Karakum Canal: Artificial River in a Desert

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Abstract The idea to use the water of the Amudarya River for irrigation of the Karakum Desert was shaped in the eighteenth century and it was partially realized during the tsarist time in Russia. But only in the 1950s the Karakum Canal, the world's major hydraulic engineering project, was designed and constructed. After Turkmenistan became an independent state this canal was renamed Karakum River. The artificial Karakum River ("outflow" from the Amudarya by analogy with inflow) connected Amudarya, Murghab, and Tedzhen rivers into a single water system making the basis for economic development of the country. This artificial river permitted to extend the irrigated lands for growing cotton, fodder crops, vegetables, and melon crops; to create fishery farms; to water desert pastures and, accordingly, stimulate development of distant-range grazing of cattle; to develop shipping and use the waters of this river in industry and power engineering.

Keywords Irrigation, Karakum Canal, Water resources

Contents

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1 Introduction

Casting glance on the map of Turkmenistan you can easily see the disproportion in the geographic combination of the main natural factors: water and land are separated by the vast expanses of the Karakum sands. Water is represented by a powerful flow of the Amudarya River going over the northern boundary of the desert; large tracts of fertile lands occurring as sports along the mountain range of Kopetdag make the southern margins of the desert. Therefore, since old times the nature itself had suggested the giant task for this region – to repair the disturbed harmony, to connect water and land to form symbiosis that will provide for maximum use of productive forces, agriculture improvement and general development of economics in the republic.

This task can be realized by implementation of a large-scale project: to withdraw the required amount of water from the Amudarya, to direct it via the canal in the desert to the lower reaches of the Murghab River, further on to the lower reaches of the Tedzhen River and to the water-deficient areas in West Turkmenistan up to the Caspian Sea.

2 History of the Karakum Canal Project

It is said that in the ancient times the Turkmen people did not ask "How much land did you have?" but they asked "How much water did you have?" Almost 90% of the Turkmen territory is occupied by deserts where life depends on availability of water. The ancient archives saved many plans on irrigation development of the Karakums, the world's largest desert. There are data referring to the Neolithic Time (late fourth – early third millennia B.C.) saying that the people used mountain springs in the piedmont areas of the Kopetdag bordering on the Karakum Desert for cultivation of cereals. In the first half of the first millennium B.C. the Murghab, Tedzhen, and Atrekriver valleys were developed for agricultural purposes. In the third century B.C., the Parthian Empire was founded here which territory expanded as far as the piedmonts of the Kopetdag Mountains. The rulers of Parthia were titled "King of Kings." In the ancient times it was the largest state after Rome.[1] The economy of Parthia was based on agriculture.

Herodotus, Polybios, and Pliny (third to first centuries B.C.) wrote in their treatises about extensive application of land irrigation in Southern Turkmenistan based on construction of large canals and irrigation facilities.

[1] Nisa was the capital of Parthia and its spiritual center and, at the same time, the core of the Parthian Empire. It occupied two uplands close to the present-day settlement of Batir 18 km from Ashgabat which was, probably, a satellite of Nisa.

The wars for conquering the territories of Southern Turkmenistan occurred till the late nineteenth century in which the irrigation canals were destroyed periodically. In 1713 Khodzha Nepe, the head of one of the clans of Mangyshlak, traveled from the Caspian Sea to Petersburg to meet Tsar Peter the Great. During this meeting he told Tsar that in the ancient times the Amudarya River ran into the Caspian Sea. In the past the presently barren plains were blossoming oases. Khodzha Nepe asked the Russian Tsar to help Turkmen people to return Amudarya into its former channel. That time Russia investigated the possibility to construct a waterway from Russia to India. Thus, in 1714–1717 Peter the Great organized two expeditions to this area, but both of them ended in failure – the Tsar's treasury had not enough money for such ventures.

By the end of the nineteenth century the communal-tribal land ownership prevailed in this region. During this time about 66 thou ha of lands in the south of Turkmenistan were under irrigation, and 47 thou ha were irrigated with waters of the Murghab River. Maintenance of irrigation systems was conducted by water users. In 1881–1884 Southern Turkmenistan was the part of Russia as the Trans-Caspian Region. This deed stirred keen interest on business circles of Russia to new lands. Cotton fever embraced various strata of the Russian society. Even Tsar Alexander III owned 25 thou desyatins (1 desyatina = 1.45 ha) in the Murghab River valley for cotton growing. In 1887 after occupation by the Russians of the Merve oasis with its fertile lands the greater part of these lands were given to private ownership of the son of Alexander III – Nikolai II, the last Russian Emperor. In 1895 some works on rehabilitation of the irrigation systems applying European hydraulic engineering and even subsurface drainage were conducted, but on a rather modest scale. From that time on "the Murghab sovereign (Tsar's) estate appeared invariably in all official documents as the most significant achievement of the Tsar's administration in irrigation development in Russian Turkestan."

The idea on transfer of the Amudarya waters across the Karakum Desert to the west into the water-deficient regions of the Trans-Caspian Region was shaped on the basis of the results of geographic reconnaissance studies and after construction in 1896 of the first railroad here that connected Krasnovodsk (present-day Turkmenbashi) with Chardzhou. Famous geologist, later on Academician V.A. Obruchev conducted surveys along the railroad route. And he suggested an idea that the chain of solonchak depressions (shors) originating near the Amudarya on the border with Afghanistan and stretching northwest into the desert represented the remnants of the ancient Amudarya channel (10–20 thou years ago) that went into the Caspian Sea in the geological past (the Aral had not yet existed that time). About 10–20 thousand years ago these channel-type depressions were known as Kelif's Uzboi. Later on it was found that the Kelif's Uzboi was a relict channel of the Bakh River in Afghanistan. Discovery of the Kelif's ancient river channel attracted the attention of the Russian engineers and businessmen.

By late nineteenth – early twentieth centuries the interest to cotton growing for development of the Russian textile industry had grown enormously. And the southern regions of Central Asia if they are ensured adequate water supply had bright perspectives in these respects.

Water resources in the south of Turkmenistan are formed by the flow of two small rivers – Murghab and Tedzhen and it should be mentioned here that their flows were formed mostly beyond the border of Turkmenistan. The average annual flow delivered to the territory of Turkmenistan with the Murghab River is 1.7 bill m^3, and with that of Tedzhen – 0.9 bill m^3. In view of the unfavorable distribution of the flow of these rivers that are principally snow and rain fed it was necessary to construct water reservoirs. The solution of this problem is very complicated here due to silting processes, which is affirmed by more than century-old experience of water reservoir maintenance.

The problem of land irrigation in the valleys of the Murghan and Tedzhen rivers with water from the Amudarya River supplied via the canal going across the Southeastern Karakums was first raised by engineer-economist G.P. Sazonov who elaborated his proposal based on the literature data. In autumn 1906 this proposal was discussed at a special meeting of scientists of Russia.

In 1907 the scheme of water diversion from the Amudarya to the west via the Kelif's Uzboi shors was suggested by engineer M.N. Ermolaev who developed it on the basis of the results of field studies. He presented the Project on the Amudarya Flow Diversion to the Merve and Tedzhen Oases for Irrigation of 516,000 Desyatins of Lands in the East of the Trans-Caspian Region. In 1915 irrigation engineer F.P. Morgunenkov suggested preliminary considerations on the use of the Amudarya water for irrigation of lands near the Murghab River and also remote areas. However, the advanced ideas of the Russian engineer required performance of significant volumes of works in extremely difficult conditions, such material and money input that for many years they were only the dream and they could be accomplished only in distant future.

Even during V.I. Lenin's Plan GOELRO it was claimed that many hopes were with connected with land reclamation and power industry. And later on these hopes proved too great. Already in the 1920s the main reliance was made not on the free initiative labor of the people, but on the forced labor of GULAG prisoners, cheap and mass. The nature transformation plan started with construction of the Belomor Canal. This plan also included construction of the Dnieper-Danube, Volga-Urals, Aral-Caspian and Great Turkmenian canals and many others.

Water supply and irrigation of the Karakum Desert became the concern of the State which was confirmed in February 1925 at the First All-Turkestan Congress of Soviets where the question on the Karakum Canal construction was raised and the resolution on the water and land reform was adopted. Soon after the Congress the results of the long work of the complex expedition to the Southeastern Karakums headed by F.P. Morgunenkov were received. He had proposed to use the natural slope of the Kelif's Uzboi to direct water by gravity from the Amudarya to the Murghab oasis. In 1927 the pilot water release was conducted into the Kelif's Uzboi from Basaga-Kerki Canal constructed in the Amudarya River valley. The water flowed by gravity in this canal to the southeastern Karakums for 100 km. Further on this experience was repeated many times. It showed that the salt cover of the Kelif's shors rapidly disappeared under the Amudarya silt (the Amudarya carried four times more of suspended solid than the Nile; 1 m^3 of water contains 4 kg

of such solids) and did not cause saltation of inflowed water, and seepage losses reduced gradually due to silting of sandy soils.

Thus, to a certain extent, already during that time the doubts expressed by some prominent engineers were refuted. Thus, Tsinzerling [1] called the project of the Karakum Canal construction a risky venture in technical terms, and D.D. Bukinich considered that this project, in general, was "a priori doomed to failure."

Large-scale surveys on various alternatives of the Karakum Canal route were developed beginning from 1940 after adoption of the Resolution of the Soviet of People's Commissars of the USSR and the Central Committee of the Communist Party "On Measures for further development of agriculture, in particular, as concerned long-stapled cotton cultivation in the Turkmenian SSR." In spite of military time, there was compiled a project plan for construction of the Karakum Canal according to the so-called "southern altlernative" under the leadership of the Ashgabad's engineer I.V. Boltenkov. The last alternative in contrast to the "northern alternative" (suggested formerly by F.P. Morgunenkov) envisaged construction of the canal through the eastern part of the Kelif's Uzboi having almost latitudinal direction. Further on, when the Kelif's shors moved to the northwest, the canal route preserving the latitudinal orientation approached the Murghab at sufficiently high elevations. This gave the opportunity to use gravity irrigation at maximum area of the Murghab delta plain lying on the elevations below the canal. When using the Northern Alternative, utilizing almost the whole Kelif's Uzboi, commanded irrigation area in respect to the canal is considerably reduced, and the cost of construction increased. Besides, there also increased inevitability of large water losses at the tremendous idle run through the Karakums and leaving the Murghab-Tedzhen lands with scanty water "ration." In favor of the Southern Alternative was also the fact that for the route from Kerki to Mary and Tedzhen there was already prepared the report of 37 volumes mentioned above. The Southern Alternative made it possible to involve local population in construction and land development in the old-developed and densely populated regions, to rest upon the railroad, the Amudarya and the cities from Chardzhou to Krasnovodsk with their manufacturing industry [2].

The Second World War had suspended the way of studies and construction works. After the end of the war I.V. Stalin initiated adoption of the Resolution of the Government of the USSR "On Construction of the Main Turkmenian Canal." This Resolution stipulated that the canal route should go from Takhia-Tash to the coast of the Krasnovodsk Bay withdrawing from the Amudarya 350–400 m^3/s of water with a possibility to increase this figure to 600 m^3/s without water diversion into the Caspian Sea.

The construction of the Main Turkmenian Canal (MTC) was started in 1950. However, in connection with discovery of considerable freshwater resources in the Yaskhan freshwater lens (which water was quite sufficient to satisfy the needs of Western Turkmenistan), the construction of MTC was ceased in 1953 [3].

3 Description of the Karakum Canal

The construction of the Karakum Canal named after N. Niyazov was resumed in 1954 following the Southern Alternative (until 1990 this canal was named after V.I. Lenin and from this time on and until 2007 it bore the name of First President of Turkmenistan S. Niyazov). It was the largest hydraulic structure of the irrigation and land reclamation importance in the deserts of the world. At present this canal branches off from the left bank of the Amudarya at Basaga settlement where it takes water and runs as far as Kazanjyk (now Bereket), the town in the northwestern foothill plain framing the slopes of the Kopetdag. Its length is 1,380 km, the head structures take out annually about 13.5 km^3 of water from the Amudarya River. After completion of construction when the canal would bound the western edges of the Kopetdag and come to the coast of the Caspian Sea its length would make to 1,400 km and the annual flow 18 km^3.

The eastern and southern regions of Turkmenistan covering one-third of the whole territory of the state are involved in the sphere of irrigating measures carried out on the canal's runoff. The region of Lebap, Murghab and Tedzhen oases, vast territory of the Kopetdag plain and the industrial regions of West Turkmenistan are supplied with the Amudarya water by means of the canal irrigation system.

In 2010 in the canal area over 900 thou ha were irrigated, almost four times more than before its construction. In the future, by means of the canal there will be irrigated up to 1 mln ha of fertile lands.

Now the width of the canal in its upper reaches is, on average, not less than 100–120 m. With lake-type expansions at certain sites it reaches 1–1.5 km. The canal is navigable from the Amudarya to Mary. By its sizes, hydrological indices, peculiarities and the scale of processes taking place in it the canal is inferior to many rivers of Central Asia delivering four times more water than all irrigation sources in the south of Turkmenistan [4]. It is quite rightfully that the Karakum Canal is called the man-made river, Karakum-Darya or Karakum River [5]. The designers used the natural slope of the land surface from 250 m on the Amudarya to minus 28 m near the Caspian Sea thanks to which the water moves in the canal by gravity from east to west.

The enormous route through which the Amudarya water now flows was not made at once. Canal construction was carried out by stages providing irrigation of certain areas independently of readiness of its subsequent sites. The canal was built without lining and had the river intake which reduced its cost and accelerated its construction. Apart from this the indicated structure of the water tract makes it possible to change the section of the ready channel according to water intake increase from stage to stage, but not to construct it from the very beginning for all water discharge required in the far future. Therefore, with each subsequent stage of construction there simultaneously expands the active part of the headworks structure till the beginning of the construction site.

The Karakum Canal was planned as a year-round functioning waterway. For this purpose, for the first time in the world practice of large irrigation canals

construction, the internal runoff regulators, i.e. reservoirs at the end of the canal sections for all construction phases were stipulated by the plan. Water reservoirs envisaged by the canal construction make it possible under conditions of continuous action to accumulate water reserves during autumn–winter period which stipulated the increase of the summer flow for irrigation by 30–35% without increase of the discharge capacity of the water main [6].

Stage I. Amudarya-Murghab Section. The first stage of the canal from the Amudarya to Murghab has the length of 397 km, out of which about 300 km pass in the desert sands. The unlined canal construction began in 1954 and already in 1959 water year arrived to the Murghab delta. Headwater discharge was 130 m^3/s, water intake of the annual Amudarya flow – 3.5 km^3. The canal provided 88 thou ha of lands with irrigation in the Murghab oasis and together with irrigated lands in the Murghab basin – about 170 thou ha. There could be made such comparisons: the first stage of the canal with earthwork volume of 129 mln m^3 and indicated above sizes was constructed within 5 years. The Panama Canal with the volume of earthwork of 212 mln m^3 and length of 81.6 km was constructed during 34 years, and the Suez Canal 173 km long with earthwork volume of 75 mln m^3 – during 11 years.

When designing and constructing the first stage of the canal there had to be solved a number of cardinal problems and almost insuperable difficulties overcome because the world practice had no such experiment of water delivery to long distances through the sand desert. The main problem concerned the seepage losses from the canal. That time it was possible to make a forecast of seepage change in interaction with forming regime of groundwater. It appeared that with large-scale of initial losses (2.4 m^3/s per 1 km of the canal) the volumes of seepage will be gradually reduced due to bed colmatation and bedrock saturation under the canal. However, if you first excavate the canal and then supply water into it then with water intake of 100 m^3/s water will reach the Murghab not less than within the year after the end of construction and in minimum quantity.

This fact obliged instead of "dry" method of construction to elaborate never formerly used method of "behind water delivery." Its essence consists in the fact that water is admitted into the narrow and short (up to 10 km) pilot cut, excavated by bulldozers and excavators, by the use of which the canal bed is enlarged to the design section by means of dredgers. It made possible to solve simultaneously several problems: to accelerate the reduction of seepage losses by ground saturation after pilot cut drive, provide for all communications by water tract (instead of land, impassable), supply builders in the desert with water, establish floating dwellings and auxiliary premises on the barges instead of surface ones, etc.

Stage II. Murghab-Tedzhen Section. The second stage of construction proceeded from 138 km from the Murghab to Tedzhen, out of which 70 km run across a sandy desert. Simultaneously, there was extended the prepared site to discharge 198 m^3/s with annual water intake from the Amudarya of 4.7 km^3. To accumulate the free autumn-water flow there was constructed the Khauskhan water reservoir 460 mln m^3 in capacity (design full storage is 1.5 km^3). Construction of the second stage began in 1960 and within unprecedented short term – 7 months, the Amudarya water was supplied to the Tedzhen River and the length of the canal reached 553 km. Irrigation area increased by 72 thou ha.

Stage III. Tedzhen-Geoktepe Section. The third phase of the canal construction started in 1961 by building of the pilot cut from Tedzhen to Ashgabad. Already on the 12th of May 1962 the residents of Turkmenistan's capital met the Amudarya water. Its capital, suburban rural economy and the zones of recreations were provided with water, and there appeared the Kurtly (Western) water reservoir of 48 mln m^3 in capacity, (Eastern) and Sport water reservoir of 6.3 mln m^3. Headwater discharge increased to 317 m^3/s with corresponding reconstruction of already built part of the canal, the length of which made up 793 km. Simultaneously the canal was elongated by 44 km from Ashgabad to Geoktepe and completed by it tail Kopetdag water reservoir of 190 mln m^3 of useful capacity (now 500 mln m^3); the volume of the Khaukhan water reservoir increased to 875 mln m^3. The canal irrigated 50 thou ha of virgin lands at the area near the Kopetdag plain and provided stable irrigation of 20 thou ha, formerly irrigated by local flow. Construction of the third stage was completed in 1975. The maximum head discharge reached 400 m^3/s and the total irrigation area reached 514 thou ha (Fig. 1).

Stage IV. Geoktepe-Karandjik Section. In 1971 with the pilot cut Geoktepe-Kazandjik the construction of the fourth stage began. Simultaneously, there was expanded the active part of the canal for head flow rate of 580 m^3/s (annual flow – 13.5 km^3). The canal reached Karandjik in 1981 and the canal length was 1,150 km.

Stage V. Karandjik-Atrek Section. In 1992 there began the construction of the fifth stage of the canal into the direction of the Atrek River for irrigation of subtropical virgin lands in Southwestern Turkmenistan. Four thousand years ago 160 thou ha were irrigated here or nearly 1 ha per each inhabitant. Construction of the canal's southwestern branch going as far as Kyzylatrek with its terminal reservoir (250 mln m^3 in capacity) will permit to irrigate about 30–35 thou ha.

The Ashgabad-Erbent water pipeline of more than 100 km long was constructed for supplying water to the cattle breeding pastures and for irrigating the arid lands of the Central Karakums. The 250-km long water pipeline stretched from Gazanjik to Nibetdag (now Balkhanabat). Turkmenbashi and Cheleken are supplying water to these large industrial centers.

At present the Zeid headwater reservoir of 3.5 km^3 in capacity is being built substituting the Kelif's Lakes which would be completely silted. In 2002 its capacity reached 1.2 km^3. Instead of the river intake the canal will receive water from the headworks built on the Amudarya River nearby the Kyzylayak settlement. It is intended for the regulation of suspended and coarse sediments of the Amudarya at the canal head and for spawning of herbivorous fish.

In general, five reservoirs with a capacity over 2.5 km^3 are built on the Karakum River. They are designed to accumulate the winter river flow for its subsequent use in the vegetation period (Fig. 2).

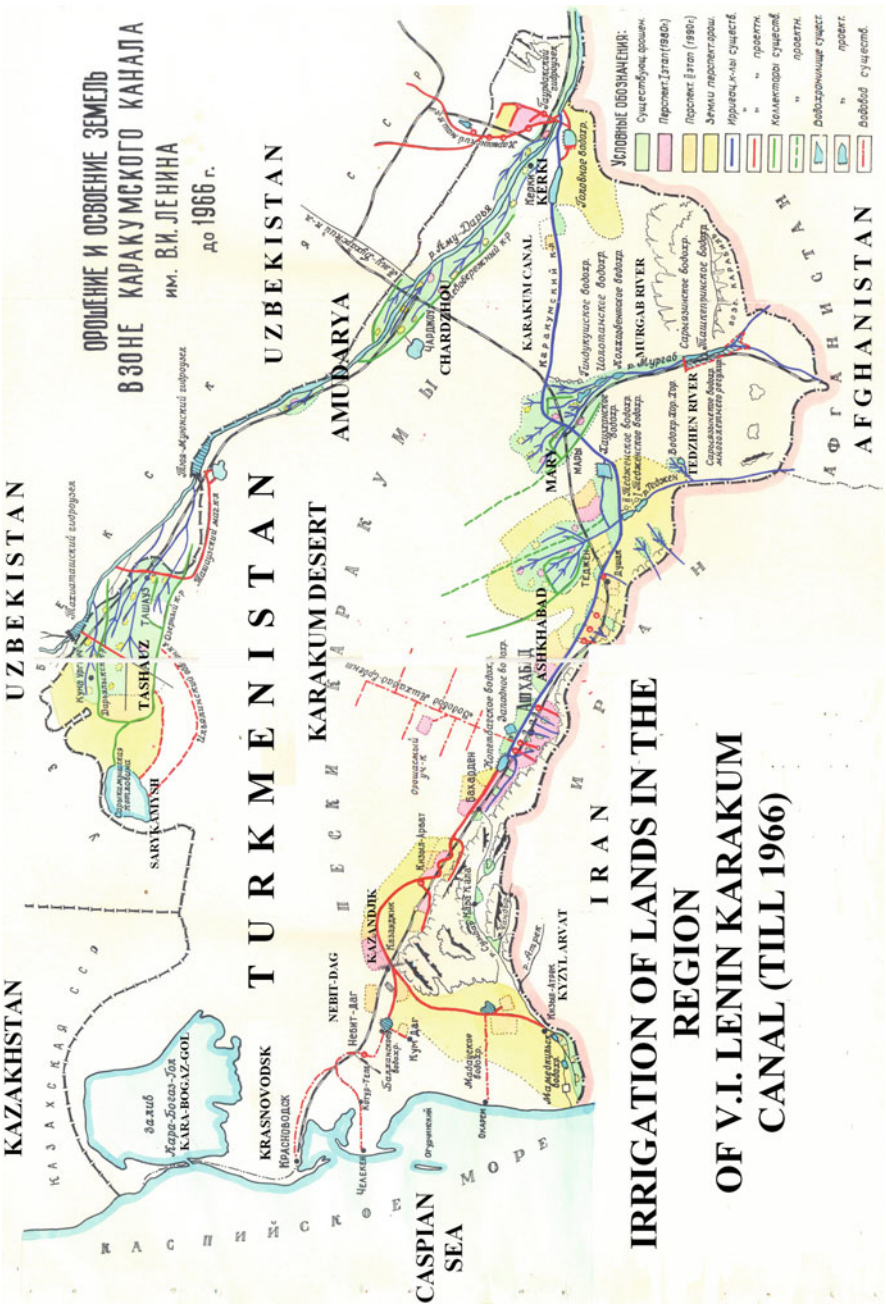

Fig. 1 Scheme of irrigation of lands in the region of V.I.Lenin Karakum Canal (till 1966)

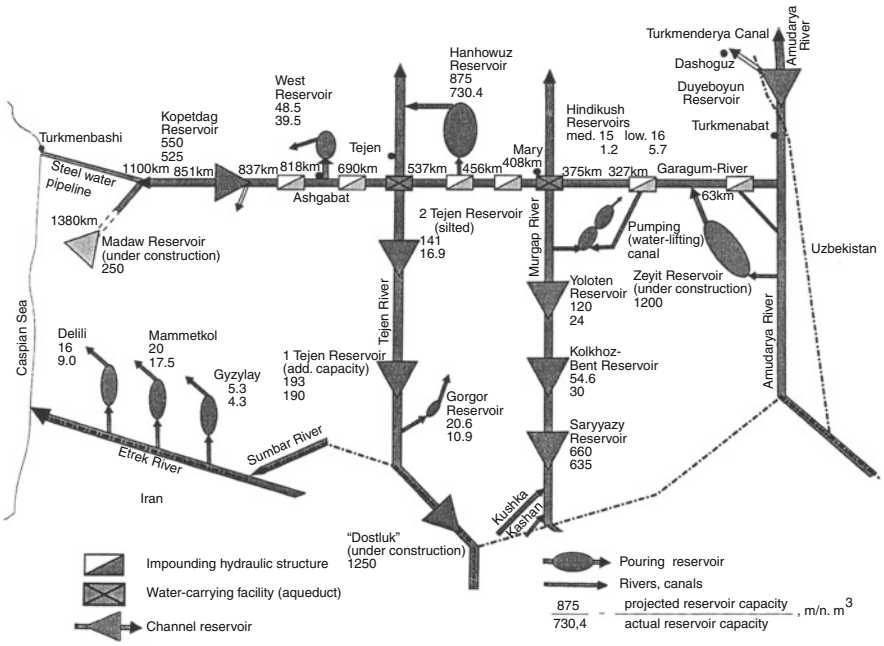

Fig. 2 Complex irrigation system of the "Karakum River" [7]

4 Importance of the Karakum Canal

When the canal was dug out and water came to the regions called "Dzhanakhyr" that could be translated as "the end of life," the people mounted donkeys and crossed hundred kilometers to look at the canal. Many of them were carrying away water in phials being afraid that other people would not believe them.

The importance of the Karakum Canal for the national economy of Turkmenistan can be hardly exaggerated. From 1958 to 1990 the cotton production in the canal zone increased 4.5 times. In 1990, out of 1,457 thou tons of raw cotton harvested in Turkmenistan the half was grown up in the canal zone, including all fine-fiber cotton varieties. The arrival of "big water" intensified cattle breeding, water supply of pastures, growth of the oil and gas industry and helped to resolve the problem of the population water supply. The canal caused reconstruction of all industrial production, stipulated formation of the new agro-industrial complex the key element of which is a large irrigation construction (Fig. 3).

The canal attracted thousands of waterfowl that chose to stay here for wintering, flight rest and feeding having changed the migration routes along the canal. The number of wild boars increased and deer – decreased because the canal traversed their migration routes. The Karakum Canal became a part of the general program of desert development.

Fig. 3 Editors of the book (Igor Zonn – *left*, Andrey Kostianoy – *right*) at the Karakum Canal near Ashkhabad in November 2011

One of the problems is overgrowing of the canal with reeds that narrows the waterways and aggravates its passability. So far in order to clear it there were used dredgers or the reeds were cut out. Now of wide use are the vegetable-food fish, such as Amur whitefish that eats only reeds, but also returns food to the people by its meat, including famous "Tolstolobik" locally called "Muksun", "Topuga" that is known abroad as silver carp. Wonderful balyks could be prepared of this fish. The Amur whitefish or grassy carp eats up to 2 kg of plants a day per each kilo of its weight and its weight may reach 25–30 kg.

In addition to real achievements that made possible construction of the Karakum Canal the extremely unfavorable ecological situation was formed around it. Withdrawing about 12 km^3 of water per year from the Amudarya, the canal, according to calculations of some Turkmenian specialists, loses to 3 km^3 to seepage and evaporation, while according to estimates of the Uzbek specialists – 5 to 7 km^3. These water losses were due to seepage. Because of water seepage in the area of the Karakum Canal at a distance to 10 km and over there formed inundated and saline lands. Many ancient channels and depressions are filled with seepage water and when you are flying over the canal route there is an impression that down in the desert the lake area appeared – "Karakum Venice." It should be noted that as a result of excessive irrigations the large land areas in the oases were taken out of use due to salinization problems. For 4 years after water supply to Ashgabad the groundwater level at 50 m from the canal rose to 10–11 m at within 1–2 km distance. Abrupt uplift of groundwater on the northern fringe of Ashgabad demanded construction of over 100 wells for vertical drainage to lower groundwater level [8].

All these negative consequences of the canal construction were unavoidable because during its design as an advanced project and with the purpose to shock the world by the scale of nature reformation the problems of consequences and impact on

the environment were not considered and even raised. It is already during the period of glasnost and perestroika the people began to speak about the canal that it became the cause of ruin of the Aral and some called it the "State crime." Today the zone of canal influence covers about 300 thou km^2 with population of over 2.5 million.

Construction of the Karakum Canal being the wide-scale flow transfer has changed radically the territorial redistribution of water resources across Turkmenistan. It helped to eliminate the century-old imbalance between the extensive areas of fertile lands locating in one part of the country and the water resources locating in the other part. Thus, about 80% of arable lands concentrate in the south and southeast of Turkmenistan, while water resources – in the east of the country.

The Karakum River is important and needed. It permits to address simultaneously several burning economic issues related to development of irrigation, agriculture and forestry, power engineering, industry, transport, and urban construction. This canal supplies water to all major industrial centers, such as Ashgabad, Turkmenbashi, Mary, and Balkhanabat.

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