – 0.3 m.

In dry years, in the process of reforming the river bed, a flood dump to one of the banks and a river moving away from the water intake point are often observed. As a result of this, the drive of planned water flows to the head regulator ABMCh and then to the pumping stations of the first lift is becoming more complicated.

Dump of the stream to one of the banks leads to its erosion and exclusion of significant sown areas from crop rotation. To protect the coast from further erosion, often in emergency order, shore protection works are carried out. In such cases, the erosion depth at the protected coast reaches 18.0–20.0 m, and in the absence of protective measures, the erosion depth does not exceed 6.0–8.0 m. According to the observations of some authors, up to 25% of the coastal area is washed out Amudarya river. The study of changes in sediment discharge shows that the highest sediment discharge in the Amudarya reaches 9.500 kg/s. The average annual flow rate of suspended sediment over a multi-year period is 6500 kg/s. The annual sediment runoff over a multi-year period is 210.000 thousand tons or 168 million m³, which gives an average flush from the basin area of 650 t/km² or 520 m³/km².

As the results of field studies of the authors of this article show, the turbidity of the river in the area of damless water intakes in the KMCh, and the ABMCh varies in wide ranges (figure 2).



As can be seen from the figure, suspended sediments are intensively transferred to the head structures of damless water intakes, which are intensively deposited on the channel bed as a result of changes in the hydrological regime under the influence of pumping stations, which contributes to a decrease in the throughput of the head structures of damless water intakes.

One of the most difficult problems to solve while ensuring high-quality water intake and water supply is the fight against the capture of bottom sediment by the water intake. Despite a large number of theoretical and experimental studies, this method of influencing the hydraulic structure of the flow is not well understood.

To solve the problems of ensuring high-quality water intake and water supply, experimental studies were carried out to determine the angle of the bottom threshold in the inlet section of the head structure in the ABMCh. An analysis of the experiments shows that for the threshold angles to the shore $\beta = 30^\circ, 45^\circ, 60^\circ$ showed an increase in the angle β from 30° to 60° helps to increase the intensity of the artificial transverse circulation formed in the flow. The aforementioned circumstance is also true for a constant angle of threshold β with an increase in the relative threshold height H_{rth} . The bottom threshold ensures the entry of bottom sediments into the head structure of the damless water intake. The threshold height is set to 1.44 m, which is determined by comparison with the height of the beds of bed sediments.

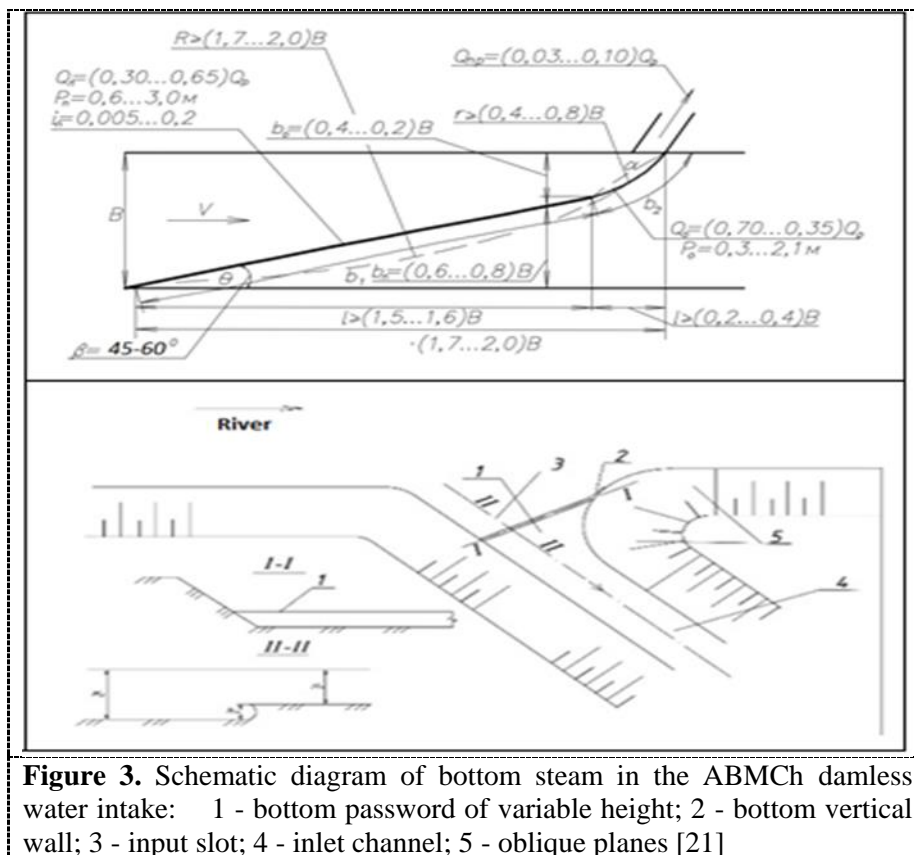


Figure 3. Schematic diagram of bottom steam in the ABMCh damless water intake: 1 - bottom password of variable height; 2 - bottom vertical wall; 3 - input slot; 4 - inlet channel; 5 - oblique planes [21]

In addition, unlike KMCh and ABMCh in the channel of the Karakum Channel, flowing in easily eroded soils, a sudden destruction of the banks is observed immediately at a distance along the river of hundreds of meters and even kilometers, which is called deigish. As a result of deigish, the morphometry of the channel of the channel changes sharply, and the direction of flow in the channel of the channel changes. The solution to this important problem is the main factor in the normal operation of damless water intake, which justifies the relevance of the presented work. The inconstancy of the river section of the Amudarya river channel creates exceptional difficulties for irrigation, constantly violating the normal water intake into irrigation channels due to constant erosion and growing banks, and also creates a threat of flooding of farmland and settlements. Of the abovementioned damless water intakes, the largest is the water intake to the Karakum Channel, the problems of which are discussed in the framework of this work.

The Karakum channel stretches from the Amudarya river above the city of Kerki to the west through the southern part of the Karakum desert and the foothills of Kopetdag. The length of the channel is over 1100 km, to the water intake at the beginning of the channel is 10 – 12 kilometers cubic. The construction of the Karakum channel began in 1954. From the Amudarya River to the Murghab river, 400 km long, the completion was completed in 1959. The first 40 km pass along the extended channel of the Bosag – Kerkin Channel, then for 70 km along the chain of basins of the Kelif Uzboy, which turned into a series of lakes. Further, the Karakum channel crosses the sands of the South-East Karakum. Subsequently, the waters of the Karakum channel were fed by a machine channel upstream of the Murghab to Turkmen-Kala. To the city of Tejen, 140 km, - in 1960.

The Khauz-Khan reservoir with a capacity of 650 million cubic meters was created (an increase of up to 875 million cubic meters is envisaged. To Geok –Tepe 300 km, in 1967. In this section, the Karakum Channel runs along the foothills of Kopetdag. In 1962 brought to Ashgabat. In 1973, the

Kopetdag Dam and two dams were built in Ashgabat. It ends with the Kopetdag reservoir under construction with a capacity of 190 million cubic meters.

Ashgabat has created two reservoirs with a capacity of 4.8 million cubic meters and 6 million cubic meters. According to the general development plan, the Karakum channel is planned to lengthen the channel with branching from Kazanjik to the Kizyl-Atrek channel to irrigate the desert lands of the southwestern part of Turkmenistan, and the Nebit-Dag channel to supply water to the oil field of Western Turkmenistan.

Further, the channel stretched to the city of Bereket, then to the Atrek river and the city of Nebit-Dag (below Balkanabat), the length of 270 kilometers. The final construction was completed in 1988. The Karakum channel is equipped with a lead structure with a capacity of over 300 m³/s, a shipping lock, and a number of waste and retaining structures, as well as releases to distributors and reservoirs. In order to eliminate the negative impact on the land fertility of the rise in groundwater level that occurred in connection with the supply of additional large volumes of water, a drainage network is being built in the channel zone.

As a result of the commissioning of the Karakum Channel, the zone's water resources and water supply to irrigation systems were significantly increased. The channel meets the water needs of the cities, industry, and agriculture of Turkmenistan.

Irrigation area in the zone of the Karakum channel increased from 170 to 300 thousand hectares; 5 million hectares of distant pastures are flooded. Fishing has developed on the Karakum Channel (catfish, common carp, rudd, barbel, silver carp).

In the area of the damless water intake into the Karakum channel and the channel itself, a typical process is the deigish process, a detailed analysis of the reasons for the formation of which was performed by A.V. Muratov. Long-term experience in operating the channel shows that intensive channel reformation of its sections lying in the light soils of the sand zone, as a rule, was accompanied by the formation of deigish.

As an analysis of the results of field studies devoted to the problems of deigish shows, in many areas of the "outbreak" of deigish formation coincide with a period of rising levels and an increase in water consumption (from mid-May to the end of June). However, there are sections of the channel where deigish appear when water levels drop. There are cases of repeated deigish formations on the same channel section. So, for example, in May 1961, Deigish formed on the right dam. In order to eliminate the danger of a channel breakthrough, urgent work was carried out to fill the erosion funnel. But these works had to be repeated five times in connection with the emergence of a new deigish after each backfill.

The erosion process during the formation of deigish takes place intensively, reaching in some cases up to 2 m/h. In places of deigish formation, within several hours, the stream is able to erode thousands of cubic meters of soil. The diameter of the erosion funnel is different and varies between 10-60 m and more, and the depth 5 – 10 m.

An analysis of the results of observations over several years has led to the conclusion that the achievement of relatively stable transverse channel forms and a longitudinal slope in the Karakum Channel, in sandy soils, is accompanied by the formation of deigish. Moreover, a certain sequence is traced in this process. First, one deigish is formed, the erosion products of which create favorable conditions for the emergence of the next deigish. So the chain of deigish "walks" along the shore. The distance between deigish, also "Step", varies widely: from 3-7 to 15-40 m or more. Then, the remaining protrusions between the deigish are washed out by the flow, which leads to a general expansion of the channel.

This process accelerates the achievement of shapes and sizes of a relatively stable channel. So, for example, on January 16, 1962, the live section of the channel 211 km before the formation of deigish was 160 m², and in June 1962, after the formation of deigish, it amounted to 204 m². The calculations allow us to conclude that in this area for a stable channel, a cross-sectional area of 192 m² is required. Thus, the actual channel turned out to be 12 m² more than the calculated one.

An analysis of long-term field observations of the process of formation and development of deigish on the Karakum Channel made it possible to establish some general point's characteristics of this process.

Deigish arises and develops in both straight and curved sections of the channel. In the latter case, they are formed mainly on the concave bank, although there are cases of their location on the convex. This means that there are corresponding conditions for its formation in both straight and curved sections of the channel. The formation and intensive development of deigish are associated with the intense channel-forming activity of the flow, which manifests itself both in the process of developing channel forms and in active sediment transport.

Local erosion (deigish) is observed in various soil conditions (homogeneous sand dunes, sandy loam, loam). This suggests that, in addition to local causes for the formation of deigish (for example, yields of indelible or difficult to eroded soils), there is also a reason due to the nature of the general process of channel formation.

The sizes of deigish in various soil and hydraulic conditions are significantly different, but at present it is not possible to establish any regularity. Apparently, the most important are the conditions that are created in this place and determine the degree of active influence of the flow on the channel shore.

Regardless of the reasons for the formation of deigish in the course of their development, a certain sequence and relationship between the links of this process is developed: the erosion of the banks and the bottom of the channel, the formation of coastal forms (ridges, sidewalls) that ensure the removal of erosion products outside the deigish. Thus, the main condition that determines the possibility of development of deigish is the establishment of a single hydraulic circuit from the area of erosion of the shore to the removal of erosion products in the zone of transit flow.

In areas of the channel where longitudinal slopes have been established that correspond to the relatively stable state of the channel, and where the live section area corresponds to the hydraulic characteristics of the flow, the formation of deigish is rarely observed. Despite the fact that at present, in many areas, the shape and dimensions of the channel are close to the stable state of the channel, nevertheless, the formation of deigish is observed. It is especially undesirable for them to form in sections of the channel that extend into the embankment, since the width of the dam along the top is less than or equal to the diameter of the deigish funnel. In such cases, erosion can lead to a burst of the dam.

According to the authors of this work, lining the surface of the channel prevents soil moisture, which stops deigish. Usually, all channel lining is divided into anti filtration and shore protection.

Anti filtrations are designed to: reduce filtration losses from channels, reduce resistance to water flow, increase the channel's efficiency (efficiency), prevent flooding and salinization of channel lands, protect the riverbed and coastal slopes from erosion by water flow, wave and ice effects. In our case, a complex lining is required, which provides at the same time anti filtration and shore protection channel. Concrete and reinforced concrete claddings are coatings made of monolithic concrete, cut by temperature-expansion or temperature-shrink seams into structural and technological maps; or from prefabricated reinforced concrete slabs such as NPK. The thickness of monolithic claddings is accepted from 10 to 20 cm, and prefabricated 8 - 12 cm. In concrete-film claddings, the anti-filter element from the polymer film is protected from above with a layer of monolithic concrete. Soil-film screens are located under the protective soil layer with a thickness of 0.5 - 1.0 m. There are also purely polymer coatings, screens made of polymer materials, laid on the surface of the bed, and channel slopes without a protective layer on top. In practice, the most often used for channel linings are prestressed, reinforced smooth plates with a thickness of 6 cm. These plates are economical and have relatively little reinforcement. However, they have low indicators of frost resistance and fracture of concrete in the slab section. In this regard, they began to use anti filtration coatings from NPK plates in combination with a polyethylene screen. Between prefabricated cladding plates, after 12 - 20 m or more, gravel and sand preparations are arranged in the form of return filters and drainage devices are

in the form of channels for removing possible filtration backpressure under fastening under the wave action of water.

In the practice of channel reconstruction, irrigation channels of trapezoidal and rectangular sections in precast monolithic reinforced concrete cladding from precast slabs are widespread. Channels with such facings work well at flow rates of up to 5 m/s, when large sediments with a diameter of more than 2 mm do not enter the channel. Bank protection and antifiltration linings (except for soil-film) provide reliable operation of channels at high slopes and flow rates, respectively, and high throughput. However, in the conditions of the mountain-foothill zone with high alluvial conditions, not all claddings withstand the design life.

4. Conclusions

An analysis of the results of observations conducted over several years led to the conclusion that:

- As a result of intensive inflow, a large number of sediments of the channel bed of KMCh and ABMCh channels are intensively silted;
- To prevent the entry of a large amount of bottom sediment into the head structure of the damless water intake, a device is sometimes recommended in the inlet section of the channel;
- An analysis of the experiments showed that for the threshold angles to the shore $\beta = 30^\circ, 45^\circ, 60^\circ$, an increase in the angle β from 30° to 60° increases the intensity of the artificial transverse circulation formed in the flow. It is substantiated that this circumstance is also true for a constant threshold angle β with an increase in the relative threshold height H_{rth} . The bottom threshold ensures the entry of bottom sediments into the head structure of the damless water intake.
- On the Karakum channel, in sandy soils, the achievement of relatively stable transverse channel forms and a longitudinal slope is accompanied by the formation of deigish. Moreover, in this process a certain sequence is traced. First, one deigish is formed, the erosion products of which create favorable conditions for the occurrence of the next deigish. So the chain of deigish “walks” along the shore. The distance between deigish also “Step”, varies widely: from 3-7 to 15-40 m or more. Then, the remaining protrusions between the deigish are washed out, which leads to a general expansion of the channel;
- It is established that deigish arises and develops in both straight and curved sections of the channel. In the latter case, they are formed mainly on the concave bank, although there are cases of their location on the convex. This means that there are corresponding conditions for its formation in both straight and curved sections of the channel. The formation and intensive development of deigish are associated with the intense channel-forming activity of the flow, which manifests itself both in the process of developing channel forms and in active sediment transport;
- To prevent the deigish process, it is necessary to carry out water management measures aimed at the shore of strengthening the channel of the channel. The implementation of concrete cladding using modern materials to reduce losses on filtering the channel in addition to preventing deigish channel and also helps to increase the efficiency of the irrigation channel.

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