INTAS RFBR

Mountain Unlimited

Scientific Information Center
of Interstate Coordination Water Commission (SIC ICWC)

«SIBICO» International

DHV The International Center of Studies (ICWS) DHV Consultants BV

«Gosecomeliovod»

INTAS – RFBR 1733 Project
with participation of
NATO Project SFP 974357

ASSESSMENT OF THE SOCIAL-ECONOMIC DAMAGE UNDER THE INFLUENCE OF THE ARAL SEA LEVEL LOWERING FOR SOUTH ARAL SEA COAST

Final Report

Vienna - Moscow - Amersfoord - Tashkent - August, 2001

Prepared by:

From INTAS-RFBR 1733

Mountain Unlimited:

Helmut Weidel
Willi Tischendorf
Albert Shwindshandl

SIC ICWC

Victor A. Dukhovny
Irina Avakyan
Erezhep Kurbanbaev
Elena Roschenko
Svetlana Zherelieva
Elena Migmanova
Raisa Kadyrova

SIBICO International:

Sergey A. Malygin
Vladimir M. Rubin

DHV Consultants BV:

Albert van Dike

Gosecomeliovod

M.G. Rubin
Y.P. Gusenkov
I.S. Zonn
A. Dukhovny

From NATO SFP 974357

Resource Analyses

Joop De Schutter
Omina Islamova

SIC ICWC

Victor A. Dukhovny
Raisa Kadyrova
Timur Kamalov

"VEP"

Aleksander Tuchin
Anatoliy Sorokin
Elena Roschenko
Konstantin Gromyko

"Aralconsult"

Mihail Gilenko
Oleg Kobylin
Albert Shapiro

Editing and main part of the report writing is made by Prof. V. Dukhovny jointly with I. Avakyan.

CONTENT

INTRODUCTION

The Aral Sea problems have been in the focus of mankind's attention for over three decades. It was an urgent issue during the Soviet times, and various states and governmental commissions tried to analyze the causes of the crisis, to assess damage and work out a wise policy to reduce negative impacts of this social and environmental problem. Several options of water transfer into the Aral Sea basin were considered as one of possible projects. Water transfer from the Ob and Irtysh rivers has been considered the most feasible. However it caused a lot of contradictions during the Soviet power decline, and was finally rejected by Gorbachev's Government.

During the independence era five sovereign states could not ignore this ignore which was especially vital for Kazakhstan and Uzbekistan, and less important for Turkmenistan. As a result, the Governments and leaders of 5 states expressed their will to participate in the process of conflict settlement and coordinated their policies by signing a range of the Agreements. Since 1994 the world community was involved in this process by efforts of the World Bank, UNDP, and other investors. Nevertheless, the problem resolution was not intensified due to economic weakness of the region, existence of other priorities, and, probably, because understanding and assessment of the actual damage from the Aral Sea shrinking were not estimated and brought to the decision-makers. Moreover, upon the USSR disintegration the world practice showed that the Aral sea precedent was not unique - use of over ten large and small water flows has lead to sea shrinkage or land desertification with water reservoirs disappearance, reduced bioproductivity resulting from excess water removal from the upper stream of the rivers (e.g. Lake Victoria, Lake Mono, Lake of Pyramids, Colorado and San Joakin basins, etc.).

Assessment of damage caused by such environmental disasters has both theoretical and practical value in the context of formulating a policy to prevent a growing damage when rehabilitation of the natural background is impossible.

Therefore not only damage assessment, but forecasting its increase on a basis of negative natural and social-economic processes is important from a methodological point of view. Initially, the present study was planned to cover the whole Aral Sea, but when RFFI financial support was reduced Southern Uzbekistan part of the Aral Sea and the area near AmuDarya river basin was set as an object of study.

In given paper as final report on INTAS-RFBR 1733 preliminary assessment of measures was supposed that will allow to rehabilitate social-economic efficiency or reduce environmental damages over Aral Sea. Taking into account limitation of means on this project as well as that in 2000 NATO NDM 974357 project was started, main goal of which was development of measures in South Aral Sea coastal zone, it was decided that preliminary results of this project should be placed in Chapter 5 of given report. Therefore its completed version presents integrated report of two projects. Project results are also used in the project«Integrated Water Resources management for Wetlands Restoration in the Aral Sea Basin» financed by NATO.

1. THE ARAL SEA AS AN OBJECT OF STUDY

The Aral lake is located between latitude 43°28' and 46°52' North and longitude 58°4' and 61°56' East of Greenwich, at the absolute altitude of 53 m at junction of three deserts: Kara-Kum, Kizil-Kum, and Ust-Urt Plateau. Since 1847 the water reservoir became an object of intensive studies by the Russian Geographical Society (*A. Butakov, A. Manashev, Y. Khanykov, N. Severtzev, A. Kaulbars*, etc.) making it one the most extensively studied regions in the former USSR.

A detailed physical and geographical description was published by Prof. *Berg* in 1908.

The Aral is the world's fourth lake by its size: it follows the Caspian lake, North American Lake Superior, and Lake Chad. The Aral Sea occupies an area of 64 490 sq. km (including the islands); its maximum length is 428 km, and maximum width is 284 km.

The lake is not very deep: its maximum depth is 68 m, and the average depth is 16 m. The maximum depth is reported near the western coast within a narrow zone; and the area with a depth below 30 m comprises 4% of the total lake area.

The western and northwestern coasts of the lake are steep; so-called Ust-Urt Plateau is located here, stretching to the north and south far to reach the desert. Occasionally it reaches up to 200 m above the Aral Sea level.

The eastern, northeastern and southern coasts are low-lying and mostly sandy. The coast is winding because water floods the grooves in ground formed by wind when the lake level rises.

This type of knobby coasts could be found only when level of the desert lake goes up, and Prof. *Berg* referred it «Aral type». The total area of the Aral Sea islands slightly exceeds one thousand sq. km.

Several islands are situated along the eastern coast of the lake, e.g. small islands - Kug-Aral in the north, Barsa-Kelmes and Revival islands in the middle part, and Takmak-Atau in the south.

Initially water in the lake had a low salt content, 1% to 1.5 % on the average. It resulted a recent (in geological time) flow from the Aral sea through Sary-Kamysh into Caspian sea due to a higher, compared to present, level of the Aral lake (in the Ice Age). Sulphates prevail in the Aral water (about 73%) making the Aral and Caspian seas (48% of sulphates) similar to the salty lakes and different from the seas with predominant chlorides, while sulphates content is about 12%.

The annual level fluctuates from 25 to 30 cm; the highest level is reported in the second part of summer resulting from the AmuDarya and SyrDarya flood, and the lowest level - from December till February.

Historically, the sea level and size have undergone changes several times. It is testified by the terraces found at different levels of 56.5, 54.5, 43.5, 40.5 and 35.0 m of absolute height, and analysis of salty silt accumulation. On space imagery one can clearly see the ancient AmuDarya - Sarykamysh, Akhchadarya, the Aral region (modern) basins. The Akhchadarya and Szhandarya canyons can be seen at the ground of Aral sea at depth of 10-12 m. The results of slit stratum and salt accumulation analysis show that the sea became salty and dried up during several millenniums B.C. followed by a long term watering. The Russian scientists *A. Konshin*, *P. Lessar, K. Bogdanovich, V. Obruchev* and *I. Valter* carried out geological investigations of the Aral Lake formation in 1980-ties and 1990-ties.

These investigations indicate that the Larger Aral flooded part of the Kara Kum desert located between Ust-Urt Plateau in the north, Murgab and Tedjen outfalls on the South, and west of Kopet Dag foot during post-Pliocene age. The eastern part of the united Aral and Caspian Sea had a Ungusy coast steep bordering the former Kara-Kum gulf. In the Caspian part this united sea had a wide line of modern Caspian region up to Kopet-Dag western foot, and united with Kara-Kum and Chilmet-Kum gulfs through two straits - the Large and Small Balkhash. During this period the Aral part flooded the entire Sarykamysh hollow and formed a gulf stretching up to Pitnyak located in the present AmuDarya basin and Khiva oasis (it explains coastal accumulations near Pitnyak). In the past Uzboy was a strait connecting these two water areas, but obviously, its modern shape was formed as the Caspian Sea separated from the Aral.

Separation of the united Aral and Caspian basin into two parts and its gradual reduction to the present size occurred during the following period until the present time. The first to separate was the watershed between the Aral and Sarykamysh and the Caspian Sea near Balla Ishem on Ust Urt had separated first, and gradually the Uzboy riverbed was formed. Drying up sequence is confirmed by the examples of transitional accumulations, e.g. from recent remnants of the Caspian mollusks (along Uzboy, in the sand of Chilmet-Kul, along the south-eastern Caspian coast), covered with lose sand covered by scarce and young vegetation, to the ancient forms in the central Kara Kum, which were transformed into the coastline, sand knolls, fixed by wooden vegetation. Being the lowest points of the sea bottom with inflowing bitter-salty solutions, the coastline bears the signs the ancient coast lakes.

Konshin, on the one hand, and *Obruchev* and *Kaylbars*, on the other hand, have different views on the AmuDarya location. According to Konshin the ancient AmuDarya riverbed was similar to the present up to Pitnyak since that period. It flew into the united sea and filling it with crumbly sand material. Other scientists believe that the AmuDarya riverbed was located between Merv and Chardjou, and gradually shifted to the present location. *Kashnin's* theory is supported by both geological and morphological data.

Historical evidences also support this opinion. According to Herodot (V century B.C.) the AmuDarya (Arax) flew into the Caspian Sea. Its delta had 40 branches. Strabon (I century BC) described the united Hirkan sea with the Oxus (AmuDarya) and 2400 stadium (300 km) north of the Yaksart river (SyrDarya) (possibly the Szhanadarya riverbed) flowing into the sea. Plinius (I century BC) also believed that the Caspian and Aral seas formed the united Hirkan sea. Ptolemeus and Ammian Marcelinus mentioned that the Oxus flew into the Oxcom fresh water sea - it could have been Sarykamysh as well as Aral. Istakhari (X century) and Adryci (XII century) tell about AmuDarya and SyrDarya which flowing into the united Aral and Sary-Kamysh sea known as Khovarzem.

All researchers and historians describe transformation processes of the Aral and Caspian seas related to water level and irrigation since ancient times. The scientists are unanimous agree that Sary-Kamysh totally dried up in the end of the XVI century when the AmuDarya did not flow into Sary-Kamysh through Kunyadarya, Daudan and Uzboy. On the way from the Caspian Sea to Bally-Item the Uzboy watershed rises 40 m at the length of 200 km.

Obruchev considers that Sarykamysh existed since VII century BC. During his expedition to Khiva in 1559 Jenckinson mentioned Sarykamysh which he had took for the Oxus flowing into the Caspian Sea. He leans upon similar evidences got from Abdulgasim Khan, Gamdulla and other Khovar chroniclers.

Based on geological and historical investigations many experts (*B. Andrianov, A. Kes, P. Fedorov, V. Fedorovich, E. Maev, I. Rubanov, A. Yanshin,* and others) came to almost the same conclusion which was finally formulated by *N. Aladin* (3). During prehistoric period the variations in the Aral level and salt content were due to natural climate changes. A humid climate phase provided SyrDarya and AmuDarya with more water, and the Aral level was the highest - 72 to 73 m (Fig. 1). In contrast, during a dry climate phase, both rivers did not have enough water, so the Aral level lowered and salt content increased. In the historic times, since ancient Khorezm exists, the sea level variations were poorly related to climate changes, but mostly to irrigation processes in the region. Intense development of the local territories and large-scale irrigation activities lead to water removal, and, hence, the Aral level was lowering immediately. During unstable periods (wars, revolutions, etc.) the irrigated land area reduced, and the rivers had plentiful water.

The Aral sea level was low in the early 19th century. In 1845 and after 1860-s the sea level slightly increased. The Aral sea level reached the lowest level at the beginning of the 1980-s, and the scholars made a conclusion upon progressive reducing of water resources in Central Asia.

The Aral level started to rise in the 80-s. The process was very slow at the beginning, then it speeded up. It lasted till 1906; the process stopped in 1907, 1908 is characterised by increase, and 1909 - decrease. The increase was reported again in 1910, 11, 12, till 1917 level changed a little. The level lowering started in 1917 - a year famous for its drought in Central Asia. In 1921 the Aral level lowered 1.3 m compared to 1915. Another level rise (slightly below 1/2 m) was reported in 1924. The level varied within about 3 m from the late 19th century till the early 20th century.

The AmuDarya natural water resources (without internal-drainage regions of Tedjen, Murgab, etc.) carry a flow of 75 km^3/year, the SyrDarya – 37 km^3/year (112 km^3/year). The annual variations of the AmuDarya and SyrDarya natural resources are quite substantial (variation coefficients C_v are 0.15

and 0.21 respectively) and characterised by significant simultaneity (correlation coefficient is 0.83). It complicates river flow consumption during the low water years.

The AmuDarya and SyrDarya basins are the regions of traditional irrigation that caused long-term variations in the natural flow of these rivers. Till the early 1950-s irreversible flow removal slightly varied both in individual river basins and in the whole sea basin area reaching 29 to 33 km^2/year. Increased water removal from the rivers up to 35 to 42 km^3/year in the 1950-s was due to expanded irrigation area and water management activities (construction of water reservoirs on the SyrDarya, AmuDarya flowing into the Karakum canal) and was compensated by a slight reduction of river-bed seepage and natural abundance of water during the decade (total amount of natural water resources was 9% above normal). As a result, the rivers inflow into the sea and its regime were almost stable till early 1960-s.

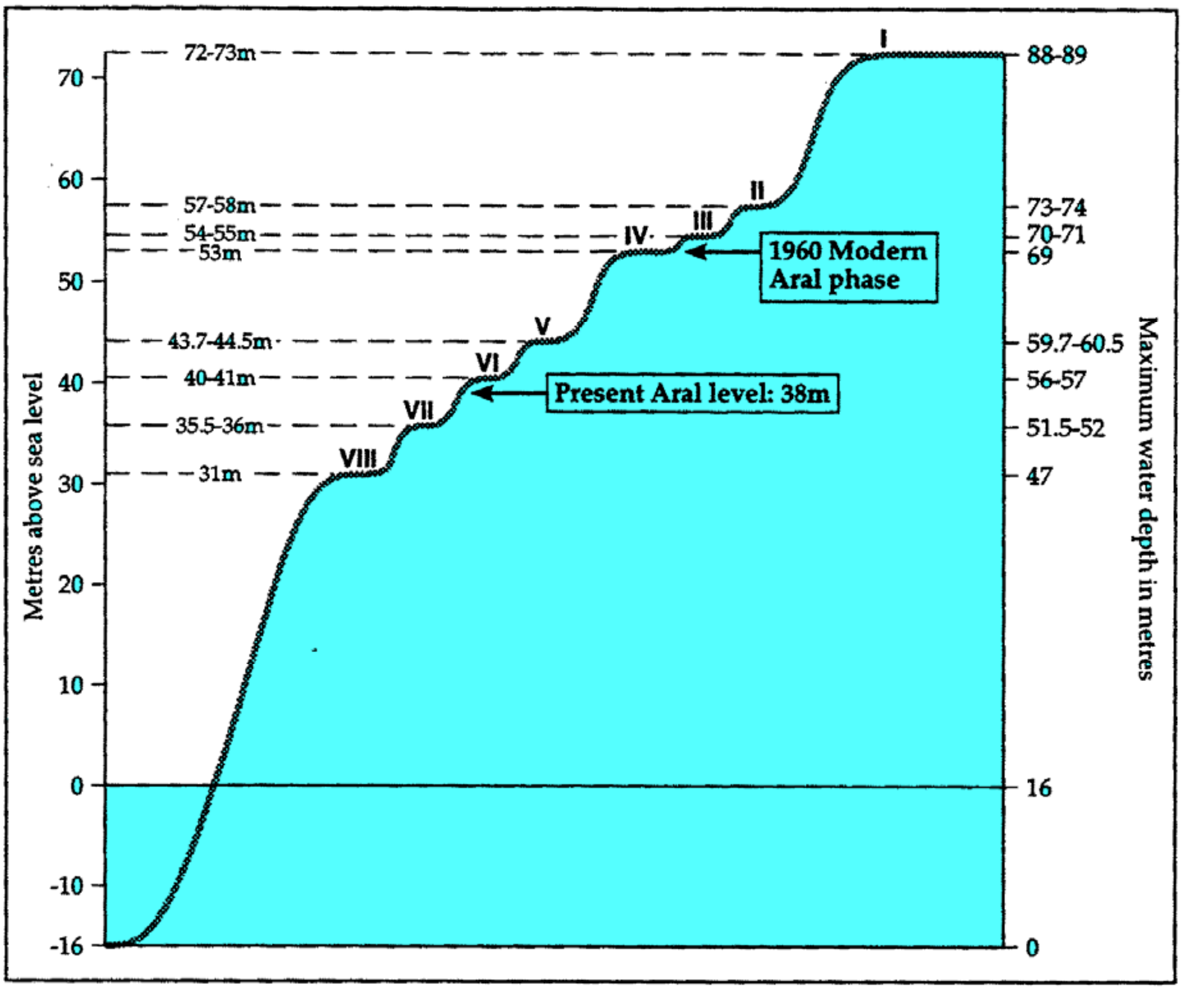


Fig. 1. Terraces of the Aral Sea /3/

The period of regular instrumental observations over sea level and other characteristics of sea regime (1911) lasted till the 1960-s, and could be referred to as conditionally natural. Approximate equality of incoming and outcoming constituents of the seawater budget (Table 1) conditioned negligible variations of the level at about 53 m absolute. This point was established as average long-term point. The average area covered by water at the 53 m absolute level was 66.1 thousand. km^2 with water volume up to 1064 km^2.

Table 1. Average long-term values of the Aral Sea water budget during different periods

Period (years)	Incoming				Outgoing (evaporation)		Water budget		Actual increase		Budget difference	
	rivers outflow		sediments						volume	level		
	km^3	cm	km^3	cm	km^3	cm	km^3	cm	km^3	cm	km^3	cm
1911-1960	56.0	84.7	9.1	13.8	66.1	100.0	-1.0	-1.5	0.1	0.1	-1.1	-1.6
1961-1980	30.0	48.9	7.1	11.8	59.7	99.4	-22.6	-38.7	-22.8	-39.1	0.2	0.4
1971-1980	16.7	29.3	6.2	11.0	53.7	95.4	-30.8	55.1	-32.3	-57.1	1.5	2.2
1981-1990	3.45	8.04	7.1	16.5	40.4	94.1	-29.8	-69.5	-30.4	-73.2	1.6	3.7
1991-1999	7.55	26.5	5.82	20.4	28.1	98.6	-14.8	-51.9	-17.5	-41.8	2.72	10.1

A quasi-equilibrium saline sea budget is typical for 1911–1960 period. Different salts at the amount of 25.5 million tons entered the sea annually. Most of the salts were subject to sedimentation during sea and river water mixing (the Aral water is supersaturated with calcium carbonate) and precipitated in the shallow waters, gulfs, bays and filtration lakes on the northern, eastern and southern coastline. During that period the average salinity of the sea varied from 9.6 to 10.3%. A large amount of the annual river flow (˜ 1/19 part of the total sea volume) conditioned a unique salt composition of the Aral water different from the salt composition of other internal closed and half-closed seas containing carbonates and sulphates.

The modern period, starting from 1961, can be defined as the time of anthropogenic impacts on the sea regime. A sharp increase of irreversible flow removal varying from 70 to 75 km^3/year during last years exhausted the compensation potential of the rivers, and low-level water during two last decades, 1960-80 (92%) disturbed water and salt budget. Excessive evaporation over total incoming constituents is a feature of the 1961-1998 period[*]. The rivers flow into the sea reduced to 30.0 km^3/year on the average in the above period and was only 16.7 km^3/year, or 30% of long-term average in 1971-1980. From 1980 to 1998 it was estimated at km^3/year. In some low water years the AmuDarya and SyrDarya flow did not even reach the sea.

The river flow quality has changed too. Increased flow of drainage water with a high salt content has significantly increased the total salt content and deteriorated the sanitary characteristics of water. In the low-water years the average annual salt content in the AmuDarya flow into the sea is 0.8 to 1.0 g/L, and the SyrDarya 1.5 to 2.0 g/L. Higher values are occasionally reported. As a result, apart from the average annual river flow decreased over 46% from 1961 to 1980, the average annual ionic flow lowered only 4 million tons (18%). Other constituents of the salt budget have also considerably changed. With a relative decrease of carbonate content, the total amount of salts subject to sedimentation in the process of river and sea mixing reduced twice.

Hence, the sea level was constantly lowering since 1961. Total level decline was 12.5 m compared to the average long-term value (identified before 1961) in early 1985. The average long-term level lowering intensity was equal to 0.5 and about 0.6 to 0.8 m^3/year during the low-level years (Table 2).

Table 2. Average annual parameters of the Aral Sea

Year	Income of river flow, km^3		Total	Precipitation, P, km^3	Evaporation, E, km^3	Level height, H, m	Water volume-	Water surface area	Salt con- tent
	AmuDarya	SyrDarya	Inflow						%
							W, km^3	F, km^2	
1. Before separation									
1950	11.9	12	23.9	9.22	66.06	52.83	1058	65607	10.17
1951	13.2	13	26.2	8.07	59.19	52.69	1049	64914	9.74
1952	18.8	19.8	38.6	8.78	62.62	52.7	1050	64964	10.67
1953	19.5	18.3	37.8	9.63	64.11	52.85	1059	65706	9.82
1954	21.1	22.1	43.2	10.87	62.87	53.12	1076	67042	10.21
1955	16.7	15.8	32.5	9.17	66.13	53.17	1079	67290	10.13
1956	16.4	16.1	32.5	9.3	67.2	53.22	1082	67537	10.19
1957	9.5	9.9	19.4	8.51	68.11	53.19	1080	67389	10.01
1958	17.9	18.3	36.2	7.94	68.93	53.16	1078	67240	10.42
1959	18.8	18.5	37.3	9.92	70.05	53.29	1086	67884	10.19
1960	20.7	21.3	42	9.41	71.13	53.41	1093	68478	9.93
1961	13.4	6.9	20.3	6.59	70.43	53.31	1087	67983	9.97
1962	5.8	4	9.8	8.63	70.93	52.98	1067	66350	10.8
1963	10.6	7	17.6	11.56	70.64	52.62	1045	64568	10.58
1964	14.9	9.4	24.3	8.12	64.04	52.5	1038	63974	10.13
1965	4.7	3.2	7.9	8.48	66.35	52.3	1026	63308	10.81
1966	9.6	6.4	16	6.64	71.13	51.88	1000	62014	11.81
1967	8.7	5.9	14.6	7.51	57.82	51.57	980.9	61060	11.02
1968	7.2	4.9	12.1	6.03	67.35	51.24	960.7	60299	11.49
1969	17.4	10.6	28	9.06	52.31	51.29	963.7	60408	10.91
1970	9,8	6.5	16.3	7.22	62.03	51.42	971.7	60692	11.2
1971	8.2	5.6	13.8	5.81	59.83	51.05	949	59885	11.38
1972	7	4.8	11.8	5.78	55.34	50.54	917.8	58935	11.95
1973	8,9	6	14.9	8.95	56.45	50.23	898.9	58494	11.95
1974	4.80	1.3	6.10	4.75	60.18	49.83	874.4	57924	13.02
1975	0.61	0.3	0.91	4.43	59.99	49.01	824.2	56757	13.4
1976	0.57	0.3	0.87	5.79	51.09	48.28	785.3	55718	14.57
1977	0	0.2	0.2	5.04	45.75	47.63	749.2	54792	15.44
1978	19.6	0.4	20	6.42	52.52	47.06	717.6	53981	14.97
1979	10.9	2.1	13	4.87	52.14	46.45	683.4	52989	15.09

Year	Income of river flow, km3		Total	Precipitation, P, km3		Evaporation, E, km3		Level height, H, m		Water volume-	Water surface area	Salt con-tent
	AmuDarya	SyrDarya	Inflow									%
										W, km3	F, km2	
1980	8.35	1.7	10.05	9.73		50.24		45.76		648.7	51743	16.8
1981	5.93	1.7	7.63	11.92		47.11		45.19		620	50714	17.7
1982	0.01	1.3	1.31	8.52		38.5		44.39		579.8	49270	18.8
1983	0	0.5	0.5	4.51		47.59		43.55		537.5	47753	20.3
1984	0	0.3	0.3	5.99		44.33		42.75		502.7	46243	21.9
1985	0	0.3	0.3	7.19		42.52		41.95		475	44382	22.9

2. After separation

Year	Income of river flow, km3		Total	Precipitation, P, km3		Evaporation, E, km3		Level height, H, m		Water volume-	Water surface area	Salt con-tent
	AmuDarya	SyrDarya	inflow	Large Sea	Small Sea	Large Sea	Small Sea	Large Sea	Small Sea			%
										W, km3*	F, km2	*
1	2	3	4	5	6	7	8	9	10	11	12	13
1986	0	0.2	0.2	7.41	0.66	41.71	2.7	41.02	40.9	442.8	42228	21.5
1987	0	1	1	8.26	0.78	34.61	2.98	40.19	40.8	414.1	40297	25
1988	12.8	5	17.8	5.38	0.59	36.19	2.96	39.67	40.7	396	39087	28
1989	0	3.1	3.1	5.51	0.41	36.19	2.9	39.1	40.6	376.3	37760	30
1990	0	2.4	2.4	6.59	0.61	35.23	3.13	38.24	40.5	335	35200	32
1991	0	2.8	2.8	6.67	0.64	35.01	2.76	37.66	40.4	278	31608	34
1992	7.4	3.2	10.6	7.26	0.7	28.85	2.79	37.2	40.2	263	30812	35
1993	11.7	5.7	17.4	5.31	0.63	28.85	2.7	36.95	40.3	259	30114	36
1994	9	5	14	5.9	0.59	27.62	2.81	36.6	40.1	247	29807	37
1995	3.1	1.6	4.7	5.54	0.45	28.53	2.62	36.11	40.5	230	28200	38
1996	5	1.5	6.5	5.32	0.53	25.75	2.53	35.48	40.5	210	26706	39
1997	2.1	4.6	6.7	4.57	0.44	25.54	2.51	34.08	40.5	180	24217	40
1998	23.1	6.7	29.8	6.02	0.62	25.01	2.48	34.9	40.6	195	25500	40
1999	7,6	6,03	13,63	4,78	0,6	22,3	2,2	33,2	36,8	169	22450	60
2000	4,1	1,7	5,8	2,1	0,41	23,8	2,61	31,9	38	131	19071	65
*) Estimated for the Large Sea												

Within one year the level changed too. It is difficult to trace level variations in the past. It varied in winter, and sharply dropped during summer time.

A significant sea level decline lead to reduction of sea area for about 22.3 thousand km^2, and its volume reduced to 618 km^3 from 1961 to 1985. The coastline has changed radically, particularly in the shallow eastern, southeastern and southern parts. Large islands in the central part have increased in area, and new islands appeared.

The sea coastline was affected by disappearance of the shallow gulfs and bays with intensive sedimentation. In the modern period the salts in the river flow do not balance with outflowing constituents completely, and saltiness of the sea increase a little. Gradual decrease of sea level exceeded the forecasts far and away. Based on models GOIN (*V. Bortnik*, 6) in 1983 it was forecast that the sea level would reach 41 to 42.5 m by 1990 (90% guaranteed) and 35.5 to 38.5 m by 2000. In reality, as shown in Table 2, the sea level was 38.24 in 1990, and would be about 34 m by 2000. Similarly sea salt content was increasing faster - 32% in reality instead of the forecast 26% in 1990, and 40% instead of 38% by 2000.

It was found that the Aral Sea saturated with calcium sulphate and gypsum starts to precipitate when saltiness exceeds 25-26%. Still more intense gypsum precipitation had started when saltiness exceeded 34-36%. In wintertime and under these conditions sedimentation of mirabilite, the most hazardous compound for the nature Aral region, starts together with gypsum precipitation. Dehydrated sodium sulphate is subject to wind erosion and can easily move for a long distance.

Sea level lowering and its growing salt content intensified the annual temperature variations in all water layers, and a shift in temperature regime happened. Changes in winter thermal parameters are the most important for biological sea regime. Further lowering of the freezing point and different autumn and winter convective intermixing between brakish and salty waters condition cooling of the whole sea down to essential negative temperatures (minus 1.5 ÷ minus 2.0°C). It appears the key factor limiting acclimation and rehabilitation of fish stock important in the near future. Sea level lowering could lead to obvious variations in ice conditions, e.g. the whole sea area could be covered by 0.8 to 0.9 cm thick ice during even average winters. It will be accompanied by the sea cooling and freezing, though reduced heat reserve will result in more rapid icing. Ice thawing time will be prolonged because of increase of ice mass per area unit.

Due to extremely low specific values of incoming biogenic compounds, their content in the seawater is low resulting in limited photosynthesis processes with further reduction in sea biological productivity. Areas with oxygen deficiency and killing effect will appear as a result of disturbed oxygen regime in summer due to by poor photosynthesis and intensive oxygen consumption for oxidation organic compounds.

Further increase of salt content has lead to reduction of phyto- and zooplankton, phyto- and zoobentos, as well as to corresponding reduction of biomass, that will condition further deterioration of hydrobionts feeding. Higher salt content in the Aral Sea water will make indigenous fauna's existence impossible.

Assessment of anthropogenic impacts under modern changes in the Aral sea regime was based on the restored values of the level and salt content in the period from 1961 to 1980 according to the restored hypothetical natural flow into the sea. Calculations show that 70% of the sea level lowering and higher salt content during modern time is induced by anthropogenic impacts. The remaining variations are due to the climate factors, e.g. natural low-water periods.

Apart from water volume and area shrinkage, increase and type-change of salt content

Formation of huge saline desert at dried sea bottom covering almost 3.6 million ha now, turns out to be the main consequences of Aral Sea shrinkage. As a result unique fresh water reservoir has transformed into a bitter-saline lake combined with a saline desert and located at the junction of three sand deserts.

Complete separation of the Large and Small seas happened in 1985-86 at the point of 41 m of absolute height. It resulted in new desert area covering 6000 km^2 and containing about 1 billion tons of salt in the top layer. Today saturated gypsum solution precipitates from seawater. When the sea level lowers down to 30 m of the absolute height (23 m) the western part of deep-water Large Sea will be separated from the shallow East sea by the islands.

Upon separation the regimen in both Large and Small seas developed in different ways. Since the SyrDarya inflow exceeded that of the AmuDarya in the last years, the Small sea level increased and its salt content lowered. A temporary rupture of a dam on the Small sea induced level lowering, though previous filling was aimed at creating a separate reservoir for the Small sea at a level from 41 to 42.5 m. A project of a dam with adjustable water spillway in the Berg Bay will provide sustainable environmental solution for this water body and its environment.

Thus, formally indivisible Aral Sea will be transformed into several separate reservoirs characterised by individual water and salt budget, and individual development scenarios will be adopted by representatives of the five countries.

At present time there is proposal (academician B.Tashmuhamedov) about water transfer from South part to deep western part of the sea to support its sustainability. But there is no donor to fund this research. World Bank took responsibility for North sea rehabilitation, but the rest part of the sea still is waiting for donors.

Unsatisfactory attention was paid to South Priaralie in 2000-2001 when AmuDarya delta did not receive water at all and all power reaches received 50% of water required.

We want to believe that this sad experience will draw attention of decision-makers in the future.

2. DEGRADATION OF THE ARAL REGION ENVIRONMENT INDUCED BY THE SEA SHRINKAGE

Intense desertification in the Aral region appears to be the main consequence of the Aral Sea shrinkage.

Some evaluations testify that during last 40 years desertification process covered 2 to 3 million ha around the sea. Territories located in about 15-250 km to the South and northeastern from the sea, near the AmuDarya and SyrDarya were subject to the most intense impacts. At the same time, the impacts on Ust-Urt Plateau and North-Eastern coastline near Kizil-Kum desert are negligible due to a higher altitude of the area and its initial desertification.

A. Rafikov (7, 8) *N. Novikova* (9) and *L. Kurkina* (10) have described desertification processes in detail.

Specific climate aridity of the Aral area and its continental character (average temperature in July is 24 to 28°C, in winter minus 8 ÷ minus 12°C) defines development of ecosystems of the region in two directions according to the water regime (9):

- Natural automorphic: only under influence of the natural precipitation; forms xerophylic desert ecosystem, covers Ust-Urt Plateau, northern and eastern parts of the Aral region;
- Hydromorphic related to incoming flows, found in the AmuDarya and SyrDarya areas, oases, and with high flood and ground water close to surface.

Obviously, the situation cannot deteriorate when desert climate impacts are constant, and hence, the most part desertification processes occurred only in formal hydromorphic ecosystems.

2.1. Factors inducing the natural complex degradation

Factors of intense desertification development are classified into two groups: (a) primary factors of desertification causing not only desertification proper but also the Aral level lowering and coastline withdrawal, and (b) secondary factors directly induced by sea withdrawal. Naturally, all factors are interdependent: their influence is combined, and they even strengthen negative effects of each other.

2.1.1. Lower river flow into the delta and sea and interrelated flooded area shrinkage

According to *N. Novikova* (9) reduction of natural water flow into delta and Aral Sea started before sea level lowering, i.e. before 1961. During 1932-60s average flow into delta was 41 km^3/year, flooded territories covered more than 2800 km^2, lakes covered 820 km^2. By 1961-1965 incoming flow decreased to 30 km^2, flooded areas and lakes covered correspondingly about 2100 km^2 and 790 km^2 (fig. 2).

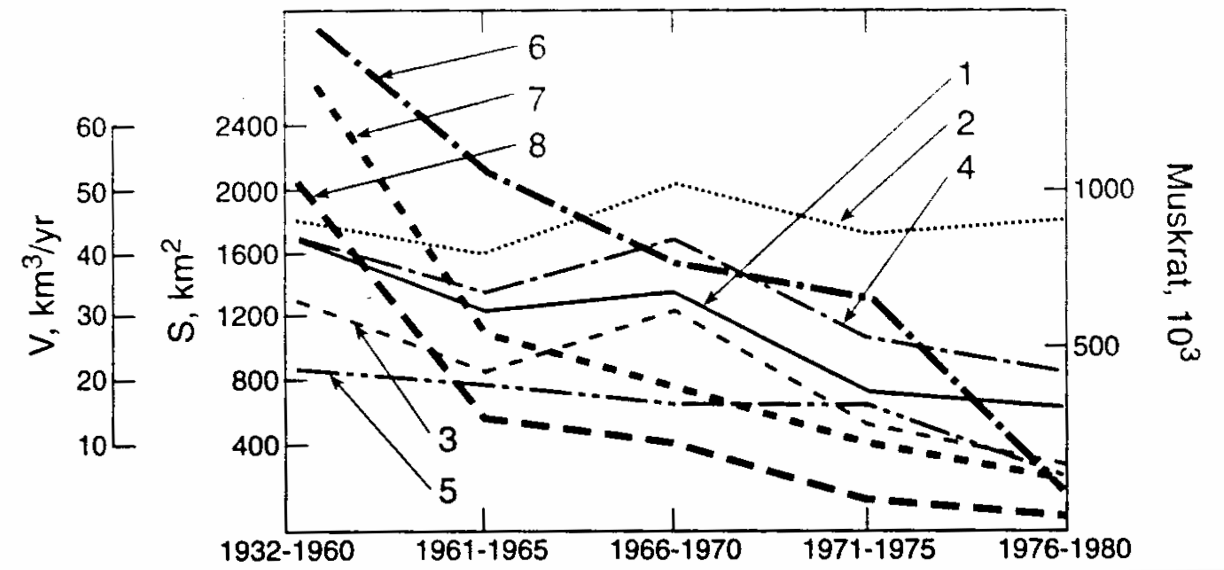


Fig. 2. Environmental changes in the AmuDarya delta induced by a lower runoff

1 - actual inflow into delta, cub. km per year; 2 - restored inflow into the delta region, cub. km per year; 3 - runoff to the Aral Sea, cub. km per year; 4 - runoff, used within delta, cub. km per year; 5 - lake area, sq. km; 6 - flooded area, sq. km; 7 - tugai forest area, sq. km; 8 - muskrat skins in units.

The amount of irrigation water removed from the AmuDarya increased considerably in the last three decades inducing radical changes in natural state of the middle and lower reaches of the river. Especially big changes have happened in the AmuDarya delta. There existed about 40 lakes covering almost 100 thousand ha in the AmuDarya delta during favourable hydrological regime. When the river flow decreased sharply, and flooding stopped, the number of lakes and their area reduced greatly. Today there are about 10 lakes, some of which were formed as a result of drainage and spillway water coming from irrigated regions. Their total area varies from year to season and not exceeding 75 thousand ha. Natural lakes cover only 5 thousand ha, but spillway water feeds them as well. As a result the areas of tugai have extremely shrunk.

When flow into upper delta decreased, the Ministry of Water Economy of Uzbekistan took efforts to improve the water regime in delta in the period from 1987 to 1993. Several temporary water reservoir were created, e.g. Mezhdurechensk, Muinak and Rybachye reservoirs, and some systems were watered as well, e.g. Karajar, Dumalak, Shege, etc. The measures contributed to the delta revival. Regretfully when the Ministry of Water Economy of Uzbekistan and the Ministry of Agriculture united the efforts were cut down: the temporary dam at Mezhdurechensk Reservoir was destroyed, and regulating water amount in the delta became impossible.

Nevertheless, watered areas in AmuDarya delta increased up to 300 km^2 thanks to these temporary activities.

Some support to actions is given by the project implemented by Uzgipromeliovodhoz on request of GEF EC IFAS and directed to maintenance ofsmall water bodies. Tender for construction works is announced by IFAS Nukus Branch.

2.1.2. Ground water level lowering

The following main factors influence ground water level lowering:

- Reduced surface water flow into delta, and hence, reduction of infiltration into ground water;

- Shrinkage of flooded by gradual reservoirs, which feed ground waters as well;
- Lowering of the drainage basis presented by Aral sea level, and hence, ground water level lowering in the zone of depression curve of flow into the sea.

Scientists have identified a correlation between remoteness from the sea and ground water level. Considering a slight slope of the dried sea bottom (0.0001 to 0.0005), a depression curve is formed as follows:

- 0.5 to 0.6 km - ground water level (GWL) is 0.5 m;
- 2 to 3 km - GWL is 0.5 to 2m;
- 4 to 6 km - GWL is 2.5 to 4 m.

With remoteness increasing, the automorphic regime of the ground water is formed. Under this regime ground water does not feed the surface layer, except trees and other plants with developed roots. Higher ground water level is registered at unwatered bottom of Adjibay, Jiltyrbas, Rybatsk and Mynak gulfs, Ordobay and Inzsheneruzek riverbeds. Surface and ground flows from AmuDarya delta are registered in these areas (Fig. 3). This fact condition high level of salt content. It varies from 15 to 75 g/L in the open part of dried sea bottom, and from 75 to 460 g/L in the ingressive narrow dried gulfs and lagoons in the southeastern part of the Aral Sea.

Approaching to the initial coastline the salt content increases, and horizontal water exchange becomes more complicated. In the littoral area up to 600 m wide with intensive water exchange, the salt content in ground water is close to seawater salt content. Because of seawater desalination the salt content in ground water is much lower in the regions of Ordobay and Inzsheneruzek outfalls. Higher saltiness of these waters in unwatered gulfs and lagoons is conditioned by irregularity of the coastline and asperity of their bottoms that result in the local stagnation of ground moisture.

Sharp prevalence of capillary moisture raise makes for chlorine and sodium ions concentration in ground water. For this reason they are of sulphate-chlorine type with high sodium content. Besides high concentration of some ions the chemical composition of ground water is similar to that of the seawater.

Incut into the riverbeds bottoms resulted in disappearance of previously existing channels and to GWL lowering (Kipchakdarya, Taldyk and Arkindarya channels, and Inzsheneruzyak and Akkay low branches). During last years the AmuDarya flows along rectified Udrubay branch. Incut influence is traced from 100 to 20 km from sea line along Temirbay hydrological station, and the river bottom lowered 3.8 to 4.5 m. Presently water is supplied to branches by pump stations. Simultaneously with incut general lowering of ground water level, head and debit of artesian wells occurs in the Aral region. According to forecasts the forced water level will lower 20 to 22 m at a distance of 60 to 100 km from the coastline (presently 4 to 20 m), and ground waters level will go down 3 to 5 m in 1990. Ground water flow into the sea is 0.2 km^3, but 6.2 million tons of salts are dashed out due to high concentration.

2.1.3. Soil salinization and restructuring of soil hydrological regimen

Soil salinization and reforming of soil hydrological regime resulted from desertification. Close bedding and high salt content in ground water promote increase of salt concentration in soil of the dried sea bottom. Therefore, the entire dried Aral bottom, excluding a narrow sand line along the native coastline, is covered with salt-marshes. At the same time in a region of active horizontal water interchange, ground water has lower salt content, accumulation of salts is slower (to 3% of dry residue). Moving away from sea edge into the heart of land soil saltiness increases rapidly 10 to 15%.

Soil chemical composition is similar to that of ground water, only the quantities are different. Thus, ground water is sulphate-chloride-sulphate throughout the region, rarely sulphate-chloride, sulphate or chloride.

Along shore of the 1960-s alluvial soils prevail, and on the seashore – hydromorphous ones. Automorphous desert sandy soils and sand older than marsh ones. Marsh soils are developing near the sea, and they are 1 to 2 years old.

Conditions of soil formation differ when consider coastline and natural shore of the 1960-s, and water salt regime changes correspondingly: typically salted soils become gradually deeply salinated and desalinated, at the same time, type of saltification changes from sulphate-chlorine to sulphate-hydrocarbonate.

General backgrounds for soil formation are saliferous sea accumulations (loams, clay sands, clays, etc.) which are directly soil forming beds. A flat relief and close bedding of the ground water with high salt content create favourable conditions for soil formation. They condition development of different salt marshes.

Big areas are covered with sors including traces of the dried lakes, infiltration supply on many islands and narrow, indented estuaries on the south-eastern coast, as well as by sands – respreaded sea accumulations. It is confirmed by the predominant types of xerophytes, halophytes and hydro-helophyte.

All soils are characterised by low humus content, small capacity of humus horizon, low content of soil components, absorption capacity. These specific features can be explained by low precipitation, high summer and low winter temperatures, which result in xerophytic and halophytic groups prevalence in plant covering.

Field studies of soil from dried sea bottom and their artiration showed prevalence of the following soils: salt marshes (marshy, meadow, boggy, crusty, plump, crusty-plump, residual, sor), desert sandy and sandy.

Today the sandy line of dried sea bottom along the native coastline becomes a territory of automorphous soils formation, especially desert sandy. It should be mentioned that influenced by a strong wind from the sea the normal formation of these soils is slowed, besides aeolian relief is not completed yet.

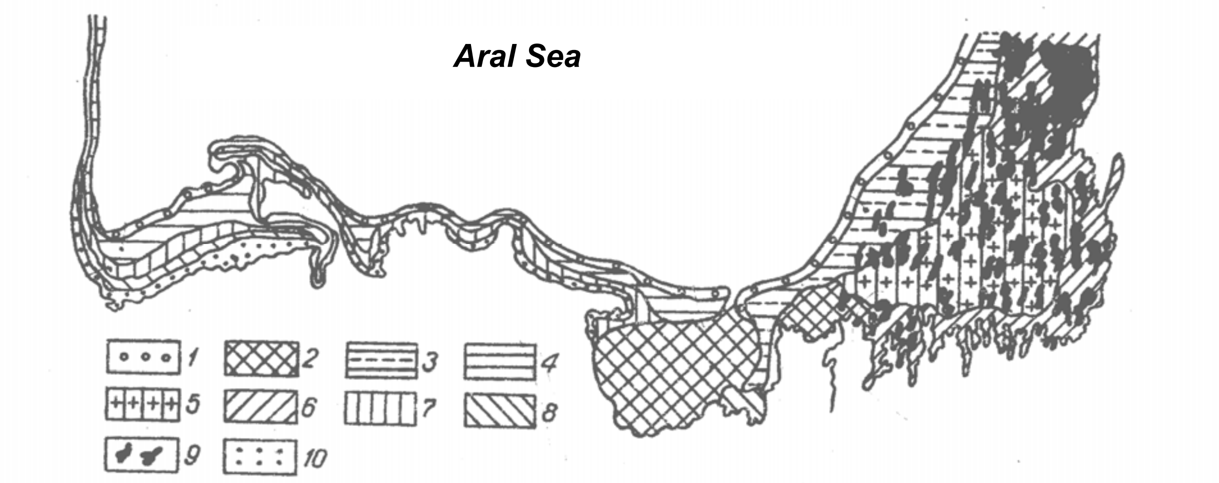


Fig. 3. Ground water levels, mineralisation rate and type in the Aral Sea region /8/

Ground water level (m): 1: 0-0,5; 2: 0-0,5; 3: 0,5-2; 4: 0,5-3; 5: 0-3; 6: 0-1 and 1-3; 7: 2-3; 8: 2,5-3,5; 9: 1-10; 10: 3-5 and 5-10.

Ground water salt content rate, g/L: 1: 10-45; 2: 5-20; 3: 30-80; 4: 30-60; 5: 80-450; 6: 100-500; 7: 40-70; 8: 30-80; 9: 30-300; 10: 20-60.

Ground water salt content type: 1, 2, 4, 8, 10 – sulphate-chloride, 3, 7 – sulphate-chloride with sodium increasing; 5 – sulphate-chloride with increased sodium content, sodium-chloride with increased sulphate content, 6 – sodium-chloride with increased sulphate content, sulphate-chloride, magnesium-sodium; 9 – sulphate-chloride with increased sodium content, sulphate-chloride.

Assessment of the modified status of reclaimed lands was based on large-scale soil studies carried out within the project network.

Four stages of large-scale soil studies of the irrigated area were carried out in Uzbekistan:

- First stage - completed in the 1930-ties;
- Second stage - from 1957 to 1967;
- Third stage - from 1982 to 1987;
- Fourth stage – from 1990 to 1995.

For the project objectives the analysis was based on the results of the second, third and fourth stages. Fig. 4 shows a soil map of the Republic of Karakalpakstan with explication. The bulk of irrigated areas are represented by meadow soils of the desert zone.

Despite a low content of humus (0.7% to 0.9%) and nutrition components, such soils are relatively fertile under modern agrotechnologies provided the salt content is low. In riverbed depressions meadow soils possess a heavy mechanical composition and high tension of solonchak process. They have the highest humus content (1% to 2%) but are less fertile compared to soils with a light mechanical composition.

Meadow flood plain and alluvial soils are common in the AmuDarya delta. Prior to a stable drying of the Aral Sea their area within the delta was estimated at about 550 thousand ha. Typical conditions of meadow soil formation are complicated by regular flooding by floodwater with subsequent drying. Depending on water turbidity and duration of floods the soil surface is covered by an annual warp hampering abundant growth of vegetation.

While the flooded area has considerably reduced, so has the area occupied by these soils. Due to specific hydrological and climatic conditions the meadow flood plain and alluvial soils are subject to rapid drying, ground water level decreases, thus the soils are transformed to meadow takyr and takyr soils.

Meadow alluvial soils are the region of oldest irrigation with land use ratio of 75%. These are primarily old irrigated soils with a powerful agro-irrigation horizon, medium cultured and flushed soils. They are considered the Republic's best soils. Newly irrigated soils are saline; they are low and mediums cultured and have a low productivity.

About 45% of solonchak and solonchak meadow alluvial soils are irrigated. These are primarily newly irrigated saline soils, low and medium cultured, medium quality and poorly drained soils.

Meadow, marsh and flood plain alluvial soils with irrigated sites are used as rangelands. Subject to flooding by floodwater they are hardly suitable for irrigation.

Land use rate of takyr soils is 11%. These are primarily newly irrigated, medium and poor cultured saline soils of medium productivity. The soils are used for rangeland cattle breeding. Their total area is about 250 thousand ha. The soils are suitable for irrigation and can be considered a reserve irrigation stock.

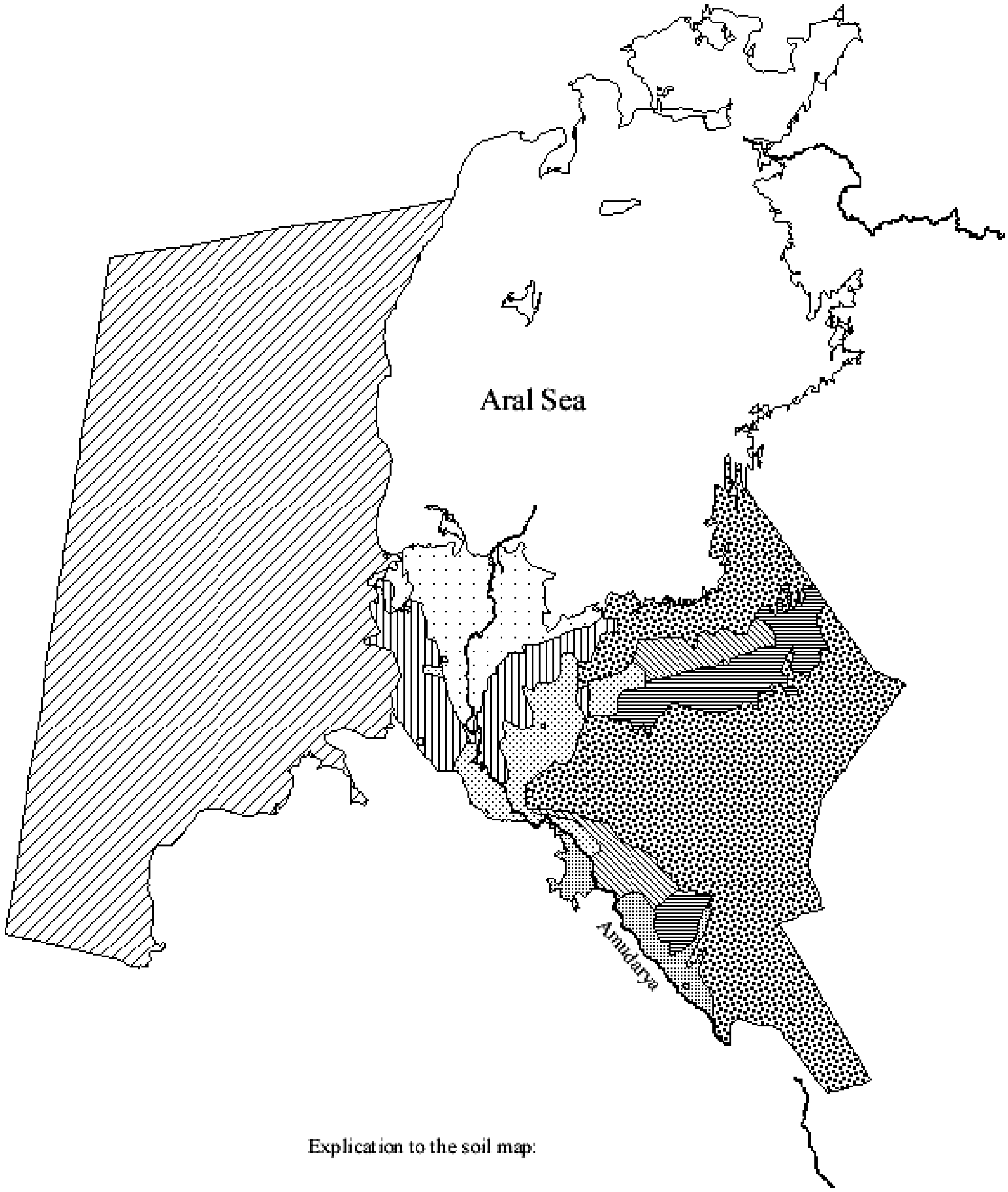
Solonchak loamy and sandy and sandy gray-brown soils are used as rangelands.

The Ust-Urt Plateau is represented by solonchak and saline-slkaline soils, primarily low thick takyrs, solonchaks and sands. They are classified as conditionally suitable for irrigation. Most of the area is presently used as seasonal rangelands.

The Kyzil-Kum sands represent poor ranglenads unsuitable for irrigation.

Salinization of irrigated lands is one of the crucial issues facing Uzbekistan including the Aral Sea zone. Table 3 shows the dynamics of irrigated land variations based on salt content in Uzbekistan and Karakalpakia.

It is clear from Table 3 that salinization processes are intensifying both in Uzbekistan and Karakaplakia. In 1975 the area of saline irrigated soils in Uzbekistan was 43.6% of the total irrigated area, 47.5% in 1980, about 50% in 1990 and 54% in 1998. The ratio of land with various salt content has changed, e.g. the area of medium and highly saline soils increased from 33.8% in the 1970-ties to 37% in 1995. The intensity of salinization processes in Karakalpakstan is more expressed, e.g. 43% of irrigated lands were saline in 1975, about 80% in 1985 and about 94% in 1997. But this relative growth of saline lands area is caused by development in 1975-1987 more than 200 th.ha of initially saline lands.



Explication to the soil map:

- Meadow alluvial soils, marsh-meadow in depressions. The ancient Amudarya delta, area 147 819 ha
- Meadow alluvial solonchak and solonchak-type soils. The modern Amudarya delta, area 460 069 ha
- Meadow marsh solonchak non-saline soils. The "living" Amudarya delta; area 803 743 ha
- Takyr solonchak soils with sand spots. The modern Amudarya delta; area 547588 ha
- Takyr solonchak soils with sand spots. The ancient Amudarya delta; area 609 450 ha
- Gray-brown solonchal and solonchak-solonetz sandy-loam soils; area 306 164 ha
- Ust-Urt Plateau. Gray-brown takyr soils, low-thick solonchaks; area 737 200 ha
- Fixed and lose sands with spots of sandy desert and solonchak soils; area 3 361 959 ha

Fig. 4. Soil map of the Republic of Karakalpakstan

Table 3. Irrigated lands variations in Uzbekistan and Karakalpakstan based on salt content

	Year	Irrigated land	Total Saline soils	Including:					
				Weakly saline		Medium saline		Highly saline	
		thou.ha	thou.ha	thou.ha	%	thou.ha	%	thou.ha	%
Uzbekistan	1975	2987.7	1683.4	863.4	66.2	309.1	23.7	131.8	10.1
	1985	3908.4	2018.6	1205.7	54.3	638.7	33.2	200.5	12.5
	1987	4109.1	2213.2	1272.2	57.5	659.2	29.7	260.6	12.8
	1990	4154.8	2121.5	1267.7	59.8	615.77	29.0	210.4	11.2
	1995	4226.3	2283.4	1489.9	65.3	628.02	27.5	165.47	7.2
	1998	4182.3	2260.5	1424.7	63.0	666.51	29.5	169.29	7.5
Karakalpakia	1975	252.0	171.4	111.8	65.2	42.5	24.8	17.1	10.0
	1985	342.9	273.2	130.3	47.7	98.9	36.2	44.0	16.1
	1987	485.1	430.1	180.4	41.9	179.0	41.6	70.7	16.5
	1991	494.75	474.0	194.6	41.1	201.4	42.5	78.0	16.4
	1995	500.92	464.95	230.17	49.5	181.79	39.1	52.99	11.4
	1997	500.9	467.9	256.7	54.9	163.1	34.9	48.1	10.2

1975 and 1985 - according to UZGIPROZEM Institute,

1987 - 1998 - according to the salt and soil survey by the Ministry of Agriculture and Water Management

Fig. 5 shows a map of saline soils in Karakalpakstan (based on 1976 data). The reason for using the 1976 map is because it most fully reflects the data on natural and secondary soil salinization.

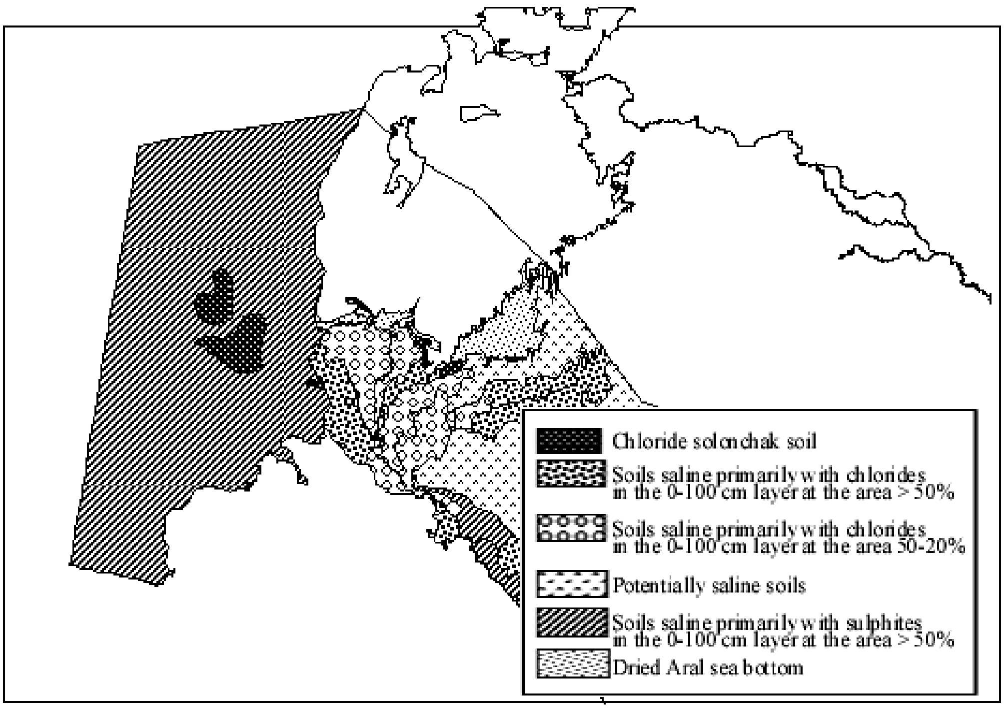


Fig. 5. Map of soil salinization in the Republic of Karakalpakstan (1976)

The data in the map (Fig. 5) shows that the territory comprises lands with varying salinity. Most soils are salinated by sulphates and chlorides. These are potentially hazardous soils in terms of secondary salinization. Bad reclamation status is caused by unfavorable water balance. If before the Aral sea was salt collector, now this role belongs to SyrDarya and AmuDarya power reaches. In particular, since 1980 till 2000 about 1mln.t salt was accumulated in AmuDarya lower reaches, but no measures were undertaken to improve this situation.

2.1.4. Development of aeolian processes and salt and dust transport from the dried sea bottom and other surrounding desert areas

Aeolian processes and salt and dust transport are the strongest factor of desertification.

Constant winds from the seaside, sandy soil and poor vegetation cover result in development of wind-erosion processes. Population activity becomes the leading factor and influences deflation processes. All types of deflation and accumulation can be observed in this case. Intense wind erosion induces formation of hollows, phytogenic knolls and even small sand dunes in a short time. It depends on specific wind regime and lithological composition of accumulations in the region.

Deflation processes are typical for the whole sandy region. However, they are especially active near the native shore of the 1960-s where upper layer of sandy soil is dry, and vegetation is scarce. Hollowy-knoll, hollowy-barkhan and barkhan relief shapes, which were formed during the last 10 to 15 years, prevail in this region. The bottom of Muinak gulf is subject to particularly intense aeolian relief formation. In summer and autumn, when the soil moisture content is the lowest, wind velocity is 5 to 5.2 m/sec (Muinak). Such velocity is sufficient to move sand. The highest wind velocity in the region can reach 20 to 22 m/sec in summer. It influences processes of substratum disperse and transport of sand from one place to another. Desert sand dunes («barkhans») typical for Kara-Kum and Kizil-Kum have formed here. Sand dunes width can reach 5 km. Today they are widening along the sea because under the Aral Sea level lowering sands of the gulf become dry and draw into deflation processes. Wind erosion processes are intensified in the region of plump salt marshes. At present they are covered with dry one-year saltwort, goosefoot and other halophites grow somewhere. A layer of pressed sea grass - zosteria - often covers large areas and creates the so-called «armored horizon» against disperse. Contact parts of old shrinkage clefts (several clefts in the same place) filled with melkozem, broken shells, salts and plants' residue, serve as the deflation points in plump salt marshes. Such clefts often have no vegetation and are subject to constant to disperse. Melkozem and other materials blow out is due to their crumbly and pouring state, and it is reported throughout the entire area where wind blows.

After elimination of dried saltwort (according to succession principle they will be replaced by tamarisk, karabarak, etc.) wind erosion processes will be undoubtedly strengthened, and hence, relief disintegration will increase. Huge amount of sulphates raises into the air together with melkozem of plump salt marshes, and it will be blown out by the wind to the south. The air above dried sea bottom in the upper part of Ust-Urt area and Muinak peninsula is extremely dusted. It is a result of aeolian processes and saline dust transportation towards the South. The air above the sea is always transparent.

A. Grigoriev and *V. Lipatov* (1980) have studied meteorological satellite imagery and discovered a powerful dust discharge into atmosphere above the Aral Sea in the spring of 1975. Dust flows reached 300 km in length and several dozen km in width. Thus, it was an event of the regional scale. Dust storms are normal in this region, and high resolution imagery showed intense production of dust storms that were registered repeatedly during the following years. Analysis of the meteorological satellite imagery showed that the same regions to the northeastern coast of the Aral Sea turned out to be the hearth of the dusty storms. According to approximate evaluation (*Grigoriev, Kondratiev, 1980*) the amount of transported dust was 15 to 75 million tons per year.

Various opinions were expressed concerning salt transport from the dried sea bottom and desert Aral territories. Despite our deep respect to the authors, their estimates vary significantly:

- Kazakstan Academy of Sciences - *Mozhaeva and Nekrasova* (1985) - 82 t/ha;
- Uzbekistan Academy of Sciences - *I. Rubanov* - 22.8 t/ha.

N. Glasovsky estimates it at 230 million tons per year, and *Lester Brown*, from unknown sources, - to 140 million tons. Observations at 45 stationary points located in the southern Aral region covering 75 thousand km^2 were organised by SANIIRI Research Institute in 1982. Aerosol samples were collected once per month (*Kosnazarov, Razakov* 11; 12). The data (Table 4) show that dust income into the Aral region varies considerably less than previous figures unsupported by experimental data - from 0.7 to 10 t/ha including salt income from 0.03 to 1.7 t/ha (Fig. 4.5) for instance, in evaluations of N.Glazovsky or L.Brown without experimental base. The isolines of aerosols diffusion based on long-term data show that the maximum income is mostly near the dried sea bottom line and near shallow local areas of excitation. The maximum impact range does not exceed 250 to 300 km.

Table 4. Temporal changes in the quantity of dry fallout in regions associated with the Aral Sea (kg/ha). Total precipitation of the dust and salt mass includes the mass of soluble salts

Sampling locality	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**
Exposed bed of Aral Sea										
n-24 (Aral beach)	1646 220	3666 802	9686 1658	2638 302	2265 382	2555 130	4418 217	3018 124	2107 111	1749 213
n-10 (Utchsay)	725 142	891 178	1856 199	681 85	7917 387	10293 111	11661 143	1651 61	1200 21	1780 164
Coastal tone of Aral Sea										
n-9 (meteorological station Poriatau)	5333 82	4058 78	1165 119	3245 52	4130 88	5597 35	919 164	4082 35	1184 22	2115 64
n-17 (Setim Kazakhdarya)	1671 201	1134 257	1078 360	636 187	1100 241	1288 177	2454 82	2S95 72	2200 87	3064 375
Non-irrigated area AmuDarya delta										
n-6 (142 km along road Nu-kus-Muinak)	1143 60	1039 199	1316 85	421 47	2455 147	2222	2822 29	3384 33	1069 13	1960 147
n-26 (13 km from road settle-ment Kazakhdarya)	—	810 192	865 63	626 139	3077 220	1222 104	662 26	662 33	265 43	696 106
Irrigated area										
n-27 (meteorological station at Takhiatash)	—	695 109	1020 138	635 112	859 112	913 22	1223 22	868 22	822 12	556 121
n-15 (meteorological station at Chimbal)	1140 180	1640 211	1840 250	924 26	1211 121	1123 110	1273 22	794 20	594 62	1511

Studies showed that amount of dissolved salts is 5 to 30%. It explains the fact that while dust and salt disperse at a height of 3 km, a possibility of aerosol formation appears. During low rate drying of the Aral Sea in 1971-1975, the total amount of ions in precipitation was 20 to 70 mg/L, reaching 100 to 300 mg/L in 1985. Hence, the average value of salt income with precipitation is 150 to 300 kg/ha.

According to our calculations on based on the average values collected from all observation points, a peculiar feature appears (Fig. 8) - activity of salt transport first gradually increased, then lowered and stabilized.

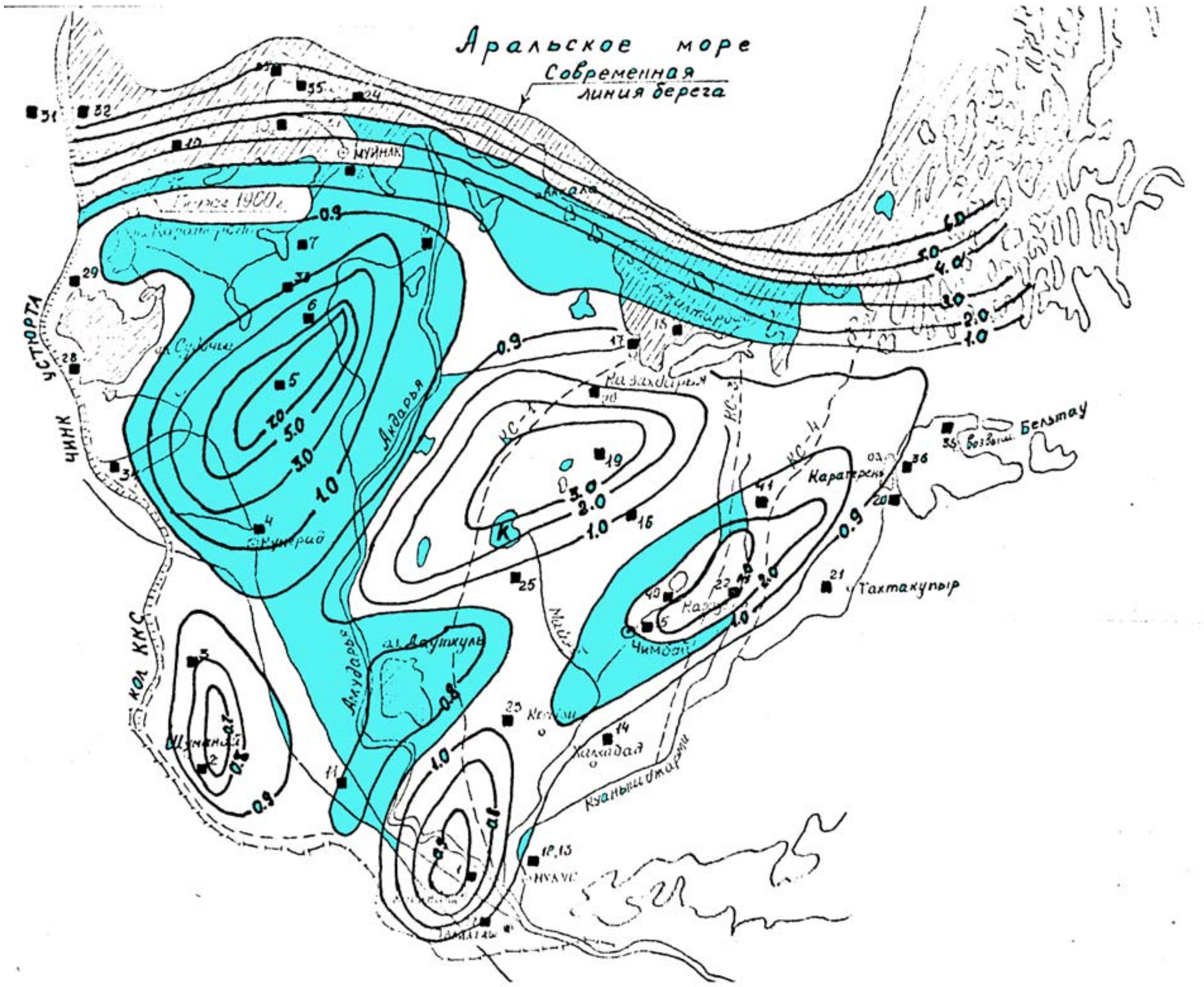


Fig. 6. Isolines of dust transport in the Aral region in 1982 - 1985 (t/ha)

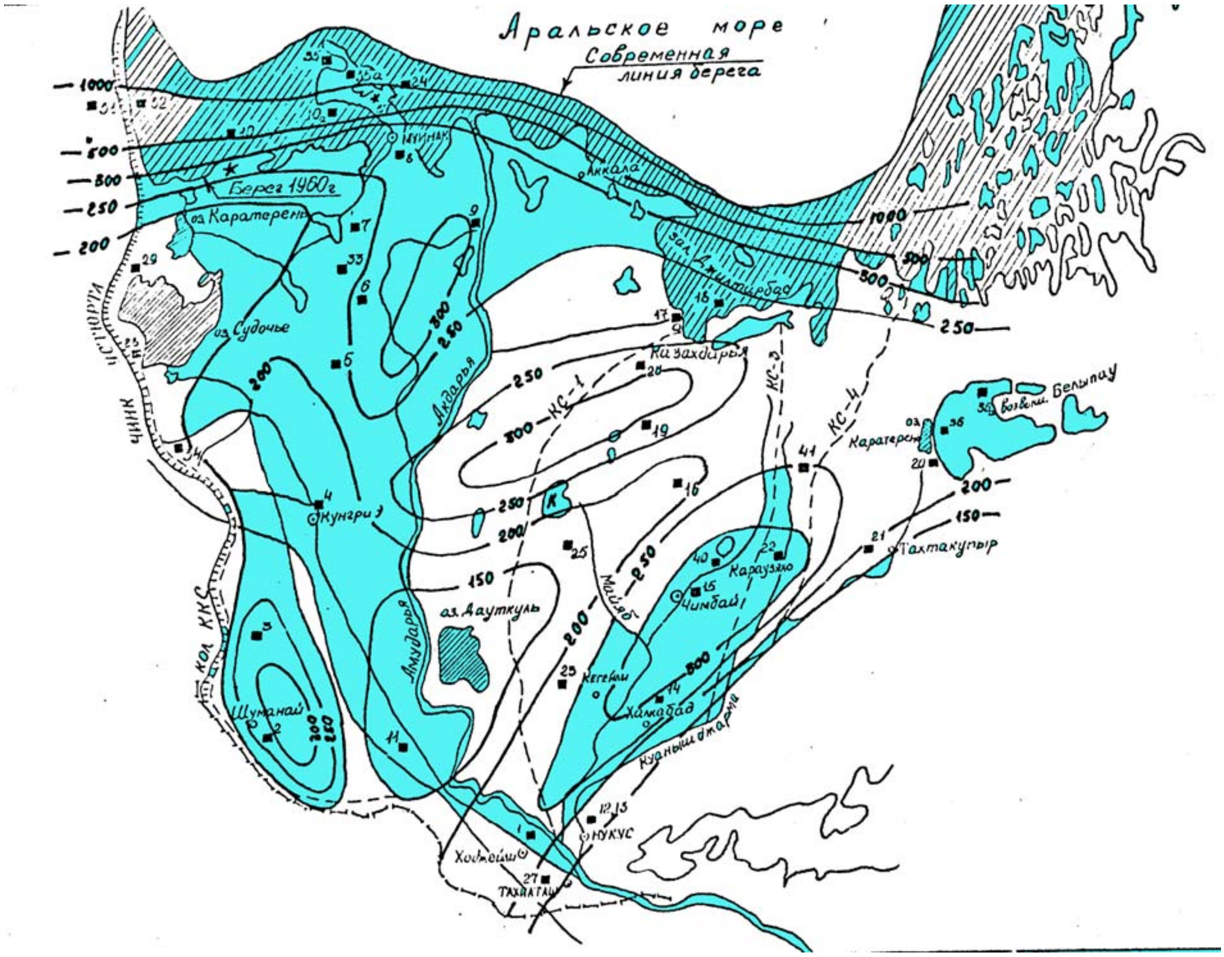


Fig. 7. Change of salt transport in the Aral region in 1982- 1985 (kg/ha)

It worth to note that data observed by SANIIRI are similar to SARNIGMI results (21).

- Below 100 km from the sea - dust income is 1.5 to 2.5 t/ha;
- 100 to 500 km from the sea - dust income is 0.5 to 1.5 t/ha;
- Above 500 km from the sea - dust income does not exceed 0.1 t/ha.

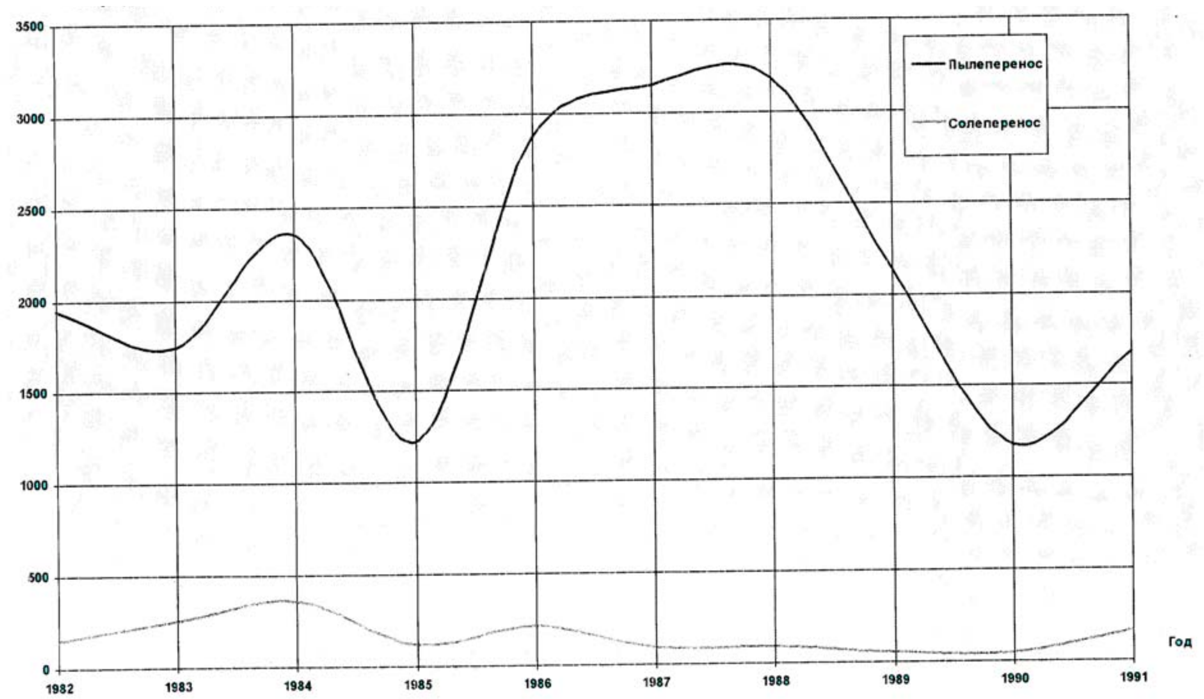


Fig. 8. Averaged dynamics of the salt transfer from the drained Aral Sea bottom from 1982 to 1991

--- Dust transport

--- Salt transport

2.2. Environmental transformations induced by these factors

Environmental transformations induced by these factors are partially the consequences of the Aral Sea lowering. But their integrated impacts induce the so-called environmental losses in the region, countries and zones located within the impact zone of the Aral Sea lowering. It is noteworthy that in the present Section we are not attempting to evaluate them in a monetary value, but limit ourselves to a quantitative estimate.

2.2.1. Loss of the Aral Sea as a natural object

It is presently quite clear that rehabilitation of the Aral Sea in any form of a fresh-water basin is absolutely impossible, and disregarding the option selected for solving the problem of the sea stabilization, we should state that the new sea cannot be considered a reduced version of the Aral Sea either in the size, sea level or salt content.

Degradation of the ecosystem of the Aral Sea follows totally irreversible patterns. It is related to variations of all characteristics of habitats of aquatic organisms. As early as 1990 the number of microorganisms reduced 2.5 times on the average, while in the Small Sea and northern Large Sea it reduced thrice. Typically fresh water phyto and zooplankton was replaced by salt-loving forms. Biomass and number of phytoplankton reduced by one order of magnitude. Zooplankton content has changed too, e.g. chyromonidae, dreisenas and shpanks lost their significance, while acclimation of nerisa and abra species resulted in a certain growth of the biomass.

Reduced fodder basis of fish, complete drying of sponging areas has eliminated reproduction of the Aral Sea fish species that previously included 20 species, including 12 commercial species. Acclimation of new species of fish and fodder has begun, but further growth of salt content has lead to their instability and practical extinction.

The Aral reservoir will exist in a form of bitter-saline combination of several closed water objects (3 or 5 depending on a decision). They will have different levels and salt content rates and will be able to fulfill the sea function partially as a receiver of drainage flows and salt, but they will not serve as a regulator and climate softener in the region, and will not be and object with biological activity at all. Most probably, these reservoirs, except the Small sea will remain stable at a level close to 28 to 30 m with evaporation value of 10 to15 km^3 and salt content 60 g/L, i.e. their parameters will be close to the Dead Sea, and similar to other bitter-saline water reservoirs, where living biota can not exist, if certain measures would not be undertaken by all countries of the basin.

2.2.2. Variations in soil and natural complex and desert landscape formation

Intense degradation of soil and natural complex occurred under factors mentioned in 2.1.

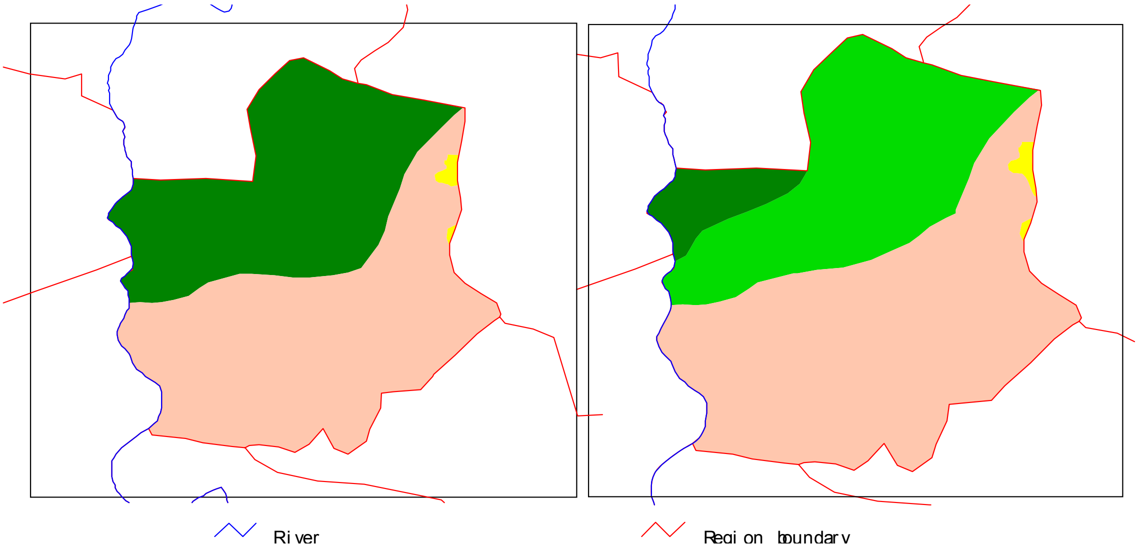
It was expected that the dried sea bottom would be overgrown with forage saltwort. Some saltworts appeared during the first 3 to 5 years that were subsequently replaced by eurytoneous perennial desert plants.

A significant heterogeneity of dried sea area due to ground water, relief, soil and morphology changes and their asynchronous area and time characteristics is observed. That is why sand formation processes, initial overgrowth with goosefoot, Paulsen saltwart, zhuzgun, saxaul and petty psalophites take place in some areas. Salted «sors» are formed in the closed hollows.

According to *Rafikov* et al. (13) stages of desert landscapes formation on the dried sea bottom and in the Aral region are as follows:

- Formation of marsh salt marshes covered by scarce vegetation.
- Reforming of the marsh salt-marshes into coastal ones with salt content up to 5%, and in salty crust - to 6 to 11%, occasionally to 37 to 56%.
- Dehydration of surface layer (3rd - 4th year), disappearance of annual halophyts, formation of salt marshes with hinge sandy cover (to 30 cm), and intrusion of desert xerophyts into halophytic ecosystem.
- Beginning of formation of the desert biocomplexes - diffusion of xerophytes, tamarisk, sarsazan, psammophytes into ground sandy sediments; when structure is heavy crusty-plump salt marshes are formed (4th to 5th year when soil is light, and 5th to 7th when the soil is heavy).
- Desert landscapes are formed in the 10th to 11th year, deflation and aeolian accumulation on sandy soils, and takyr is formed on heavy soils. Saline regime is negative.
- Sustainable irreversible season and annual desalination, and desertification happens during the 14th to 16th year.

Our studies of soil variations are based on comparison of the 1960 and present mapping information. Using this information and the data on variations in vegetation cover, habitats, fish and bird number and diversity, a conclusion can be made on landscape variation. For instance, a typical feature of Bozatauz region (Fig. 9) is meadow, wetland solonchak and non-saline soils reduced 30 thousand ha and emergence of up to 30 thousand ha of meadow alluvial solonchak and solonchak-like soils, negligible growth of solonchaks and sands (up to 4 thousand ha) and also takyr solonchak-like soil (up to 50 thousand ha).



Bozatauz region in 1960 **The present status**

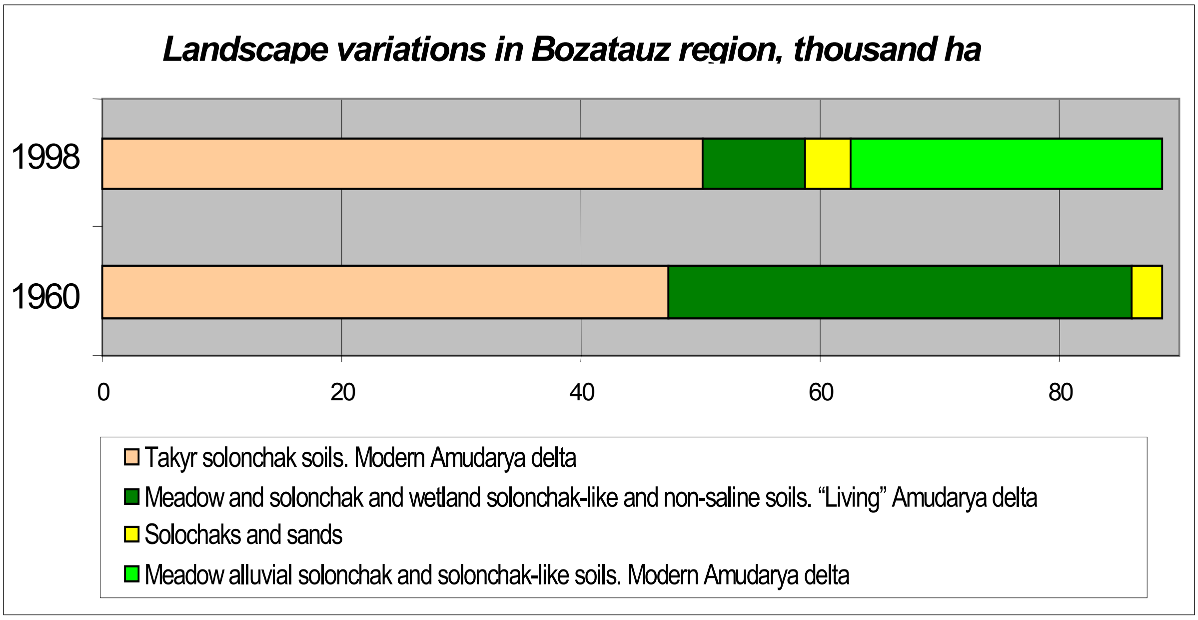
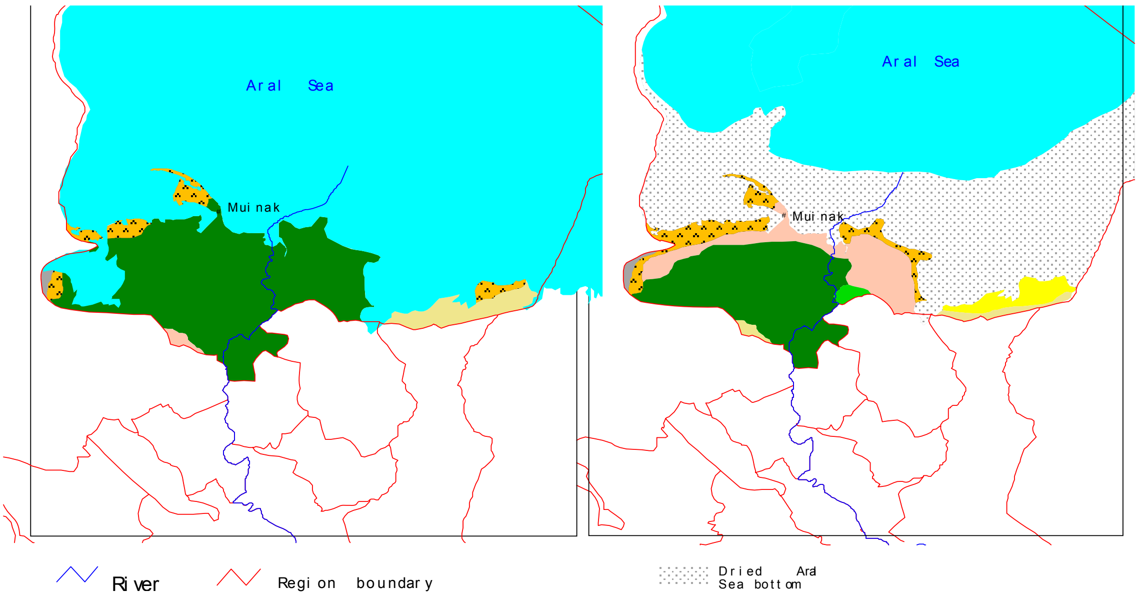


Fig. 9. Soil cover variations in Bozatauz region of Karakalpakstan from 1960 to 1998



Muinak region in 1960 **The present status**

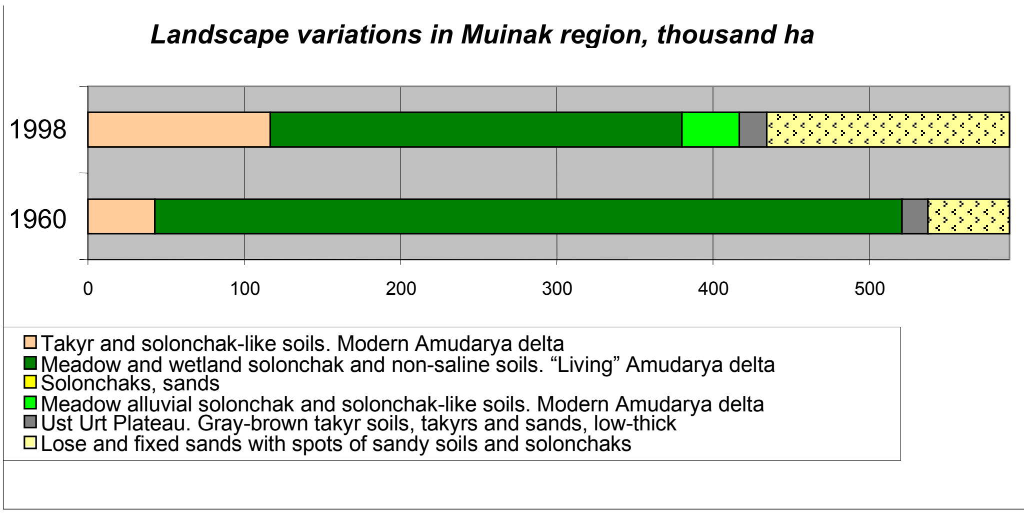


Fig. 10. Soil cover variations in Muinak region of Karakalpakstan from 1960 to 1998

In the Muinak region in the period under review over 2.5 times increase was reported in solonchak soils (from 42 to 116.5 thousand ha), fixed and lose sands (from 52 to 155.6 thousand ha). The area under meadow and wetland soils reduced from 478 to 264 thousand ha, and meadow alluvial and solonchak soils appeared (36.5 thousand ha).

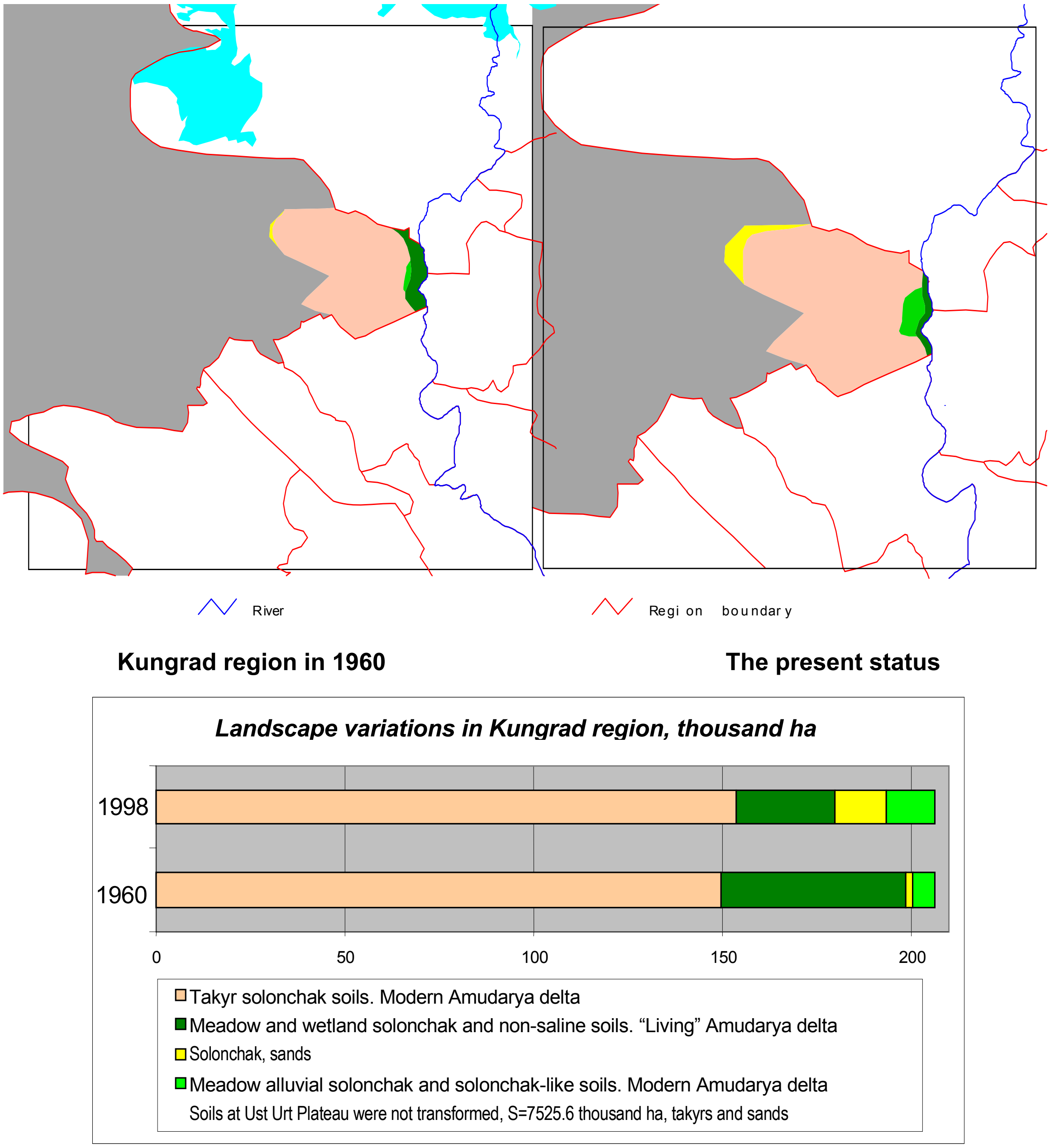
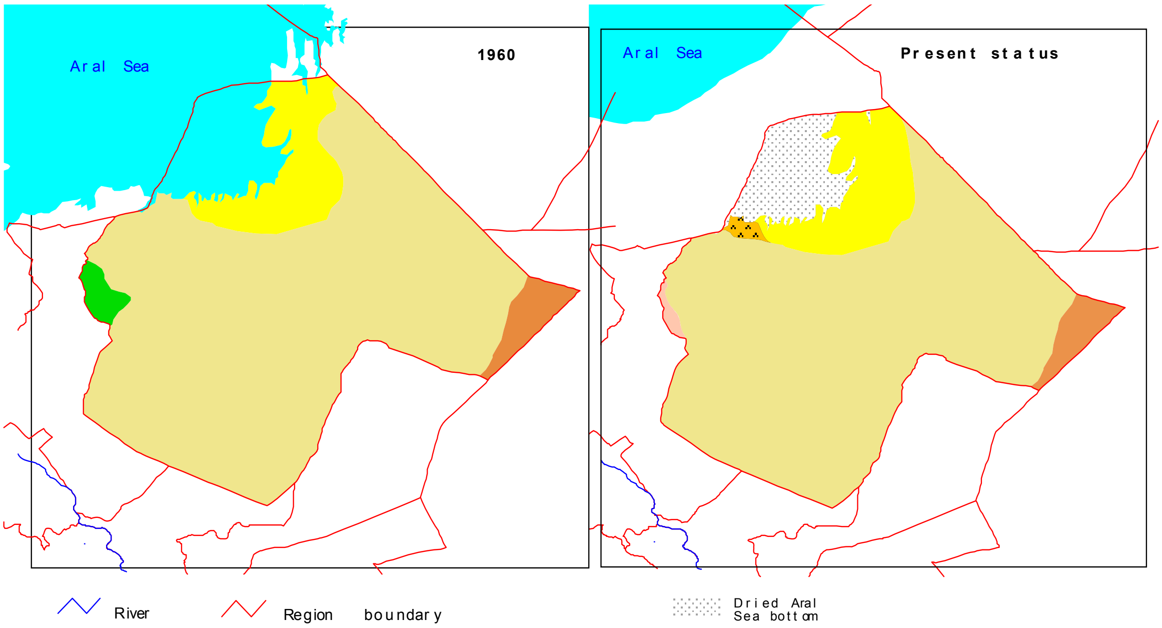


Fig. 11. Soil cover variations in Kungrad region of Karakalpakstan from 1960 to 1998

Solonchak and non-saline soils were considerably transformed in Kungrad region (Fig. 11). Alongside their reduction by 23 thousand ha, solonchak and sands increased 12 thousand ha, and also alluvial solonchak and solonchak-like soils increased up to 37 thousand ha. The area of takyr solonchak soils has increased 4 thousand ha.



Tahtakupyr region in 1960 **The present status**

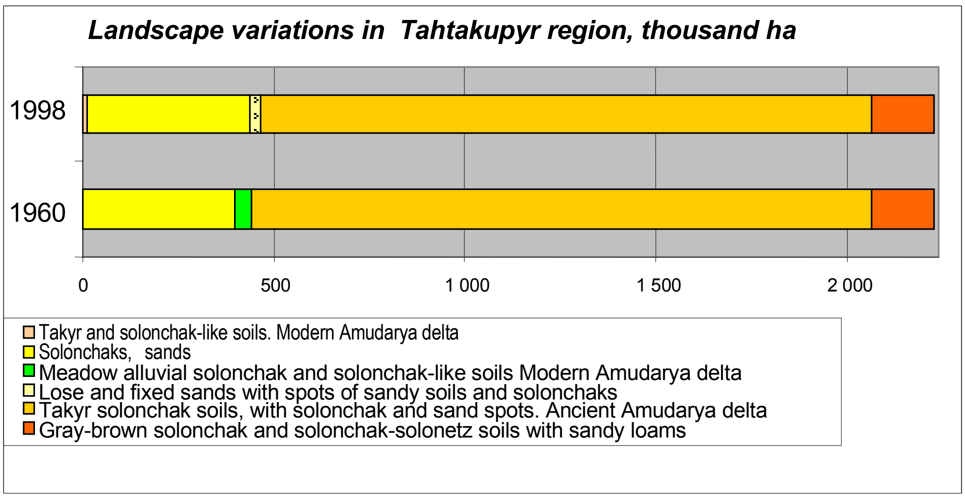
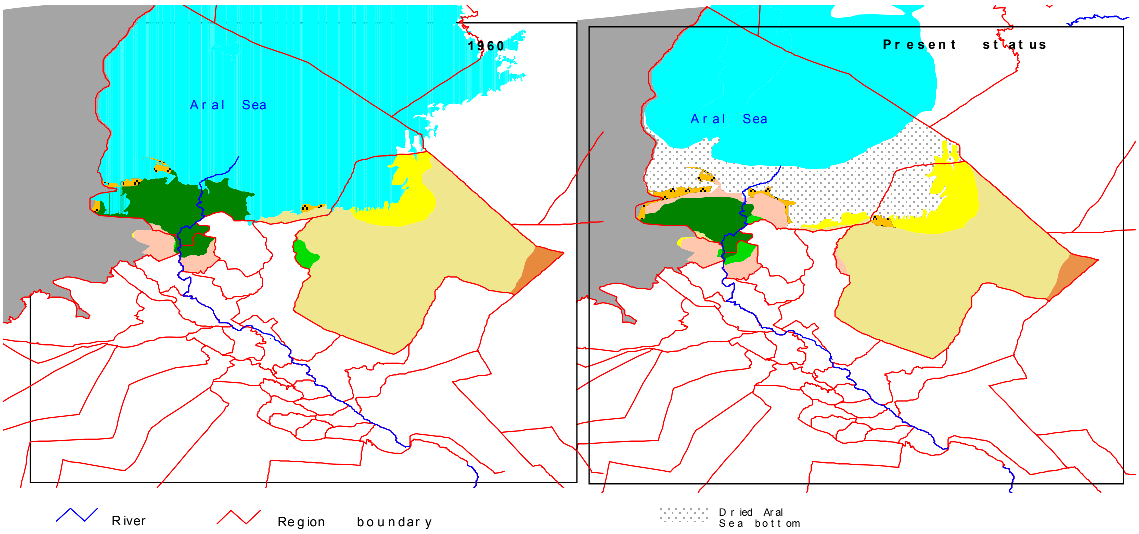


Fig. 12. Soil cover variations in Tahtakupyr region of Karakalpakstan from 1960 to 1998

Soil transformations in Tahtakupyr region (Fig 12) are negligible. Takyr solonchak soils representing the modern AmuDarya delta are estimated at 12.4 thousand ha compared to 1.8 thousand ha in 1960. The areas of solonchaks and sands increased 30 thousand ha, gray-brown soils have remained practically unchanged, while takyr solonchaks with sand and solonchak spots have increased about 20 thousand ha. Moreover, in the period under review about 30 thousand ha of lose and fixed sand with spots of desert sand soils appeared, while meadow alluvial solonchak and solonchak-like soils completely disappeared from the modern AmuDarya delta.

The overall situation in the Aral Sea region is as follows (Fig. 13). Takyr and solonchak soils have increased 91 thousand ha, solonchaks and sands - 43 thousand ha; fixed and lose sands with spots of desert sand soils and solonchaks - 130 thousand ha. Transformations in takyr solonchak soils with spots of sand soils and solonchaks, and also gray-brown solonchak-like soils are negligible. Meadow and wetland solonchak and non-saline soils have reduced 266.6 thousand ha. The dynamics of soil cover variations in each region of the Aral Sea zone are shown in Table 5.



The Aral Sea regions in 1960 | The present status

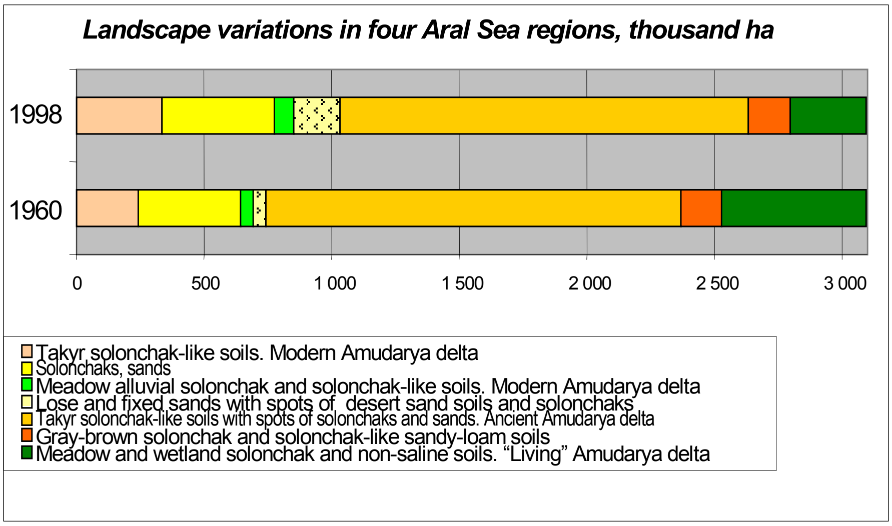


Fig. 13. Soil cover variations in four regions of the Aral Sea from 1960 to 1998

Table 5. Dynamics of soil cover variations in the Aral Sea regions, thousand ha

Reg.	Yr.	Soil type							
		Takyr Solonchak-like Modern delta Amudarya	Meadow and Solonchak-like Non-saline "Living" Amudarya	Solonchak sand	Meadow alluvial Soils solonchak Solonchak-Modern delta Amudarya	Ust-Urt Plateau Brown-gray soils Solonchak and Low-thick	Fixed and lose Sands with With spots of desert sand, solonchak	Takyr Solonchak- soils spots of desert sand, ancient delta Amudarya	Gray-brown Solonchak-like Solonetz-like Sandy-loam soils
Bozatauz	19	47.	38.	2.					
	19	50.	8.	3.	26.				
Kungrad	19	149	49.	1.7	6.	7525			
	19	153.	26.	13.	12.	7525			
Muinak	19	42.	478			16.	52.		
	19	116.	264		36.	16.	155.		
Tahtakupyr	19	1.		395	43.			1	163
	19	12.		425.			26.	1601	163.
Aral Sea	19	241	565	399	49.	7	52.	1	163
	19	332	299	442	75.	7	181	1	163

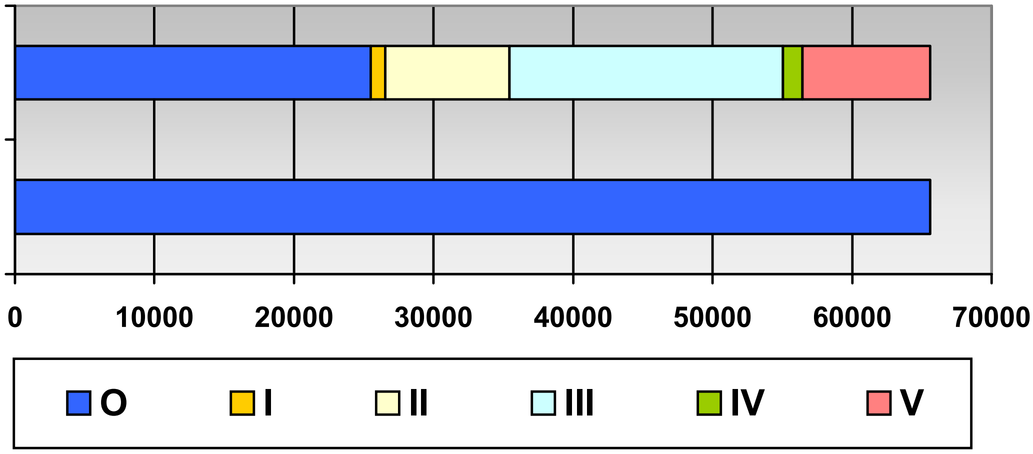


Fig. 14. Landscape variations in the dried Aral Sea bottom

Based on the latest observations *Rafikov* (7) specifies the following distribution of landscapes and soils:

- Fairly lopsided shore sandy area with ground water depth 0 to 0.5 m, soils in a form of sandy marsh salt-marshes - 2.6% **(I)**;
- The same, with ground water depth 0.5 to 2.0 m, soils in a form of meadow sandy salt-marshes – 22.2% **(II)**;
- The same, with ground water depth 2.0 to 3.0 m, sandy salt-marshes – 48.9 % **(III)**;
- Alternating salt spots in the sands – 3.5% **(IV)**;
- Sand dunes with loams and sandy loams underlayer with water depth below 5 to 7.0 m - 22.8% **(V)**.

Table 6. Dynamics of landscape variations at the Aral Sea bottom related to the sea drying

Year	Total area, sq. km	Including					
		Lake area	Sandy marsh solonchaks	Meadow sandy solonchaks	Sandy solonchaks	With salty spots	Sand dunes with sandy loam under layer
1950	65607	65607	--	--	--	--	--
1970	65607	60692	127.79	1091.13	2403.435	172.025	1120.62
1998	65607	25500	802.14	4211.23	22259.39	1604.28	11229.96

Vegetation cover changes correspondingly.

Drying of the deltas happened in parallel with landscape formation under sea shrinkage. The area of hydromorphous soils during the process of delta drying out have decreased from 630 thousand ha in 1950 to 80 ths ha at present.

Variations in hydromorphous soils in delta and disappearance of alluvial soils from evolution, disappearance of transition state between hydromorphous types of meadow and marsh soils, typical for alluvial plains occurred under sharp aridisation and during short period. The total area of salt marshes has increased to 273 thousand ha (34%) compared to 85 thousand ha (7%) in 1953. Salinization is usually higher in the direction towards the former Aral Sea coastline. Desertification of delta lands is accompanied by inevitable degradation of the initial soils, lower biological activity and provision of organic compounds and main nutrition elements for plant growth, loss of potential fertility, and sharp reduction of productivity. In future development of sandy-desert soils, takyr, residual and takyr salt marshes is expected. Humus content due to wind decrease from 3-4% to 0.5-0.6%.

2.2.3. Vegetation cover variations induced by landscape variations

The most development vegetation was located in the river deltas and formed huge tugais - unique woods combining bushes and trees. Occasionally flooded, they became covered with drift layers. *Gerasimov et al.* (13) give the following explanations and evaluations of the processes in the 1970-s:

«The delta used to have hydrophilic landscapes, cut into and sharply discording with surrounding desert zone landscapes. Alluvial-meadow and meadow-marsh soils along terraces, tugai, cane bushes served as the sources for tugai vegetation growing up, and fed on this fauna.

Turinga, lokh, and willow bushes gradually disappeared and were replaced by halophytic vegetation. This process of plant development is ephemeral - yield of halophyts was 2.7 hundred kilos per ha in 1977, 28 hundred kilos per ha in 1978, and 0 (zero) in 1979.

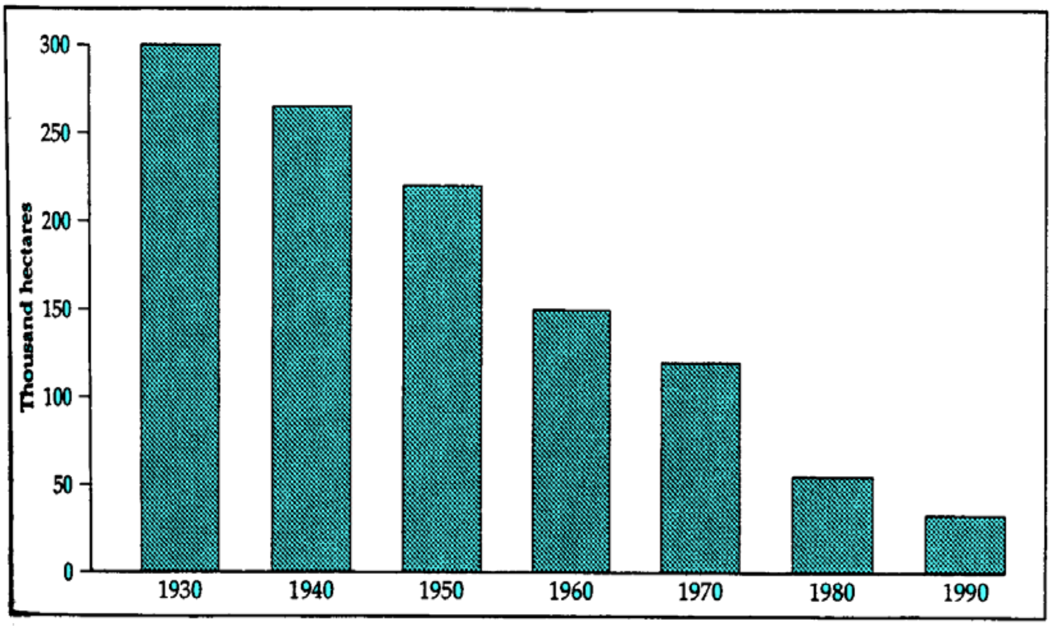


Fig. 15. Reduction of tugai forest in the AmuDarya delta

Degradation of active vegetation cover is presented in the following table.

Table 7. Degradation of vegetation cover in the AmuDarya delta

Period	Cane		Tugai	Haymaking		Rangelands	
	Area, ths ha	Yield, hundred kilo per ha	Area, thou. ha	Area, thou. ha	Yield, hundred kilo per ha	Area, thou. ha	Yield, hundred kilo per ha
Before the 1960-s	≈ 600	40	1300	420	15 to 40	728	1.5 to 15
End of the 1970-s	100	5	50	75	5 to 16	145	0.6 to 6.0
End of the 1990-s				16.5		10.6	

The data by other investigators are different. *S. Tereshkin* et al. (14) show that tugai woods in the AmuDarya delta are shrinking (Fig. 7). Tugai woods occupy much less area even in 1930 (300 thousand ha), and their decrease happened before Aral Sea lowering – for 150 thousand ha before 1960, and 120 thousand ha more as of today.

By means of these investigations authors describe reduction of tugai vegetation not only in area, but in production as well. The parameters of wood, bush and grass yields in tugai decreased during last 35 years as follows:

Table 8. Dynamics of tugai woods mass per area unit

Activities	Production	1960	1995	% of decrease
Total phytomass	t/ha	170,1	128,9	24,2
Ground phytomass	t/ha	29,1	19,2	34,0
Wooden phytomass	t/ha	38,7	28,6	26,1
Roots	t/ha	102,3	81,1	20,5

Considering that tugai production is provided by green and woody mass it is stated that its average decrease occurred from 67.8 t/ha to 37.8 t/ha or for 45%!

According to *N. Novikova* tugai degradation was accompanied by their replacement by tamarisk and halophytic bushes. Typical tugai reduced from 42% (1960) to 18% (1993) (Fig. 8).

Cane bushes were important parts of vegetation cover structure before delta became dried. Cane bushes grew in shallow water of the lakes and flood-lands and covered about 600 thousand ha before 1960. They were main highly productive pasture and grasslands in the downstream AmuDarya. They have reduced 30 to 50 thousand ha with productivity decreased from 30 – 40 to 13 – 15 t/ha of dry mass. Some cane regions are irrigated artificially in order to create favourable conditions and use cane for hay supply and grazing. Today the landscapes with cane bushes on meadow-marsh soil in the AmuDarya delta have slightly restored due to delta watering during last years. The Akdarya and Kipchakdarya floods also restored slightly, though internal low regions in the Kunadarya delta have dried out completely. On the left bank of delta such landscapes occupy only internal plains of the lakes Moshankul-Khojakul-Ilmenkul-Kipsyr and area north of Lake Sudochye. They exist because of drainage waters.

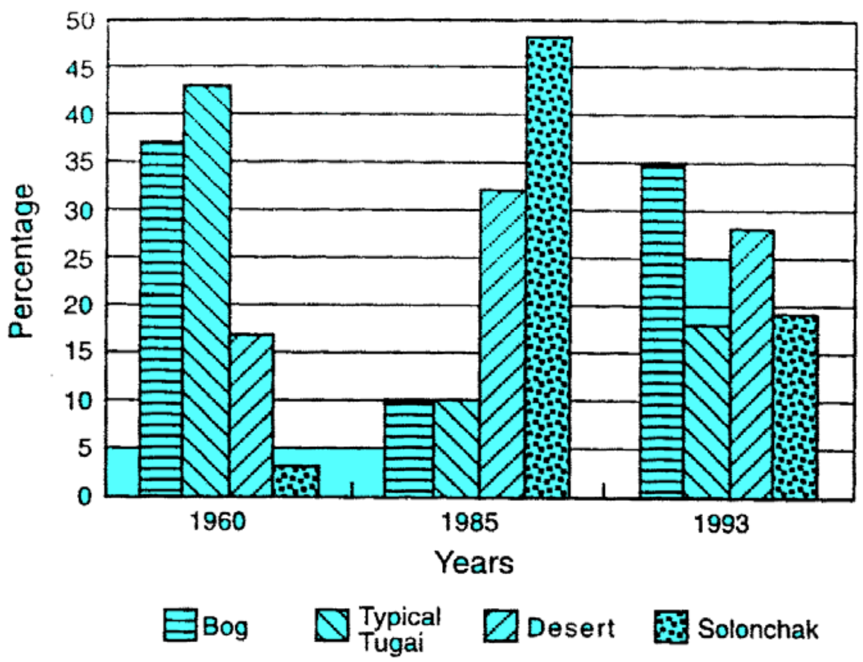


Fig. 16. Changes in the distribution of tugai plant communities in the AmuDarya delta

Landscapes area with tamarisk five-stamen bushes on meadow and meadow-marsh soils have increased. Today they prevail in the northern part of delta and are typical of all plains near riverbeds and flood-lands.

The area with tamarisk bristly and karabarak bushes expand on highly salty soils and salt marshes and on low plains near Sudochye Lake. Such landscapes are formed on the internal channel of Kunadarya delta.

Area with black saxauls on takyr soils and saltworts on desert-sandy soils have increased slightly. Such territories usually grow due to desalination of the formally irrigated soils in the eastern part of delta north of Turkmenkyrylgan sands.

Compared to the early 1960-s the irrigated area slightly increased particularly in the seaside of the AmuDarya delta. It resulted from developing new lands located in different parts of the delta. Generally it is typical for delta that meadow and tugai landscapes are reduced, while salt marsh, takyr and sandy plains area increase gradually. It is difficult to quantitatively assess landscape and vegetation changes based on 2.2.2 and 2.2.3. These estimates are important for environmental damage assessment, since the absolute estimation of the area changes is rather hypothetical. We will try to provide assessments based on GIS-technologies using data from different remote sources mentioned in section 5.

2.2.4. Ground water level lowering

Generally the ground water level (GWL) lowering in the entire southern Aral region was reported from 2 to 15 m (1960 – 1995) due to several reasons described above in 2.1.2. Depending on geomorphology range, the radius of GWL lowering and artesian waters does not exceed 50 to 100 km. However some areas of water supply from ground water could be effected.

As for ground water flow into the Aral sea, *Sidikov et al.* (16) forecast the total amount of these waters is 0.21 cub. km in 1960 (Fig. 16) and will stay almost the same. It will be redistributed between the water area and dried bottom in favour of the latter. At the same time these waters will bring salts into the sea and dried bottom estimated at about 9 million tons per year.

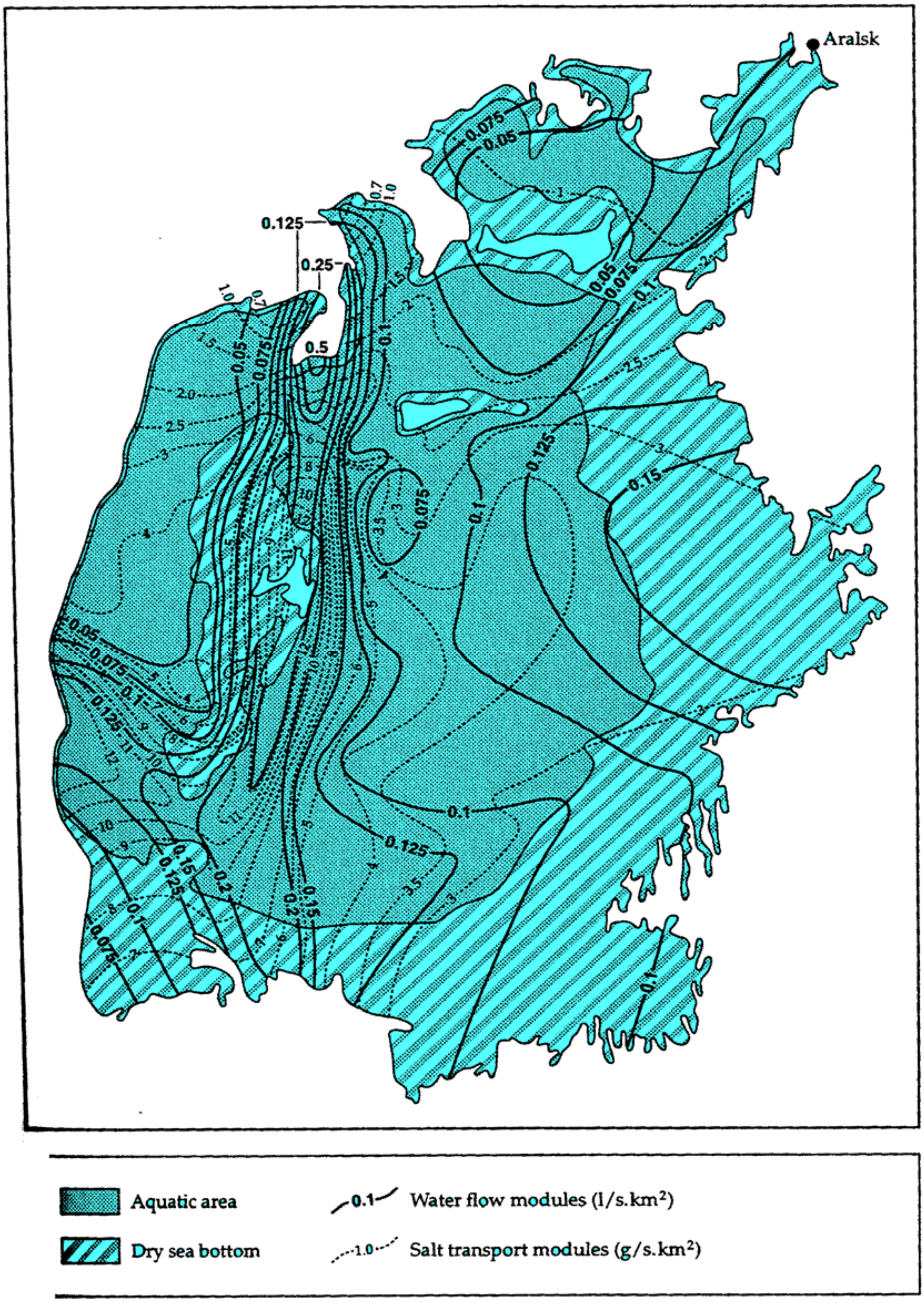


Fig. 17. Artesian flow and transport in the Aral depression

2.2.5. Climate change

A range of investigators have reviewed climate changes in the Aral region (18, 19, 20). Following are the general conclusions.

Constant changes in regional atmospheric deflation inducing climate changes in the Aral basin have been reported during several dozens of years. Their direction mostly coincides with the neighboring regions. As a result of hydroengineering activities in the rivers, river plains, near irrigated areas, and in the Aral region, and also local changes under human activity occurs in a scale of 100 to 10000 km^2. The last figure indicates the impact zone of relative changes in the Aral region.

The Aral region is characterised by significant changes in local climate. Microclimate changed within a distance of several dozens kilometers from the coastline in the 1960-s. These changes were especially dramatic during coastline retreated 40 to 60 km. It is difficult to forecast future changes. The air average temperature increased in summer time 0.1 to 0.4°C, in spring 0.5 to 0.7°C. Winter and autumn temperatures decreased correspondingly 0.2 to 0.6°C and 0.5 to 1.3°C. The range of dijurnal temperature on the coastline has broadened, and relative air humidity decreased, especially during warm seasons. Observation data from Muinak meteorological station represent the air temperature, precipitation and evapotranspiration rate during 1881 – 1996 (Tables 6 - 8).

A growing number of dust storms with the maximum activity is observed from April to July.

The number of sunny and extremely hot days has increased 15% while the number of sunny and humid days decreased 4 % accompanied by local climate transformations in the dried out territory. The occurrence of weather activity unfavorable to human activity has generally increased.

Tables 9 and 10 and Fig. 18 show the data on Muinak meteorological station, particularly air temperature, precipitation and evapotranspiration in the period from 1881 to 1996.

Table 9. Air temperature (ÑÎ) data on Muinak meteorological station

Years	Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Average annual
1881- 1960		-7,1	-6,2	0	8,5	17,3	23,2	25,9	24,7	19,3	11,1	3,7	-2,7	9,8
1961- 1985		-6,5	-6,2	0,5	10,3	18,6	24	27,1	24,8	18,7	10,3	3,5	-1,9	10,3
1986- 1996		-6,3	-5,3	1,2	11,9	20,1	26,8	26,4	25,3	19	12	1	-3,1	10,8

Table 10. Precipitation (mm) data on Muinak meteorological station

Years	Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Average annual
1981- 1960		7	11	12	14	7	7	4	5	4	11	8	8	98
1961-1985		9	10	13	18	8	7	5	4	5	13	12	9	11
1986- 1996		9	7	13	14	17	3	3	2	3	8	8	9	96

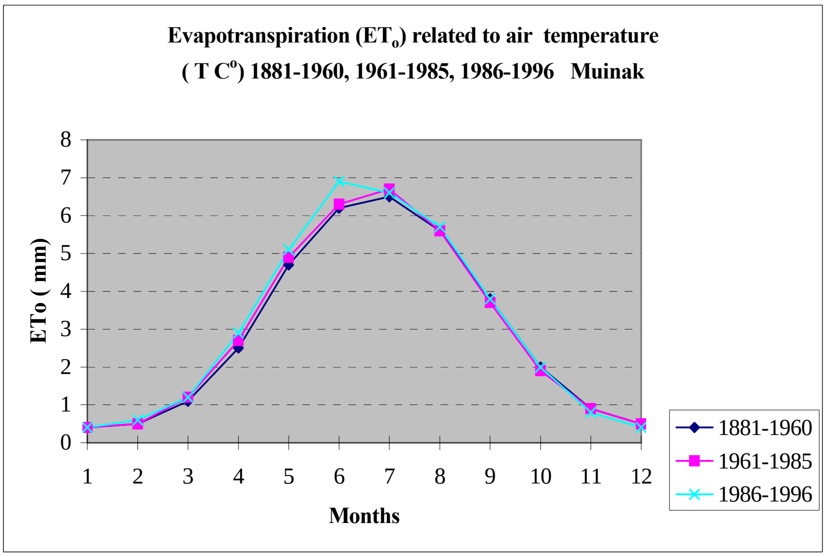


Fig. 18. Evapotranspiration related to air temperature at Muinak meteorological station in the period 1960-1996

2.2.6. Salt transport impacts on lower production of natural and artificial landscapes

As shown in 2.1.4. the total income to desert areas does not exceed 0.5 t/ha or 0.05 g/m^2 including precipitation. SANIIRI carried out experiments on salt transport in 1982-1985 showing that under such concentration of aerosol the following effects are observed:

- Damage to cotton-plants does not exceed 9 – 11% for bolls and 25% for flowers;
- Damage to rice is negligible;
- Damage to fruit orchards is 10 to 15%;
- Damage to rangelands does not exceed 10%.

2.2.7. Changes in bird populations

Birds used to be an important constituent of the Aral Sea region fauna in the past. According to Abdreimov (15) 115 species of birds, and according to Rustamov et al. (17) over 300 species were found in the sea and the lakes. The lakes were ideal for wintering, and for this reason the downstream AmuDarya was a migration route since times immemorial. Tens of thousands birds had rested on the lakes during their migration. Birds from North Kazakhstan and Siberia wintered here usually. For example, in 1994-96 there were hundreds thousands of birds of which 40% were ducks.

Thanks to rice-growing in the Aral region and creation of artificial lakes it became possible to preserve the number of migratory birds, especially on Karadjar, Sudochye and Mezhdurechye and other lakes. Nevertheless, there is still some risk for some rare birds such as *Pelicaneformes* and *Ciconeformes*. It is possible to maintain favourable production of bird populations when realising the regulation system in the delta lakes. The most promising are Sudochye, Mezhdurechye, Jiltyrbas and Karajar (17).

2.2.8. Fish production variations in the Aral Sea and other reservoirs

Besides there were only 20 fish species, the Aral fish was well-known throughout the USSR during initial period. Fish catch reached 50 thousand tons per year (fig. 10). Since 1929 acclimation period for salt-tolerant fish started, and 18 species were set into the sea. But acclimation of these species was slow (23) (first two species, presently four species).

Intense movement of fish industry from the sea to the Aral region water bodies started in 1960 mainly through importing fish from the Far East (mirror carp, grass carp), and only 14% of the native species were used. Nevertheless, fish amount decreased 10 times even when the lake fishing industry started to develop.

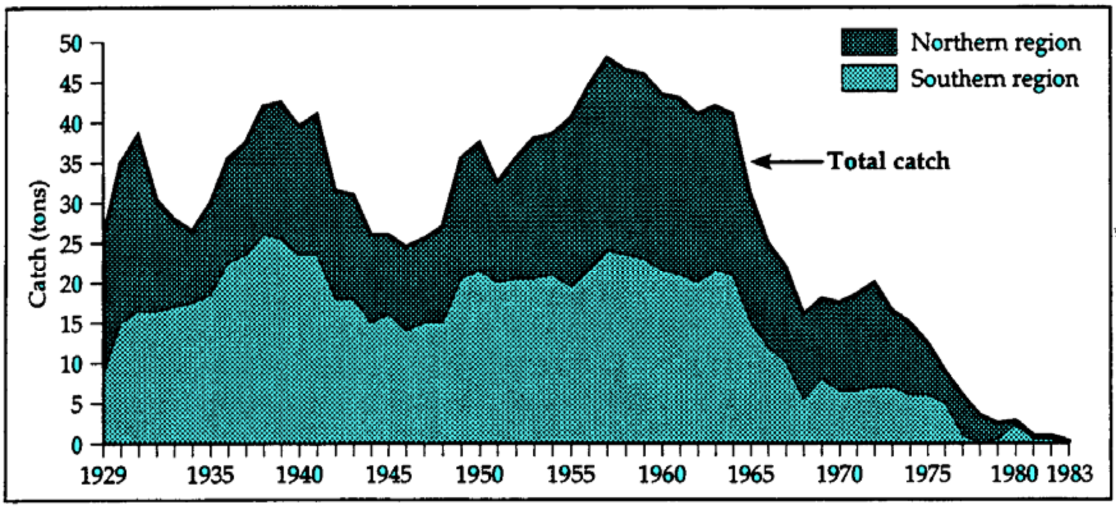


Fig. 19. Fishing industry in the Aral Sea /22/

3. DYNAMICS OF SOCIO-ECONOMIC AND ENVIRONMENTAL LOSSES INDUCED BY THE ARAL SEA SHRINKAGE

3.1. Parameters of social and environmental losses

We suggest preliminary ranging the parameters in two groups: (a) economic losses including direct and indirect ones, and (b) social losses. The ranging is shown below.

3.1.1. Direct losses

Agriculture:

- Irrigated agriculture in the impact zone;
- Fishery industry;
- Musk-rat catch;
- Cane collection;
- Cattle breeding;
- Recreation and tourism.

Industry:

- Fishery industry;
- Fur production;
- Cane production.

Transport:

- Lower traffic flows

3.1.2. Indirect losses

- Higher costs of fish processing;
- Losses of capital funds;
- Freezing and retirement of capital funds.

3.1.3. Social losses

- Migration of population;
- Loss of skilled labor;
- Health hazards;
- Shorter life span;
- Lower living standard;
- Deteriorated water supply;

- National income losses;
- Growing unemployed people and loss of workplaces;
- Loss of territories for recreation and tourism.

3.2. Direct economic losses

3.2.1. Irrigated farming

There exist various definitions of the term. *S. Ziyadullaev, E. Rakhimov* et al. (22) estimate losses based on lower agricultural production 14 to 15% in the Aral region by volume, primarily raw cotton. This reduction caused loss of Rubles 30.0 million in 1973 or USD 60 million respectively.

At the same time, according to their calculations 65 thousand ha of new lands should be developed, and cost of capital investments for this process is Rubles 326 million (USD 650 million) and reduced annual cost is USD 52 million.

In his report «Evaluation of the Aral Sea damage» on the USAID project (1996) *B. Anderson* (23) identifies the zone of agricultural losses as the entire territory of Khorezm region and Karakalpakstan, and estimates losses at USD 350 million per year with Turkmenistan volumes not specified (Ddashkhauz region).

Such approaches cannot be applied for assessing agricultural losses caused only by Aral Sea shrinkage and also environmental degradation in the region. It should be taken into account that in Karakalpakiya, Khorezm and Tashauz regions land degradation is induced by lower quality of river water, reduced rate of washing flows that hampers data comparison in this region in general. Besides, climate worsening in the Aral Sea region, salt transport, etc., causes a reduction of coastal areas. The Aral region should be clearly identified, and its losses should be obtained by comparing Muinak and part of Kungrad regions with the average values in Karakalpakstan.

The main impact zone of the Aral Sea drying comprises four regions in Karakalpakstan: Muynak, Bozatau, Kungrad and Tahtakupyr, much less Chimbay and Karauzyuk.

Within the project ECO «Aral Sea» agricultural production in the above-listed was analyzed for the period from 1960 to 1999.

Analysis of the crop pattern in the irrigated land shows that rice is the main crop in Kungrad and Tahtakupyr regions. Cattle breeding are predominant in Muynak and Bozatau regions with land occupied mostly by fodder crops (Muynak region also specializes in fish production).

Analysis of variations of irrigated cotton fields shows that their are in Kungrad regions in the period from 1960 to 1999 reduced almost thrice. It was primarily due to growing rice fields (upon engineer rice growing farms were created). Staring from 1990 cotton fields stabilized at 3400 to 4800 ha with a slight reduction in 1995-97. A similar situation is observed in Tahtakupyr region with cotton field varying from 1820 to 3200 ha. Cotton fields in Bozatauz regions vary from 560 to 600 ha.

Starting from 1991 cotton fields in Karakalpakstan stabilized at the level 145 to 149 thousand ha. Cotton fields in Kungrad and Tahtakupyr regions have increased 5 to 5.5 times in 2000 compared to 1960.

Specialized rice growing farms were created in 1963-65 with newly irrigated areas (throughout Karakalpakstan) reaching 15 to 17 thousand ha per year. Depending on water supply the rice fields in Kungrad region vary from 17 to 19 thousand ha with a gradual reduction since 1996. In the period 1996-96 rice fields reduced almost 3 thousand ha. A similar reduction or rice fields is reported in Tahtakupyr region.

Since 1991 grain fields have increased in accordance with the policy to secure grain independence. Grain areas in all the regions are increased at the cost of reducing fodder crop fields, primarily alfalfa. It has negative impacts on crop rotation, contributes to zero growth of crop yield and lowers cattle breeding effectiveness.

The total grain fields in the Republic of Karakalpakstan in 1999 were estimated at 32 660 ha.

Starting from 1991-92 the areas under vegetables, cucurbits and fodder crops including forage maize have reduced in the studied regions.

Starting from 1994-95 the areas of irrigated lands in agricultural use have reduced both in the studied regions and the Republic of Karakalpakstan as a whole.

The dynamics of irrigated lands availability and use in the period 1976-1997 (Table 9) shows that the total irrigated land use in Karakalpakstan is estimated at 80 thousand ha. The most serious reduction in the above-mentioned period was reported in Muynak regions estimated at 50% of the total irrigated land. The total used irrigated lands throughout the Aral Sea region have reduced 20 to 25% on the average.

While in Karakalpakstan the total used irrigated lands reduced 16%, the percentage in the Aral Sea region was 25%.

Table 11. Dynamics of irrigated lands availability and use (thousand ha)

Indicators	1976	1980	1985	1990	1995	1997
Karakalpakstan						
Available	261.0	344.1	455.1	496.5	498.7	500.9
Used	261.0	335.7	455.1	496.5	454.6	421.27
Unused	0	8.4	0	0	44.1	79.63
%	0	2	0	0	8,8	15.9
Bozatauz region						
Available	n/a	17.1	30.47	n/a	29.81	30.0
Used		17.1	30.47		25.76	25.5
Unused			0		4.05	4.5
%			0		13.586	15
Kungrad region						
Available	23.8	29.0	37.97	43	41.32	41.5
Used	23.8	28.5	37.97	43	38.39	32.7
Unused	0	0.5	0	0	2.93	8.8
%	0	1.7	0	0	7	21.2
Muinak region						
Available	1.7	5.5	7.09	18.7	12.54	11.8
Used	1.7	5.4	7.09	18.7	11.56	5.3
Unused	0	0.1	0	0	0.98	6.5
%	0	1.8	0	0	7.8	55
Tahtakupyr region						
Available	12.4	20	31.27	34.49	34.22	34.6
Used	12.4	19.6	31.27	34.49	28.31	25.4
Unused	0	0.4	0	0	5.91	9.2
%	0	2	0	0	17	26.6

Analysis of the data on the yield and production of basic agricultural crops shows that both in Karakalpakstan as a whole and in the four studied regions in the Aral Sea zone crop yields have been growing since 1960 reaching the peak level in 1980.

The yields of all crops have been steadily reducing since 1980.

Based on the preliminary analysis of vast information the following conclusions were made:

- Based on calculated data presented in Fig. 20 for period since 1976 till 1985 years irrigated lands gross production increase 1.3 times more can be observed over Karakalpakstan without Aral Sea coastal zone, over Ara Sea coastal zone appropriately 1.1 times more. Gross production increase rates over Karakalpakstan, which constitutes 3.84 % per year, is not accompanied by the same increasing as that in Aral Sea coastal zone - 3.36% per year. The most volume of gross production has been observed over Karakalpakstan excluding Aral Sea coastal zone in 1885 and was equal to $275 400 th., over Aral Sea coastal zone - $62 600 th. (Fig. 20)

  Since 1985 till 1997 gross production decrease was observed over Karakalpakstan regarding 1976 by 47% that constitutes $94 mln, over Aral Sea coastal zone decrease was on average 39% of total gross production volume.

  Irrigated lands retirement over Karakalpakstan excluding Aral Sea coastal zone on 1997 was 16% or 79.63 th ha of 500.9 th ha, over Aral Sea coastal zone - 25% or 29 th ha of 117.9 th ha. Gross production loss related to irrigated lands retirement was determined according to comparison of trends of Karakalpakstan without Aral Sea coastal zone and Aral Sea coastal zone itself as difference in retirement rates on these two zones (9%) in average year and estimated on average as $2,71 mln over Aral Sea coastal zone.

  Assessment of irrigated lands efficiency in Aral Sea coastal zone showed that for period 1976-1997 years irrigated lands specific efficiency has decreased 1.4 times less (1976 - $739 per ha, 1997 -$179 per ha). Natural result of this process is irrigated farming production loss that over Aral Sea coastal zone at the expense of Aral Sea factors impact and in comparison of efficiency trends (Fig. 21) on average is $3,84 mln.

Thus direct losses in irrigated farming in Aral Sea coastal zone are estimated on average as $ 6,55 mln.

- The most sensible crops in terms of lower yields are rice, forage maize, cotton, vegetables and cucurbits. Compared data on the crops are shown in Table 12.
- Analysis of lower crop yields since 1960 shows that a trend became obvious in 1980 throughout the Aral Sea zone excluding Tahtakupyr region. This region had the highest yields of basic crops similar to the 1975 level. Since 1980 the crop yields have considerably reduced.
- In the last two decades major crop yields in Karakalpakstan have reduced on the average from 1.5 times (vegetables) to 3.8 times (forage maize).
- A comparison of lower crop yields in the Aral Sea zone shows that the lowest yields were reported in Muinak region with the yields of all analyzed crops exceeding one time and above the average figures for Karakalpakstan, and forage maize yields have reduced practically twice compared to the average Karakalpakstan level.
- Lower crop yields in other three regions of the Aral Sea zone is similar to the average Karakalpakstan level.

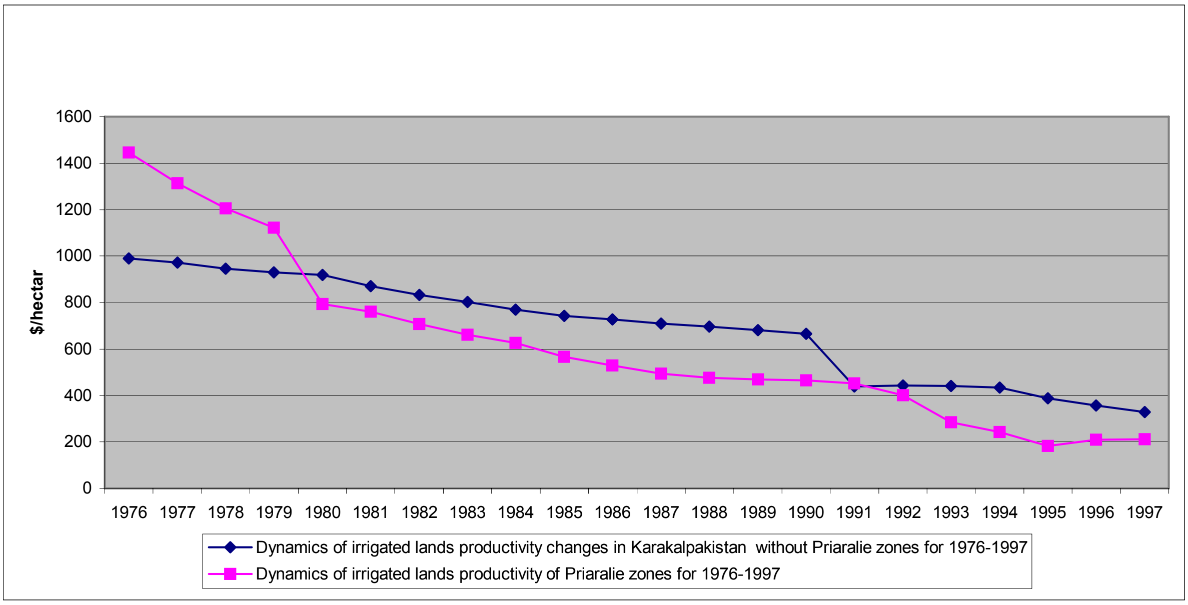


Fig. 20. Dynamics of irrigated lands productivity changes in Karakalpakistan with and without Priaralie zone for 1976-1997 years

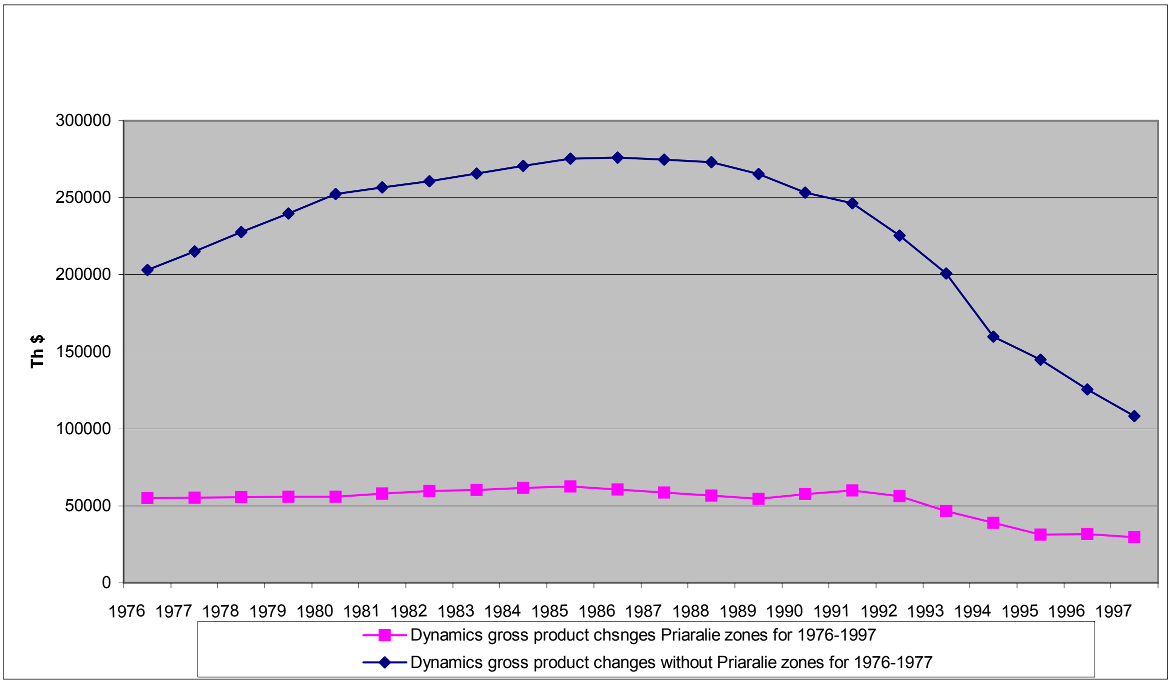


Fig. 21. Dynamics of Prialie zones gross product changes for 1976-1997 years

Table 12. Comparison of major crop yields in Karakalpakstan and the Aral Sea zone

Zone	Crops					
	Grain crops	Rice	Forage maize	Cotton	Vegeta-bles	Cucurbits
Karakalpakstan						
1980	4.85	4.73	22.48	3.23	15.19	11.76
1999	2.0	2.0	5.91	1.35	10.25	7.18
reduced (times)	2.43	2.37	3.80	2.39	1.48	1.64
Muinak region						
1980	3.8	3.0	26.49		7.9	8.64
1999	1.05	0.93	4.63		4.28	3.86
reduced (times)	3.62	3.23	5.72		1.85	2.24
Kungrad region						
1980	5.62	5.59	22.29	2.62	15.69	9.91
1999	2.31	2.38	5.91	1.33	5.43	4.83
reduced (times)	2.43	2.35	3.77	1.97	2.89	2.05
Bozatau region						
1980	4.47	2.4	23.97		10.2	9.66
1999	1.83	1.84	6.87		7.64	6.42
reduced (times)	2.44	1.30	3.49		1.34	1.50
Tahtakupyrsk region						
1975	4.45	3.51	29.29	2.27	14.7	9.94
1999	1.69	1.7	5.21	1.52	8.8	8.67
reduced (times)	2.63	2.06	5.62	1.49	1.67	1.15

In this situation all factors inducing lower crop yields in the Republic of Karakalpakstan cannot be considered solely as a result of the Aral Sea drying. Obviously the sea disappearance (although 100 thousand ha of rice paddies was created as a water area) and lower water quality, as well as substantial reduction of specific water removal for irrigation purposes play an important role in reducing crop yields. However it should be noted that lower yields are also due to violating agrotechnologies including equipment use, application of fertilizers and agrochemicals, etc. following the 1986-88 period. Lower yields in Karakalpakstan can be justifiably explained by other factors, while the yields below the average level can be directly related to the Aral Sea drying. Based on the calculations it was found that cotton yields in the period under review did not drop below the average Karakalpakstan level. Lost production of rice, forage maize, vegetables and cucurbits was calculated based on comparing the yields with the average figures with prices expressed in USD equivalent for the relevant period. Total losses of the above-listed crops in the period from 1975 to 1999 are estimated at USD 31.67 million.

3.2.2. Fishery industry

Fish catches in the AmuDarya delta decreased 10 times in the period from 1958 to 1985 - from 244 to 23 thousand hundred kilos. Due to a higher salt content in seawater (to 14 g/L) fishing operations in the Aral Sea completely stopped in 1983, and it was possible to catch fish only in the internal delta lakes and in Lake Sarykamysh.

Fishery in Lake Sarykamysh started in 1966 after Drujba collector was constructed and hollows were filled with drainage waters. Fishing companies from Tashauz region of Turkmenia take part in fish catching, and their catch was 177.8 thousand hundred kilos in the period from 1966 to 1985. The peak catch of 29.4 thousand hundred kilos was reported in 1982, though it gradually decreased in the further years to reach 21.2 thousand hundred kilos in 1985 (3% decrease during 3 years).

Muinak industrial administration started to catch fish in Lake Sarykamysh since 1980, and fished out 56.6 thousand hundred kilos during 1980-1985. Similar to Turkmenians, their maximum catch was reported in 1982 (16.4 thousand hundred kilos), but was 8.0 thousand hundred kilos, decreased twice in 1985.

Due to absence of inflow in Lake Sarykamysh the salt content in its water will increase annually. During five years (1980-985) it has increased from 8 g/L to 11 g/L. According to Turkmenhypro-vodkhoz it increased from 12.5-13.4% to 16-17% in 1995. Hence, by the end of the 12-th five-year Plan Lake Sarykamysh will run out of fish.

Therefore the minimum fish catch in the southern Aral Sea in recent years is 4.0 thousand tons per year.

Lower fish catches and deteriorated fish qualities have resulted in higher costs of products and other non-productive costs in fisheries in Muinak region. Moreover, to sustain the cannery operation ocean fish was transported (by railroad and automobiles) from the Far East and Baltic states, and also from Lake Sarykamysh with extra transportation costs exceeding Rubles 4 million per year. As a result net cost of one thousand of cans increased 1.6 times from 1964 to 1984. Total losses calculated per total products are estimated at Rubles 121.5 million (USD 217 million) or USD 10.85 million per year. Losses from closing fishery farms and decommissioning of fishing vessels are estimated at Rubles 5.5 million (USD 9.82 million). Per year losses are USD 0.786 million using the 0.08 coefficient.

Net losses of fish catch are estimated at Rubles 20.0 thousand per year at the price of Rubles 0.8 per kilo - a total of Rubles 16 million (USD 28.57 million per year).

The present status of fishing industry can be evaluated only on the basis of sociological questionnaire and other unofficial documents. According to *Ogay* and *Izimbetov* 94% of the families in the Aral region (Muinak and Kungrad areas) consumed to 30 kg of fish per month. According to I. Zholdasova (25) the population in these two regions consumed 2000 tons of fish in 1997, while according to official data by Muinak fish authority, the fish catch was 500 tons per year. At the same time I. Zholdasova presented data that fish catch only in Sudochie Lake was 900 tons in 1996. It can be concluded that about 3.5 thousand tons of fish was caught in the Aral region (including the right coast), and only 1 thousand tons was used in the official production.

A higher level of fishery is obtained by state association Karakalpakbalik based on fish production on its lakes and reservoirs (Table 8). It is clear from the Table that productivity of the reservoirs varies from 1.5 to 50 kg/ha. Provided production could be increased at least to 35 kg/ha, mainly due to sustainable water supply and special biological conditions, productivity of existing water bodies could reach 15 750 thousand tons of fish per year.

***Table.* List of the lakes and reservoirs owned by the State Joint Stock Company Karakalpak Fisheries**

Name of the lakes and reservoirs	*Area, ha*	*Depth*	*Width*	*Productivity, t/ha*	*Reservoir location*	*Name of enterprises*
Domalak, Janly – close to Domalak lakes	2000	1,2 - 1,5	3,5 - 4,0	80	Muinak region right bench of AmuDarya	Muinak fish plant
Karateren lake – located at Damalike side	1000	1,2 - 1,5	3,5 - 4,0	40	Muinak region right bench of AmuDarya	Kazakhdarya fish plant "
Shege-	3000	1,3 - 1,8	3,5	66	Muinak region, north-western part of Mezhdurechye	AmuDarya fishing sovkhoz
Kok-suu	1500 - 2500	1,3 - 1, 8	25	40		
Sudachye including Ak-ushpa, Taily and Urge lakes/	33000	0,7 - 0,8	1,7	59	North-eastern part of the left bank of AmuDarya near GLK collector in the west part of Sudachye Lake	Uchsay fish plant
Large Sudachye Lake					Near GLK collector in the east part of Lake Sudachye Lake	Konyrat fish plant
All close to Makpalkol Lakes: Makpal, Sarho-cha, Birkazan, Kisilkeme	600	1,0- 1,5	3	24	Muinak region, left part of lower Amu-Darya	Tentekarna fishing sovkhoz
Keyser Lake located at Karajar side	16000- 20000	2,0 - 2,2	3	39	Muinak region, left part of AmuDarya	Taly-uzyak fishing sovkhoz
Ilmekol Lake located at Karajar side	1000 – 1500	1,0- 1,2	3	88	Muinak region, central part of AmuDarya left bank near Karakhar	Tentekarna fishing sovkhoz
Khojahol Lake located at Khojakol side	1000	2	3,5	55	Kungrad region, southern part of Khoja-kol Lake	Pkonrat fish plant
Koptin-kol Lake located at Khojakol side	9500	1,2 - 2,0	6	209	Kungrad region, central part of Amu-Darya left side and near Khojakol Lake	Konrat fish plant
Jaunger-kol Lake located at Khojakol side	532	1,7 - 1,8	2,5 - 3,0	8	Kungrad region, central part of Amu-Darya left side and near Khojakol Lake	Konrat fish plant

Name of the lakes and reservoirs	*Area, ha*	*Depth*	*Width*	*Productivity, t/ha*	*Reservoir location*	*Name of enterprises*
Muinak gulf	9750	1,65	3	78	Muinak region, south-eastern part of the Aral Sea	Nurly-hol fishing collective farm
Rybachy gulf (Sarybas)	4000	1,0 - 1,5	3,4	34	Munaik region in 1 km to the North of Muinak in the southern part of dried territory of the Aral sea	Tentek Arna fish plant
Sarykamys	300000	5,7	47	33	On the south-western part of the Aral sea, 200 km from Turkmenistan border with Karakalpakstan	
Shygys Carateren	4000	3 – 5	30	52	Tahtakul region, foot of Beltau Height	Tahtakul fishery
Botakol and nearby lakes	2000	1,5 - 2,0	4	18	Tahtakulsky region between Karateren Lake and Kokdarya River (KS – 4)	
Atakol and nearby lakes	2000	1,5 - 2,0	3,5 - 4,5	10	Tahtakulsky region	
Tashpenkol	1000	1,5 – 3	10	1.2	Wimbaisk region, AmuDarya right side, Kuskanatau Height	Wimbaisk fishery
Dauytkol reservoir	5000	1,5 - 2,0	7	80	AmuDarya right side in 47 km to the North of Nukus	Nukus fish plant
Karakol	7000	0,9 - 2,6	2,6	115	North-western part of Shumanai region	Shumanai fishery
Akshakol	4000	1,5 - 20,0	7	20	Ellicalin region, AmuDarya right side in 20-30 km from south-eastern part of Sultanuzdaga	Ellikalin fishery
Ayazkala	9000	2 – 3	8	40	Berunian region, AmuDarya right side and southern part of Sultanuzdag	Berunina fishery

Name of the lakes and reservoirs	*Area, ha*	*Depth*	*Width*	*Productivity, t/ha*	*Reservoir location*	*Name of enterprises*
Zhyltyrbas	30000				Muinak region	Kasakhdarya fish plant
Kobeyshungil, Sarykol, Magnit zhargan	50	1,0- 1,5	2	0.3	Karauzyak region	Karauzyak fishery
				4456.5		

3.2.3. Musk-rat pelt production

Muskrat pelt production was concentrated in the AmuDarya delta. Muskrat acclimation started in 1944 by releasing 335 animals (brought from Balkhash Lake) into Taldyk irrigation cannel. The local environment was favourable, and muskrat was successfully acclimated and began to breed. Muskrat pelt production started since 1947 reaching the peak in 1957 when 1130 thousand pelts were produced.

As a result of the Aral Sea level lowering and water shortage in the delta, the muskrat habitat has considerably shrunk. It resulted in a reduction of muskrat number, and muskrat catching completely stopped in 1977-1978. Muskrat catching was somewhat restored when water was supplied to the delta by means of dam on the AmuDarya in 1979-1984, and muskrat pelt production was estimated at 25.3 thousand units in 1984.

Low labor efficiency, high non-production losses (transportation, etc.) increase pelt production costs. For example, cost of an item was Rubles 0.85 in 1962 compared with Rubles 5.15 (6 times higher) in 1985. A conversion of total number of produced pelts shows that the general price increased Rubles 2.0 million during 1964-1984. Moreover, the national economy lost 1.5 million muskrat pelts at the cost of Rubles 8.0 million or a total of Rubles 17.86 million with average annual loss of USD 0.893 million.

The situation with muskrat catching is similar to fishery. According to sociological study in Lake Sudochie about 25.3 thousand pelt units were produced in 1985, 19.5 thousand units in 1986, 11.9 thousand units in 1987, 18.6 thousand units in 1988, and above 8.0 thousand units in 1989. A 1996 study showed that muskrat catches exceeded 10 thousand units worth USD 40 thousand. However SCEP inspectors and fishermen consider this data to be lowered, because people conceal poaching profit.

3.2.4. Pasturable cattle breeding

Cane bushes are used by the indigenous population as the basic natural rangeland. Cane is a green forage in spring and summer time, and cane hay is reserved for winter. In the past industrial procurement of cane forage from Sudochie and Karajar deltas was 10 thousand tons sufficient to feed 40 thousand heads of cattle in Muinak and Kungrad regions, and Khorezm rangelands. Private-owned cattle are not included. Cane forage can be procured twice a year - in the first decade of May, and in early August. Its forage value is lower than that of the corn hay. It leafs contain ascorbic acid that increase milk productivity of cows. From 10 to 12 tons of cane per ha can produce 9 to 10 tons of silage containing 1500 to 1800 forage units (1 kg of silage contains 0.13 forage units). Cane usage for mat and frame production is limited. Loss of coarse forage potential is estimated at about 420 thousand tons of cane. Loss of forage units is estimated at 50 thousand tons. Cost estimates are shown below in 3.2.9.

3.2.5. Meat cattle-breeding

Before the World War II a network of collective farms was operational in Kungrad, Kegeylin, Karauzyak and Muinak regions. Collective farm cattle breeding were primitive but profitable. Prime cost of 1 hundred kilos of meat was Rubles 70 to 80. As a result of water shortage in the delta situation worsened since the 60-s. It was necessary to supply water to the delta, and floating pump stations and a temporary dam on the AmuDarya were constructed.

Thanks to these measures in the six cattle-breeding state farms of the Aral Sea region the cattle stock increased from 29.7 to 58.5 thousand in 1974, and meat production increased from 2540 tons to 3560 tons (40%). State profits amounted Rubles 3.5 million.

Apart from water supply to the AmuDarya delta, cattle breeding were promoted by growing up and fattening of young animals on rangelands. A wise policy of cow calving allowed younger to animals to move together with the old ones to summer rangelands in late April or early May. They stayed there till late autumn. In the period from 1965 to 1974 the average cost of meat was Rubles 157 per hundred kilos.

During last decade (1975-1985) removal of river water in the region downstream the Takhiatash hydrojunction became rare. It was decided to create special cattle-breeding farms based on local foraging. Though reduction of forage resources during this period lead to decrease in head of cattle for 18 thousand, and cost of 1 hundred kilos of meat increased from Rubles 157 (1975) to Rubles 233 in 1984 (1.5 times).

Lower cattle productivity deteriorates the farms financial situation. Instead of being profitable in 1974 they became unprofitable. Termination of rangeland and hay lands watering and unwise policy for calving are considered to be the main reasons of low-effective development of meat cattle-breeding in the AmuDarya delta. Cost increase is estimated at USD 4.2 million.

As a result of reforming the agricultural sector upon Uzbekistan gained its sovereignty, the cattle stock shifted to private owned farms and land plots.

In the Republic of Karakalpakstan the total area of natural rangeland and hay mowing land is estimated at 4900 thousand ha (as of June 1996) concentrated in Muynak, Kungrad, Bozatau,

A relatively high density of cattle grazing per 1 ha of rangeland is reported in the lacustrine-type rangelands in the Sudochinsk-Karadjar system, Daut-Kul, Aspan-Tai and Togus-Tore. Cattle density here is 5 to 6 heads of cattle per 1 ha including cattle, sheep, goats, horses and camels.

Table 12 shows that general variations in the cattle stock in Karakalpakstan and in the Aral Sea zone are similar to the average Republic variations. For instance, cattle stock in Karakalpakstan remains relatively stable. Against this background the sheep and goat stock in Kungrad and Tahtaupyr regions reduced, particularly in Tahtaupyr regions. In view of the fact that sheep and goats in the region comprise 24% of the total stock of these animals in Karakalpakstan, the stock in the four regions of the Aral sea zone reduced 52% compared t0 1990 which is quite tangible.

It is well-known that a lower river inflow in the delta and drying of vast areas of the former sea bottom have radically reduced the area of natural highly productive rangelands and hay mowing areas with negative impacts on cattle breeding. A lower river flow induces degradation and destruction of the vegetation cover. It resulted in acute shortage of forage sources, lower productivity of cattle breeding and reproduction and reduced cattle stock.

Cattle breeding productivity in Karakalpakia and generally in Uzbekistan has reduced compared to 1990. Absolute production of meet (slaughter weight) and milk remains rather stable both in Karakalpakstan and in the four regions of the Aral Sea zone since 1980. Such indicators of cattle breeding productivity as wool and Astrakhan pelts production have reduced almost twice. On the one hand, it can be explained by a considerable reduction of sheep and goat stock in the Aral Sea zone, and on the other hand, results from deteriorated conditions of rangeland cattle breeding and lower rangeland productivity. Main losses of cattle breeding products account for wool and Astrakhan pelts production. They were reported following 1994 when the sheep and goat stock sharply reduced alongside a sharp decrease of forage areas and their productivity. Losses of cattle breeding products are calculated on the basis of lower procurement of wool and Astrakhan pelts as well as meet and milk production in the period from 1990 to 1999 using the appropriate prices. Cumulative losses of cattle breeding products in the period are estimated at USD 29.3 million.

Table 13. Dynamics of cattle stock in all types of farms (thousand heads)

Name	Cattle	Sheep and goats	Camels	Horses
1	2	3	4	5
Uzbekistan *)				
1990	4580.8	9229.5	-	105.2
1995	5203.3	9322.3	22.8	150.0
1997	5370.6	9858.2	20.2	147.5
1999	5376.0	20300.7	17.7	150.5
Karakalpakstan*)				
1990	373.2	530.0	5.0	13.8
1995	386.5	485.9	5.0	18.1
1997	390.8	476.5	4.7	17.7
1999	379.8	497.4	4.5	16.9
Muinak region **)				
1990	16.4	5.3	-	4.6
1995	12.7	5.1	-	3.9
1997	11.9	5.3	-	2.8
1999	10.5	5.2	-	1.6
Kungrad region **)				
1990	26.5	71.9	0.8	0.8
1995	26.9	75.1	1.3	2.0
1997	26.7	57.9	1.2	1.5
1999	25.7	53.1	0.8	1.2
Bozatau region **)				
1990	36.7	9.2	0.1	0.8
1995	26.7	9.6	-	1.5
1997	25.5	9.1	-	1.5
1999	21.6	9.7	-	1.5
Tahtaupyr region **)				
1990	11.5	142.2	0.5	1.2
1995	13.5	94.2	0.6	1.8
1997	13.1	55.0	0.5	1.9
1999	13.0	52.0	0.6	1.7

Sources: *) *- State Statistical Department.*

**) *- Results obtained under the ECO «Aral Sea» Program.*

Forage basis composition is directly related to average daily gain in weight of grazing animals. Starting from the 1980-85-ties the average daily gain in weight of grazing sheep in Kungrad and Tahtaupyr regions reduced over twice. The average daily gain in weight of cattle in the same regions reduced 2.3 to 3 times. Against the background of reduced number of some cattle types these facts had negative impacts on cattle breeding productivity in the Aral Sea zone.

While a reduced productivity of cattle breeding was reported primarily in sheep breeding, it can be concluded that this a major result of varying rangeland productivity as a result of the Aral sea drying.

3.2.6. Loss of recreational value of the Aral Sea

Seawater appeared to be one of the most important recreational resources of the lower part of the Aral Sea. It contains bromine, iodine, chlorine, and calcium ions, and such composition is considered to be physical-chemical complex for balneological treatment of diseases. For this reason a range of sanatorium were built at the Aral Sea shore (Muinak town) in 1972-78. 20 395 people took a rest there in 1973-82. Because of fast retreating water line further development of sanatorium activities became impossible. Potential population losses caused by this reason at a rate of Rubles 400 per capita are estimated at Rubles 8.0 million (USD 14.6 million). The average annual loss is USD 1.46 million.

Other losses are related to a lower tourism activity. According to rough estimates about 50 thousand tourists with 5 days average duration who came for rest, fishing, and hunting in 1960. Average expenses of one tourist were Rubles 25 per day. Today 5 thousand tourists come to rest, and their expenses increased to Rubles 50 per day. At the same life expectancy the loss is estimated at Rubles 5 million (USD 9.7 million), total USD 11.16 million.

3.2.7. Losses in industrial fish processing

Muinak fishery plant processed over 4 thousand tons of fish at an average added value of Rubles 3 USD per one kg in 1960, and only 1000 tons in 1995. Industrial losses are estimated at Rubles 9 million USD. Besides, large-scale individual fish processing i takes place in Kungrad and Muinak regions, but the amount and cost are not accounted for.

3.2.8. Losses in pelt processing

Pelt processing is provided in accordance with fur volume of storage. 1.5 million of fells were processed and stored in 1960. Nowadays, comparing the data to the results of Lake Sudochje project (10 thousand pelts per 40000 thousand ha or 0.25 pelt unit per 1 ha of water area), total amount of the processed pelt units does not exceed 10 thousand per year. Hence losses in pelt processing since 1960 at the added value of USD 20 per one pelt are estimated at about USD 18 million per year.

3.2.9. Reduced cane processing into mats and forage

The potential amount of cane storage was about 500 thousand tons per year in 1960-s. It can be assumed that similarly to Sudochje Lake about 80 thousand tons were processed in the entire southern Aral region in 1996-1997. At the added value of USD 30 per ton, total losses are estimated at USD 12.6 million per year.

3.2.10. Lower volume of marine transportation

Losses in marine transportation in the Aral Sea are estimated at about 2000 tons per year compared to 1960. The added value per one ton is USD 0.5. Transportation losses are estimated at about USD 1 million per year.

Thus direct losses in the Aral Sea region are estimated per year (USD million):

- Irrigated farming – 6,55
- Fisheries and fish catch – 28.57
- Muskrat catches – 4.0
- Cattle breeding products – 8.4
- Recreation and tourism – 11.16

Agriculture, total – 58,68

- Fishery industry – 9.0
- Pelt processing – 18.0
- Cane processing – 12.6
- Transportation losses – 1.0

Industry, total – 40.6

Production, total – 99,28

3.2.11. Indirect economic losses

The above data show higher costs for fish processing and loss of basic assets in fishery industry (3.2.2) per year estimated at USD 10.85 million and USD 0.79 million respectively. Similarly higher costs of muskrat pelt processing averaged USD 0.9 million per year (3.2.3), and higher costs of meet production (3.2.5) were estimated at USD 4.2 million.

Indirect total losses per year are estimated as follows:

- Fishery industry – USD 11.64 million
- Muskrat pelt production – USD 0.9 million
- Meet production – USD 4.2 million

Total: USD 16.74 million.

3.3. Social losses

Social losses present the most difficult parameters of social-economic assessment of the Aral region.

The situation was complicated due to sharp worsening from 1960 to 2000 not only in the Aral region, but in all Central Asia and other regions of the former USSR. The national income and welfare in the whole USSR, including Central Asian republics was constantly growing from 1960 to 1975. During 1975-1985 stagnation started and since 1985 (particularly since 1990) GNP and national income sharply reduced in general and per capita.

The Aral Sea economic area includes two neighboring regions - the Republic of Karakalpakstan and Khoresm region covering 38.4% of the country’s territory with 11.5% of the total population.

In 1997 the area's contribution to the country's industrial production was 6.3% and agricultural production 12.5%.

The average per capita GNP in the Republic of Uzbekistan and Karakalpakstan substantially differ (Table 14).

Table 14. Comparison of GNP indicators in Uzbekistan and Karakalpakstan

Indicators	Per capita GNP, USD		Percentage to the average republic level	
Years	**1996**	**2000**	**1996**	**2000**
Uzbekistan	2469	2483	100	100
Karakalpakstan	1686	1480	68,3	59,6

Analysis of data for the period 1996-97 shows that per capita GNP in Karakalpakstan does not exceed 60% of the average Republic level. Taking into account that GNP growth in Uzbekistan in 1997 was estimated at 5.7% and the population growth rate in Karakalpakstan is below the Republic average, the difference between per capita GNP indicator for the Republic average and Karakalpakstan will be more profound

The Report on Human Development in Uzbekistan in 1998 /31/ shows an index of human development integrating per capita GNP, education level, expected life span and reflecting certain socio-economic trends in the regions.

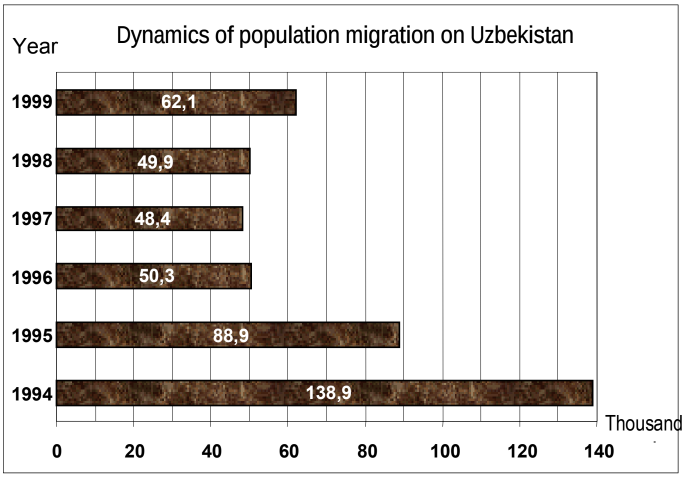
Table 15. Human development dynamics

	GNP index		Education standard		Human development index	
Years	**1996**	**1997**	**1996**	**1997**	**1996**	**1997**
Republic of Uzbekistan	0.399	0.425	0.895	0.896	0.682	0.692
Northern Uzbekistan	0.379	0.341	0.894	0.897	0.676	0.665
Republic of Karakalpakstan	0.267	0.247	0.894	0.896	0.637	0.631

The data in Table 15 shows that the human development index is largely differentiated. For instance, the Republic of Karakalpakstan has the lowest human development index, which was relatively low in 1996 that continued to fall in 1997. It creates variable conditions for fulfilling social programs aimed at human development. Taking into account the human development index and nature of its variations, special attention should be paid to industrial potential development in the Republic of Karakalpakstan to provide the growing population with opportunities for employment, incomes and conditions for normal vital activity.

3.3.1. Analysis of migration processes

Analysis of migration processes was based on the data by the State Statistical Department of the Republic of Uzbekistan.



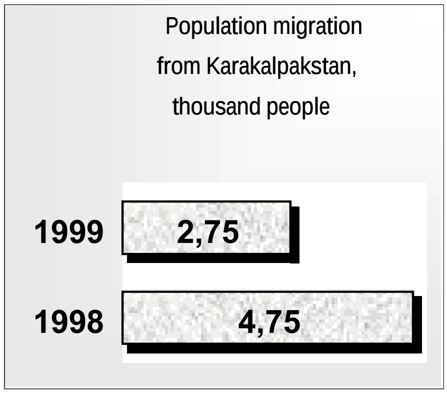


Fig. 22. Dynamics of population migration on Uzbekistan and Karakalpakstan

The diagram (Fig. 22) shows that the maximum migration of population was reported in 1994 and was estimated at 138.9 thousand; the situation stabilized in the period from 1996 to 1998 (migration was estimated at about 50 thousand people).

Migration from Karakalpakstan regions, especially from Muinak reached its peak in the 1970-80-s when fishery, fish processing and shipping lost their economic significance.

During this period 14.5 thousand people left the Aral region, including 3.2 thousand skilled specialists, German families, Russians and Ukrainians who historically worked in the region.

Further migration can be discussed on a basis of two sociological reviews – first, held by the World Bank in 1996 for water supply project, and second – held for Sudochje project in 1998. The results of the last project show that over 6 to 7 thousand people left Kungrad and Muinak regions in the last 7 years, mainly Kazakh people. Much more people are willing to leave, but as they are offered low prices for their houses they have not got enough money to start living at a new place.

It predetermines a low rate of population growth in Kungrad region (rural population increased from 39.0 to 42 thousand in 1989-1997, or 0.9% annually), though urban population in the same region grew from 56 to 74 thousand – hence, annual growth came to 3.46%.

Situation is even worse in Muinak region. During the same period the urban population increased 2 thousand compared to 12 thousand initially, or 1.73% annually, and regarding rural population – migration came to 2000 people.

It is difficult to estimate losses caused by migration. According to the World Bank approximate estimations (Aisha Kudat) migration per capita expenses amount to USD 300. Total losses can be calculated for the whole period:

16.6 thousand people x 300 = USD 4.95 million.

Calculated per year within a 20 year period, the losses will not seem too high – USD 0.250 million per year.

3.3.2. Losses of intellectual and skilled labor

Losses of intellectual and skilled labor are estimated as high. Considering that labor ability coefficient of a single family is 3.0, losses of skilled labor is estimated at 5.5 thousand with migration of the most highly skilled people. Hence the intellectual potential losses with education costs of USD 10 thousand per capita multiplied by 5.5 thousand total USD 55 million or USD 4.4 million per year.

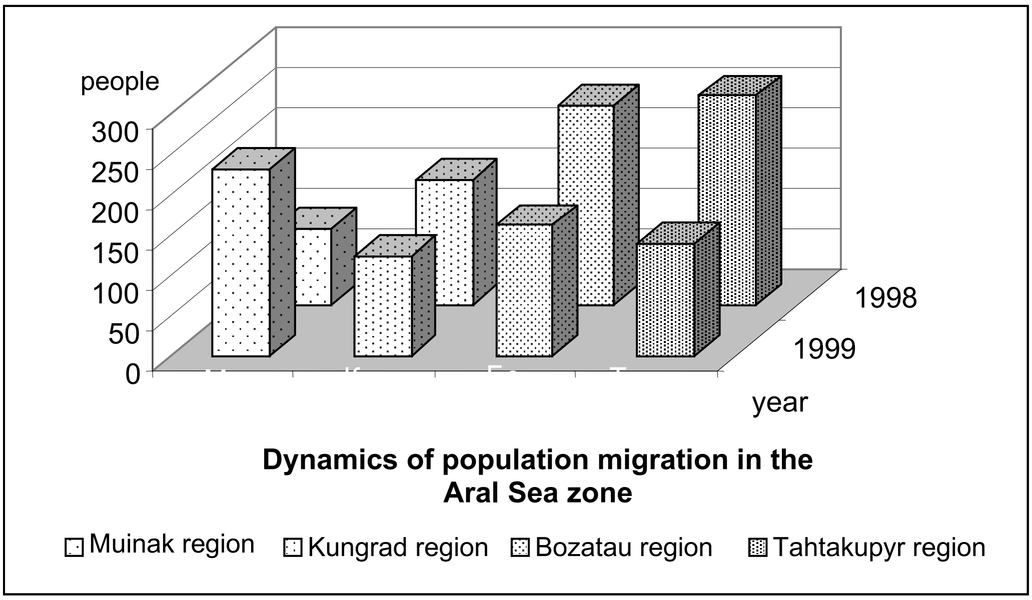


Figure 23. Dynamics of population migration in the Aral Sea zone

3.3.3. Health impacts

Worsening of economic and environmental situation in the AmuDarya downstream has deteriorated population health not only in the Aral region, but in the whole downstream region.

It is due to the following reasons:

- Worsening of river and ground water quality, content of pesticides, herbicides, salts;
- Worsening of climate in the Aral Sea region;
- General worsening of economic situation in the region, including the Aral region.

Listed below are the comparative data from different sources show their dispersion (26, 27, 28, and 31).

Unfavorable socio-economic and sanitary conditions of life have negatively affected population health in the Aral Sea zone. Medical examination of adult population of Karakalpakstan showed health deviations in 63.5% of cases (66% of children). The occurrence of intestinal infectious diseases among the local population exceeds 3 times the average level in CIS states /13/.

A comparison of average rates of population growth in Uzbekistan and Karakalpakstan (Fig. 24) shows that population growth in Karakalpakstan in the recent years is slightly below Uzbekistan level, while the situation was quite opposite before 1990. Reduced natural rates of population growth are due to such factors as infant, child and mother mortality; birth, mortality and morbidity rates and migration processes.

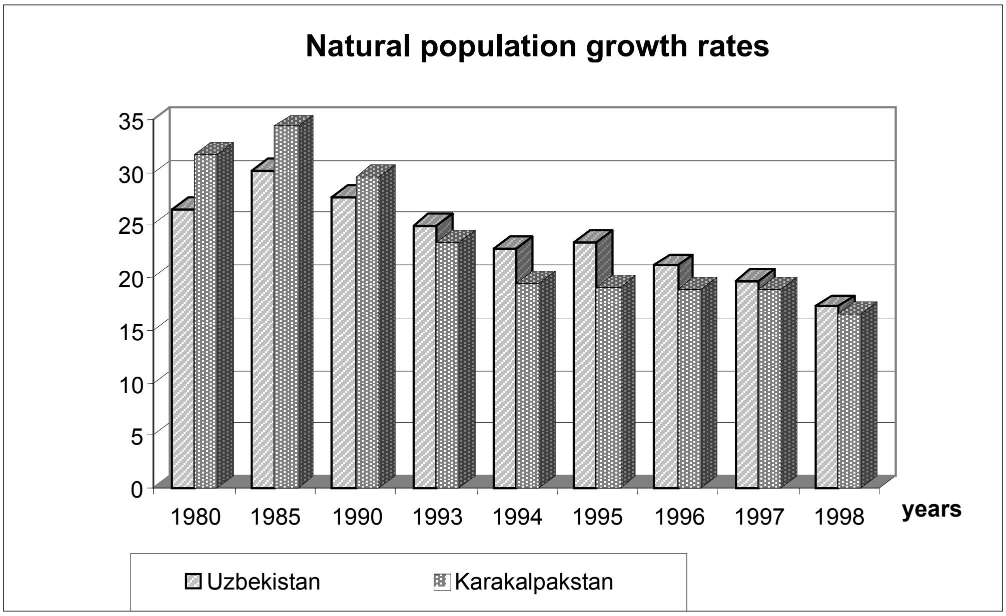


Fig. 24. Natural population growth rates

Except the birth rate figures, the above-listed indicators in Karakalpakstan exceed the average Republic level. For instance, infant mortality rate in Uzbekistan is 21.8 per 1000 infants and 24.9 in Karakalpakstan. The highest infant mortality rate in the Aral Sea zone is reported in Tahtaupyr region - about 30. Fig. 23 shows the dynamics of infant mortality in the four regions of the Aral Sea zone in the period from 1994 to 1999.

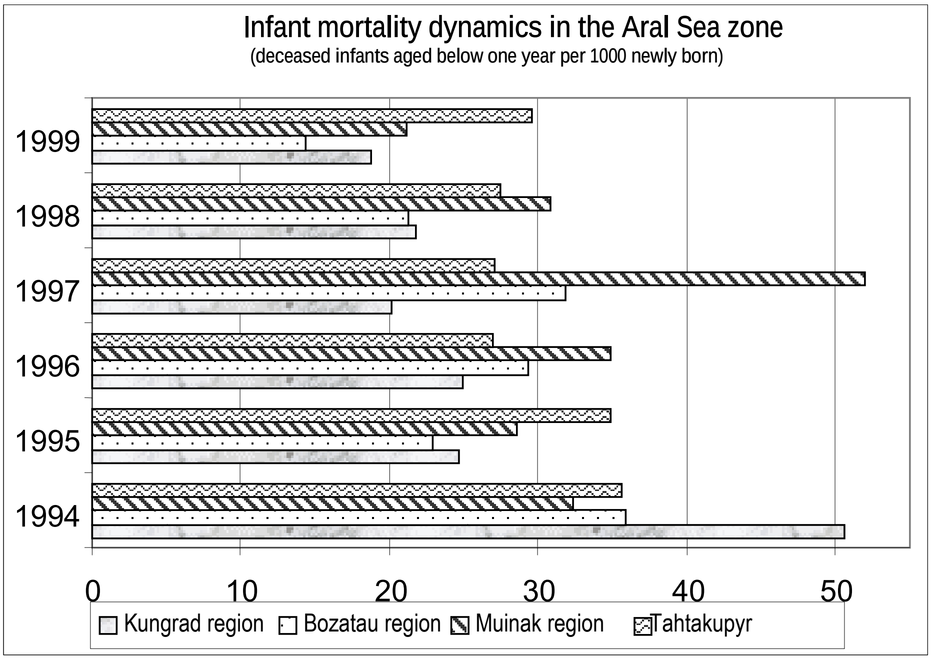


Fig. 25. Infant mortality dynamics in the Aral Sea zone

It is clear from Fig. 25 that the infant mortality rate has generally lowered, particularly in Kungrad and Muinak regions. Infant mortality rate in Kungrad and Bozatauz regions is lower than the average Uzbekistan level.

The number of diseased per 1000 people is 5.8 in Uzbekistan and 6.2 in Karakalpakstan. In the Aral Sea zone this indicator is about 5 in Kungrad and Bozatauz regions, and about 7 in Tahtaupyr largely exceeding the average Uzbekistan level (Fig. 26).

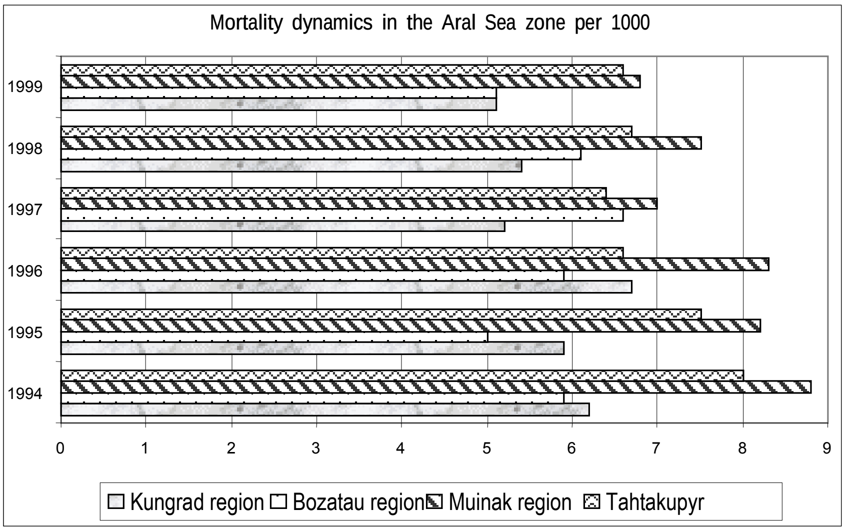


Fig. 26. Mortality dynamics in the Aral Sea zone

Analysis of the results of the public poll carried out within the World Bank project showed the following indexes of population health status in different parts of the Aral Sea basin (Table 16).

Table 16. Comparison of health status indexes in different part of the Aral Sea basin

Indexes	Life span, years		Infant mortality per 1000 infants below 1 year		Hepatitis per 100 thousand residents
	1980	**1995**	**1980**	**1995**	**1995**
Central Asia	67.9	68.1	20.4	19.6	360
Uzbekistan	69.0	70.1	37.7	30.3	235
Karakalpakstan	67.6	68.0	46.0	45.2	258
The Aral Sea zone	64.2	64.8	59.4	61.0	1980
Turkmenistan	65.0	66.7	54.7	46.1	264
Tashauz	64.0	64.1	n/a	75.2	547

Laboratory tests of Muynak tap water carried out by the Uzbekistan Hydrometeorology Service showed the following results:

- Sulphates - 562 mg/l;
- Chlorides - 40 mg/l;
- Nitrates - 0.65 mg/l;
- Hexachlorane - 0.04 mkg/l.

According to the medical examination data by Dr. Sh. Esirkepov, Chief Narcologist of Muynak region, member of a Council for Protecting the Aral sea and AmuDarya, pesticides and other toxins hazardous for infants health (e.g. hexachloran) were identified in breast milk of 30 examined women. In 1991a comparative study of 11 mothers and newly born infants was carried out in Muynak and 18 women and infants in Nukus. The comparative analysis shows that the hair samples of mother-infant pairs in Muynak had a higher content of phosphorus, iron, manganese, cobalt and toxic elements (e.g. lead and cadmium) compared to Nukus. Excessive accumulation of heavy metals (e.g. lead, cadmium) in the organism may depress blood forming organs, hamper CNS development, injure kidneys and bone tissues. It also results in protein deficit in the infant organism. A daily rate of protein consumption by an infant is 7 grams, up to 25 kg per year. Such food is rarely available to children in Muynak. Newly born infants have various degrees of asphyxia, cephalohematomes and other anomalies.

About 60% of women in Muynak are supplied with contraceptives for health reasons. A total of 1114 infants were born in Muynak in 1991 to compare with 642 in 1995. About 50% of Muynak residents have zero resistance to infectious diseases. The average age of the diseased in 1995 and by April 1996 was 28.5 years. The residents of Muynak consume practically no vegetables and cucurbits. Bread is the basic food product. Toxin content in fish in the Muynak lakes exceeds 3 to 19 times the maximum allowable concentration.

Examinations performed under the Program «Physicians without Frontiers» /28/ show interesting data collected in the downstream regions, e.g. Shuman region near Nukus outside the Aral Sea impacts, Kungrad and Muynak regions situated within the Aral Sea zone (Table 17).

Table 17. Diseases occurrence in 3 regions of the Aral Sea compared (1998)

	All answers	*All participants*		*Shumanai*		*Kungrad*		*Muinak*		*p**
	No.	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	
Anemia	*874*	*229*	*26.2*	*73*	*24.6*	*68*	*25.1*	*88*	*28.8* V	p=0.45
Kidney stones	876	39	*4.5*	*12*	*4.0*	*17*	*6.2*	*10*	*3.3*	*p=0.21*
Other kidney diseases	*874*	*117*	*13.4*	*36*	*12.1*	*33*	*12.2*	*48*	*15.7*	*p=0.34*
Tuberculosis	*879*	*17*	*1.9*	*5*	*1.7*	*7*	*2.6*	*5*	*1.6*	*p=0.66*
Asthma	*880*	*16*	*1.8*	*9*	*3.0*	*4*	*1.5*	*3*	*1.0*	*p=0.15*
Chronic bronchitis	*880*	*71*	*8.1*	*32*	*10.7*	*27*	*9.9*	*12*	*3.9*	*p<0.05*
Hepatitis	*881*	*20*	*2.3*	*7*	*2.3*	*7*	*2.6*	*6*	*,2.0*	*p=0.88*
Heart diseases	*878*	*56*	*6.4*	*17*	*5.7*	*28*	*10.3*	*11*	*3.6*	*p<0.05*
Eyes infections	*881*	*120*	*13.6*	*43*	*14.3*	*37*	*13.6*	*40*	*13.0*	*p=0.90*
State of skin	*880*	*31*	*3.5*	*18*	*6.0*	*10*	*3.7*	*3*	*1.0*	*p<0.05*
Cancer	*880*	*4*	*0.5*	*3*	*1.0*	*0*	*0.0*	*1*	*0.3*	*p=0.19*
Goitre	*880*	*51*	*5.8*	*13*	*4.3*	*19*	*7.0*	*19*	*6.2*	*p=0.38*
Hypertonia	*876*	*119*	*13.6*	*43*	*14.4*	*35*	*12.9*	*41*	*13.4*	*p=0.81*
Arthritis, swollen, red or unhealthy joints	*880*	*44*	*5.0*	*14*	*4.7*	*16*	*5.9*	*14*	*4.6*	*p=0.73*

The following conclusions can be made:

- Decrease of kidney disease cases, anemia and other diseases is mostly related to poor water quality is typical for the whole Karakalpakstan;
- The number of hepatitis cases and the infant mortality have increased, while life span has lowered. There are different reasons for that including water quality, the environmental disaster in the Aral Sea impact zone and the significantly lower per capita income.

Losses related to a higher morbidity and the lower living standard can be calculated using the following method. One working day missed by an employee, causes losses equal to the wages and the expenses on the medical treatment. An average cost of losses in Central Asia amounts to USD 10 per capita. Based on the studies the number of days off because of the diseases increased since 1960 on 5 days per year. So losses per one employee amounts to USD 50 per year. The population in the Aral region amounts to 0,2 mln, the family rate is 3,1 and the number of employees amounts to 51%. The cumulative losses amount to:

$$\frac{0.2 \times 10^6}{3.1} \times 0.51 \times 50 = \text{USD } 1.645 \text{ mln.}$$

Apart from losses related to a life span on 3 years shorter in the Aral region in comparison with the other regions, using the Anderson method, to 1800 USD per year for one deceased person. Taking into consideration that this calculation is based on the comparing the life standard in the USA and in the Aral region and the difference is too great, it is obvious that this figure can not be higher than the per capita GNP, which is USD 450 in Karakalpakstan. And losses resulting from a higher mortality can be calculated using a formula:

Number of deceased persons in a year x the cost of living per a year x decreased life span =

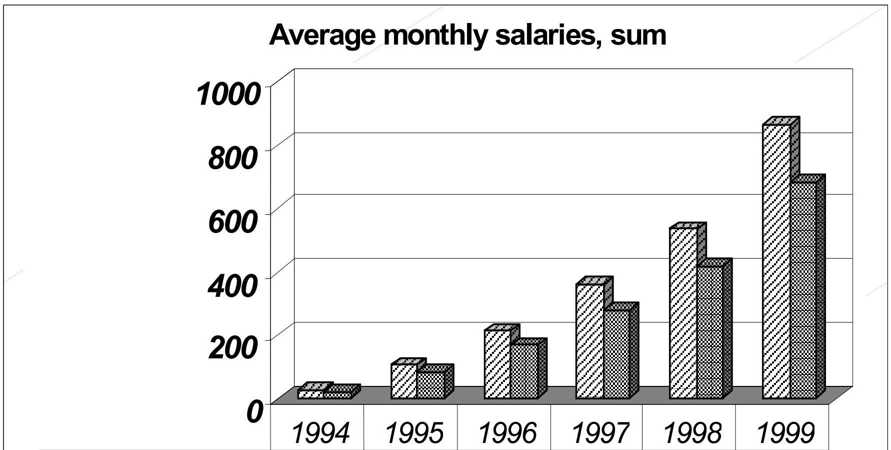
$$(0{,}2 \times 10^6 \times 0.013) \times 450 \times 3 = 3.510 \text{ mln. per year.}$$

3.3.4. Worsening of the living conditions

The living standard of population is related to the following factors:

- Population incomes;
- Production level;
- Unemployment level.

Population incomes primarily comprise monetary incomes and profits gained from private owned land plots. According to the State Statistical Department the average monthly salary in Karakalpakstan is below the average Republic level. In the period from 1994 to 1999 the average monthly salary in the Republic is 1.3 times higher compared to Karakalpakstan level. Therefore a lower level of population incomes has negative impacts on the living standard, particularly the population ability to purchase commodities including basic necessities (Fig. 27).



	1994	1995	1996	1997	1998	1999
Uzbekistan	279,7	1059,2	2137,0	3589,8	5349,4	8661,8
Karakalpakstan	214,7	855,5	1692,5	2804,8	4183,7	6834,2

Fig. 27. Comparative diagram of average monthly salaries in the Republic of Uzbekistan and Karakalpakia

Unbalanced incomes are primarily reflected in consumption of basic food products. A relatively low level of food products consumption in Karakalpakstan (Fig. 28) results not from a shortage of food products but from low incomes limiting the population consumption ability.

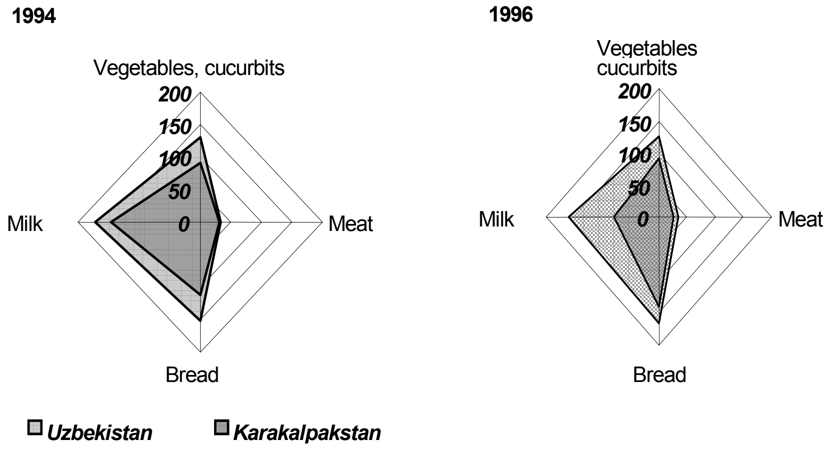


Fig. 28. Comparative food products consumption in Uzbekistan and Karakalpakstan

The unemployment level in Karakalpakstan twice exceeds the average Uzbekistan level (Fig. 27) that contributes to a lower living standard in the region.

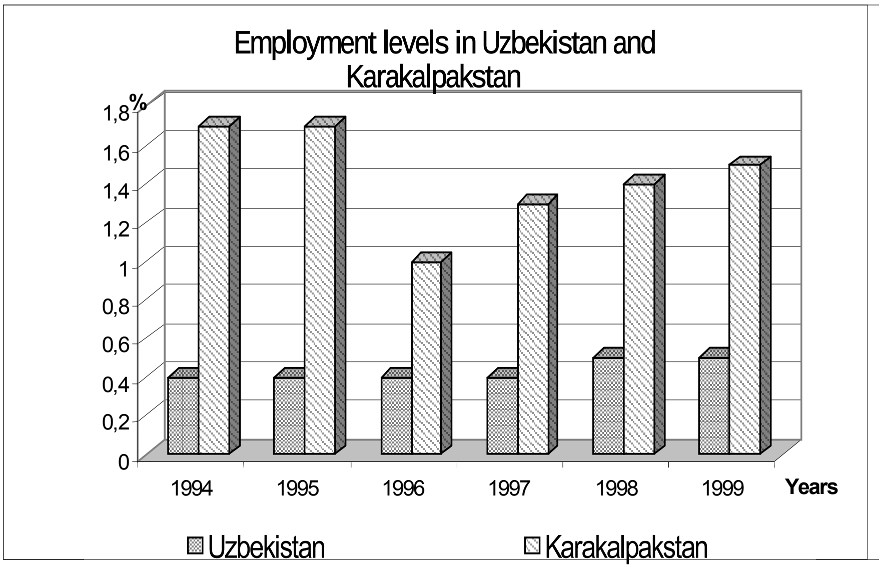


Fig. 29. Comparative diagram of employment levels in Uzbekistan and Karakalpakstan

Within the framework of the 1996-2000 territorial programs on rural population employment a total of 401.4 thousand workplaces were created in the period 1996-97 including 19.7 in Karakalpakstan. Fig. 29 shows that starting from 1996 the unemployment level in Karakalpakstan has been constantly growing.

A relative worsening of the living conditions could be approximately estimated using a range of parameters for population from the regions, located in the centre of ecological disaster (Kungrad and Muinak regions) and near it (Shumaisk region – 300 km from sea). For this aim we will use the above-mentioned results of the «Medicine without Frontiers» Programme and we will provide social-demographic characteristics for these regions.

Table 18. Socio-demographic characteristics in the studied regions

	All regions		*Shumanai*		*Kungrad*		*Muinak*		*p – Accuracy index*
	No.	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	
Age (years)									p = 0.35
18-25	*211*	*24.0*	*70*	*23.3*	*64*	*23.4*	*77*	*26.1*	
26-35	*232*	*26.3*	*87*	*28.9*	*60*	*25.9*	*85*	*27.7*	
36-45	*200*	*22.7*	*65*	*21.6*	*73*	*26.7*	*62*	*20.2*	
46-55	*90*	*10.2*	*25*	*8.3*	*28*	*10.3*	*37*	*12.1*	
56-65	*88*	*10.0*	*29*	*9.6*	*28*	*10.3*	*31*	*10.1*	
>65	*60*	*6.8*	*25*	*8.3*	*20*	*7.3*	*15*	*4.9*	
Total	*881*	*100*	*301*	*100*	*273*	*100*	*307*	*100*	
The highest level of education									p<0.05
No	*42*	*4.8*	*28*	*9.3*	*7*	*2.6*	*7*	*2.3*	
Primary	*56*	*6.4*	*23*	*7.6*	*11*	*4.0*	*22*	*7.2*	
Secondary	*440*	*50.0*	*172*	*57.1*	*111*	*40.8*	*157*	*51.1*	
Secondary special	*281*	*31.9*	*69*	*22.9*	*107*	*39.3*	*105*	*34.2*	
Higher	*61*	*6.9*	*9*	*3.1*	*36*	*13.2*	*16*	*5.2*	
Total	*880*	*100*	*301*	*100*	*272*	*100*	*307*	*100*	
Main activity in present time									p<0.05
Full time employee	*363*	*48.3*	*151*	*50.3*	*100*	*36.8*	*112*	*36.5*	
Part time employee	*55*	*6.3*	*36*	*12.0*	*8*	*2.9*	*11*	*3.6*	
Unemployed	*193*	*22.0*	*20*	*6.7*	*72*	*26.5*	*101*	*32.9*	
Pensioner	*157*	*17.9*	*54*	*18.0*	*51*	*18.8*	*52*	*16.9*	
Housewife	*56*	*6.4*	*20*	*6.7*	*17*	*6.3*	*19*	*6.2*	
Other	*55*	*6.3*	*19*	*6.3*	*24*	*8.8*	*12*	*3.9*	
*Total***	*879*	*100*	*300*	*100*	*272*	*100*	*307*	*100*	
Monthly household income									p<0.05
Less 5000	*300*	*35.3*	*106*	*38.1*	*49*	*18.3*	*145*	*47.5*	
5000-10000	*363*	*42.7*	*127*	*45.7*	*106*	*39.6*	*130*	*42.6*	
Over 10 000	*188*	*22.1*	*45*	*16.2*	*113*	*42.2*	*30*	*9.8*	
*Total***	*851*	*100*	*278*	*100*	*268*	*100*	*305*	*100*	

	All regions		***Shumanai***		***Kungrad***		***Muinak***		***p – Accuracy index***
	No.	***%***	***No.***	***%***	***No.***	***%***	***No.***	***%***	
Enough money for the living									$p<0.05$
Always enough	*157*	*17.9*	*56*	*18.7*	*70*	*25.6*	*31*	*10.2*	
Sometimes enough	*720*	*82.1*	*244*	*81.3*	*203*	*74.4*	*273*	*89.8*	
*Total****	*877*	*100*	*300*	*100*	*273*	*100*	*304*	*100*	

** Value of **p** criteria xi-sguare, verifying the allocation between two or more groups*

*** Value of **p** criteria Kruskal Wallis, verifying the differences in average group value*

**** Difference from the total number of respondents (n=881) is caused by excluding from the analyses cases with the lack of data on described characteristics*

These figures show the following:

- Age structure of the population is approximately the same in all investigated regions. In the Muinak region the smallest age group is the population in the age of more than 65 years – only 4.9%, whereas in other regions this population group is 7-8% and averages 6.8% in the investigated zone. Also the high percentage of the young population in the age under 25 years is observed in all investigated zone which serves the evidence of the high birth rate growth and low migration ability of the population;
- There is practically no difference in the education level – 90% of the population in all the regions have secondary and higher education;
- There is a striking difference in the employment – the number of economically unoccupied population (unemployed, pensioners and housewives) in Shumanai amounts to 31.4% of the population, 51.6% in Kungrad, and 56% in Muinak. Pensioners and housewives part in all three regions is approximately the same – 17-18.8% and 6.2-6.7% correspondingly. Thus only the difference in the amount of unemployed is essential. It varies from 6.7% in the Shumanai region to 32.9% in the Muinak region. In the Aral Sea region the amount of full employment does not rise higher than 37% whereas in the Shumanai region this index amounts 50% of all investigated occupied population. The level of full employment in Muinak is 14,8% lower than that in other regions and the level of unemployment is higher on 26,2%!
- The housekeeping incomes also sharply vary – in the Shumanai region the housekeeping with incomes less than 5000 Sum amount 38.1%, in the Muinak region – about 50% and in the Kungrad region – only 18.3%. The percentage of housekeeping with incomes more than 10 000 Sum is rather high.
- In spite of the fact that in the Shumanai and Kungrad regions the part of the housekeeping with low incomes is essentially lower than in the Muinak region, about 82% of the interrogated population have answered that they did not often have enough money to “make both ends meet”. And, on the other hand, in the Muinak region where the part of indigent housekeeping is rather high, 25.6% of the interrogated population have answered that they had enough funds.

Total social losses per year are the next:

- Population migration – USD 0.25 mln.;
- Losses of the qualified personnel – USD 4.40 mln.;
- Health damage – USD 1.65 mln.;
- Reducing of the length of the human life – USD 3.51 mln.;
- Worsening of the living conditions – USD 19.0 mln.;

Total: USD 28.81 mln.

Total direct and indirect socio-economical losses as a result of the ecological disaster in the Aral Sea region are estimated at USD 144,83 mln.

4. ENVIRONMENTAL DAMAGE EVALUATION

The most sophisticated methodological and practical aspect is evaluating environmental damage resulting from natural degradation that cannot be expressed by direct or indirect socio-economic indicators.

Analysis of data on environmental transformations shown in Section 2 shows that the major types of natural degradation related to and manifested by the Aral Sea lowering are:

- Loss of the Aral Sea as a natural water body;
- Deterioration of water quality has reached the limit of loss of bioproductivity of macro- and meso-forms of ichthyofauna;
- Loss of land productivity as a result of desertification and loss of soil potential;
- Loss of tugai vegetation;
- Loss of wetland area;
- Loss of specific forms of flora and fauna.

4.1. Methodological approaches to damage evaluation during environmental activities

International practice offers various methods for evaluating impacts of nature deteriorating phenomena.

4.1.1. CERLA - based method (USA)

The US government has adopted CERLA (Comprehensive Environment Response Compensation and Liability) method laying down a mechanism for financing activities to prevent damage from nature deteriorating activities and emission of hazardous substances. Following this procedure damage is related to expenses for restoring a natural complex plus economic cost of gains.

Several countries (e.g. Brazil, the Netherlands) apply a similar method expressed in a sum of expenses necessary for a user to obtain the same environmental status that existed prior to activities. It is based primarily on a functional analysis and evaluating specific losses and specific costs for restoring particular properties of the environment /24/.

4.1.2. Method of economic effectiveness of environment protection activities (USSR State Committee for Science and Technology, State Planning Board, 1983)

The method approved by the state bodies of the former USSR was based on the necessity of evaluating the prevented or compensated damage from natural degradation by a specific activity. Evaluation was expressed by a formula:

$$\frac{Z_p - Z_b}{U_p - U_b} \qquad (1)$$

Effectiveness of any environmental activity is evaluated by a difference between total expenses on the proposed alternative and expenses on restoring natural productivity (or part of it) using the cheapest methods based on a functional indicator at a specific site or a substitute indicator at another site.

The method was broadly practiced to evaluate various environmental activities, e.g. treatment of effluents of purification of rive water, rehabilitation of land damaged by open pit mining. However it can hardly (if ever) be applied for evaluating unique natural complexes like the Aral Sea and region.

4.1.3. Method of replacing activities

The method was broadly used in some environmental activities, e.g. substantiating the effectiveness of nature reserves or game ranges. Similar to the previous method and it is based on evaluating a possibility of functional replenishment through replacing activities or measures to restore these functions in the context of nature reserves. It requires evaluation of preservation (or restoration) of gene fund at the specific site, preserving biological species, rehabilitation of landscape or its profile and maintaining natural environmental processes, etc.

We shall attempt combining the above-mentioned methods to evaluate the Aral Sea status and its sustainability.

4.2. Proposals on evaluating environmental damage not related to economic effects

The main objective of evaluating environmental damage should be based on the principal made famous by the Brundtland Commission: «We have not inherited the Earth - we borrowed it from future generations»

If we succeed in combining this approach with the methods for evaluating acceptable costs the future generations «would be ready» to pay, we would create an excellent methodological tool. But our economic, environmental and social priorities are so vague that we often fail to project evaluations for a decade, not to mention 30 to 50 years. For this reason we would try to make hypothetical evaluations.

Let us assume that environmental damage is related to the costs that me could spend in the name of future generations on restoring the completely or partially damaged natural complexes.

4.2.1. Restoring the qualitative and quantitative aspects of the Aral Sea as a natural objects

It implies that the whole sea or part of it will be restored as an object with the biologically active water area and/or evaporator replenishing moisture resources in the global moisture transport. There exist several alternatives:

- Supplying to the Aral Sea 10 cub. km from the Caspian Sea - total investment cost USD 6 billion, present value USD 1.2 billion per year, and costs per one cub. m of water is USD 0.12;
- Large-scale introduction of modern irrigation techniques with network performance of 0.85 and switching over to local irrigation techniques in Central Asian area of 4 mln. ha would help reduce water removal for irrigation 20 cub. km per year. It would require a total investment of USD 30 billion, present value USD 3.6 billion, and costs per one cub. m of water USD 0.18;
- Transfer of Siberian rivers into the Aral Sea - approximately same costs.

Therefore, based on rough estimates of one cub. m costs USD 0.12 to 0.18, the total cost estimates would be:

$$\approx 0{,}15 \text{ by } 600 \text{ by } 10^9 = \text{USD 9 billion.}$$

4.2.2. Loss of irrigated lands as a result of desertification

As shown in 2.3.3. a total of about 800 thousand ha are subject to desertification and soil degradation. The results of soil studies by SANIIRI (*E. Kurbanbayev*) soil quality index has dropped 20 units on the average using a 100 point scale. In this case at the capitalized land rent of USD 2000 per ha, loss of soil quality index can be estimated at a total of USD 320 million or USD 25.6 million per year.

4.2.3. Loss of tugai vegetation

Reproduction of the natural volume of tugai vegetation as a result of rehabilitation activities described in 4.2.1 would require USD 500 per ha or total:

USD 500 by 260 thousand ha = USD 130 million

4.2.4. Wetland restoration in the AmuDarya estuary

Implementing the activities outlined in 4.2.1 and adequate water supply could result in water replenishment in wetlands, but further amelioration similar to Lake Sudochie project (total area 40 thousand ha, costs USD 4.8 million) with specific expensed USD 120 per one ha and total area of 500 thousand ha would require a total of USD 60 million.

4.2.5. Restoring bioproductivity

Regretfully the data on this problem are unavailable.

Therefore, total expenses for restoring the environmental potential of the Aral Sea could be estimated at about USD 9.5 billion. Annual expenses based on a 0.08 ratio would amount to USD 760 million.

It is difficult to say whether future generations would be able (and wish) to afford such a price for environmental welfare, but these estimates could be helpful in estimating water management and other activities to promote economic and sustainable development. The above estimates could be useful to compare different projects and also introduce payment for water removed from water sources above the allowable limits.

4.3. Cost estimate of one cub. m of water removed from the natural complex

Cost estimate of water removed from the Aral Sea and region water complex could be carried out on two directions:

- direct and indirect socio-economic losses
- costs for restoring the natural complex

For this purpose it is necessary to estimate water resources removed above the allowable level from the Aral Sea basin and related losses as well as their feasibility. The allowable limit for water use in the basin was exceeded in 1961 with water removal above 76 cub. km per year. Therefore the average long-term value that caused the above-mentioned adverse phenomena is:

115 – 76 = 39 cub. km per year

4.3.1. Price of one cub. m of water

Price of one cub. m of water in the basin in terms of direct and indirect socio-economic losses is estimated at:

USD 144,83 mln /39 by 10^9 cub. m = USD 0.00371 per one cub. m

4.3.2. Price of one cub. m of water

Price of one cub. m of water in terms of expenses for restoring the natural complex is estimated at:

9,5 by 10^9 USD/1200 by 10^9 cub. m = USD 0.008 per one cub. m

Thus the total estimates of one cub. m of water based on losses estimates is

USD 0.01171 cub. m.

Assuming that the Agreement between the littoral states would envisage this price of one cub. m of water removed above the quota of 76 cub. km, payments to the environmental fund in 1999 for removing water above the quota 103 - 76 = 27 cub. km would amount to:

27 by 0,058 by 10^9 = USD 1.566 million.

It would be sufficient to restore the natural complex productivity or saving water at the amount required for restoration of the Aral Sea and region.

5. MEASURES ON SOCIO-ECOLOGICAL AND ECONOMIC DAMAGE TO SOUTH PRIARALIE MITIGATION

In this section SIC ICWC, Uzvodproekt, ECO Priaralie, Aralconsult with participation of Soyuzvodproekt findings on South Priaralie ecologically sustainable natural complex creation partially compensating losses due to degradation.

These measures are developed in NATO SFP № 974357 Project but are yet not completed and will be completed in 2002. We hope that together with INTAS project we can finalize these measures development.

5.1. Existing hydrological situation in Priaralie and analysis of available water bodies and their water requirements.

The development of irrigation in the AmuDarya river basin and accordingly magnification of irreversible outflow volumes has significantly reduced water inflow to the AmuDarya delta. Because of insufficient supply of optimum water-salt exchange in these lakes the deterioration of water quality and accordingly overall ecological conditions happens.

At present time all existing water reservoirs in the AmuDarya delta can be divided into 2 parts according to the mode of their water supply (figure 30):

a) lakes with the collector water;
b) lakes with the AmuDarya water.

During many decades such lakes as Karatereng, Akchakul, Sudochie, Akchiel served as collectors of return and drainage waters from irrigated lands. These lakes without fresh water inflow will not be used for fish breeding and forage cultivation.
The AmuDarya river delta can be divided into 3 zones according to a character of water supply and quality of used water:

1. Left bank part is a Suenly canal, Main Left Bank collector, lake Sudochie and Ajibai bay system.
2. Priamudarinskaya – it is seaside and lakes within delta supplied from the Amu Darya river and large irrigated channels (Mexhdurechenskoye, Rybachie, Muinak).
3. Rightbank – System of the Kizketken canal, collectors КС - 1, КС - 3, КС - 4 and the Karateren lake.

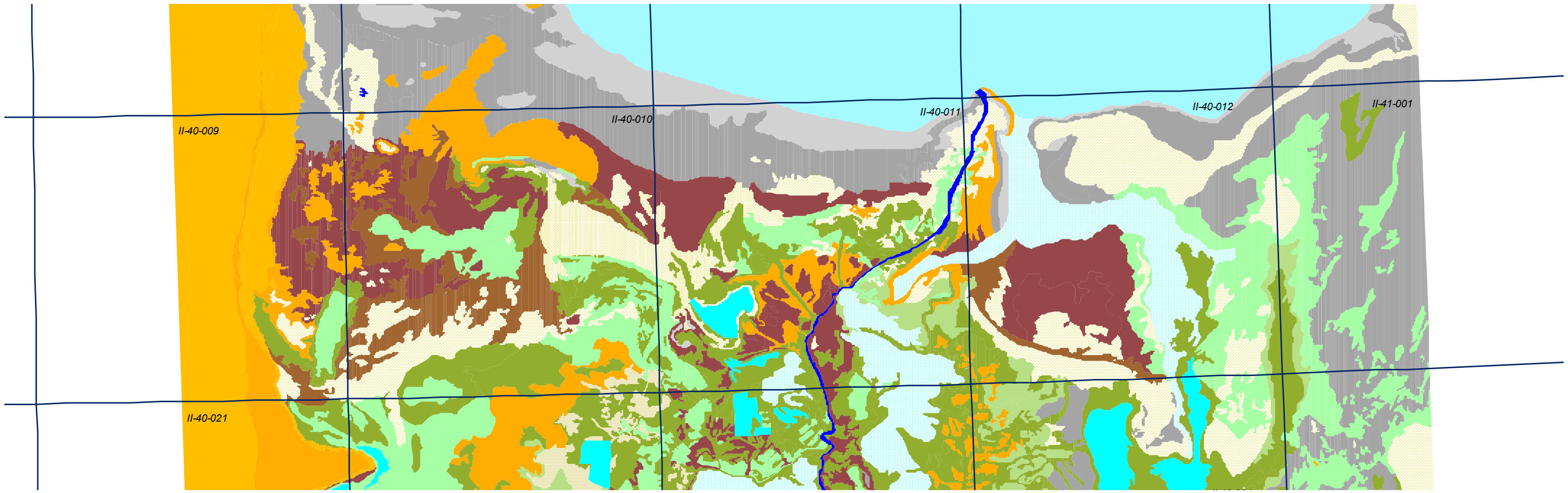
First zone is where lakes are fed based on Main Left Bank and Ustyurt collectors' flow is unfavorable for further development. Main issue here is lake Sudochie as a natural object, Karatereng lake and lake Kyvsir system which is foreseen by the GEF project's component "E" through Raushan canal.

The most perspective is the Priamudarinskaya zone. Under release of the guaranteed flow through Tahiatash hydrosystem more or less favorable ecological and hydrological situation along the whole river bed from the Tahiatash hydrosystem river station up to the sea will be created. Here in Mejdurechye it is necessary to have a large capacity regulating reservoir, which will enable restoring of productive fisheries, muskrat catch and livestock breeding. It depends on how the water transmission through Tahiatash hydrosystem into delta will be carried out.

The third zone is Rightbank. The situation in this region depends on the water content of a year and, mainly, on water discharges through the Kizketken canal. In this zone there are numerous local lakes existing on both fresh and collector water (lakes: Jiltirbars, Kokchiel, Karateren, Dautkul, Atakul, Maukul and the others).

Figure 30. Map of the Southern Priaralie's dried zones.

The following materials were used: satellite information over 1982-1991,prepared by GS "Priroda" and SPA "Planeta", pfotoschemes and subject maps 1:500 000 - 1: 100 000; research materials over 1987-1991 of Remote Sensing Division; research materials of SANIIRI, Soil Science and Agrochemistry Institutes, Gidroingeo, and Ecological Division by Tashkent State University. A. K. Chernyshev produced the map in 1991.



Caustal plain. Area of groundwater (salinity at 25-50 g/l) discharge with hydromorphic conditions for maritime alkali soils; sandy loam is prevalent in the delta. Microrelief. Water erosion. Salt wort vegetation. The Area relates to formation of polygonal soil structures.

Sea plain with microrelief and maritime hydromorphic alkali soils. Soils comprise sand and clay with sandy loam interlayer. Vegetation Rikhter's salt worts; general coverage - 0,1 %. The area relates to the end of polygonal soil structures formation.

The plain is comprised by alluvial-delta and marine sandy, loamy and silty soils. Maritime hydromorphic and semihydromorphic thin and fhick alkali soils covered by sands and sandy loams. Poligonal structures make for the shrinkage of soils, suffer from rainfall and winds, are filled by sandstones, and promote salt transfer. Polygonal elements make for ephemeral and perennial vegetation. On heavier soils minimum size of polygonal structures is 40-50 m.

Differs from coastal plain by soil texture and finer structure. Topsoil allows for salt migration. Vegetation is presented by orach group. Water and soil erosion.

Wide sea plain comprised by clays with sandy loam and sand interlayers. Automorphic and semiautomorphic alraly soils; thin alkali soils in microsinks. Salts, sands and sandy loams are easily washed off by rainfall to cracks in polygonal desalination and takyr development. Vegetation: annual and perennial plants (up to 5%)

Area with unstable landscape. *Sea plain comprised by sandy -loamy and sandy silty-loamy sediments. Coefficient of vegetation cover is 15-30%. Favorable conditions for ephemeral and perennial plants due to partial desalination of top soil*

Sea plant within Adzhibay. Soil Texture: sandy loam, loam and clay (fine fractions prevalent). Vegetation: orachs and tamarix.

Sea plant comprised by clays, heavy and medium loam with sandy loam and sand interlayers. Area of potential desalination and takyr development. Vegetation: annual and perennial plants.

Sea plain, relief is formed by streams. Most area is presented by mesorelief. Vegetation: annual saltworts.

Area comprised by heavy silty-loamy sediments with sandy loam interlayers. Soils suffer from secondary salinization. Vegetation cover is less than 1-2%.

Area with unstable landscape. *Sands. Most part of sand is not fixed, i.e. running sands. Fixing process is slow and relates to formation of barhans and ridges. Sand mobility causes salt transfer. More intensive fixing of sand is observed in the Amudarya delta. Vegetation spreads over the areas where sand layer (10-15 cm) combines with sandy loam and clays. Such combination keeps soil moisture.*

Natural sinks, flooded from time to time.

Preservation of these lakes and improving of ecological conditions and economic situation in this region depends on water availability and quality, basically on Amu Darya discharges. During the wet years 1991, 1992, 1993, 1994 as a result of high water release to the AmuDarya river delta through irrigation channels and their tail parts, the conditions of these lakes were considerably improved (especially in the Priamudarinskaya zone) and their open water surfaces even extended.

Estimation of approximate water supply capacity to maintenance seaside and delta lakes.

The lightening of the Aral disaster consequences should be carried out by creation of artificially regulated reservoirs on the place of former seaside and delta lakes and marine bays, this idea was grounded by Prof. V.Dukhovny and others in 1983, together with phito-melioration measures.

The preservation of these lakes and bays, keeping them in good hydrological and hydrochemical conditions completely depends on river inflow; i.e. AmuDarya discharges in the Tahiatash hydrosystem zone. During the wet and dry years (inflow from AmuDarya in these lakes is more than 4,5 mlrd. m^3 per year) the favourable conditions for preservation of these lakes will be provided.

The difficulties will be observed in dry years, and also in the long term due to the reduction of the river discharges and volume of a drainage returnable flow.

According to ECO “Priaralie” estimate, for normal level of water in deltaic and maritime water bodies support minimum volume of water 4.33bln. m^3 /year net is needed.

Table 19. Required river discharges (m^3/sec) and volumes of flow (mln.m^3), necessary for preservation of seaside and delta lakes (preliminary estimation)

Zones	Open water surface of reservoirs (thousand ha)	Average per year (m^3/sec)	Flow volume (km^3)
Leftbank	96.0	35.0	1.1
Priamudarinskaya	122.0	99.3	3.14
Rightbank	64.7	32.4	1.03
Total	282.7	166,7	5,27

5.2. Overview of works fulfilled in the southern part of Priaralie

The problem of Priaralie revival is differentiated within three zones, which are given below:

The 1st zone is factually AmuDarya delta within irrigated area in the south and up to the former Aral sea seashore in the north.

The 2nd zone - is the dried out bottom of the sea from the former Aral Sea seashore on the level 53.0 m and up to isobaths on the level 29.0-30.0m, which are supposed to be the level of the future sea stabilisation.

3rd zone - is existed now remaining part of the Aral sea.

Each of the mentioned above zones is divided into several ecological zones distinguished by the forming factors: availability of populated areas and their social settings; availability of water resources (river and drainage) and degree of their deficit; flora and fauna and degree of their degradation; soils; underground waters and etc.

The solution of problems of each from these zones requires fulfilment of interrelated technical and ecological activities with the following aims:

- For the 1st zone – developing of the AmuDarya delta in order to rehabilitate its historically formed ecological mode and create normal life conditions for the population.
- For the 2nd zone – developing of the dried out bottom of the sea for lightening negative consequences by combining of reservoirs and forest protection zones.
- For 3rd zone – preservation of the existing sea biopotential and reduction of the sea shrinkage negative consequences.

Problems of struggle with a desertification of the AmuDarya delta and rehabilitation of the Priaralie ecosystem have been investigated in studies and proposals of leading specialised design and scientific-research institutions of Uzbekistan and foreign countries.

- Institute "Sredasgiprovodhlopok" (nowadays "Uzgipromeliovodhoz") in 1989 has prepared feasibility study for construction of structures for level control and water mode regulating of shallow coastal parts of the Aral Sea in the AmuDarya delta area. The main parameters of water reservoirs in former gulfs of the Aral Sea (Ribachiy, Muinak, Adjibay and Djiltirbas) have been determined, the scheme of their filling by drainage and fresh river water inflows have been prepared (figure 31).

For maintaining a necessary flushing mode and keeping certain water levels in the Ribachiy, Muinak and Jiltirbas reservoirs as well as in the system of natural lakes Dumalak, Maklapul etc. parameters of Mejdurechenskiyi reservoir have been defined considering seasonal regulation of the AmuDarya river flow. In 1990 the same institute developed the feasibility report (FR) for creation of an artificially regulated reservoir in area of Muinak city. This study has executed the substantiation of water management parameters; filling and operation mode of the Muinak and Ribachiy reservoirs and the possibility of their economic use.

- NPO SANIIRI has studied problems of development of the small water bodies on the dried up bottom of the sea (so called untipolders) and elaborated general approach based on subdividing of region into zones depending on an ecological classification (there were classified 6 zones). In particular the zone of fresh water wetlands has been also separated (Mejdurechye, Ribachiy and Mujnak gulfs, lake Mashankul) (figure 32).

- Assosiation "Vodproekt" has proposed in its studies to construct on the dried bottom of the sea along its former coastal line continuous fresh water lagoon extending from Usturt Chinks up to Akpetkinskiy archipelago with length 180 km. and a water level 53.0m., which corresponds to a former sea level. The dam of the lagoon will block located in a delta canals, and will support their mouths. Dam will accumulate whole river water, which inflows to the delta periphery, and distribute it to the areas between canals and lakes for filling them also up to the level 53.0m.

For creation of water flushing in the lagoon and keeping the necessary level of water it has been foreseen using of the Mejdurechenskiyi seasonal regulating reservoir with water-distributing hydrosystem in a river station Parlitau.

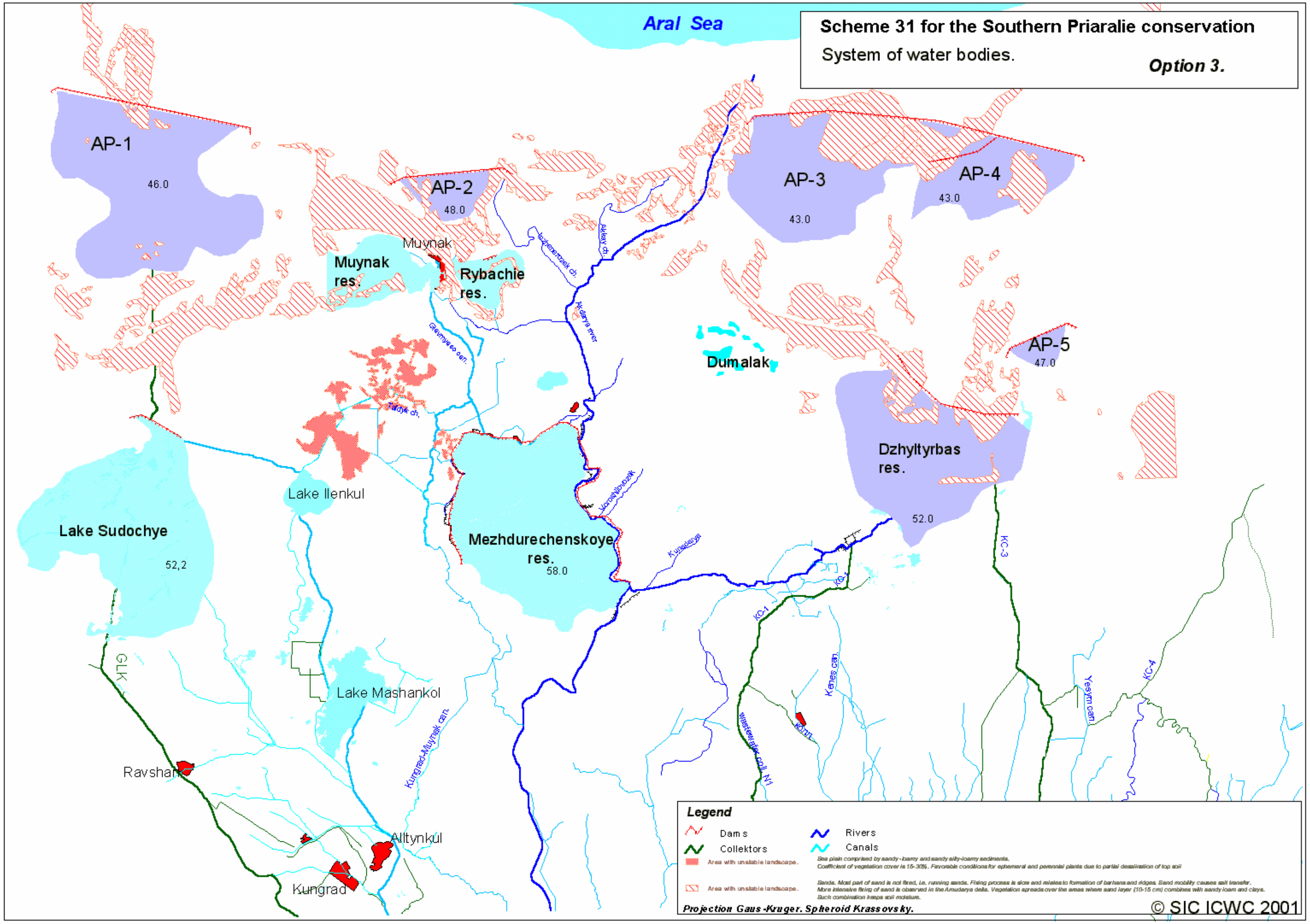
For maintaining a necessary flushing mode of the natural lakes Sudoche, Mashankul, Ilenkul, Maklakul, Dumalak etc. construction of a system of canals and distributive structures has been proposed (figure 33).

- Consortium of the companies consisting of Euroconsult (firm - leader), Wetlandgroup (Netherlands) and Agricultural Centre LTD from Tashkent in 1996 have presented to Executive Committee of IFAS and World Bank the report of the developed by them project, " Rehabilitation of the Aral sea wetlands in the Uzbekistan Republic " (figure 34).

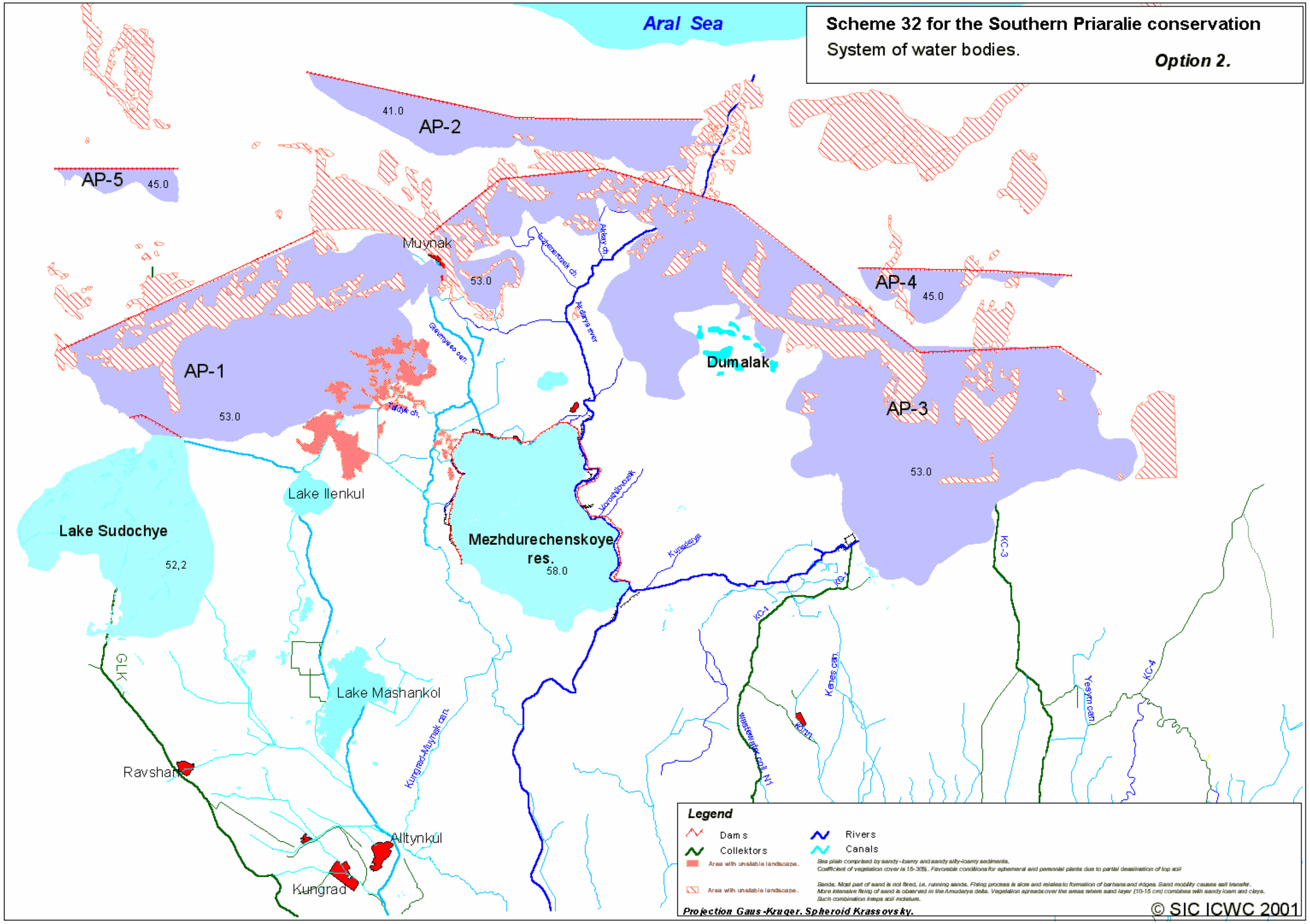
In the project the Consortium has foreseen creation of four areas of inundated flood-plains with a new management system:

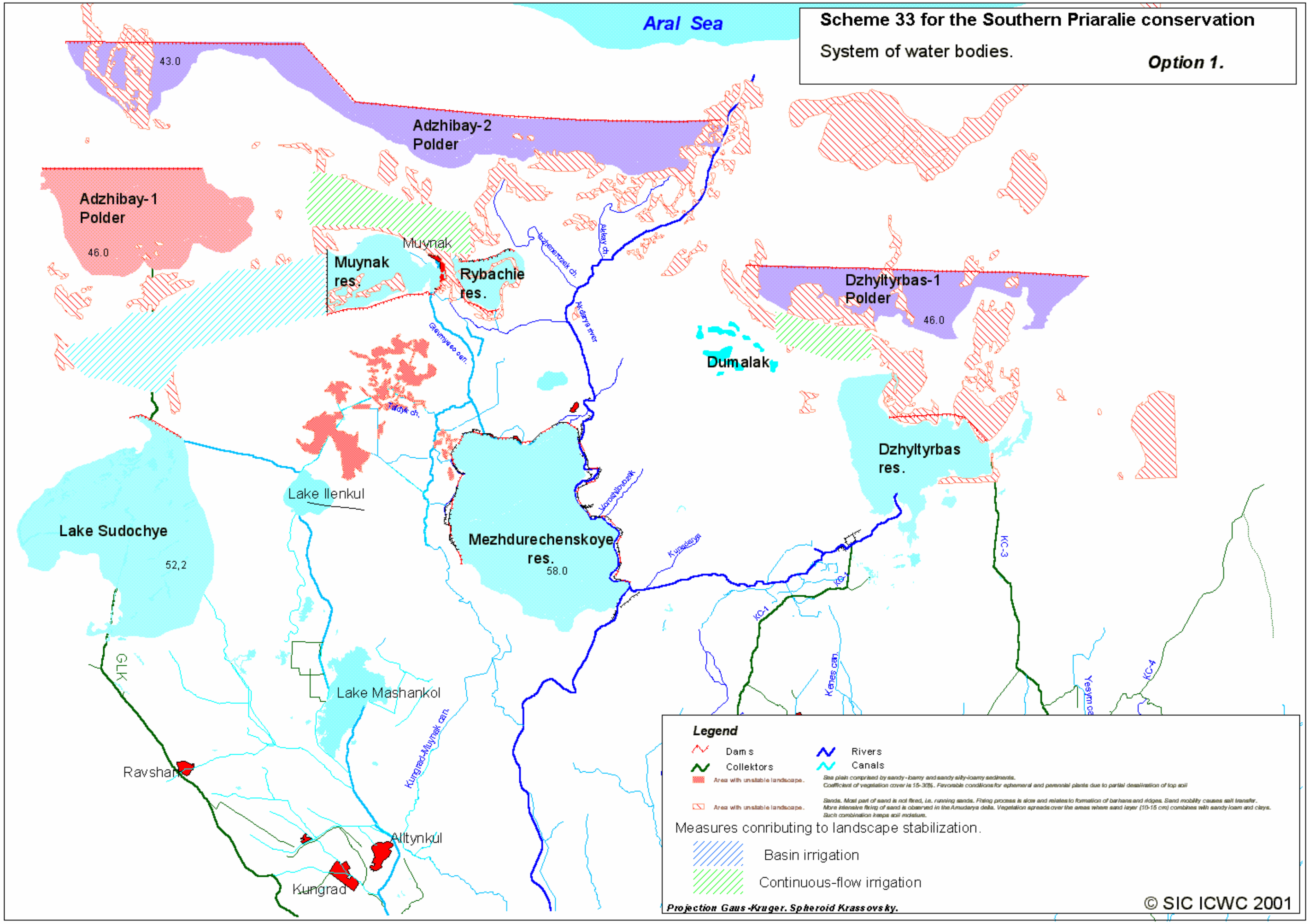
- inundated flood-plains Mashankul, Zakirkol, Ilmenkol;
- inundated flood-plains in the south from a Mujnak gulf;
- inundated flood-plains around the lake Tuz on the north of Karadjar;
- inundated flood-plains of the Sudoche and Karateren lakes system.

The project executed by the Consortium has faced serious objections from Minselvodhoz of Uzbekistan, interested parties and local experts, since has not given the full large-scale strategy of creation of the wetlands landscape ecosystem in the AmuDarya delta; has not proved and solved problems of water supply to the delta, its regulation and distribution; has not solved problems of the flood waters transmission and their use for watering of the delta; has not defined the necessary complex of structures and their parameters, construction; has not developed pilot project and has not solved the other questions, which had to be developed according to TOR.



Scheme 31 for the Southern Priaralie conservation
System of water bodies.
Option 3.
Aral Sea
AP-1
46.0
AP-2
48.0
AP-3
43.0
AP-4
43.0
AP-5
47.0
Muynak
Muynak res.
Rybachie res.
Dumalak
Dzhyltyrbas res.
52.0
Lake Ilenkul
Lake Sudochye
52,2
Mezhdurechenskoye res.
58.0
Lake Mashankol
GLK
Ravshan
Altynkul
Kungrad
KC-1
KC-3
KC-4
Legend
Dams
Collektors
Area with unstable landscape.
Sea plain comprised by sandy-loamy and sandy silty-loamy sediments.
Coefficient of vegetation cover is 15-30%. Favorable conditions for ephemeral and perennial plants due to partial desalination of top soil
Rivers
Canals
Area with unstable landscape.
Sands. Most part of sand is not fixed, i.e. running sands. Fixing process is slow and relates to formation of barhans and ridges. Sand mobility causes salt transfer.
More intensive fixing of sand is observed in the Amudarya delta. Vegetation spreads over the areas where sand layer (10-15 cm) combines with sandy loam and clays.
Such combination keeps soil moisture.
Projection Gaus-Kruger. Spheroid Krassovsky.
© SIC ICWC 2001


Scheme 32 for the Southern Priaralie conservation
System of water bodies.
Option 2.
Aral Sea
AP-1
53.0
AP-2
41.0
AP-3
53.0
AP-4
45.0
AP-5
45.0
Muynak
53.0
Dumalak
Lake Ilenkul
Lake Sudochye
52,2
Mezhdurechenskoye res.
58.0
Lake Mashankol
Ravshan
Alltynkul
Kungrad
GLK
KC-3
KC-4
Kenes can.
Yesym can.
Kungrad-Muynak can.
Legend
Dams
Collektors
Rivers
Canals
Area with unstable landscape.
Sea plain comprised by sandy-loamy and sandy silty-loamy sediments.
Coefficient of vegetation cover is 15-30%. Favorable conditions for ephemeral and perennial plants due to partial desalination of top soil
Area with unstable landscape.
Sands. Most part of sand is not fixed, i.e. running sands. Fixing process is slow and relates to formation of barhans and ridges. Sand mobility causes salt transfer.
More intensive fixing of sand is observed in the Amudarya delta. Vegetation spreads over the areas where sand layer (10-15 cm) combines with sandy loam and clays.
Such combination keeps soil moisture.
Projection Gaus-Kruger. Spheroid Krassovsky.
© SIC ICWC 2001


Scheme 33 for the Southern Priaralie conservation
System of water bodies.
Option 1.
Aral Sea
43.0
Adzhibay-2 Polder
Adzhibay-1 Polder
46.0
Muynak
Muynak res.
Rybachie res.
Dzhyltyrbas-1 Polder
46.0
Dumalak
Dzhyltyrbas res.
Lake Ilenkul
Lake Sudochye
52,2
Mezhdurechenskoye res.
58.0
GLK
Lake Mashankol
Kungrad-Muynak can.
Ravshan
Alltynkul
Kungrad
KC-1
KC-3
KC-4
Kenes can.
Legend
Dams
Collektors
Rivers
Canals
Area with unstable landscape.
Sea plain comprised by sandy-loamy and sandy silty-loamy sediments.
Coefficient of vegetation cover is 15-30%. Favorable conditions for ephemeral and perennial plants due to partial desalination of top soil
Area with unstable landscape.
Sands. Most part of sand is not fixed, i.e. running sands. Fixing process is slow and relates to formation of barhans and ridges. Sand mobility causes salt transfer.
More intensive fixing of sand is observed in the Amudarya delta. Vegetation spreads over the areas where sand layer (10-15 cm) combines with sandy loam and clays.
Such combination keeps soil moisture.
Measures conributing to landscape stabilization.
Basin irrigation
Continuous-flow irrigation
Projection Gaus-Kruger. Spheroid Krassovsky.
© SIC ICWC 2001

Analysis of the previously executed projects and proposals allows to define preliminarily a complex of measures and structures, which conditionally can be combined into the following three large systems of water management:

1. System from artificial reservoirs in the delta and on the dried out bottom of the sea.
2. System for preservation of natural lakes in a delta.
3. System of liman irrigation and phito-reclamation.

The short description of each from them is presented in Section 5.3.

5.3. Measures on creation of regulated reservoirs and wetlands in the AmuDarya delta and on the desiccated sea bed

5.3.1. System of artificial reservoirs in the delta and on the desiccated sea bed

This structure consists from Mejdurechenskiyi, Mujnak, Ribachie and Djiltirbas reservoirs and untipolders Adjibay -1, Adjibay -2 and Djiltirbas -1 allocated in the Aral Sea former bays of the same name.

Mejdurechenskiyi reservoir

Mejdurechenskiyi reservoir is located in natural depression between Akdarya river and Kipchakdarya canal in the central part of the delta. At the present time in a section line of this hydrosystem the dam on Akdarya river has been built with a crest level 57.5 m., that allows to receive a regulating capacity about 200 mln.m^3. Also temporary surface spillway with the construction period capacity
3700 m^3/sek, regulator with discharge 40m^3/sek and 9 water-discharge pipes into small-sized channels have been built. During the high discharges in the past reservoir dam and its spillway repeatedly were destroyed. This reservoir is now main source of the guaranteed water-supply to the Mujnak region.

The reservoir is intended for seasonal regulation of the AmuDarya flow in the delta and guaranteed water supply to systems of artificial and natural reservoirs in the delta. Main problems of this reservoir creation are struggle with sedimentation and transmission of high discharges to the lower reach.

According to Uzgipromeliovodhoz, Mezhdurechenskoye water reservoir after completion will have following parameters:

Level of the dam crest.............. 59.5 m.

Level of water......................….. 58.0 m.

Capacity of reservoir......……... 900 mln.m^3.

Irreversible losses on

evaporation and filtration...........180 mln.m^3/year

Discharges of admission structures.... 10400m^3/sec

Cost of the hydrosystem complex is USD 290 mln.

It is clear, that construction of such a structure will be executed during the long period, that will not allow in the near future to use its regulating ability for maintaining necessary modes in the depending natural lakes and artificial reservoirs. Furthermore from year to year regulating ability of such a reservoir will be reduced because of its intense sedimentation.

Therefore it is expedient to consider as well possibility to create in Mejdurechie a small reservoir with capacity about 200 mln.m^3 (water level - 56.0 m.), by restoring earlier constructed and then destroyed dam and to built in it a distributive hydrosystem regulator Parlatau with discharge up to 2000 m^3/sek.

Here within wet and average humidity years in the AmuDarya basin water supply to preserved system of natural lakes (Sudoche, Dumalak, Maklapul, Mashankul) and artificial reservoirs in the delta and desiccated sea bed will be carried out by distribution of water through hydrosystem-regulator Parlatau. During the dry years it will be regulated also by means of using reserved for these purpose necessary capacity of Tuyamuyun reservoir and transit of recharging water to the delta exactly from the AmuDarya bed.

Discharging of AmuDarya to the Aral Sea through hydrosystem section within flooding periods, will be carried out by using existing canal Maipost-Dumalak and old river bed. Special protection measures should be provided for prevention of washing out of river beds and canals in the tail water.

Mujnak and Ribache reservoirs

Mujnak and Ribache reservoirs are established near Muinak city in the former Aral Sea bays of the same name. They have ecological, fishery and recreation significance.

Construction of these reservoirs has allowed reducing of salt and dust storms formation from the dried out sea bed and their migration in the direction to Muinak and neighbouring settlements as well as promoted self-vegetation of the areas surrounding reservoirs.

Now both reservoirs are already constructed, although they are not operating with the full capacity and their spillway structures are not completely built.

These reservoirs are filled by fresh river water from the Glavmyaso channel with discharge 35m^3/sek. In order to provide uninterrupted water supply it is necessary to reconstruct intake structure from Mejdurechye and channel itself.

Water from reservoirs is supposed to be delivered through channels to designed "antipolders" Adjibay-1, 2.

For effective management of water levels in reservoirs, their flushing and water exchange it is necessary to construct bottom spillway-outlets with total spillway capacity about 70 m^3/sek.

Reservoir parameters are given in Table 20:

Table 20

Parameter	Unit	Mujnak	Ribache	Jiltyrbas
Level of water	m	52.5	52.5	52.0
Capacity of reservoir	mln. m^3	161	135	280
Irreversable losses on evaporation and filtration	mln. m^3	137	97	360
Volume of reservoir drawdown	mln. m^3	161	135	376
Spillway discharges	m^3/sec	2 x 35	2 x35	80
Protecting dams: length	km	21.5	8.0	38.0
height	m	2.0-4.0	2.0-5.3	2.0-4.0
Costs of construction	$US mln.	14.2	18.2	24.0

Jiltyrbas reservoir

Jiltyrbas reservoir forms by dam with length 38km, partitioning off a bay from the north. The filling of reservoir is supposed by drainage water from collectors KC-1-3 with mineralization 15 g/l and volume up to 446 mln.m^3/year. For keeping water mineralization in reservoir within 4-3 g/l; providing flushing mode and overall water exchange during a year the transmission of fresh river water in volume 290 mln.m^3/year is foreseen.

Discharge of water from reservoir is forecasted into project "antipolder" Jiltyrbas-1. A part of the dam and the east part of the reservoir are now built. For maintaining of necessary water levels and creation of flushing mode should be constructed bottom spillway-outlets with overall discharge capacity of 80 m^3/sec.

Reservoir parameters are given above in Table 20.

5.3.2. Artificial reservoirs ("antipolders") in Adjibay and Jiltirbas bays

So-called "antipolder systems", are considered as the second line of watering of the desiccated sea bed by mineralised and fresh river water arriving from the delta and the first line of water bodies and lakes into the remained part of the sea.

The system of "antipolders" assumes their establishment in shallow part of a bioplateau for sorbtion of pesticides and other kinds of pollution. Due to availability of a bioplateau and creation of flushing mode in "antipolders" their deep-water zones become suitable for fisheries. The availability of "antipolders" behind the first line fresh water zone also creates favourable conditions for watering of significant area of the desiccated sea bed between the delta and "antipolders" and by that ensures efficiency of phito-reclamation works for prevention of salt dust storms from the desiccated sea bed to the delta lands.

Taking into account scarcity of water resources and allocation of the first line reservoirs and lakes, it is rational to consider in the given project organisation of "antipolders" in the former sea bays Adjibay and Jiltirbas in means of using outflow from the lake Sudoche as well as Mujnak, Ribache, Jiltirbas reservoirs.

To establish a two-stage system of "antipolders" including reservoirs Adjibay-1 and Adjibay–2 in the former Adjibay bay, instead of construction of the Adjibay reservoir as have been proposed by many authors, would be more rational. In this case water supply to the located in the upper part of the delta Adjibay -1 reservoir will consist of mineralised and fresh water from the Sudochie lake and in case of necessity, fresh river outflow from Mujnak and Ribache reservoirs. Water supply to the Adjibay–2 reservoir which is located in the lower part of the delta will be carried out by outflow from Adjibay-1 and recharging from the same reservoirs.

Set up of two smaller reservoirs, instead of one large Adjibay reservoir, will allow more effective operating of this zone limited water resource and thereby creating more favourable conditions for fisheries. Placing these "antipolders" closer to the former seashore line will practically allow watering of the whole area, surrounding settlements, and preventing salt dust storms in that area.

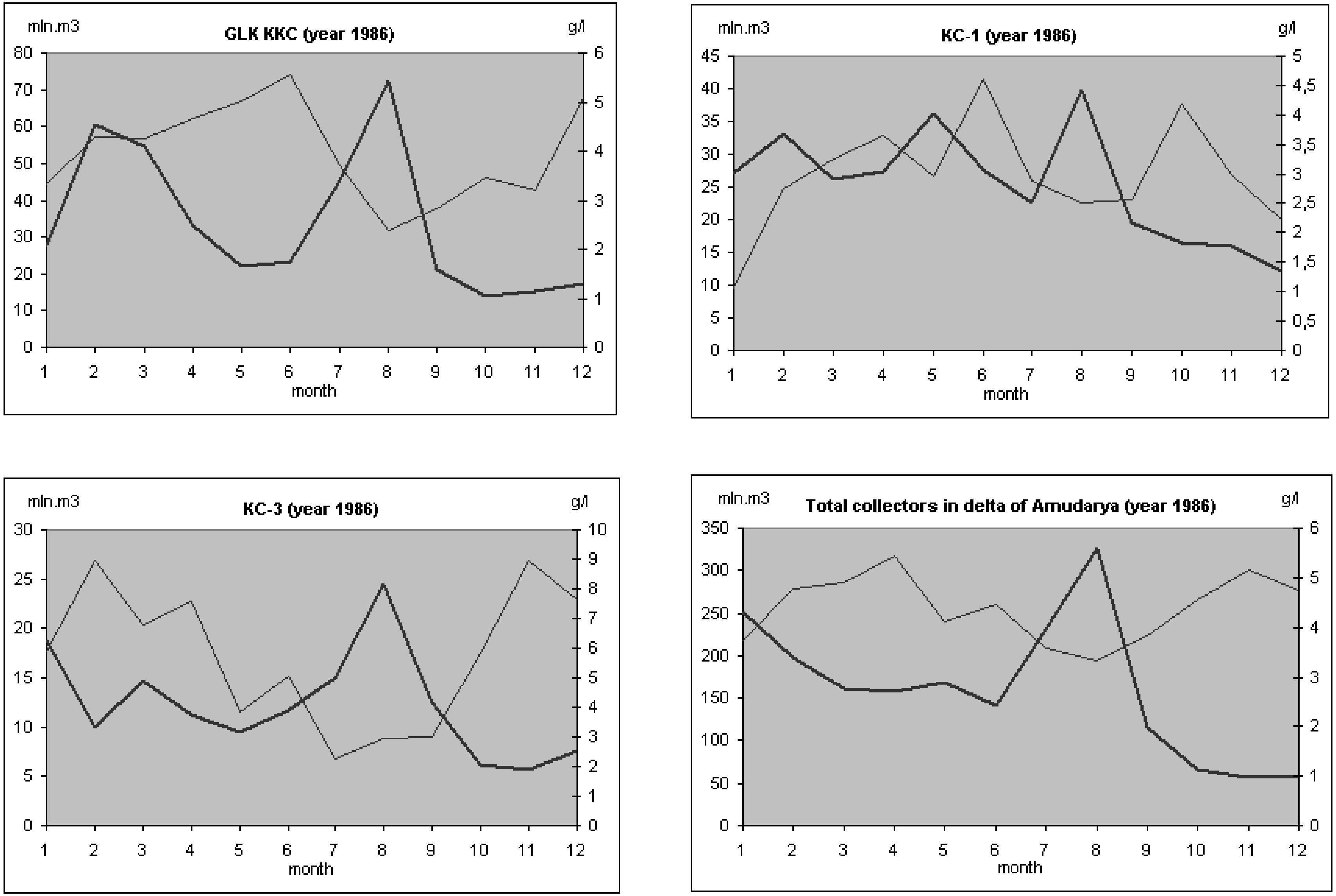
It is also necessary to mean, that now in the Adjibay bay on the dried out sea bed is carrying out prospect drilling on petroleum and gas, and in case of success flooding in area of Adjibay reservoir will be inadmissible.

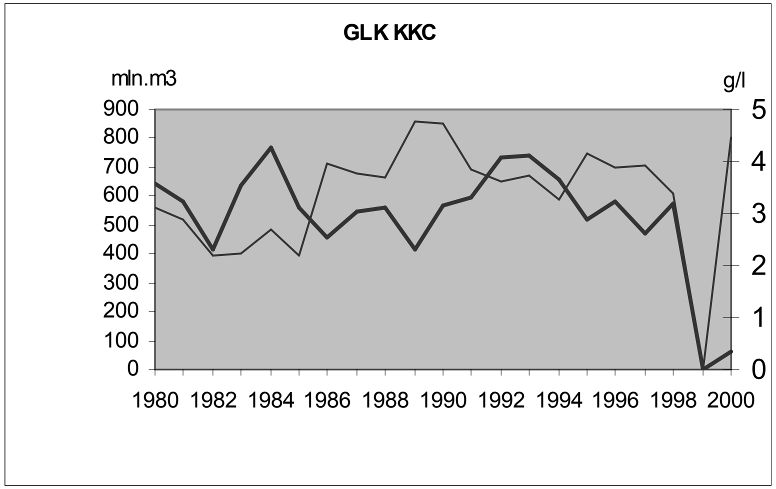
Third "antipolder" Jiltirbas -1 is supposed to be placed on the entrance to the former sea bay of the same name. It will be supplied only by mineralised outflow from Jiltirbas reservoir.

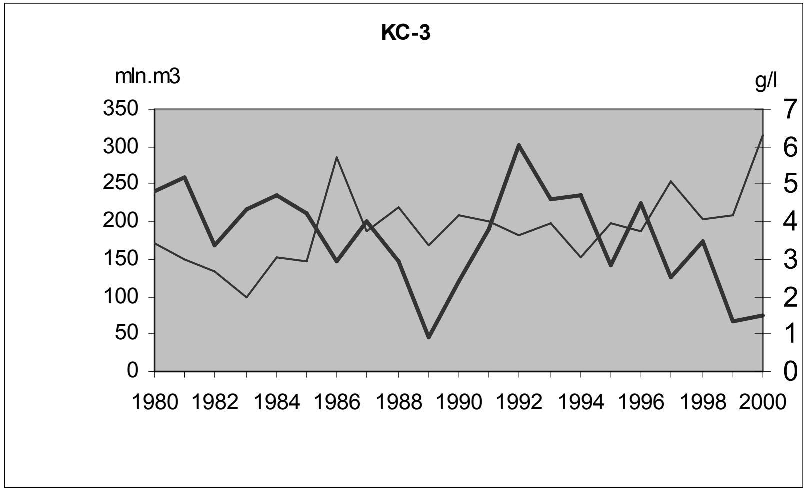
Proposed location of three "antipolders" does not exclude hereafter, in case of expected increase of water supply to the delta and effective work of "antipolders", possibility to organise similar "antipolders" on the lower sea bed levels.

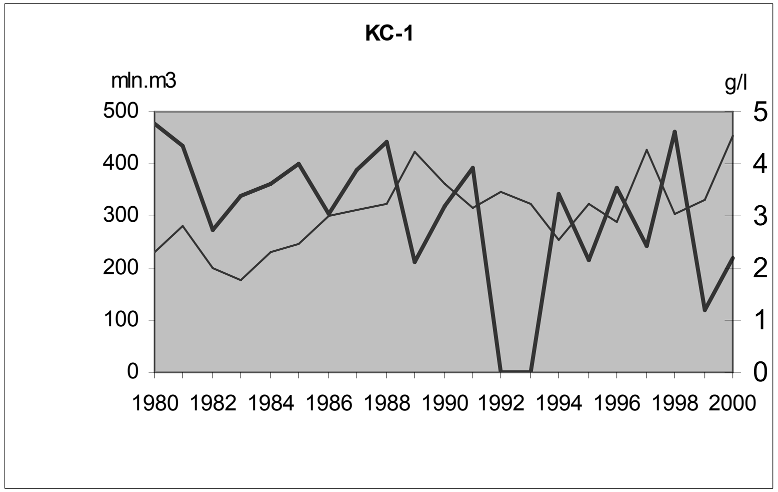
The approximate parameters of "antipolders" are indicated below in Table 21 It should be mentioned, that specific design of "antipolder systems", their allocation on the area and development of a construction haven't been executed earlier. All available materials are the scientific substantiation of their parameters and efficiency of their operating.

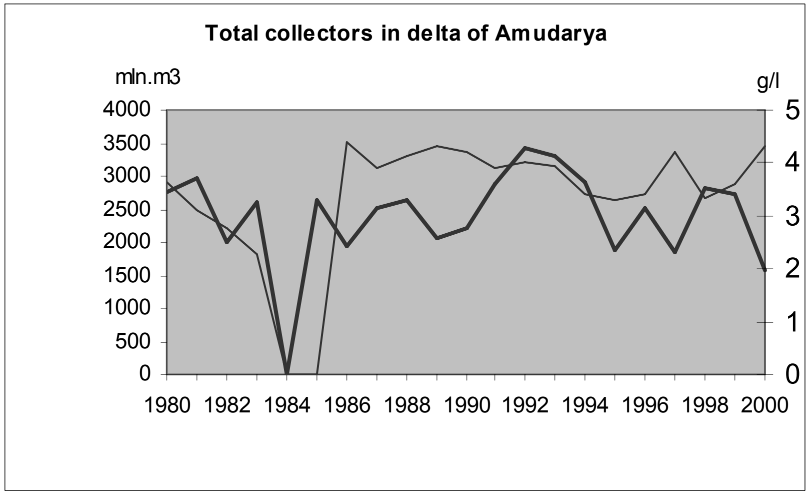
Pic. 35
Monthly Variation of drainage flow and its mineralization in the main collectors in delta of Amudarya River
(The ultimate dry year -- 1986, probability = 98%)











Multi-year variations of drainage flow and its mineralization in the main collectors in delta of Amudarya River

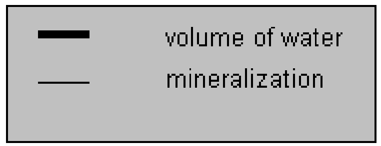


Table 21

Parameter	Unit	Adjibay-1	Adjibay-2	Jiltyrbas-1
Level of water	m	51.0	47.5	46.0
Capacity of reservoir	mln. m^3	160	250	175
Irreversible losses on evaporation and filtration	mln. m^3	175	285	245
Volume of reservoir draw down	mln. m^3	655	370	325
Spillway discharges	m^3/sec	70	50	60
Protecting dams: length	km	24	30	25
height	m	1.5-5.0	1.5-4.0	1.5-3.5
Costs of construction	$US mln.	25	30	20

5.3.3. Natural lakes preservation system in the delta

In order to restore and maintain a flowing mode of delta lakes, the main from which are lakes Sudoche, Karateren, Dautkul, Dumalak, Hodjakul, Mashankul and Ilenkul, water supply should be guaranteed in volumes sufficient to cover losses for filtration, evaporation from a water surface, vegetation transpiration and creation of a flowing mode. Taking into account that overall area of lakes is 48.5 thousand ha. Demand for river water will be 1380 mln.m^3/year, including irreversible consumption – 990 mln.m^3 and water offtake – 790 mln.m^3/year.

In order to discharge lakes it is necessary to construct an extensive distributive network of channels and to execute exactly in reservoirs specific measures, such as deepening, watering etc.

Main intake unit of a system is supposed to be placed in area of the lake Dautkul, from which will start up system of channels Taldik on the right bank and Erkindarya - on the left bank. Another intake will be constructed in a river station Parlitau at Mejdurechye reservoir. The system of small-sized hydrosystems, partitioning structures and distributive channels will ensure the guaranteed supply of water into lakes and reservoirs. Total length of this system will make about 500 km. and construction costs will be approximately $US 375 mln.

Special place in the delta lake system restoring project takes the largest lake Sudochie, which is recommended to be kept as a main fishery and ecological reservoir.

To rehabilitate this lake it is supposed to use whole drainage flow from the Main Left Bank Collector (MLBC or KKC) in amount of 560 mln.m^3/year and Usturt collector in amount of 100 mln.m^3/year, and also to provide ecological releases of river water in amount of 300 mln.m^3/year.

For arrangement of fishery conditions in this lake it is obviously necessary to consider variant of its partitioning by a low dam on two interconnected between themselves parts - western, discharged by KKC drainage waters with water mineralization of 3-5 g/l, and eastern, discharged mainly by river water, with mineralization 1-1.5 g/l, that creates in this part of the lake suitable living conditions for fish fry and young fish population.

It should be mentioned that specific design of a system of distributive channels and hydrostructures to restore delta lakes has not been developed yet.

5.3.4. System of estuary irrigation and forest- phito-reclamation

In the AmuDarya delta it is supposed to create zones of estuary irrigation and forest-phito-reclamation, which will form the green barrier separating an irrigated zone from the dried out sea bed and will serve as a forage source.

Area of lands, suitable for estuary irrigation, is evaluated in 200 thousand he. Water supply to these lands is supposed during flooding period (March - April) in volume 980 mln.m^3 of fresh river water per year. Water inflows into estuaries through system of channels - distributors. Estimated cost of works on development of estuary irrigation zones is $US 95 mln. Except estuary irrigation it is supposed also to irrigate natural meadows and haymaking on the area 27 thousand he. by river water of sanitary releases through the AmuDarya.

5.3.5. Generalised parameters of the whole complex of technical activities

In table 22 a general water demand to whole complex of water management measures in the AmuDarya delta and desiccated sea bed is presented. It comes to 5220 mln.m^3, including 3825 mln.m^3 of river water per year. From this volume of inflow to the delta an irrevocable water consumption on evaporation and filtration makes 3450 mln.m^3, including 2375 mln.m^3 of river water per year. The rest of water in volume 1770 mln.m^3 will outflow into the sea after using it in artificial reservoirs and antipolders, creating there necessary flowage and water exchange.

Table 22

Measures	**Water consumption**			**Irreversible losses**			**Outflow into the sea**	**Costs**
	Total	**River**	**Drain**	**Total**	**River**	**Drain**	**mln.m^3**	**mln. $US**
1. System of reservoirs, water bodies and antipolders								
a) Without Mejdurechye	2280	1545	735	1300	645	605	980	130
б) With Mejdurechye	2460	1725	735	1480	875	605	980	420
2. System for preservation of natural lakes								
Total	1780	1120	660	990	520	470	790	375
including Sudoche	960	300	660	760	290	470	-	
3. System of estuary irrigation and forest-phito-reclamation								
Total	980	980	-	980	980	-	-	95
Grand total on all systems								
a) Without Mejdurechye	5040	3645	1395	3270	2195	1075	1770	600
б) With Mejdurechye	5220	3825	1395	3450	2375	1075	1770	890

Despite the fact that there are a lot of proposals prepared by local design institutions, mainly justified by the schematic studies, all of them have the similar point of view on structure of water management measures in the delta, particularly in necessity to construct Mejdurechye seasonal regulating reservoir; construction and reconstruction of the system of channels - distributors for maintaining required operational mode of natural lakes Sudochie, Ilmenkul, Mashankul, Dumalak and the others.

As to development of artificial reservoirs on the desiccated sea bed along the former coastal line the common strategy and structure of water management measures until now is not elaborated.

The analysis of studies on restoring wetlands in the AmuDarya delta and along the former coastal line of the Aral Sea comes to conclusion that within the given project it will be necessary to develop possible variants of water management measures with their in-depth technical and economic substantiation. At the same time problems of water delivery into the delta and water distribution within the different levels of general water supply to the AmuDarya basin has to be solved in more profound and substantiated way.

5.4. Measures on maintenance of the remained part of the former sea

Under the preservation of current tendencies the Aral Sea will shrink intensively and hereinafter it will transform into several separated, shallow and biologically dead reservoirs with high mineralization (80 g/l and more).

As an alternative to disappearing of the Aral Sea as a geographical and biological natural object the idea to restore its part is proposed by an Academy of Sciences of Uzbekistan (Decree of Presidium AC RUz № 8/2 as of 18.06.1996).

This idea is based on the fact that shrinking sea is divided by Vosrozhdenie island into two parts (western deep with v=85 km^3, F= 6 th.km^2 and big shallow part with V=35$км^3$, F=10 th.km^2), united each other by deep creek.

It is suggested to gather all flow (river and collectors) after its utilization in AmuDarya delta (near 10$км^3$ /year) and forward it to southern part of the Western sea in Adzhibai bay.

It is supposed, that inflow of relatively fresh water will allow first of all to reduce mineralization, and then desalinate this reservoir up to 15-18 g/l which will make possible to restore effective fishery.

Consequently salt from the Western Sea will be superseded through a canal into the East Sea, which mineralization will increase (80-100 g/l).

As a visual analogue of the proposed project can be the Balhash lake in Kazakhstan, which naturally has been divided into freshwater and salty parts.

Together with restoring the Western Sea hydrological mode it is necessary to reconstruct its initial ecosystem, which includes re-introduction of whole disappeared aquatic life (first of all ichthyo-fauna of fishery), unique components of half-freshwater marches, estuaries and open areas of the sea.

The high content of mineral fertilizers in the AmuDarya flow is a factor, favorable for forcing photosynthetic activity of the sea, which will increase a biomass of primary and intermediate food links necessary for final ichthyo-fauna.

Demineralisation of the Western Sea and consequently appearance of abundant water vegetation (reed, reed mace etc.) along the seacoast can promote increase of waterfowl and land fauna. The revived Western Sea coast can be a nesting place for migrant birds, in spite of lost nesting areas in the delta. Moreover highly mineralised East Sea can be used for cultivation of valuable forage as sandhopper «Artemiya».

Water transmission to a southern part of Western Sea requires construction of the joining channel for transportation of the AmuDarya and collector flow along the delta from the former archipelago Akpetki on the east up to the former Adjibay bay on the west with partial use of already available here river beds and collectors (Figure 33).

After finding an engineering solution for diversion of runoff for wide-ranging rehabilitation of the Western sea ichthyo-fauna the following activities are necessary:

- Development of biotechnological modes for artificial cultivation of specific fish species;
- Creation of fish-farming complexes and schemes of their allocation;
- Industrial cultivation of fish larva, fish fry and second year fish and their settling in open reservoirs;
- Reconstruction of whole hydroflora and hydrofauna, including restoring of the fodder basis.

5.5. Modelling calculations of inflows to the AmuDarya delta under the different development scenarios

Aspirations for delta watering which were supported in wet years due to water supply to the Aral Sea in amount of 25 km^3/year failed in dry 2000 and 2001 where Karakalpakstan, Khorezm and Tashauz were provided with water only on 54-65%.

In this connection the Aral Sea basin's development and management strategy alternatives become very important.

5.5.1. Assumed development scenarios

Vision XXI is based on several options of water development in the Aral Sea basin which determine possibilities to improve situation in the basin.

1. Optimistic under the close co-operation.
2. Intermediate variant.
3. Variant of the existing tendencies preservation.

These alternatives have being developed within UNDP "ASBMM" project by team under leadership of prof.V.Dukhovny (I.Avakyan, M.Ruziev, V.Prihodko, A.Sorokin, D.Sorokin. Their description is presented below.

Optimistic under the close co-operation

The region will develop on the basis of improving those integral processes, which nowdays are developed and scheduled by governments of all countries, including:

- mutually beneficial joint use of all transboundary water resources by means of water saving and unified environmental approaches;
- mutually beneficial development of agrarian sector with maximum accent on regional economic specialization taking into account production of the most profitable cultures;

The rates of the local population growth will decrease and will be by 2025 about 0,99 % per year and population will come up to 60 mln. people; average annual growth of gross national product(GNP) within period 2000-2010 years will be - 4-6 % per year, within 2010 - 2015 about 6 % per year, within 2015- 2025 no less than 5 % per year. At the same time total GNP in region is expected about $US 140.0 mlrd., that will make $US 2425.0 per capita per year. Thus, according to this scenario the given parameter will be enlarged almost three times on a comparison with a year 2000. It is supposed, that realized by regional governments water saving policy, will provide the following parameters of water use efficiency: specific water consumption for irrigation will come to 10,1 thousand m^3/ha; specific water consumption by the population will come to 0,08 m^3/person/year; the efficiency of water use will be about 1,51$US / per m^3.

Assumed, that the difference between available water resources for utilization and water demand in the region will be about 30 km^3 by year 2025. This water can be accessible for Aral sea and Priaralje.

Intermediate variant

The integral processes in the field of transboundary water resources management will develop by slower rates, than in the optimistic scenario. The growth rates of the population will decrease unsignificantly, reaching up to year 2010 - 1,7 % per year and by 2025- 1,55 % per year. The population accordingly will make 62,01 mln. people in year 2025. The growth rate of GNP will make 2-4 %. GNP in region is expected in about $US 76.0 mlrd. by the year 2025 or $US 1222,6 per capita per year.

Development of the new lands is limited not only by availability of water resources and their quality, but also by absence of the necessary investments. Taking into account, that in the given scenario the minor development of economy and limited financial resources for introduction of water saving policy in all branches of economy is supposed, the parameters of water use efficiency will be the following: the specific water consumption for irrigation will make 12 thousand m^3/ha; the specific water consumption by the population will make 0,079 m^3/person/year; the efficiency of water use will be about
0,76 $US/$m^3$.

The water resources accessible for Aral Sea under the given scenario are evaluated within 22.1 km^3 by the year 2025.

Variant of the existing tendencies preservation

The region will develop under the retention of the existing tendencies in joint utilization of trans-boundary water resources and also in the field of development of regional agrarian sector integration, both on agricultural production and on its processing. The main efforts of the states will be directed to water saving of local water sources. Growth rates of the population will remind constant at a level 1,7% per year, accordingly population will be about 62,7 mln. people; the rate of average annual growth of GNP will not exceed 4 % per year. At the same time regional GNP is expected up to $US 92,56 mlrd., that will make $US 1476 per capita per year.

Parameters of water use efficiency in the correspondence with the existing tendencies are expected by the following: for irrigation - 15,7 thousand m^3/ha; for the population - 0,078 m^3/person/year; and in general for economy 0,73 $US / m^3.

Results of calculations

In table 23 the results of the hydrological model calculations of the described above three development variants to evaluate a total river surface runoff to the Aral Sea (the SyrDarya river and AmuDarya).

Hydrographs of consumers demand to a transboundary flow (offtakes to the region states) as well as hydrographs of the returnable flow to the transboundary rivers from water consuming regions for 20 years have been given as an input data for the hydrological model. This information was obtained as an outcome of socio-economic model calculations within the same three development variants. Demanded offtake from the transboundary rivers under the development scenarios has changed from 90 km^3 (present situation) up to 45 km^3 (optimistic scenario) … 120 km^3 (preservation of the existing tendencies) by a year 2020.

Hydrological calculations are preliminary and give an idea of the quantitative estimation of inflow to the AmuDarya delta under the variation of only antropogeneous component. Hereinafter it is supposed to execute detail calculations taken as a basis predicted natural river flow hydrographs and consider under the three development scenarios possible options of flow regulation by using reservoirs and depending on different management criterions.

Table 23. Inflow to the Aral Sea from the SyrDarya and AmuDarya rivers (km^3)

Year	Variant 1	Variant 2	Variant 3
2001	9	9	9
2002	10	10	8
2003	13	11	6
2004	15	13	5
2005	18	15	2
2006	21	17	2
2007	25	20	1
2008	27	22	1
2009	29	24	1
2010	30	26	1
2011	33	28	1
2012	34	30	1
2013	36	32	0
2014	38	33	0
2015	39	34	0
2016	41	36	0
2017	44	37	0
2018	46	39	0
2019	47	40	0
2020	48	41	0

Inflow to the AmuDarya and SyrDarya river deltas

The inflow to the AmuDarya and SyrDarya deltas includes both river and collector inflow to the lakes and Aral Sea.

Total inflow to the delta forms of the following:

- AmuDarya inflow to the Aral Sea;
- Drainage inflow to the Aral Sea (collectors KC-1, KC-3, KC-4);
- Inflow to the Aral Sea from canals' system (Kizkent, Suenli);
- Drainage inflow to the system of lakes (Kattashor, Sudochie) through collectors (KKC);
- Inflow to the Sarakamish depression (collector Daryalik).

Annual inflow to the Aral Sea through collectors at the present time is about 1.0 … 1.5 km^3; inflow from the system of canals is estimated as 0.5 … 1.0 km^3. Drainage inflow into lakes through collectors comes to 1.5 … 2.0 km^3, inflow into Sarakamish depression is estimated as 4 … 4.5 km^3. The ecological releases into irrigation systems of the downstream part of AmuDarya make 1 … 0,75 km^3. Inflow to the Aral Sea from AmuDarya makes 6 km^3 (modern level), to a perspective (2020) 30 km^3 (optimistic variant) … 25 km^3 (intermediate variant). Thus, total inflow (river and collector) to the AmuDarya delta (without discharges into Sarakamish) is now estimated approximately to 12 km^3/year.

Annual distribution of inflow to the Aral Sea through the AmuDarya river (% from total per year) for average year will make:

October – 7 %	February – 4 %	June – 13 %
November – 5 %	March – 5 %	July – 20 %
December – 5 %	April – 4 %	August – 14 %
January – 6 %	May - 7%	September – 10 %

The inflow to the SyrDarya delta is now estimated (for average year) as 5 km^3, from which SyrDarya discharges to the Aral Sea is about 3 km^3, ecological releases into channels are 2 km^3. In 20 years inflow to the Aral Sea from SyrDarya will make for optimistic variant 18 $км^3$, for intermediate variant 16 $км^3$.

SFP НАТО № 974357 Project has accepted following ideological evaluations of the South Priaralie development:

- for each development alternative hydrograph of water supply to Priaralie and the Aral Sea based on which water bodies water-salt regime sustainability will be evaluated for each of project decisions.
  Water bodies will be divided in two types: permanent and intermitted flooding depending on hydrograph sustainability. Acceptable economic option will be assessed based on "cost-benefit" analysis with regard for data presented in first four chapters of the report.
- final decision will be made depending on the region development alternative accepted by the states of the region while considering strategy of water resources perspective development in the Aral Sea basin.

CONCLUSION

Due to INTAS и RFBR joint project № 1733 participants have fulfilled big job and approach to socio-economic damage from the Aral Sea desiccation assessment.

Accuracy of data and methodological approach can be argued but what is true: annual losses account for 100mln. USD.

Report was translated into English and sent for comments and proposals to more than 40 organizations. Comments have come from tenths of them, but nobody express comments on principle approach. That is why we decide to send this report to all concerned organizations and put it on SIC ICWC web site.

The factors that caused degradation of the Aral Sea natural complex were identified and analyzed, namely:

- Reduced inflow to the delta and seaside and related reduction of flooded areas;
- Ground water lowering;
- Formation of the autonomous regimen of groundwater;
- Increased salt content in ground water;
- Desertification - aeolian processes, salt and dust transport;

Ongoing transformations were analyzed in:

- Soil and natural cover complex (soil maps of the Aral Sea region);
- Vegetation cover in the Aral Sea region (tugai vegetation);
- Lower productivity of artificial and natural landscapes;
- Bird populations;
- Fish productivity.

The authors have identified the categories of social, economic and environmental losses as well as direct and indirect losses. The losses were preliminary estimated and calculated.

The following conclusions are based on the results of the first year studies:

The sea level and size were subject to several variations in the historic perspective. The evidence are terraces at points 56.5, 54.5, 43.5, 40.5 and 35.0 m of absolute height and analysis of silt and salt accumulation.

Before the 1960-ties the inflow of river water to the sea and its regimen remained relatively stable. The period from 1991 when regular instrumental observations over the sea level and other sea characteristics started to the 1960-ties can be considered hypothetically normal. The present period in the sea life starting from 1961 can be characterized as the period of active anthropogenic impacts on the sea regimen. The period from 1961 to 1998 is characterized by a marked increase of evaporation exceeding total incoming components. The river inflow into the sea from 1961 to 1980 was 53% of the average long term level observed from 1991 to 1960 (53 cub. km), from 1971 to 1980 - 30%, from 1981 to 1990 - 6%, and from 1991 to 1999 - 13% of the average long term level.

In some low water years the AmuDarya and SyrDarya flow practically did not reach the sea. The river runoff quality was transformed greatly. A higher content of discharge and drainage water with high salt content resulted in high salt content and deteriorated rive quality. As a result of a marked lowering of the Aral Sea level from 1961 to 1985 its area reduced about 22.3 thousand sq. Km and volume 618 cub. km. The coastline was seriously transformed, particularly in shallow eastern, south-eastern and southern parts of the sea.

Over 70% of the present sea level fall and growing salt content is due to anthropogenic factor, the remaining part is induced by climatic factors, e.g. natural low water period. Main impacts of the Aral Sea drying apart from reduced volume, area, increased and modified nature of salt content were reported at the dried bottom in the form of a vast salt desert with the present area of about 3.6 million ha.

Subsequently the unique fresh water body has been replaced by a vast bitter-salt lake combined with an enormous salt desert at the juncture of three sand deserts. The Small sea was completely separated from the Large sea in 1985-1986 at the point 41 m of absolute height. It resulted in formation of a new desert area of 6000 sq. Km with salt depot in the top layer up to 1 billion tons. Thus the Aral sea, a previously uniform water body will in the near future be transformed to a series of isolated water bodies with individual water and salt budgets, and their fate will depend on the strategy selected by the five littoral states.

The core zone of the adverse impacts of the Aral Sea drying comprises four regions of Karakalpakstan, namely: Muinak, Bozatauz, Kungrad and Tahtakupyr.

The Aral Sea drying has resulted in the following consequences:

- Intense development of desertification processes in the territories adjacent to the Aral Sea.
- Lower inflow to the delta and seaside and related reduction of the flooded area.
- Acute decrease of the AmuDarya runoff, termination of spring floods and floodplain inundation, the number of lakes and their are has sharply reduced. About ten lakes are reported here today. Their total water area varied significantly in years and seasons not exceeding 75 thousand ha. Natural lakes account for only 5 thousand ha, yet they are fed by extra water.
- Lower level of ground water.
- Progressing process of soil salinization. About 43% of irrigated land in Karakalpakstan were salinated, in 1985 - about 80%, and in 1997 - about 94%.
- The most serious factors of desertification are aeolian processes, salt and dust transport from the dried sea bottom and other parts of surrounding deserts.
- A typical feature of salt and dust transport is its growing activity at the initial stage that reached its peak in 1986 to 1988, followed by gradual reduction and stabilization.
- Intense degradation of the soil and natural complex. Takyr and solonchak soils in the Aral Sea region have generally expanded by 91 thousand ha, solonchak and sand - by 43 thousand ha, fixed and lose sands with spots of desert and sand soils - by 130 thousand ha. Variations in takyr solonchak soils with spots of gray-brown solonchak soils are negligible. Meadow-swamp solonchak and non-saline soils have reduced 266.6 thousand ha.
- Variations in vegetation cover correlate with landscape transformations.
- The area of tugai vegetation and cane has reduced by over one order. Typical of the AmuDarya delta is decreased area of meadow and tugai landscapes with gradual increase of landscapes with solonchak, takyr and sand plains.
- Local climate has modified considerably. Microclimate varies within several dozen kilometers from the former waterfront of the 1960 sea level. On the average summer air temperature increased 0.1^o to 0.4^{o}C, spring 0.5^o to 0.7^o C. Winter and autumn temperature lowered 0.2^o to 0.6^{o}C and 0.5^o to 1.3^{o}C respectively. Dijurnal amplitude of temperature increased, while relative air humidity decreased, particularly in the warm season.
- Rice growing near the Aral Sea zone and a network of artificial lakes facilitated protecting the number of migratory bird species in general, particularly in the Karajar, Sudochyie and Mezhdurechyie systems. The currently planned system for regulating delta lakes will help preserve favorable productivity of bird populations. The most prospective areas are Sudochyie, Mezhdurechyie and Karajar Lakes.
- The number of fish in the Sea and adjacent lake systems has reduced tenfold.
- Starting from 1994-95 the area of used irrigated lands reduced both in Karakalpakstan in general and in the studied regions in particular. Irrigated lands use throughout the Aral Sea zone has reduced 25%. Withdrawal of irrigated lands from production is accompanied by loss of plant growing production.
- The most vulnerable crops (in terms of lower crop yield) are grain crops, rice, forage maizecotton, vegetables and cucurbits. The data on these crop yields were compared.

- Analysis of crop yields since 1960 showed that a downward trend was reported since 1980 throughout the Aral Sea zone excluding Tahtakupyr region. High yields of basic crops here corresponded to the earlier period - 1975 that subsequently reduced in the years to follow.
- Comparison of crop yield decline in the Aral Sea regions shows that the most drastic reduction took place in Muinak region with yields of all analyzed crops decreased below one and more times the Karakalpakstan average, and forage maize crop yields reduced practically twofold compared to the average Karakalpakstan level.
- Muskrat habitats sharply diminished resulting in lower number of muskrat and lower productivity of muskrat hunting.
- Decreased river runoff into the AmuDarya delta and drying of vast areas of former sea bottom resulted in acute reduction of natural highly productive rangelands and hay mowing areas that negatively affected cattle breeding, the number of sheep and goats, particularly in Tahtakupyr region.
- Such indicators of cattle breeding effectiveness as production of wool and Astrakhan pelts dropped significantly - practically twofold. It is explained, on the one hand, by a significant fall of sheep and goats number in the Aral Sea region, and on the other hand, results from deteriorated conditions of pasture cattle breeding and lower production of rangelands.
- Rapid withdrawal of coastline hampered rehabilitation activities in the coastal zone; the number of tourists attracted by hunting and fishing sharply decreased.

According to rough estimates, direct losses in the Aral Sea area amount to (USD million per year):

- Irrigation farming - 6,55
- Fisheries and fish breeding - 28.57
- Muskrat hunting - 4.0
- Cattle breeding - 8.4
- Recreation and tourism - 11.16

Agriculture, total – 58,68

- Fish industry – 9.0
- Muskrat pelt processing – 18.0
- Cane processing – 12.6
- Transportation losses – 1.0

Industry, total - 40.6

Production, total – 99,28

- Indirect losses - USD 16.74 million
- Social losses - USD 28.81 million

Thus total direct and indirect socio-economic losses as a result of environmental disaster in the Aral Sea region are estimated at USD 144,83 million.

Some completed and ongoing projects allow to estimate preliminary total cost of hydrostructures necessary to create sustainable water supply to Priaralie. This hydrostructure complex needs about 880mln.USD plus 140-160mln.USD to support Western sea. To determine what part of this complex can be restored and how damage can be reduced more detail calculations are needed. But it is evident that annual damage is comparable with proposed investments.

How realistic it is will depend on water resources management practice: regional collaboration or own interests of each state. We hope that wisdom and care about future generations will forward general trends to water saving and optimistic development alternative when Priaralie will receive new impulse to intensive development.

LIST OF LITERATURE

1. Molchanov A.A., “Ozyera Sredney Asee”, 1982, ”Gidrometeoizdat”, M., p.p. 7…9.
2. Konshin A.M., “Razyasnenie voprosa o drevnem techenee Amudaryi”, Zapiski Rossiyskogo Geographicheskogo Imperatorskogo obshchestva XXXIII, № 1, 1897, Sanct-Peterburg.
3. Aladin N.V., “Some paleontological reconstruction and history of the Aral Sea basin and its catchment area”, in the collection “Ecological research and monitoring of the Aral Sea deltas”, UNESCO, 1998, p.p. 3…12.
4. Lester Brown, “The Aral Sea going, going…”, World Watching Institute, 1991, p.p. 20…27.
5. Chernenko I.M., “Perspectivnye zadachi po spaseniyu Arala”, “Problemy osvoyeniya pustyn”, № 1, 1989, p.p. 3…10.
6. Bortnik V.N., “Sovremennoye i prognoziruyemoye izmeneniye gidrologicheskih, gidrochemicheskih i gidrobiologicheskih usloviy Aralskogo morya”, Vodnye resursy, № 5, 1983, p.p. 3…16.
7. Rodionov A.A. in the collection “Ecological research and monitoring of the Aral Sea deltas”, UNESCO, 1998, p.p. 66…85.
8. Raphikov A.A., “Prirodnye usloviya osushayushchegosya Yuzhnogo poberezhya Aralskogo morya”, T., izd. FAN, 1982, 146 p.
9. Novikova N.M. and other, “Contemporary plant and soil cover changes in the AmuDarya and SyrDarya river deltas" in the collection “Ecological research and monitoring of the Aral Sea deltas”, UNESCO, 1998, p.p. 100…128.
10. Kurochkina L.I. , Makulbekova G.B. “Fitomelioration in shrinking zone of Aral Sea”, “Problemy osvoyeniya pustyn”, № 4, 1984, p.p. 27…30
11. Rasakov R.M., Kosnasarov K.A., “Dust and salt transfer from exposed bed of the Aral Sea and measures to decrease its environment impact”, NATO ASI Series, № 112, 1996, p.p. 95…102.
12. Dukhovnyi V.A., Rasakov R.M., Kosnasarov K.A., “Izucheniye eolovogo vynosa pyli i soli s obsykhayushchego dna Aralskogo morya, putyem perenosa i accumulyacee”, zaklyuchitelny otchyet po zadaniyu 085.01., zadaniyu 07.01. p. 4, SANIIRI, № 2R01840073129, 1985.
13. Gerasimov I.P., Kuznetsov N.T., Kes A.S., Gorodetskaya M.E., “Problema Aralskogo morya i antropogennogo opustynivaniya Priaralya”, “Problema osvoyeniya pustyn”, № 6, 1983, p.p. 22…33.
14. S.Y. Treshkin, S.K. Kamalov, A. Bahiev and other, “Present status of the tugay forests in the lower AmuDarya basin and problems of their protections and restoration”, in the “Ecological research and monitoring of the Aral Sea deltas”, UNESCO, 1998, p.p. 43…53.
15. Z.S. Sydykov, V.I. Poryadin and other, “Estimation and forecast of the state of ecological – hydrogeological process and systems” in the “Ecological research and monitoring of the Aral Sea deltas”, UNESCO, 1998, p.p. 159…178.
16. E.A. Rustamov, A.N. Poslavsky and other, “Water and Swamp bird population as a component of the ecosystem of AmuDarya delta”, in the “Ecological research and monitoring of the Aral Sea deltas”, UNESCO, 1998, p.p. 235…248.
17. Kuvshinova K.V., “Climat Aralskogo regiona i yego vozmozhnoye izmeneniye v svyazi s osusheniyem morya”, Moskva, trudy GO, 1980, p. 17.
18. Moloskova T.I., Ilnyek E.P., “Climaticheskiye kolebaniya v generalnoy circulyatsee atmosphery i tipy sinopticheskih processov v Centralnoy Asee”, trudy SARNIIGMI, Gidrometizdat, 1991, № 141, p.p. 3…102.
19. Zolotokrylin A., “Climate fluctuations and change in the Aral Sea basin within the last 50 years”, in the “Creeping environmental problems and Sustainable development in the Aral Sea basin”, by M. Glantz, Cambridge University press, 1999, p.p. 86…99.

20. V. Ivanov, V. Chub and other, “Review of the scientific and environmental issues of the Aral Sea basin”, in the “The Aral Sea basin”, NATO ASI Series, 2 env vol. 2, 1996, p.p. 9…21.
21. I.M. Joldasova and other, “Biological bases of fishery development in the water bodies of the southern Aral Sea region”, in the “Ecological research and monitoring of the Aral Sea deltas”, UNESCO, 1996, p.p. 213…233.
22. Ziyadullayev S.K., Rakhimov E.D. and other, “Socialno-economicheskie problemy Arala i Priaralya”, FAN, 1990, p. 144.
23. Anderson B., “Opredeleniye vreda, nanosimogo Aralskomu moryu”, otchyet USAID, 1996, rukopis 26 p.
24. Ogay O, Izimbetov E., “Rezultaty socialnogo obsledovaniya na severe Karakalpakstana po proyectu WSS”, 1996, blue print.
25. Joldasov, “Socialnaya otsenka proyecta ozera Sudochie”, blue print, 1998, otchyet Vsemirnomu Banku, 29 p. s prilozeniyem.
26. L. Elpiner, “Public health in the Aral Sea coastal region and the dynamic of changes in the ecological situation”, in Proceeding of M. Glantz, 1999, p.p. 128…156.
27. “Central Asia 2010 – prospect for Human development”, UNDP, 1999, 226 pages.
28. E. Krivton, Yost van der Meer and other, “Vliyaniye ecologicheskogo bedstviya na psikhicheskoye zdorovye i blagopoluchiye naseleniya”, “Vrachi bez granits”, September 1999, p. 33.
29. Gloria la Gava and other, “Social and economic feasibility of Rural credit Pilot component Uzbekistan Water Supply, Sanitation and Health project, 1996, 52 pages.
30. Doklad o chelovecheskom razvitee, Uzbekistan, Tashkent, 1998, UNDP, Center economicheskih issledovaniy, 113 p.
31. Osnovnye polozheniya vodnoy strategee basseina Aralskogo morya, Almaty-Bishkek-Dushanbe-Ashgabad-Tashkent, 1997, 274 p.
32. Finalny otchyet po proyectu “Water Resources and Environmental Management in the Aral Sea Basin”. Component E. “Sudochie Lake”, Resource Analysis, NIC MKVK, Tashkent, 2000.