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The monograph has been written based on results of the research study conducted from 2004 to 2008 in the lower of the Syrdarya river and Northern part of the Aral Sea with financial support from the NATO, Science for Piece.

Drying process of the Aral Sea has caused ecology issues in the delta of the Syrdarya river, and which expressed as exposed sea-bed, biodiversity depletion, uncontrolled of water resources and regime of the lakes systems, and brought about ecology catastrophe in the region. Range and consequences of the ecology catastrophe of the Aral Sea are huge. Authors of the research detected causes after investigation and proposed particular measures for restoration of the ecosystems in the delta of the Syrdarya river and northern part of the Aral Sea.

This monograph on solving of this issue has been carried out for the first time and meant for scientists, production workers, designers, undergraduates, students and all who concern oneself with ecology issues of the Central Asia.

CONTENT

INTRODUCTION

The problems of the Aral region are well known all over the world. They are the consequences of the irrational employment of water resources that was aggravated by the fact that the Aral Sea is a drainless water body, cut off from the world system of oceans and seas. The Aral Sea, being recently the forth landlocked sea to the size, currently appeared to be the basin with the water mineralization more than 60g/l. The lands around the sea experience desertification and became the sources of dust storms for the region where 3 mln people reside. Until the middle of 1960 the Aral Sea and the Aral coastal area of the Syrdarya River were economically rich and ecologically clear regions. The sea and the delta of the Syrdarya River represented the united compensated ecosystem.

The hydrological and hydrochemical modes of the sea experienced a complete dependence of the water flow of two Central Asian rivers – the Amudarya and the Syrdarya. Within this period the above mentioned rivers carried to and supplied the Aral Sea with up to 56 km3 water per year in average.

The Syrdarya River lower the Kazaly hydro-station was full-flowing. The average annual flow in the location of the hydro-station made in average 13 km3 per year that took place mainly within the spring and summer periods. Such mode of the river contributed to flooding of the fishy lakes and the natural complex of the Delta.

However, starting from the middle of 1960^{th} there took place the permanent withdrawal of water resources of the above rivers for the economic and land-reclamation needs, the volume of which reached by 1980 70-75 km3 per year and in the 1990s it reached 100 km^3. The above actions resulted in gradual decrease of the rivers flow to the Aral Sea and therefore the lowering of its level from 53.0 m down to 38.0 m. In 1988 the seal level dropped down to the critical one- to 38.0 m resulting in sea division into two independent basins – the Big (Bolakes systemhoi) Aral and the Small (Malyi) North Aral. The dynamics of lowering of the sea level for the period from 1942 up to 1990 is shown on Figure 1.

The reduce of arrival of the river flow to the Aral Sea Basin and lowering of the level of the Aral Sea resulted in the processes of desertification of the territory and degradation of the delta ecosystems that caused changes in the ecological and social and economic conditions of the Lower River and the Aral Sea.

The Governments of the CIS countries supported by the world community (UNEP, UNDP, and WB) had developed the program of the Aral Sea basin. The program provided for researches and assessment of existing technological solutions, the preparation of the projects and creation of artificially irrigated landscapes in the delta of the Amudarya and the Syrdarya as well as on the drained bottom of the Aral Sea.

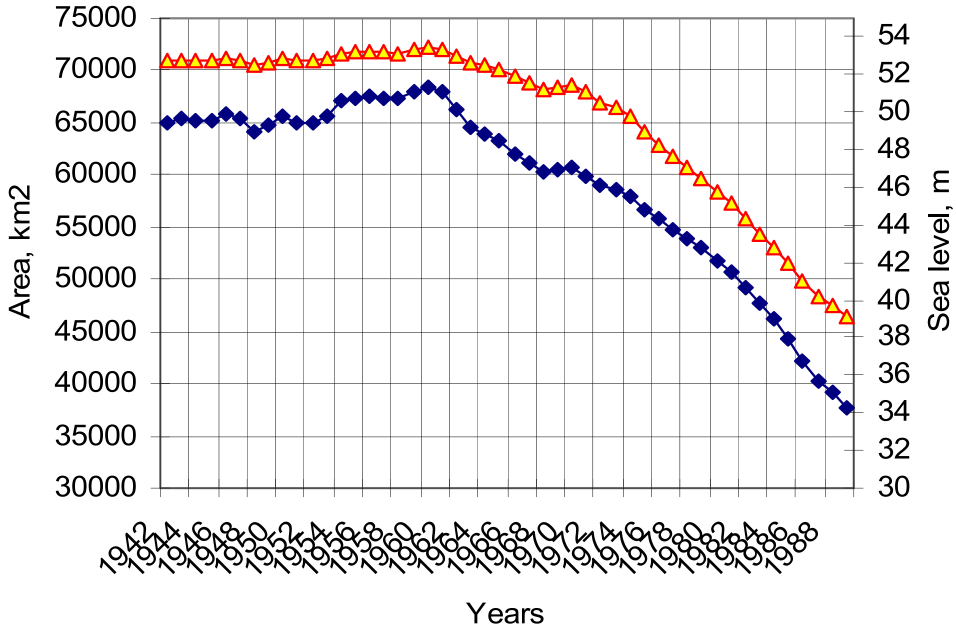


Figure 1 - The dynamics of the Aral Sea level and area lowering for the period from 1942 up to 1990

The agreement for joint operations concerning the settlement of the problem of the Aral Sea and the Aral Sea Basin, ecological improvement and ensuring the social and economic development of the Aral region, signed by the Heads of the States of the Central Asia on 26 March 1993, emphasized the guaranteed supply of water to the Aral Sea in volumes allowing to maintain its lessened as to the steadiness area of water at the ecologically accepted level which allows to maintain the sea as the natural object.

The following measures should be implemented for restoration of the natural complex in the delta of the Syrdarya river:

- averting the continuing degradation of land resources;
- elimination of instability of distribution of water between the delta, the Aral Sea Basin and the sea;
- maintenance of the biological variety and productivity of the biological resources.

The following specialists had taken participation in the research activities: hydrology and water infrastrucuture – Ms. L. Toleubaeva, Ms. T. Sorokina, Mr. A. Tairov, Mr. A. Askarov, Mr. S. Koptleuov, Ms. T. Krikova, Mr. K. Kartanov; biodiversity – Mr. B. Sultanova, Mr. A. Baibulov, Mr. A. Ermahanov, Mr. A. Isaev, Mr. Z. Alimbetova; soil –Mr. E. Karazhanov, Mr. E. Kartanov; social and economic conditions – Mr. A. Kulikov, Ms. B. Ashirbekova, Ms. M. Mahambetova, Ms. A. Mustafaeva, Ms. N. Kulbatyrov, Ms. K. Mahanova; mathematical modeling – Ms. E. Roschenko, Ms. E. Temlyantseva; designing – Ms. G. Kipshakbai, Ms. M. Elubaeva.

1. CURRENT STATUS OF WATER RESOURCES IN THE DELTA OF THE SYRDARYA RIVER

1.1 Features of the existing water infrastructure

The project object occupies the northern part of the Aral Sea and present delta of the Syrdarya river staring from the Kazaly hydro-station to north-eastern coastal of the sea. The length of the delta is about 200 km. By administrative division the project object is located within Kazaly and Aralsk rayons of the Kyzylorda oblast.

Flow of the Syrdarya river is controlled by five large reservoirs (Toktogul, Andizhan, Kairakkum, Charvak and Shardara) and by large quantity of small reservoirs located in tributaries of the Syrdarya river.

The most important Toktogul reservoir for many years river flow control with capacity 19.5 km3 is located in the Naryn river in the Republic of Kyrgyzstan. Shardara reservoir was constructed at the point of entry of the Syrdarya river to Kazakhstan in 1965 with useful capacity 4,2 km^3. The reservoir implements seasonal regulation of the river flow and it is intended for power and irrigation purposes. During the high-water years, as emergency protection measure against flooding and break-up of waterside structures along Syrdarya river bed, the overflow water had been discharged from Shardara reservoir to Arnasai cavity which is located in the area of the neighboring Republic of Uzbekistan.

Since 60-s considerable changes have happened in the condition of Syrdarya river flow's form and regime that were ridden by construction of large-scale irrigation systems and reservoirs. If volume of water resources of the Syrdarya river in the Kazaly cross-section during natural conditions was 15 km3/year, during last 35 years the average volume of water resources sharply reduced up to 5.4 km3. Especially low water period was from 1974 to 1987 when construction of the Toktogul reservoir was concurred with natural low-water period; at this time the flow in the Kazaly cross-section was 0.5-0.8 km^3.

Last years water inflow to the delta is characterized by higher water, which is caused by natural water content, reduction of water intake and discharge increasing from Toktogul reservoir for power generation.

As a result of regime change and reduction of river water flow, flooding of the lakes systems in the lower and middle streams of the Syrdarya river is very problematical. Unsatisfactory condition of existing water infrastructure which supports water-salt and level regimes of the lakes systems, served its negative purpose.

Starting from 1988 and up to 1997 a lot of water distribution facilities and channels were broken by spring ice drifts and backwater from the lakes systems. A major overhaul and regular preventive measures weren't done. Channels capacity was reduced because of overgrow, sedimentation and collapse of beach berm. Often, temporary dams on the channels are diffused, and water comes back to the

Syrdarya river, that results in trouble of water-salt regime of the lakes systems.

Transformation of natural ecosystem and its components are happened under influence of natural and anthropogenic factors.

Figure 2 – Mr. N. Nazarbaev, the President of the Republic of Kazakhstan during the visit of the lower part of the Syrdarya river (April, 2003)

Principal causes of beginnings of the ecological disaster in the delta of the Syrdarya river are:

- Drying and shallowing of the Aral Sea, abrupt reducing of inflow water to the Aral Sea, decreasing of delta flooding, drop in sea and ground water levels are accompanied by siccation of delta area;
- Reduction and change of water flow regime (volume and flood) of the Syrdarya river. Ecological destabilization of the lakes systems and landscapes are accompanied by beginnings of new and activation of existing negative desertification processes. Unstable water regime of the Syrdarya river, annual change of water availability have given rise considerable changes in the growth;
- Shallowing of the water bodies (lakes) furthers to great heating of water in summer, its “flowerage” and is accompanied by fish death. Lack of water in spring is accompanied by loss of spawning area, fattening area for young fishes, and has negative impact to food reserve for fishes;
- Irrational water and land use in the delta caused by unbalanced system of apportioning of water, water supply and water use. Major ecological consequences of impact of the irrigation systems to landscape are increasing ground water level, second salinization of soil and discharge of saline water to the river;
- Transformation of soil cover takes place as a result of changes of Syrdarya river water volume and regime and drying of the Aral Sea;

- Irrational bio-resources use – as grasping uprooting of semishrubs, shrubs and saksauls for heating, off-normal stocking, firing of old vegetation, results in simplification of vegetation composition and structure, reduction of producing capacity of lands, loss of habitats and worsening of food reserve for wildings;
- Trend of climatic parameters conduces to rapid area desertification.

The lake systems and wetlands of the Syrdarya delta is the basis of the sustainable existence of aquatic and semi-aquatic ecosystems of the Aral region of Kazakhstan, the basis of the fisheries and fodder production, an important condition of life activity of the population of Kazaly and Aralsk rayons of Kyzylorda oblast.

The water infrastructure in the delta of the Syrdarya river has been divided into six lakes systems: Aksai, Kuandarya, Kamystybas, Akshatau, Seaside right-bank and left-bank. Each of the lake systems is a combination of lakes and bogs related by a complex net of natural and artificial channelakes system. Within the area of lake systems influence there is a number of populated areas as well as the main fishery bodies, basal areas of hay lands and pastoral territories, forests and accrue growth.

Based on geographical location the following can be distinguished:

– *deltaic* lake systems, located within the delta of the Syrdarya River, below the territory of irrigated farming (Kuandarya, Aksai, Kamystybas and Akshatau lakes systems);
– *coastal* lake systems, located on the part of the dried up seafloor (Seaside right-bank and left-bank lakes systems).

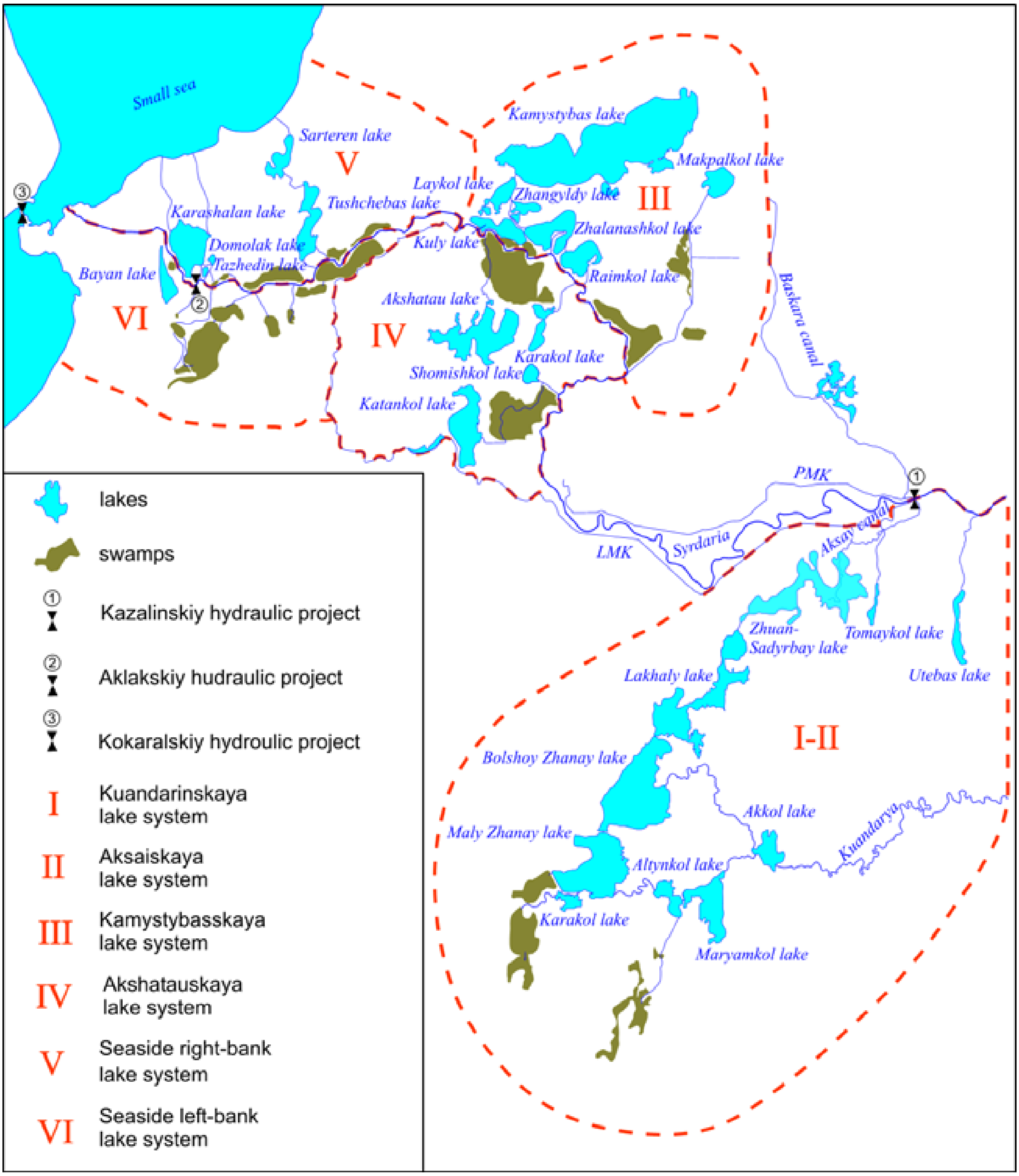


Figure 3 – Water bodies of the Aral Sea Basin

By type of feeding, lakes systems can be watered by river waters or collection-drain flow with water discharge to the streamway, as well as to the basins of the Large and Northern seas.

Within the lake systems the following can be distinguished: lakes – reservoirs of over 1,5 m depth and bogs – flood plain and riverside reservoirs of less than 1,5 m.

In general, there are 53 priority water bodies within the lake systems of the delta, including 27 lakes and 26 bogs of economic and environmental importance.

The water economy infrastructure of the delta includes 54 natural and artificial channels of different length, as well as 55 hydro-engineering water-regulating constructions.

During completed First International Symposium of Global Infrastructure Organizations in October 1991 in Atlanta city (USA) were discussed issues of withdrawal from this ecological crisis and measures for render specific assistance to population of the Aral Sea Basin.

For this period lasted from this Symposium, The Government of the Republic of Kazakhstan has taken several additional decisions directed to normalization and improvement of living conditions of the population of the Aral Sea Basin.

In spite of taking measures, social conditions of life-support and life-activity of the population in the disaster area, which included all rayons of Kyzylorda Oblast are not improved. Drying process of the sea has been continuing. Disaster area has been widening. Annually more than ten million tons of salt-dust ejections throw out from dried seabed to atmosphere, and extend for sizeable area. Climate is becoming worse, sickness rate is increasing, especially among children and women.

Decision of the Aral Sea issue undoubtedly was being burdensome to the republic that just stood on the way of independence and sovereignity. Understanding that population of the region should have enough assured arrangement of social defence, the Government was conducting development of special law on Aral Sea Basin that provide for rights and legal status of the citizenry suffered from ecological disaster.

Mentioned activities, taking into account its character, were mean for relatively time-limited period, and later on for prospects, stabilization measures was planning to implement based on developed Aral-2006 Program. As the title shows that this Program should had been completed by 2006.

State Committee for Water Resources of the Republic of Kazakhstan in 1992 created Aral Sea Issue Department, which coordinated all solving decisions related with Aral Sea catastrophe.

Social, economical and ecological consequences of Aral Sea catastrophe are huge. For identification of damage from ecological disaster in Kazakhstan part of the Aral Sea basin it has been marked out 3 zones: Right-bank and Left-bank Seaside Lakes systems are belonged to lower zone, Kamystybas and Akshatau Lakes systems – middle zone, and Aksai-Kuandarya lakes system – to upper zone. Area of these three zones administratively are belonged to Aralsk and Kazaly Rayons of Kyzylorda Oblast. On the whole, the damage from ecological disaster could be separated to economical and social losses. Diagrams of these losses in money terms are shown in Figures 4 and 5. Summary average annual damage on the 1st January 2000 was 52.350 mln USD.

Issues solving requires to taking united efforts as on national, and international levels, because ecosystem violation has global character. In this regard at the initial stage (1992-1994) the Global Infrastructure Fund (GIF) took pushing participation in overcoming of Aral Sea crisis's consequences. In succeeding years the World Bank, European Union, USAID, Asian Development Bank and other joined.

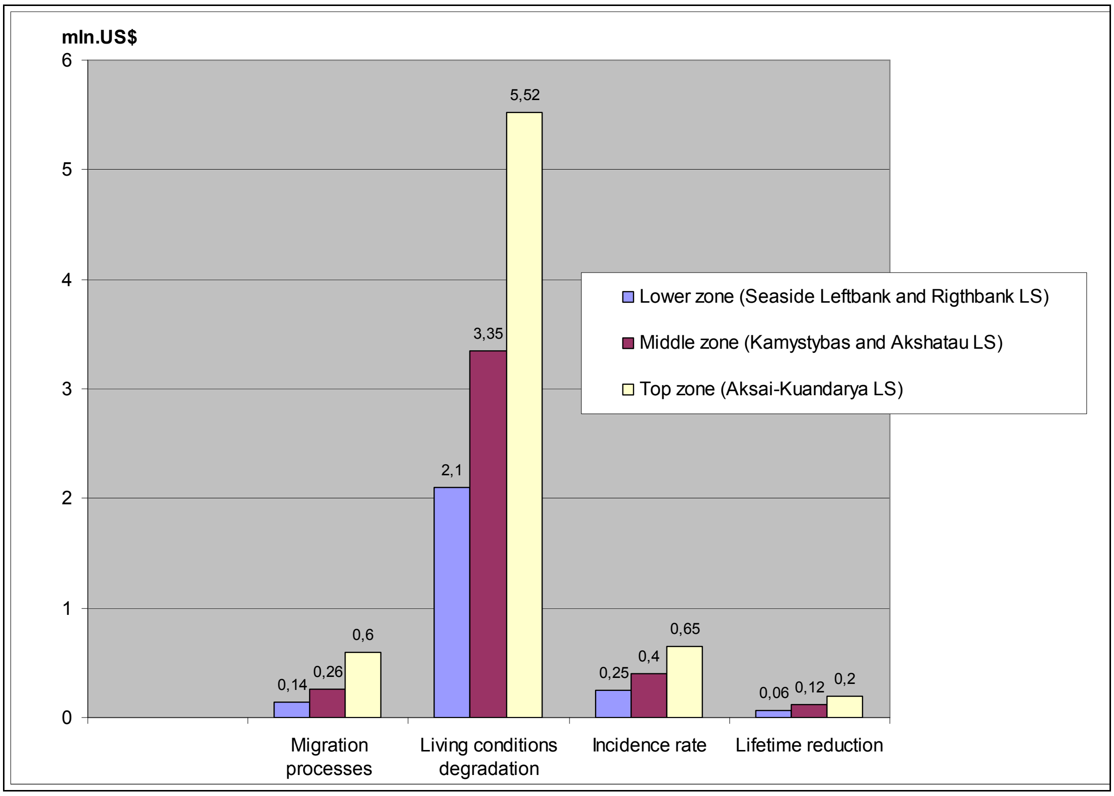


Figure 4 – Average annual social losses from ecological disaster in the Kazakhstan part of the Aral Sea Basin

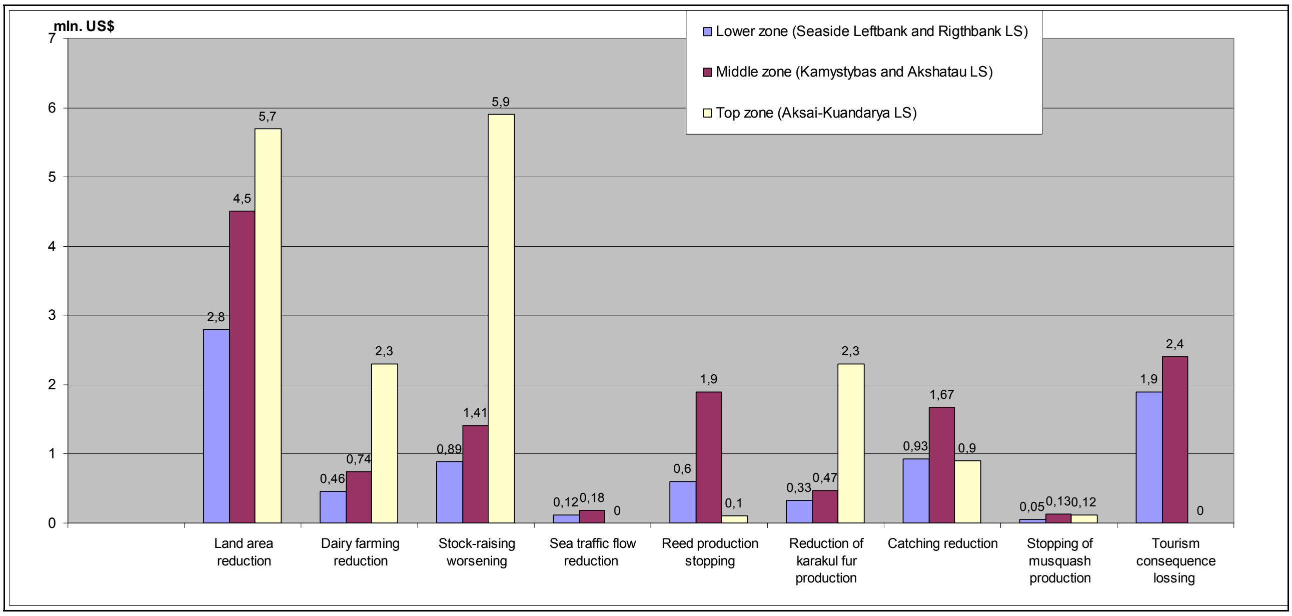


Figure 5 – Average annual economical losses from ecological disaster in the Kazakhstan part of the Aral Sea Basin

Present delta of the Syrdarya river has area about 1100 ths. ha, including about 350 ths. ha of dried bed of the Aral Sea which describes happened here changes during 30 years. In the delta there are more than 20 settlements with population about 40 ths. persons. Comparison explication of floodplain land shows the land transformation degree during the stated period (Table 1).

Table 1 - Comparison explication of floodplain land (thousand ha)

Land name	Parameters, ths. ha	
	1960	1990
Total area of the delta	750.0	1100.0
including: Dried bed of the Aral Sea	-	350.0
Fish-industry lakes	69.1	32.5
Small (non fish-industry) lakes	6.7	2.2
Wetlands	51.9	56.7
Tugai forests and bushes	21.0	16.5
Drainage network	5.6	8.0
Agriculture lands	273.0	253.0
Other lands of little use	322.7	381.1

In the natural conditions water consumption in the delta (without irrigation) was 1.5-2.0 km^3, sometimes it reached in high-water years 3-4 km^3 and more. The water came into lakes systems and flooding hayfields be natural descents or many flow paths.

Last tens years the flow downstream of Kazaly was reduced and water level in the river didn't permit to fill the lakes and flooding hayfields in the delta. Since shallowing of the Aral Sea base level had been reduced too, that resulted in embedding of the Syrdarya river bed and stipulated for considerable hardship upon fill of mentioned lands. Reducing of water income to the delta stated on the verge of destruction existence of all ecosystems, and sharpen social, economical, and ecological issues of the region exceedingly.

For supporting of a command level over lakes systems and other lands, temporary Amanotkel and Aklak diversion dams with capacities 150 and 60 m^3/sec were constructed. On passing of high water flow in the river earth dams of these facilities were disclosed and water followed a detour. Next recession of level in the river followed to hereto that the most part of accumulated water in the lakes systems came back to the Syrdarya river and went to the sea.

For improvement of situation in the delta of the river and creation here of control lake-delta ecology system it was required to execute the several complex arrangements:

- create control system for lake-delta complex;
- carry out reconstruction and replacement of existing hydrostructures on the river to new fundamental ones, which will be complied with passed flood flow and guarantee command during low-water period;
- carry out reconstruction of system for control and delivery water to the lakes systems, hayfields, wetlands, and other ecosystems of the delta by construction of new channels and reconstruction of existing ones with appropriate water-control facilities;

- rehabilitate fish capacity of the delta lakes thanks to increasing of its water availability, flowage, and special fish industry targets;

- flood in-delta part of the dried seabed on purpose reduction of salt-dust transfer by creation here of shallow firths are overgrown with reed, fish lakes, and other wetlands on the base of entry of waste water from irrigated lands;

- phyto-melioration of the dried seabed on purpose of it densification and suppression of deflation;

- construction of additional social and cultural infrastructures for improvement of social conditions for local people.

Water demand in the delta of the river after implementation of the planned arrangements is going to come to 2,0 km^3 per year with guarantee supply in independency from water content year.

Long low-water period, concerned with not only water content, but with big water intake for irrigation, has caused sizeable reduction of the Syrdarya river throughput due to silting and construction of water intake facilities at low water level.

During high-water years spring-summer water gives rise to flood area in the lower part of the river, useless water loses and the valuable detriment of the economy. Last time the situation was redoubled because of winter power discharges from Toktogul reservoir.

The issue of passing high water by the Syrdarya river was arisen from conversation of Toktogul Hydropower Station to power exploitation regime. necessarily and contrary to working regulations the winter discharge to the Syrdarya river have been increased from 450 up to 700 m^3/sec and more, that resulted in a whole series of destroying inundation and flooding of irrigation systems and settlements of South-Kazakhstan and Kyzylorda Oblasts with corresponding damages. So, only in Kyzylorda Oblast in 2004 were flooded 805 houses, evacuated 2084 persons, inundated 55733 ha of land; in 2005 - inundated 30460 ha of land, 447 houses and evacuated 1500 persons.

With a view to remove consequences of flooding and made of repair and reconstruction works, and also river-banks protection, construction of check dams, it were assignment of funds from republic and oblast budgets annually. Size of annual damage from flooding for Kyzylorda Oblast for the period 2004-2008 is shown in the Figure 6.

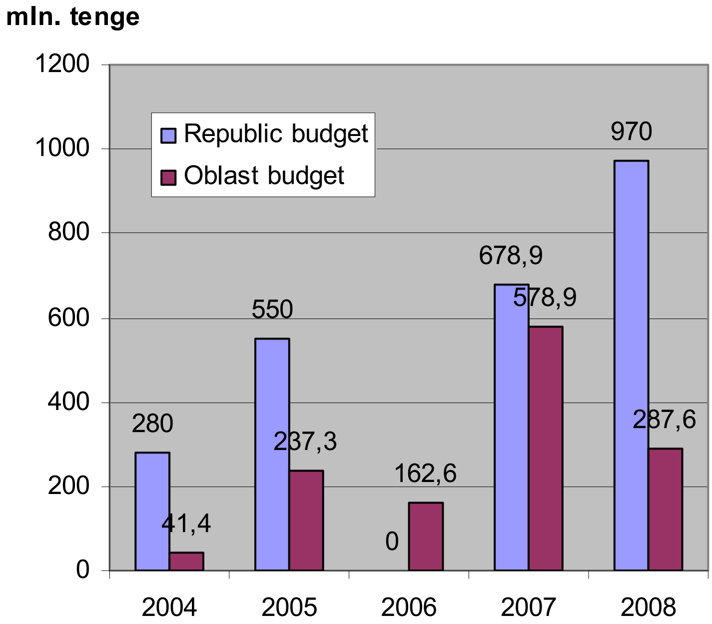


Figure 6 – Annual damage from flooding for Kyzylorda Oblast for the period 2004-2008

Ice conditions in the lower part of the river, under uneasiness of it bed, create even greater hardship on water delivery to the sea. Before flow control the protection of area and water passing were carried out by dams (about 700 km), which have became worthless to date.

For increasing of the Syrdarya river throughput and barring of wasteful losses it is necessary to implement several hydrotechnical measures which will be reviewed below.

1.2 Hydrology and water infrastructures of the delta

1.2.1 River flow regime

In its natural state, the bed of the Syrdarya River within the limits of the delta had the length of 189 km and at the bed slope of 6.35 cm/km enabled the pass to the Aral Sea of average annual water flow of 490 m^3/s. Within this period an average of 60 m^3/s was used to watering the delta. At that, delta watering reflected peculiar features of the level regime of the feeding Syrdarya River. The phase of flooding of deltaic reservoirs was observed in April-June. The dumping phase was observed in August-March.

The decrease of outflow of Syrdarya due to anthropogenic reasons in the 60s and the fall in the Aral Sea level (erosion base level) have aggravated the problem of the delta watering: in the 70s two temporary water-lifting hydroelectric stations were arranged enabling gravity water supply to deltaic lake systems.

The Amanotkel water-retaining structure (intake weir) was constructed in 1976 69 km from the mouth of the Syrdarya River. The mainstream of the river and the Malenkiy Channel were weir with earth dams (crest level 66.5 m in total).

In order to enable water pass an open spillway weir was constructed with 85m of width and threshold level at 55.0 m in total and tube spillway. Amanotkel water-lifting hydroelectric complex provided the dominance of water level in the river to enable watering of Kamystybas and Akshatau lake systems.

Aklak water-retaining structure, constructed in 1975, is the lowest hydro technical construction on the Syrdarya River located at the distance of 25 km from the coastline. Here the mainstream of the river was weir with earth dam of 350 m length and crest level of 53.0 m abs. The regulating tube outlet with threshold level at 49.0 m in total is equipped with five sliding water-gates of 2 m width and 2 m height. The maximum estimated outlet discharge is 60 m3/s.

Besides, within the complex of hydroelectric complex the riparian outlets were constructed working as water regulators. The hydroelectric station is intended for gravity water intake to supply coastal right and left lake systems.

Thus, by fixed thresholds levels at 55.0 and 49.0 m in total, the bed of the Syrdarya River below Kazaly hydroelectric station was dissected into 3 specific locations (table 2):

- Upper-deltaic with the length of 145 km and average slope of 6.9 cm/km;
- Lower-deltaic with the length of 44 km and average slope of 9,1 cm/km;
- Mouth reach with the length of 25 km and dynamic slope, determined by the level of the Aral Sea and general riverbed erosion due to the change of the erosion basis.

Table 2 – Hydraulic characteristics of the Syrdarya riverbed with water-lifting hydroelectric complexes in the delta (Amanotkel and Aklak within the period of 1975-1993 and Aklak within the period of 1993-2001)

Dam sit	Distance between dam sits, km	With Amanotkel and Aklak			With Aklak		
		Threshold level m abs.	Exceeding m	Declivity, cm/km	Threshold level m abs.	Exceeding m	Declivity, cm/km
Baskara, tail-water		65.0			65.0		
Amanotkel, head water	145.0	55.0	10.0	6.9	52.7	12.3	8.5
Amanotkel, tail-water	0.0	53.0	2.0		52.7	0.0	
Aklak, head water	44.0	49.0	4.0	9.1	49.0	3.7	8.5
Aklak, tail-water	0.0	44.0	5.0		44.0	5.0	
Small River	25.0	40.5	3.5	14.0	40.5	3.5	14.0

Figure 7 – Aklak water-retaining structure (2009)

As the result of construction of water-lifting facilities within the period of 1975 – 87, the hydro-regime in the delta has become relatively stable, under which the inflow to the head of the delta amounts in average to 2.5 km^3 annually, from which 1,0 km^3 were consumed for economic needs, 0,6 km^3 were used to supply the lake systems with water and 0.9 km^3 went to the Aral Sea (with fluctuation in some years from 0.4 up to 4.0 km^3 per year).

Since 1988, with the restored release to the Aral Sea under conditions of a limited flow capacity of the constructed hydro technical facilities, the hydro regime of the delta has become changeable. This affected the conditions of water supply to the lake systems of the delta.

During spring flood in 1993 – 94, there occurred a breach of wing dams of Amanotkel and Aklak hydroelectric complexes, as the result of which their dominance over the lake systems has been lost. From this moment the limited capacity of supplying the lake systems with water occurred only in cold period of the year when water level of the river exceeded the water levels of the lakes.

Due to the breach of the stream flow, the processes of general riverbed erosion started in the delta bypassing fixing thresholds of hydroelectric complexes.

The change in the flow of suspended loads throughout the length of the river resulting from the breach of Amanotkel and Aklak hydroelectric complexes evidenced of the activation of the general riverbed erosion processes. At fixed thresholds in the dam sit of Amanotkel and Aklak, the river bed has become the accumulator of suspended loads throughout the length of the delta. According to observational data, the accumulating capacity of riverbed preserved only in the part of the upper delta up to Kyzylzhar dam sit where the average annual suspended load decreases from 111 g/l to 54 g/l. In the rest part of the delta, a general riverbed erosion is confirmed by the decrease of suspended load in Karateren dam sit up to 88 g/l. Formation of the multi-arm micro-delta in the mouth of the Syrdarya River and mouth-bar is the result of washout by the river of suspended load formed in large part by seaside and coastal loads brought to the bar shallow waters by wind-generated and compensatory currents.

Table 3 specifies the showings of the Syrdarya runoff distribution within the 10-year period, from 1988 to 1998. Within this period the inflow to the head of the delta changed from 3.59 km3/year to 9.50 km3/year with average value of 6,00 km3/year. From the aggregate volume of inflow to the delta 22% of out-flow was used for watering of its territory below Kazaly hydroelectric complex, 46% was used for watering of the northern part of the Aral Sea including its flooding and evaporation from water surface, and 32% was used as discharge to the Large Sea.

Irretrievable water consumption of the delta, irrespective of Kuandarya and Aksai systems, amounted to 1.17 km3 in 1997, which is considered an average in terms of the dryness of the year, and 1.4 km3 in 1998, considered as a wet year, with the yield of 1.6 and 1.8 km3 and discharge of 0.42 and 0.41 km3 respectively.

Table 3 – Consolidated indices of the Syrdarya runoff distribution, (km3/year)

Years	Inflow to the head of the delta	Delta water consumption	Inflow to the Small Sea	Sea water consumption	Discharge to the Large Sea
1988	6.84	1.72	5.12	1.97	3.15
1989	4.35	1.15	3.20	1.92	1.28
1990	3.59	1.10	2.49	1.57	0.92
1991	3.69	1.05	2.64	1.50	1.14
1992	4.47	1.08	3.39	3.39	0.00
1993	9.50	1.70	7.80	5.45	2.35
1994	9.27	1.61	7.66	2.75	4.91
1995	5.87	1.25	4.62	2.75	1.87
1996	4.71	1.01	3.70	2.75	0.95
1997	5.23	1.17	4.06	2.19	1.87
1998	8.63	1.40	7.23	7.23	0.00
Average value	6.00	1.29	4.72	3.04	1.68

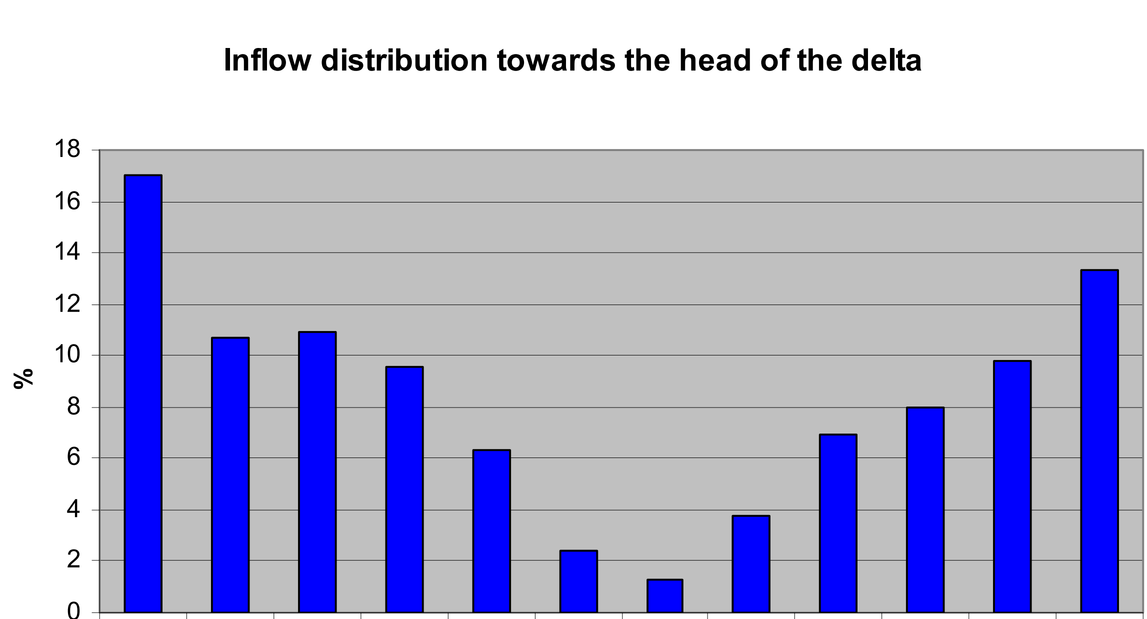
The regulating effect of the delta found its expression in the accumulation of the river runoff in the cold period of the year and water discharge to the riverbed during warm period of the year.

Average mineralization of the river water in the head of the delta was ranging between 0.75 – 0.65 g/l, with the increase in the river mouth to 0.90 and 0.80 g/l respectively.

The salt wash-off to the delta amounted to the average 3.80 and 5.80 million of tons. Within the delta limits, accumulated salt amounted to 0.25 – 0.40 million of tons respectively. With the salinity of lake waters generally tending to decrease, the salt build-up was, apparently, occurring within the soil cover of the delta.

Due to the change in the recent years in the operation conditions of Naryn-Syrdarya multi-reservoir system, the maximum river inflow to the delta is observed in winter, whereas the minimum water consumption – in summer. At that, the range of observations of water level in the riverbeds was 3 meters.

Currently, construction of the Aklak permanent run-of-river complex is being finalized in order to enable sustainable intake for delta watering and the pass of transient waters to the North Aral Sear.



month	1	2	3	4	5	6	7	8	9	10	11	12
%	17	10,7	10,9	9,6	6,3	2,4	1,3	3,8	6,9	8	9,8	13,3

Figure 8 – Inflow distribution towards the head of the delta

1.2.2 Northern Aral Sea (SAM)

As the result of the drop in water level of the Aral Sea, in 1987 its water area was divided by a natural rift (riverbed level 39,0 m abs.) into two parts – the Large and Small (Northern) Sea, fed by the residual runoff of the two seas respectively – Amudarya and Syrdarya. The Small Sea has a positive water balance, when the river runoff exceeded natural rift it was discharged to the Large Sea through a channel. In 1992 the level difference between water areas of the Sea exceeded 3 meters (the Small Sea – 40.3 m abs., the Large Sea – 37.1 m abs.). The continuing cross flow of water due to level difference resulted in erosion of the rift's bottom which divides the two seas, and in four years its level lowered to 38.0 m abs. Further development of this process might, within several years, lead to a complete degradation of the Small Sea, this being the case its water area would be divided into isolated stretches.

In 1993 the local authority and the State Committee for Water Resources, thanks to the funds collected by local people, closed out the closure channel and constructed dam on purpose of water conservation in the Northern Aral Sea.

Increased level of water in the Sea was accompanied by demineralization of mouth seaside, mineralization of sea waters from the mouth to the Kokaral dam was ranging between 1.40 – 4.42 g/l.

In 1996 the Kazgiprovodhoz Institute developed the a project of Kokaral hydroelectric complex which stipulated the construction of earth dam with the use of sand available in the locality, of 3 m height, 12.7 km length, with the upstream slope 1:45, downstream slope — 1:10. The weir width on the crest is 10 m, it is fixed with locally available gravel-rubble materials

At the same year the channel connecting Small and was closed.

At the beginning of the second quarter of 1999 the sea level reached a peak level – 42.30 m abs. However, within the period of extreme climatic conditions, on 20 April 1999, as the result of high positive surge and big wind waves in the Small Sea, the water spilt over the uncompleted Kokaral dam and, further, eroded it. As the result of more than 7 km3 discharge of sea water into the Large Sea, by mid 1999 the level of the northern part of the sea lowered to 40.0 m abs.

In October 2002, the Contractor, «Zarubezhvodstroy» company, started construction of Kokaral hydroelectric complex to restore the Northern Sea under the Project of «Kazgiprovodkhoz» Institute. In November 2005 the dam and outlet of the hydroelectric complex were put into operation, and in spring of 2006 the flooding of the Northern Aral Sea reached the projected level of 42.0 m abs (Figures 9 and 10).

The area of the sea water surface was 3550 km2, the volume – 29.3 km3 (Figures 11 and 12). Supporting sea at the specified parameters will be maintained by normative river inflow of average volume of 3.1 km3/year owing to water resources of the transboundary basin of the Syrdarya river.

Picture 9 – Hydraulic works on the Northern Aral Sea

Picture 10 - Kokaral hydro-engineering complex in the Northern Aral Sea

Picture 11 – General conditions of the Aral Sea
(Space image of the Aral Sea (June, 2006))

Picture 12 – Space image of the Aral Sea (August, 2009)

It is expected that flooding of the Small (Northern) Sea will allow preventing further development of desertification processes in the Aral region of Kazakhstan, by reducing effect of dust-and-salt leaching to the territory adjoining the sea. At that, additional effects may be observed from restored volumes of fish catch in desalted water as well as from organization of economic activity on new stable shores of the north-eastern part of the sea. All this facilitates solution of severe social problems of Aral region, which include improvement of medical and biological environment, increase of the employment rate, improvement of demographic situation.

Many specialists consider the implemented project of Kokaral hydro-engineering complex as the first phase of the program aimed at restoration of the Northern Aral Sear at the level close to its natural state (53,0 m abs.). A retrospective analysis of water balance of the Northern Aral Sea shows that with the construction of a dam of the required height in conditions of recent relatively wet 15 years , the sea level might be restored up to the level of 46,0-47,0 m abs.

Renascence of the Northern Aral Sea also will help increase stability of water-salt regime солевого of the sea and restore hydraulic relations between the sea and lake systems in the Syrdarya delta, i.e. restore integrity of the natural-and-economic complex of the Aral area of Kazakhstan.

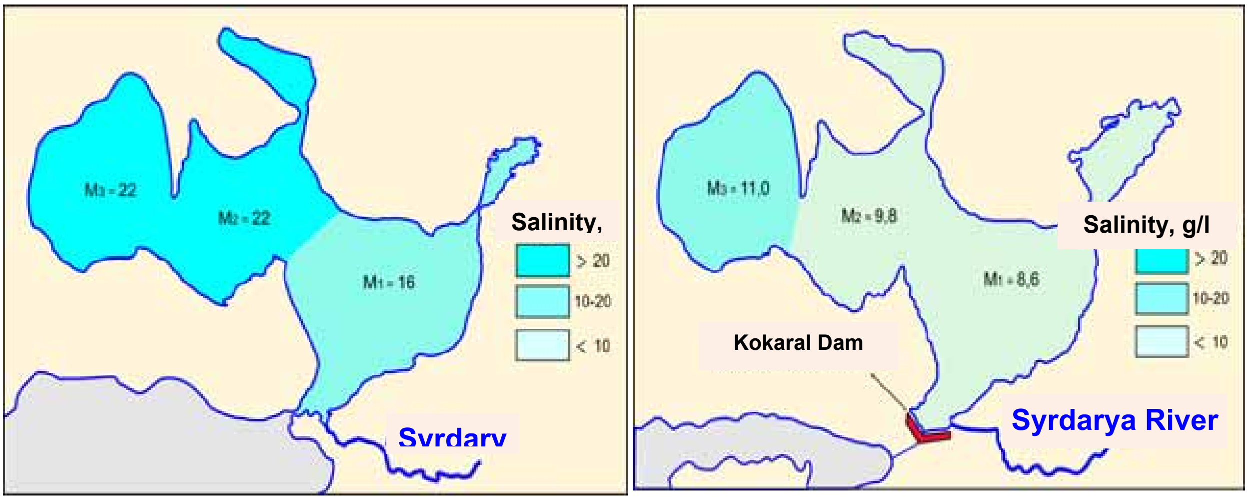
Kokaral hydro-engineering complex in the Northern Aral Sea (NAS) has, in fact, become a water reservoir – the lower stage of Naryn-Syrdarya multi-reservoir system. With the NAS level stabilized demineralization of NAS continues. Average mineralization of its waters was 9.5 g/l in 2006 (Fig. 13).

Table 4 represents data on water discharges to the Large Sea via water-regulating unit of Kokaral hydro-engineering complex.

Table 4 –Water discharges to the Large Aral Sea from the Northern Aral Sea, 2006-2010

Year	Water discharge to the Large Aral Sea, mln.m^3
2006	2,3
2007	3,2
2008	2,5
2009	0,32
2010	0,64

The level of the Large Aral Sea continues to reduce. In 2007, Tuschebas bay (29.9 m abs.) and Chernyshev bay (28.92 m abs.) separated from water area of the Large Sea (Figure 14).



1994 2006

Figure 13 – Dynamic of the water mineralization in the Northern Aral Sea, 1994 and 2006

Figure 14 – Separated bays of the Aral Sea

1.3 Hydrology regimes of lake systems

The system of deltaic lakes is one of the main hydrographic elements of the mouth of the Syrdarya River. In conditions of the natural water regime the total area of open water surface of numerous (over 500) lakes in the lower reaches of the Syrdarya River was approximately 1500 km2.

A property that defines the system is the open water surface of the lakes surrounded by emergent vegetation. At that the ratio of the plant-filled area of lakes surface to the total surface area ranges between 0.1 – 0.3. Lake percentage in the delta exceeded 7%. The number of lakes in the delta was 28 with total surface area of over 10 km^2, and the surface area of the Kamystybas Lake was 178 km^2. Within this period discharge of river runoff for watering of the lake systems was almost 12% of the discharge in the head of delta which amounted to the average of 1.87 km^3 /year.

Effect of increase of water intake from the Syrdarya River for irrigation purposes on water regime of deltaic lakes was observed in the 30s. In several decades of intensively developing irrigation in the basin of the Syrdariya River the total area of water surface reduced almost twice, reaching the level of about 830 km^2 in the 50s.

Prior to the 60s the water inflow to the head of the delta was 40–46% of the Syrdarya runoff, whereas in the second half of the 70s is did not exceed 4%. According to aerosurvey results, by 1976 the total area of deltaic lakes reduced to 400 km^2, and volume of water in the lakes amounted to approximately 1.5 km^3. At that, significant commercial fishing importance was preserved only by Kamystybas, Akshatau and Seaside lake systems due to their watering via channels, which became practicable after the construction of Amanotkel and Aklak dams in 1975–76.

The lake systems and wetlands of the Syrdarya delta is the basis of the sustainable existence of aquatic and semi-aquatic ecosystems, the basis of the fisheries and fodder production, an important condition of life activity of the population of Kazaly and Aralsk rayons.

With the natural water regime, fluctuations of water level of lake systems of the delta reflected peculiar features of water level of the feeding Syrdarya River. At that, due to significant accumulating capacity of the systems in the annual change of their level, water regime phases were less distinct. The filling phase of the system's reservoirs was observed in April-June. The dump phase was observed in August-March.

Following the construction of Amanotkel and Aklak temporary intake dams in 1974 on the Syrdarya River, the level of lake systems became regulated in accordance with the Regulations of hydro-engineering complexes operation. However, within the period of high water in 1993-94 the part of dam facilities was destroyed and newly formed water regime of the Syrdarya River could be determined only by releases from the upstream Kazaly hydro-engineering complex. Relevant principle changes occurred in the water regime of lake systems.

Currently, accumulation of water within the lake systems was observed in fall-winter period (August-February). Intensive drawdown occurs in the warm period: April-June. The maximum annual level of the lakes was observed in March and the minimum — in August-September.

The determining factors of this phenomenon are the higher evaporation from the lake surface during summer months and transformation of the runoff regime of the Syrdarya River due to withdrawals for irrigation purposes within vegetation period and performance of winter power releases from Toktagul reservoir.

Figure 15 - Map-mask of the deltaic lake systems of the Syrdarya River based on the IRS satellite data
(September 2006)

With resumed releases to the delta, there formed an active water cycle between lake systems and channel runoff, under which up to 15% of their water body was yearly replaced by fresher river water. Starting from 1993, interannual tendency towards a decrease of saltiness was observed with respect to all deltaic lakes.

Regime of filling and dumpling of the lake systems are performed according to two schemes of principle difference: «flowing» and «cycle». The «flowing» scheme implies availability with water body of separate «inlet» – for filling the reservoir, and «outlet» – for its dumping. Normally, the structure of running-water lake systems is formed based on the cascade principle. The typical representative of the flowing watering scheme is the Aksai lake system. The system is feeding from the Syrdarya River via a single channel with consecutive water cross flow through a cascade of reservoirs consisting of four lakes and four bogs. Accordingly, an increase in the mineralization of lake waters is observed from the upstream to the downstream reservoirs.

The typical representative of the «cycle» scheme of watering is Kamystybas lake system. Its filling is performed via four channels within the period of high water level in the Syrdarya River and the dumping – within the period of low water. Thus, the cycle of watering of the lake system is characterized by a filling phase and a dumping phase of the reservoir under the reversing (alternating) regime of water supply channels.

Established mechanism of water- and salt exchange between river and lake waters allowed diagnosing salinization of deltaic lakes that occurred within the period from 1974 to 1992. Erection of temporary water-lifting hydro-engineering complexes (Amanotkel and Aklak) under restricted inflow of river waters to the delta enabled the maintenance of a sufficient water level of the riverbed to feed lake systems. At that, however, the river’s natural desalinating effect on the lake system was broken which became the main factor of its salinization.

However, in the recent years due to insufficient flow capacity and the loss of regulating functions of Amanotkel and Aklak hydro-engineering complexes, watering of lake systems of the delta became problematic.

At that a complicating factor is a poor condition of channels network which feeds the lake systems.

According to the remote sensing findings, in 2006 the area flooded by lake system of the Syrdarya River delta was 79.6 thousand ha, in 2007 – 83.2 thousand ha. Spring flood of lake systems in 2000, 2001 and 2005 was 118.8, 103.9 and 97.6 thousand ha respectively. In these years, the area of lakes was 80.6, 85.8 and 73.3 thousand ha (Table 5).

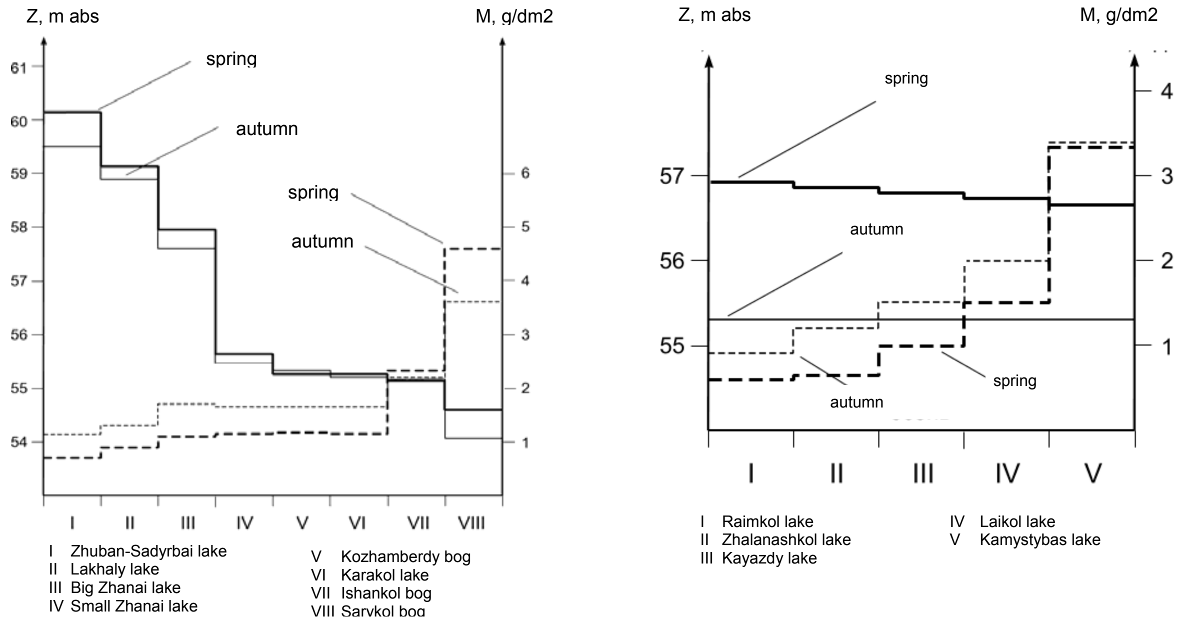
According their usage status, reservoirs can be classified as follows:

– fishery reservoirs which include spawning and feeding areas, with renewable natural fishery resources of local species and the possibilities of artificial stocking with fish and catching;

– economic reservoirs of average depth of 1.5-2.5 m with inundated costal flood-lands with possibilities of producing construction and fuel reed, fodder production on the basis of watered pasture-lands and hay fields, waterbird breeding, development of melon-growing and market gardening;

– ecological reservoirs with average depth of 1.0-1.5 m located mainly on the dried up seafloor of the eastern seashore with the opportunities to mitigate negative effects of dust and salt transport, sand shifts, etc., as well as creation of wildlife habitats.

Last years high water inflow to the delta has observed in winter, low water flow – in summer. Due to a high water content of recent years and a higher flowage of the lake systems, mineralization of lake waters was low – average 5.0 g/l.



a) b)

Figure 16 – Levels and mineralization of the water bodies of the Aksai (a) and Kamystybas (b) lakes systems in 2006

The formed winter regime of the lake systems watering in the delta is a forced regime which was conditioned by unnatural water regime of the Syrdarya River. Such a regime is contra-indicative to the watering of territories occupied by forests and bushes, is unacceptable for reservoirs inhabited by muskrats and is not efficient for fisheries.

Water level reduction in the river during low and middle water years prevents from flooding of the delta. Existing hydraulic facilities and outlets aren't complied with engineering water control especially during high water periods and command conditions during low water periods. As a result of this it was risen necessity of its improvement or construction new control facilities that will enable to efficiently distribution and integrated water resources management in the delta.

Table 5 - Area and water consumption dynamics of lake systems in the delta of the Syrdariya River

Lakes system	2000		2001		2005		2006		2007	
	Area (ha)	W/consump. (mln. m^3)	Area (ha)	W/consump. (mln. m^3)	Area (ha)	W/consump. (mln. m^3)	Area (ha)	W/consump. (mln. m^3)	Area (ha)	W/consump. (mln. m^3)
Kuandarya	9243.00	89.15	6299.00	60.81	5252.00	51.47	3900.00	38.90	670.00	6.68
incl. lakes	7448.00	74.29	5109.00	50.96	4714.00	47.02	3900.00	38.90	670.00	6.68
bog	1795.00	14.85	1190.00	9.85	538.00	4.45	0.00	0.00	0.00	0.00
Aksaiskaya	25445.00	242.86	21405.00	204.50	29388.00	279.84	26350.00	256.21	52820.00	499.71
incl. lakes	19001.00	189.53	16101.00	160.61	21561.00	215.07	22450.00	223.94	36840.00	367.48
bog	6444.00	53.32	5304.00	43.89	7827.00	64.77	3900.00	32.27	15980.00	132.23
Kamystybasskaya	31582.00	304.94	51444.00	503.84	35079.00	337.49	31830.00	305.94	19110.00	190.62
incl. lakes	25649.00	255.85	45966.00	458.51	27770.00	277.01	25030.00	249.67	19110.00	190.62
bog	5933.00	49.10	5478.00	45.33	7309.00	60.48	6800.00	56.27	0.00	0.00
Akshatauskaya	21637.00	205.38	20286.00	193.89	24626.00	233.48	16500.00	154.22	9980.00	95.73
incl. lakes	15490.00	154.51	15308.00	152.70	17473.00	174.29	10400.00	103.74	7730.00	77.11
bog	6147.00	50.87	4978.00	41.19	7153.00	59.19	6100.00	50.48	2250.00	18.62
Seaside Right-bank	16717.00	160.25	3710.00	36.18	2143.00	20.55	1050.00	10.47	640.00	6.38
incl. lakes	12891.00	128.59	3226.00	32.18	1654.00	16.50	1050.00	10.47	640.00	6.38
bog	3826.00	31.66	484.00	4.01	489.00	4.05	0.00	0.00	0.00	0.00
Seaside Left-bank	14194.00	117.65	791.00	6.76	1071.00	9.12	0.00	0.00	0.00	0.00
incl. lakes	112.00	1.12	127.00	1.27	150.00	1.50	0.00	0.00	0.00	0.00
bog	14082.00	116.53	664.00	5.49	921.00	7.62	0.00	0.00	0.00	0.00
TOTAL:	118818.00	1120.22	103935.00	1005.99	97559.00	931.95	79630.00	765.75	83220.00	799.13
incl. lakes	80591.00	803.90	85837.00	856.22	73322.00	731.39	62830.00	626.73	64990.00	648.28
bog	38227.00	316.33	18098.00	149.76	24237.00	200.56	16800.00	139.02	18230.00	150.85

1.3.1. Kuandarya lake system

Kuandarya lake system includes: Akkol, Mariyamkol, Altynkol lakes, and Shatkol, Shubar and Zhuanbalyk bogs (Figure 17). A horologic structure of Kuandariinskiy lake system is represented by Figure 18.

The system's water-distribution network includes:

Kuandariya channel 336 km of length performs water supply of all LS reservoirs from the collection-drain system of Kyzylorda massive. In the part of the channel from the Syrdarya River to Akkol Lake there is a water regulating facility Sarybulak. Further, in the north-western part of Akkol Lake, at the reservoir outlet, the riverbed of the River divides into two arms: upper arms – Old arm of Kuandarya which, bypassing Otgon settlement, flows into Bolshoy Zhanai (Aksai LS), and the lower (7 km), which flows into Mariyamkol Lake. Within the latter, a twisting riverbed of Kuandarya flows as partially drowned through the length of 12 km and is broken by Kosa dam. The average width of the channel floor is 3 m.

The runoff from Mariyamkol Lake to Shatkol, Shubar, Zhuanbalyk bogs and drained bays of the Large Sea occurs through *Kosa* diversion channel. *Kosa* channel starts from the southern extremity of Kosa dam.

Erdes dam – is an earth-fill coffer-dam which dams the channel of Staraya Kuandarya (Old Kuandarya) River. The length of the coffer-dam is 20 m, the width - 8 m, width at the bottom – 16.0 m, height – 6.0 m. Within the dam, 1.0 km below Akkol Lake, a one-pipe metal water outlet Erdes was constructed with the pipe of 1.0 m in diameter, length - 12 m, with no pipe seal. Threshold level of the construction is 57.97 m in total. In June 2006 a weak earth-filled cofferdam Erdes was broken because of the high water level of Akkol Lake. Due to this, a runoff to Kuandarya LS in summer 2006 did not occur. In December 2006, a toe wall Erdes on Old riverbed of Kuandarya below Akkol Lake was restored. Within the period from January to March 2007 Mariyamkol and Altynkol Lakes received 11.6 million m^3. In April 2007, the dam was destroyed again because of erosion of the stream flow dyke. The level of Akkol Lake reduced by 1.0 m. The waters of Kuandarya system, from May to August 2007, went to Bolshoi Zhanai of the Aksai System.

Kosa dam of 3.0 km length is located within the riverbed of Kuandarya channel. The width of the upstream bed is 6,0 m, at the bottom (in the riverbed) – 24,0 m, the height from the bottom of the riverbed - 9,0 m. The dam performs protective functions with respect to Kaukei settlement and communication facilities of the region. In the dyke there are 2 one-pipe metal outlets Kosa with 1.0 m in diameter, length 11 m, without regulator for water supply to Altynkol Lake and Shatkol, Shubar, Zhuanbalyk bogs. The marks of constructions' thresholds – 57.16 m in total and 58.01 m in total respectively. A road between Tasaryk and Kaukei settlements runs along Kosa dam.

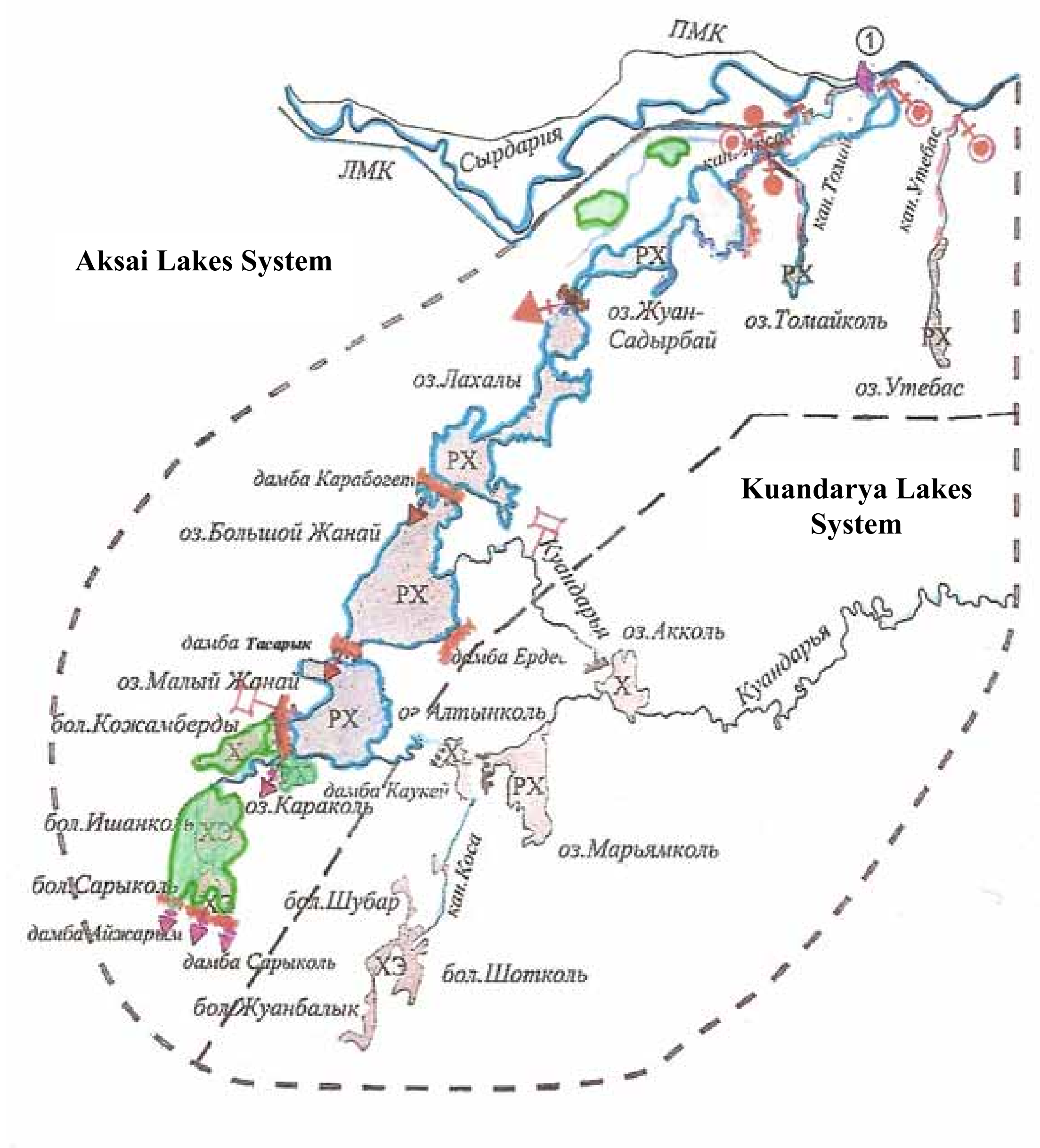


Figure 17 – Aksai-Kuandarya Lakes system

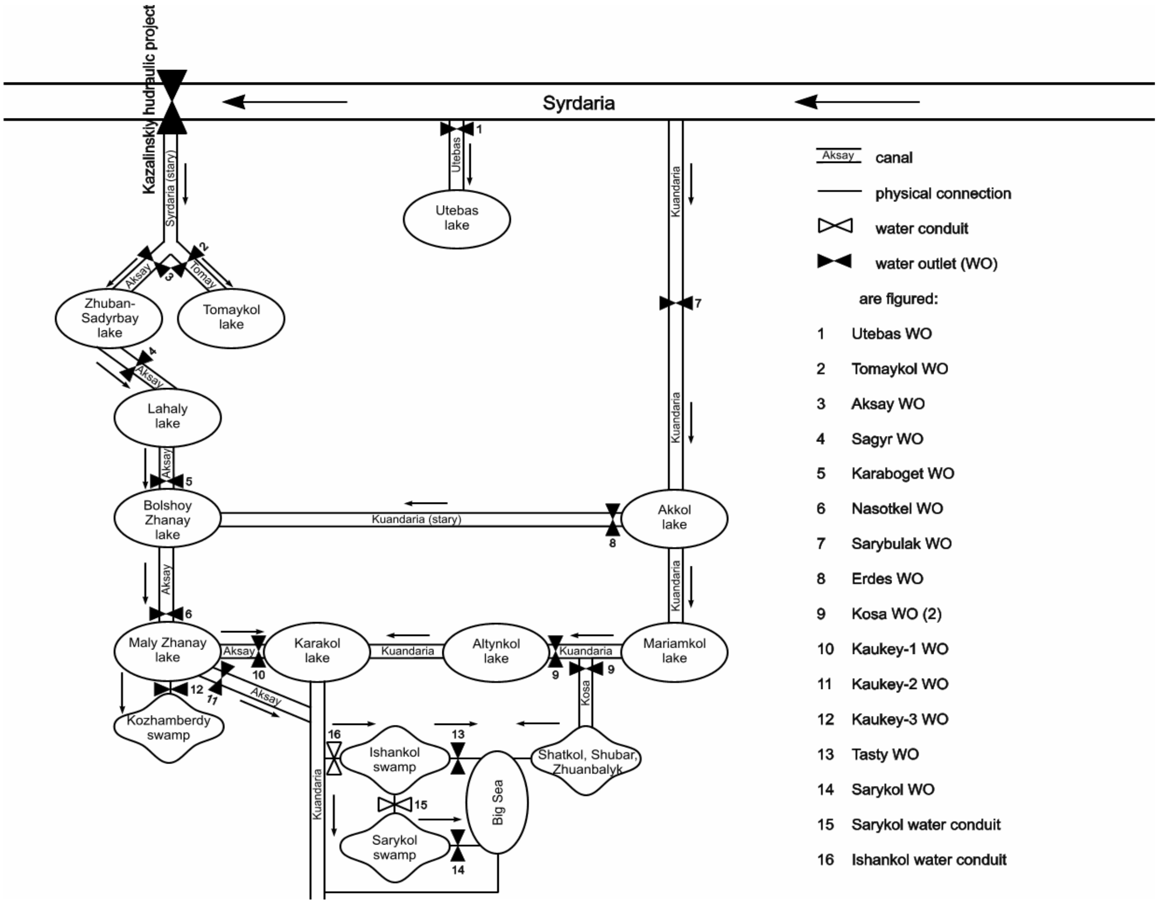


Figure 18 - Horologic structure of Kuandarya and Aksai Lake Systems

Table 6 - Dynamics of area of Kuandarya LS bodies, 2000-2007 (ha)

Code	Name	Body type	2000	2001	2005	2006	2007
0101	Akkol	lake	809.00	649.00	544.00	1200.00	670.00
0102	Mariyamkol	lake	6538.00	4420.00	4134.00	2500.00	0.00
0103	Altynkol	lake	101.00	40.00	36.00	200.00	0.00
0104	Shubar, Shatkol, Zhuanbalyk	bog	1795.00	1190.00	538.00	0.00	0.00
	Total:		9243.00	6299.00	5252.00	3900.00	670.00
	Incl.: lakes		7448.00	5109.00	4714.00	3900.00	670.00
	bogs		1795.00	1190.00	538.00	0.00	0.00

Table 7 - Actual water consumption of Kuandarya lake system, 2000-2007 (net, mln m^3)

Code	Name	Body type	2000	2001	2005	2006	2007
0101	Akkol	lake	8.07	6.47	5.43	11.97	6.68
0102	Mariyamkol	lake	65.22	44.99	41.24	24.94	0.00
0103	Altynkol	lake	1.01	0.40	0.36	2.00	0.00
0104	Shubar, Shatkol, Zhuanbalyk	bog	14.85	9.85	4.45	0.00	0.00
	Total:		89.15	60.81	51.47	38.90	6.68
	Incl.: lakes		74.29	50.96	47.02	38.90	6.68
	bogs		14.85	9.85	4.45	0.00	0.00

In 2007 the lakes of Kuandarya lake system were practically unwatered as the result of destruction of water-regulating dams Erdes and Kosa.

Figure 19 – Water bodies of Kuandarya lake system

1.3.2 Aksai lake system

Aksai lake system includes Utebas, Tomaikol, Zhuban-Sadyrbai, Lakhaly, Bolshoy and Maliy Zhanai, Karakol Lakes and Kozhamberdy, Ishankol and Sarykol bogs.

The system's water distribution network includes the following:

Utebas Lake is watered by the Syrdarya River via *Utebas* channel the length of which is 11 km, average width (width of the bed) is 3 m, depth – 2 m. The main water intake is a 2-pipe regulated water outlet of the ferro-concrete structure, with passage and fish trap. The tubes consist of rings of 1.5 m in diameter.

Tomai Lake is watered by head-water lock of Kazaly hydro-engineering complex, by the route Staroye riverbed of the Syrdarya River – Tomai diversion channel the length of which is 6.3 km, average width (of the channel bed) – 3 m.

Aksai channel performs runoff to reservoirs of the system from water-head of Kazaly hydro-engineering complex with threshold mark 58.00 m abs, and pipe diameter of 3 m. Further, the channel passes through the Staroye riverbed of the Syrdarya River. Within the area which stretched up to Zhuban-Sadyrbai Lake its length is 12 km, average width of the bed – 12 m, depth – 4 m. Right there, there is a water-regulating construction Alsai. In the channel segment from Zhuban-Sadyrbai Lake to Lakhaly lake (2.5 km) a water-transmitting unit Sagyr (with threshold mark 57.14 m abs.) functions as the regulator of waters supply to Lakhaly Lake. It is a doubled water outlet: pipes (4 pcs) with aggregate diameter of 12 m and length of 20 m.

Karboget dam was constructed within the channel segment from Lakhaly Lake to Bolshoy Zhanai Lake; it performs the function of Lakhaly Lake. It is an earth-fill dam stretched from the south to the north through the area of higher lands via earth cofferdams arranged in the lowland and inter-lake channels. The length of the dam is 8.0 km, the width (width of top at the points of earth cofferdams) does not exceed 6 m. In the northern part of the unit the runoff is performed through two dam breaches of 5 m and 15 m of width. Besides, the dam disposes a water-regulating unit Karaboget with threshold mark 57.48 m abs. and aggregate diameter of 9 m. There was observed a cross flow over the dam at lower points where the water level exceeded the level of Lakhaly Lake.

Within the channel segment between Bolshoy and Maliy Zhanai Lakes, *Tasotkel* earth dam is constructed of 500 m length. It performs the function of the retaining structure of Bolshoy Zhanai Lake. The dam disposes a water-regulating unit Tasotkel with threshold mark 55.63 m abs. and aggregate diameter of pipes 9.5 m.

Within the channel segment between Maliy Zhanai and Karakol Lakes Kaukei dam is constructed with the length of 7.2 km. It performs the function of the retaining structure of Maliy Zhanai Lake. The width of the top is 10 m, at the bottom – 20 m, the average height is 3 m. The dam disposes a water-regulating unit *Kaukei-1* with threshold level 55.25 m abs. and aggregate diameter of pipes 5.4 m. Further, the runoff from Karakol reservoir to Ishankol bog is performed via *Kuandariya-2* and *Ishankol* channels. Ishankol bog is located on the site of the former gulf Bozgol. To the south, the above mentioned bog communicates with Sarykol bog via the channel of the same name. Sarykol bog (at the site of the former gulf) is the final one in the Aksai group of reservoirs.

Within the segment of Aksai channel between Maliy Zhanai Lake and Kuandarya channel there is a water-regulating unit *Kaukei-2* with threshold mark 55.25 m abs. and aggregate diameter of pipes 5.4 m.

Between Maliy Zhanai Lake and Kozhamberdy bog there is a water-regulating unit *Kaukei-3* with threshold mark 55.50 m abs. and aggregate diameter of pipes 1.6 m.

Tables 8 and 9 represent the dynamics of area and estimated water consumption of Aksaiskiy LS bodies

Table 8 - Area of Aksaiskiy LS bodies, 2000-2007 (ha)

Code	Name	Body type	2000	2001	2005	2006	2007
0201	Tomaikol	lake	353.00	715.00	581.00	300.00	180.00
0202	Zhuban-Sadyrbai	lake	5238.00	3190.00	3560.00	2300.00	21500.00
0203	Lakhaly	lake	3791.00	4364.00	5822.00	6050.00	3730.00
0204	Bolshoi Zhanai	lake	5509.00	4149.00	6500.00	7460.00	5930.00
0205	Maliy Zhanai	lake	3468.00	3060.00	4442.00	5140.00	4400.00
0206	Karakol	lake	642.00	623.00	656.00	700.00	710.00
0207	Utebas	lake				500.00	390.00
0208	Kozhamberdy	bog	2271.00	2222.00	2526.00	1400.00	1680.00
0209	Ishankol	bog	4173.00	3082.00	5301.00	2500.00	14300.00
	Total:		25445.00	21405.00	29388.00	26350.00	52820.00
	Incl.: lake		19001.00	16101.00	21561.00	22450.00	36840.00
	bog		6444.00	5304.00	7827.00	3900.00	15980.00

Table 9 – Actual water consumption of bodies of Aksai lake system, 2000-2007 (net, mln m3)

Code	Name	Body type	2000	2001	2005	2006	2007
0201	Tomaikol	lake	3.52	7.13	5.80	2.99	1.80
0202	Zhuban-Sadyrbai	lake	52.25	31.82	35.51	22.94	214.46
0203	Lakhaly	lake	37.82	43.53	58.07	60.35	37.21
0204	Bolshoi Zhanai	lake	54.95	41.39	64.84	74.41	59.15
0205	Maliy Zhanai	lake	34.59	30.52	44.31	51.27	43.89
0206	Karakol	lake	6.40	6.21	6.54	6.98	7.08
0207	Utebas	lake				4.99	3.89
0208	Kozhamberdy	bog	18.79	18.39	20.90	11.59	13.90
0209	Ishankol	bog	34.53	25.50	43.87	20.69	118.33
	Total:		242.86	204.50	279.84	256.21	499.71
	Incl.: lake		189.53	160.61	215.07	223.94	367.48
	bog		53.32	43.89	64.77	32.27	132.23

Figure 20 – Water bodies of Aksai lake system

1.3.3 Kamystybas lake system

Kamystybas lake system occupies the right-bank territory of the middle delta of the Syrdarya River and includes Makpalkol, Raimkol, Zhalanazhkol, Zhangyldy, Kayazdy, Kuly, Laikol, Kamystybas lakes and Zhaltyrkol, Kokshekol, Kokkol, Taldyaral, Kobikty bogs. The horologic structure of Kamystybas lake system is represented in Figure 22.

The system' water distribution network includes the following:

Kenesaryk channel – with the length of 35 km from the Syrdarya River to Makpalkol lake, the width (of the bed) - 12 m, the width at ground level - 17 m, at crest level of coastal dams - 19 m. The slope of the channel and coastal dams m = 1.5. The average depth: from bed to ground level – 1.6 m, from bed to crest level of coastal dams – 2.4 m. The width of coastal dams at the top level – 3 m, at the low level – 5.4 m. The height mark of the existing channel bed at its beginning point is 56.78 m, end channel bed level – 50.50 m.

Through *Almatzharma* water-regulating unit, Kenesaryk channel waters Kokkol bog. The unit's pipe diameter is 1.5 m.

The segment of Kenesaryk channel from its beginning to *Bekbaul* protective dam has the length of 11.6 km. Bekbaul coffer-dam is located to the south from Zhaltyrkol bog. Its length is 3.5 km, width at the top level - 9 m, at the low level - 33 m, height – 2.70 m. There is a reinforced-concrete water outlet *Bekbaul:* two round cross-section pipes of 1.5 m in diameter and two dubbings of 2mx2m and 1.5m x 1.5m size. The regulator is installed on dubbing of 2m x 2m size. The threshold mark of the construction is 56.04 m abs. Zhaltyrkol bog is watered via Bekbaul water-regulating unit.

Three water-regulating units of Kokshe water Kokshekol bog from Kenesaryk channel. Threshold mark of the constructions is 55.20 m abs., pipe diameter – 1.5 m.

Water intrusion of Lake Raimkol is performed from the Syrdarya through the *Sovetzharma* channel which length is 3.9 km, average width upon the bottom is 20 m. In 1978 the channel was broadened with deepening. Reinforced concrete, composed one-funneled water intake with crossing was demolished in the eighties. The regulation is performed by means of an earth cofferdam. Besides, there is *Sovet* water regulating construction.

Raim protecting dike is situated in the north part of the Raimkol River. Length is 2.1 km; the upper blanket is 7 m width at the point of 59.0 m. A road to the Raim water pump station goes upon the upper side of the dike.

Water intrusion of Lake Zhalanashkol is performed from the Syrdarya through the *Taupzharma* channel which length is 4.0 km, average width upon the bottom is 8 m. The main water intake *Taupzharma* – outlet is reinforced concrete, composed one-funneled with crossing.

Water intrusion of the Taldyaral and Kobykty bogs is performed from the Syrdarya through the *Taldyaral* channel with length 0.2 km and 3 m width upon the bottom to the Taldyaral bog and 6 m – to the Kobykty bog. The main *Taldyaral* intake – outlet is reinforced concrete, composed, regulated with crossing.

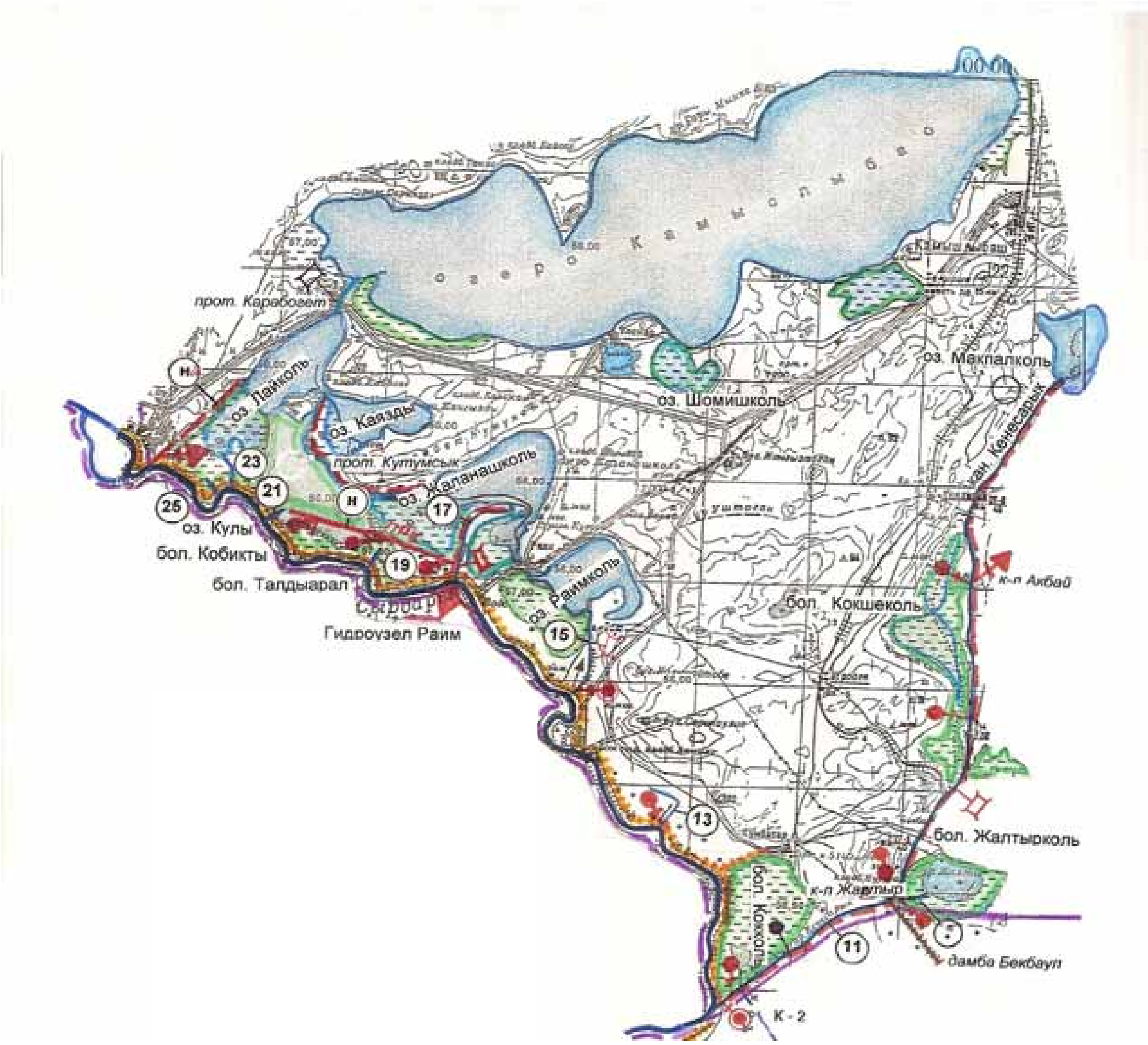


Figure 21 – Kamystybas Lakes System

Water intrusion of Kuly Lake is performed from the Syrdarya through the *Kuly* channel with length 0.6 km and average width upon the bottom 8 m. The main water intake Kuly – outlet is reinforced concrete, composed, three-stacked, regulated with crossing.

Water intrusion of Lake Laikol is performed from the Syrdarya through the *Zhasulan, Keragar* channels with length 1.5 km and 0.1 km correspondingly and average width upon the bottom is 3 m. the main water intakes *Zhasulan* and *Keragar* (point of construction weir is 55.84 m abs) on the channels – outlets are reinforced concrete, composed, regulated with crossing were demolished late in the eighties. Regulation is being performed by earth cofferdams.

The *Kutumsyk* channel connects Lake Zhalanashkol with Lake Kayazdy which in its turn supplies Lake Laikol with water through the *Zhaibike* channel. Besides, the Kayazdy is physically connected to Lake Zhynkyldy.

Lake Kamystybas closes Lake Kamystybas. It is connected to Lake Laikol by the *Karaboget* channel, average width of which upon the bottom is 25 m.

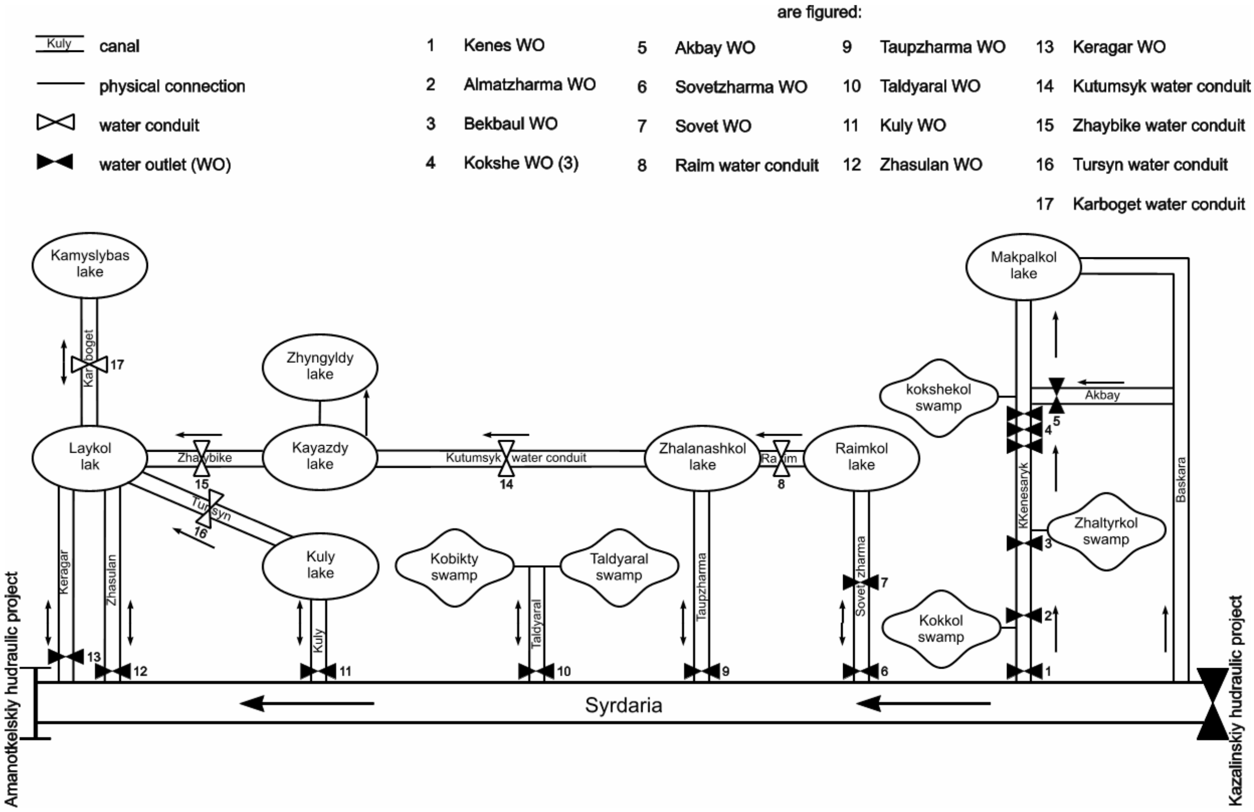


Figure 22 - Chronological structure of the Kamystybas lake system

Tables 10 and 11 represent dynamics of the facilities area and calculated water consumption of the Kamystybas lake system.

Table 10 – Area of the Kamystybas lake system, 2000-2007 (ha).

Code	Name	Body type	2000	2001	2005	2006	2007
0301	Kokkol	bog	4709.00	4126.00	5284.00	2800.00	0.00
0302	Zhaltyrkol	bog	216.00	380.00	637.00	3100.00	0.00
0303	Kokshekol	bog	272.00	371.00	624.00	700.00	0.00
0304	Taldyaral	bog	736.00	601.00	764.00	200.00	0.00
0305	Makpalkol	lake	413.00	409.00	1120.00	1300.00	950.00
0306	Raimkol	lake	1661.00	1322.00	2028.00	1370.00	400.00
0307	Zhalanashkol	lake	2871.00	24443.00	3091.00	2200.00	1000.00
0308	Kayasdy	lake	1048.00	954.00	1101.00	460.00	240.00
0309	Kuly	lake	596.00	522.00	623.00	900.00	760.00
0310	Laikol	lake	1714.00	1561.00	1775.00	1200.00	760.00
0311	Kamyslybas	lake	17346.00	16755.00	18032.00	17600.00	15000.00
	Total:		31582.00	51444.00	35079.00	31830.00	19110.00
	Incl.: lake		25649.00	45966.00	27770.00	25030.00	19110.00
	bog		5933.00	5478.00	7309.00	6800.00	0.00

Table 11 – Actual water consumption of the Kamystybas lake system, 2000-2007 (net, million m^3)

Code	Name	Body type	2000	2001	2005	2006	2007
0301	Kokkol	bog	38.97	34.14	43.73	23.17	0.00
0302	Zhaltyrkol	bog	1.79	3.14	5.27	25.65	0.00
0303	Kokshekol	bog	2.25	3.07	5.16	5.79	0.00
0304	Taldyaral	bog	6.09	4.97	6.32	1.66	0.00
0305	Makpalkol	lake	4.12	4.08	11.17	12.97	9.48
0306	Raimkol	lake	16.57	13.19	20.23	13.67	3.99
0307	Zhalanashkol	lake	28.64	243.82	30.83	21.95	9.98
0308	Kayasdy	lake	10.45	9.52	10.98	4.59	2.39
0309	Kuly	lake	5.95	5.21	6.21	8.98	7.58
0310	Laikol	lake	17.10	15.57	17.71	11.97	7.58
0311	Kamyslybas	lake	173.03	167.13	179.87	175.56	149.63
	Total:		304.94	503.84	337.49	305.94	190.62
	Incl.: lake		255.85	458.51	277.01	249.67	190.62
	bog		49.10	45.33	60.48	56.27	0.00


Figure 23 – Water bodies of the Kamystybas lake system

1.3.4 Akshatau lake system

The Akshatau lake system occupies left territory of the Syrdarya River delta. The system comprises lakes Kotankol, Shomiskol, Karakol, Akshatau; bogs Shakhai, Karakol. Cronological systems of the Akshatau lake system is represented in the Figure 24.

Water distributing network of system comprises:

The *Ardana* channel supplies Lake Shomishkol with water. Its length is 3.2 km, average width upon the bottom is 6 m. The main water intake Ardana was situated in 100 m from the Syrdarya. It is reinforced concrete, composed, two-funneled 1.5 m in diameter, was demolished in 1992 by an ice drift. Currently regulation of inflow and prevention of coming off is performed by closure through the earth cofferdams.

The *Elshibai* Channel begins from the Ardana channel and supplies Shakhai bog with water. Its length is 13 km.

The *Zhakayimaryk* channel supplies Lake Kotankol with water. The length is 3 km, average width upon the bottom is 8 m.

The *Beszharma* Channel supplies Lake Karakol with water. Its length is 5.3 km, average width upon the bottom is 3 m. earlier in the canal head Beszharma there was water intake there. Reinforced, composed, outlet tubes are 6 m length, 1.5 m in diameter. Early in the ninetieth it was demolished by an ice drift. The outlet was equipped by a passage and fish-protection structure in the upper pound.

The *Akkoisoigan* canal supplies the Karakol bog with water. Its length is 1.5 km from the Syrdariya River, average width upon the bottom is 6 m. Earlier in the Akkoisoigan Canal head there were water intakes of reinforced concrete constructions. The tubes of the outlet are 6 m length, 1.5 m in diameter from the composed reinforced concrete rings. Early in the nineties they were demolished by an ice drift.

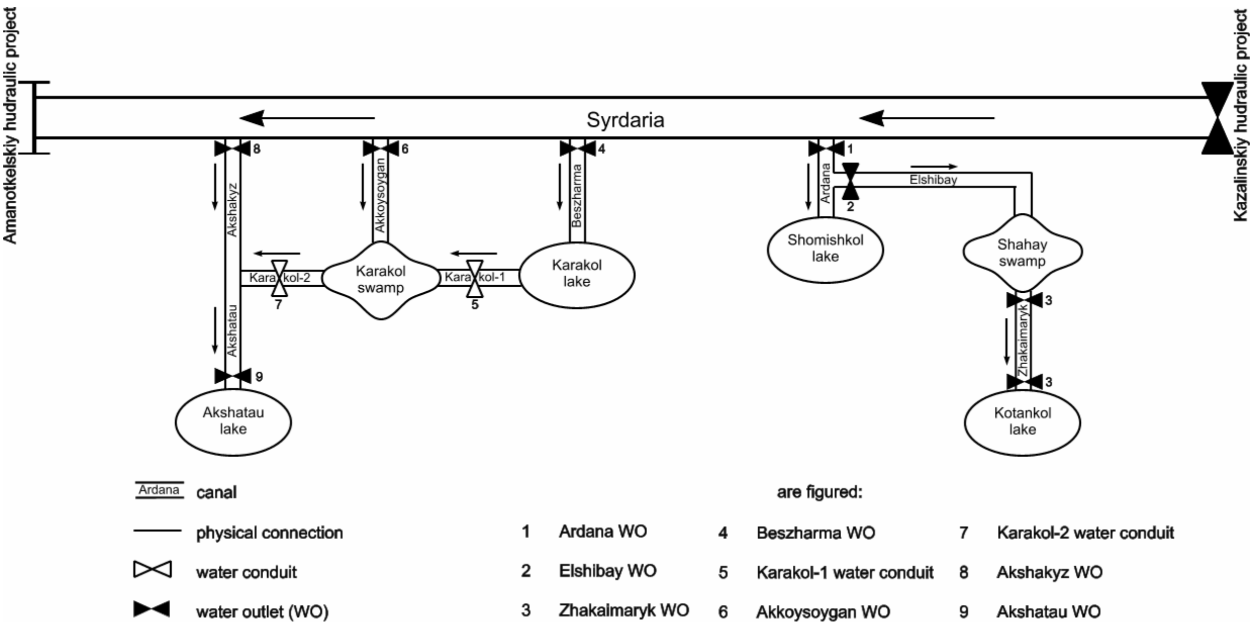


Figure 24 – Chronological structure of the *Akshatau* lake system.

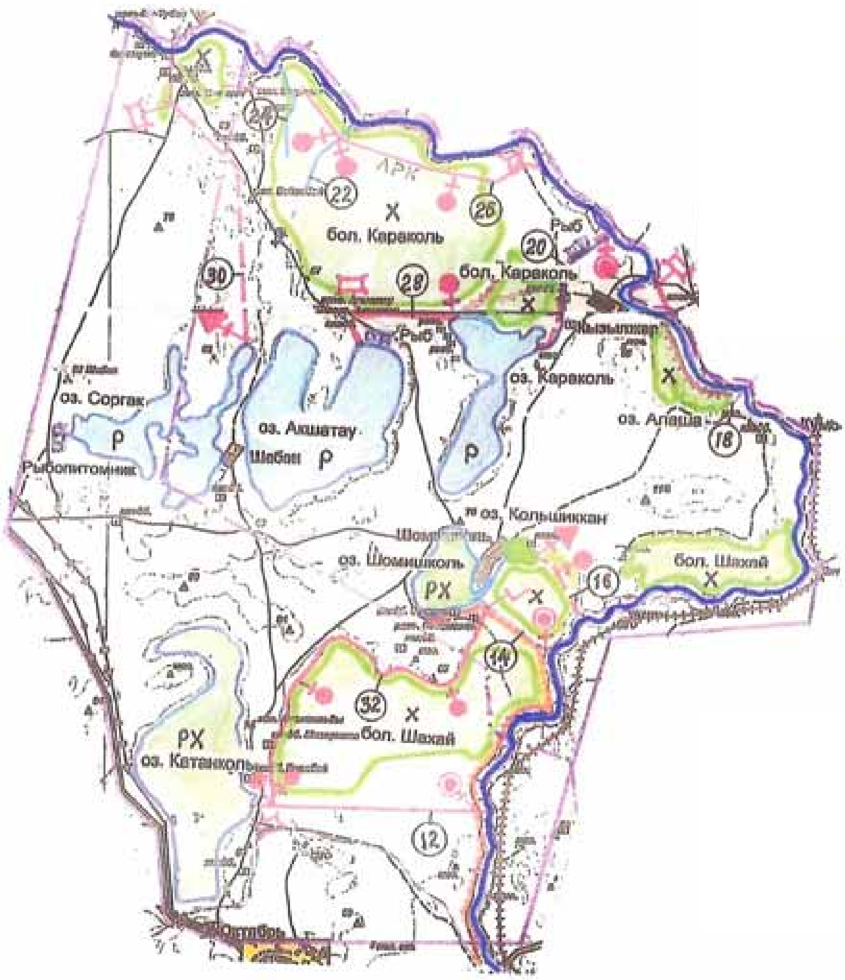


Figure 25 – Akshatau Lakes System

Lake *Akshatau* is irrigated from the Syrdarya through the *Akshakyz* and then the *Akshatau* canals. The *Akshakyz* canal is 1.2 km length, its average width upon the bottom is 6 m.

The Akshatau canal is 2 km length, average width upon the bottom is 6 m. The Akshatau canal near Akshatau village has two-funneled regulated outlet of reinforced concrete construction with a passage and fish-protection structure. Tubes from reinforced concrete composed rings 1.5 m in diameter. From the erection (1990) the construction had not been operated due to low location and flooding in freshet periods.

Tables 12 and 13 represent dynamics of the facilities area and calculated water consumption of the Akshatau lake system.

Table 12 – Dynamics of the Akshatau lake system facilities, 2000-2007 (ha).

Code	Name	Body type	2000	2001	2005	2006	2007
0401	Shakhai	bog	5819.00	4771.00	6705.00	3100.00	0.00
0402	Karakol	bog	328.00	207.00	448.00	3000.00	2250.00
0403	Kotankol	lake	2717.00	3253.00	3681.00	2400.00	1300.00
0404	Shomishkol	lake	472.00	456.00	470.00	1100.00	740.00
0405	Karakol	lake	7406.00	6735.00	7619.00	1400.00	1130.00
0406	Akshatau	lake	4895.00	4864.00	5703.00	5500.00	4560.00
	Total:		21637.00	20286.00	24626.00	16500.00	9980.00
	Incl: lake		15490.00	15308.00	17473.00	10400.00	7730.00
	bog		6147.00	4978.00	7153.00	6100.00	2250.00

Table 13 – Actual water consumption of the Akshatau lake system, 2000-2007 (net, million m^3)

Code	Name	Body type	2000	2001	2005	2006	2007
0401	Shakhai	bog	48.15	39.48	55.48	25.65	0.00
0402	Karakol	bog	2.71	1.71	3.71	24.83	18.62
0403	Kotankol	lake	27.10	32.45	36.72	23.94	12.97
0404	Shomishkol	lake	4.71	4.55	4.69	10.97	7.38
0405	Karakol	lake	73.87	67.18	76.00	13.97	11.27
0406	Akshatau	lake	48.83	48.52	56.89	54.86	45.49
	Total:		205.38	193.89	233.48	154.22	95.73
	Incl: lake		154.51	152.70	174.29	103.74	77.11
	bog		50.87	41.19	59.19	50.48	18.62

Figure 26 – Water bodies of the Akshatau lake system

1.3.5 Seaside right bank system

Seaside right bank system occupies wellhead right bank site of the Syrdarya River. The system comprises lakes Tushshebas, Sarteren, Tazhedin, Domalak, Karashalan; bogs Akzhar, Esenbai-Batpakty, Nasoskol, Aimeken. Chronological structure of the seaside right bank system is represented on Figure 28.

Water distributing network comprises:

The *Aidynzharma* canal irrigates the Akzhar bog from the Syrdariya. The lengths is 0.3 km, average width upon the bottom is 3 m.

Lake *Tushshebas* is supplied by water from the Syrdariya through the Balgabai, Beketai canals.

The *Balagabai* canal has 3.9 km length, average width upon the bottom is 6 m. It was built in 2001 without water outlet, regulator and passage. There are earth cofferdams in two places to regulate flow and outflow.

The *Beketai* canal is 2.8 km length, 6 m average width upon the bottom. There is water intake with two funnels, regulated water outlet of reinforced concrete construction with passage and fish protection construction. Tubes are from the composed rings 1.5 m in diameter.

The *Sartoren* canal irrigates Lake Sarteren from the Lake Tushshebas. Its length is 6.0 km, average width upon the bottom is 3 m. There is a bridge with 3 funnel regulated water outlet of reinforced concrete on the intersection of the Sarteren canal with Amanotkel – Bogen highway. The funnels consist of the composed rings 1.5 m in diameter. The bridge was reconstructed in 2001 into the regulated outlet. In 1988 to create the reservoir Sarteren in south-west part of the hollow 6 km length earth dike was constructed. Upper width is 4 m, lower width is 12 m. height is 4.5 m.

The *Karakol* canal irrigates the bog Esenbai-Batpakty. Its length is 1.0 km, average width upon the bottom is 3 m. There is two-funneled water intake, regulated outlet is reinforced concrete with passage and fish protection construction. The funnels consist of composed rings 1.5 m in diameter.

The *Kyzylzhar* canal irrigates Nasoskol bog from the Syrdariya. Its length is 1.4 km, average width upon the bottom is 4 m. Water intake on the canal is two-funneled, regulated outlet is of reinforced concrete construction with passage and fish protection construction. Funnels consist of composed rings 1.5 in diameter.

The *Nasoskol* channel irrigates the Aimeken bog. Its length is 0.3 km, average width upon the bottom is 5 m.

The Baisary canal irrigates lakes Domalak, Tazhedin, Aimeken bog. Its length is 1.5 km, average width upon the bottom is 4 m.

The Domalak canal irrigates lakes Domalak, Tazhedin. Its length is 2.8 km, average width upon the bottom is 4 m.

The Sagymbai canal irrigates Lake Karashalan. Its length is 4.0 km, average width upon the bottom is 6.0 m. The canal was constructed in 2001 along the highway of the earlier existed Sagymbai canal.

Discharge canal Sinyavin from Lake Domalak into Lake Karashalan. Its length is 2.0 km, average width upon the bottom is 1.0 m.

Discharge canal *Tikasha* from Lake Karashalan into SAM. Its length is 6.0 km, average width upon the bottom is 4.2 m.

Toe wall cofferdam *Taur* with two spillway outlets. Its length is 5.0 km, upper width is 6 m, at the bottom 12 m, height is 2 m. The cofferdam is situated on the former channel Taur between the original seashore near the Karashalan village and sand barchans westward the channel.

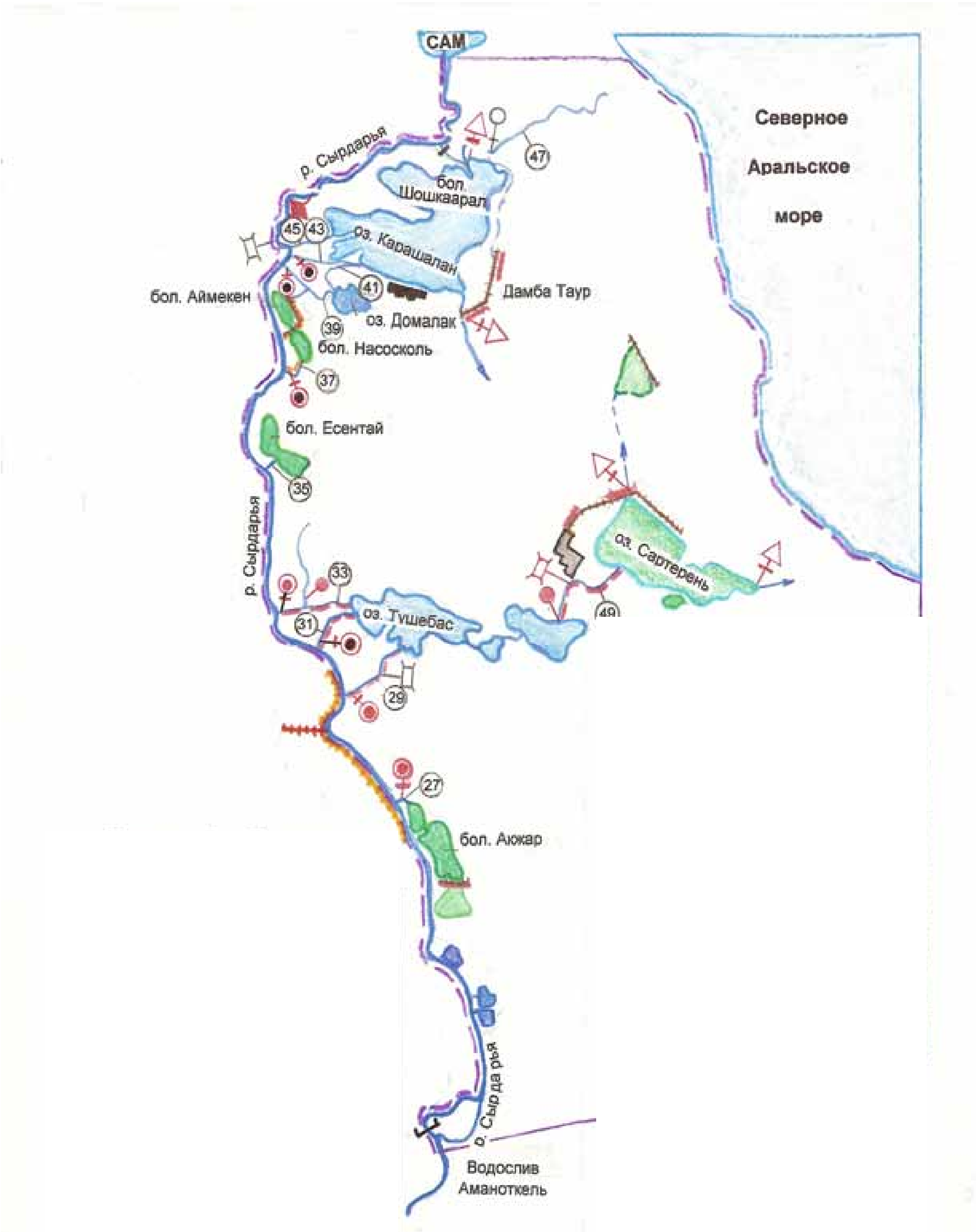


Figure 27 - Seaside right bank system

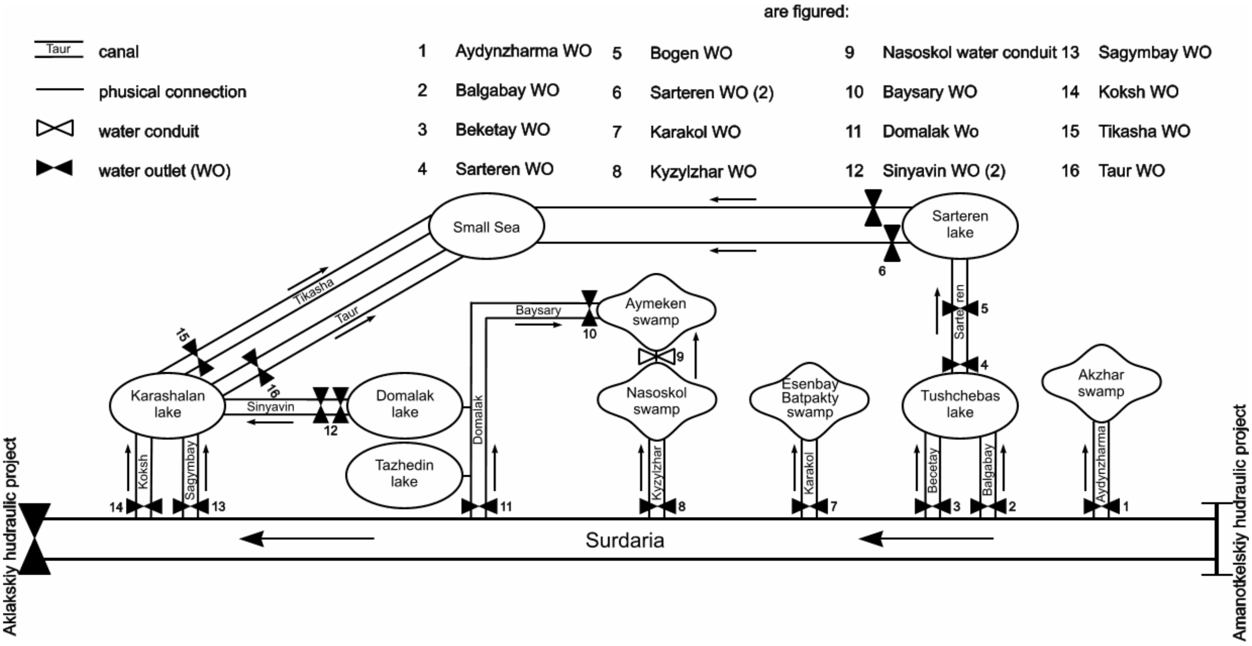


Figure 28 – Chronological structure of the Seaside right bank LS

Due to the liquidation of the temporal Aklak hydro-system since 2001, LS almost was not irrigated. In 2000 space of the water surface constituted 16.7 thousand ha, including lakes – 12.9 thousand ha. Calculated water consumption – net 160 million m^3.

Tables 14 and 15 represent dynamics of facilities area and calculated water consumption.

Table 14 –Area of Seaside right bank lake system, 2000-2007 (ha)

Code	Name	Body type	2000	2001	2005	2006	2007
0501	Akzhar	bog	1150.00	302.00	266.00		
0502	Esenbai-Bakbakty	bog	2215.00	115.00	143.00		
0503	Aimeken	bog	461.00	67.00	80.00		
0504	Tuschebas	lake	2029.00	1238.00	1146.00	1050.00	640.00
0505	Sarteren	lake	1804.00	1054.00	257.00		
0506	Domalak	lake	882.00	140.00	24.00		
0507	Karashalan	lake	8176.00	794.00	227.00		
	Total:		16717.00	3710.00	2143.00	1050.00	640.00
	Incl.: lake		12891.00	3226.00	1654.00	1050.00	640.00
	bog		3826.00	484.00	489.00	0.00	0.00

Table 15 – Actual water consumption of facilities of the Seashore right bank lake system, 2000-2007 (net million m^3)

Code	Name	Body type	2000	2001	2005	2006	2007
0501	Akzhar	bog	9.52	2.50	2.20	0.00	0.00
0502	Esenbai-Bakbakty	bog	18.33	0.95	1.18	0.00	0.00
0503	Aimeken	bog	3.81	0.55	0.66	0.00	0.00
0504	Tuschebas	lake	20.24	12.35	11.43	10.47	6.38
0505	Sarteren	lake	17.99	10.51	2.56	0.00	0.00
0506	Domalak	lake	8.80	1.40	0.24	0.00	0.00
0507	Karashalan	lake	81.56	7.92	2.26	0.00	0.00
	Total:		160.25	36.18	20.55	10.47	6.38
	Incl.: lake		128.59	32.18	16.50	10.47	6.38
	bog		31.66	4.01	4.05	0.00	0.00

Figure 29 – Water bodies of the Seaside right bank lake system

1.3.6 Seaside left bank system

Seaside left bank system occupies lower left bank site of the Syrdariya River. The system comprises lakes Akbasty, Ushaidyn, Kogaly, Nausha, Zhylandy, Kartma, Karakamys, Kuilys, Zharykkol, Zhangalaysharal, and Lake Bayan. Chronological structure of the seaside left bank system is represented on Figure 31.

Water distributing network comprises:

The *Tonzharma* canal irrigates Akbasty bog from the Syrdarya. The lengths is 0.4 km, average width upon the bottom is 7 m. Water intake Tonzharma is two-funneled, regulated outlet is reinforced concrete with fish protection construction. The funnels are 1.5 m in diameter. Demolished in 1998.

The *Kyzketken Sug*a canal irrigates bog Kogaly. Its length is 5.0 km, average width upon the bottom is 4 m.

The *Zhylandy* canal irrigates bog Zhylandy with grassland. Its length is 4.1 km, average width upon the bottom is 7 m.

The *Akkol* canal irrigates Nausha bog. Its length is 9.0 km, average width is 12 m. In 300 m from the Akkol canal four-funneled regulated outlet of reinforced concrete construction with passage is situated. Funnels consist of composed rings 1.5 m in diameter.

The *Karateren-1* channel irrigates Zharykkol bog. Its length is 5.5 km, average width upon the bottom is 8 m. Main water intake was demolished during washaway of cofferdams of the Aglak dike in 1998.

The *Karateren-2* canal irrigates Kartma bog. The canal begins southwards Tastak village. Its length is 4.8 km, average width upon the bottom is 6 m. Water intake is missing.

The *Motorozek* channel is situated between basins Kartma and Kuilys. Its length is 6 km, width is 20 m and depth is 2 m. At the output from the Kartma basin there situated two-funneled regulated outlet of reinforced concrete construction with passage and fish protection construction. Funnels consist of composed rings 1.0 m in diameter.

The *Bayan* canal irrigates Lake Bayan. Its length is 5.0 km, average width upon the bottom is 8 m. It was demolished on the initial site with length 1.0 km in 1998 at breakthrough of the right bank site of the Aklak dyke.

The channel *Kindikozek* irrigates bog Zhangylysharal from the lake Bayan. Its length is 400 m, average width upon the bottom is 8 m. The channel has one-funneled regulated outlet of reinforced concrete construction with passage. The diameter of the outlet funnel is 1.5 m.

The protecting *dike Kuilys* is situated on the place of channel from the basin Kuilys of the Karakamys bog into the Big Aral Sea. The dike is 600 m length, its upper width is 6 m, at the bottom 25 m, the height is 2 m. There is a passage in the dike formed in 2001 due to washing out of its upper part.

The protecting *dike Kumboget* was situated on south-west part of Lake Bayan on the channel between the basin and the Big Aral Sea. The dike is 50 m length, its upper width is 10 m, at the bottom 20 m, and the height is 1.5 m.

Tables 16 and 17 represent dynamics of the facilities area and calculated water consumption of the Seaside left bank lake system.

Table 16 – Area of the Seaside left bank lake system, 2000-2007 (ha)

Code	Name	Body type	2000	2001	2005	2006	2007
0601	Akbasty	bog	3000.00	232.00	360.00		
0602	Ushaidyn	bog	900.00	27.00	39.00		
0603	Kogaly	bog	109.00	66.00	3.00		
0604	Nausha	bog	143.00	47.00	239.00		
0605	Zhilandy	bog	5255.00	90.00	220.00		
0606	Kapakamysh	bog	4675.00	202.00	60.00		
0607	Bayan	lake	112.00	127.00	150.00		
	Total:		14194.00	791.00	1071.00	0.00	0.00
	Incl.: lake		112.00	127.00	150.00	0.00	0.00
	bog		14082.00	664.00	921.00	0.00	0.00

Table 17 – Actual water consumption of the facilities of the Seaside left bank lake system, 2000-2007 (net, million m^3)

Code	Name	Body type	2000	2001	2005	2006	2007
0601	Akbasty	bog	24.83	1.92	2.98		
0602	Ushaidyn	bog	7.45	0.22	0.32		
0603	Kogaly	bog	0.90	0.55	0.02		
0604	Nausha	bog	1.18	0.39	1.98		
0605	Zhilandy	bog	43.49	0.74	1.82		
0606	Kapakamysh	bog	38.69	1.67	0.50		
0607	Bayan	lake	1.12	1.27	1.50		
	Total:		117.65	6.76	9.12	0.00	0.00
	Incl.: lake		1.12	1.27	1.50	0.00	0.00
	bog		116.53	5.49	7.62	0.00	0.00

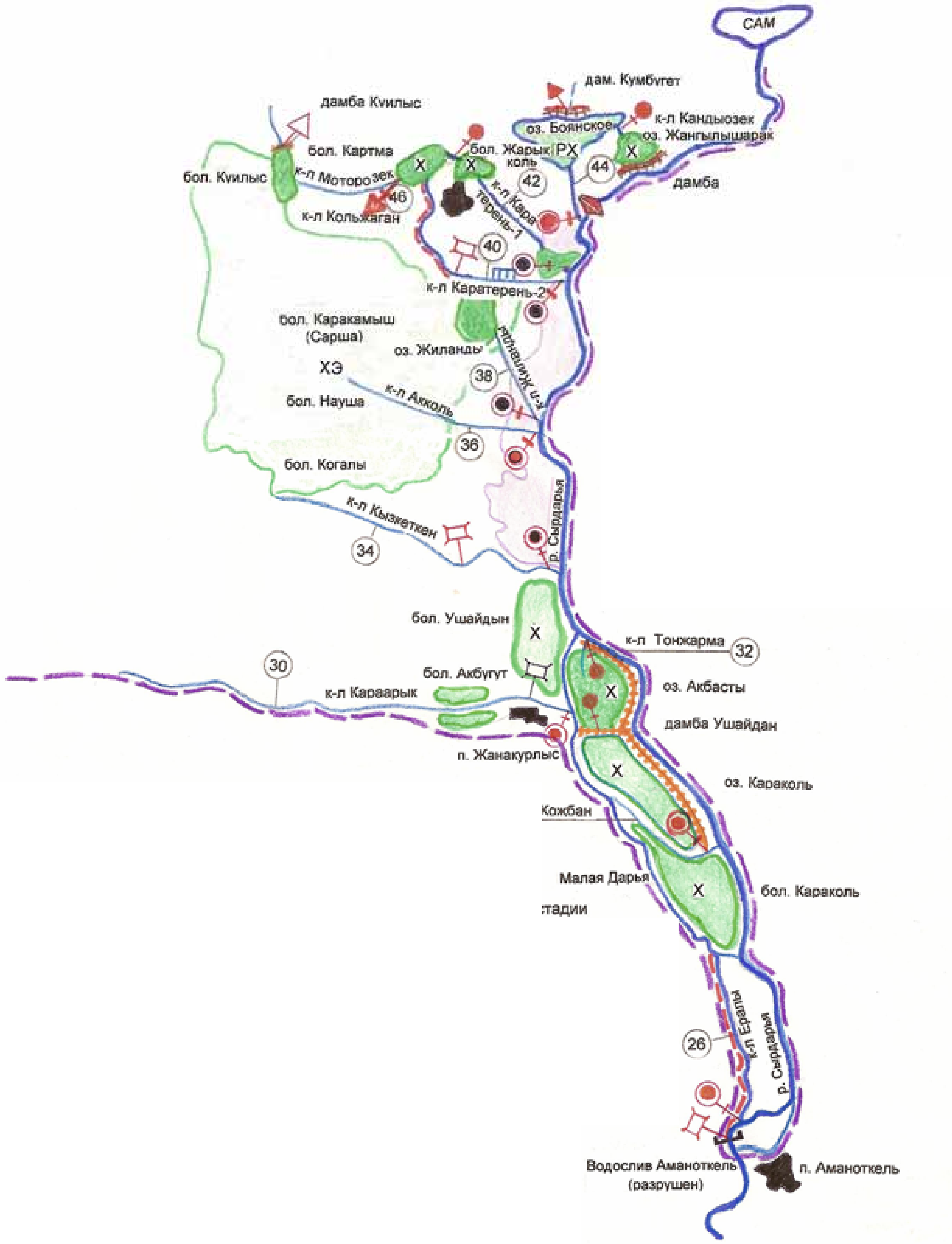


Figure 30 - Seaside left bank system

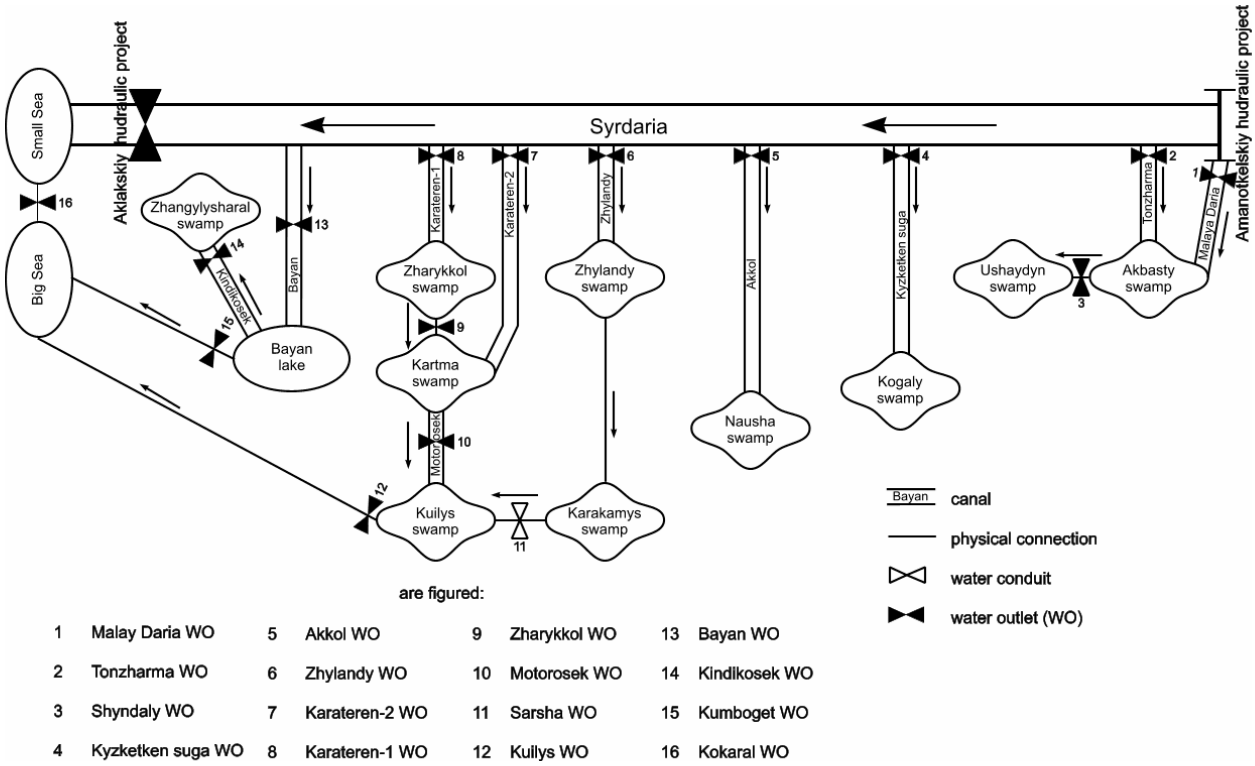


Figure 31 - Chronological structure of the Seaside left bank LS

Figure 32 –Water bodies of the Seaside leftbank lake system

2 BIODIVERSITY OF THE SYRDARYA RIVER DELTA

Botanical diversity is pivotal element of biology diversity of this area. It includes diversity of plants (flora) and plant association (phytocenosis).

Project territory is the delta of the Syrdarya river and northern part of the Aral Sea. It locates in the desert zone on the border of average (current) and north deserts of Turan. In accordance with map of botanical and geography zoning it (project territory) is belonged to the Sahara-Toby arid region of Iran-Turan sub-region of North-Turan province of West-North-Turan sub-province.

Defining factors of formation of natural ecosystem are droughtiness of climate, high amplitudes of temperature, lack of moisture, poverty and salinity of soil. Dynamics of hydromorphic ecosystems have random nature and depends on sufficiency of water supply of the specific year.

2.1 Present condition of the wetlands vegetation

Zonal ecosystems form on high plains with brown and grey-brown soils of different level of salinity in automorphous and semi-hydromorphic regime of damping. Vegetation is represented by combination of sagebrush (*Artemisia terae-albae*) and perennial saltwort (*Anabasis salsa, Salsola arbusculiformis)* communities. For wind plains with desert sandy soil refer psammophytic absinthial sagebrush (*Artemisia albicerata, A.songarica*), psammophytic gramineous (*Agropyron fragile),* psammophytic suffruticose *(Krascheninnikovia ceratoides, Eremosparton aphyllum)*, psammophytic dumetosous *(Haloxylon persicum, Calligonum aphyllum, C.alatum, C.cristatum, C.leucocladum, Amregimendron conollyi*) communities.

Ecosystems of semihydromorphic habitat refer to negative relief forms and low plains and characterized by predominance of suffruticose *Anabasis salsa, A. Aphyllum* and sarsazan (*Halocnemum strobilaceum*) communities at common and shor salt-marshes.

Business purpose:– year-round pasture for wild and domestic animals, resources of fuelwood (saxaul, brushwood).

Intrazonal ecosystems or wetlands form exceptionally under the effect of water factor on hydromorphic soils of meadowy and paludous rows of various levels of salinity and adjacent to the coasts of lakes, sea, valley and delta of rivers. Within the inspected territory marked the following main types of ecosystems (biotopes) with certain set of key species of plants and formed plant communities. They are also habitat and vital habitat of wild animals.

Grass moors or reedbeds (hydrophytic) form in conditions of excessive moistening on soils of swamp variety (slimy-swampy) with anaerobic processes of soil formation. They are confined to channel and lake degradation, flow channels and widely spread in shallow area of many deltoid lakes and in the bottomland of Syrdarya river. Generally, landscape value take rushes of bulky rootstock grass – reed (*Phragmites australis*) and other macrophytes: reed mace (*Typha* *angustifolia*), cane (*Scirpus lacustris, S. Tabernaemontani, S. littoralis).* On the coast in cane communities there is a herb (*Lythrum salicaria, Althaea officinalis, Xanthium strumarium, Inula salicina*).

Wide distribution of the frog's-bit (Hydrocharis morsus-ranae) and biting knotweed (Polygonum amphibia) groups were identified in the investigated water bodies. The following air-to-water macrophytes are found in the shallow: flowering rush (Butomus umbellatus), water plantain (Alisma plantago-aquatica), bur-reed (Sparganium stoloniferum). s Miscellaneous herbs participate on the coastal reed communitie (Lythrum salicaria, Althaea officinalis, Xanthium strumarium, Inula salicina).

Grass bogs everywhere are noted for poorness of floristic composition. So, investigated wetlands have 23 types of the higher plants. Floristic diversity of the grass bogs is not much increased during seabed drying. The following types of the reed and cat's-tail communities are emerged: spike rush (Eleocharis argyrolepis, Eleocharis acicularis), and a sea club-rush on the salt habitation area (Bolboschoenus maritimus, Bolboschoenus compactus).

The largest areas of grass moors were noted in Kuandarya, Aksai-Kuandarya and Kamystybas lake systems.

Also small fragmentary sections of the grass bogs have been stated in the shoals of the following lakes: Tuschibas, Laikol, and Kamystybas. Mono-dominant reed communities (Phragmites australis) are prevailed sometimes with participation of small groups of cattail (Typha angustifolia). Maximum floristic and phytocenosis diversity is characterized grass bogs in the Raim and Zhalanashkol lakes (Kamystybas lakes system). Communities with domination of cane (Scirpus lacustris, S. Tabernaemontani, S. littoralis), cattail (Typha angustifolia), reed (Phragmites australis) and rich participation of aquatic (Potamogeton crispus, Potamogeton filiformis, Ceratophyllum submersum, Batrachium eradicatum) and air-to-water (Butomus umbellatus, Alisma plantago-aquatica, Sparganium stoloniferum) macrophytes are distributed here. It is necessary to note that endemic type – Cane Kazakhstan (Scirpus kasachstanicus) is found very rarely. Relict endemic type – floating moss (Salvinia natans), which had been registered in the Red Book of Kazakhstan, was found on the Akshatau lake.

In decrease of water supply grass moors interchange by swamp meadows.

Ecological purpose – food reserve and nesting places for water fowls and reparian birds, spawning grounds and meadows, ondatra habitat, protective zone between water and ground ecosystems.

Business purpose – reed as a construction material, selective hay-fields (70-120 kintal/ha) hunting areas if required in winter time.

Swamp meadows (hydrophobic) form in the conditions of annual short-time (15-20 days) and periodic long-term flooding on meadow-swamp soils at the level of ground water of 1-2 m. They confined to negative relief forms. There is a domination of communities with dominance of reed *(Phragmites australis*), clubroot (*Bolboschoenus maritimus, Bolboschoenus compactus*). By dryness there is an increase of abundant of bluejoint (*Calamagrostis epigeios, C.*

pseudophragmites) and herbs (*Sonchus arvensis, Cirsium arvense*), and on salinized soil – annual saltwort of seepweed (*Suaeda acuminata, S. linifolia*) and red goosefoot (*Chenopodium rubrum*). Swamp meadows widely represented in flooding of Aksai-Kuandarya lake system (swamp lake Bozkol and Lakhal lake) and in the inlet of Syrdarya river.

In dryness swamp meadows interchange by current and galosere meadows and in excess surface flooding by grass moors.

Ecological function – landscape stabilizing, food reserve and habitat of wild animals (wild hog, jungle cat), nesting of riparian birds.

Business purpose – high-productive (25-45 kintal/ha) hay-fields, hunting areas.

True meadows (mesophytes) form on flat elevations with alluvial under-salted soils of meadow variety (swampy-meadow, alluvial-meadow) on the level of ground water of 1,5-3 m in the conditions of periodic short-time flooding. They are abundant locally, on washes from salts areas of bottom-lands and inlet of Syrdarya river.

Edificators are perennial long-rootstock grasses – wheat-grass (*Elytrigia repens*) and woodreed (*Calamagrostis epigeios, C. pseudophragmites*). On saline soils subdominants are halosere grass plants: very thin *Puccinellia tenuissima* and multicaulis wild rye (*Leymus multicaulis*), and in dryness penetrate виды phreatophyte motley grasses – peavine (*Glycyrrhiza uralensis*) and *Alhagi pseudalhagy*.

Ecological function – landscape stabilizing, soil-protecting, humus accumulation.

Business purpose – high-productive natural forage lands for wild and domestic animals, the most valuable by hay quality and productive (8-16 kintal/ha) hay-fields.

Desertificated meadows are seral stage of swampy and true meadows and form in stop of surface flooding and deepening of ground water more than for 3m. Predominant role in the communities take types of phreatophyte herbs: licorice (*Glycyrrhiza glabra*), (*Karelinia caspia*), (*Sphaerophysa salsula*) and camel's-thorn (*Alhagi pseudalhagi, A. kirghisorum*). Subdominants are salt-tolerant grasses (*Aeluropus littoralis, Puccinellia tenuissima, P. dolicholepis, P. diffusa*). In further dryness of the territory observed shrubs intrusion: salt tree (*Haliregimendron halodendron*), desert thorn *(Lycium dasystemum, L.ruthenicum*), and in salinization –(*Halostachys caspica*), tamarisk (*Tamarix ramosissima, T. hispida)* and seepweed (*Suaeda microphylla*).

Desertificated meadows with domination of the (Alhagi pseudalhagi) and with participation of the tamarisk (Tamarix ramosissima), marsh-beet (Limonium otolepis) are presented in the inter-ridge saddles to the south of Tasaryk settlemet in the Kuandarya lakes system. Shrubby areas of the desertificated meadows are more presented near to the Raimkol lake.

Ecological function – landscape stabilizing, habitat and food reserve of wild animals and birds.

Business purpose – selective haymaking with productivity of 5-15 kintal/ha, especially for haymaking of camel's-thorn for camels and licorice drug stock.

Halophytes meadows form on meadow salt-marshes with close deepening of ground water (1.5-2.5m) and usually take small areas. Dominate halophytes grasses: (*Aeluropus littoralis*), (*Puccinellia tenuissima, P. dolicholepis, P. diffusa*) and annotinous saltworts (*Salicornia europaea, Suaeda prostrata*).

Rarefied reed communities (Phragmites australis varacanthophylla) are found with annual glassworts (Salicornia europaea, Suaeda prostrata) and marsh-beets (Limonium otolepis). Small areas of halophytic meadows with dominated reed (Phragmites australis var.acanthophylla) has been found on the Tuschebas lakesides (Kamystybas lakes system) and the Syrdarya river outlet.

Ecological function – landscape stabilizing, habitat and food reserve of wild animals and birds.

Business purpose – selective haymaking with productivity of 5-8 kintal/ha.

Grass of tall meadows within the inspected area can be met only as small groups of massive grasses: (*Achnatherum splendens*) and giant wild rye (*Leymus racemosus*) on impounding sandy variety of Kuandarya lake system in the area of Kaukei district (Shengeldy). The chievniks (Achnatherum splendens) are too much distributed in Baskary rayoun. They play a role of sub-dominant in the composition of psammous-, halophytic-shrubby (Calligonum aphyllum, Haloxylon persicum, Tamarix hispida, T.ramosissima) communities.

Ecological function – landscape stabilizing, habitat and food reserve of wild animals and birds.

Business purpose – provision of *Achnatherum splendens*, as a construction and finishing material.

Brushwood is seral stage of swampy meadows in desertification or secondary salinization of abandoned farmlands. They also form in flooding environment in the area of irrigation mass effect and on channel edges. Overstory forms shrubs: in the bottomland of Syrdarya river-tamarisk *(Tamarix hispida, T. ramosissima),* salt tree (*Haliregimendron halodendron*) and desert thorn (*Lycium dasystemum*), and on the secondary saline lands of deposits *–Halostachys belangeriana*. Cereals (reed, bluejoint, wild rye) and annual saltwort (seepweed, petrosimony) are usually in the lower deck. Most wide areas of dumetums have been found within the Karaozek river (to the south of Karaozek settlement). Sacazan subshrub (Halocnemum strobilaceum) and saltwort (Kalidium caspicum, K.foliatum) are distributed around water bodies with salt water.

Ecological purpose – landscape stabilizing, water protecting, habitat and food reserve of wild animals and birds, recovery of soil fertility.

Business purpose – provision for shrub fuel. Hunting areas.

Tugai – flood plain forests, hardy-shrub and shrubby grasses in the area of extra-tropical deserts. During the inspection small islands of tugai with domination of desert poplar – Asiatic poplars (*Populus diversifolia*) were marked in the area of Kotankol lake (Akshatau lake system). Narrow bands of shrubby tugai with domination of sumpweed (*Salix songarica, S. wilhelmsiana*), tamarisk (*Tamarix ramosissima),* single trees of Lough Erne *(Elaeagnus oxycarpa)* with reedgrass

(*Calamagrostis pseudophragmites*) field layers partially spread in the bottomland and inlet of Syrdariya river.

Ecological purpose – landscape stabilizing, water protecting, habitat and food reserve of wild animals and birds, including many rare ones, recovery of soil fertility.

Business purpose – recreation zones, hunting areas.

Aksai lake system is represented by 7 lakes.

Tamaikol lake is surrounded by hilly-ridgy sands. Water supply is sufficient. Floristic diversity is represented by 54 species of tracheal plants (Figure 33). In the vegetation cover dominates grass moors and swamp meadows. Band width with hydromorphic vegetation fluctuates in different parts of the lake from 20 to 250 m.

Ecological variety of communities of lacustrine terrace from water line to hilly-ridgy sands with zonal psammophytic vegetation is the following: *grass moors (Phragmites australis, Typha angustifolia, Scirpus lacustris) on shallow waters ----swampy meadows (Phragmites australis, Bolboschoenus compactus) on low level ---- true reedgrasses (Calamagrostis epigeios, C. pseudophragmites) meadows on medium level ---- halosere meadows (Alhagi pseudalhagi, A. kirghisorum, Aeluropus littoralis, Achnatherum splendens) on high level ---- desertificated meadows (Alhagi pseudalhagi, Aeluropus littoralis, Artemisia nitrosa, Climacoptera aralensis) on plateau of high level.*

Heavy anthropogenic deformation of vegetation caused by overexploitation is observed.

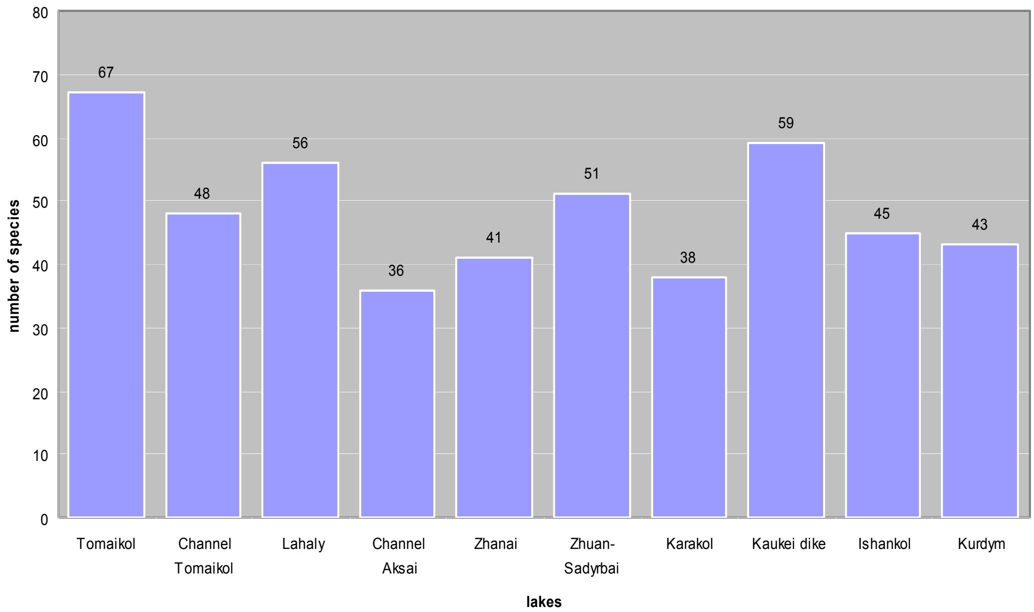


Figure 33 – Floristic diversity of Aksai lake system

Lakhaly lake is close to populated areas, therefore the vegetation is mostly transformed due to overgrazing of cattle and represented by groups of weed species *(Peganum harmala, Acroptylon repens, Salsola nitraria).* Water sufficiency is satisfactory. Grass swamps dispersed by narrow line (5-10 m) or by separate small islands on sand flats. Band width with intrazonal vegetation does not exceed 500 m, dominate brushwood of halosere shrubs *(Tamarix hispida, Lycium dasystemum, Halostachys belangeriana*). Total floristic content is 56 species of vascular plants.

Karakol-Kaukei lake is located in shallow hilly sands. On tops and slopes of sandy hills dominate communities with ephemers domination *(Carex physodes, Eremopyron orientalis),* sagebrushes *(Artemisia terrae-albae)* and psammophytic brushwood *(Salsola arbusculiformis, Eremosparton ahyllus*). In intra-hilly degradations desert grasses are abundant *(Agropiron fragile, Stipa richteriana*). Intrazonal vegetation takes considerable areas in intra-hilly degradations around the lake, the length of areas reaches in some places 2-3 km. Its dispersion is connected with volumes of overflows, which are regulated by firth system. Dominate true *(Glycyrrhiza glabra, Calamagrostis epigeios)* and halosere (*Aeluropus littoralis, Puccinellia dolicholepis, P. diffusa*) meadows. On wet salt-marshes spread groups of annotinous saltworts *(Suaeda acuminata, Salicornia europaea)*. Total quality of flora species of vascular plants is 59.

Typical ecological variety of communities of lake recesses is the following: cattail *(Typha angustifolia) grass swamps in combination with swampy meadows (Phragmites australis, Bolboschoenus maritimus) on low terrace –reedy with forbs (Phragmites australis, Sonchus arvensis) swampy meadows on low terrace --- reedgrass (Calamagrostis epigeios) true meadows on middle part of slope of bench ----brushwood shrubs (Tamarix hispida, T. ramosissima) on top part of slope of lake terrace – dersertified meadows (Alhagy pseudalhagy) on top part of slope of bench.*

Water supply is not enough. Additional water supply will increase mass with meadow vegetation.

Factors of anthropogenic disorder are haymaking and pasture. The level of anthropogenic disorder is moderate.

Lake ***Zhuan-Sadyrbai, Zhanai, Ishankol, Kurdym*** **–** located among flat hilly sands in the area of Sagyr district. By populated area closeness specified high anthropogenic transformation of vegetation around Zhuan-Sadyrbai lakes due to cattle pasture. Water supply is not enough. Band wisth with intrazonal vegetation fluctuates within 300-2000m.

For these lakes specific the following ecological variety of communities: grassy swamps *(Phragmites australis, Scirpus lacustris, S. tabernaemontani)* ---- swampy meadows *(Phragmites australis, Eleocharis acicularis)* on coast edge and shallow water---brushwood shrubs *(Tamarix ramosissima, T. elongata)* in combination with reedgrass *(Calamagrostis epigeios)* meadow glades on flat slope of bench----desertified meadows *(Alhagi pseudalhagi, Climacoptera aralensis)* on top part of slope and top of bench.

For **Kuandarya** lakes system there are descriptions of phytocoenotic diversity of three lakes - ***Akkol, Mariyam and Altynkol*** with Kuandarya channel. These lakes are regulated by firth system to increase hay-making. Water supply is not enough. All lakes surrounded by small sandy hills. The area of intrazonal vegetation around lakes among sandy mass reaches 10-12 square km, dominate halosere meadows. Floristic diversity of certain lake degradations fluctuates from 35 to 43 species (Figure 34).

Ecological variety of communities is the following: grassy swamps *(Phragmites australis, Typha angustifolia)* on shallow and narrow line along the coast --- swampy meadows *(Phragmites australis, Bolboschoenus maritimus, Juncus gerardii)* ----true gramineous *(Calamagrostis epigeios, Leimus multicaulis)* meadows --- halosere meadows *(Aeluropus littoralis, Puccinellia diffusa)* meadows---desertified meadows *(Alhagy pseudalhagy, Karelinia caspica)* in the low part of slopes of sandy mass during waterlogging.

Factors of anthropogenic disorder are haymaking and pasture. The level of antropogenic disorder is moderate.

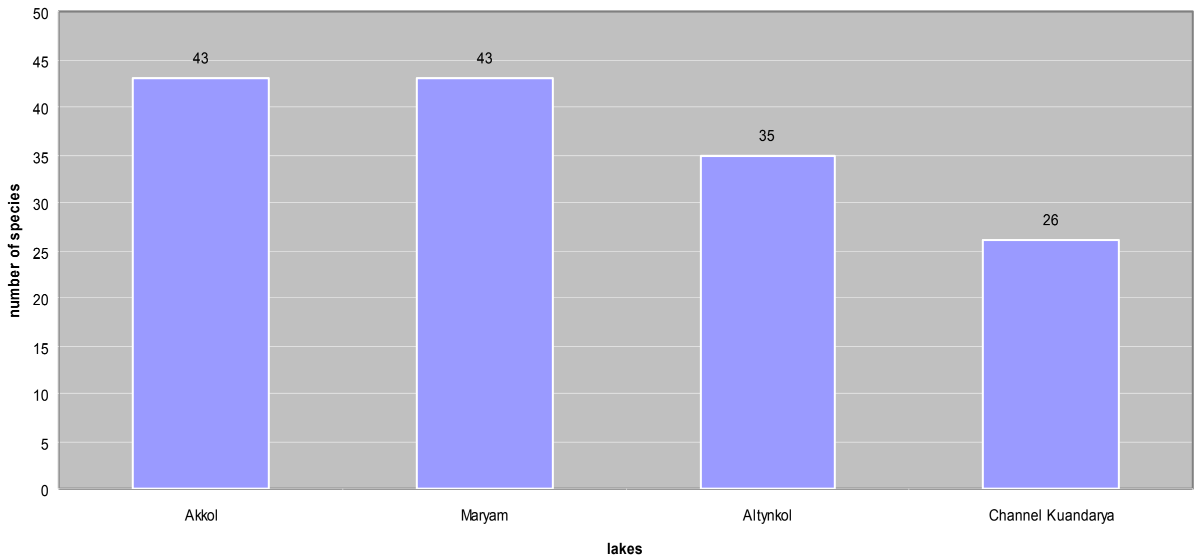


Figure 34 - Floristic diversity of Kuandarinsk lake system

In **<u>Akshatau</u>** lake system current state of vegetation of lakes Kostankol, Karakol, Akshatau, Shomishkol was studied. Floristic diversity of Akshatau lake system is in the Figure 35.

Kotankol lake surrounded by south-east part gypsiferous bald peaks in the south-east part with zonal sagebrush (*Artemisia terrae-albae*) and by perennial saltwort *(Salsola arbusculiformis, Anabasis salsa, A.aphyllum)* vegetation.

Intrazonal vegetation in different areas of the lake takes a band from 20m to 2 km; dominate swampy, true and halosere meadows. Floristic diversity represented by 47 species. Water supply is not satisfactory. Around the lake can be met small copses of Asiatic poplar (*Populus diversifolia*) – rare type included into the Red book of Kazakhstan.

Ecological variety of communities in south-east part of the lake is the following: grassy swamps *(Typha angustipholia, Scirpus lacustris, S. tabernaemontani)* on shallow water --- swampy meadows *(Phragmites australis, Bolboschoenus maritimus)* on the coast band on the low bench ---- halosere meadows *(Aeluropus littoralis, Chenopodium rubrum)* on the low bench ---- annotinous saltwort *(Suaeda acuminata, Frankenia hirsuta)* on meadow salt-marshes in the crossing band between bench and zonal gypsiferous bald peaks ---- sagebrush *(Artemisia terrae-albae)* and perennial saltwort *(Salsola arbusculiformis, Anabasis salsa, A.aphyllum)* on the slopes of gypsiferous bald peaks.

Factors of anthropogenic impact to vegetation are cattle pasture and fire. These are reasons of dissemination of weedy vegetation (*Lepidium perfoliatum, Peganum harmala, Acroptylon repens).*

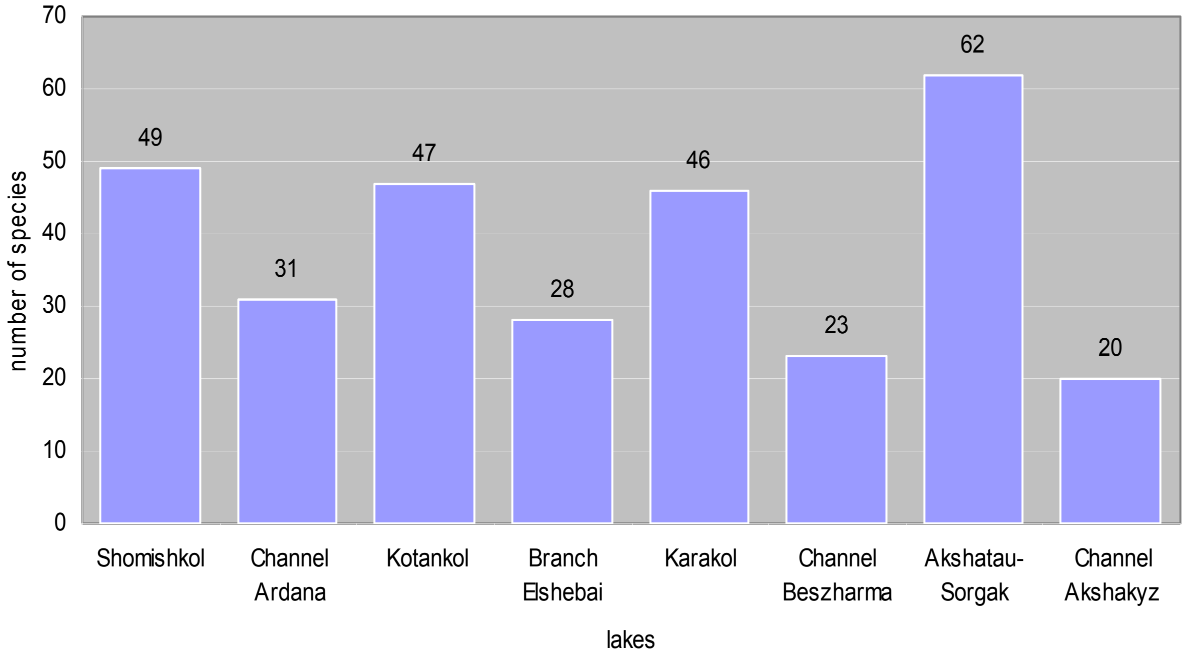


Figure 35 – Floristic diversity of Akshatau lake system

Kotankol lake surrounded by south-east part gypsiferous bald peaks in the south-east part with zonal sagebrush (*Artemisia terrae-albae*) and by perennial saltwort *(Salsola arbusculiformis, Anabasis salsa, A.aphyllum)* vegetation.

Intrazonal vegetation in different areas of the lake takes a band from 20m to 2 km; dominate swampy, true and halosere meadows. Floristic diversity represented by 47 species. Water supply is not satisfactory. Around the lake can be met small copses of Asiatic poplar (*Populus diversifolia*) – rare type included into the Red book of Kazakhstan.

Ecological variety of communities in south-east part of the lake is the following: grassy swamps *(Typha angustipholia, Scirpus lacustris, S. tabernaemontani)* on shallow water --- swampy meadows *(Phragmites australis, Bolboschoenus maritimus)* on the coast band on the low bench ---- halosere meadows *(Aeluropus littoralis, Chenopodium rubrum)* on the low bench ---- annotinous saltwort *(Suaeda acuminata, Frankenia hirsuta)* on meadow salt-marshes in the crossing band between bench and zonal gypsiferous bald peaks ---- sagebrush *(Artemisia terrae-albae)* and perennial saltwort *(Salsola arbusculiformis, Anabasis salsa, A.aphyllum)* on the slopes of gypsiferous bald peaks.

Factors of anthropogenic impact to vegetation are cattle pasture and fire. These are reasons of dissemination of weedy vegetation (*Lepidium perfoliatum, Peganum harmala, Acroptylon repens).*

On ***Karakol*** lake zonal vegetation is represented mostly by sagebrush *(Artemisia terrae-albae)* communities with ephemers *(Poa bulbosa, Eremopyron orientale.* Area of intrazonal vegetation depends on watering and the depth of lake recess channel and on the specific area its width can fluctuate from 10-30 m to 1 km. Specified diversity is represented by 46 species. Water supply is not satisfactory. Grassy swamps take up to 1/4 parts of lake water zone.

Ecological variety of communities in the west part of lake recess is the following: swampy meadows *(Phragmites australis, Bolboschoenus maritimus)* on the coast band on the low bench--- halosere gramineous meadows *(Aeluropus littoralis)* in combination with brushwood *(Tamarix ramosissima, T.hispida)* shrubs on the low bench ----desertified meadows *(Lepidium perfoliatum, Petrosimonia triandra)* on the high bench ---- perennial saltwort *(Anabasis salsa, A.aphyllum)* zonal communities on the low part of low channel. High anthropogenic disorder is caused by overgrazing.

During inspection in June 2005 of ***Akshatau*** lake considerable territory of benchs were flooded, supply was not satisfactory. Quantity of flora species of vascular plants is 62.

Ecological variety of communities is the following: *grassy swamps (Phragmites australis, Typha angustipholia, Scirpus lacustris, S. tabernaemontani, Bolboschoenus maritimus) on shallow water ---reedy (Phragmites australis) groups on the inshore banks ---- halosere meadows (Aeluropus littoralis, Suaeda acuminata) on the low terrace ---- true meadows (Calamagrostis epigeios, C .pseudophragmites) on the terrace of middle level --- shrubby (Tamarix ramosissima, T.hispida) brushwood on the top level ----groups of weedy species (Peganum harmala, Ceratocarpus utriculosus, Lepidium perfoliatum, Alhagy pseudalhagy) and zonal sagebrush (Artemisia terrae-albae) communities on flat slope of outlier unland*.

High anthropogenic disorder is caused by overgrazing.

Shomishkol lake has a considerable slope of benches. Therefore wetland vegetation is marked mostly on the coasts and lake shallows. Floristic diversity is represented by 49 species of vascular plants.

Ecological variety of communities is the following: reedy *(Phragmites australis),* on shallows and on flat areas of low benches --- reedy-annual saltwort *(Phragmites australis, Suaeda acuminata, Atriplex littoralis)* halosere meadows--- brushwood of halosere shrubs *(Tamarix ramosissima, T.hispida,Halostachys belangeriana, Suaeda physophora)* on salt-marshes---desertified meadows *(Alhagy pseudalhagy)* on meadow desertified soils. Anthropogenic disorder is moderate, main factor is pasture.

Kamystybas lake system unites 9 lakes, out of them the biggest ones are: Kamystybas, Raimkol, Zhalanashkol. Floristic diversity of Kamystubas lake system is represented in Figure 36.

Kamystybas is the biggest delta lake. Water supply is satisfactory.

It is surrounded by outliers with zonal ephemer-sagebrush (*Artemisia terrae-albae, Agropyron fragile, Poa bulbosa, Eremopyrum orientalis, Anithantha tectorum*) communities on ridges and perennial saltwort-sagebrush (*Artemisia terrae-albae, Salsola arbusculiformis, Salsola orientalis*) on slopes. The width of area with intrazonal meadow vegetation fluctuates from 30 to 600 meters. Dominate brushwood shrubs, swampy meadows and halosere meadows.

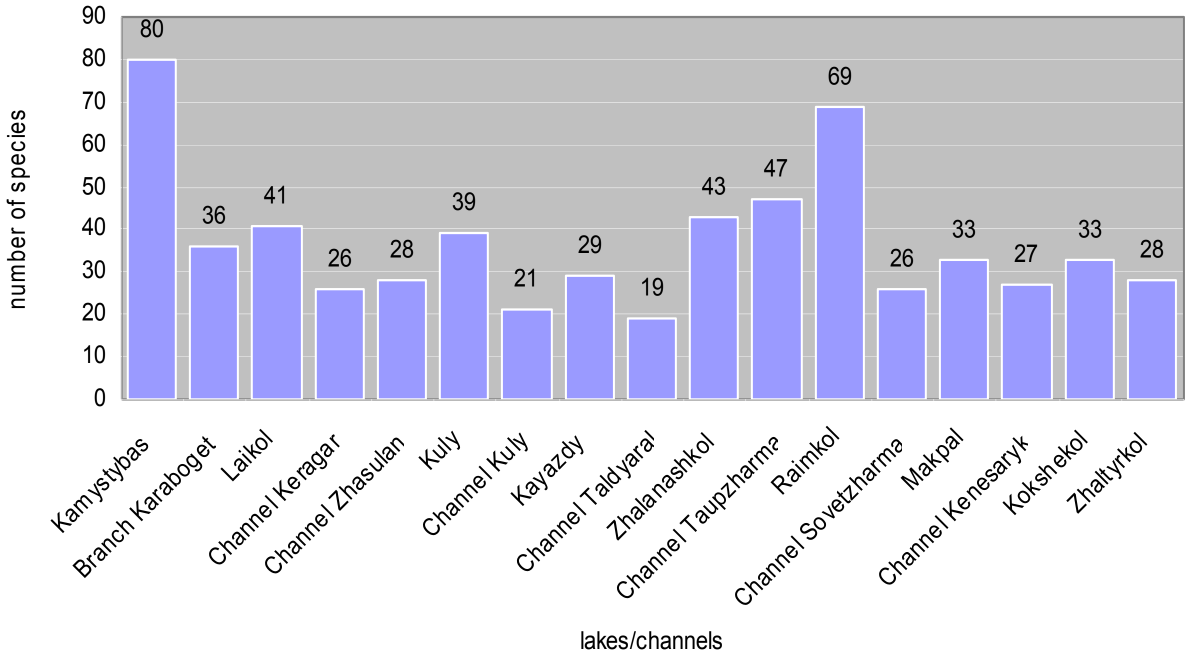


Figure 36 – Floristic diversity of Kamystybas lake system

Generalized ecological variety of communities is the follwing: reed shrubs and others haloseres (*Phragmites australis, Typha angustifolia, Scirpus lacustris, S.kazachstanicus,)* on shallows ---clubroot-reed swampy meadows *(Phragmites australis, Bolboshoenus planiculmis)*---halosere annual saltwort-sagebrush (*Salicornia europaea, Suaeda acuminata, Aeluropus littoralis)* meadows---desertified meadows *(Chenopodium album, Climacoptera brachiata, Karelinia caspia, Alhagi pseudalhagi)*--- shrubs of halosere brushwood (*Tamarix ramosissima, Tamarix hispida, Kalidium caspicum).*

Anthropogenic disorder is moderate and specified by overgrazing, plowing of bald peak slopes, recreation. Graded areas of heels and slopes of bald peaks in some places plowed and abandoned.

Vegetation cover of lake valley of ***Zhalanashkol*** differs from the previous one as it is located close to Syrdarya river bed. The general species diversity is 43 species. Ecological variety in the southward is represented by the following communities: brushwood shrubs (*Haliregimendron halodendron*) with single trees of oleaster (*Elaeagnus oxycarpa*) and herb-gramineous (*Leymus multicaulis, Glycyrrhiza uralensis*) meadows on channel bank of Syrdarya river--- gramineous – brushwood (*Aeluropus littoralis, Tamarix ramosissima, T.hispida, Lycium* *ruthenicum*) ---desertified meadows (*Climacoptera brachiata, Suaeda linifolia, Artemisia schrenkiana*) with dwarf semishrubs (*Halocnemum strobilaceum, Kalidium foliatum*) on salt-marshes.

In the north part of ***Zhalanashkol*** lake **vegetation is represented by narrow band**, microzonal ecological variety is the following: *grassy swamps (Phragmites australis, Typha angustifolia, Scirpus lacustris, S.kazachstanicus) on shallows ----annual sappy saltwort (Salicornia europaea, Suaeda acuminata) and halosere meadows (Aeluropus littoralis) ----brushwood shrubs (Tamarix hispida, Lycium ruthenicum, Halostachis belangeriana, Suaeda physophora).*

Strong anthropogenic disorder is specified by pasturing.

The vegetation of ***Raimkol*** lake by content and structure is different, dominate grassy swamps on shallows and halosere meadows with brushwood on the coast. Floristic diversity is represented by 69 species. Ecological variety of communities is the following: *grassy swamps (Phragmites australis, Typha angustifolia, Scirpus lacustris, S.kazachstanicus) on shallows --- annual sappy saltwort (Salicornia europaea, Suaeda acuminata) meadow salt-marshes--- thinned shrubs of hyper halosere of subshrubs (Halocnemum strobilaceum, Kalidium foliatum)---- desertified annual sappy saltwort meadows (Climacoptera lanata, Petrosimonia triandra) in combination with sagebrushes of halosere shrubs (Tamarix hispida, Halostachis belangeriana*) *on salt-marshes --- impassable shrubby tugai (Tamarix ramosissima, T.hispida, Lycium ruthenicum, Haliregimendron halodendron)* with participation of single trees of oleaster *(Elaeagnus oxycarpa*) on channel bank of Syrdarya river.

Strong anthropohenic disorder is caused by pasturing and fire.

Lakes ***Makpal, Kokshekol, Zhaltyrkol*** located in flat-hilly sands. Water content of Makpal lake is good enough. On shallows dominate reedy (*Phragmites australis*) grassy swamps, which through narrow band of gramineous herb (*Calamagrostis epigeios*, *Glycyrrhiza uralensis)* meadows intrachanged by zonal psammophytic vegetation *(Calligonum aphyllum, Dendrostellera arenaria, Artemisia terrae-albae).* Floristic diversity is represented by 33 species of vegetation.

<u>Left bank seaside lake system includes</u> 4 lakes: Zhilandy, Zhuldyz, Kartma, Bayan. Floristic diversity of Left bank coastal lake system accounts from 30 to 41 species (Figure 37).

Vegetation is represented by thinned halosere reedy- *Aeluropus* meadows in combination with brushwood shrubs (*Tamarix ramosissima, T.hispida, Haliregimendron halodendron*). On dried bottom of lakes heavy beds of sprouts of tamarisk *(Tamarix ramosissima)*. Water well holes form heavy beds of sappy saltworts *(Salicornia europaea, Suaeda acuminata)* and seepweeds. Strong anthropogenic disorder is caused by pasturing and disastrous water shortage.

Hydromorphic vegetation of lakes ***Laikol, Kul, Kayazd*** take slopes of benches with the length from 500 to 2000m.

Generalized ecological variety of communities is the following: reedy and cattail *(Phragmites australis, Typha angustifolia)* grassy swamps on shallows---- swampy meadows *(Salicornia europaea, Scirpus lacustris)* on low bench----

samphire- *Aeluropus* and clubroot *Aeluropus* halosere meadows *(Salicornia europaea, Aeluropus littoralis, Bolboschoenus maritimus)* of average level ---- brushwood (*Tamarix ramosissima, T.hispida, T. laxa*) shrubs in combination with desertified meadows (*Climacoptera brachiata, Karelinia caspia, Alhagi pseudalhagi)* on bench slope----halosere shrubby (*Halostachis belangeriana)* communities on salt-marshes on slope of outlier hills.

Anthropogenic disorder is moderate and specified by pasturing and fire.

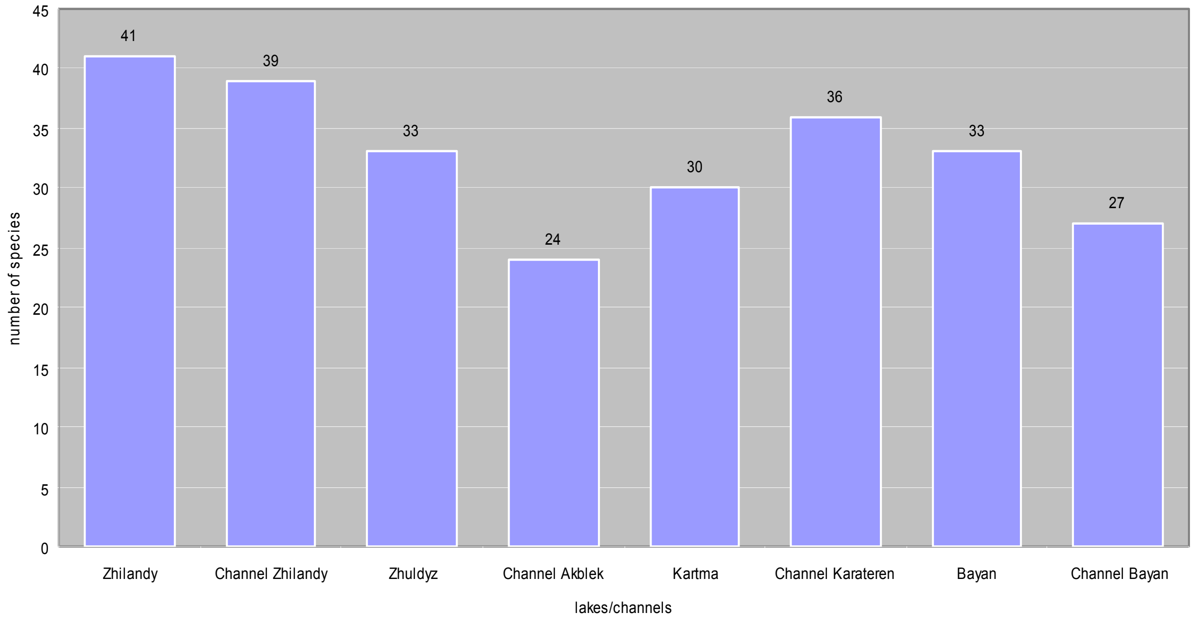


Figure 37 – Floristic diversity of left bank Seaside lake system

Right bank Seaside lake system includes 5 lakes: Domalak, Karahsalan, Taur, Tushebas, Sarteren. Water supply is unsatisfactory. Floristic diversity is given in the Figure 38.

Tushebas lake is elongated to north-south and surrounded by hilly-ridgy sands with zonal vegetation. In the south part the lake confines to the damp valley of Syrdariya river. Species diversity in this part of the lake is 53 species.

Ecological variety of communities is the following: cattail-reedy and clubroot-reedy *(Phragmites australis, Typha angustifolia, Scirpus lacustris, Bolboschoenus maritimus)* grassy swamps ---- thinned reedy *(Phragmites australis)* swampy meadows on low bench---- true gramineous *(Calamagrostis epigeios)* meadows----halosere *(Aeluropus littoralis)* meadows--- brushwood (*Tamarix ramosissima, T.hispida, T. laxa, Lycium ruthenicum*) ---- zonal sagebrush-psammophytic brushwood *(Calligonum aphyllum, Amregimendron argenteum, Artemisia terrae-albae)* communities on hills and top parts of sandy ridge.

By area dominate swampy and halosere meadows.

Sarteren lake is one of the closely located to the coast of Aral sea. During the study period water supply was highly unsatisfactory.

Water-swampy vegetation is almost not available. Vegetation cover is highly rare. Dominate halosere meadows on meadow salt-marshes. Ecological variety of the communities is the following: single examples of annual saltworts (*Salicornia europaea, Suaeda acuminata*) and reed (*Phragmites australis)*---thinned sprout of tamarisk (*Tamarix hispida)*---desertified meadows (*Climacoptera aralensis, Karelinia caspia)*----zonal ephemer-white-land-sagebrush *(Poa bulbosa, Artemisia terrae-albae)* with psammophytic brushwood (*Calligonum aphyllum, Eremosparton aphyllum, Amregimendron argenteum)* communities on hilly sands----heavy brushing of tamarisk *(Tamarix laxa)* phytogenous hills.

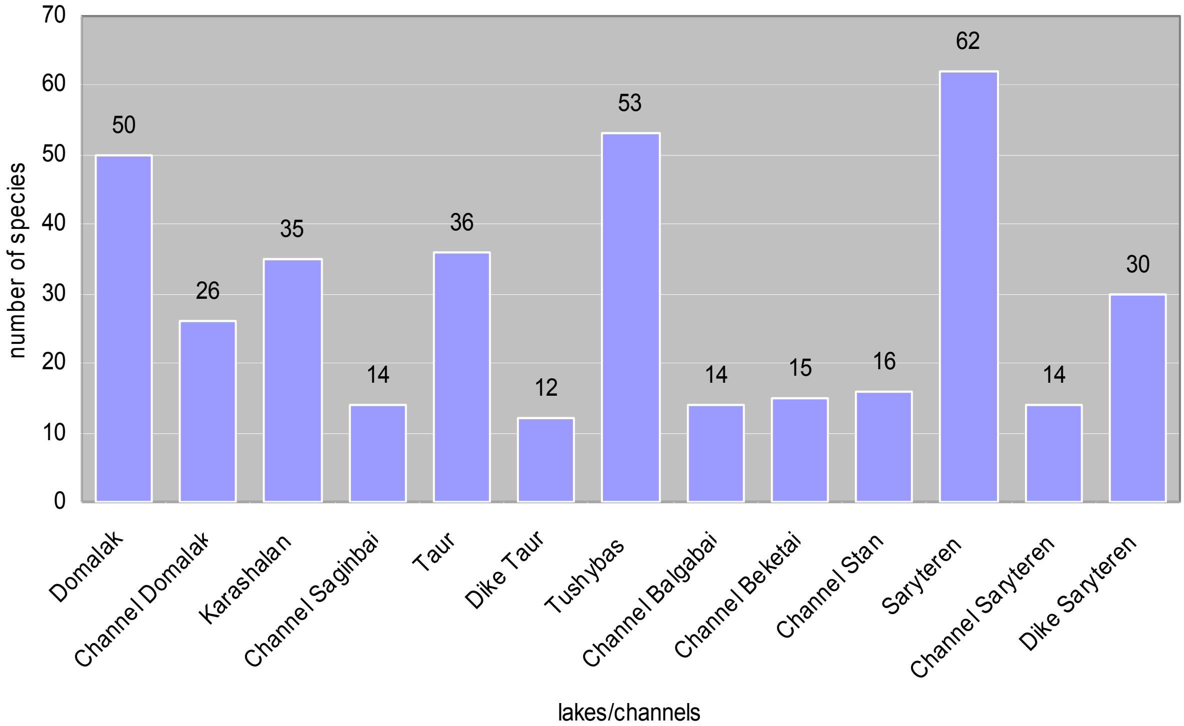


Figure 38 – Floristic diversity of right bank seaside lake system

Botanic diversity of vegetation cover on dam locations in the bottom of ***Syrdarya river***– characterizes the description of vegetation of two profiles in the right bank (***Karashalan***) and left bank ***(Avandelta)***. Floristic diversity on these dam locations is 71 and 78 species (Figure 39).

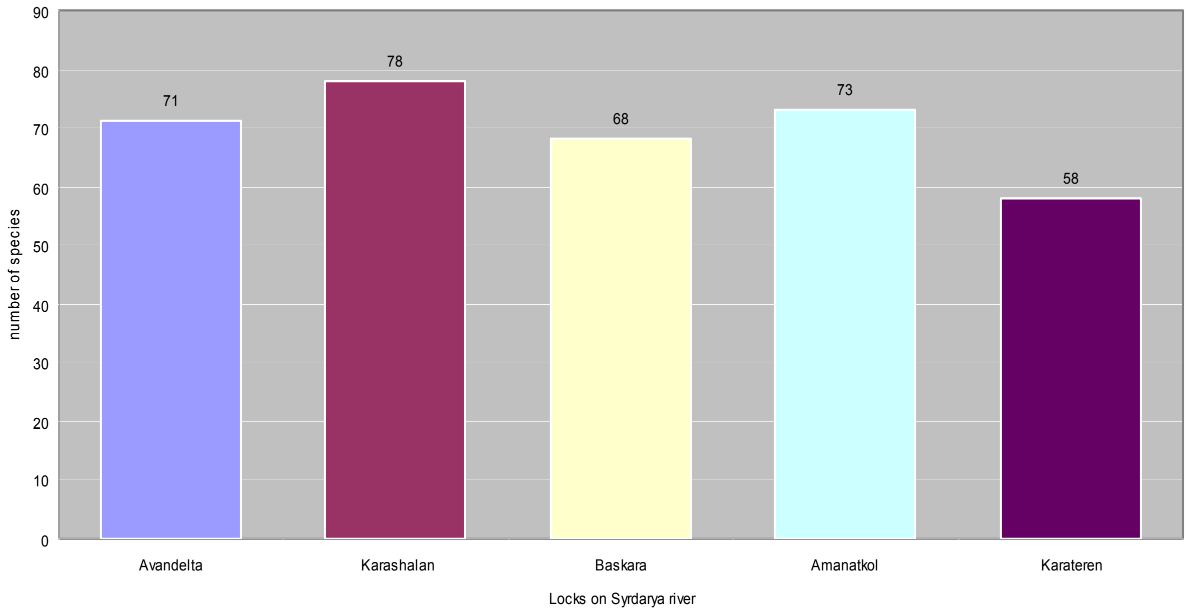


Figure 39 - Floristic diversity of vegetation in the bottomland of Syrdarya river

Phytocoenotic diversity of vegetation in ***left bank*** in Syrdarya bottom is represented by the communities forming the following ecological variety: herb-gramineous *(Calamagrostis epigeios, Elytrigia repens,Glycyrrhiza uralensis*) true meadows in combination with brushwood (*Haliregimendron halodendron, Salix soongorica, Tamarix ramosissima*) with oleaster *(Elaeagnus oxycarpa)* tugai on channel bank of Syrdariya ----annual saltwort-herb-reedy *(Climacoptera lanata, Phragmites australis, Zygofyllum oxyanum, Dodartia orientalis)*---desertifying meadows in combination with shrubs of halosere brushwood (*Tamarix hispida, Suaeda microfilla, Nitraria sibirica)*.

Ecological variety in the ***right bank*** of Syrdarya bottom is the following: hardy-shrub *(Haliregimendron halodendron, Salix soongorica, S. Alba, Elaeagnus oxycarpa)* tugai on channel bank----gramineous (*Calamagrostis epigeios Sphaerophyza salsula*) true and halosere (*Limonium gmelinii, Aeluropus littoralis*) meadows---brushwood of halosere shrubs *(Tamarix hispida, Halostachys belangeriana, Nitraria sibirica)*.

Floristic diversity varies on lakes of lake system and ranges of Syrdarya river from 11 to 80 species, which specified by the diversity of ecological conditions of habitat, mainly by water sufficiency.

By damping reduction in the direction from water edge to the main shoreside, on lake benches can be noted regular change of vegetation communities displaying conditions of water supply. Their generalized spatial temporary ecological variety is the following: grassy swamp on shallow water and swamp soils of the coast at the level of ground water no more than 0,5 m. ---- swampy meadows at the level of ground water 0,5-1,5 m. On meadow-swampy soils ---- true grass and gramineous and grass meadows on swampy-meadow and alluvial-meadow soils and halosere Aeluropus and Puccinelia meadows at the level of ground water 1,5-2,5 m. on meadow salt-marshes ---- desertified meadows at the level of ground water 2,5 -3,5 m. on desertified hydromorphic soils ---- shrubs brushwood at the level of ground water 3,5-7,0 m on common salt-marshes.

2.2 Piscifauna of the Aral Sea and lakes systems

All large lakes and hole lakes systems in the delta of the Syrdarya river have fish industry importance. Good lakes flooding and supporting of water level have positive impact to efficiency of natural fish reproduction. Fish capacity of the lakes depends on catch volume too. Analysis of data on all lakes systems shows that in spite of its inadequate water availability in 90-s the catch and fish capacity were sufficiently high. So, for example, the most catches for the last 15 years in the Kamystybas lakes system were fixed in 1992 and 1993, appropriately 448 and 446 tons. The same situation is in all lakes systems, except Aksai and Kuandarya lakes systems. Catch and fish capacity were relative stable during last 15 years in the Aksai system, with minor fluctuation by years, but in the Kuandarya system on the contrary, since 2000 catch was risen sharply, that connected with increasing of water inflow in these systems during last five years.

Reduction of catch volume and fish capacity of most lakes systems are connected with not only its water availability, but with overfishing during the hard years for country economic and practically total lack of fish seeding measures. Official returns on poaching catch are missed. But, answering data received from fishermen confirm that for ten years (1995-2005) the poaching catch far exceed licensed catch. It is especially visibly in the lakes systems located in more densely populated rayons, big cities and highways. These are lakes of the Kamystybas and Akshatau lakes systems, Tuschibas lake and other lakes of right and left banks. Distant and difficult of access Aksai and Kuandarya lakes systems have minor fluctuation of catch and fish capacity by years.

Receives data on dynamics of catch and fish capacity show high potential of all lakes with fish production importance on conditions of its stability hydrology regime and standard operation of hydrotechnical facilities (channels, locks, etc.).

Aksai lake system includes next lakes: Tomaikol, Lahaly, Zhanai, Zhuban-Sadyrbai, Karakol, Ishankol, Kurdym.

14 fish species is composition of piscifauna in Aksai lake system.

Native species: Aral wild carp, Aral roach, Oriental carpbream, Goldfish, Aral asp, Zander, River perch, Pike, Sabrefish, and Sheat-fish.

Exotic species: Grass carp, White silver carp, Colored silver carp, and Amur snakehead.

Table 18 - Dynamic of fish yield in Aksai lake system, ton

Fish species	Years										
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Wild carp	3	1	3	2.4	1.5	2.7	2.6	2.5	2	2.1	3
Grass carp, silver carp	7	5	7	4	5	6.5	6.5	6	4	5	4
Goldfish	4	4	4	4.5	3	3.8	4	4	2	3.5	2
Carpbream	2	1.5	3	3	2	2.4	2.3	2	1.5	2	4
Zander	1	1.2	1.5	1	0.8	1.5	0.8	0.6	1	1.5	3
Asp	1	1	1	0.8	0.6	1	0.6	0.4	0.8	0.5	2
Other species	5	1.3	5	2.3	2.1	5.1	1.7	2.2	2.7	4.4	8
Total	23	15	24.5	18	15	23	18.5	17.7	14	19	26

Table 19 - Feet base of Aksai lake system

Years	Group of organisms			
	Zooplankton		Macrobenthos	
	Quantity specimen/m^3	Biomass mg/m^3	Quantity specimen/m^2	Biomass gr/m^2
2004	252570	1049.0	200	3.28
2005	332524	1358.8	340	16.6

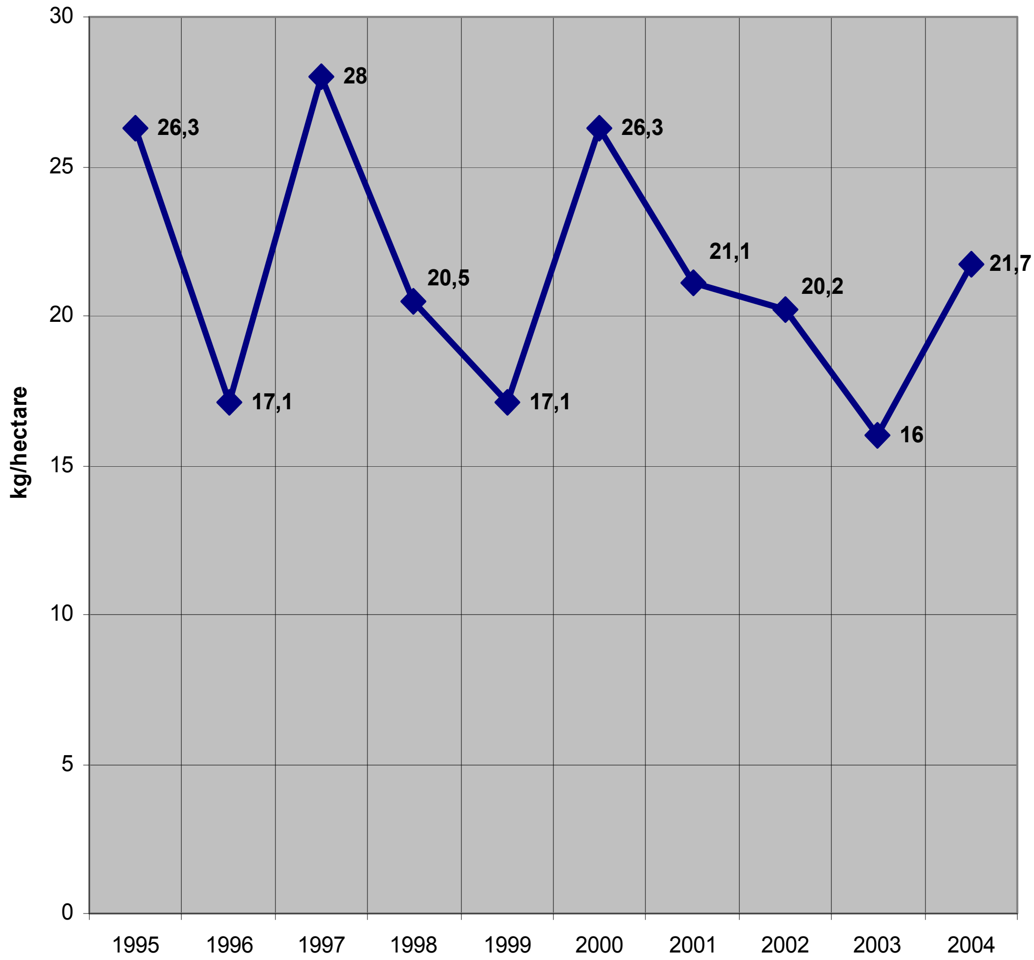


Figure 40 - Productivity of fish in Aksai lake system

Kuandarya lake system includes next lakes: Akkol, Maryam, Altynkol.

16 fish species is composition of piscifauna in Kuandarya lake system.

Native species: Aral wild carp, Aral roach, Oriental carpbream, Goldfish, Aral asp, Turkestan orfe, Zander, River perch, Pike, Sabrefish, Sheat-fish, and Aral white-eye.

Exotic species: Grass carp, White silver carp, Colored silver carp, Amur snakehead.

Table 20 - Dynamic of fish yield in Kuandarya lake system, ton

Fish species	Years									
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Wild carp	5	6.1	4.5	6	3.1	7.8	3.2	3.5	6.4	4
Grass carp, Silver carp	12	18.5	18	11	6	24	12	16	20	17
Goldfish	8	17	12	7	5.5	16	9.8	10	15	11
Carpbream	9	5	8	8	3	12	7	6	8	5
Zander	4	4	5	3.5	1.7	10	4	3.5	7	4
Asp	3	3	4	2	6	8	3	4	5	3
Other species	4	15.4	12.5	4.5	8.1	9.7	11.5	13	11.6	14
Total	45	69	64	42	28	87.5	50.5	56	73	58

Table 21 - Feet base of Kuandarya lake system

Years	Group of organisms			
	Zooplankton		Macrobenthos	
	Quantity specimen/m^3	Biomass mg/m^3	Quantity specimen/m^2	Biomass gr/m^2
2004	336345	1860.7	813	2.13
2005	177054	3393.7	1853	38.1

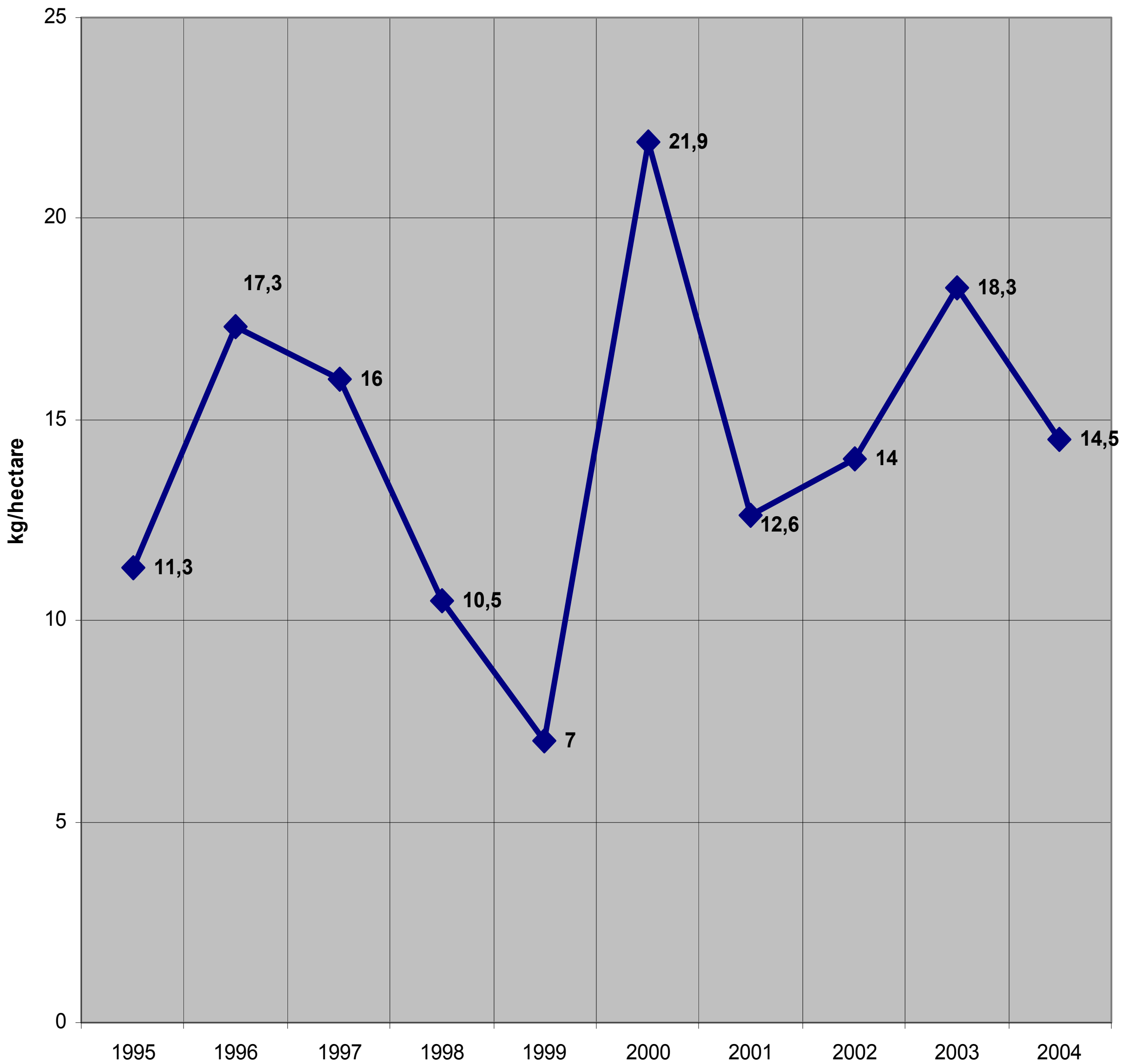


Figure 41 - Productivity of fish in Kuandarya lake system

Kamystybas lake system includes next lakes: Kamystybas, Laikol, Kayazdy, Zhalanash and Raim.

16 fish species is composition of piscifauna in Kamystybas lake system.

Native species: Aral roach, Oriental carpbream, Aral wild carp, Redeye, Sabrefish, Goldfish, Aral asp, Zander, River perch, Pike, Aral white-eye, Ruff, and Sheat-fish

Exotic species: Amur snakehead, Grass carp, and Silver carp

Table 22 – Dynamic of fish yield in Kamystybas lake system, ton

Fish species	Years												
	1991	1992	1993	1994	1995	1996	1997	1999	2000	2001	2002	2003	2004	2005
Roach	231	146	193	82	52,7	101,7	38	1	6,7	8,5	0,4	22,4	-	15
Zander	12	34	45	5	24,1	40,0	35	3,0	5,2	24,7	0,6	1	1	5,75
Wild carp	6	27	8	-	10,0	-	6	7,2	4,7	5,5	0,4	1,5	1	3,95
Sheat-fish	-	4	1	-	1,5	0,1	3	1,3	1	0,3	0,1	-	-	-
Carpbream	15	45	60	18	33,6	40,6	10,5	101	238	106,1	19,4	31,7	24,62	20

Pike	36	36	33	9	11,3	8,2	1,2	5,0	14,2	2,4	0,1	1,5	-	1
Silver carp	8	8	1	18	2,3	0,9	0,53	-	0,4	0,8	-	1,5	-	-
Asp	-	-	-	-	-	-	-	3,0	3,5	0,3	-	-	-	-
Snakehead	-	1	2	-	0,4	-	-	0,05	2,2	0,4	-	2,7	-	-
Sabrefish	1	9	1	-	0,1	-	4	-	-	0,3	-	-	-	-
Small fry	52	123	128	90	95,8	128,5	231	0,8	1,3	9,5	2,0	-	-	-
Goldfish	-	5	11	-	-	1,0	-	-	1,1	0,3	-	-	-	-
Carp	-	-	-	-	1,4	-	-	15,0	9,9	4,7	-	-	-	-
River perch	4	10	3	1	0,9	1,1	-	-	-	-	-	-	-	-
Other species	-		-	-	-	-	-	-	-	-	-	-	85,2	7,97
Total	357	448	486	213	234,1	322,1	329,1	137,3	288,2	168,8	23,0	62,3	111,82	53,67

Notice: Official date about catch for 1999 – 2004 years is lower, than real situation. Interview shows real catch is higher, than figure listed above. During those years accounting of catch is unsatisfactory.

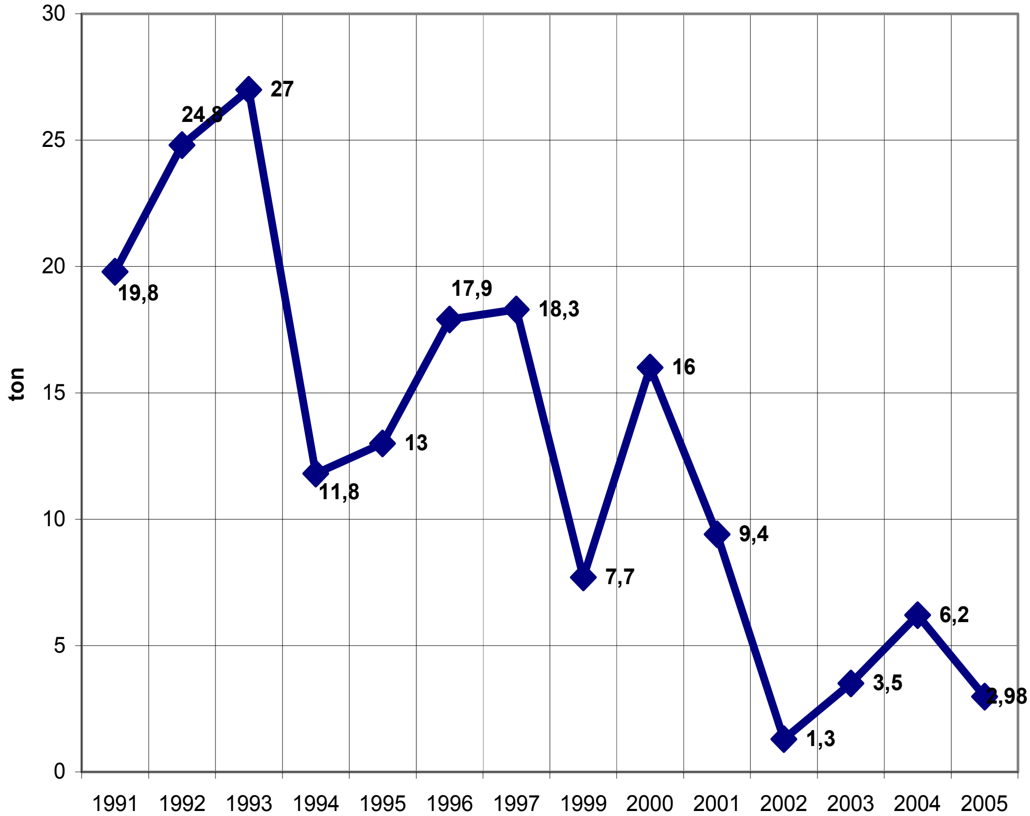


Figure 42 - Productivity of fish in Kamystybas lake system

Table 23 – Feet base of Kamystybas lake system.

Years	Group of organisms			
	Zooplankton		Macrobenthos	
	Quantity specimen/m^3	Biomass mg/m^3	Quantity specimen/m^3	Biomass gr/m^3
2004	205416	525.8	196	4.36
2005	253869	807.5	444	5.34

Akshatau lake system includes next lakes: Akshatau, Sorgak, Karakol, Kotankol and Shomishkol.

16 fish species is composition of piscifauna in Akshatau lake system.

Native species:Aral roach, Oriental carpbream, Aral wild carp, Redeye, Goldfish, Turkestan orfe, Aral asp, Zander, Pike, Ruff, and River perch.

Exotic species: Silver carp, Grass carp, Amur snakehead

Table 24 - Dynamic of fish yield in Akshatau lake system, ton

Fish species	Years										
	1991	1992	1993	1994	1999	2000	2001	2002	2003	2004	2005
Roach	59	52	59	51.4	0.4	2.8	0.5	1.0	49.3	-	15
Zander	17	5	15	6.8	3.4	1.3	1.2	0.3	1	-	0.5
Wild carp	5	11	8	21.5	3.5	2.7	1.6	-	0.5	-	1
Sheat-fish	-	-	-	2.0	0.5	0.1	1.2	-	-	-	-
Carpbream	87	37	44	27.2	90	28	33	27.9	6.2	22	4
Pike	24	10	5	34.1	1.4	4.0	0.9	-	-	-	-
Silver carp	10	-	-	-	-	-	0.3	-	-	-	-
Asp	-	-	-	-	1.2	1.0	0.2	-	-	-	-
Snakehead	1	2	1	3.9	-	-	-	-	2	-	-
Sabrefish	12	1	1	15.5	-	-	-	-	-	-	-
Small fry	4	94	16	4.4	-	0.4	5.1	-	-	-	-
Goldfish	2	6	1	6.1	-	0.3	-	-	-	-	-
Carp	-	-	-	-	12	4.3	4.3	-	-	-	-
River perch	9	-	-	-	-	-	-	-	-	-	-
Other species	-	-	-	-	-	-	-	-	-	25	32
Total	253	218	152	173.4	112.4	45.9	47.1	29.2	59	47	52.5

Notice: Official date about catch for 1999 – 2004 years is lower, than real situation. Interview shows real catch is higher, than figure listed above. During those years accounting of catch is unsatisfactory.

Table 25 - Feet base of Akshatau lake system.

Years	Group of organisms			
	Zooplankton		Macrobenthos	
	Quantity specimen/m^3	Biomass mg/m^3	Quantity specimen/m^2	Biomass gr/m^2
2004	266729	884.3	272	5.83
2005	190552	12011.1	495	3.45

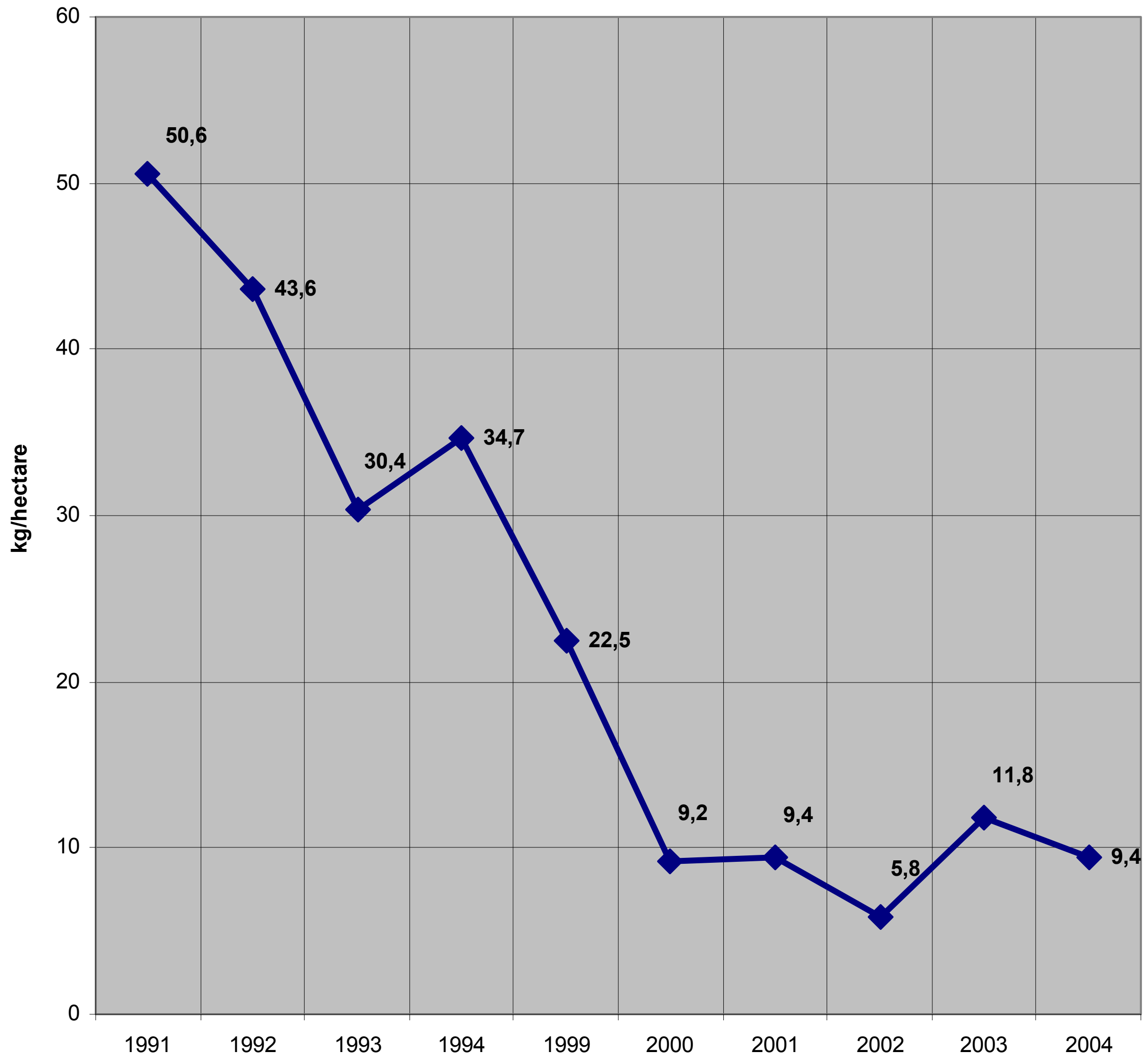


Figure 43 - Productivity of fish in Akshatau lake system

Rightbank and Leftbank lake systems. All lakes in leftbank lake system are dry. Tuzshy lake is still exist in rightbank lake system, the others are dry on lower part of river. After launch Aklak hydro development all lakes in leftbank and rightbank lake system will be restored.

8 fish species is composition of piscifauna in Lake Tuzshy.

Native species: Aral roach, Oriental carpbream, Aral wild carp, Redeye, Goldfish, River perch, Pike.

Exotic species: Amur snakehead

Table 26 - Dynamic of fish yield in Lake Tuzshy, ton

Fish species	Years										
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Carpbream	7.0	8.0	12.0	15.0	20.0	10.0	5.0	0.5	4.0	3.0	2
Aral roach	13.0	11.0	6.0	12.0	8.0	6.0	4.0	7.5	2.5	4.0	2
Wild carp	10.0	12.0	10.0	5.0	6.0	2.0	2.5	0.5	0.5	0.3	1
Snakehead	2.0	3.0	2.0	1.0	3.0	3.0	2.0	1.0	0.5	0.4	-
Pike	8.0	4.0	3.0	6.0	12.0	2.0	2.0	1.0	2.0	0.7	1
Other species	3.5	2.5	3.5	5.5	4.0	1.5	0.5	2.5	1.5	1.8	1
Total	43.5	40.5	36.5	44.5	55.0	24.5	15.0	13.0	11.0	10.2	7

Notice: Official date about catch for 2000 – 2004 years is lower, than real situation. Interview shows real catch is higher, than figure listed above. During those years accounting of catch is unsatisfactory.

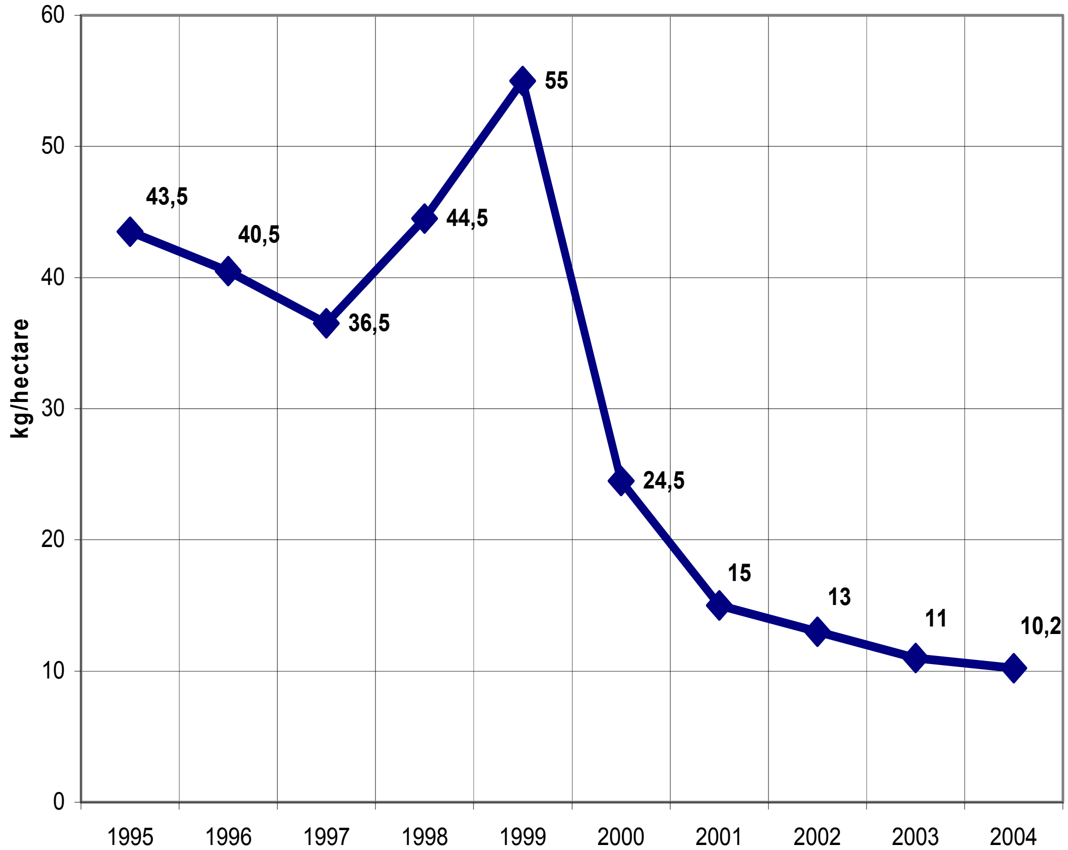


Figure 44 - Productivity of fish in Lake Tuzshy

Table 27 - Feet base of Lake Tuzshy.

Years	Group of organisms			
	Zooplankton		Macrobenthos	
	Quantity specimen/m^3	Biomass mg/m^3	Quantity specimen/m^2	Biomass gr/m^2
2004	672177	1726.9	200	1.93
2005	55383	2138.2	840	13.9

Table 28 - Quantity of stocked fry from Kamystybas fish farm (Koszhar and Tastak area)

Launch years	Annual fry (thousand specimen)				Biennial fry (thousand specimen)			
	Carp	Silver carp	Grass carp	Carp	Silver carp	Grass carp	Carp	Total
1991	4100	3200	-	7300	514	-	-	514
1992	1530	300	50	1880	121	13	10	144
1993	809	895	187	1891	614.2	-	-	614.2
1994	1780	920	250	2700	370	70.2	40	480.2
1995	1791	890	350	3031	310	30	17	357
1996	1007	943	161	2111	146.6	46.9	25	218.5
1997	2485	431	676	3592	32.2	90.2	30	152.4
1998	1667	-	453	2120	12.9	57.7	23.4	94
1999	2006.4	540	290	2896.4	73.3	-	-	73.3
2000	2677.6	956	300	3933.6	-	-	-	-
2001	1999.3	1000	505	3504.3	-	-	-	-
2002	5868.8	3943.2	2192.7	12004.7	-	-	-	-
2003	6600	4000	1400	12000	-	-	-	-
2004	7648.5	4234	1533	13415.5	-	-	-	-
2005	7300	5200	1500	14000	-	-	-	-

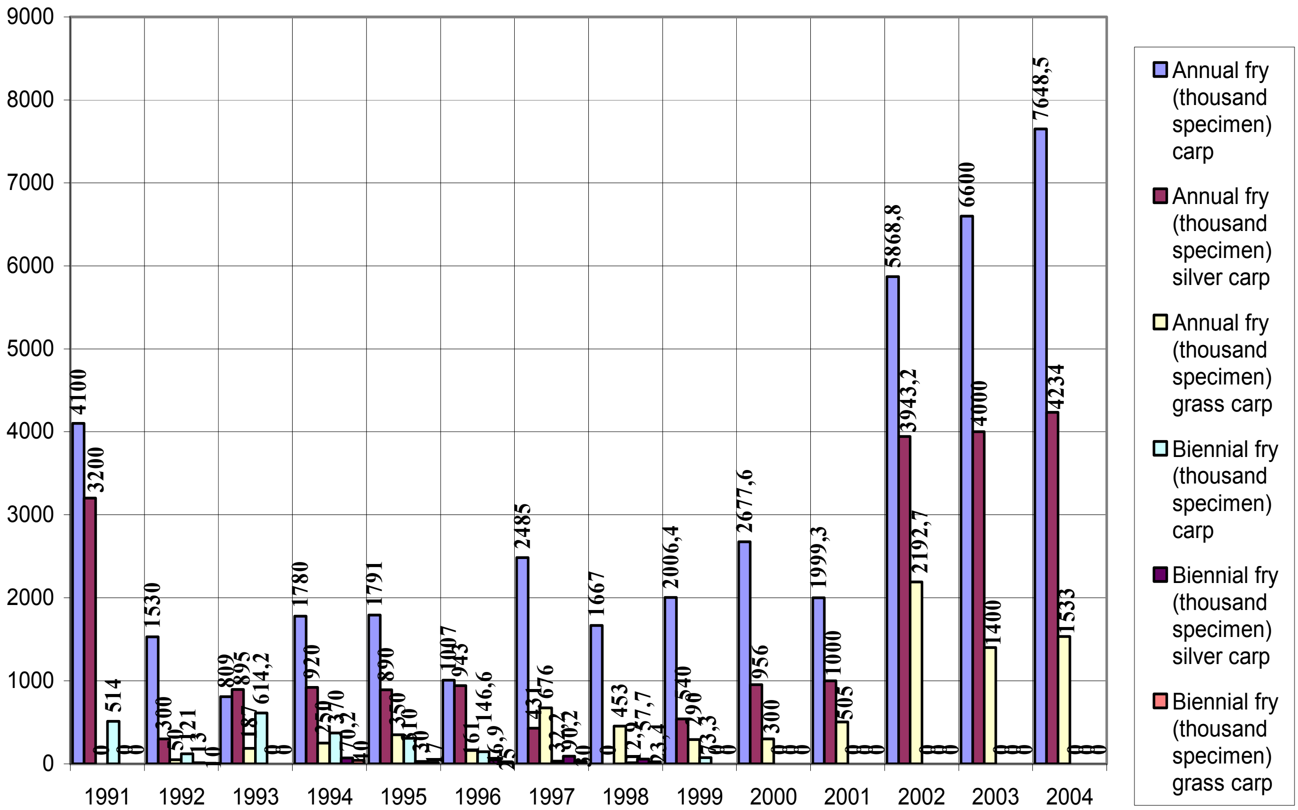


Figure 45 - Quantity of stocked fry from Kamystybas fish farm (Koszhar and Tastak area)

Spawning-ground is filled up satisfactory during last years (2001-2005), because much water in Syrdarya. However, water regulation device absent on

Balgabai, Beketai, Stan channels, it is occur to water flow back to river from lakes in dry years. This situation has negative influence to fill up of spawning-ground and effective natural breeding of value industrial fish species.

Early spawning fishes: aral roach, river perch, pike. Usually they are spawning in Mart-April. All fish species listed below spawn in Lake Tuzshy.

Late spawning fishes: oriental carpbream, aral wild carp, redeye, goldfish, amur snakehead. Usually they are spawning in May-June. All fish species listed below spawn in lake Tuzshy.

Official date about illegal catch is absent. But asking fishermen proof that during last ten years (1995-2005) illegal catching is higher than legal catch.

Effective natural breeding depend from good filled up lakes and support optimal water level in spawning-ground. If natural breeding of fish is growth, were better species diversity and yield grow.

Lake Tuzshy is need saving for fishery. Restore all lakes in leftbank and rightbank lake systems. Water regulation devices should be built on the Zhylandy, Akblek, Karateren, Bayan, Stan, Saryteren working channels for support optimal water level in lakes. After conducting restoration measures of lakes yearly should launch annual fry of carp, grass carp, silver carp in lakes from Kamystybas fish farm.

On the basis of Tuzshy, Saryteren, Domalak, Zhuldyz lakes should create cultural trade fish farm in the future. In this case breeding of all industrial fishes would be managed by human.

2.3 Ecology requirements of the natural objects and resource-valuable types of flora to water quality, regime and volume

Preservation of landscape and biological diversity of wetlands in drought zone can be successfully achieved in recovery of ecological conditions, close to natural ones. These are a rational dispersion of limited water resources of Syrdarya river, organization of optimum hydrological regime during regular superficial flooding of single mass, recovery of soil fertility (due to alluvium deficiency) and creation of optimum water-salt regime of biotopes.

The prime result of irrigation is mineralization of river water. The reason of it is “back” water, (pinching out ground water into the river bed, aggregated salts from irrigating data), “drained” water and drainage water. These types of water contain big amount of salt, toxic chemicals and others. River water with high concentration of salt causes salinity and alkalinisation of soil and serves as a factor of vegetation halosere. Fall of level of Aral Sea led to increase of general mineralization of water reservoir.

Moreover, the investigation has defined the environmental requirements to water quality and quantity, and water delivery term to the lower components of the natural complex.

2.3.1 Requirements for reed

Effective development of arundinaceous monocoenosis is possible in certain conditions:

- in water zone on shallow water – water salinity is to be no more than 20%, it is required a compliance of water quality standards in terms of pollution of Persistant organic pollutions, heavy metals, oil products, pesticides and others;
- reeds forming in negative relief positions on soils of swamp rows and used as a construction material, necessary to be watered by surface water for 30-35 days in spring and summer annually;
- reeds for grass usage (callow) necessary to flood annually for 10-15 days in spring and for 10-20 days in summer. Level of ground water shall not be lower of 2,0 m. In case of water deficiency, the periodicity of surface flooding shall not exceed 3-4 years.

2.3.2 Requirements for haymaking

In natural hydrological regime in the bottomlands of Syrdarya, considerable mass of meadows were developed. Lack of surface flooding in 2-4 years causes abrupt changes in the content, structure and productivity of meadow communities and in 10-12 years of no flooding regime complete interchange of species composition occurs and meadow vegetation modifies into low-valued low-productive annotinous saltwort coenosis. Provision of optimum hydrological regime for meadows formation implies purposive water supply by engineering facilities for certain mass of delta plain in spring and summer period. For grasslands of high food value (true meadows on alluvial meadow soils) it is necessary annual surface flooding for 10-15 days (salt washing) from the end of April up to end of June for the period no more than 20 days;

Level of ground water no more than 2,5-3,0 m in summer period. Level of ground water should not be deeper than 2,5 m. In case of water deficiency the flooding periodicity shall not exceed 2-3 years.

2.3.3 Requirements for tugai

Tugai forests in the bottomland of Syrdarya (Aral and Kazalinsk regions) spread along river channel bank and delta ducts at the distance from 300 m to 3 km. They formed at the level of ground water 1,2 – 3,0 m and created favorable microclimate of the territory, lowering temperature and increasing air humidity. Tugai areas from the beginning of 60th decreased from 21,3 thousand ha to1,3 thousand ha, that is almost to 20 times. In lack of surface flooding more than 5 years tugai get desertified. In the areas where preserved natural tugai areas, it is necessary to create micro protecting areas with full prohibition of cattle grazing, clear cutting and fire fighting measures. Minimum ecological requirements to retain and recovery of tugai complexes in the delta are arrangement of regular or periodic (no less than 1 time in 3 years), surface flooding in the period of end of

May till the beginning of July during seed maturation of trees (osier, oleaster, Asiatic poplar) for the period no more than 20 days.

The main result of anthropogeneous change of river flow is intrachange of annual flow of water consumption. In natural conditions the main capacity of their annual flow of (70-80%) is in spring-summer time. In behalf of hydroenergetics admitted winter water flush, which ecological role is assessed as very negative. Such overflows can cause formation of considerable frzils by area, which facilitates degradation of hydromorphic communities – cause seeds loss in the soil, water supply of soils does not happen, perish green trees and brushwood. Therefore, one of the ecological requirements for optimum development of tugai is prevention of flooding in autumn and water discharge in winter.

Together with dehydration of biotopes increase pasture load to vegetation communities, which leads to breakdown of vegetation state and its degradation. Mainly vegetation communities are sensitive during vegetation. Therefore for tugai complexes in pit and delta of river it is necessary to prohibit pasturing in spring and summer period and limit pasturing in autumn.

2.3.4 Requirements for landscapes

In landscape structure of wetlands reasonable balance of ecosystems diversity, types of soils and vegetation are to be kept to furnish stations and food reserves by wild animals, spawining grounds and breeding areas for fish, nesting sites for birds. Analysis of space images showed that mostly favourable ratio of hydromorphic and deserted landscapes observed in water capacity coming to delta no less than 5.5 bln km3. Taking into consideration that for impoundment of Small Aral it is necessary no less than 3 bln km3 per year, total capacity of coming water should be no less than 8.5 bln km3 per year.

2.3.5 Requirements on conservation of musquash habitat

Musquash was acclimatized in Priaral in 1948, 120 bions were put into delta. Manufacture of fells was carried out since 1951, maximum development was in 1965 (68 thousand fells), and by 1976 due to drying of musquash lands the production was stopped. In connection with the limited capacity of water supply to delta observed massive musquash kill. Presently some recovery of musquash population is observed in delta lake but there is no production. To increase musquash population it is necessary to recover regime of water supply close to natural (in spring and summer) and prohibit winter spill water.

2.3.6 Requirements on conservation of hunting areas

Presently hobby hunting for water fowl, wild hog, roe deer and tolai-hare are carried out in limited quantities. For conservation of hunting areas it is necessary to preserve habitat of floating and reparian birds (lakes, grassy swamps, swampy meadows), wild hog (reed swamps, swampy meadows) and roe deers (tugai, brushwood shrubs) true and halosere meadows. For it required annual (grassy swamps, swampy meadows) and periodically (true meadows, tugai, brushwood shrubs) surface flooding to keep species composition and productivity of areas.

3 SOIL CONDITION OF THE SYRDARYA DELTA

3.1 Soil transformation of the present Syrdarya river delta

Development of irrigation along with regulating the Syrdarya run-off as well as the increase of water withdrawal and irretrievable water consumption in its upstream and middle reach has led to acute deficiency of water resources, antropogenic aridization and soil transformation in its downstream.

Until the Syrdarya run-off was regulated, the dynamics of the delta landscapes was determined by the river regime which was mostly active during the flood seasons. Such circumstances facilitated soil and groundwater desalination and prevented the significant accumulation of toxic salts. Since the run-off flow was regulated, the Syrdarya seasonal floods have stopped and the delta valley water regime has changed. The landscapes started drying and turning into deserts, which caused degradation of the ecosystems, decrease of the area of the hydromorphical soils, as well as diminishing of their fertility and their salification. With regard to the extremely aridic climate, the delta territories' top-soil transformation depends on the rate of the hydrologic and hydrochemical factor change, the soil irrigation conditions, and the location in the system of the river run-off. Most of the changes have occurred in the landscapes of the present Syrdarya delta.

The decrease of run-off, the termination of seasonal flooding, and drying of the Aral sea-bed dramatically changed the soil formation conditions and substantially impacted the soil ecological environment in the present Syrdarya delta. As a result of the change of climate factors, the climate aridity has grown up, while the contrast between the delta and the adjoining deserts that existed earlier has decreased. Since the decrease of seasonal floods, the delta has lost its position as an accumulation area of solid and biogeneous run-off, the growth conditions for hydrophilic plants have deteriorated, and the differences in hydrologic conditions at various surface profiles that existed earlier have diminished.

In the 50's of the last century (before the regulation), the Syrdarya river's water mineralization ranged from 0.2 to 0.5 g/l. Since the beginning of irrigation development, its water mineralization has been constantly growing and has reached 1.5-1.8 g/l; in the dry years of 1974-1977, it even reached 3 g/l. Later on, the mineralization sometimes decreased to 1 g/l. At the same time, the ionic content in the water has transformed from being carbonate calcic to being sulphate-sodium. By the way, the analysis of the water sample taken from the Syrdarya river in June 2005 in the area of the Amanotkel river crossing showed 1.7 g/l.

Since commencing the river run-off regulation, the groundwater level in the areas of earlier floods has lowered to 4-5 m. Its seasonal fluctuation has reduced and the hydrological regime subtype turned into the irrigation and the off-run regime subtype. Decrease in the groundwater level is usually followed by the increase in mineralization that mostly has the sulphate-chloride and natrium-magnesium constitution. The maximum groundwater mineralization reached 50 g/l.

Since termination of floods, wide spread juncaceous plant communities have disappeared in the most of the delta territory and have been replaced with mesoxerophilic weeds in the basins between river beds and with the thinned weeds of the haloxerophilic groups on the basin margins. On the natural levees, herb meadow and grass vegetation has been replaced with halomesoxerophilic annual plants. Among the halophytes, the insigek has appeared in the vegetation of watersheds. The change of the vegetational species has caused rapidly decreased the biomass accumulation and the transformation of ash constituent cycle, i.e. the decrease of calcium ingress and the increase of natrium and chlorine ingress into soil. There is no doubt that this has negatively impacted the soil formation processes in the delta.

The drying and the desertification of the hydromorphical soils of the present Syrdarya delta is followed with intensification of the salification processes. Depending on the occurred hydrologic conditions, the intensity of the salt accumulation process varies in the soils of different areas of the delta. Thus, salification degree in the 0-100 cm meadow soil layer has risen twice and in the swamp soil layer has risen three times. The degree of soil salification has risen rapidly on the contact line with the irrigated fields where crusted puffed saline soil (solonchaks) is often formed.

All the above has aggravated the already poor meliorative condition of the Kazaklinsk irrigation zone which was initially caused by the complex meliorative environment of the present Syrdarya delta, i.e. close location of the confining bed that has shallow hollow profile. Deterioration of the soil meliorative environment has been caused not only by the territory aridization but also by the human economic activities. Because of the Soviet collective farms reorganization and transfer of the agricultural land to private ownership, transition to the primitive nomadic agriculture has occurred. This has naturally impacted the soil condition. Rice cultivation on the saline-land without any engineering systems is leading to reallocation of the salt mass and the secondary soil salification.

Hense, the change of the direction of the soil water-salt regime caused progressing salification and local salt reallocation in the most part of the present Syrdarya delta. Salt location has moved from the watersheds to the river basin and the watercourse territories as well as to the natural levee slopes and pothole margins. Overall, in the dried and desertifying territories, the salification process dominates over desalination.

In the present Syrdarya delta, the degree of the soil transformation can be assessed based on the results of the comparison of the research materials of different years. The soil area calculation was made on the soil maps at a scale of 1:200000 as of the years 1956, 1969, 1990, 2001 and 2005. Table 29 shows that for the period of 1956 to 1969, saline land area has increased by 10 thousand ha, and alluvial-meadow saline soil area increased from 22 thousand ha to 40 thousand ha. Therefore, it can be concluded that a lot of soil was transformed to saline soils. Dramatic changes in the soil structure have occurred as the result of aridization. For example, the 1969 research revealed significant area of desertifying hydromorphical soils that were not indicated earlier on the map as of 1956. Later on, these soils have turned into takyr-type soils. For 34 years (from 1956 to 1990), the takyr-type soil area has grown up for almost three times.

Since 1990, the antropogenic process of aridization has slowed down, which is well illustrated with the comparison of the data as of the years 1990 and 2001. The area of the takyr-type soils and the desert hydromorphic soils has increased insignificantly for the some period.

Table 29 – Soil transformation process in the present delta of the Syrdarya river and dried-out Aral Sea bed (1956 – 2005)

Soil	Area, thousand ha									
	1956		1969		1990		2001		2005	
	ha	%	ha	%	ha	%	ha	%	ha	%
Gray-brown and solonetz	117.1	18.3	117.4	18.3	117.5	9.3	115.1	7.5	145.5	8.6
Takyr	24.3	3.8	31.4	4.9	67.6	5.3	68.9	4.5	80.3	4.8
Alluvial-meadow and alluvial-meadow tugai	66.4	10.3	13.3	2.1	5.9	0.5	5.5	0.4	6.3	0.4
Alluvial-meadow saline soil	22.3	3.5	40.2	6.3	8.0	0.6	7.7	0.5	8.2	0.5
Alluvial-meadow desert soil	-	-	12.0	1.9	0.8	0.1	0.9	0.1	2.9	0.2
Swamp-meadow	-	-	25.4	3.9	1.8	0.1	0.8	0.1	13.3	0.8
Swamp-meadow dried saline soil	-	-	50.4	7.8	61.6	4.8	61.8	4.0	109.7	6.6
Swamp-meadow desert soil	-	-	0.5	0.1	11.7	0.9	11.8	0.8	19.0	1.1
Swamp and meadow-swamp	228.1	35.6	156.4	24.4	33.0	2.6	30.8	2.0	36.4	2.2
Rice-swamp	-	-		-	30.0	2.4	28.7	1.9	29.6	1.8
Swamp and meadow-swamp dried saline-soil	-	-	2.9	0.5	111.7	8.8	114.4	7.5	99.9	6.0
Meadow-swamp desert soil	-	-	-	-	6.6	0.5	8.2	0.5	9.4	0.6
Coastal	-	-	-	-	109.9	8.7	164.3	10.7	311.1	18.6
Sandy soil	68.3	10.7	68.6	10.7	144.9	11.4	145.5	9.5	143.2	8.6
Saline-land	94.5	14.7	104.5	16.3	430.0	33.9	755.3	49.3	644.5	38.5
Lakes	19.3	3.1	18.0	2.8	127.8	10.1	12.3	0.8	11.2	0.7
TOTAL	640.3	100.0	641.0	100.0	1268.8	100.0	1532.0	100.0	1670.5	100.0

An interesting situation is revealed through the comparison of the data of the years 2001 to 2005. For this period, the area of the present Syrdarya river delta and adjoining dried seabed increased by 137.5 thousand ha as a result of the Big Aral Sea drying process. The area of automorphic soils increased mainly due to joining of the continental parts of the former Barsakelmes island. The solonchak area decreased by 110 thousand ha due to flooding of the part of the former dried Big Aral seabed to the south from Kokaral Dike (dam) and transformation of marsh saline land of light texture into coastal salinized soils. The increase of the coastal soil area for two times has been caused, firstly, by the increase of the dried seabed area and, secondly, by the transformation of marsh saline land, as it was mentioned above.

The growing water intake of recent years into the present Syrdarya delta has positively effected the hydrmorphical soil condition. The alluvial-meadow soil area on the levees increased by 1.3 thousand ha, while regular swamp and meadow-swamp soil area on the right coast in the Kokkol tract region and on the left coast in the region of Aksai lake system increased by 5.6 thousand ha.

Desertification is usually followed by diminishment of the hydromorphical soil fertility. The major components determining soil fertility are humus and nitrogen; and the major role in forming the latter is played by biogenic factors.

The change of the soil fertility factor is related to soil degradation resulting from aridization and decreasing intake of the sediment and the biogenic run off during the of change the hydrologic regime. The change of vegetation species and their productivity in the course of aridization also affected the content of humus and other fertility components in the soil. Along with regulation of the river runoff, humus accumulation through the root mass decay has reduced. The desertification process has been followed by substantial loss of organic substances. In the meadow-type soils within the 0-50 cm layer, the humus loss is 25%, in the swamp-type soils it is up to 30% of the initial stock (Table 30).

In the course of desertification, physical, hydro-physical and physicochemical properties of the hydromorpical soils significantly deteriorate. In the desertifying soils, the ingress capacity usually goes down and the exchangeable cation ratio in the soil absorbing complex changes. In particular, the content of the absorbed calcium decreases, while the content of the absorbed magnesium increases.

The man-made aridization around Aral has also affected the transition zone between the delta plain and the dried-out Aral sea-bed that is mainly covered with automorphic, half-hydromorphic and halomorphic soils. All those soils are to some degree salinized. Swamp-meadow dried soils are less saline. The salt content along the whole soil profile does not exceed 1%. Takyr saline soil resulting from transformation of the takyr solontchak is more salinized. The salt content in the shallow peofiles is approximately 2%. The crusted puffed saline soil is highly salinized, and its shallow horizons contain 7% of salt.

The dried area of the Aral sea adjoining the present Syrdarya delta is three times larger than the delta area, and 75% of its soil consists of solochaks (the marsh, the costal, typical, etc.). This area also has coastal soils with various degree of salinization and sometimes with the 30 cm thick overblown sand cover as well as sandy soils.

Table 30 - Humus and nitrogen content in the soil of the present Syrdarya delta within the 0-50 cm layer (numerator is measured in % and denominator is in t/ha)

Soil	Humus		Total Nitrogen	
	Average	Margins of fluctuation	Average	Margins of fluctuation
Alluvial-meadow	1.51 98.7	0.95-2.08 61.3-136.4	0.08 5.2	0.06-0.10 4.5-5.9
Alluvial-meadow tugai	0.91 78.0	0.74-1.26 41.4-114.4	0.06 4.7	0.05-0.07 4.0-6.0
Alluvial-meadow Saline-land	0.81 63.2	0.68-0.96 42.0-84.5	0.05 3.9	0.04-0.06 3.5-4.5
Swamp-meadow	1.36 92.2	0.04-1.77 72.4-113.3	0.09 5.8	0.07-0.11 5.0-6.6
Swamp-meadow dried	1.06 78.0	0.92-1.20 68.3-86.0	0.08 5.5	0.06-0.10 4.1-6.0
Swamp-meadow desert soil	0.97 69.5	0.81-1.27 58.3-89.6	0.06 4.6	0.05-6.08 3.8-5.1
Meadow-swamp	1.86 116.7	1.44-2.44 92.3-156.5	0.13 7.9	0.10-0.15 5.2-10.8
Meadow-swamp dried Л	1.71 110.7	0.97-2.22 69.8-148.2	0.12 7.6	0.08-0.14 6.4-8.9
Meadow-swamp desert soil	1.31 89.9	0.97-1.47 69.1-98.8	0.09 4.8	0.06-0.12 3.5-6.8
Muddy-swamp	2.15 136.4	1.96-3.13 123.8-203.1	0.11 6.4	0.09-0.14 5.7-6.9
Rice-swamp	1.61 102.5	1.27-1.96 80.7-124.3	0.11 6.1	0.08-0.13 5.0-6.7
Saline-land typical	0.70 47.8	0.51-0.95 33.7-62.0	0.05 3.3	0.04-0.06 2.9-3.5

Overall, the Aral sea-bed soils have low content of humus and nutrients, low biological activity, high content of carbonates and alkalis, low absorbing capacity, irregular structure, and high content of dust fractions in its texture. With regard to domination of highly salinized soils and thinned vegetation, all these indicators show that the soils of the observed territory are irresistible to the anthropogenic load, and agricultural development of this area requires large capital investments.

The critical condition of the Aral coastal top-soil is aggravated by the intensification of erosive and deflationary processes. The erosive and deflationary processes are in turn mainly resulting from the climatic and geomorphological conditions. Low precipitation level along with wide air temperature fluctuation and substantial number of days with strong winds provide suitable environment for rapid soil deflation in the Aral coastal area, especially in the course of its aridization.

In the investigated area, wind erosion occurs in the form of deflation of the sandy and the automorphic soils, dust storms and deflation of solonchaks, while water erosion occurs only locally on the slopes of the Tertiary remains. Besides natural factors (soils yielding to deflation, high wind activity, etc.), the anthropogenic factor also plays significant role in the development of soil deflation. Thus, unregulated cattle pasturing (excessive load), cutting down shrub vegetation, and disorderly off-road vehicular traffic intensify deflation processes that change the structural composition, the bulk weight and the content of humus and thus cause soil degeneration and its loss of fertility.

3.2 Soil investigation of the Syrdarya delta

The studies were conducted in the west part of the Aral Sea basin within Kazaly district of Kyzylorda Oblast. The investigation targeted the soils around the 160 km long regime soil profile (Birlik – Aral Sea) which covers the left bank of the present Syrdarya delta, the transition zone between the present delta and the dried-out Aral sea-bed, as well as the dried-out Aral sea-bed itself. The basic (supporting) cuts where the soil samples for analysis were taken during the three-year period were made in the following types of soil:

1) swamp-meadow dried saline soil (section №3);
2) meadow-swamp dried saline soil (section №7);
3) rice-swamp soil (section №6);
4) solonchak turning into takyr (section №5);
5) coastal soil with overblown sand cover (section №4).

Since section №6 was filled with water during the field studies in 2005, the results of the monitoring investigation of the rice-swamp soil are based on the data as of 2003 and 2004. The route soil investigation targeted the whole territory of the present Syrdarya delta and the dried-out Aral sea-bed, since their top-soil has undergone man-made transformation to the utmost.

The top-soil of the present Syrdarya delta includes the alluvial-meadow, the swamp-meadow, and the meadow-swamp soils with various degrees of drying, desertification and salinization, as well as the meadow and the typical solonchaks and the rice-swamp soils.

The alluvial-meadow soils have been formed on the slopes of the Syrdarya river's levee, on the slopes of the second degree flat watersheds under grass-arundinaceous vegetation which includes shrubs (salt tree, tamarisk) and saltwort, as well as on the highly salinized soils. The soils consist of the stratified alluvium mainly composed of loam. The 20-30 cm thick layer of humus is quite visible, and the humus content varies within 2-4%. The amount of the absorbed foundations is 13-20mg-equiv./100g of soil. The soil absorbing complex is saturated with calcium (60-80%) and magnesium (8-30%). The reaction of the soil solution is of alkaline type (pH 8,2-9,0).

The profile structure of the swamp-meadow soils combines both the swamp (to a lesser degree) and the meadow soil properties. The swamp-meadow soils take an interim position between the meadow-swamp soils and the soils of positive profile elements (the alluvial-meadow soils). They therefore combine two types of the properties: the meadow and the swamp ones. The alluvial-meadow soil properties dominate in the upper layer of the profile, and the meadow-swamp soil properties dominate in the lower layer. It is worth to note that in the shallow horizons they have higher humus content which drops down in the deeper horizons.

By the salinity level, the swamp-meadow soils vary within the large scale from basically non-saline to highly saline. In the drying soils, salts are usually located in the shallow horizons. The saline soils with the salt accumulation peak in the shallow horizon dominate (Table 31). The 0-50 cm layer accumulates up to 40% of the salts that are contained in the two-meter thick strata. Salt allocation in the soil cut profile is directly related to its texture, and the least salinized are the horizons with heavy texture.

Table 31 - Dynamics of the chemical characters of the swamp-meadow saline dried soil (section №3)

Sample depth cm	Humus, %		Total nitrogen %		Gross forms: Phosphor, %		Gross forms: Potassium, %		Salt sum %		pH		CO_2 %	
years	2003	2005	2003	2005	2003	2005	2003	2005	2003	2005	2003	2005	2003	2005
0-10	3.19	3.07	0.17	0.15	0.16	0.10	2.60	2.25	3.744	1.388	7.9	8.0	7.4	7.7
26-36	0.58	1.05	0.04	0.07	0.14	0.12	2.34	2.27	0.471	0.155	8.5	8.3	7.9	8.7
37-47	0.83	1.00	0.05	0.05	0.12	0.10	2.34	2.17	1.362	1.716	8.3	8.3	9.9	9.2
50-60	0.37	0.80	0.02	0.03	0.10	0.09	2.42	2.32	0.252	0.932	8.8	8.6	6.6	8.7
70-80									1.340	1.502	8.5	8.6	9.8	9.8
120-130									0.320	0.867	8.7	8.7	8.1	8.2

Variously mineralized (1-30 g/l) ground water is bedding in the 1-2 meters depth. Where ground water level goes down to 3 meters, the soils turn into the drying type; low productive reed grows specifically in such soils. Where ground water level goes down over 4 meters, the soils turn into the dried and the drying types. On these soils, the reed remains undersized and thin.

The monitoring investigation demonstrates that the swamp-meadow drying saline soil has a tendency of siccation of the soil profile that results in insignificant loss of humus and nitrogen, especially in the shallow horizons, and insignificant change of pH and CO2. In such circumstances, the most flexible are water-soluble salts. The data as shown in Table 31 and the Figure 46 clearly demonstrate that within two years the saline profile of the swamp-meadow drying saline soil has substantially decreased due to precipitation. While in 2003, the upper 10 cm soil layer contained the 3.744 % amount of salts, in 2005, their content reduced to 1.388 % and at the same time it rose in the deeper horizons. With this regard, the most mobile among anions are chlorides and among cations are calcium and magnesium.

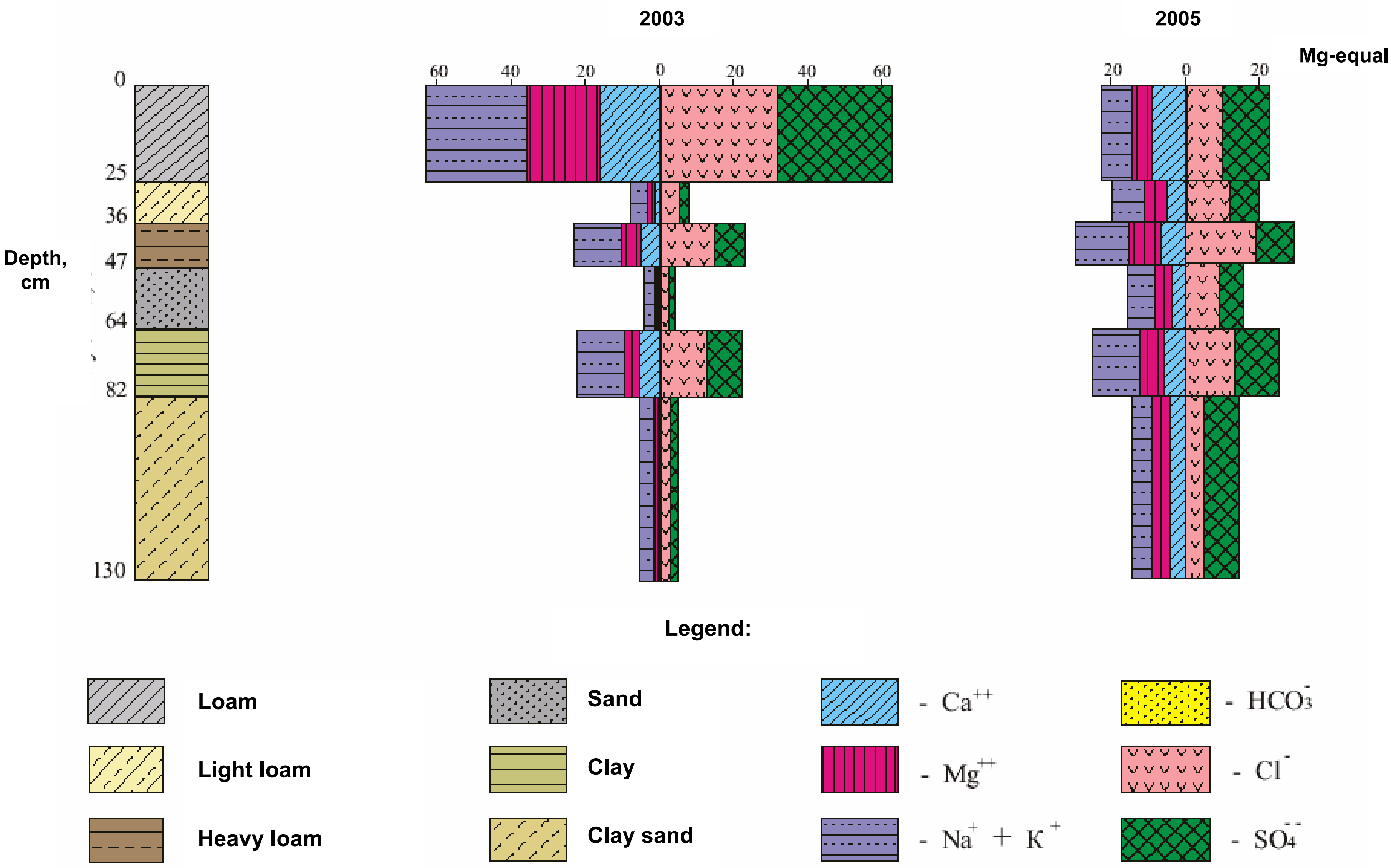


Figure 46 - Dynamics of the chemical characters of the swamp-meadow saline dried soil (section №3)

The meadow-swamp soils are formed under reed in the wide flat basins between river beds and on the lower parts of wavy watershed slopes around lakes. Depending on the salinization and aridization degree, the reed in such areas is mixed to the larger or lesser extent with the halophyte and the xerophyte vegetation. The soils have a stratified structure and primarily heavy texture (loam and clay). Wide variation of the humus content in the shallow horizons of the meadow-swamp soils ranging from 1.5-2.0% (desertifying types), 3-4% (dried types) to 5-6% (regular types) stipulates variation of the total amount of the absorbed foundations ranging from 12 to 30mg-equiv./100g of soil. The major role in the soil absorbing complex is played by calcium (50-85%) and magnesium (10-25%). The soil solution reaction is the alkaline one (pH 8.1-9.0). The meadow-swamp soils are salinized to some extent (0.3-1.3%).

At arid years when there is no natural flooding, substantial part of the delta territory is drying. The ground water level goes down to 3-4 and more meters, which is to the large extent facilitated by the high transpiration ability of the reed.

The meadow-swamp dried soil profile has specific features such as siccation of shallow horizons, vertical fissures, and lumpy structure. The latter is also specific for the soils with heavy texture.

According to the monitoring investigation, the meadow-swamp drying saline soils also undergo the aridization pressure. Similar to the swamp-meadow drying saline soils, they have been losing humus, regular nitrogen, gross forms of phosphorus and potassium (Table 32). There have not been noticed visible changes in the content of pH and CO2.

Table 32 - Dynamics of the chemical characters of the meadow-swamp saline dried soil (section №7)

Sample depth, cm	Humus, %		Total nitrogen, %		Gross forms				Salt sum, %		pH		CO_2, %	
					Phosphor, %		Potassium, %							
Years	2003	2005	2003	2005	2003	2005	2003	2005	2003	2005	2003	2005	2003	2005
0-10	3.41	2.61	0.20	0.16	0.22	0.11	2.66	2.27	1.146	0.788	8.1	8.2	5.4	5.6
15-25	1.03	0.95	0.08	0.07	0.20	0.12	2.63	2.21	0.745	0.673	8.8	8.8	9.4	9.8
30-40	1.16	1.33	0.08	0.08	0.17	0.12	2.56	2.25	0.601	0.749	8.8	8.8	8.4	8.1
45-55									0.635	0.551	8.7	8.8	8.9	10.0
70-80									0.514	0.466	8.7	8.7	11	10
120-130									0.598	0.886	8.6	8.5	10	9.6

Similar to the swamp-meadow drying saline soils, the most mobile in the meadow-swamp drying saline soils are water-soluble salts. While 2003 the upper layer had 1.146% of salts, by 2005 their amount had reduced to 0.788%. The Figure 47 shows that despite the drying, the salts along the whole profile are quite mobile. Thus, salt accumulation in the below part of the examined soil profile is caused by the impact of the ground water which flows from the surrounding irrigated territories and from the long-distance channel Birkazan.

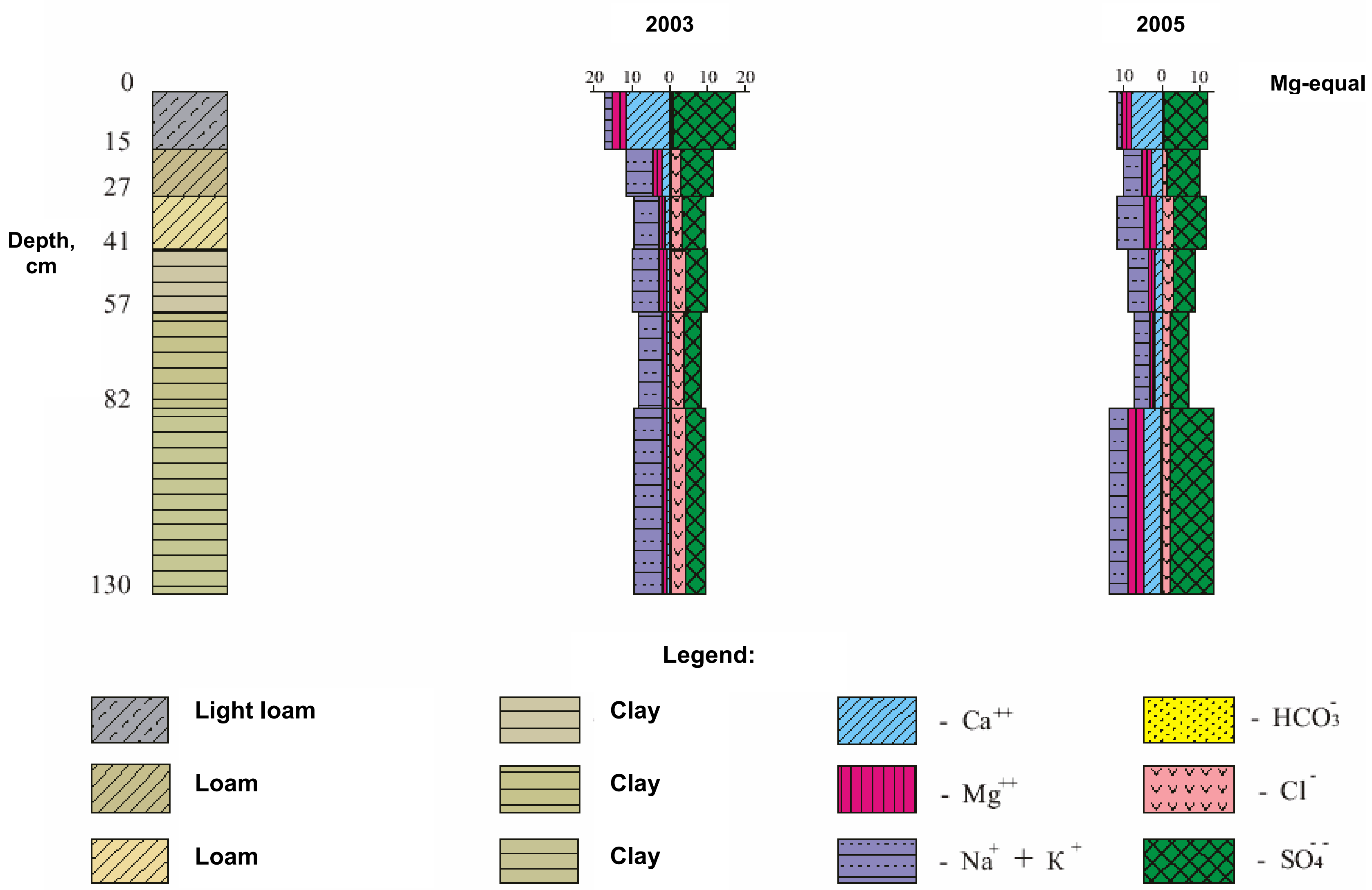


Figure 47 - Dynamics of the chemical characters of the meadow-swamp dried saline soil (section №7)

The present Syrdarya delta rice crops are located on the meadow-swamp and the swamp-meadow soils (sometimes on solonchaks) which due to the influence of this crop turn into specific rice-swamp soils. The soils' humus profile is graded and extremely stretched.

The monitoring investigation carried out on the cross-section of the rice-swamp soil have demonstrated that in the course of cultivation of rice in these soils, he nutrients content (humus, nitrogen, phosphorus and potassium) decreases, and the pH of the soil solution slightly increases (Table 33).

Table 33 - Dynamics of the chemical characters of the rice-swamp dried soil (section № 6)

Sample depth, cm	Humus, %		Total nitrogen, %		Gross forms				Salt sum, %		pH		CO_2, %	
					Phosphor, %		Potassium, %							
Years	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
0-10	1.43	1.25	0.11	0.17	0.16	0.11	2.89	2.13	0.282	0.257	8.3	8.3	8.3	7.9
25-35	1.01	0.78	0.09	0.07	0.16	0.12	3.01	2.37	0.170	0.134	8.4	8.5	8.8	8.2
45-55	0.81	0.65	0.07	0.06	0.19	0.12	3.02	2.40	0.361	0.118	8.3	8.6	8.7	8.7
70-80									0.403	0.138	8.2	8.5	9.3	8.3
140-150									0.184	0.151	8.5	8.6	9.0	8.9

The salts are in mobile condition and due to groundwater outflow in the direction of Aral Sea as well as multiple use of these soils for sowing rice, they are well washed (Figure 48). Thus, according to the data as of 2003, salt content in the soil profile does not exceed 0.3-0.4%, the soil samples that were taken in 2004 turned out to be practically salt-free.

The soils of the transition zone between the delta plain and the dried-out Aral sea-bed are mainly represented with automorphic, half-hydromorphic and halomorphic soils. All of them, except sandy soils, are to some extent salinized. The meadow-swamp desertifying soils are less salinized. Their salt content does not exceed 1%. Takyr-type saline soils resulting from transformation of the takyr-type solontchak are more salinized. The salt content in the shallow horizons is approximately 2%. The crusted puffed solonchaks with their shallow horizons containing up to 7% of salts are highly salinized.

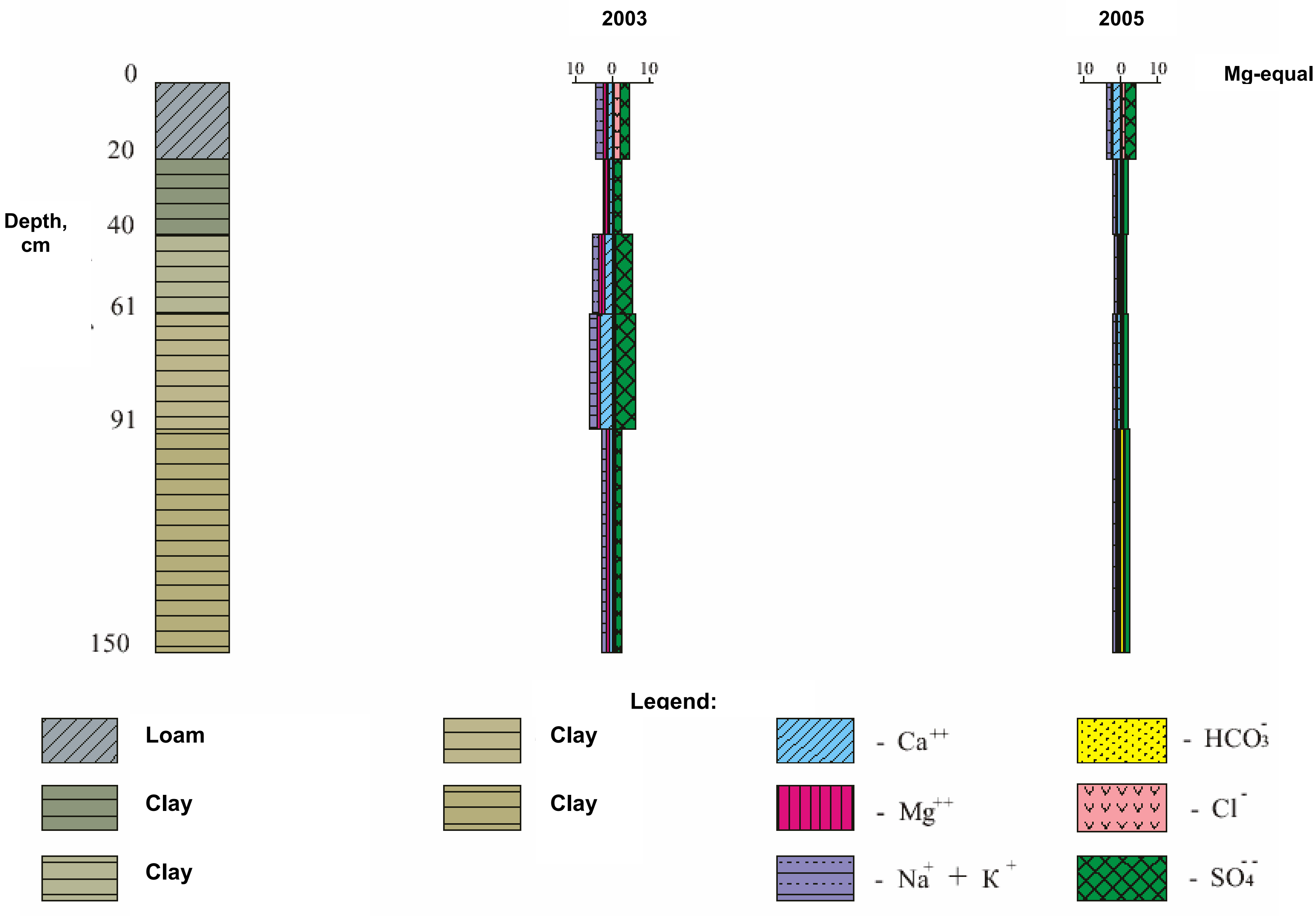


Figure 48 - Dynamics of the chemical characters of the rice-swamp soil (section №6)

The most representative soils in the transition zone are *solonchaks* turning into takyr that during further desertification turn into takyr-type solonchaks.

Solonchaks turning into takyr and takyr-type solonchaks are stages of the typical evolution of solonchaks into desert takyr-type soils. In the course of disalination of typical solonchaks, the fragile up to 1 cm thick salt crust is replaced by the dense 2-3 cm thick crust consisting of the melkozem. While the solonchaks turning into takyr keep the puffed undercrust horizon, in the takyr-type solonchaks it gradually transforms into denser horizon.

Table 34 - Dynamics of the chemical characters of the solonchaks (section № 5)

Sample depth, cm	Humus, %		Total nitrogen, %		Gross forms				Salt sum, %		pH		CO_2, %	
					Phosphor, %		Potassium, %							
Years	2003	2005	2003	2005	2003	2005	2003	2005	2003	2005	2003	2005	2003	2005
0-10	0.70	0.94	0.05	0.09	0.12	0.08	1.68	2.04	4.152	6.198	9.0	9.1	8.2	6.5
1 0-20	0.43	0.37	0.04	0.05	0.13	0.07	2.30	1.86	1.395	0.800	9.0	8.7	8.7	5.9
35-45	0.39	0.23	0.02	0.03	0.12	0.07	2.34	1.90	1.453	0.483	8.8	9.1	7.6	5.7
60-70									0.823	0.197	9.0	9.5	7.4	5.3
100-110									0.354	1.803	9.1	9.0	6.7	9.2

The solonchaks turning into takyr have low content of humus, nitrogen and phosphorus. Their shallow horizons are highly salinized (the amount of salts reaches 4-6%).

According to the data of Table 34, the tendency of loosing nutrients remains present. Movements of readily soluble salts along the profile of the solonchaks turning into takyr are insignificant and are mainly caused by precipitation (Figure 49).

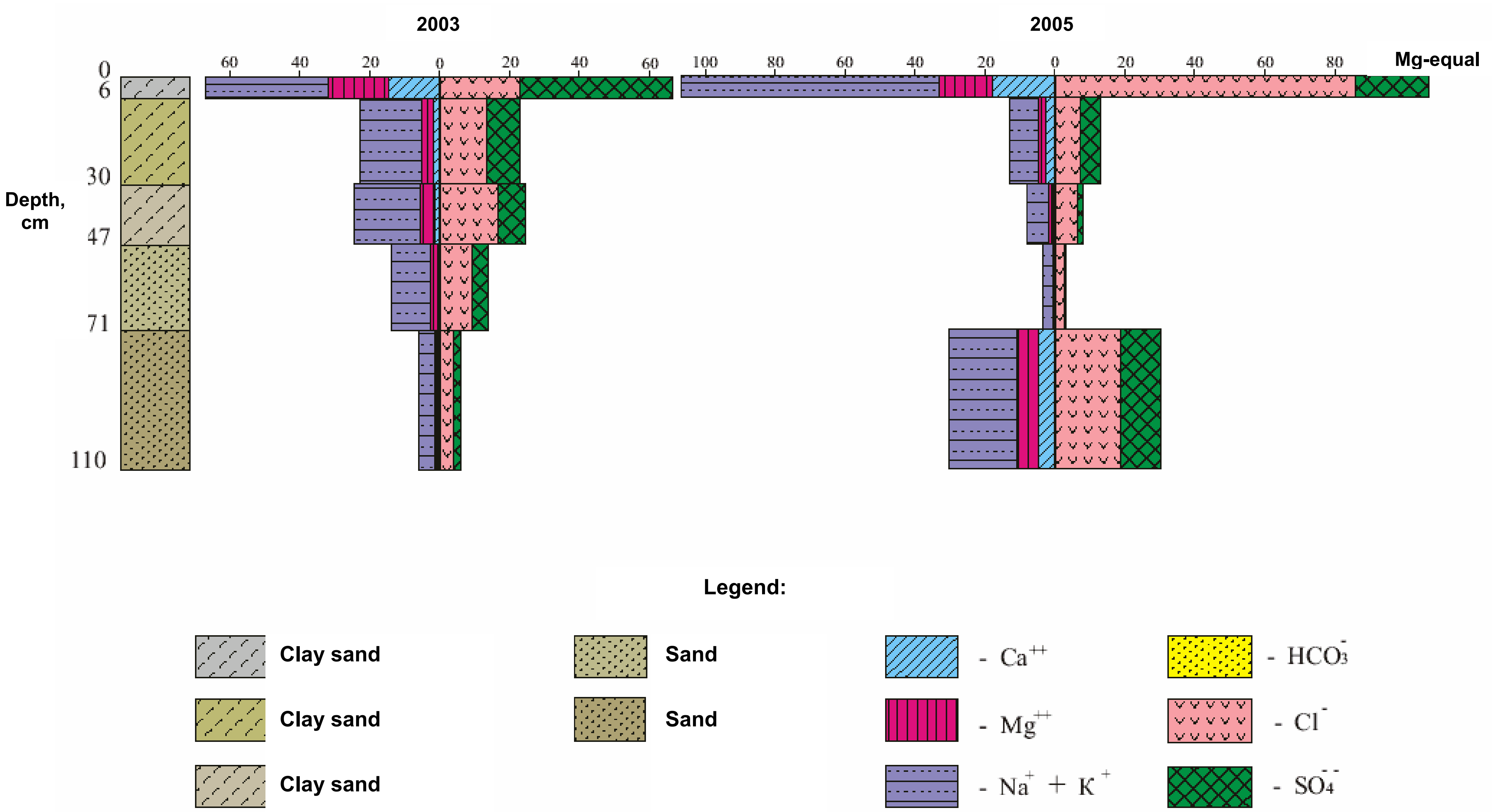


Figure 49 - Dynamics of the chemical characters of the solonchak turning into takyr (section №5)

The soils of the dried-out Aral sea-bed are represented with coastal and marsh solontchaks, coastal soils, coastal soils with overblown sand cover of various thickness, as well as with sand soils.

Coastal soils with overblown sand cover take significant area in the exposure zone, they are formed in the 6-8th year during formation of cumulose sands. The overblown sand cover of these soils is up to 30-50 cm thick. It is formed along with the crusted solonchaks. Their vegetation is represented with xeromezophytes, ebelek, goose-foot, perennial shrub, and bush vegetation that have various projective cover. In the 40-50 and more centimeters deep shallow layer of the soils, the physical siccation horizon is formed and the bedding level of the capillary border goes deeper.

The monitoring investigation of the coastal soils with overblown sand cover demonstrates that they have a low nutrient content, because they are at the initial formation stage. The variation of the humus and the general nitrogen content in the soil profile is related to its texture. The shallow sand horizons have less humus and nitrogen than the below sabulous ones. The humus profile has not been formed yet. The comparison of the data as of the years 2003 and 2005 demonstrates that during soil development the shallow horizons tend to gradually get enriched with humus and nitrogen (Table 35).

Table 35 - Dynamics of the chemical characters of the coastal soil (section № 4)

Sample depth, cm	Humus, %		Total nitrogen, %		Gross forms				Salt sum, %		pH		CO_2, %	
					Phosphor, %		Potassium, %							
Years	2003	2005	2003	2005	2003	2005	2003	2005	2003	2005	2003	2005	2003	2005
0-10	0.08	0.20	0.01	0.08	0.06	0.04	1.58	1.57	0.059	0.064	9.0	9.0	1.6	2.0
22-32	0.12	0.57	0.02	0.05	0.06	0.04	1.76	1.57	0.219	0.926	8.5	8.1	0.9	1.7
40-50	0.62	0.38	0.07	0.03	0.07	0.03	2.20	1.50	1.083	1.595	8.0	8.6	1.0	0.9
70-80									1.906	2.250	8.9	9.3	1.9	2.5
130-140									2.180	2.033	8.9	9.0	0.7	0.6

According to Figure 50, in the current stage, the coastal soils with overblown sand cover are in the process of salinization of the middle and below parts of the profile. The shallow sand horizons that undergo repeated blowing and over-blowing remain practically non-saline.

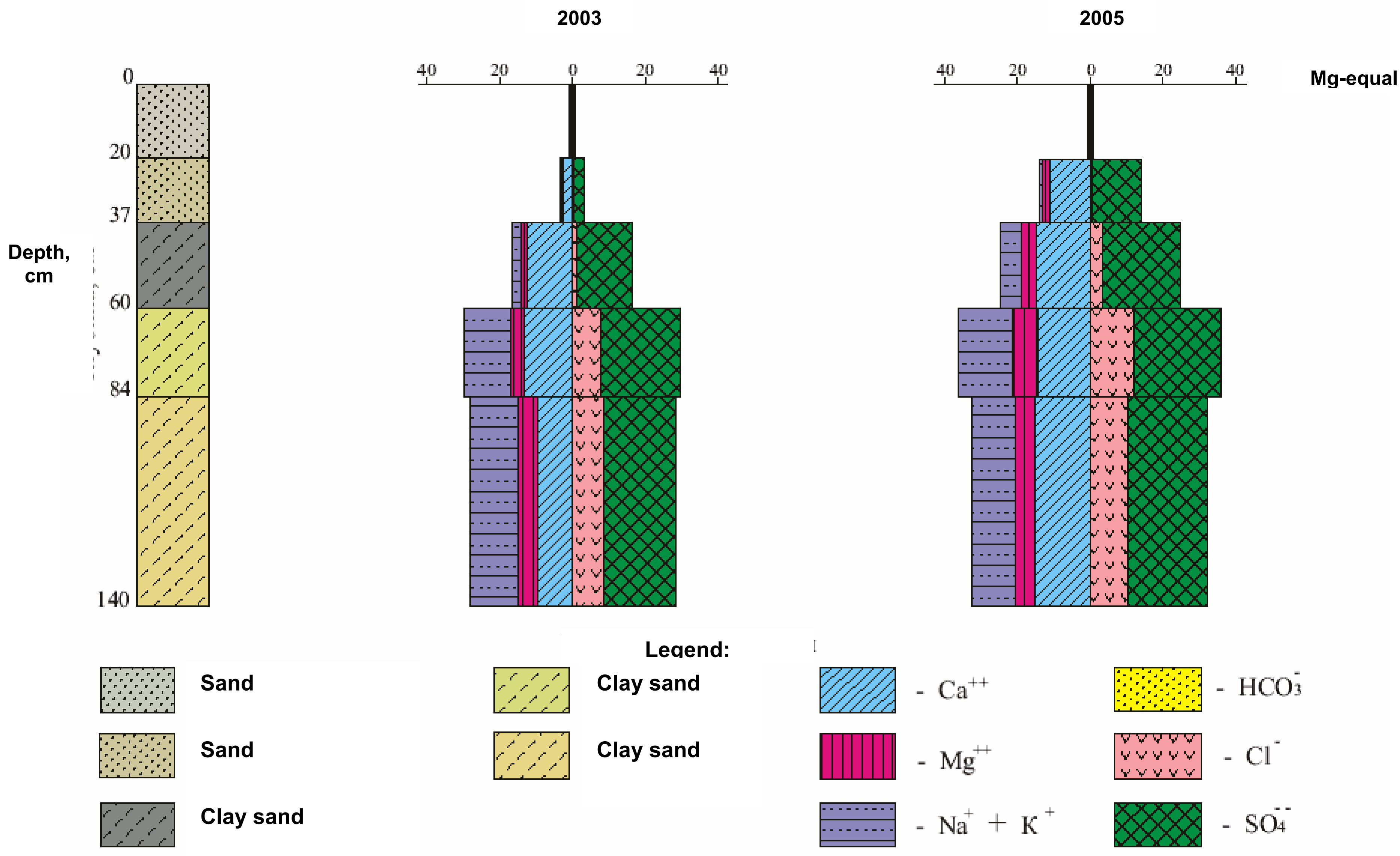


Figure 50 – Dynamics of the chemical characters of the coastal soil with overblown sand cover (section №4)

3.3 Proposals for neutralization of soil degradation process

Efficiency of irrigation of the delta soils should be aimed to restoration of the soil fertility, i.e. to increase of the humus stock and biological activity of the soils. Measures for control of wasting water in the irrigation systems are necessary. It will be appropriate to reconstruct the irrigation networks, to take measures for minimization of vertical drainage in the middle reach of the river in order to keep decreasing discharge of salt mass into the downstream. For the efficient use of the overflow water in the desertifying delta territories, the water should be allocated not for maintenance of reed hayfields, but for irrigation of sown grassland which provides 5-8 times more protein than reed.

Water saving technologies should be implemented into agricultural use of the soils. For production of forage, the area of cultured and irrigated landscapes with green crops should be expanded; periodic flooding (inundation) of the grasslands should be practiced. Because of reduction of the area of natural grassland, development of irrigation in the estuary should be prioritized. With this regard, the order of the development of the estuary areas to be flooded should be determined. Deficit of water resources also occurs due to water overflow in some cases and its insufficient supply in other cases. Such waste adversely affects both the irrigated land and the adjoining territories.

Along with the development of new technologies, general agricultural practices should be improved by means of restoration of the system of rice and alfalfa intercropping where rice making out is not less than 43% of the intercropping schedule.

For the purpose of forage production, it will be appropriate to implement such forage crops as melilot, alfalfa, and Sudan grass. In order to prevent soil degradation in the delta territories, while having extreme deficit of water resources, it is required to carry out additional water release for watering natural complexes not less than one time in 3-4 years.

In the dried-out Aral Sea bed, a set of measures addressing formation of phytocenosis (plant communities) should be taken in order to prevent further soil deflation. Such measures include implementation of perennial vegetation at the earliest stages of ecological system development before the beginning of intensive deflation of its soils.

4 ASSESSMENT OF SOCIAL AND ECONOMICAL CONDITIONS OF THE SYRDARYA RIVER DELTA

4.1 Socio-economic development level

The level of socio-economic development of Aral Sea region of Kazakhstan is characterized by very low production and consumption of material values. The gross regional product in 2000 was 2.4% in the structure of the national gross domestic product (GDP) and was the lowest among all oblasts of Kazakhstan. In 2000 a GDP of Kyzylorda oblast amounted to 56,450.5 million KZT, increasing its value by 2.7 times compared with 1995.

In 2000 a gross value added per capita in the Kyzylorda oblast amounted to 93.6 thousand KZT against 156.6 thousand KZT for the Republic of Kazakhstan. In the currency equivalent the gross regional product per capita of Kyzylorda oblast from 1985 to 2000 decreased from 3,223.68 USD to 647.75 USD, in nearly 5-fold, while in the national currency its growth is observed.

Table 36 - Social and economic development level

Parameters	2002	2003	2004
Industry production, billion tenge			
Kyzylorda Oblast	116.233	142.512	231.489
Aralsk rayon			1.085
Kazaly rayon			1.627
Agriculture production, billion tenge			
Kyzylorda Oblast	10.782	13.099	16.108
Aralsk rayon	0.4	0.5	0.62
Kazaly rayon	1.0	1.2	1.49
Crop production, billion tenge			
Kyzylorda Oblast	6.368	8.107	10.495
Aralsk rayon	0.042	0.053	0.066
Kazaly rayon	0.446	0.535	0.664
Livestock production, billion tenge			
Kyzylorda Oblast	4.414	4.913	5.613
Aralsk rayon	0.358	0.447	0.554
Kazaly rayon	0.554	0.665	0.826

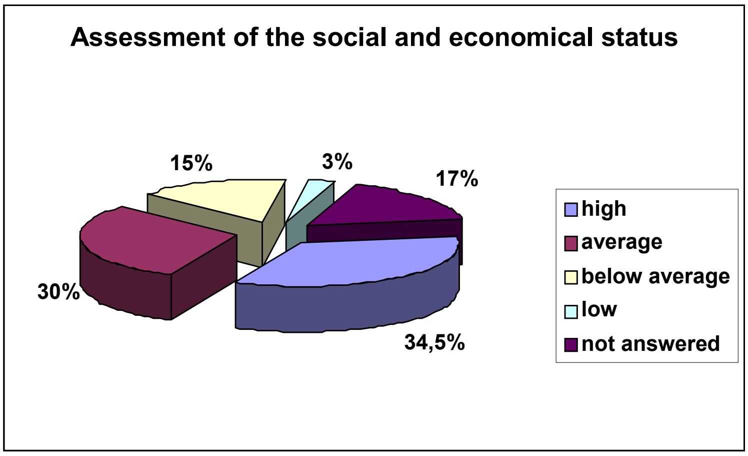
Table 37 – Basic capital investment

Parameters	2002	2003	2004
Republic budget, million tenge			
Kyzylorda Oblast	2184	7736	11736
Aralsk rayon		266.1	580.0
Kazaly rayon		218.97	418.6
Local budget, million tenge			
Kyzylorda Oblast			
Aralsk rayon		66.2	50.7
Kazaly rayon		92.46	305.6
Organization, enterprises and other, million tenge			

Kyzylorda Oblast	20419	28994	20653
Aralsk rayon		202.6	110.0
Kazaly rayon		17.6	7.1
Foreign investors, million tenge			
Kyzylorda Oblast	9831	16362	10511
Aralsk rayon		514.2	1903.8
Kazaly rayon		186.9	570.44

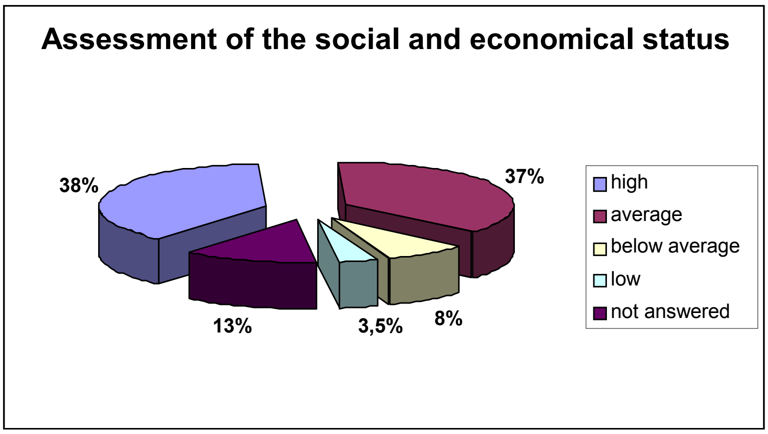
4.2 Social and economical status of the inhabitants

Aralsk rayon



Third part of the respondents evaluated the social and economical status as high. Less than third part of the respondents evaluated the social and economical status as average. About fifth part of the respondents selected the variant – as low and below average.

Kazaly rayon



More than third part of the respondents evaluated the social and economical status as high. About same part of the respondents evaluated as average level. More than tenth part of the respondents evaluated as low and below average level of the social and economical status.

Family composition

The most prevalent family composition answered by the respondents from two rayons is 4-6 persons.

Composition from 7 to 9 persons was selected by the forth part of respondents from Aralsk rayon and third part of the respondents from Kazalinsk rayon.

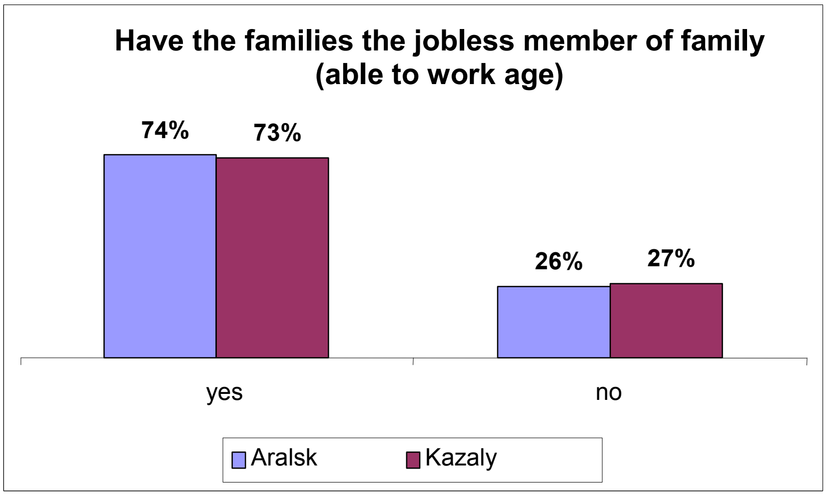
Family composition from 10 persons and more was selected less than tenth part of the respondents from Aralsk rayon and more than tenth part of respondents from Kazaly rayon.

Family composition from 1 to 3 persons more often selected by respondents from Aralsk rayon.

During investigation it was identified that inhabitants from Kazaly rayon have large in number families in which live representative of three generations.

Each second family live with pensioners, and more rarely answered the respondents from Kazaly rayon.

Each tenth family has an invalid.



Three fourth families answered that have the jobless member of able to work age.

The most prevalent family in studied settlements is family with several generations. The dependant load is high – for one working member of the family is fall at up to three jobless adults.

4.3 Parameters of the inhabitants standard of living

The main indicators of living standards are the money income of the population, wages, living wage, the average size of a pension, and an indicator of human development index, considered as an integrated assessment of the development and use of human potential.

In the first half of the 90s there were downward trends in the living standards in relation to the objective difficulties of the transition period.

Table 38 – Parameters of the inhabitants standard of living

Parameters	2002	2003	2004
Cash income (in average per head in month), tenge			
Kyzylorda Oblast	52834	68139	71099
Aralsk rayon	43343	55957	60766
Kazaly rayon	48088	62048	65933
Cash outcome (in average per head in month), tenge			
Kyzylorda Oblast	47208	61643	64234
Aralsk rayon	39009	49802	54898
Kazaly rayon	42798	55843	58680
Monthly average salary per 1 worker, tenge			
Kyzylorda Oblast	17046	19928	26399
Aralsk rayon	13683	15504	19896
Kazaly rayon	15623	18590	24497
Monthly average salary per 1 worker form agriculture sector, tenge			
Kyzylorda Oblast	6559	8703	10430
Aralsk rayon	5372	5565	6368
Kazaly rayon	6314	6853	6847
Monthly average salary per 1 worker form agriculture sector, tenge			
Kyzylorda Oblast	8233	9632	13694
Aralsk rayon	5187	6090	8659.2
Kazaly rayon	0	0	0

Average monthly nominal wages for Kyzylorda oblast in 2004 was 26,399 KZT or 195.5 USD, for Aralsk district – 19,896 KZT or 147 USD, for Kazaly district – 24,497 KZT or 181 USD. The average monthly wages of workers in the Aral Sea region of Kazakhstan is 22,196.5 KZT or 164 USD, representing 84% from average index for oblast. Since 2002, an increase in the size of average monthly nominal wages is observed.

In national currency a growth of the index occurred, but in the foreign currency equivalent a decrease in cost of living, both in the studied region and in the Republic is observed due to inflation, which indicates the deterioration of socio-economic situation in general.

Thus, the size of wage of workers of the Aral Sea region of Kazakhstan in the foreign currency equivalent is not yet reached the level of 1975. And wages in 1990 was 2.5 times higher than at present time, which is directly connected with the income of the population. And this fact confirms the deterioration of socio-economic situation of the Aral Sea region of Kazakhstan.

The main part of money income consisted of income from employment, i.e. from wages - 69%. The social transfers (pensions, scholarships, grants) accounted for 13%, on the proceeds of other sales - 15% and miscellaneous receipts - 3%.

The money income of population, in connection with a predominance of workers employed in low-profit agriculture up to 1996 was among the lowest in the Republic.

In the structure of the cash expenditures on the examined families of Aralsk and Kazaly districts in 2005 the expenses for meals (60%) dominated, expenses for purchasing of non-food products amounted to 25%; expenses for taxes, fees and charges - 7%, for miscellaneous expenses - 8%.

In the national currency the growth of the index occurred, but in the foreign currency equivalent a decrease in the cost of living is observed, both in the studied region and in the Republic as whole due to inflation, which indicates the deterioration of socio-economic situation in general.

Table 39 - Education and culture level

Parameters	**2002**	**2003**	**2004**
Infant schools			
Kyzylorda Oblast	64	64	62
Aralsk rayon	9	9	10
Kazaly rayon	5	6	6
General education schools			
Kyzylorda Oblast	288	288	292
Aralsk rayon	49	50	50
Kazaly rayon	40	41	41
High education institutes			
Kyzylorda Oblast	7/14	8/18	8/19
Aralsk rayon	-/-	-/-	-/-
Kazaly rayon	-/-	-/-	-/-
Theaters			
Kyzylorda Oblast	1	1	1
Aralsk rayon	-	-	-
Kazaly rayon	-	-	-
Libraries			
Kyzylorda Oblast	202	203	205
Aralsk rayon	38	38	38
Kazaly rayon	26	26	26
Museums			
Kyzylorda Oblast	8	9	10
Aralsk rayon	1	1	1
Kazaly rayon	1	1	1
Clubs			
Kyzylorda Oblast	163	164	158
Aralsk rayon	23	24	24
Kazaly rayon	23	23	23

Table 40 - Medical complex

Parameters	**2002**	**2003**	**2004**
Hospitals			
Kyzylorda Oblast	61	52	66
Aralsk rayon	8	9	9
Kazaly rayon	5	5	6
Number of beds			
Kyzylorda Oblast	5930	5735	5930
Aralsk rayon	455	455	475
Kazaly rayon			
per 10000 persons			

Kyzylorda Oblast	98,2	95	97,6
Aralsk rayon	65	65	67,4
Kazaly rayon			
Number of medical centers			
Kyzylorda Oblast	122	126	127
Aralsk rayon	51	52	53
Kazaly rayon	26	27	27
per 10000 persons			
Kyzylorda Oblast	89,5	95,0	97.6
Aralsk rayon	65	65	67.4
Kazaly rayon			
Number of doctors			
Kyzylorda Oblast	1958	2280	1970
Aralsk rayon	165	160	156
Kazaly rayon	128	130	130
per 10000 persons			
Kyzylorda Oblast	32.4	37.8	32.4
Aralsk rayon	23.8	22.8	22.1
Kazaly rayon			
Number of paramedical personnel			
Kyzylorda Oblast	6084	6643	6226
Aralsk rayon	536	538	549
Kazaly rayon	338	340	341
per 10000 persons			
Kyzylorda Oblast	100,8	109.3	102.5
Aralsk rayon	76.6	76.9	77.9
Kazaly rayon			

4.3.1 Demography

In the territory of the Aralsk and Kazaly districts around 23% of the total population of Kyzylorda oblast is concentrated. In terms of population size the studied districts are approximately equal, but on the processes of population reproduction and their growth rate the districts differ against each other.

In the Aralsk district the proportion of rural population is 38.0%, in Kazaly – 42.0%.

As main source of population growth of population of Aral Sea region of Kazakhstan is a high natural population growth, which is recovered through the occurrence of environmental refugees, and outflows from the zone of ecological disaster. In general, the favorable conditions to provide labor resources for the future are created.

In Aralsk and Kazaly districts of Kyzylorda oblast, mortality rates from respiratory diseases and infectious and parasitic diseases are above the national average rate, and moreover, by causes of death in 2000, the oblast ranked first among all oblasts of Kazakhstan, and mortality rates in these districts 1.5 times greater than the oblast's rates and 2 times – average republican.

High rates of population mortality from respiratory diseases, infectious and parasitic diseases are a direct reflection of the unfavorable environmental conditions, inadequate water supply and, of course, the low level of medical care.

Table 41 – Demography parameters

Parameters	2002	2003	2004
Population, thousand person			
Kyzylorda Oblast	600.7	603.8	607.5
Aralsk rayon	68.6	69.1	69.4
Kazaly rayon	70	70.4	70,7
Urban population, thousand person			
Kyzylorda Oblast	359.3	360.5	362.3
Aralsk rayon	42.9	43	42.9
Kazaly rayon	40.9	41	41.1
Rural population, thousand person			
Kyzylorda Oblast	241.4	243.3	245.2
Aralsk rayon	25.7	26.1	26.5
Kazaly rayon	29.1	29.4	29.6
Number of newborns, person			
Kyzylorda Oblast	12429	12491	14010
Aralsk rayon	1673	1615	1770
Kazaly rayon	1557	1462	1586
Number of deceased, person			
Kyzylorda Oblast	4586	4528	4313
Aralsk rayon	565	537	501
Kazaly rayon	578	536	518
Natality, person			
Kyzylorda Oblast	7843	7963	9697
Aralsk rayon	1108	1078	1269
Kazaly rayon	979	926	1068

One of the main factors influencing the change in population size is migration. In recent years the socio-economic and demographic indicators, defining the nature of migration flows dramatically changed.

Since 70s an outflow of population from the Kyzylorda oblast increased. High outflow of population from Kyzylorda oblast associated with the deterioration of the ecological state of the Aral Sea region, which led to the emergence of a new type of migrants - environmental. In the period of high productivity of water reservoirs and the sea, much of the population engaged in fisheries and industries associated with the processing of fish products, repair of fishing vessels, etc. Fall in the level of the Aral Sea and the closure of fishing industries led to the loss of jobs and searching of the new employment in other districts or outside the oblast.

In 2004 a migration balance amounted to minus 4928 people. 9772 people left the oblast and 4844 came to it (33% of the total migration). From the total migration flow of population of Kyzylorda oblast the international migration amounts to 19.2%, the interregional migration – 34.5% and regional (oblast) migration – 46.4%.

Aralsk and Kazaly districts in 2004 fall within 12% and 11% of the volume of regional (oblast) migration. Since 2002, there a gradual decrease in the outflow of population is observed.

Table 42 – Migration parameters

Parameters	**2002**	**2003**	**2004**
Number of incoming persons			
Kyzylorda Oblast	6681	6310	4844
Aralsk rayon	588	438	523
Kazaly rayon	924	936	784
Number of outcoming persons			
Kyzylorda Oblast	11409	10586	9772
Aralsk rayon	1178	1204	1111
Kazaly rayon	1566	1519	1322
Balance of migration, чел			
Kyzylorda Oblast	-4728	-4276	-4928
Aralsk rayon	-590	-766	-588
Kazaly rayon	-642	-583	-538

4.3.2 Medical care

The emergence of a number of diseases of the local population is directly related to pollution of soil and water with toxic compounds, as a result of economic activity. Application for reclamation systems of fertilizers and pesticides in quantities exceeding the approved standards, are accompanied by their removal of the surface and drainage water that significantly affects the quality of water in the basin of the Syrdarya.

In the Kyzylorda oblast in the process of progressive anthropogenic desertification a set of factors formed conditioning an epidemiological trouble on the main forms of infectious diseases. The dominant importance of the following factors has been noted:

- *Existence of the large number of diverse sources of infections* in connection with multiyear high level incidence, which not show a significant downward trends and creating a high risk of infection for all groups of population. In the development of the epidemic process of viral hepatitis and other enteric infections, the situation of morbidity in the region remains extremely tense. A possible reason is wide availability of the implementation of all modes of pathophoresis - water, food, contact and community-acquired.

- *Poor conditions of water supply and water use* of population, lack of planned removal and disposal of domestic waste, sewage, waste water resulted in the creation of extremely adverse health background, where against it the epidemic process of the most comprehensive group of intestinal infections is developed.

- *Specific climatic conditions of the Kyzylorda oblast* have a significant impact to the spread of intestinal infections, acting on the mechanism of their transfer. Such conditions include the long-term and drought period, low atmospheric precipitation, high groundwater, expressed aggressive properties of underground water which determine fragility and constant accidents of the underground pipelines.

- *The active intervention of human activity*, expressed in an intense withdrawal of water from the vitally important natural water bodies - the Aral Sea and Syrdarya aggravated their epidemic hazard in connection with decrease in self-purification ability, as evidenced by the high content of enteric bacteria, including pathogens, poor physical, chemical and organoleptic properties of these water reservoirs.

Under conditions of progressive anthropogenic desertification these negative impacts may strengthen if steps are not taken to limit their effect.

- *High level of contamination of water sources and soil* is crucial in maintaining the extremely high incidence of intestinal bacteria and viral infections, the water route of transmission of intestinal infections continues to occupy a significant place that brings enormous damage to human health and to the national economy of the oblast. For many years it is confirmed by the massive spread of viral hepatitis, typhoid and paratyphoid, acute dysentery and other intestinal infections.

At high incidence of tuberculosis remains in the oblast, against the background of its growth in the whole Republic. The threshold in this trend began in 1994, when a general trend for increasing of incidence has been observed.

For all other types of diseases, namely, respiratory diseases, diseases of the digestive system, diseases of the urogenital system, separate conditions occurring in the perinatal period, the oblast indicators are also exceed the Republican.

Unfavorable situation for child morbidity is the cause of high infant mortality and is a reflection of the critical environmental situation formed in the region, the low socio-economic living conditions, poor material and technical base of health authorities, and also highlights the poor health of parents, which transmit many types of disease in families.

For instance, a half of interviewed citizens in rural districts of the Aral district said that they have the opportunity to acquire the necessary medicines. A third of the respondents indicated that they have largely restricted themselves to gain the opportunity to buy medicines. The minimum number of respondents indicated that they have no opportunity to buy medicines.

Regarding the availability of paid medical services of opinions of the respondents were divided into two groups: 46% of respondents said about its availability, while 42% of respondents noted a lack of access to such services.

Almost all respondents mentioned that they have an opportunity to buy hygiene products (toothpaste, powdered detergents, soap, etc.)

Almost the same number of respondents in Kazaly district noted that they have the opportunity to buy the necessary medicines, and a part of them must limit themselves largely to buy medicines - 45% and 44% respectively. Less than a tenth of respondents stated that they have not an opportunity to purchase medicines.

Same number of respondents noted both accessibility and inaccessibility for paid medical service – by 47% of respondents.

Approximately one fifth of the respondents noted that they had no opportunity to acquire a sufficient number of hygiene products.

The considerable part of the population in rural districts is limited to the ability to receive necessary medical treatment, to purchase medicines.

Direct reflection of deteriorating of the socio-economic conditions and unfavorable ecological situation of Aral Sea region of Kazakhstan supported by the health status of people living in the disaster zone, which is considered by us through indices of fertility, mortality, morbidity of the population.

The health deterioration of population of the Aral Sea region is caused by the following reasons:

- decreasing of the already existing low rates of socio-economic development of Aral Sea region and the deteriorating of the living conditions of local population.
- weak development of material-technical base of health in the territory of Aral Sea region of Kazakhstan;
- poor conditions of water supply and water use of population;
- deteriorating the quality of surface water and groundwater with toxic compounds, as a result of human activities;
- specific natural and climatic conditions of the Aral Sea region of Kazakhstan.

Thus, the Aral Sea area is a zone of most severe socio-economic conditions in Central Asia.

Diseases of the population of the region are linked primarily to the deteriorating of the quality of drinking water, climate changing, low nutrition due to low income households. As a consequence, in the region there are higher rates of infant and child mortality, and population mortality. Analysis of data on the morbidity of viral hepatitis and acute intestinal infections on the Kyzylorda oblast and the pollution of the water Syrdarya River caused by pesticides and phenols confirmed the role of water factor in the spread among the population of viral hepatitis, typhoid and dysentery.

4.3.3 Manpower resources

The main reason of the underemployment is the limited scope of application of labor. An increment of workforce outruns the job creation. This led to the emergence of such social phenomena as unemployment.

In the Kazaly district an increase in the number of employed persons in the district’s economy from 27.3 thousand in 2002 to 35.5 thousand in 2004 is observed. In the Aralsk district, employment indices are lower than in Kazaly district.

Proportion of women among the unemployed population in 2002 is reduced. In 2004, the number of unemployed women decreased in Kazaly area by 21%, in the Aral region by 17%. The reduction has affected industrial production, primarily to the employment of the male population and female labor is used in the fields of non-productive sphere.

In Kazaly district during 1996-2001 period a tendency to reduce a number of employed in the economy from 29.1 thousand in 1996 to 27.7 thousand in 2001 is observed.

Table 43 – Manpower resources

Parameters	**2002**	**2003**	**2004**
Economy working population, thousand person			
Kyzylorda Oblast	275.3	287.6	297.4
Aralsk rayon	32.7	33.5	31.1
Kazaly rayon	27.3	31.2	35.5
Incl.: **Employed , thousand person**			
Kyzylorda Oblast	240.8	254.7	267.1
Aralsk rayon	27.6	27.3	26.5
Kazaly rayon	23.3	27.6	32.4
Unemployed, thousand person			
Kyzylorda Oblast	34.4	32.8	30.3
Aralsk rayon	5	6.2	4.5
Kazaly rayon	4	3.6	3.1
Unemployment rate, %			
Kyzylorda Oblast	12.5	11.4	10.2
Aralsk rayon	15.4	18.4	14.5
Kazaly rayon	14.8	11.5	8.7
Unemployed distribution, thousand person			
Kyzylorda oblast			
Men	16.7	15	17.5
Women	17.8	17.8	12.8
Women part, %	51.6	53.9	42.2
Aralsk rayon			
Men	2.1	2.4	2.5
Women	2.9	3.8	2
Women part, %	58.3	61.3	44.4
Kazaly rayon			
Men	1.6	1.1	1.6
Women	2.4	2.5	1.5
Women part, %	59.8	69.4	48.4

Based on the performed analysis the following conclusions may be made:

- in the Aral Sea region of Kazakhstan a decline of workforce, i.e., the loss of human resources having occurred. It is associated with the outflow of population from the zone of ecological disaster;
- the Aral Sea region of Kazakhstan has always been characterized by significant potentialities for involvement to the social production of labor resources, but they are used by far not enough;
- in the areas of the Syrdarya delta the employment in social production is the lowest in the republic;
- During the period under review there have been changes in fields and sectors of the economy, the percentage of employment in non-productive sector increased from 27.5% to 52.36%, and employment level for people engaged in material production, respectively, decreased;
- qualitative composition of the workforce associated with higher levels of education of the population has been changed.

4.4 Economic parameters

4.4.1 Irrigation

Association of distribution of the agricultural lands to the delta of the Syrdarya is the main feature of the Aral Sea region of Kazakhstan. Agricultural lands in the Kazakh part of the Aral Sea region are concentrated in Kazaly district (99% of all irrigated lands in the region). Melioration conditions are unfavorable for crop production; the soils require drainage and leaching.

Starting from 1985 to 2001 decreasing of agricultural lands in Kazaly district in 1.7 times has occurred by reducing the irrigated area of arable lands, hayfields and pastures. While in the Aral district for the same period there was an increase of 1.18 times.

Analysis of the trends for agricultural lands of the region showed the instability of the areas of different types of agricultural lands, through the intensification of the negative processes of desertification (erosion, deflation, salinity, vegetation degradation of pasture, etc.).

In the structure of agricultural lands, both in the Aralsk district (99.7%) and Kazaly district (97.3%) traditionally has been a steady trend of the prevalence of pasture area over irrigated agriculture area.

The percentage of using of irrigated lands in these districts is slightly lower than the average for the oblast.

Irrigated agriculture in the districts under review is in a tight situation, although in the past few years some improvements were outlined. Analysis of data on the crop yields since 1960 detected that the downward trend in yields of major crops of Aral Sea region of Kazakhstan is observed since 1980. Comparison of yields falling on the districts of Aral Sea region of Kazakhstan shows that the yield felt in the greater degree in Kazaly district where for all analyzed crops a decline in yields is over one or more times in comparison with average data for Kyzylorda oblast.

The general trend of development of agricultural lands of Syrdarya River delta and their current status shows the degradation of irrigated agriculture, manifested in the decrease of agricultural land and crops and their productivity.

The structure of agricultural land and the nature of their use are fully dependent on the drainage characteristics of the Syrdarya delta and its water supply, as well as the state of logistics enterprises.

Table 44 – Structure of agriculture land

Parameters	**2002**	**2003**	**2004**
Irrigated area - availability, ths. ha			
Kyzylorda Oblast	277.7	277.7	277.7
Aralsk rayon			
Kazaly rayon			
Irrigated area - used, ths. ha			
Kyzylorda Oblast	139.89	153.21	145.95

Aralsk rayon	0.555	0.562	0.501
Kazaly rayon	17.134	18.051	11.476
Grain and leguminous area, ths. ha			
Kyzylorda Oblast	70.038	84.686	79.562
Aralsk rayon	0.13	0.128	0.126
Kazaly rayon	8.602	9.27	4.942
Rice area, ths. ha			
Kyzylorda Oblast	52.59	70.0	66.58
Aralsk rayon	0	0	0
Kazaly rayon	6.0	6.501	3.574
Potatoes area, ths. ha			
Kyzylorda Oblast	7.933	7.077	7.858
Aralsk rayon	0.088	0.085	0.065
Kazaly rayon	0.758	0.851	0.641
Vegetables area, ths. ha			
Kyzylorda Oblast	6.946	6.768	7.296
Aralsk rayon	0.113	0.119	0.055
Kazaly rayon	0.929	0.565	0.559
Melons and gourds area, ths. ha			
Kyzylorda Oblast	8.46	7.842	9.318
Aralsk rayon	0.197	0.185	0.219
Kazaly rayon	0.874	0.985	0.747

4.4.2 Pastures and hayfields

The vast areas of lands of the Aral and Kazaly areas historically used as pastures for sheep, camels, horses, and far less for cattle. The natural fodder supplies for livestock are white land- wormwood, biyurgun, teresken, keyreuk, yerkek pastures for using in spring, summer and autumn in brown, gray-brown loamy and super-sandy soils and solonetzic soils, yerkek, absinthial and wormwood and psammophytic- shrubby pastures on sandy soils using mainly in spring and winter and autumn-winter sarsazan and lush-saltwort pastures of alkaline soils. The area provided poorly with grasslands.

The basic grasslands of the Aral Sea region are presented by cane, tallgrass, club-rush, herb-tallgrass communities. Degradation of grasslands began after the cessation of augmentations; acquiring irreversible character after 1974, when the average water flow at the “Kazaly” site decreased almost 10 times from the amount of year 1960.

Changes in environmental conditions caused by falling of groundwater levels, have led to a sharp reduction in grasslands. From 1960 to 1985, their area has decreased - in the Aralsk district of more than 7 times (from 59.1 thousand hectares to 8.4 thousand hectares) and in Kazaly district - more than 3 times (from 92.3 thousand hectares to 29.4 thousand hectares).

Increased water augmentations in the Aral Sea after 1989 contributed to the improvement of food quality and increasing of grasslands productivity, but their changes with regards to areas were not actually observed.

According to the INTAS-1059 “Aral Sea region of Kazakhstan” Project in 1960 the productivity of grasslands was 12.8 centners / ha or 5.1 centners / ha of soil-feeding capacity with total feed reserve of 772.1 thousand centners of soil-feeding capacity, by the year 1990-1991 it dropped to 3.2 centners / ha (1.2 centners/ha of soil-feeding capacity).

The greatest transformation the cane hayfields were exposed, which in 1960 amounted to 39.9 thousand hectares or 62% of the hayfields in the Aralsk district and 43.5 ha (47%) in Kazaly district. By 1990, their area has decreased 14 times in the Aralsk district and more than 4 times in Kazaly district. The productivity of hayfields during this period as a whole in the Aral Sea has decreased in 3.5 times from 19.6 centners / ha (7.4 centners / ha of soil-feeding capacity) up to 5.6 centners / ha (1.9 centners / ha of soil-feeding capacity).

In 2001 the losses of grassland forage compared to 1960 amounted to 171.4 thousand tons (68.7 t / ha of soil-feeding capacity), from which the losses of cane were 149.6 thousand tons (56.6 t / ha of soil-feeding capacity). Change of hydrological regime in the Syrdarya delta and lake systems of the Aral Sea has had a direct impact on the hayfields: by 1985-1991 their area has decreased nearly five-fold, and productivity – up to four-fold. By 1990 the semi-hydromorphic ecosystems were on the verge of extinction. Increased water augmentations and the reduction of anthropogenic stress has led to some stabilization of hayfields, however, the widespread increase of salt-marsh processes highly constrained reconstruction processes in the delta ecosystems.

The fall of the Aral Sea level has influenced the development of grazing: reduction of size of irrigated pastures from 1985 to 2001 by 25% in the Aralsk district and more than 2 times in Kazaly district caused by decrease in groundwater levels and increasing its salinity. Over-grazing on irrigated pastures contributed to the decline in yield, feed reserve, and loss of biodiversity. In the last decade due to a sharp decrease in livestock production on pastures of Aral Sea region tendency to restore the resource potential of rangeland ecosystems is outlined.

4.4.3 Livestock

In Aral Sea region of Kazakhstan the cattle breeding is the second branch in the farms of the region under review (40%) on the commodity output. Main products of beef cattle breeding is beef. For most households of the Aral Sea region of Kazakhstan the stock-rearing is unprofitable and profitable only to those households that have the hayfields.

Table 45 - Livestock

Parameters	2002	2003	2004
Cattle, ths. head			
Kyzylorda Oblast	170.2	178.6	199.5
Aralsk rayon	22.9	25.0	30.7
Kazaly rayon	27.2	27.8	27.9
Sheep and she-goat, ths. head			

Kyzylorda Oblast	559.8	585.8	637.5
Aralsk rayon	96.0	102.9	105.2
Kazaly rayon	80.8	80.8	81.6
Horse, ths. head			
Kyzylorda Oblast	48.3	48.9	50.4
Aralsk rayon	12.2	12.5	13.1
Kazaly rayon	7.3	7.4	7.5
Camel, ths. head			
Kyzylorda Oblast	20.2	21.3	23.2
Aralsk rayon	14.1	14.7	15.8
Kazaly rayon	2.1	2.4	2.42
Total, ths. head			
Kyzylorda Oblast	820.5	856.6	933.6
Aralsk rayon	143.6	151.5	155.5
Kazaly rayon	117.4	118.4	119.42
Shear			
Kyzylorda Oblast	0.94	0.95	0.96
Aralsk rayon	0.12	0.13	0.15
Kazaly rayon	0.11	0.11	0.10
Meat (live weight), ths. tons			
Kyzylorda Oblast	26.3	26.9	27.6
Aralsk rayon	2.67	2.8	2.94
Kazaly rayon	4.2	4.23	4.36
Milk, ths. tons			
Kyzylorda Oblast	55.615	56.864	60.588
Aralsk rayon	4.682	4.82	5.097
Kazaly rayon	7.532	7.841	8.48
Egg, ths. pcs.			
Kyzylorda Oblast	28.64	39.958	32.581
Aralsk rayon	0.35	0.355	0.361
Kazaly rayon	1.501	1.56	1.571
Poultry, ths. head			
Kyzylorda Oblast	444.5	438.3	428.2
Aralsk rayon	10.6	10.9	11.0
Kazaly rayon	29.9	29.6	33.3

In 1994-2004 the cattle breeding of the Aral Sea region of Kazakhstan and the whole Kyzylorda oblast, characterized by a number of negative factors, main among which are the reduction of livestock of all kinds, falling its productivity as well as the structural system of management in the rural areas. In course of the implementation of reforms in the agricultural sector, undertaken after the establishment of Kazakhstan's independence, the livestock moved to the small peasant and individual farms. Along with sheep and cattle farms in the region horse breeding and camel breeding are developing.

According to the INTAS-1059 "Aral Sea region of Kazakhstan" Project all the Karakul farms of the Aralsk and Kazaly districts prior to 1985 were profitable. The level of profitability in the some farms reached 60%. The farms received income from the sale of livestock products. In the structure of commodity output the Karakul pelts (32.0 – 39.7%), wool (36.2 – 40.6%) and mutton (24.1 -27.4%) are distinguished. Analysis of the production of Karakul pelts showed that a sharp decline in these products occurs and production of pelts has decreased. Major losses occurred in the period after 1990, when a number of sheep and goats sharply reduced and productivity of rangelands decreased. The main losses of livestock products, both in the Aralsk and in Kazaly districts account for the loss of Karakul pelts. Currently Karakul sheep breeding in the region is not available.

Reduction of livestock and reducing of its productivity negatively affected the economic efficiency of the livestock industry in general, which is currently unprofitable. Sharp increase in costs occurred due to increased costs for feed, which portion in the cost structure is more than 50%.

The main decrease in productivity of livestock in the Aral Sea region began in 1985 and that the most paradoxical, the rate of decline in Kazaly district in many respects higher than in the Aral district. That leads to the conclusion that the main cause of degradation of the industry driven by the general deterioration of socio-economic conditions of the region, rather than drying of the Aral Sea.

4.4.4 Use of lake resources

The population of the rural districts of the Aralsk district showed the great activity on this matter, living in the zone of active degree of exploitation of the lake system.

According to a third part of interviewed of population of this area, at present time using the resources of lakes has an average degree of efficiency.

The fourth part of respondents noted a high degree of efficiency, more than fifth part - the low degree of operational efficiency of the lakes.

Among residents of rural districts of Kazaly district the respondents dominated who left this question unanswered. This is explained by the fact that the filling of lakes in this part of the Aral Sea basin has a short-term seasonal character. Lakes do not have time to fill with, fishing is not developed.

Only a little over a tenth of the respondents noted a high degree of the operational efficiency of the lakes. In the responses of the majority the middle and lower middle estimates of the operational efficiency of the lakes are dominated.

The respondents in most cases do not tend to evaluate highly the ecological conditions of lakes. Exception is the state of the lake Kambash, which is a province not only for Aral region, but throughout the Kyzylorda oblast.

According to most respondents, the resources of lakes are not used sufficiently.

The development (undeveloped) of the lake system has a direct impact to the socio-economic situation of the population in the studied rural districts of the zone of the northern Aral Sea region. The highest ratings of the socio-economic situation are given by the residents of Koszhar rural district, where the fish hatchery is located. Among the working population of this settlement unemployment is not registered.

The lowest ratings of socio-economic situation of the population were made in the aul Bogen County, located in the zone of direct drying up of lakes.

In connection with the drying up of lakes, the lack of conditions for fishing in the population of rural districts of the Kazaly district the refocusing to other types of production occurs.

In general, the restoration of wetlands in the northern zone of the Aral Sea basin is of great practical importance for raising the living standards of the population and improvement their socio-economic status.

4.4.5 Fish farming

If until recently the fishing industry was one of the industries specializing in the region, now it is completely lost its leading position and degraded.

Industrial fish catching in the North Aral Sea has its maximum in 1963 and amounted 17 thousand tons / year in the lake systems of the Syrdarya delta - around 5.5 tons / year. Since 1966 there has been a downward trend in fish catch in the North Aral Sea to 7 tons / year and about by 1975, with a slight increase in the 1971-72, remained at the same level. Fall of industrial fish catching in the North Aral Sea was noted from 1976, and since 1979 it was terminated. The fish catching resumed since 1997, when the North Aral Sea has reached a high number of acclimatized Black Sea plaice-gloss. However, it catches up to date not exceed 200-300 t / year.

The species composition of fish in North Aral Sea comprised 20 species in 1938; it has increased in the years 1954-1980 up to 30 species. However, as a result of the salinity of the sea by 1994, only 9 species remained, including 8 acclimatized species. From the native species Aral stickleback only survived.

In the lower reaches of the Syrdarya more or less stable catches of fish occurred in the range of 2 tons / year until 1995, then they dropped up to 0.03 tons in 2001. An irregular flooding floodplain and the complete disappearance of some lake systems manifested itself.

The fish catches in the lakes of the lower reaches of Syrdarya began to fall after the overlap of river with Shardara dam.

In 1976 on the lake Kamystybas a farm for salable fish rearing has been established. This gave a positive effect, because 23 thousand centners of fish was taken at this lake system in 1985 that more than in 1970.

Таблица 46 - Fish industry

Parameters	**2002**	**2003**	**2004**
Fish catch by lakes systems, tons			
Kuandarya	56.0	73.0	58.0
Aksai	17.7	14.0	19.0
Kamystybas	23.0	62.3	111.82
Akshatau	29.2	59.0	47.0
Right-bank Seaside	13.0	11.0	10.2
Left-bank Seaside	0	0	0
Total	**138.9**	**219.3**	**246.02**

Regulation of flow of the Syrdarya and Amudarya rivers and its exclusion for the purposes of agricultural industry resulted in a decline of level of the Aral Sea. If until recently the fishing industry was one of the industries specializing in the region, now it is completely lost its leading position, and degraded. The fish catches in the lakes of the lower reaches of Syrdarya began to fall after the overlap of river with Shardara dam. Today in the Aral Sea is found only one from fish species - plaice-gloss. Although according to the recent figures of the ichthyologists it is on the verge of extinction due to the fact that its spawn cannot withstand to increased water salinity.

Currently fishery importance retains only two lake systems - Kamyshlybash and Akshatau and partially – Aksay-Kuandarya. However, in the remaining lakes, the number of major commercial fish species - carp and bream markedly decreased, but increased sharply the number of roach, predatory and weed fishes.

Fish and fish products are the staple food, and sometimes the main type of income among the local population.

The residents of the Aral Sea region for many years suffered from severe environmental and socio-economic problems and, above all, the quality of drinking water. Fisheries and paper industry, whose development depended on the fish and reeds, as the raw material, disappeared, thus depriving of livelihoods for thousands of people.

4.4.6 Using and processing of cane for industrial purposes

Reed is a plant which is becoming more widely used in the national economy: in construction, paper-pulp and chemical industries.

In the Aral Sea region the coastal, border and swamp reeds in the hayfield-boggy, peat-boggy, swamp-boggy (around lakes) soils have had have industrial value. Height of vegetation in some places reaches 3 to 4 meters and a gross yield of dry matter in the best years varied in the range of 10-15 tons / ha.

In 1958 in Kyzylorda city a construction of the paper-pulp mill began, where as raw materials of which were to be the local industrial cane. According to L.F. Demidovskaya et al, under process scheme for Kyzylorda paper-pulp mill for one-year period in 1965 the need for the normal functioning of the plant amounted to 140 thousands. The main raw materials for paper-pulp mill were Kara Uzyak and Koksu blocks near Kyzylorda city. In the Aralsk and Kazaly districts the industrial cane reeds were of secondary importance.

According to the Institute of Botany of the Ministry of Education and Science of the Republic of Kazakhstan in the years 1959-1963 the total reserves of industrial cane in the area as of 1960 amounted to 87.54 thousand tons (32.4 tons of soil-feeding capacity).

By 1978, according to S.A. Yerimbetov et al, the cane reeds in the Aralsk and Kazaly districts completely lost their industrial importance. A projective cover declined to 50%, cane height not exceed 0.2-1m and cane reeds lost the industrial value and passed into category of pastures and under selective haymaking.

In 1960 the Aral Sea region of Kazakhstan a stock of reed feed was 163.5 thousand tons (at 19.6 yield / ha feed yield), by 2001 it had fallen to 13.9 thousand tons.

4.4.7 Muskart farming

An acclimatization of muskrat in the Aral Sea region in Kazakhstan was begun in 1948, when the Syrdarya delta was released more than 120 species. Procurement of muskrat pelts began in 1951, peaking maximum limit in 1965, when 68 thousand muskrat pelts were procured, but by 1976 because of drying of muskrat landing the hunting of the animal had stopped completely.

In the future, due to decline in the level of the Aral Sea, as well as the termination of water flow into the delta, there was massive mortality of animals in the muskrat lands, which led to the closure of this branch of production.

4.4.8 Tourism

Coast of the Aral Sea was the center of recreation of the local population, on which rested a year up to 2.0 thousand people. Due to the rapid reliction of the sea level, using of the coastal zone for recreational purposes has become impossible. Since 1982, on the seaboard of the Aral Sea the Aral suburban recreation area is no longer functioning, for construction of which in due time had been invested tens of millions of rubles. There were built a children's camp, campsites, a beautiful beach equipped.

As a result of swallowing of the Aral Sea a summer children's camp near Aralsk city closed since 1976, which existed since 1968 and having the 200 beds. On the coast of the lake Kamyshlybash in 1978-1982 a summer children's camp functioned for 150 beds for children of military personnel working in the region.

In Aralsk city the local balneological center was built on the basis of the thermal source for the treatment of several skin diseases, whose services are enjoyed annually up to 500 people. In connection with decrease in temperature of thermal waters, since 1986 the continuation of recreational activities proved impossible.

At present, in the Aral Sea region two children's camps are functioning. The first camp "Chaika" (Kazaly district) on the banks of the Syrdarya River from 1972 takes every year in the summer 150 people. The second camp was opened in 1986 on the coast of the lake Kamyshlybash (Aral Sea region), for 100 beds.

The Lake Kamyshlybash is a tourist recreation place. According to tentative data in 1970-1985 a number of local and nonresident tourists coming for fishing, hunting comprised up to 3 thousand people per year with an average duration of rest up to 5 days. Currently, the number of tourist arrivals dropped to 1 thousand people per year.

4.5 Recommendation for social and economic issues solving

The enhancement of the situation in the region is possible on the base of improvement of the water resources management and water consumption. LS restoration activities by construction of the channels, head water intakes, control structures and dams are not difficult technically and they are not required a lot of the financial expenditures.

For improvement of the social conditions in the region it is necessary to construct the missing industrial objects, public amenities, and engineering and transport infrastructure.

The Development Plans for Aral and Kazaly rayons includes the following activities by trades:

a) industry - construction of the fish treatment factory (“Center Kambash Balyk”) and fish treatment process management authority («Aral Tenizi»);

b) agriculture and agro-industry – restoration of the lakes systems’ area recommended by the project (i.e. 75.32 ths. ha – lakes, 30.17 ths. ha – bogs), hayfields and pastures – 61.857 ths. ha, will permit to increase cattle stock up to: cattle – 66600, sheep and she-goad – 462500, horses – 31500, camels – 20400 heads;

c) health – construction of the diagnostic polyclinic in Aralsk city, 2 hospitals for consumptives (100 beds each) in Aralsk and Kazaly cities, 2 rural hospitals and 2 family polyclinics;

d) education – construction of the 4 urban and 13 rural schools, and 12 infant schools;

e) engineering network – construction of the water pipelines from Main Aral-Sarybulak Water Pipeline to settlements, reconstruction of the water pipelines in Kazaly city and Kent Aiteke Bi, water supply projects for Zhanakazaly and Aralsk city, power supply projects for 12 settlements, and boiler-house, reservoir repair, etc.;

f) culture and sport – construction of the central library in Kazaly city, 3 clubs, 1 stadium in Kazaly city, sport-and-health complex, sport schools, and 2 gyms;

g) house construction for young specialists;

h) Forest-melioration activities on the dried sea-bed under the GTZ Project, river control activities and construction of the hydrostructures under the SYNAS Project.

Totally, the received results evidence of necessity of the planned activities on establishment of the control lakes system and NAS in the delta of the Syrdarya river and on the dried bed of the Aral Sea.

4.6 Damages of the lakes systems

INTAS-1059 “Aral Sea region of Kazakhstan” Project has defined the average loss from ecological disaster - desiccation of the Aral Sea in the area of the Aral Sea region of Kazakhstan.

The total direct and indirect socio-economic losses from environmental catastrophe in the Aral Sea region of Kazakhstan amounted to 52.35 million USD.

Maximum damage associated with losses in irrigated agriculture, comprised 24.8% of the total losses.

Table 47 – Damages of the lakes systems

Annual average damage, mln. USD	Left-bank Seaside and Right-bank Seaside LS	Kamystybas and Akshatau LS	Aksai-Kuandarya LS	Total
Economic damages caused by:				
Decrease of the lands area	2.8	4.5	5.7	13
Decrease of the milk production volume	0.46	0.74	2.3	3.5
Deterioration of the conditions for livestock	0.89	1.41	5.9	8.2
Decrease of the shipping operations	0.12	0.18	0	0.3
Termination of the reed processing	0.6	1.9	0.1	2.6
Decrease of the karakul production	0.08	0.12	0.7	0.9
Indirect damages in the fish industry	0.45	0.15	0.2	0.8
Indirect damages in the skin production	0.25	0.35	1.6	2.2
Decrease of the fish catch	0.48	1.42	0.7	2.6
Termination of the musk-rat skin production	0.05	0.13	0.12	0.3
Termination of the tourism significance	1.9	2.4	0	4.3
Social damages caused by:				
Migration process	0.14	0.26	0.6	1.0
Loss of the skill specialists	Not calculated			0
Decrease of the living standard	2.1	3.35	5.52	10.97
Increase of the sickness rate	0.25	0.4	0.65	1.3
Decrease of the life interval	0.06	0.12	0.2	0.38

4.7 Economic parameters from living conditions improvement in the region

In case of the Project implementation, population residing at places of the Aral Sea region and involved in agriculture and homestead lands, and fishing will have improved conditions of life that is urgent for Kyzylorda oblast where agriculture is mostly developed industry, the government will get funds in the form of taxes from population and enterprise. It is worth noticing, that after ecosystem restoration in the delta of the Syrdarya river and the Northern Aral Sea some social problems of population of rural districts of the region will be solved and therefore economical position of population in living conditions will be significantly improved.

The amount of prevented damage from restoration of the lake system is considered in the project further:

- Damage from non-receiving of revenue from hay-fields.
- Loss from fish industry
- Costs for treatment of sick persons,
- Other indirect costs

Expected benefits from restoration of lake system on the delta of Syrdarya river.

- Profits form fishing industry and haymaking

Useful volume decrease of the salt-dust transfer will permit to improve the conditions of the pastures and increase the forage production. Similarly, improvement of the water supply quality in the delta will permit to increase the fish production. Particularly, it will have positive impact to hayfields of all lakes systems which area is 61 857.00 ha, it will restores the fish lakes with area 75 840.00 ha and ponds – 4 250.00 ha.

Table 48 - Forecast fish catching volume

Name	Area, ha		Forecast production (t)		Net profit(1000US$)	
	Lakes	Hayfields	Fish	Hay	Fish	Hay
			Productivity (t/ha)		US$/t	
			Lakes - 0.05 Ponds – 0.139	1.50	1500.00	25.00
Lakes systems in the delta of Syrdarya river						
Lakes Ponds	75840 4250	61857	3792 590.75	92785.5	6574.1	2319.6

Notes:

Productivity of haymaking is accepted in accordance with annual reports of Kyzylorda oblast.

Productivity of fish production s accepted in accordance with forecast of KazSIIF.

Table 49 - General prevented damage from restoration of lake systems

№	Name	Unit.	Quantity	Unit cost, ths. tenge, (net profit)	Cost, mln. tenge	Prevented damage, в %	Cost of prevented damage, mln. tenge
1	Hayfields	ha	61857	4.56	281.84	50	140.92
2	Fish production	ton	4382.75	182.25	798.76	50	399.38
3	Health	mln. tenge			4973.37		4973.37
4	Ecology prevented damages	mln. tenge			846.855		846.855
	Total				6900.82		6360.53

For calculation of economical efficiency about 2-year period is under evaluation, where term of construction is 36 months with taking into account of pre-production period. Operation of enterprise is accepted as 23 years.

4.8 Calculation of direct production costs and assessment of production activities

In accordance with specifics of project construction the operational costs include costs for materials, energy costs, costs for complete overhaul and technical maintenance, remuneration of labour and allocations to social insurance, depreciation charges. Depreciation charges for taxation purpose are determined on fixed assets in accordance with the Law of RK as of 24.04.1995 «Concerning taxes and mandatory payments to budget». Standard amortization is accepted for depreciation charges.

Taxation is accepted in accordance with current tax code of RK, property tax - 1% out of capital investments. Other taxes, security of the project, and other charges are stipulated in other charges that amount to 6% out of operation costs minus depreciation charges for complete restoration. Calculation of costs for the 25-year period is accepted with taking into account inflation in accordance with methodical recommendations, inflation coefficient in the project is accepted within 7%.

Ecological prevention of damage is based on principals of complete recoupment of costs with present value PV= 13%. As a rule, basing on practice of international financial organizations funding governmental projects, present value is taken at rate 10%-15%. Alternative option for choosing present value is the rate of refunding of National Bank of the Republic of Kazakhstan characterizing weighted average cost of money means on the market of Kazakhstan.

At present, refunding rate of National Bank amounts to 11%. Taken into account governmental character of the object, significant amounts of investments, present value is rated at rate 13%.

Table 50 - Production costs (by economical elements)

No. of item	Kind of costs	Aggregate amount
		Million tenge
1	Inventory holdings	37.14
2	Costs for electrical energy	5.49
3	Water on owned needs	1.16
4	Depreciation and current repair of transport vehicles, 10%	0.95
5	Cost of fuels and lubricants	2.12
6	Remuneration	113.04
7	Allocation for social assurance 10%	11.30
8	Fund of mandatory social insurance 1,5%	1.70
9	Depreciation of fixed assets on complete restoration	181.34
10	Depreciation charges to complete overhaul	65.99
11	Costs for current repair	25.36

12	Property tax	17.95
13	TOTAL	463.55
14	Services and other costs	16.93
15	Production costs	480.48

Table 51 - Structure of production costs on economical elements. Production costs (on economical elements)

No.	Economical elements	Amount	specific weight of element in %
		Million tenge	
1	Material costs	45.91	9.56
2	Costs for remuneration of labor	113.04	23.53
3	Allocations to fund of remuneration of labor	13.00	2.71
4	Depreciation of fixed assets and costs fir current repair	273.65	56.95
5	Taxes	17.95	3.74
6	Interests for credit	0.00	0.00
7	Other costs	16.93	3.52
8	Total	480.48	100

Analysis of sensitivity for basic parameters in which the project retains acceptable level of efficiency and financial consistency shows that internal and external factors have basic impact:

- change in capital investments.
- change in operational costs.

Stability of investment project at possible changes of given risk factors in its implementation is agglomerated, checked on results of calculation of commercial efficiency for basic variant though analysis of dynamics of real money flow. At this, mandatory condition of stability is high values of integral indicators. In particular, positive value of net income and liquid money means within all period of planning.

Table 52 – Analysis of project sensitivity

Name	Unit of measurement	Indicators		
		Maximum	Base	Minimum
Sensitivity rate	%	125	100	75
Benefits from restoration of lake system	mln.m3	6360.53	6360.53	6360.53
Capital investments	mln.tenge	5792.07	4633.66	3475.24
Net income	mln.tenge	3450.65	3450.65	3450.65
Net discounting revenue	tenge/m3	12894.92	13701.01	14507.11
Internal rate of revenue	tenge/m3	42.22	46.91	52.28
Discount of present value PV	mln.tenge	13.00	13.00	13.00
Discounting recoupment term	%	3.00	2.00	2.00

Table 53 - Financial technical and economical indicators

No item	Kind of costs	Unit of measurement	Indicators
1	Capacity of enterprise in natural terms		
	Lake system in the delta of the Syrdarya	ha	75840.00
2	Profits from elimination of damage on lake system	mln.tenge	6360.53
3	Total number of employees	person	85
4	Cost of construction	mln.tenge	4633.66
5	Cost of current fixed assets	mln.tenge	0.00
6	Investment for calculation of economical efficiency	mln.tenge	4878.48
7	Floating assets	mln.tenge	94.14
8	Operation costs	mln.tenge	672.67
9	Duration of construction	month	36
13	Profit	mln.tenge	4929.51
14	Net profit	mln.tenge	3450.65
15	Net present value	mln.tenge	13701.01
16	Index of revenue		4.78
17	Internal rate of revenue	%	46.91
18	Discount recoupment term	year	2
19	Common recoupment term	year	2
20	Discount	%	13.00

Analysis of sensitivity shows that to provide positive values meeting objectives of the project it is necessary that:

-level of capital investments is not exceeding 25%. Since with increasing of capital investments the internal rate of revenue is decreasing, and term for recoupment of the project is increasing.

Conclusions on results of financial analysis.

The resulted data are favourable for the project at present value PV= 13%. The indicators given in Table 47 show sufficient efficiency of the project since:

- net present value (NPV)>0
- efficiency coefficient of capital investments >1
- internal rate of revenue is higher that rate of revenue for capital required by investor IRR >PV= 13%,
- discount recoupment term is 2 years,
- common recoupment term is 2 years.

Investments in the given investment project are justified.

4.9 Calculation of economic efficiency indicators

Calculations of economic efficiency are performed at the level of national economy. The calculations are performed in conditions the same to above given financial calculations. Revenue part corresponds to calculations of earnings in the financial section. Income tax and VAT are excluded from expenditure part which is the revenue part of national economy. Economic indicators of the Project efficiency are given in Table 54.

Table 54 - Financial technical and economical indicators

No item	Kind of costs	Unit of measurement	Indicators
1	Capacity of enterprise in natural terms		
	Lake system in the delta of the Syrdarya	ha	75840.00
2	Profits from elimination of damage on lake system	mln.tenge	6360.53
3	Total number of employees	person	85
4	Cost of construction	mln.tenge	4633.66
5	Cost of current fixed assets	mln.tenge	0.00
6	Investment for calculation of economical efficiency	mln.tenge	4878.48
7	Floating assets	mln.tenge	94.14
8	Operation costs	mln.tenge	491.33
9	Duration of construction	month	36
10	Profit	mln.tenge	5775.05
11	Net profit	mln.tenge	5775.05
12	Net present value	mln.tenge	12648.97
13	Index of revenue		4.49
14	Internal rate of revenue	%	22.52
15	Discount recoupment term	year	6
16	Discount	%	13.00

Budget expenditure includes funds assigned for direct budget funding of the project and is made up with taking into account of replacement of equipment and works in the amount of 4,878.48 million tenge. Basing on indicators of annual budget effects the following is determined:

- internal rate of budget efficiency;
- term of budget recoupment;
- degree of financial participation of the government in project implementation;

The resulted data are favourable for the project at present value PV = 13%. Indicators evidence sufficient efficiency of the project since:

- net present value (NPV) >0,
- efficiency coefficient of capital investments > 1
- internal rate of revenue is higher that rate of revenue for capital required by investor (IRR)>PV=13%.
- discount recoupment term – 6 years.

5 INTEGRATED WATER RESOURCES MANAGEMENT (IWRM) OF THE SYRDARYA RIVER DELTA

5.1 Existing management of the Syrdarya river basin

In the world there are many approaches to solving the water problems. Depending on natural and climatic conditions, adopted system of economic management, traditions and other factors, each state decides in its own way the issues of management, use and protection of water resources. However, owing to a joint experience, the methods or approaches to water management have drastically changed and reduced to more or less universal platform and to unified principles. Recently, more and more scientists and experts believe that the concept and principles of IWRM are among the basic assumptions to sustainable development.

Therefore, the main directive of the Summit in Johannesburg for each country was the preparation of National Plan for Integrated Water Resources Management and Water Efficiency. The President of the Republic of Kazakhstan N.A. Nazarbayev signed this directive, and thus, Kazakhstan adopted a commitment to improve water management through the adoption of the principles and practice of IWRM. Pursuant to this directive Kazakhstan developed a National Plan of IWRM and Water Efficiency.

The National IWRM Plan determines which steps and actions needed at the state level to support the resources in the river basin level, where the practical management is performed. An implementation of the Plan should provide a guaranteed amount of pure water for use and ecological safety of the natural environment.

National Plan of IWRM and Water Efficiency is the first step in the process of organization of IWRM and improving water use efficiency in Kazakhstan. It reflects all the stages of implementation and relies on other plans, strategies and programs that are either being implemented or to be initiated.

The main objectives of the IWRM Plan are fully corresponding with the main focus of water policy and long-term goal, announced by the state in the “Strategy of Kazakhstan – 2030”, is the preservation and rational use of water resources for the health and welfare of citizens.

In order to implement the National Plan of IWRM a proper allowance should be made for gradual decrease of water resources of the country by reducing the income of water from the territory of neighboring states. Therefore, the implementation of IWRM plan shall be carried out in two directions: the rational use and protection of water resources within the country and the establishment of water relations with neighboring states. Water requirements in the future will not be fully protected until steps will be taken to reduce water losses through improved water conservation and to develop effective mechanisms for the relationship in the sharing and protection of water resources with neighboring countries with whom we have transboundary watercourses.

Management of water resources of transboundary rivers is very important for

Kazakhstan, since almost half of the total volume of water resources entering through the border from neighboring countries, and considerable part of the water also flows to the neighboring countries from Kazakhstan. Water flowing into Kazakhstan has usually of poor quality, because already polluted by industrial enterprises, agriculture facilities and urban wastewater. Similarly, Kazakhstan continues to pollute the rivers before they cross the borders of other countries.

Thus, the efficient use of water resources and relevant institutional reforms in water sector based on the integrated management of water resources both nationally and regionally, should ensure a balanced solution of socio-economic challenges and problems of restoration and preservation of water-resource potential of the river basin, including Syrdarya River. The regulatory role of government in all this is fundamental, and the economic activities of industrial, agricultural and other enterprises should incorporate environmental priorities.

In the present time for distribution of water resources on the consumers of the Delta and release to the Aral Sea along the Syrdarya River there are 35 major waterways.

With a view to improve opportunities for sharing and managing water flow on the river four hydraulic projects are available and scheduled for construction.

Basic indicators of hydraulic units are given in Table 55.

Table 55 - Basic indicators of the hydraulic units

Name	Capacity, m^3/sec	Basic indicators
Kazaly hydraulic unit	1000	Is located at 1,450 km from Shardara hydraulic unit. Is operated since 1970. It has right-bank discharge outlet with 85 m^3/s discharge and two left-bank ones with 100 и 30 m^3/s discharge, respectively. The hydraulic unit was reconstructed in 2006. It is intended for water supply to the left-bank and right-bank irrigation massifs and to Aksay irrigation system.
Rayim hydraulic unit	400	It is planned new hydraulic unit (1,567.1 meters). It is intended for water supply to the Kamystybass and Akshatau lake systems.
Amanotkel spillway	150	Is located at 1,584 km along river. Built in 70s for water supply to the lake system. The recovery work is required.
Aklak hydraulic unit		Is located at 1,631 km along river. Currently is under completion of construction. It is intended for water supply to the left-bank and right-bank lake systems.
Aytek hydraulic unit	300÷760	As a result of construction of the set of Aytek structures a discharge in Syrdarya River achieved to 300-760 m3/s, the level of water supply for 15.3

		thousand ha of irrigated lands has been performed, the water passage to NAS increased the bed of Syrdarya River stabilized and underflooding with groundwater of Kyzylorda city decreased.
Shardara dam		The reconstruction of the Shardara Dam allowed to improve the reliability of the structure and its operating life, to improve the operating mode of the Shardara hydro-electric power station and accordingly to increase the electricity production in winter time, to increase the level of water supply of the economy sectors and preservation of ecosystems of Syrdarya Delta, reducing the threat of Arnasay Dam failure and stopping of the water release to Arnasay depression.

Water inflow to the lake systems and flood-lands depends on the dryness of the year. The simplest structures built in the last period - dams and pilot ditches may mitigate the effects of lack of water. However, the overall process of degradation, in spite of this, and periodic increases in water content, is continuing.

Currently the river flow is fully regulated and therefore flow of water to the Aral Sea region does not depend much on the natural, but on human factors, as well as the decisions of legislative water resources authorities. Consequently in water apportioning of the flow of the Syrdarya River the interests of all water users of the delta should be taken into account.

Analysis of hydrological data of water inflow to Kazaly hydraulic station for period of 1912-2004 showed that:

- in the natural period of before 1965 the water inflow to the hydraulic station averaged 12,987 mln.m3/year;
- during 1966-1992 a human influence to the river flow; a water inflow to the hydraulic station was reduced from 1,540 to 390 mln.m3/year;
- during 1992-2005 the water inflow increased and averaged 7,167 mln.m3/year.

Natural water resources in the site of Kazaly Dam on the river life periods are shown in the Figure 49.

To improve the efficient use of available water resources in the delta, it is necessary to perform a set of measures for distribution of the available water resources.

Preliminary studies showed that for recovery of the lake systems and wetlands of the delta and feed flow to the NAS to support the horizon of the sea at around 42.0 m it must have an annual flow in the of Kazaly Dam at least in the volume of 5.5 km3.

Preliminary results of field studies and planning of the project showed that it is possible to save the Northern part of the Sea, through improved water management in the basin and regulating the flow of the Syrdarya River.

To this end it was decided to build in the Berg Strait the permanent dam with the escape. Currently the construction of Kokaral Dam has been completed.

Kokaral Dam will allow to accumulate annual river flow and salinity of the NAS will be maintained at 17 g/l, thereby providing the breeding of valuable species of local fishes.

NAS is a separate consumer; its necessary consumption consists of volume of water equal to the evaporation and filtration as well as leaching in order to control mineralization at a level no higher than 17 g/liter. The most part of the inflow into NAS occurs in winter since in summer irrigation consumes almost all the water dropped from Shardara reservoir, and in spring and autumn, the grasslands flooded and the fish lakes are filled.

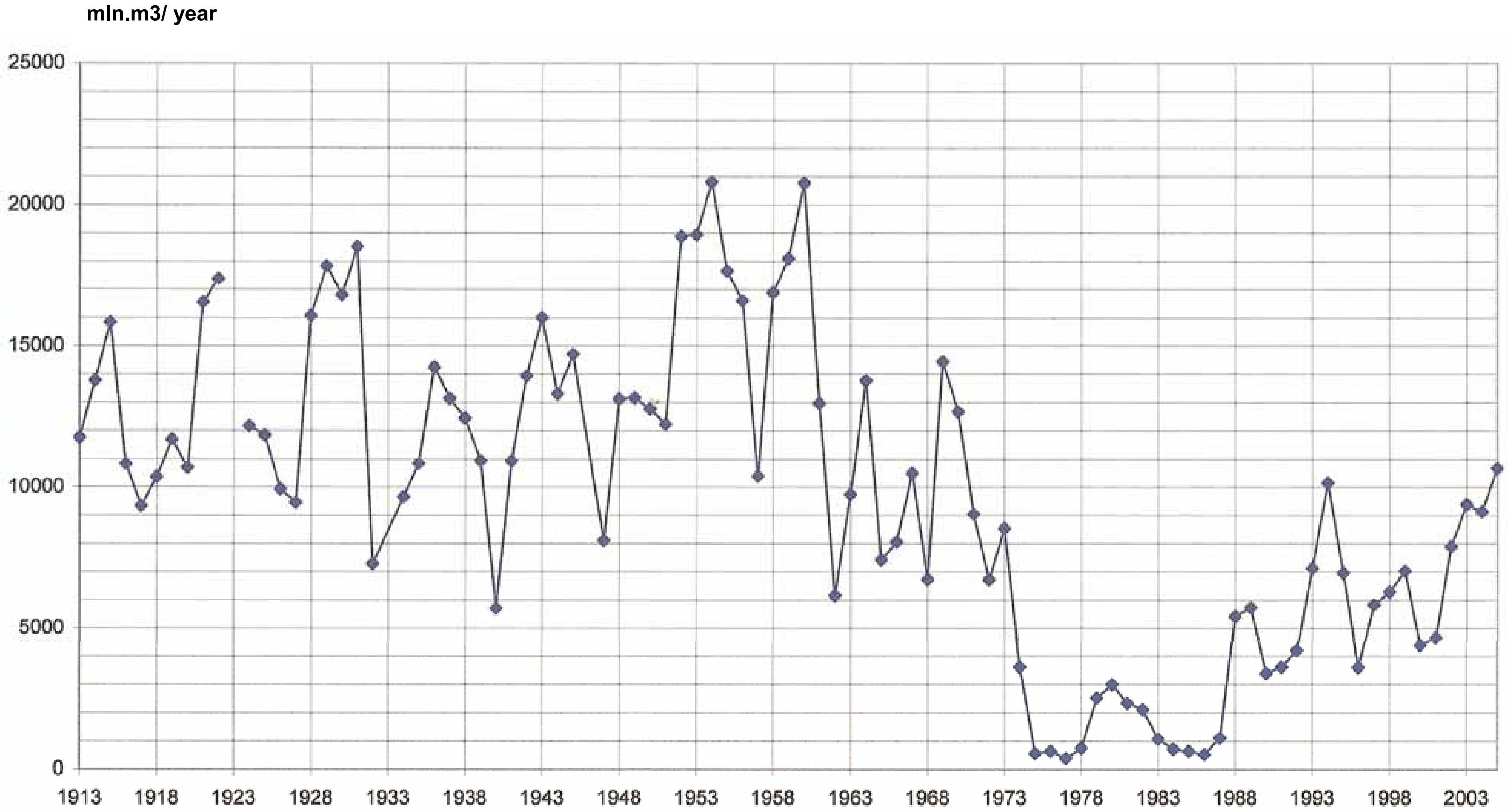


Figure 51 – Natural resources of the Syrdarya river

Table 56 – Natural resources of the Syrdarya river, Kazaly station (data extracts for 1912-2004)

Life intervals of the river	Year	Water resources	Unit	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Annual average
Natural regime of the river	1912/1913 - 1964/1965	Average	mln.m^3	1020	1072	939	798	858	1171	1596	1705	1704	1696	1341	976	12987
			m^3/s	381	424	351	298	352	450	616	636	658	633	501	376	500
		Max	mln.m^3	2518	1991	1358	1104	1176	1845	2644	2705	2644	2673	2665	2696	20808
			m^3/s	940	768	507	412	482	689	1020	1010	1020	998	995	1040	896
		Min	mln.m^3	458	0	474	279	422	0	542	197	69	38	23	26	0
			m^3/s	171	207	177	104	173	153	209	73	27	14	9	10	196
Active anthropogenic impact to river flow	1965/1966 - 1992/1993	Average	mln.m^3	416	394.7	409.7	387.7	395.3	484.3	528.3	443.3	402	335.7	409.7	484	5090.3
			m^3/s	155.3	152.3	153	145	162	181	203.7	165.7	155	125.3	153	187	161.7
		Max	mln.m^3	1749	1682	1393	801	935	1299	1835	2057	1537	1661	1907	1475	14438
			m^3/s	653	649	520	299	383	485	708	768	593	620	712	569	457
		Min	mln.m^3	19	21	21	48	49	27	16	10	10	4	3	10	390
			m^3/s	7	8	8	18	20	10	6	4	4	2	1	4	12
After dissolution of the USSR and change of Toktogul reservoir to power operating regime	1993/1994 - 2004/2005	Average	mln.m^3	549	644	784	870	773	827	831	538	268	238	344	500	7167
			m^3/s	205	248	293	325	317	309	321	201	103	89	129	193	228
		Max	mln.m^3	1077	1267	1513	1495	989	1175	1499	994	581	565	750	1034	10675
			m^3/s	402	489	565	558	405	439	578	371	224	211	280	399	339
		Min	mln.m^3	60.5	77	195	463.4	417.4	415.2	536.5	174.4	20.5	16.3	20.5	43.5	3602
			m^3/s	22.6	29.7	72.8	173	171	155	207	65.1	7.9	6.1	7.5	16.8	114.9
Total:	1912/1913 - 2004/2005	Average	mln.m^3	744	745	672	635	651	844	1133	1138	1095	1072	908	741	9607
			m^3/s	278	291	251	237	267	319	437	425	423	400	339	286	353
		Max	mln.m^3	2518	1991	1513	1495	1176	1845	2644	2705	2644	2673	2665	2696	20808
			m^3/s	940	768	565	558	482	689	1020	1010	1020	998	995	1040	896
		Min	mln.m^3	18.7	0	21.4	48.2	48.8	0	15.6	10.4	10.1	4.3	2.9	10.4	0
			m^3/s	7	8	8	18	20	10	6	3.9	3.9	1.6	1.1	4	12.4

Table 57 – Discharge water volume to the NAS, 1975-2003

Year	Discharge to the Aral Sea, mln.m^3/year		
	total	including	
		winter	summer
1975	617	556	61
1976	547	410	137
1977	479	387	92
1978	780	670	110
1979	3233	1384	1849
1980	2489	1517	972
1981	2190	1241	949
1982	1830	1670	160
1983	870	710	160
1984	740	580	160
1985	680	440	240
1986	530	410	120
1987	1330	930	400
1988	6980	4210	2770
1989	3888	2234	1654
1990	3513	2040	1473
1991	4051	2771	1280
1992	4610	3285	1325
1993	7840	4966	2874
1994	8466	4932	3534
1995	4575	2922	1653
1996	5597	4047	1550
1997	4745	3038	1707
1998	7716	2463	5253
1999	6035	3963	2072
2000	3865	3003	862
2001	3563	3011	552
2002	8641	4834	3807
2003	9764	5752	4012

5.2 Proposed structure of the IWRM for the delta of the Syrdarya river

At the present time water flow of the Syrdarya river on the whole of the basin is fully control and so income of water resources to the Kazaly station depends on not only natural conditions, but anthropogenic factors and activities of the interstate organizations.

The problem of the guarantee water delivery to the Aral Sea Basin and the Northern Aral Sea (NAS) should be regarded as interstate, and result will be depended on understanding between the states of supporting optimal water volume and a discharge regime from tandem reservoirs system along all river distance.

In this connection it is necessary a close connection of requirements and rights of Kazakhstan on satisfaction of water needs for perspective with regional requirements on ecosystem saving. Acceptance of this concept determines the main regulations of the National Water Strategy (which is part of the regional one):

Available water resources in the basin are limited, and that generates need to transfer all water users to intensive water saving development way.

Decision of ecological, social and economical issues of the Aral Sea Basin makes demand of struggle against pollution of water and land resources in the all area of its using and all subjects of the water management complex.

The Aral Sea and ecosystem of the delta are considered as independent and eligible water beneficiaries which water demands are defined with consideration regional ecological, social and economical interests.

Unnatural flow regime of the Syrdarya river, as a result of control by tandem reservoir system, has caused major changes in landscapes of the river-lands. Therefore, issues of vegetation conservation and re-vegetation in the wetlands have had the particular consequence and required new approach to its solution. Re-vegetation in the delta can be achieved on conditions on arrangements of ecological conditions closed to natural.

Estimated water volume for flooding and distributed channels has been defined with consideration of environmental requirements to botanical structure of the wetlands.

Table 58 shows estimated total water resources requirements for ecosystems restoration in the delta of the Syrdarya river.

Table 58 - Annual irrigation rates, gross

Water users	Irrigation rate, m^3/ha	
	net	gross
Lakes	9200	10700
Swamps	13180	15500
Hayfields and pastures	8300	9700
Forests and bushes	8500	10000
Ponds	9200	15500

Based on available information and developmental works it is provided to realize activities for reconstruction of the northern part of the Aral Sea and the delta of the Syrdarya River with its lakes systems, tugai and reed beds, flooding hayfields and pastures.

Preliminary decisions are includes activities on the delta arrangement by construction of the control facilities, channels which should provide stability water supply, save the most valuable lakes systems and lands, and locate waste strong-saline water bodies and land.

Restoration and supporting of stability operation of water industry in the Aral Sea Basin are one of the primary factors of social and ecological problem solving, because the social and economic structure of the delta strongly depends on effective water industry administration and integrated water resources management.

Toward this end the structure of the integrated water resources management was proposed for the delta of the Syrdarya river. It has been produced as General Linear Scheme with indication of engineering structures, water flow direction in the delta in connection with operation regime of the Koksarai reservoir, and for each six lake systems.

The General Linear Scheme of proposed water management activities in the project area and Linear Scheme for each lakes system are shown in the Figures 50-55.

Reduction of water level in the river in low and middle flow years doesn't permit to flood the delta. Because of absence of the necessary water infrastructure, existing hydraulic facilities and water outlets on the river don't satisfy to the engineering requirements of high water discharge and command conditions during low-water period. As a result of this, it is necessary to reconstruct of existing facilities and construct new additional control facilities which enable to well distribute and control of available water resources of the delta.

At the present time with the object of supporting of the delta's natural system, the construction of two new control concrete dams in the Syrdarya river have been proposed.

First control dam – is the lower dam "Aklak" is being built near to old Aklak dam for passing flood flow in winter - 395 m^3/sec, and in summer - 476 m^3/sec. At the present time the dam is in final construction phase. The dam will enable to supply water to all seaside lakes system, part of hayfield and natural complex by existing channels, 8 main facilities are under construction (Sagimbai, Domalak, Karateren-1, Karateren-2, Kyzylzhar, Zhilandy, Kyzketken, Beketai).

Second control dam has been designed near to Raim village in the main water intake facility of Taupzharma main channel which mean for water supply to Kamystybas and Akshatau lakes systems.

The Raim dam has been estimated for passing about 514 m^3/sec in summer and 395 m^3/sec in winter. The facility has right and left-bank regulators. Main water consumers in the delta are: flooding hayfields, forests and bushes, fish lakes and other natural objects.

Water supply to the Aksai lakes system is came by Aksai channel from Kazaly control structure.

Kuandarya lakes system, in comparison with other lakes systems in the delta of the Syrdarya river, has the highest coefficient of reed area, i.e. 3 m2 of reeds for 1 m2 of the water surface. In particular, this index defines the specific functioning of the Kuandarya lakes system. Required volume of the water supply, stated after the modeling process, is 200 mln. m3/year in average. This index is four times more than the water supply volume stated by the Hydrology Research Team during the initial stage of the project. The main causes are: understated the evaporation volume from water surface unit (1 m3/year instead of 1.4 m3/year for water bodies of the Syrdarya river delta), at that it is missing the calculation on evapotranspiration of reed.

Research results for 2006 shows (artificial understated volume of water supply – 170 mln.m3/year), that even good conditions the reeds are oppressed in the water bodies. This process under the regular water deficit will result in breach of the ecological balance, especially in vegetation (reed area will reduce insensibly).

Functioning of the hydrotechnical structures shows inconsistency in the route Maryamkol – Altynkol – Karakol.

The section Maryamkol – Altynkol has the discharge capacity 10 m3/sec, whereas the section Altynkol – Karatereng has the discharge capacity 40 m3/sec taking into account that Altynkol lake are supplied only through Maryamkol lakes, or necessary to reduce the requirements to route Altynkol – Karakol, or increase the discharge capacity of the route Maryamkol - Altynkol.

Table 59 – Estimated water consumption of the Syrdarya river delta

Water users	Area, ha	Irrigation rate, m^3/ha	Volume, mln.m^3
Delta Fish lakes	47,370.0	15,500	734.24
Natural complex (small lakes and swamps)	28,598.0	10,000	285.98
Hayfields and pastures	52,151.0	10,700	558.02
Forests and bushes	29,823.0	9,700	289.28
Ponds	4,250.0	15,500	65.88
Total for the delta:	**162,192.0**		**1,933.40**
Water losses in distribution main channels			19.9
Water losses along the Syrdarya river bed			40
Total for the delta with losses:			**1,993.30**
Kuandarya lakes system			
Fish lakes	2,870.0	15,500	52.55
Natural complex (small lakes and swamps)	1,570.0	10,000	15.70
Hayfields and pastures	1,960.0	10,700	20.97
Forests and bushes	151.0	9,700	1.46
Total for the Kuandarya system:	**6,551.0**		**90.68**
Aksai lakes system			
Fish lakes	25,080.0	15,500	388.74
Hayfields and pastures	7,746.0	10,700	82.88
Forests and bushes	19,085.0	9,700	185.13
Total for the Aksai system:	**51,911.0**		**656.75**
Grand total for the delta:	**220,654.0**		**2,732.67**
Discharge to the Aral Sea			**3,000**
Total with the discharge:			**5,732.67**

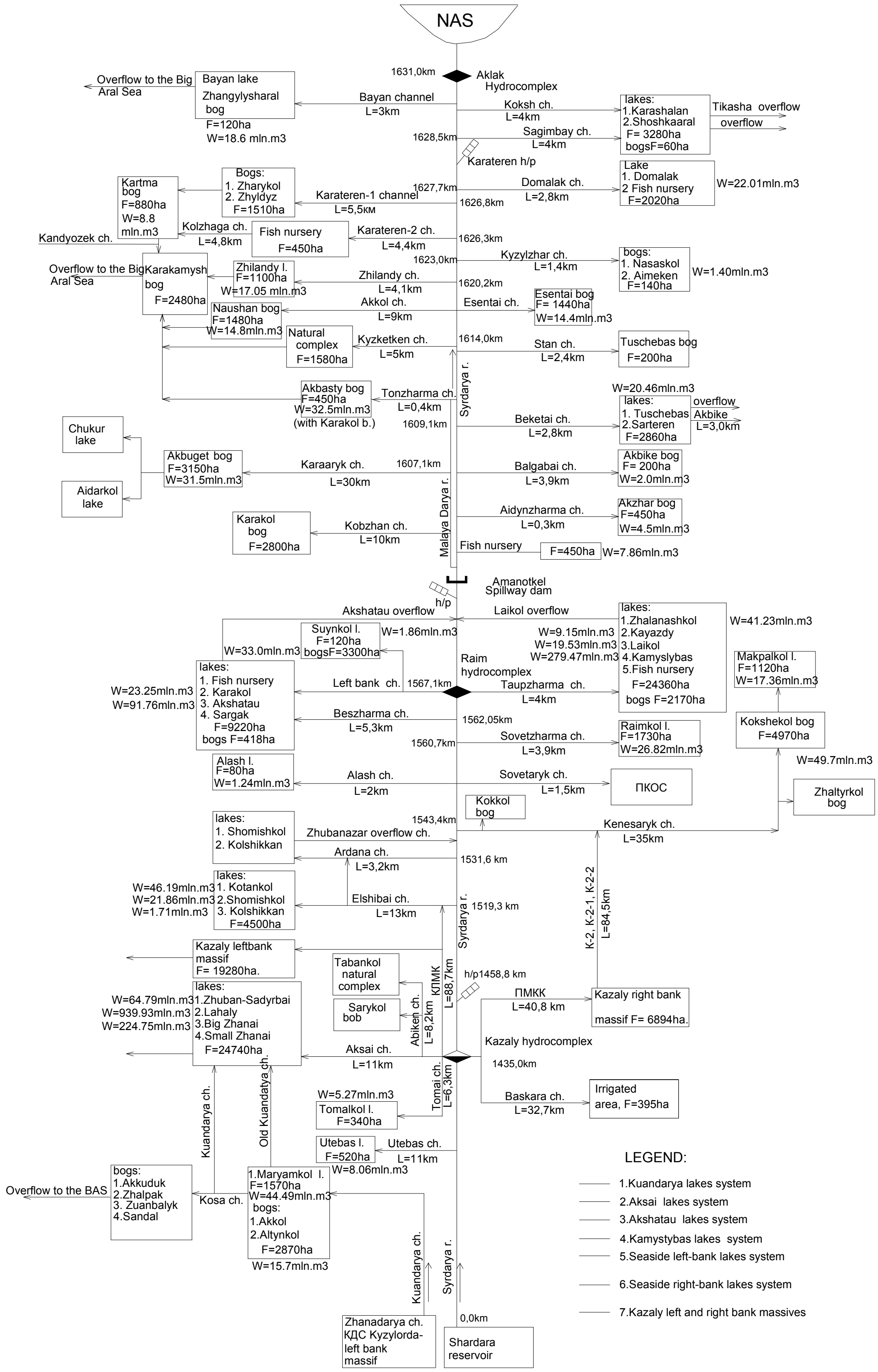


Figure 52 – General Linear Scheme with infrastructures and water flow direction in the delta of the Syrdarya river

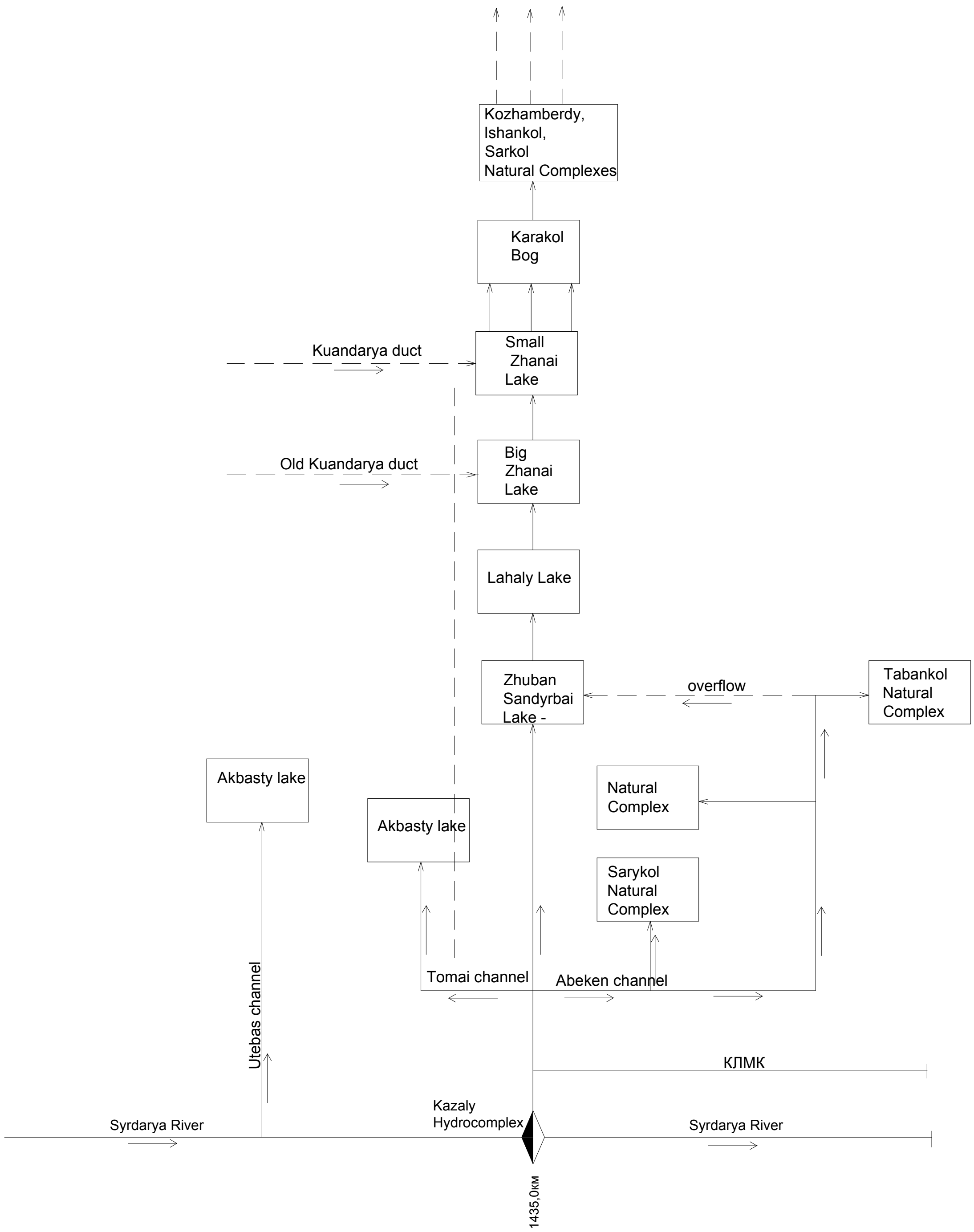


Figure 53 - Aksai-Kuandarya Lakes System Linear Scheme with infrastructures and water flow direction

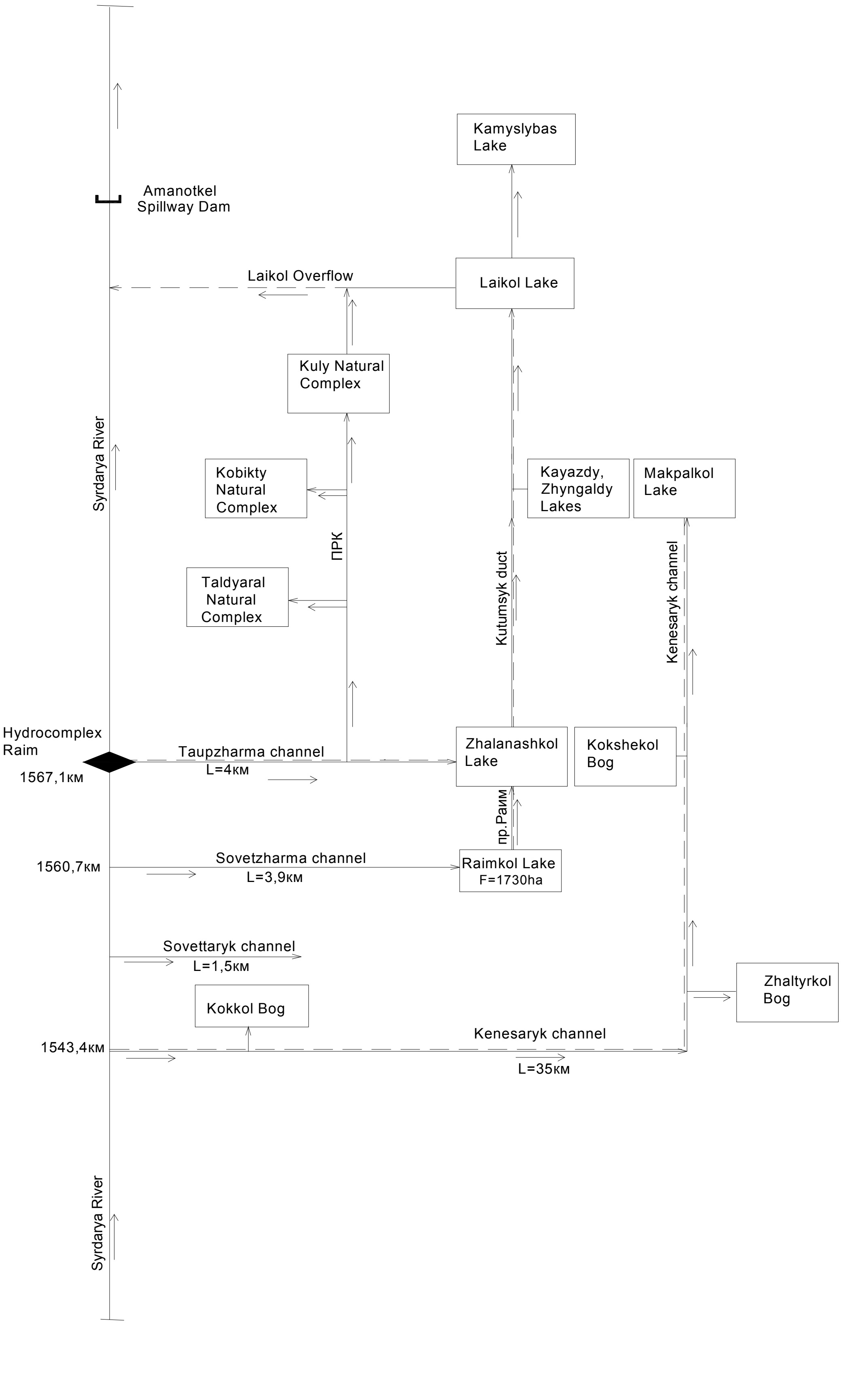


Figure 54 - Kamystybas Lakes System Linear Scheme with infrastructures and water flow direction

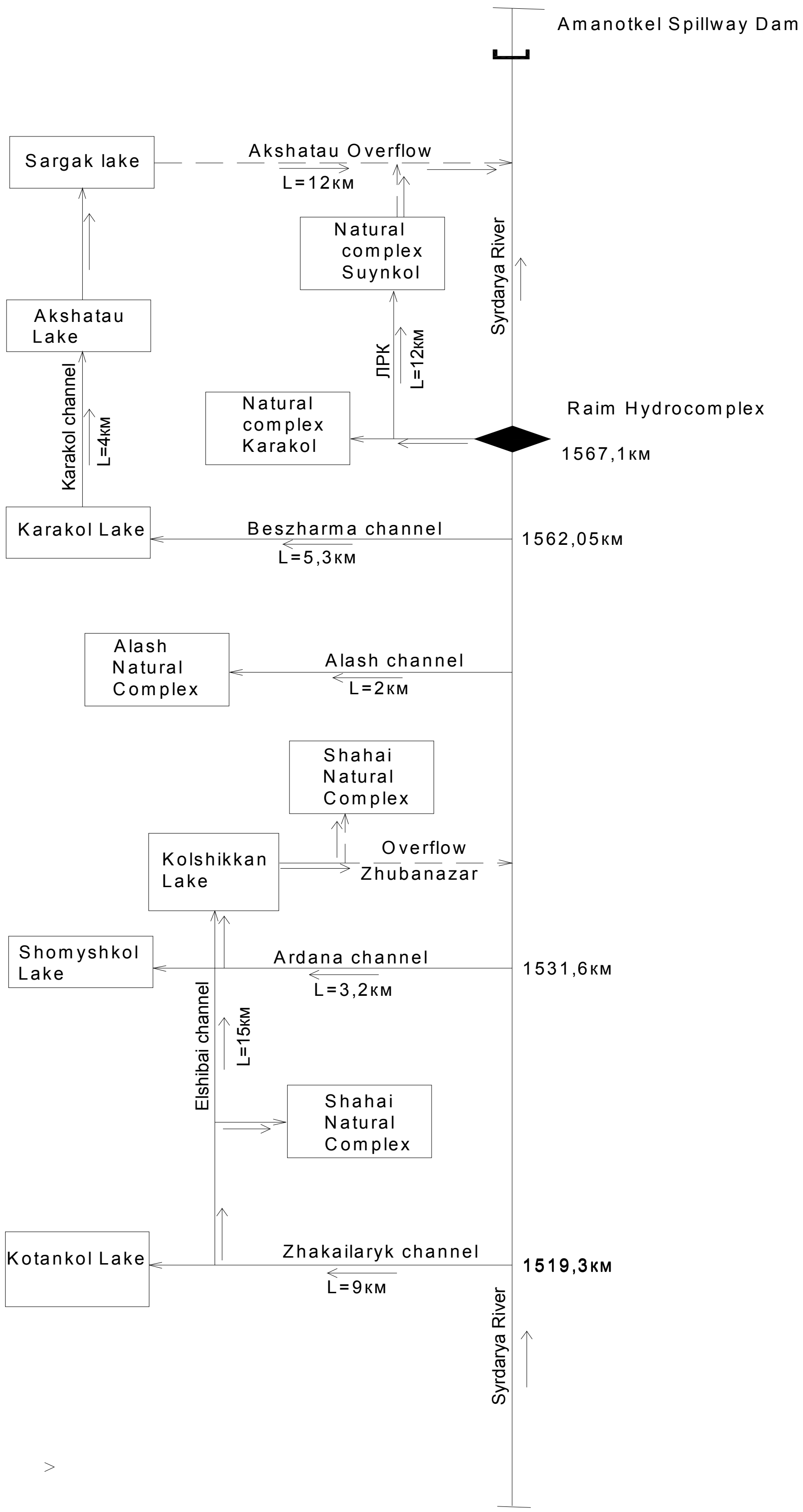


Figure 55 - Akshatau Lakes System Linear Scheme with infrastructures and water flow direction

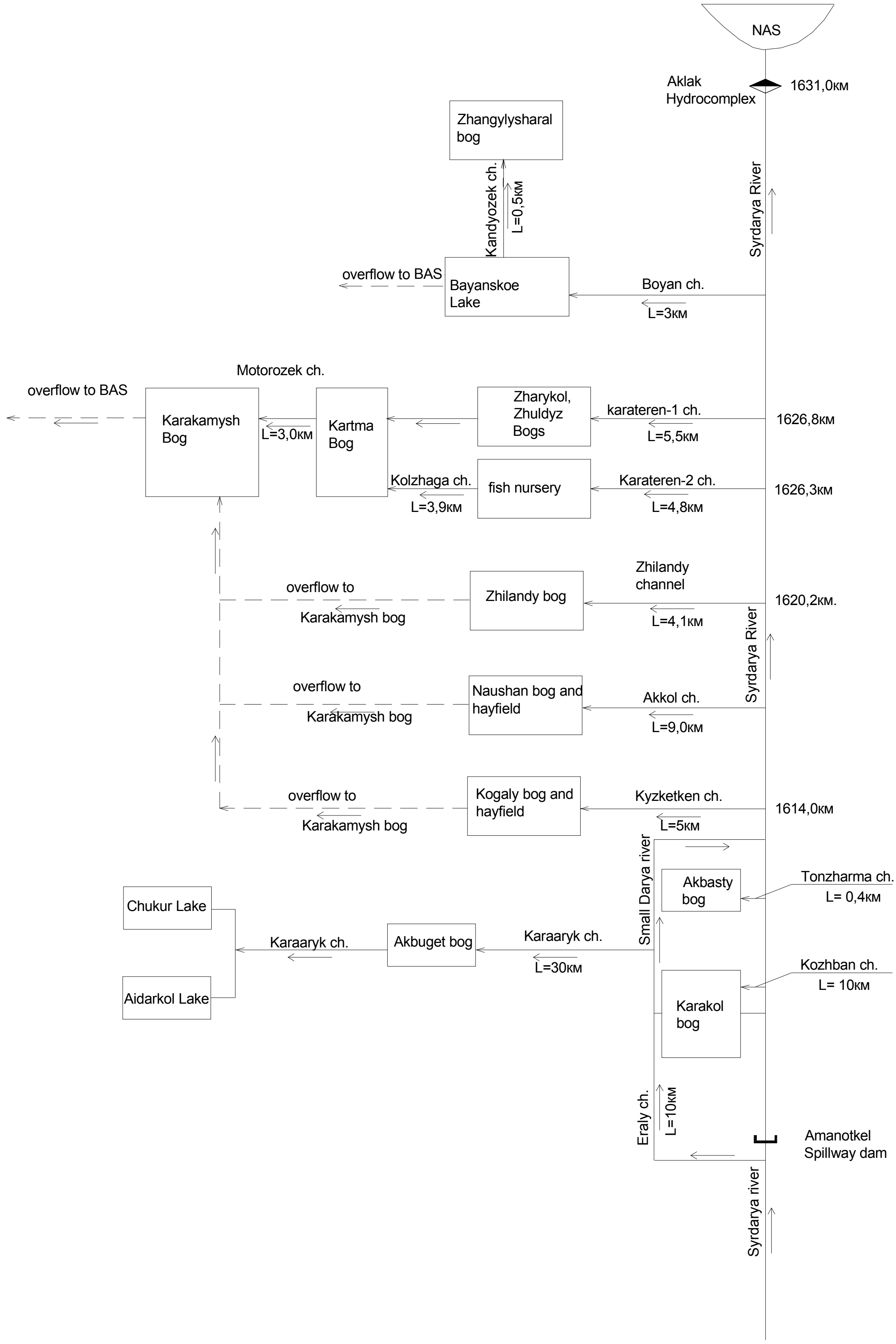


Figure 56 - Seaside Left-bank Lakes System Linear Scheme with infrastructures and water flow direction

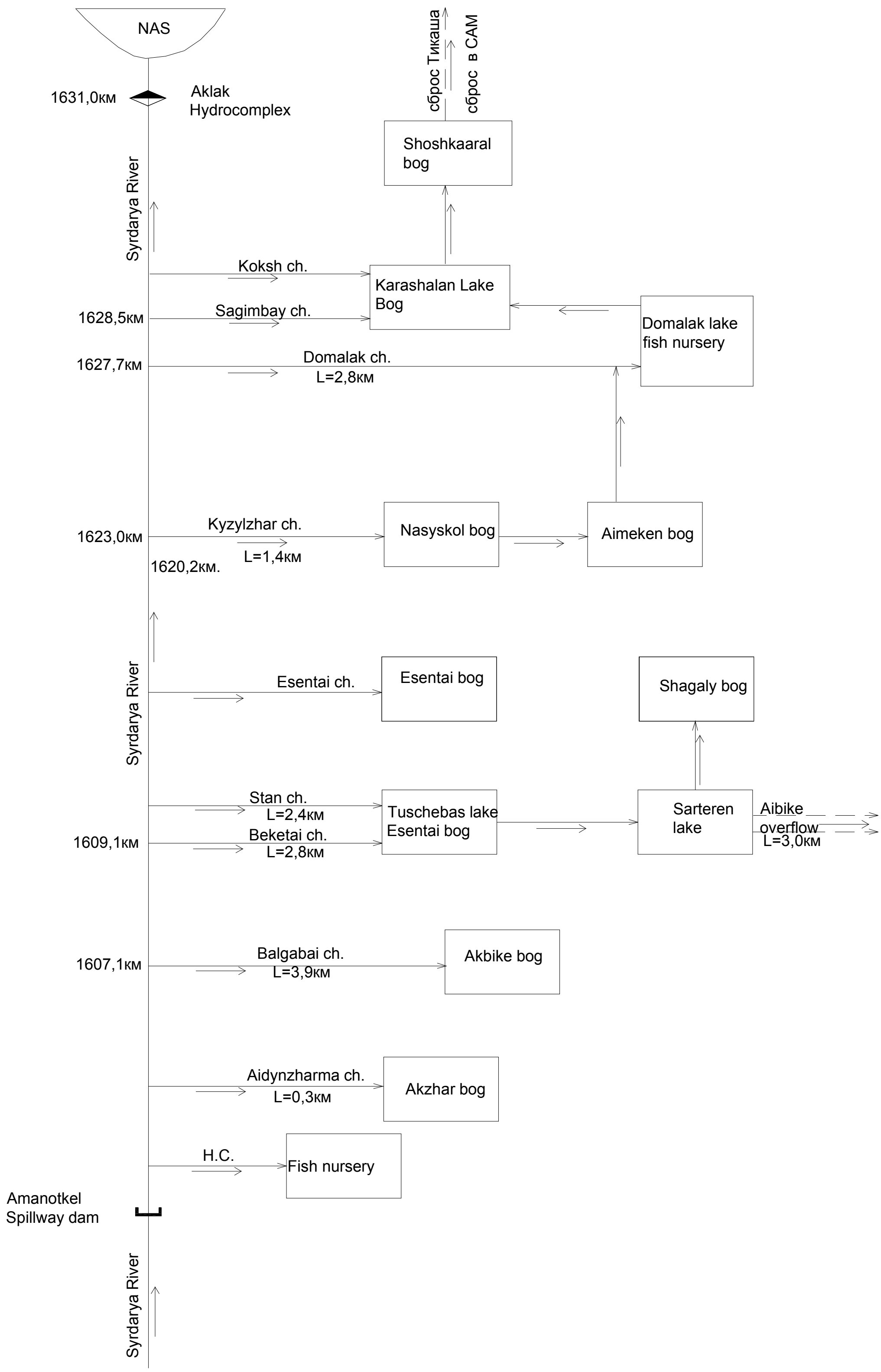


Figure 57 - Seaside Right-bank Lakes System Linear Scheme with infrastructures and water flow direction

Aksai lakes system is more stable to water content variation in comparison with Kuandarya LS due to Kazaly hydro-complex. Aksai system stored 50 mln.m3 in the high-water year (2005 – 720 mln. m3/year), and during the next low-water year (artificially understated water volume 350 mln. m3/year) it discharged from owned capacity in addition 210 mln.m3. Stable balance for Aksai lakes system is the water supply in the amount – 600 mln.m3/year. Lesser order in the difference of the water volume determined by the lower coefficient for reed in the Aksai lakes system (for this system coefficient is 1).

Akshatau lakes system in comparison with other lakes systems in the delta has lowest coefficient of reed – 1. So, each 1 m2 water surface has about 1 m2 of reed area.

Required water supply volume determined is 500 mln.m3/ year in average. This index exceeds the water supply volume stated during the initial stage of the project. The main causes are: understated the evaporation volume from water surface unit (1 m3/year instead of 1.4 m3/year for water bodies of the Syrdarya river delta), at that it is missing the calculation on evapotranspiration of reed.

At the present time the total discharge capacity of the 4 channels permits to transfer the required water volume, but after drop of the Syrdarya water level in summer and missing of control structures, about half of the intake water (approximately 45%) comes back to the river. As a result, optimal regime is not created for bio-products development.

The Akshatau lakes system consists of two non-connected parts. First part – Shomishkol lake, Kotankol lake, Shahai bog which are supplied by Ardana channel.

Second part – Karakol lake, Akshatau lake and Karakol bog which are supplied by three other channels

Akshatau lake has the special rule because it is a sole lake which has the positive infiltration balance. Obviously, the constant injection from ground water explains the stability high mineralization which in twice higher than other lakes and is not depend from volume.

It is necessary to reconstruct the water intakes from the Syrdarya river for guarantee the two-sided water keeping. Guarantee the constant water level by backing in the Syrdarya river is connect with high risk level, because reverse water flow could wash away the head water intakes.

The following reconstruction consecution is recommended: Akshagys, Akkoisoihan, Ardana, Beszharma channels.

Beszharma channel plays the weaker part in the Karakol lake water delivery because Karakol-1 waterway transfers water to the reverse site during the most part of time (from Karakol bog to Karakol lake).

Modeling for Right and Left-bank lakes systems has nor been done.

To solve the problems with the desertisation in the delta of the Syrdarya, rehabilitation of the ecosystems, improvement of the social and economic condition of the population as well as improvement of ecological condition of the region there were determined and implemented the large-scale arrangements at the expense of the loan of the World Bank and the budget of the Republic of

Kazakhstan. The implemented works consist of two phases:

- the first phase – improvement of water supply, sanitation and health of the population of Aralsk and Kazaly regions and implementation of control over the river-bed of the Syrdarya River and the North Aral Sea;
- the second phase – development and maintenance of the delta of the Syrdarya River and rehabilitation of wetlands and lake systems of the Northern part of the Aral Sea.

The developed by us Project "The integrated water resources management for wetlands rehabilitation in the basin of the Aral Sea (the Northern part)" constitutes the scientific and practical basis of the economic and ecological advisability of and need in the implemented actions.

5.3 Proposals for reconstruction of the Aksai-Kuandarya lakes system

The steady water supply of the Aksai lake system is recommended to be defined on the area of 51.9 thousand hectares, including lakes – 25.1 thousand hectares (Table 60). Lakes Zhuban-Sadyrbai, Lakhaly, Large and Small Zhanai of fish industry importance are recommended to be defined as the priority objects of the system.

The forecast system water consumption is evaluated in volume of 412 million m3 at the expense of delivery of river water along the Aksai channel.

In case of availability of the Koksarai reservoir on the Syrdarya River outside the territory of the delta there is no need to erect the hydro-technical constructions for the breakdown of floodwater to protect settlement Aiteke bi from floods aong the Aksai channel. It will greatly reduce budget for Aksai lakes system reconstruction.

Table 60 – Area and volume of water consumption of the Aksai lake system

Lake system	Area, hectares	Volume, million m^3
Aksai	51911.0	656.75
Lakes	25080.0	388.74
Hayfields and pastures	7746.0	82.88
Forests and bushes	19085.0	185.13

Steady water delivery of Kuandarya LS is recommended to be determined on the area of 7.1 thousand hectares, including lakes – 3.4 thousand hectares, Bogs – 1.6 thousand hectares. Lake Marjamkol of fish industry value is recommended as the priority reservoirs of the system (Table 61).

Table 61 – Area and volume of water consumption of the Kuandarya lake system

Lake system	Area, hectares	Volume, million m^3
Kuandarya	7071.0	90.68
Lakes	3390.0	52.55
Bogs	1570.0	15.70
Hayfields and pastures	1960.0	20.97
Forests and bushes	151.0	1.46

The forecast water consumption - gross LS is determined in volume of 90.68 million m3at the expense of use of the collecting-drainage waters of Kyzylordinskiy irrigated field.

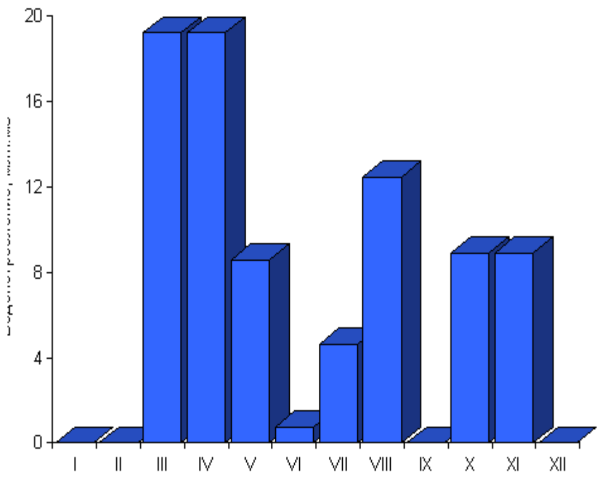


Figure 58 - Estimated water consumption for the Kuandarya lakes system, mln.m3

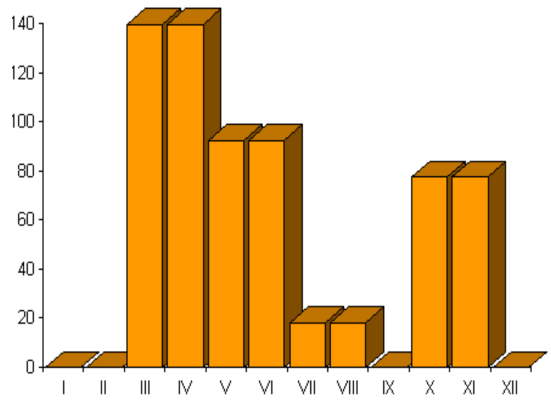


Figure 59 - Estimated water consumption for the Aksai lakes system, mln.m3

Following the lowering of the level of the Aral Sea down to +37m and water discharge from the Boskol bay the changes in the Aksai-Kuandarya ecosystem have commenced. At the same time there were observed the reduction and change of the mode of the Syrdarya river flow and climate conditions in the region.

The arose unfavorable natural conditions in the Aksai-Kuandarya lake system resulted in the necessity of implementation of a number of urgent hydro-economic measures intended for solution of economic, social and ecological problems.

The measures of high priority among the scheduled are:

- a construction of the distribution units in the lead unit of the Aksai canal, according to the canals of Abeken they are designed for the rate of consumption of 5 m3/sec, Aksai for the rate of consumption of 60 m3/sec and Tomai for the rate of consumption of 5 m3/sec;

- a reconstruction of the Aksai canal with the length of 11 km up to Zhuban-Sadybai Lake with strengthening of the canal dams, for irrigation and pass of the designed flood waters through the Aksai LS and rehabilitation of the fish filled in lakes and ecological bogs;
- a construction of the tubular wasteway structure with the water gate designed for the consumption of 25 m3/sec in the dams of the Erdes, for the management of the water flow of Mariyamkol Lake flooding;
- a construction of the new breastwall-based dam of the Erdes within the river-bed of the old Kuandarya in the range of the existing, destroyed coffer-dam, approximately 1 km lower the lake, which will allow to support the water horizons in the basin of the Akkol;
- filling up the earth bed of the Kosa dam of 3 km that will serve the supporting structure of Mariyamkol Lake and protection from Kaukey settlement flooding;
- a construction of the lead unit of the Utebas canal with the fish protection designed for the rate of consumption of 5 m3/sec with the crossing;
- cleaning and deepening the Utebas canal of 11 km to improve flooding of Utebas canal and to prevent from back water discharge from the lake to the Syrdarya River;
- a reconstruction of the upper coffer-dam on the old canal of the Syrdarya River, the length of the coffer-dam constitutes 80 m with the upper road, and to construct in the body of the upper dam the intake reinforced concrete structure designed for the rate of consumption of 40 m3/sec, for the emergency discharge of flood-waters through the Aksai system;
- a change of the existing discharging construction in the Sagyr dam to a new one designed for the rate of consumption of 50 m3/sec, for the purpose of pass of flood-waters along the system of fish filled in lakes of the Aksai canal.

5.4 Proposals for reconstruction of the Kamystybas and Akshatau lake systems

Steady water supply of Kamystybas LS is provided on the area of 61.1 thousand hectares, including lakes – 25.4 thousand hectares, Bogs – 7.1 thousand hectares (Table 62). Lakes Kamystybas, Laikol, Zhalanashkol, Raimkol, Makpalkol of fish industry importance are recommended to be defined as the priority objects of the system.

The forecast system water consumption is evaluated in volume of 772.17 million m3.

The scheme of current water delivery to the system is submitted in two alternative options – with erection of the water-engineering system in the location of Amanotkel and Raim. At the present level of issue study the more preferable option is the erection of the Raim water-engineering system, providing more steady water intake to the irrigation channels of the left and right bank lake systems as well as better conditions of their drainage.

It seems possible to use the lake hollow Kamystybas as the seasonal regulator of the river flow with useful capacity of about 250 million m^3.

Table 62 – Area and volume of water consumption of Kamystybas lake system

Lake system	Area, hectares	Volume, million m^3
Kamystybas	61080.0	772.17
Lakes	25390.0	393.55
Bogs	7140.0	71.40
Hayfields and pastures	25073.0	268.28
Forests and bushes	2577.0	25.00
Pond fish culture	900.0	13.95

The restoration of the Akshatau LS is recommended on the area of 42.5 thousand hectares, including lakes – 12.1 thousand hectares, Bogs – 8.7 thousand hectares (Table 63). Lakes Akshatau, Karakol, Shomishkol, Kotankol of fish industry importance are the priority water basins.

The forecast system water consumption is evaluated in volume of 509.43 million m3.

Table 63 – Area and volume of water consumption of Akshatau lake system

Lake system	Area, hectares	Volume, million m^3
Akshatau	42500.0	509.43
Lakes	12120.0	187.86
Bogs	8698.0	86.98
Hayfields and pastures	13834.0	148.02
Forests and bushes	6048.0	58.67
Pond fish culture	1800.0	27.90

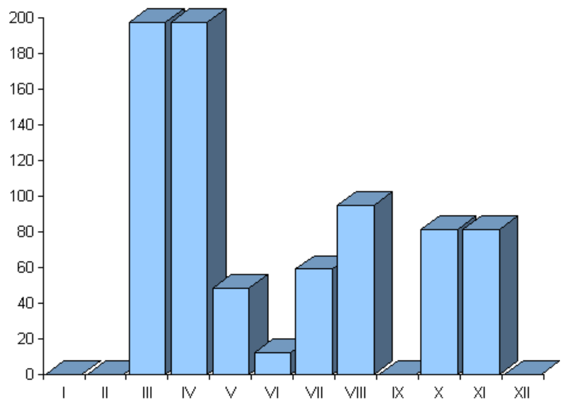


Figure 60 - Estimated water consumption for the Kamystybas lakes system, mln.m3

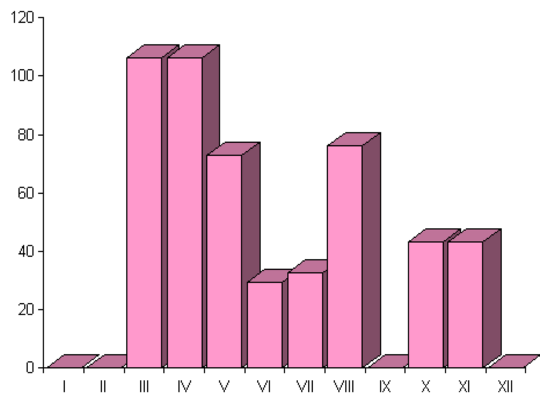


Figure 61 - Estimated water consumption for the Akshatau lakes system, mln.m3

The Kamystybas lake system is mainly filled in within the spring season with the water from the Syrdarya River, further the lakes are interconnected with the canals. The existing system of the water supply does not allow to regular managing the required modes of control, therefore the efficiency of use of bio-resources is extremely decreasing.

To provide the stable controllability and increase of water efficiency and bio-resources related to the Kamystybas lake system there was recommended a number of water management actions.

To supply and control the flooding of Makpalkol Lake and the Kokkol, Zhaltyrkol and Kokshekol bogs for the purpose of ecological rehabilitation of the territory and increase of efficient use of the system of the Kenesaryk canal as well as the increase of productivity of fishery there were scheduled as the first priority:

- a construction of the lead units on the Kenesaryk canals designed for the rate of consumption of 25 m3/sec with the crossing and the Sovetzharma designed for the rate of consumption of 5 m3/sec with the crossing and the fish protected device,
- a re-construction of the river-bed of the Kenesaryk canal of 8 km starting from the water intake up to the Bekbaul dam, including the rehabilitation of the near canal dams;
- a construction of the spillover unit through the Bekbaul dam of the Kenesaryk canal;
- a construction of the discharging canal designed for the rate of consumption of 10 m3/sec with the end-cutting structure with the crossing and fish protection device from Laikol Lake up to the Syrdarya River of 3.5 km.

The arose negative natural conditions within the Akshatau lake system resulted in the necessity of implementation of a number of urgent water management actions intended for the resolution of the ecological and economic and social problems.

For the purpose of the rational use and distribution of water resources in the system there scheduled a construction of the complex of hydro-engineering facilities and operational works.

Among them there are the works of high priority as follows:

- a construction of the new irrigation canal designed for the rate of consumption of 11 m3/sec of 9 km with the reinforcement of the right dam of the canal with the lead unit of the water intake structure on the Zhakaimaryk canal with the crossing and fish protector for water intake and control over water supply to Kotankol Lake and the bog of Shakhai;
- a construction of the lead unit designed for the rate of consumption of 22 m3/sec on the canal of Beszharma with the fish protecting device and the crossing, for the water intake and mode of flooding of the Akshatau LS and the bog of Akkol.

5.5 Proposals for reconstruction of the Seaside lake systems

Steady water supply to the Seaside Right-bank LS is provided on the area of 19.7 thousand hectares, including lakes – 7.6 thousand hectares, Bogs – 2.5 thousand hectares (Table 64). Lakes of fish industry importance Tuschebas, Sarteren, Domalak, Karashalan are the priority objects of the system.

The forecast system water consumption is evaluated in volume of 249.04 million $м^3$.

Table 64 – Area and volume of water consumption of the Seaside Right-bank lake system

Lake system	Area, hectares	Volume, million m^3
Seaside Right-bank	19722.0	249.04
Lakes	7560.0	117.18
Bogs	2490.0	24.90
Hayfields and pastures	6755.0	72.27
Forests and bushes	1817.0	17.63
Pond fish culture	1100.0	17.05

Restoration of steady water supply of the Seaside Left-bank system is planned on the area of 38.9 thousand hectares, including lakes – 2.3 hectares, Bogs – 10.3 thousand hectares (Table 65). Lake Bayan is the priority object of LS.

The forecast water consumption of the system is estimated in 402.76 million m3.

Table 65 – Area and volume of water consumption of Seaside Left-bank lake system

Lake system	Area, hectares	Volume, million m^3
Seaside Left-bank	38890.0	402.76
Lakes	2300.0	36.65
Bogs	10270.0	102.70
Hayfields and pastures	6489.0	69.43
Forests and bushes	19381.0	188.00
Pond fish culture	450.0	6.98

The right-bank lake system occupies the right-bank part of the Syrdarya River. The beginning of LS is spill way of Amanotkel, the end – the Aral Sea.

Due to the destruction of the breastwall construction of the Aklak on the Syrdarya River the lake systems dried out and do not exist any more. To rehabilitate LS there were commended:

- a construction of the lead unit on the Aidynzharma canal designed for the rate of consumption of 1 m3/sec with the crossing for the purpose of irrigation of the bog of Akzhar;
- a construction of the lead unit on the Stan designed for the rate of consumption of 1 m3/sec with the crossing and fish protection device for the purpose of irrigation and the mode of flooding of Tuschebas and Sarteren lakes;
- a re-construction of the Beketai canal lead unit designed for the rate of water consumption of 10.5 m3/sec of 3.0 км for the pass of the designed volume of water consumption and rehabilitation of fishery in Tuschebas lake.

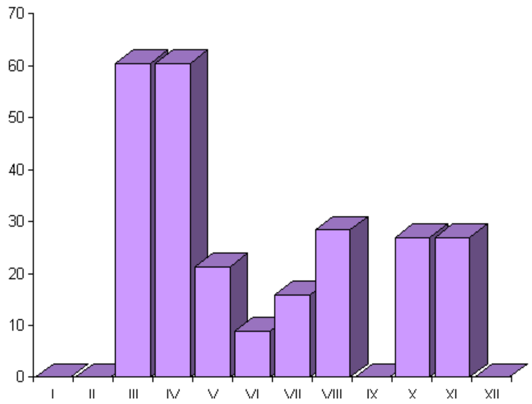


Figure 62 - Estimated water consumption for the Seaside Right-bank lakes system, mln.m3

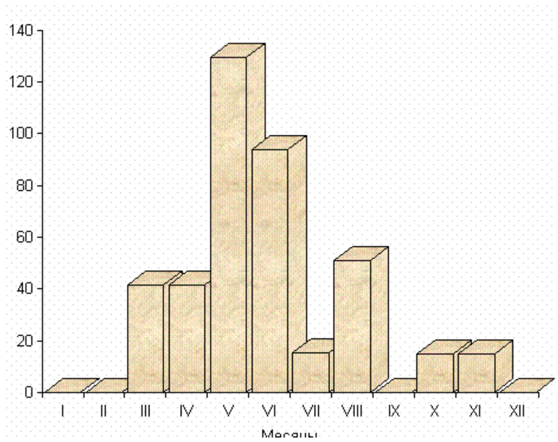


Figure 63 - Estimated water consumption for the Seaside Left-bank lakes system, mln.m3

The left seaside lake system occupies the Lower Syrdarya. The system starts from the spill way of the Amanotkel and runs up to the Aral Sea.

In 2002 the flood destroyed the breastwall construction of the Aklak on the Syrdarya River, and as a result thereof the Left seaside lake system is in the drying out condition.

The rehabilitate the ecological and economic conditions and the botanical variety of wetlands and the lake except for the construction of the hydroelectric complex of Aklak there was recommended a number of actions that will allow to rehabilitate the ecological environment of the landscape:

- a construction of the lead unit designed for the rate of consumption of 26 m3/sec on the Eraly canal with the crossing and cleaning of the canal of 10 km for the purpose of irrigation and the mode of flooding of the lake system of the Karaaryk canal;
- a construction of the lead unit designed for the rate of consumption of 5 m3/sec on the Tonzharma canal with the crossing for the purpose of irrigation of the basins of Karakol, Sarkol and Akbasty;
- a construction of the lead unit designed for the rate of consumption of 26 m3/sec on the Karaaryk canal for the purpose of irrigation of the Akbuget bog – 1350 hectares, hay lands and pastures – 47 hectares and the riparian areas - 14057 hectares;

- a construction of the lead unit designed for the rate of consumption of 3 m3/sec on the Akkol canal with the crossing for water intake and irrigation of the Naushan bog – 1480 hectares and the riparian areas - 65 hectares.

5.6 Proposals for flow control in winter

The issue of passing maximal water flow through the Syrdarya river appeared after change of operation regime of the Toktogul Hydropower Station to power generation.

Water discharge from the Toktogul Station was 11.5-12.5 km^3 during average water year; 2.5-3.0 km^3 of them was discharged to the downstream in winter and 8.5-9.5 km^3 in summer.

Since 1991-1993, winter discharges had increased and up to 1997-1998 it had been fully changed to power operation regime.

Increasing of the winter flow (under due decreasing in summer) was 5.5-6.0 km^3, this is about in 1.5-2.0 times increased winter water income to the Shardara reservoir.

Because of limited capacity of the Syrdarya river since 1991 the regular discharges of spill water to Arnasai plain has been started; the plain had been overfilled in 2004.

Owing to necessity and contrary to existing rules, the winter water discharges in the Syrdarya river had been increased from 450 up to 600-700 m3/sec, that resulted in destructive flooding of the irrigation systems and villages in South-Kazakhstan and partly Kyzylorda oblasts with appropriate damages.

The risk of high water discharge in the river in winter has been observed since 2005.

Grand problem of the passing of high water flow is forecasting complexity of ice forming period in the lower reach; it is necessary to reduce discharge flow from in time from Shardara reservoir up to acceptable volume in the northern part of the river (Kazaly station) 20 days prior to freezing (this is time of water lag from Shardara reservoir to Kazaly station).

At the present time additional spillway facility in the main part of the Karaozek river was constructed which permits starting from 2006 to discharge part of the spill water to the Karaozek river and thereby partly unload the main river in the section below Aitek dam.

However, as the practice passing of the high winter flow during the last years shows, that these measures are not enough for solving this issue. Hence, it is necessary to find more rational and safety control of winter un-natural flow of the Syrdarya river by construction of a re-regulating reservoir which should smooth of winter flow peaks and supply of required and timely water volume to the delta of the Syrdarya river. These requirements are met the Koksarai re-regulating reservoir which is under construction in 140 km downstream of the Syrdarya river from Shardara reservoir.

The re-regulating reservoir at first was mainly aimed at considerable increasing of water availability of the existing irrigated area in Kyzylorda Oblast, and reduction up to minimum of water discharge to the Arnasai plain. At the same time it solves the issue of the winter flow passing through the Syrdarya river. But in the Governmental debat of this project the Kyzylorda Oblast Authority proposed to obtain water dispensing of the part of spill water for renewal and water supply of the ecosystems in the adjusted area of the Syrdarya river instead of construction of the Koksarai re-regulating reservoir. In accordance with this proposal because of summer water deficit the irrigation essentially is limited on the level of existing irrigated area. Layout with Koksarai re-regulating reservoir is presented in the Figure 64.

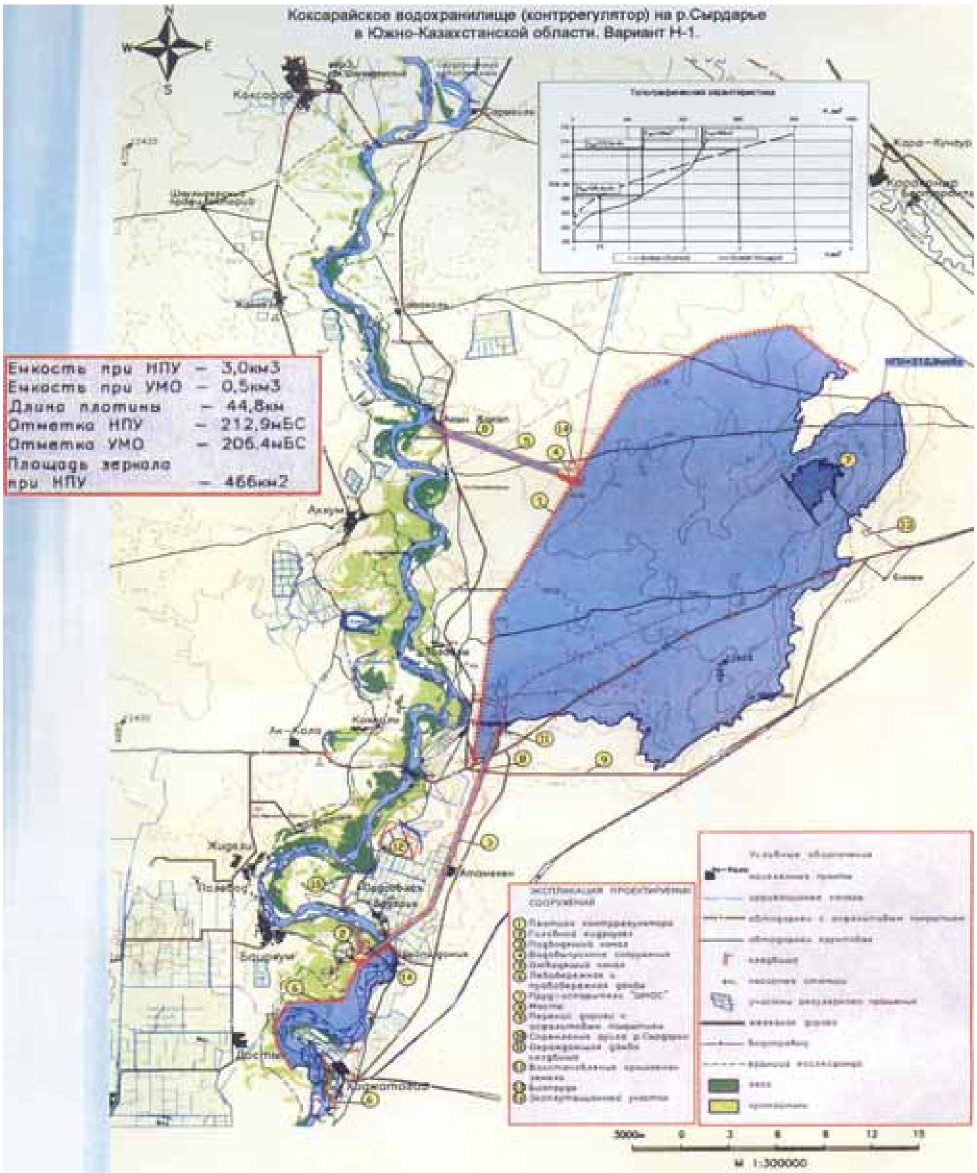


Figure 64 - Koksarai re-regulating reservoir

Both variants require certain capital investment to construction of the water facilities which efficiency had been investigated in the re-regulating reservoir project.

For guarantee a suitable comparison of these variants, i.e. earning of the equal and close effect for each of them, the volume of the Koksarai re-regulating reservoir was reviewed and reduced from 3 km^3 up to level sufficient for export from the river corresponding part (up to 1.5 km^3) of spill maximal winter water.

The most appropriate places for relief of the Syrdarya river bed during high winter flow discharge from Shardara reservoir has been defined for the variant of Kyzylorda oblast. As these places have been defined areas near to the existing Zhanadarya and Aksai-Kuandarya intakes, and under construction Karaozek main facility.

Transformation of the river flow was evaluated for cold and warm periods separately. As a result it was stated that unmanaged overflow water along the river in winter exceeds the similar water flow in summer (in similar volume of water discharge from the Shardara reservoir), and total water flow to ecology (flooding, lakes filling and etc.) for the last 25 years, (in similar volume of water discharge from the Shardara reservoir) is higher than previous years. Obviously, last fact is related with construction of fair quantity of flooding channels during last years, which contribute to increasing of water intake from the Syrdarya river under lesser water level in the river.

Water income to Shardara reservoir is analyzed for the period from 1976 to 2000, i.e. for the period after putting into operation of the Toktogul reservoir. Water income data have been taken from the Hydromet data for Kokbulak station with adding of water flow of the Keles, Kurukkeles rivers and drainage water discharge got into the reservoir below the stated station.

On the whole a first part of the period is characterized as average-water period with inflow within 12 km^3, but the inflow wasn't increased 10 km^3 during four sharply dry-water years. The second part is high water period with average inflow - 18.5 km^3, including period from 1993 to 2000, when idle discharges was made to the Arnasai, is rarely high-water with average water inflow (except 1977) – 21.3km^3.

The analyzed data is separated by seasonal distribution of water inflow (winter, summer) to the same for Toktogul three periods: irrigation, semi-power and power regimes of water inflow. If up to 1988 the relative density of winter inflow was 48.5% in average, it was increased up to 61.4% for the period 1989-2000 with appropriate reduction of summer inflow.

Table 66 – Dynamic of water inflow to Shardara reservoir

Years	Average winter, billion m^3	Average summer, billion m^3
1976-1988	5.9	6.2
1989-2000	11.5	7.2

Volume and regime of inflow to the Shardara reservoir analysis allows to make the following conclusions:

• During period of irrigation regime the average annual water inflow to the reservoir was about 12.1 km^3 with the following distribution: in winter – 5.9 km^3, in summer – 6.2 km^3. Under such distribution the interests of lower reach of the

Syrdarya river in water supply was observed as for limit of water allocation, and for regime of water consumption.

• For the period from 1992 to 2000 the average winter inflow to the Shardara reservoir was increased up to 12.6 km^3, i.e. more than in twice with variation from 9 to 18 km^3. Consequences of this were high idle discharges to the Arnasai plain in Uzbekistan. Capacity of the Shardara reservoir and Syrdarya river below the reservoir didn't allow to control and pass such volume of water inflow. As a result, for the last eight years the water resources losses in the lower reach of the Syrdarya river come to more than 26 km^3 or 16% of the water inflow. Average many-years water inflow to the reservoir is 15.3 km^3/year.

Table 67 – Average water volume in the station "Shardara reservoir downstream" for the period 1976-2000

Station	Average month water volume, m^3/s												Average annual water volume, m^3/s	Annual flow, km^3
	1	2	3	4	5	6	7	8	9	10	11	12		
Shardara reservoir downstream														
average	195	212	348	582	824	729	681	351	201	206	236	236	400.0	12.61
max	446	429	782	669	122	107	989	803	572	487	352	380	680.6	21.39
min	49	52	53	369	641	508	459	166	55	56	56	59	210.0	6.63

Table 68 – Water discharge to the Arnasai, km^3

Year	Inflow to the Shardara reservoir	Discharge to the Arnasai	%
1993	24.0	2.4	10
1994	29.5	9.2	31
1995	17.8	3.9	22
1996	16.3	0.9	6
1997	14.6	1.1	7
1998	25.6	2.9	11
1999	19.1	3.2	17
2000	16.0	2.8	18
Total	**162.9**	**26.4**	**16**
Average	**20.4**	**3.3**	**16**

6 MODELING AND DSS DEVELOPMENT

6.1 Mathematical description of a water body

The mathematical description of processes determining water body evolution is based on a set of three ordinary differential equations, which reflect inflow and outflow of water resources, variation of salinity levels and overgrowing of water areas with reed. Selection of such a set of ecosystem components is conditioned by the importance of the analysis of assigned components, and by the possibility of carrying out an indirect assessment of other ecological parameters using these above-mentioned components. The most important component for a water balance is evaporation from free-standing water surface, which during the summer period in the Aral Sea region amounts to about 300 mm/month. Significantly more losses take place from water surfaces that are occupied by vegetation. Evapotranspiration from reed and cattail increases the evaporation by a factor of 1.6 to 1.7 and results in losses of approximately 340 mm/month with an average annual value of 1600 mm/year. Therefore, among the basic parameters that constitute water and environmental balances of lakes are those areas occupied by reeds and parameters such as water salinity.

For definition of the mathematical model we consider an elementary volume, the geometry of which is described by two functions Ω *(z)* and *L (z),* where z is the water surface elevation, Ω *(z)* is the free-standing water surface at the same z-elevation, and *L (z)* is the contour encompassing the free-standing water surface Ω *(z)* at the same z-elevation. Both functions are dependent on the topography of a particular locality where the water area is located. Hereinafter, under the term "elementary volume" we will understand this as a volume within which water can be considered to have a unified elevation *z (t)*, mean salinity *s (t)* and a reed mass *m(t)*. The interaction of the elementary volume with an external environment (e.g. open air) takes place through the free-standing water surface Ω, in the form of evaporation and rainfall, through the bottom in the form of seepage, and through the contour *L* via conjunction with different canals, drains or other elementary volumes. Mass conservation equations for water and salts as applied to the elementary volume are as follows:

$$\frac{dW}{dt} = \int_L Q(l,z,t)dl + Q^0(t) - Q^f(t) - Q^e(t)\,; \qquad (1)$$

$$\frac{dS}{dt} = \int_L (s(l,t) \times Q(l,z,t))dl - Q^{S,f}(t)\,; \qquad (2)$$

$$W(z)=\int_{z^d}^{z} \Omega(h)dh\,; \qquad (3)$$

where: Q(l,z,t), ∀ l ∈ L – is water discharge determined by conditions of conjunction at the contour L,

Q^0(t) – is precipitation,

Q^f (t) – is filtration outflow,

Q^e(t) – is evaporation from the free-standing water surface,

$Q^{S,f}$ (t) – is salt outflow at the boundary “water – bottom”.

The evaporation flux from the free-standing water surface $Q^e(t)$ depends on the percentage of reed coverage; if we express through $q^{tr}(t)$ – reed evapotranspiration intensity, and through $q^0(t)$ - intensity of evaporation from the open water surface, we will receive the expression for $Q^e(t)$:

$$Q^e(t)= q^0(t)\times \Omega^0 + q^{tr}(t)\times \Omega^{tr} \quad (4)$$

where, Ω^0 , Ω^{tr} are the open water area and the area occupied by reed, respectively, $\Omega^{tr}+\Omega^0 = \Omega$ is the free-standing water surface area.

The process of reed growth within the surface water area is predominantly conditioned by two parameters: water salinity – *s* and a water body depth - *h*. It has been experimentally proven that reed grows only at depths of less than one meter in the Sudochye Lake. On sites, where water levels increase more than one meter, reed growth gradually declines. Assuming that such conditions of reed growth are contained within the Pearle’s water area, we consider the dynamics of these areas under reed growth. Assuming $\Omega^{tr}(z)$ to be a part of the water area covered by reed growth, and $\Omega^1(z)$ to be a section of water area with a depth of less than one meter, then

$$\Omega^1(z)= \{ \Omega (z)- \Omega (z – 1) \text{ при } h>1; \Omega (z) \text{ при } h\le 1\} \quad (5)$$

Assuming that both expansion and reduction of reed growth are linearly dependent, gives the equation for $\Omega^{tr}(z)$

$$\frac{d\Omega^{tr}}{dt} = \lambda(T)\times(\Omega^1 - \Omega^{tr}) \quad (6)$$

where: $\lambda(T)=\lambda 1(T)$, at Ω 1 - Ω tr >0 and $\lambda(T)=\lambda 2(T)$, at Ω 1 - Ω tr ≤ 0 are rates of expansion and reduction, respectively. The functions q0(t), qf (t), are determined from the hydrological data, and in addition, values W(0), S(0), and Ω tr(0) are known. Therefore, in order to complete the set of equations (1) – (6) it is necessary to determine discharges along the contour of an elementary volume.

The contour of an elementary volume should coincide either with typical areas of the relief, for which it is possible to use relationships as “Chezy Equation” or with hydraulic works, where discharges are determined using hydraulic formulas by means of known structures and flow parameters; the number of these formulas (equations) are equal to the number of conjunctions of elementary volumes. Any water area may be practically arranged by a set of elementary volumes. For this purpose, the contours of prospective water areas, which cover the whole possible water area, are delineated on a topographic map. Then, using this topographic map for each elementary volume the functions $\Omega(z)$ – an area of the free-standing water surface at the elevation *z* and *L (z)* – a contour encompassing the area $\Omega(z)$ at the same elevation (*z*) are calculated. This results in a set of bathymetric curves for all selected contours. By superposing those curves with the least bed elevation along the contour, an integral bathymetric curve is plotted for the whole water area, and will be used at the first stage of the study.

The indicators of water area functioning consist of integral characteristics that represent an average weighted status of elements for various periods of time. These indicators are ranked according to their significance by the following way.

- a volume of a water area $W(t)$ and relative annual and long-term variations of the volume $\delta W(t)/ W(t)$, measurable parameters: water-surface area - $\Omega(t)$, $\forall t \in \{t\}$.
- water salinity within the water area – $s(t)$ and relative temporal and spatial variations of salinity $\delta s(t)/ s(t)$ and $\delta s(X)/ s(X)$, measurable parameters: salinity in different points of the water area for various time points: $s(X,t)$, $\forall$ $s(X,t)$, $\forall t \in \{t\}; X \in \{\Omega\}$.
- an area occupied by reeds – $\Omega^{tr}(t)$, measurable parameters: a water-surface area under reed growth.

Equations (1), (2), and (6) correspond with these indicators. Numerical approximation of the mathematical model (1) – (6) is made on the basis of discrete temporal mesh using the finite-difference method. For this purpose, a time interval $\{t^0:t^K\}$ should be divided into equal intervals Δt in such a way that t can take on values from the set of $\{t^0, t^0+\Delta t, t^0+2\Delta t, \ldots, t^0+K\Delta t=t^K\}$. Besides, a partial-linear approximation of contour L should be made, as a result of which we obtain J conjunctions. For each conjunction a discharge direction Q is assigned and they are grouped on the basis of equal signs that gives J^+ and J^-, ($J= J^+ + J^-$), (if during the computation the sign of Q is negative, this implies an opposite flow direction). The values of elementary volume parameters should be attributed to points of time $t\in\{t^0, t^0+\Delta t, t^0+2\Delta t, \ldots, t^0+K\Delta t\}$, while parameter values in conjunctions will be attributed to points of time $t\in\{t^0+0.5\times\Delta t, t^0+1.5\times\Delta t, t^0+2.5\times\Delta t, \ldots, t^0+(K-0.5)\times\Delta t\}$. The system of water bodies is formalized in the form of the oriented graph **G**(J,I), where J = {0, 1, ..., j} is a set of nodes corresponding to volume objects, while I = {0, 1, ..., i} is a set of arcs reflecting links as to water distribution within the system. Each element $i\in I$ is characterized by such a pair (j, k) that ($\forall$(j, k), $j\in J$, $k\in J$, $k\neq j$), where j is the starting node and k is the end node of arc i. Thus, each node **G**(J,I) is associated with some object having a water volume, while each arc is associated with a structure generating water flow between nodes. Equations that describe functioning of individual water bodies are based on a system of ordinary differential equations reflecting inflow, outflow, and evaporation of water resources, salinity changes, and water areas overgrown by reed. The equations are associated with objects from the set of nodes J = {0, 1, ..., j} as described in the previous section. The given section describes formalization of objects relating to the set of I = {0, 1, ..., i} - arcs (i = (j,k) $\forall$ $j\in J, k\in J$, $j\neq k$), which determine conjunctions between reservoirs themselves and the outer boundary of the Aral Sea territory. The system of $2\times|\{J\}|$ differential equations on discrete spatial-temporal mesh is reduced to the system of $2\times(K+1)\times|\{J\}|$ nonlinear algebraic equations in variables in nodes connected through $2\times K\times|\{I\}|$ variables at arcs, of which $K\times|\{I\}|$ variables are controllers. Here $|\{.\}|$ is a number of elements in the specified set. The given mathematical model belongs to models of the so-called "compartment" type. These models strictly follow the law of conservation of mass and use semi-empirical equations of hydraulics for waterworks instead of laws of conservation of momentum and energy. Models of this type were studied in detail; therefore, here it is only necessary to note that calculation of salt precipitation and their consequent leaching that change both salinity and capacitance characteristics, is the most complicated task of modeling water bodies having high salinity levels.

6.2 Indicators of shallow lake system functioning

The comprehensive assessment of functioning of shallow lake system in the Syrdarya downstream requires quantitative indicators that, on one side, adequately represent the status of river and lake, and, on other side, allow the comparison of different directions of its development dynamics. The procedure starts from identification and justification of a dominant factor of aquatic ecosystem functioning. The dominant factor of aquatic ecosystems in the Syrdarya downstream is amount and salinity of its flow.

For selection and justification of various management regimes for shallow lake system, let consider three groups of the main indicators:

A) Water-ecological indicators:

- Water volume in a water body;
- Water quality in a water body;
- Natural environment around water bodies (area under vegetation);
- Biodiversity in water bodies (fish quantity and variety);
- Biodiversity in zone of water body influence (muskrat, birds);

B) Engineering indicators:

- Availability of water bodies inside the delta with assistance of engineering structures depended from parameters of structures (discharge, levels of water, height and elevation of dams, elevation and size of flatbed and so);
- Irrigation and collector-drainage network infrastructure (same parameters as above);
- Operation and management of the system of water bodies (regime of water delivery, water release, water accumulation).

C) Socio-economic indicators:

- Demographic indicators (population, its growth, migration, employment, settlements and so);
- Economic growth of fishery and muskrat farming;
- Improvement of living conditions and health of local population (recreation, health-care);
- Development of local infrastructure (fish, muskrat and reed processing, tourism, hunting);
- Development of animal breeding on the base of reed forage.

In order to form assessment criteria of water body creation and management, the above-listed components described on qualitative level should be formalized in form of quantitative relationships (algorithms). Most of the listed indicators do not have standard values. Therefore, first, in each group we select components that have quantitative economic evaluations (or algorithms for calculating these values) and form linear (or non-linear) convolution. Then, components are selected that do not have economic evaluations but are computable in form of concrete value of indicator (or values of indicators if the component is vector). Rest of components is ranked according to their significance by the group of independent experts, with following statistical processing of results. In order to formalize assessment criteria of water body distribution, let consider each scheme of engineering structures as a system, which is characterized by the following parameters:

- geographical location,
- bowl volume and water surface area (bathymetric curves),
- costs of building hydro structure,
- costs of structures for water supply,
- economic indicators of (fish, reed, muskrat) production and processing increase,
- zone of water body influence on environment,
- changes in social and environmental areas.

Quantitative assessment of the system of indicators can be provided by linking them to volume and water surface area of water bodies under normal headwater level, i.e. W_j, Ω_j and Z_j, respectively. Here $j \in \{J^K\}$is a set of water bodies referring to given option "K" of hydro structure distribution. Variables W_j , Ω_j and Z_j are linked with each other through bathymetric curves, which, in turn, depend on the relief, geographical locations of the bowl $(x_j ,y_j) = \mathbf{x}_j$ and on the cost of hydro structures C_j (W_j) forming dam. Construction costs of water delivering structures depend on both $\mathbf{x}_j$ and Z_j . Those costs can be described as a function of waterway discharge and length, i.e.

$$m_{j,k}= C_{j,k} (Q_{j,k})\times L_{j,k} , \tag{7}$$

where $L_{j,k}$ is the length of waterway connecting the points $\mathbf{x_j}$ and $\mathbf{x_k}$. The economic indicators of production increase are linked to the values of $\mathbf{x}_j$, Ω_j , s_j and W_j /Ω_j , and, the latter parameter is the mean depth of water body, which forms fishing conditions, and s_j is water salinity. The zone of water body influence may be estimated on the basis of its water surface area. Then, the changes in socio-environmental conditions in the zone of influence may be directly proportional to the number of residents N_j and to water increase in water body δW_j, (provided that the mean annual salinity is within admissible limits). Assuming that economic conditions of the residents are almost on the same level and equal "D" in given region, one may formulate test of significance for water body reconstruction in the general lake system.

$$\aleph_j = D\times N_j \times(\delta W_j / W_j) - \sum_{k\in J^K} m_{k,j} ; \tag{8}$$

where: $m_{j,k}$ is determined by formula (8), and J^K is "K" option of hydro structure distribution.

If we consider the mathematical model in previous section as a tool for estimating hydrochemical and biological parameters of water body, the task of economic evaluation of water body distribution may be formulated as follows: determine the coordinates $\mathbf{x}_j$ and surface elevations Z_j of a system of water bodies that maximize the sum $\aleph_j$.

6.3 Freezing of shallow water bodies

In the Syrdarya delta, the system of shallow water bodies functions in winter quite differently than in summer on the following reasons:

- In summer, hydraulic slopes of this system are mainly formed by evaporation from the free water surface; therefore, in October-November, the shallow part fills up and later freezes.
- Shallow waterways are subjected to earlier freezing, resulting in changes of water cycle within the system of water bodies.
- Oxygen regime suddenly changes since due to wind mixing, quantity of dissolved oxygen is close to 100% in shallow water bodies in summer, whereas after coating of water body by ice, the oxidizing processes of biocenoses that take place at the bottom use practically the whole dissolved oxygen (because of shallow depth).
- Water body salinity changes because of both the salt sedimentation due to decreased temperature and the less studies reason, which refers to the effect of lower salinity of formed ice as compared to freezing water. This effect can be explained on the basis of well-known fact of freezing point lowering as water salinity increases. Due to heterogeneity of water mass, this leads to freezing of fresher part of water body in the first place. This matter has not been studied thoroughly; however, it was important for environmental assessment in the Syrdarya river delta since under shallow depths, volume of ice and quantity of water were of the same order of magnitude.

According to observations, ice phenomena in the delta are characterized by the following:

- Mean annual date of freeing the lake from ice is late March.
- Mean date of autumn ice phenomena is mid November.

Thus, the mean duration of ice phenomena is about 120 days. The average thickness of ice cover in the lakes depends on the total negative air temperatures and varies within 0.8 m.

One of additional problems in recent decade is the change in hydrological flow of the Syrdarya river in winter. This is caused by the operation of Toktogul reservoir in energy-generation regime, thus destabilizing technological and environmental conditions in the Syrdarya downstream through excessive water discharge.

Dynamics of ice cover growth in shallow water bodies depends on many elements, the major of which is heat transfer between air and aquatic media through ice and snow layers. Precipitation depth in the Syrdarya delta is minor

(~107 mm/year), and moreover, most precipitation falls in the period of time, which is free from ice. The mean annual precipitation is approximately 23 mm/year in winter. However, availability of even minor snow cover on ice reduces sharply heat conductivity coefficient of the system «ice + snow» through low heat conductivity coefficient of snow.

The next, equally important reason to consider in calculating dynamics of ice cover growth is an increase in salinity of water body itself during its freezing. According to available estimations, ice forming out of saline water captures only minor part (~ 10%) of dissolved salts, and, consequently, the moving ice boundary (lower), in fact, acts as a membrane extruding 90% of salt back into water. Taking into account that the bulk of water in shallow water bodies is concentrated in the surface layer ~ 1 ÷ 1.5 m, and the ice cover thickness is ~ 0.8 m, winter increase in water salinity may be substantial. Additional requirement to the mathematical model of water body functioning in winter conditions was formulated by the group of hydraulic engineers under the project, based on actual management conditions in the Syrdarya delta.

This requirement proceeds from operation of Toktogul waterworks facility in the so-called energy-generation regime, when excess water is delivered in winter period. The latter requires that supplementary problems be solved, that is the change in dynamics of water body freezing due to river water inflow to formed layer of saline ice. In terms of physics, dynamics of water body freezing is a heat-and-energy process; therefore, the law of enthalpy conservation and Fourier law are used for its quantitative description. Let consider the two-layered system: «snow + ice», Figure 65, where Z0 is water level in a water body at the moment of ice cover formation.

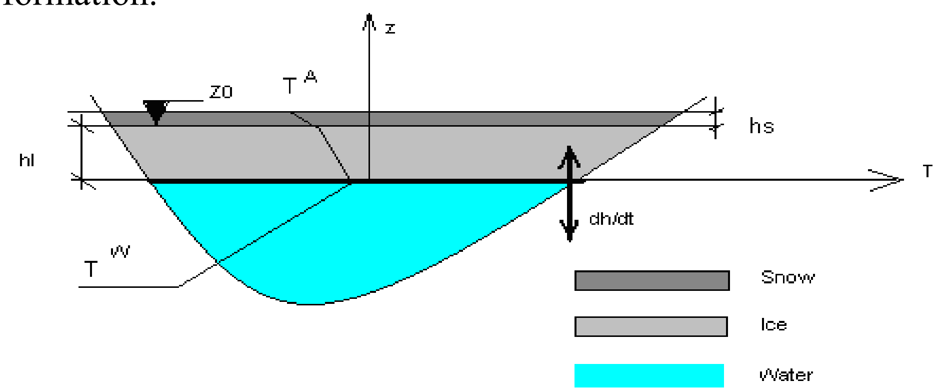


Figure 65 - System «water+ ice + snow»

Further development of snow and ice covers takes place through precipitation and movement of interface «ice – water». Precipitation can be considered in form of set time function, $h^s = h^s(t)$. Then, the main energy of «ice – water» interface movement will result from change in aggregate state of water «water ↔ ice» (first order phase transition) under impact of temperature gradient. By neglecting change in enthalpy of ice and snow cover (usual assumption in hydrology), equation of “ice-water” interface movement may be written for unit surface as:

$$L^{W,I} \rho^{I} \frac{dh^I}{dt} = \frac{\lambda^*}{h^I}(T^W(s) - T^A); \quad (9)$$

where: h^I is ice layer thickness, ρ^I is ice density (ρ^I = 917kg/m^3), $L^{W,I}$ is specific heat of phase transition «water ↔ ice» ($L^{W,I}$ = 333 ×10^3 J/kg), $\lambda^*(t)$ is equivalent coefficient of system heat conductivity, $T^W(s)$ is water freezing temperature as a function of water salinity "s", T^A is air temperature.

For slightly saline water (s < 3 g/l), value of $T^W(s)$ is taken as constant and equal to 273.15^o K = 0^o C, and these conditions are used in calculating increase of ice cover in river channel. The equivalent coefficient of system heat conductivity for the above mentioned two-layer system is determined by summing up the specific thermal resistance of each layer (h^j/λ^j) with its subsequent reduction to ice layer thickness:

$$\lambda^*(t) = \frac{\lambda^S \lambda^I}{\lambda^S + \alpha(t)\lambda^I}; \quad (10)$$

where: λ^S, λ^I are snow and ice heat conductivity coefficients (λ^I = 2,24 W/(m × ^{o}C)), $\alpha(t)$ is zero-dimension parameter characterizing relative thickness of snow cover on ice ($\alpha(t)=h^S/h^I$), which will be considered further as a function of weather conditions. The thickness of snow cover on ice is determined through precipitation layer "h^W" and snow density "ρ^S ".

$$h^S = h^W \times \rho^W / \rho^S; \quad (11)$$

Here ρ^W is water density (ρ^W= 1000 kg/m^3), ρ^S is snow density, for the Syrdarya river downstream the mean snow density in winter is ~ 280 kg/m^3 and increases to during ~ 450 kg/m^3 peak melting. Practically during the whole period of ice cover growth, snow density is within the limits of G.Abels' formula (10) satisfaction and therefore, snow heat conductivity is calculated as:

$$\lambda^S = 2,85 \times 10^{-6} \times (\rho^S)^2; \quad (12)$$

The mean value of snow heat conductivity coefficient for winter period in the Syrdarya river downstream is $\lambda^S = 2,85 \times 10^{-6} \times (280)^2 = 0,2234$ W/(m × ^{o}C). Velocity of free water surface movement "z" is connected with velocity of ice limit movement dh^I/dt through the equation:

$$\frac{dz^W}{dt} = -\frac{\rho^I}{\rho^W}\frac{dh^I}{dt}; \quad (13)$$

where: z^W and ρ^W are water surface elevation and density, respectively. If follows from inequality $\rho^W > \rho^I$ that during ice cover augmentation at interface «water – ice», an excessive pressure is created and compensated (taking into account practical incompressibility of water) first by increase of elevation "Z0" and then after freezing of ice and ground together by share of water extruded into the ground. Multiplication of free water surface movement velocity "z" and reservoir surface area "Ω(z)" is a flux from water into ice and inversely. By inserting (13) in (9) and considering flux «water → ice» as positive, and taking into account the above comment, we will have:

$$Q^{W,I} = -\Omega(z)\frac{dz^W}{dt} = \Omega(z)\frac{\rho^I}{\rho^W}\frac{dh^I}{dt} = \Omega(z)\frac{\lambda^*}{h^I L^{W,I}\rho^W}(T^W(s) - T^A); \qquad (14)$$

In equation (14), value "z" is calculated as $z = Z0 - h$, and only solution freezing temperature $T^W(s)$ is undefined. Change of the latter, within Raoult law satisfiability and normal atmospheric pressure, may be written as:

$$T^W(s) = T^0 - \frac{N^S}{N^W}\frac{R\times[T^0]^2}{L^{W,I}}; \qquad (15)$$

where: T^0 is clean water freezing temperature ($T^0 = 273.15\ ^oK$), R is absolute gas constant (R=1.986cal/degree×mole), N^W , N^S are moles of solvent (water) and dissolved matter, respectively. Taking into account relationship between molar and bulk concentrations of solution:

$$\frac{N^S}{N^W} = \frac{\mu^S N^S \rho^W}{\mu^W N^W}\frac{\mu^W}{\mu^S\rho^W} = \frac{m^S m^W}{m^W V}\frac{\mu^W}{\mu^S\rho^W} = s\frac{\mu^W}{\mu^S\rho^W}; \qquad (16)$$

where: s is bulk concentration, V is unit volume, m^S, m^W are masses of dissolved matter and water, respectively, μ^S, μ^W are molecular weights of dissolved matter and water, respectively;

By inserting (16) in (15), we will have final expression for $T^W(s)$:

$$T^W(s) = T^0 - s\frac{\mu^W}{\mu^S\rho^W}\frac{R\times[T^0]^2}{L^{W,I}}; \qquad (17)$$

For multicomponent solutions usually present in practice, the value μ^S is calculated as the weighted average one:

$$\mu^S = \frac{\sum_{j\in S}\mu^j N^j}{\sum_{j\in S} N^j}; \qquad (18)$$

If one assumes conservatism of the process of salinity increase in reservoir, that mainly observed in practice ($\mu^S = constant$), it follows from equation (18) that freezing temperature lowers linearly, depending on concentration growth, i.e.

$$T^W(s) = T^0 - s(t) \times \text{constant}; \qquad (19)$$

where *constant* is derived from (17), (18) and may differ for various reservoirs. It needs to be noted that equation (14) is valid only for $T^A < T^0$. For winter conditions, the equation of water mass conservation is divided into two:

$$\frac{dV^W}{dt} = \int_L Q(l,z,t)dl - Q^{W,I}(t); \qquad (20)$$

$$\frac{dV^I}{dt} = \frac{\rho^W}{\rho^I}[Q^0(t) + Q^{W,I}(t)]; \qquad (21)$$

here V^W and V^I are water and ice volumes, respectively.

Similarly salt mass conservation equation is divided:

$$\frac{dS^W}{dt} = \int_L [s^W(t)\times Q(l,z,t)]dl - Q^{S,I}(t) - Q^{S,f}(t); \qquad (22)$$

$$\frac{dS^I}{dt} = Q^{S,I}(t); \qquad (23)$$

where S^W and S^I are salt masses in water and in ice, respectively, $Q^{S,I}$ is salt flux water ↔ ice.

The process of salt exchange between water and ice is pronounced and non-symmetrical. When ice melts, all salts enter into water; however, when water solution freezes, only minor portion of salts (~ 10%) gets into ice, and therefore this is taken into account in writing equation for salt mass flux «water ↔ ice». Let express water and ice salinities through s^W and s^I, respectively.

$$s^W=S^W/V^W;\ s^I = S^I/V^I; \tag{24}$$

We consider fluxes from water to ice as positive direction of flux $Q^{W,I}$, thus for $Q^{S,I}$ we have:

$$Q^{S,I} = \begin{cases} s^I Q^{W,I} \dfrac{\rho^I}{\rho^W} & |Q^{W,I} < 0; \\ \beta \times s^W Q^{W,I} & |Q^{W,I} > 0; \end{cases} \tag{25}$$

where β can be considered as coefficient of membrane «water ⇒ ice» according to, (β= 0.1).

It is important to note here that despite the condition $T^A < T^0$, flux $Q^{W,I}$ may be both positive and negative, depending on sign of difference ($T^W(s)$ - T^A). Therefore, *in case of saline water bodies, the process of unfreezing may take place from the bottom even under negative air temperatures, unlike freshwater water bodies, where unfreezing always starts from upper ice surface.*

When positive air temperature period begins, water body unfreezing intensifies due to both the abrupt increase of heat conductivity coefficient and the contribution of upper ice layer, area of which is always larger than that of lower one under natural conditions. Melted snow forms thin water layer having temperature ~ 0°C on upper ice layer. During this short period, snow density increases abruptly and thickness of snow layer decreases (at $\rho^S > 350$ kg/m^3, Abels formula needs adjustment, according to A.Kondratyeva's work, the first coefficient rises from 2,85 to 4,85, p.45). Detail modeling of snow melting during this short period is not possible under given project. Therefore, with the beginning of positive temperatures, the snow layer is completely transferred to equivalent ice layer with clean water heat conductivity coefficient at 0°C:

$$h^{S,*} = h^S \frac{\rho^S}{\rho^I}; \tag{26}$$

$$\lambda^{S,*}=\lambda^W;\ (\lambda^W=0.569\text{Wt}/(\text{m}\times{}^o\text{C}))$$
(27)

Value h^S is counted upward from Z0 ; therefore, while developing equation for dynamics of this layer by analogy with (9), it is necessary to change direction of temperature gradient, and based on (24) and (25) we will have:

$$\frac{dh^S}{dt} = \frac{\rho^I \lambda^W}{L^{W,I} h^S (\rho^S)^2}(T^0 - T^A); \tag{28}$$

At the same time, equation for basic ice layer is changed:

$$\frac{dh^I}{dt} = \frac{\lambda^I}{L^{W,I}\rho^I h^I}(T^W(s) - T^0); \qquad (29)$$

The general water inflow to water body is comprised of surface runoff and ground flow, and by summing up fluxes (28) and (29) and considering respective areas, we will obtain:

$$Q^{W,I} = \Omega(z)\frac{\lambda^I}{L^{W,I}h^I\rho^W}(T^W(s) - T^0) + \Omega(Z0)\frac{\rho^I\lambda^W}{L^{W,I}h^S\rho^W\rho^S}(T^0 - T^A); \qquad (30)$$

All terms correspond to the above mentioned ones, and the sign of flux in equation is negative, according to mass conservation equations (20), (21).

Using equations (28) and (29), calculation is made until zero value of $h^{S,*}$ is achieved, and then only equation for basic ice layer remains. This layer melts mainly from upper surface. By neglecting velocity of lower surface movement at final stage of melting, we will have:

$$\frac{dh^I}{dt} = \frac{\lambda^I}{L^{W,I}\rho^I h^I}(T^0 - T^A); \qquad (31)$$

from which follows the equation of water inflow to water body:

$$Q^{W,I} = \Omega(Z0) \times \frac{\lambda^I}{h^I L^{W,I}\rho^W}(T^0 - T^A); \qquad (32)$$

For quantitative description of water body functioning dynamics in winter water inflow to ice, let consider physics of individual stages of this process. The term «water inflow to ice» implies that some quantity of warm water inflowing from the upper reaches will be directed to any water body. Inflow is in form of surface flow, which, first, causes melting of thin snow layer covering the ice, followed by occurrence of water layer above the main ice cover. Then, this water layer gradually freezes up, starting from the upper edge. The below conditions should be met so that the process of water inflow to ice follows the above-mentioned scenario:

1 – Intensity of water inflow to ice should be higher that rate of inflowing water layer freezing.

2 - Proper enthalpy of inflowing river water should be higher than that of phase transformation of snow layer on the ice.

Breach of the first condition causes series of ice mounds, followed by ice jams at entry point instead of uniform coating of the formed ice cover by water layer. Ice jam gradually blocks the entry point to water body, thus leading to only partial filling of water body. Let denote discharge, quantity and depth of a layer of inflowing river water by $Q^{w,r}$, $V^{w,r}$ and $h^{w,r}$ respectively so that to set them apart from similar denotations of discharge, water quantity and depth directly in water body. The depth of river water layer will be counted vertically upward, while the depth of ice layer formed onto the river water layer will be counted, as earlier, vertically downward. The lower surface of river water layer is fixed on the surface of main ice layer Ω(Z0). In opposite to previous task, where the upper boundary is fixed, here the upper boundary is moving, and the rate of moving is equal to the rate of moving the upper surface of river water layer, which, in turn, is determined by intensity of inflow.

$$\frac{dh^{w,r}}{dt} = \frac{Q^{w,r}}{\Omega(Z0 + h^{w,r})}; \tag{33}$$

The intensity of ice cover formation on the river water layer may be written as:

$$\frac{dh^{I,r}}{dt} = \frac{\lambda^I}{L^{W,I}\rho^I h^{I,r}}(T^0 - T^A); \tag{34}$$

According to the first condition:

$$\frac{dh^{I,r}}{dt} < \frac{dh^{w,r}}{dt}; \tag{35}$$

From (33) – (35) we get lower limit of inflowing river water discharge:

$$Q^{w,r} > \frac{\lambda^I \Omega(Z0 + h^{w,r})}{L^{W,I}\rho^I h^{I,r}}(T^0 - T^A); \tag{36}$$

The quantitative expression of the second condition is based on comparison of enthalpy increments for snow layer and inflowing river water regarding the temperature of its freezing T^0, then:

$$c^w \rho^w h^{w,r}(T^{w,r} - T^0) > \rho^S h^S [L^{W,I} + c^S (T^0 - T^S)]; \tag{37}$$

where: c^W и c^S are specific heat capacities of water and snow, respectively, under the constant pressure; T^S is snow temperature, which can be taken approximately equal to air temperature T^A, $T^{w,r}$ is the temperature of inflowing river water. Other denotations correspond to the above-mentioned ones. Non-meeting of the second condition is less dangerous but not desirable also since instead of uniform water layer (with its further transformation into equal ice layer), we also will have series of ice mounds in distant places of water body. In this case, we have more filling of water body than in case of non-meeting of the first condition but it is not complete as well. In inequality (37), the control variable is $h^{w,r}$, which can be defined as:

$$h^{w,r} = \frac{V^{w,r}}{\Omega(Z0 + 0.5h^{w,r})} = \frac{Q^{w,r} \times \Delta t}{\Omega(Z0 + 0.5 \times h^{w,r})}; \tag{38}$$

where: Δt is time space, during which water inflow to the ice; $Q^{w,r}$is mean discharge. The value of delivered discharge is regulated by inequality (36); therefore, by inserting (38) in inequality (37) and solving it for Δt , we get minimum time, during which water inflow to the ice is needed.

$$\Delta t > \frac{\rho^S h^S [L^{W,I} + c^S (T^0 - T^S)] \times \Omega(Z0 + 0.5 \times h^{w,r})}{Q^{w,r} c^w \rho^w (T^{w,r} - T^0)}; \tag{39}$$

The inequalities (36) and (39) produce solutions of the task “water inflow to ice” for one time step. If inflow takes a few time steps, it is necessary to know the time of interruption between each step of water inflow since under partial freezing of inflowing water quantity the local breaks are possible with occurrence of ice mounds. Time taken for freezing the delivered water quantity may be defined by integrating equation (34), with following solution for time space, then:

$$\Delta t^{w,r} = \frac{L^{W,I}\rho^I [h^{w,r}]^2}{2\lambda^I (T^0 - T^A)}; \tag{40}$$

where: $\Delta t^{w,r}$ is time space between the beginning of each step, is the mean value of negative temperatures within this time space; and $h^{w,r}$ is defined by equation (38). When freezing of the river water layer is completed, the reference surface elevation shifts to the value:

$$Z0^I = Z0\ \rho^w\ h^{w,r}/\rho^I; \tag{41}$$

During the period of time $\Delta t^{w,r}$, the lower layer in the saline water body is unfrozen at a rate:

$$\frac{dh^I}{dt} = \frac{\lambda^I}{L^{W,I}\rho^I h^I}(T(s) - T^0); \tag{42}$$

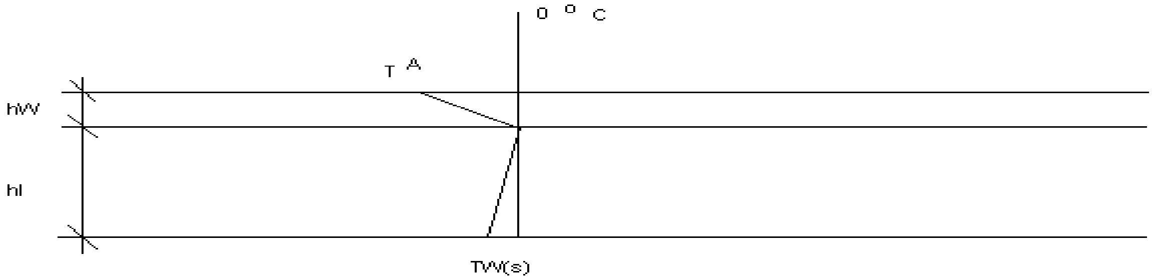


Figure 66 - Design scheme of water inflow to ice

By integrating the last equation and taking into account direction of the process and (41), we get:

$$h^I(t + \Delta t^{w,r}) = h^I(t) + h^{w,r}\frac{\rho^W}{\rho^I} - \sqrt{\frac{2\lambda^I}{L^{W,I}\rho^I}\int_0^{\Delta t^{w,r}} |T^0 - T^W(s(\tau))|\, d\tau}\ ; \tag{43}$$

From the equation (43) it is clear that the process of basic ice layer unfreezing takes place exclusively in saline water bodies. In fresh water bodies such effect does not occur. This completes the model of shallow water body functioning in winter conditions.

Evaluation of waterway capacity in winter conditions is based on Chezy equation and recommendations. The flow capacity decreases because of both the reduced flow cross-section area and the increased roughness coefficient. Changes in flow cross-section may be defined as:

$$\omega^1 = \omega^w - \int_{Z0-h^I}^{Z0} b(\zeta)d\zeta\ ; \tag{44}$$

where: ω^w is an area of free flow cross-section, ω^I is an area of flow cross-section in winter conditions, $b(\zeta)$ is channel width at a distance "ζ "from the bottom.

Discharge is estimated by Chezy formula:

$$Q^I = \omega^1\ \frac{(R^I)^{\frac{2}{3}}\sqrt{J^I}}{n^*}\ ; \tag{45}$$

where: J^I is hydraulic slope. Hydraulic radius is calculated by formula:

$$R^I = \frac{\omega^I}{\chi^r + \chi^I}\ ; \tag{46}$$

where: χ^r and χ^I are wetted perimeters of channel and lower ice surface, respectively. For given coefficient of roughness the formula is recommended:

$$n^* = 0.7\sqrt{(n^r)^2 + (n^I)^2}\ ; \tag{47}$$

where: n^r and n^I are coefficients of roughness for the channel and the lower ice edge, respectively.

6.4 Modelling of flow in the Syrdarya river

Hydrodynamic model based on rated inflow to the mouth of the delta (the station of Kazaly hydraulic work) allowed for predicting water level on different stations of the Syrdarya river. Identification of river model was performed for different stations of the Syrdarya river connected with main water inlets of the lake system. Comparison of rated and actual levels gives good correlation.

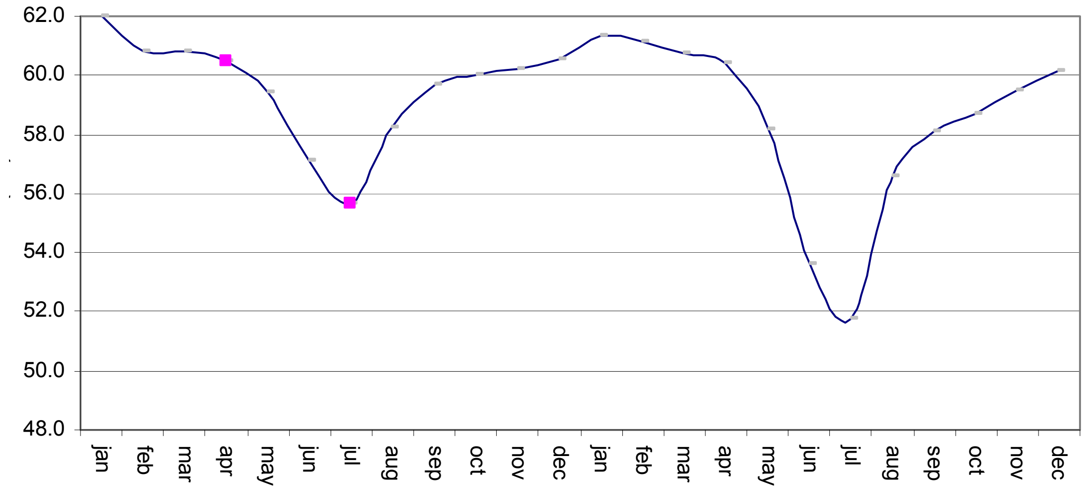


Figure 67 –Level trend of the Syrdarya river, “the Ardan channel” section (Baltic Level System)

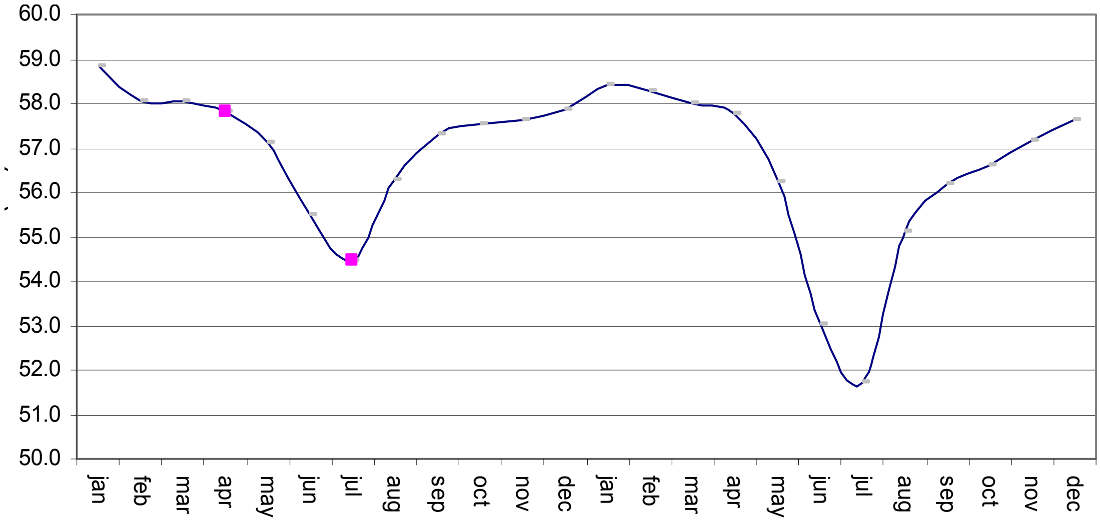


Figure 68 - Level trend of the Syrdarya river, “the Beszharma channel” section (Baltic Level System)

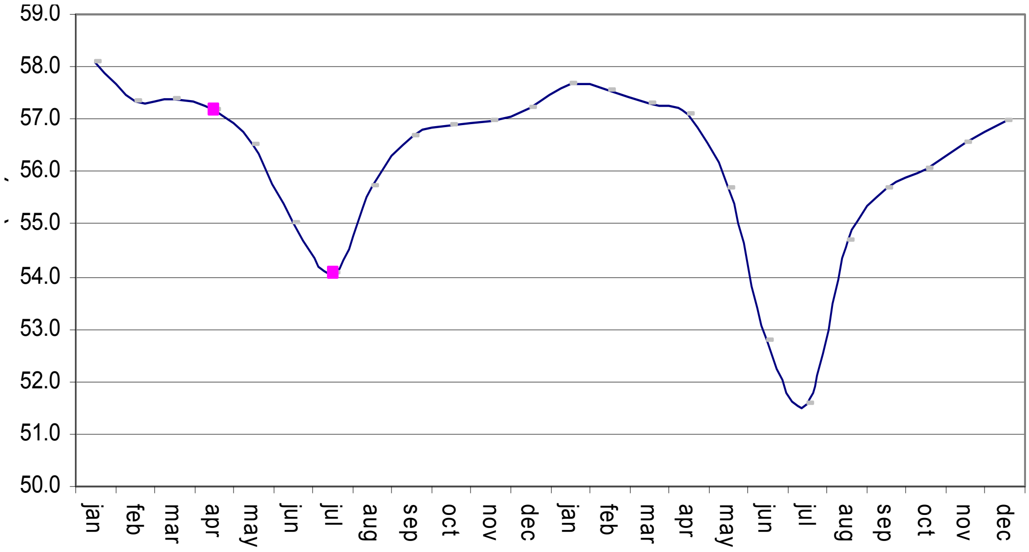


Figure 69 –Level trend of Syrdarya river, "the Akkoisoigan channel" section (Baltic Level System)

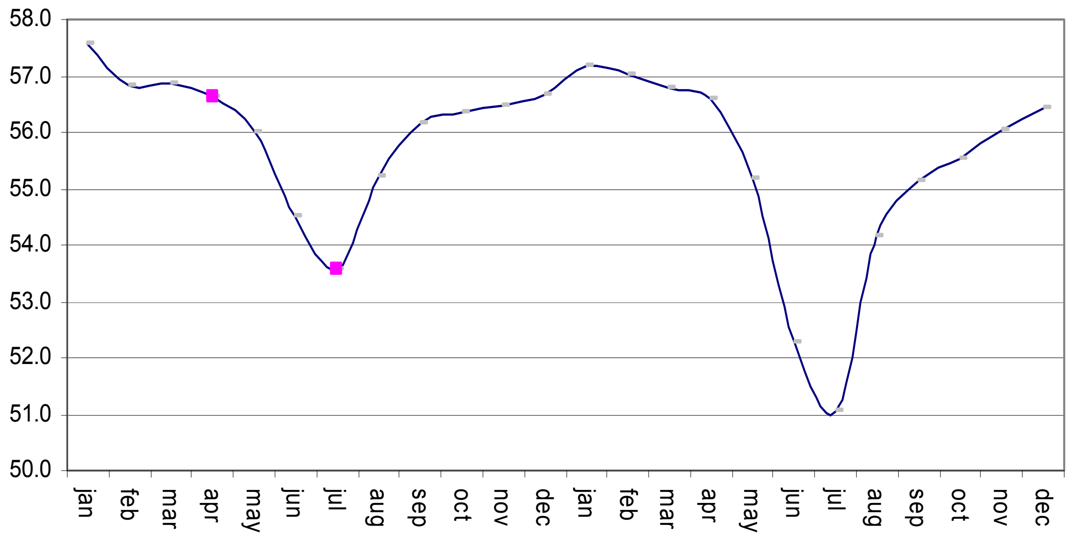


Figure 70 –Level trend of the Syrdarya river, "the Akshagyz channel" section (Baltic Level System)

6.5 Model identification

6.5.1 Criteria of flow identification

There are plenty of books about problems of assessment of models reliability used to numeric research of physical and technological processes where as general assertion one can say that, practically, any mathematical model, besides basic equations, has some phenomenological parameters which are not determined within the model. Obtaining number values of these parameters (or formula for their computation) is usually called identification of model, and tasks originated are reciprocal. It is worth mentioning that complexity of solution, resulted reciprocal task often is higher than complexity of solution of the original task. Accuracy of investigations of process of reservoirs functioning with regulated regime on the basis of model formulated n the previous report is determined, in many ways, by accuracy of task, parameters of waterworks and hydraulic characteristics of passages between some reservoirs. In this case, these are the characteristics that are mostly uncertain. Additional complexity is resulted from lack of information on work of certain waterworks at different times, therefore, in equations for passages through waterworks there will be inequalities instead qualities limiting maximal value of flow rate. This means that, lake system has multiple trajectories which are passing through set (observed) points. Therefore, method of identification applied in this work to remove uncertainty uses principals of optimal equation where multiple criterions plays the role of criterion of regulation quality taking into account results of full-scale measurements, work conditions of waterworks and physical specifics of shallow-water lake systems. Lets determine state of certain lake in the form of two-component vector $\mathbf{u}_j(t) \equiv [z_j(t), m_j(t)]$; $z_j(t)$ – mark of free surface, $m_j(t)$- water mineralization.

Dynamics of this vector is determined by system of ordinary differential equations (1) and (2) of the previous report written on the column. Elements of water balance - evaporation, precipitation and filtration outflow are completely determined (via relevant formulas) by vector $\mathbf{u}_j(t)$ of certain lake, while flows (water, saline) depend on condition of neighbouring lakes and selected strategy of regulation $Q_{i,j}(t)$.

$$\aleph = \sum_{j\in\{J\}} \int_{t1}^{t2} \{\lambda_j^z(t)\times[\frac{z_j(t)-z_j^*(t)}{z_j^*(t)}]^2 + \lambda_j^m(t)\times[\frac{m_j(t)-m_j^*(t)}{m_j^*(t)}]^2\}dt; \qquad (48)$$

Where, λ^z и λ^m - scale multipliers for marks and mineralization, z(t) and m(t)- mark and mineralization of the lake resulted from solution, z*(t) and m*(t) – mark of the lake resulted from location observation. Now formulate the following task: determine $Q_{i,j}(t)$ bringing minimum to function of function (48), provided dynamics of lakes is determined by the system of ordinary differential equations (1) and (2) of the previous report written in the column. Taken into account uncertainty in regulation one can obtain few variants of solution, therefore one say about certain variant only in the context of ***possible***.

As the example, take some possible variants of dynamics of the Big Zhanai lake bringing minimum to formulated function of function.

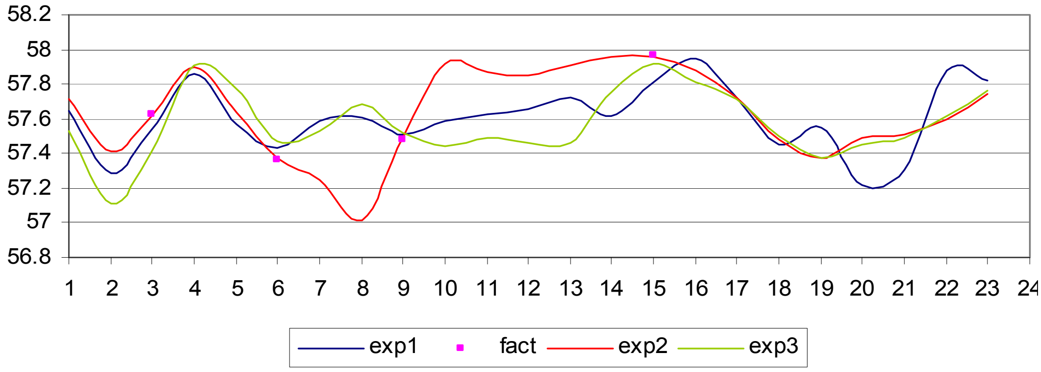


Figure 71 – Variants of dynamics of free surface of the Big Zhanay lake

X-direction number of months are set starting from January 2005. Points of location observations are marked.

6.5.2 Climatic conditions

Climatic factors: Precipitation and temperature were take on actual and monthly mean values of weather station of the city of Kazalinsk for the years 2005 and 2006 (report by the hydrology group).

Evaporation: to calculate evaporation from free surface of reservoirs middle-old location measurements of evaporation were used from weather station of the Aralsk city and table of distribution of evaporation over Central Asia by B.I. Zaikov. Resulted function of within-year evaporation distribution used in this work is given in Figure 72.

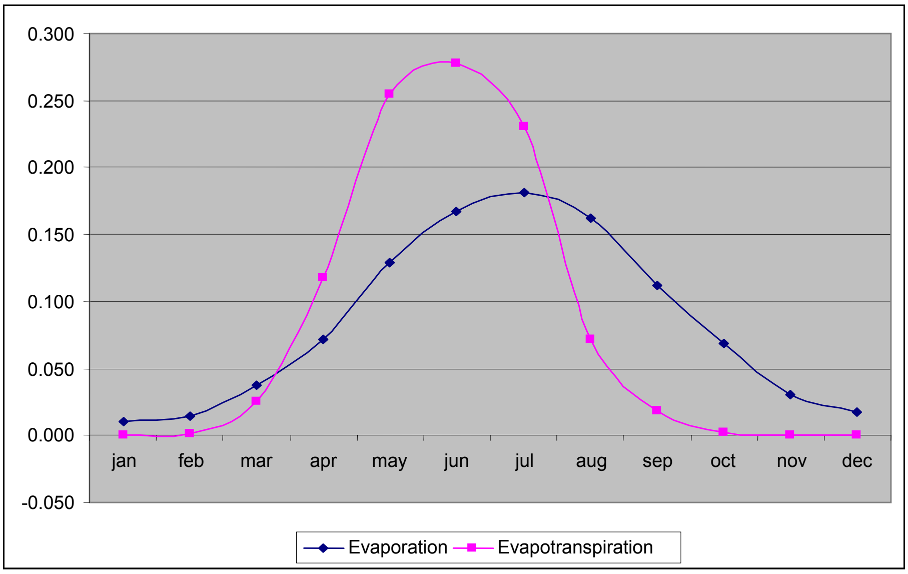


Figure 72 - Function of within-year evaporation distribution and evapotranspiration of the reed.

Evapotranspiration of the reed***:*** calculation of evapotranspiration of the reed is based on many location observations generalized within the projects. Basic results of these generalizations consist in evaluation of evapotranspiration value from free surface exceeding layer of ordinary evaporation by 1.6 times. Evapotranspiration of the reed located beyond water surface is sharply decreasing to values 30%-40% from E^0, E^0 – evaporation layer from surface of water. Besides, within-year intensity of evapotranspiration E^{tr} does not consist with E^0. Process of reed growing in area of water of the lakes is conditioned by two factors – depth of lakes and water mineralization. By experiment it was found out that reed in area of water is appearing at depth of less that one meter. With deeper depth more than one meter density of reed is sharply decreasing.

The similar picture can be seen for reed located beyond water surface of the lakes. Assuming that conditions for reed appearing are the same for reservoirs of North Aral Sea Basin we can obtain assessment of evapotranspiration layer from areas of the reeds in the form:

$$E^{tr} = E^0 \times [1.6 \times \lambda^w + 0.35 \times (1 - \lambda^w)] \quad (49)$$

Here: λ^w – ratio of area of reeds located on shallow water to total area of the reeds.

6.6 Kamystybas Lakes System modeling

6.6.1 Water flow motion scheme

Total area of the Kamystybas lakes system water surface, fed by water resources of the Syrdarya river, is valued within 328.1 km^2, lakes part ~ 272.1 км^2, and other part is bogs. During high-water years this lakes system obtains characters of the good running water bodies. But, after decreasing water level in the Syrdarya river and in the periods of reducing of water inflow from rivers this system strongly evaporates and discharges water back to the Syrdarya river. As a result physical and chemical properties of the water are sharply changed and accordingly biology productivity is changed too. Morphologically, these lakes consist of shallow-shaped plains with depths from 0.8 to 14.5 m parted by small underwater and above-water ridges and overgrown reeds. Kamystybas lakes system includes eight lakes and five bogs fed fully owing to water resources from the Syrdarya river by Kenesaryk, Sovetzharma, Taupzharma, Taldyaral, Kuly, Zhasulan, and Keragar channels. Lakes system management is carried out using complex of the hydraulic facilities located on the rivers between lakes, and includes floodwalls and checks.

Figure 73 – Kamystybas lakes system scheme

Analysis of the Kamystybas lakes system water dynamic shows that this system consists of three sub-systems unconnected with surface waterways.

Sub-system 1 – first downstream of the Syrdarya river includes: one lake – Makpalkol and three bogs – Kokkol, Kokshekol, and Zhaltyrkol. Feed of this system is carried out by Kenesaryk channel.

Sub-system 2 includes two bogs: Kobikty and Taldyaral. Feed of this sub-system is carried out by Taldyaral-1 and Taldyaral-2 channels.

Sub-system 3 includes seven lakes – Raimkol, Zhalanashkol, Kayazdy, Zhyngyldy, Kuly, Laikol, Kamystybas. Feed of this sub-system is carried out by channels: Sovetzharma, Taupzharma, Kuly, Zhasulan, Keragar, and rivers: Raim, Kutumsyk, Zhaibike, Tursyn, Karaboget.

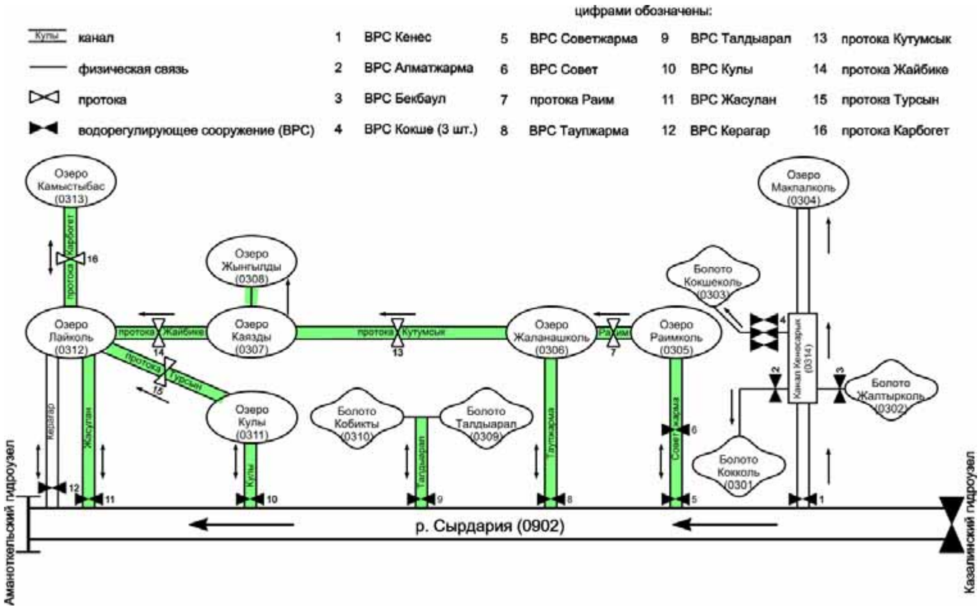


Figure 74 – Linear scheme of the Kamystybas lakes system

Bathymetric curve have been constructed at the first approximation based on metering results of level and water plane area for the different point of time, at that as a first unknown parameter was taken level of the sea bed. Assumed that relationship between depth and water plane area is closely to squared, we receive the following:

$$\Omega_j(z(t)) = \alpha_j \times (z(t) - z_j)^2 \qquad (50)$$

where α_j and z_j – lake parameters determinate by two metering for the different points time t_1 and t_2, j – definite lake index, Ω_j – water plane area of a lake, z(t)- water plane level of a lake, z_j – the lake bed level. Based on (50) the volume of the lake is calculated by the following formula:

$$W_j(z(t)) = \frac{1}{3}\alpha_j \times (z(t) - z_j)^3 \qquad (51)$$

Kamystybas lakes system management is carried out using temporary closure dams on the channels: Sovetzharma, Taupzharma, Taldyaral, Kuly, and Zhasulan. In this connection the estimated water flows to the all channels were calculated by formulas for spillway with wide threshold without governors.

Table 69 – Metrics of the intersystem water control facilities

Object name	Main object code	Slave object code	Average wide of the bed	Coefficient of slope rate	Slope	Shezi coefficient	Extreme value of water flow (m3/sec)
Kenesaryk Ch.	0901	0304	17.00	1.00	0.00005	34.40	8.1*
Sovetzharma Ch.	0901	0305	14.00	1.00	0.00041	37.40	29.1
Raim river	0305	0306	20.00	1.00	0.00008	41.10	108.0
Taupzharma ch.	0901	0306	8.00	1.00	0.00026	38.00	19.3
Kutumsyk river	0306	0307	10.00	1.00	0.00030	36.10	24.4

Kayazdy-Zhyngyldy	0307	0308	8.00	1.00	0.00100	34.40	24.3
Zhaibike river	0307	0312	8.00	1.00	0.00013	34.40	8.9
Taldyaral ch.	0901	0309	3.00	1.00	0.00080	33.30	9.0
Taldyaral ch.	0901	0310	6.00	1.00	0.00080	34.40	16.6
Kuly ch.	0901	0311	8.00	1.00	0.00350	28.60	4.7
Tursyn river	0311	0312	8.00	1.00	0.00080	34.40	21.8
Zhasulan ch.	0901	0312	3.00	1.00	0.00121	33.30	11.0
Karaboget river	0312	0313	25.00	1.00	0.00035	41.10	209.6
* Kenesaryk channel has maximum water flow at the beginning 8.1 m^3/sec and at the end part – more that 30 m^3/sec (in accordance with the Hydrology Research report).							

Large quantity of the literatures is given up to the issue of models reliability rating which applied for computational investigation of physical and technology processes. As a general statement we can choose that practically any mathematical model, besides main equations, has several phenomenological parameters undetected within the model. Getting value of these parameters (or formulas for its determination) is named as model identification, and tasks nascent at that – inverse tasks. It is significant that solving complexity of the inverse task exceeds often complexity of the original task. Research accuracy of the water bodies functioning process with managed regime based on model, formulated in the previous report, in many respects is determined by accuracy of parameters of the hydraulic facilities and hydraulic parameters of the rivers between lakes. But, in this case just these parameters are more indeterminate. Additional complexity is missing of information about operation regime of the specific hydraulic facilities at the different points of time, so equations for flows passing through the hydraulic facilities has inequality instead of equality which limits only maximal value of water flow. It appears from this that lakes system has great number of trajectories passing through given points. Therefore, the identification method for avoiding of an ambiguity uses principles of optimal management where role of management quality criteria is played by a composite criterion which takes into account in-situ measurement results, operation environmental of the hydraulic facilities, and physical features of the shallow lakes systems. Condition of a lake is determined as two-component vector uj(t) ≡ [zj(t), mj(t)]; zj(t) – water plane level, mj(t)- water mineralization.

Dynamic of this vector is determined by system of ordinary differential equations (50) and (51). Water balance components – evaporation, precipitation and filtration flow-out, are completely determined (through appropriate formulas) by vector $\mathbf{u}_j(t)$ of a separate lake whereas flows (water, salt) depend on conditions of the adjacent lakes and selected management strategy $Q_{i,j}(t)$. For identification task the quality criterion is detected as following functional:

$$\aleph = \sum_{j\in\{J\}} \int_{t1}^{t2} [\lambda_j^z(t)\times(z_j(t)-z_j^*(t))^2 + \lambda_j^m(t)\times(m_j(t)-m_j^*(t))^2]dt\,; \qquad (52)$$

where λ^z и λ^m – scale factors for levels and mineralization, z(t) and m(t) – level and mineralization of a lake received as a result of solving, z*(t) and m*(t) – lake level based on in-situ measurements. The following task is to determinate $Q_{i,j}(t)$

which delivers of minimum to the functional (52), under the stipulation that lakes dynamic is determined by system of ordinary differential equations (50) and (51).

Taking into account of indetermination in management we can receive several alternate solutions therefore specific variant can be considerate as *possible.*

Climatic factors: precipitation and temperature are taken based on actual monthly average of the weather station in Kazaly city for 2005-2006 years.

Evaporation: Average annual in-situ evaporation measurements of the weather station in Aralsk city and table with evaporation distribution for the Central Asia (Prof. Zaikov) were applied for calculation of evaporation from water plane of the water bodies. Resultant function of within-year evaporation distribution, used in this research work, is shown below.

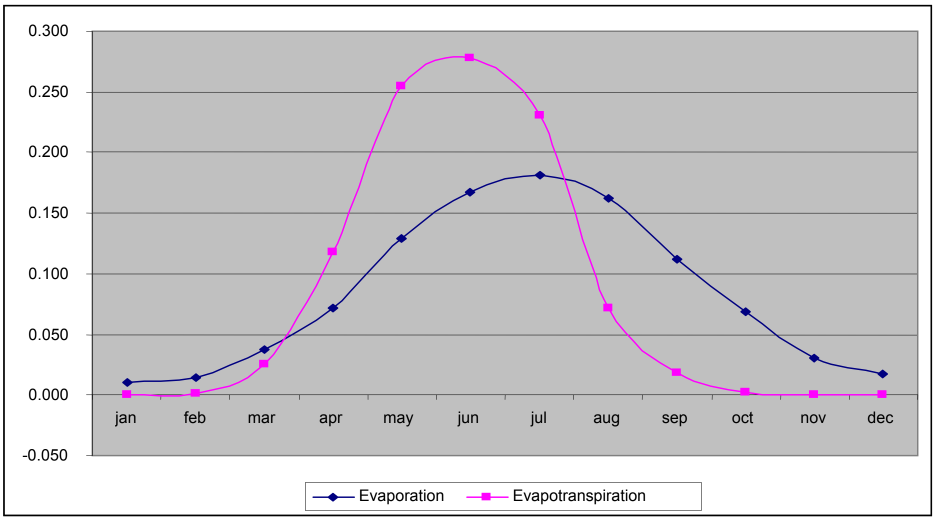


Figure 75 – Functions of the within-year evaporation distribution and reed evapotranspiration

Reed evapotranspiration: Calculation of the reed evapotranspiration is based on large quantity of the in-situ observation summarized within this project. Main results of these summaries are assessment of the evapotranspiration value from the water plane exceeded layer of ordinary evaporation 1.6 times. Evapotranspiration of reed located outside of water surface is sharply reduced up to value 30%-40% from E^0, E^0 –layer of evaporation from surface of pure water. Moreover, within-year activity of evapotranspiration E^{tr} isn't congruent with E^0, both functions are shown in the Figure 75. Reed development process in the lakes area is conditioned mainly by two factors – lakes depth and water mineralization. Experimentally assigned that reed is developed in the area only in depth less than one meter. Reed density is sharply reduced when water depth has been exceeding one meter. Similar situation is for reeds located outside of the lakes water surface. Assumed that conditions for reed forming are kept safe approximately same as for water bodies of the Northern Aral Sea Basin, we have received value of evapotranspiration layer from reed-bed area as the following:

$$E^{tr} = E^0 \times [1.6 \times \lambda^w + 0.35 \times (1 - \lambda^w)] \qquad (53)$$

where: λ^w – ration of reeds area located in shallow water to total area of reeds.

6.6.2 Level coupling of the river and water bodies

Identification of management harmonizing for the Syrdarya river and lakes systems has been conducted on purpose of coordination of the Syrdarya river and lakes systems data.

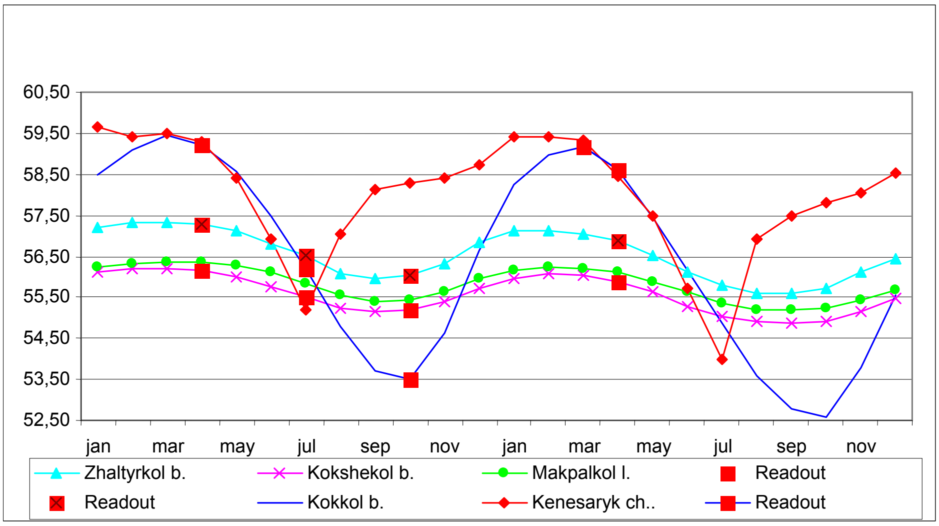


Figure 76 – Course of the Syrdarya river levels at the sections: Kenesaryk channel, Kokkkol, Kokshekol and Zhaltyrkol bogs, and Makpalkol lake, 2005-2006

In accordance with Figure 76 the minimal observed level is July 2005 and July 2006 (Kokshekol bog) for the period under review. In that case two conditions are met:

✓ Simultaneous decreasing and increasing of the Syrdarya river and lakes levels;

✓ Maximal water discharge of the Kenesaryk channel isn't exceeded.

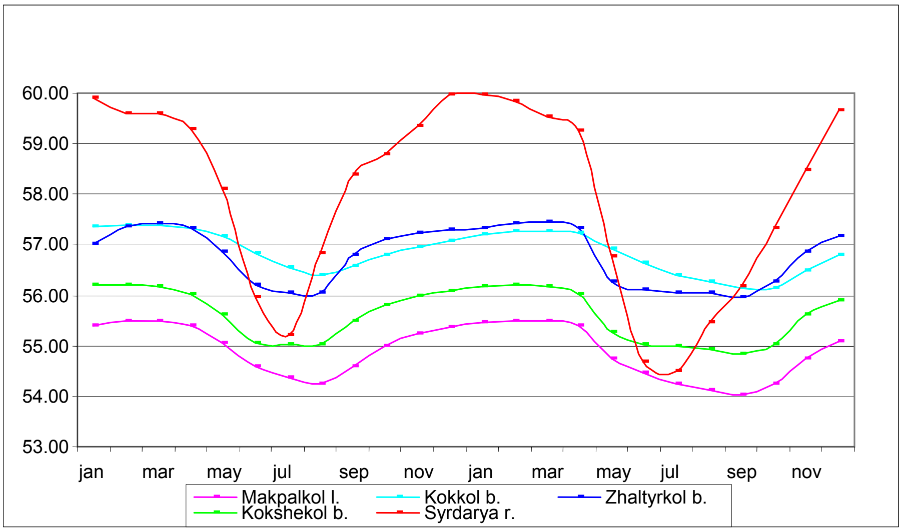


Figure 77 - Course of the Syrdarya river levels at the sections: Kenesaryk channel, Kokkkol, Kokshekol and Zhaltyrkol bogs, and Makpalkol lake

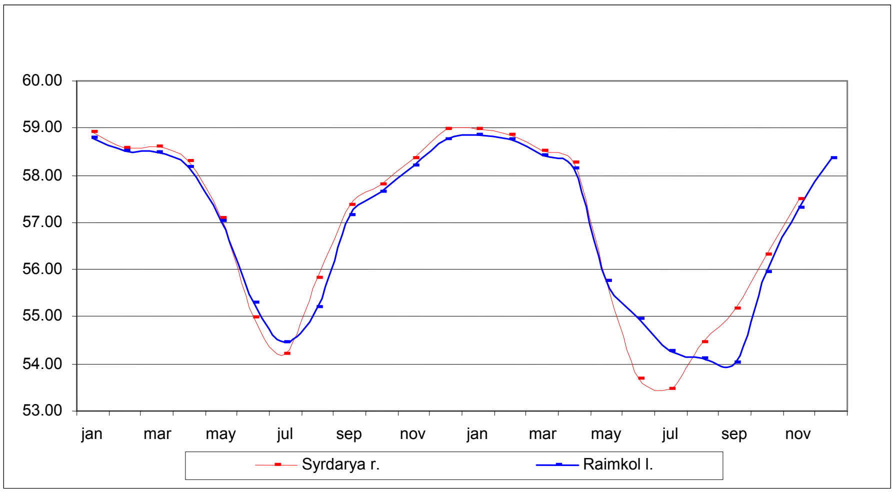


Figure 78 - Courses linking of the Syrdarya river levels at the section Sovetzharma channel and elevation of the Raimkol lake

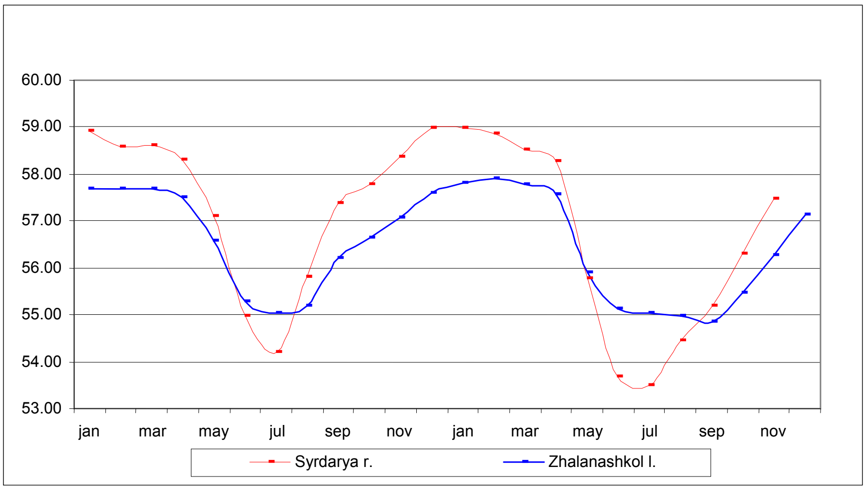


Figure 79 - Courses linking of the Syrdarya river levels at the section Taupzharma channel and elevation of the Zhalanashkol lake

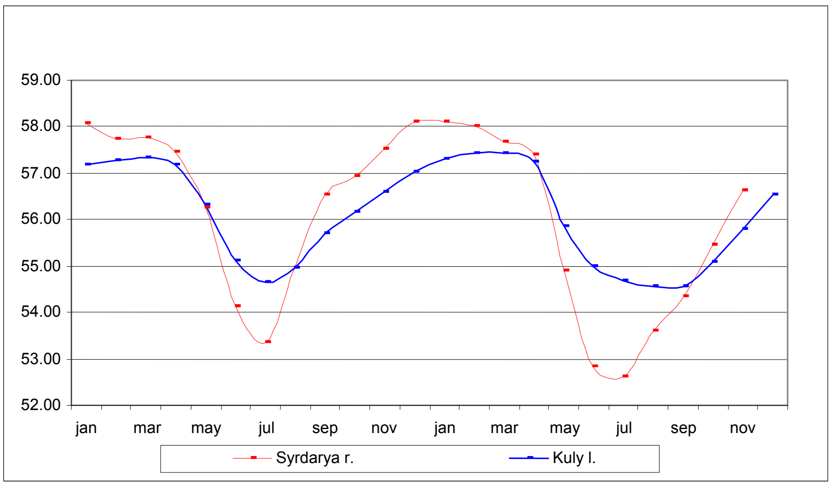


Figure 80 - Courses linking of the Syrdarya river levels at the section Kuly channel and elevation of the Kuly lake

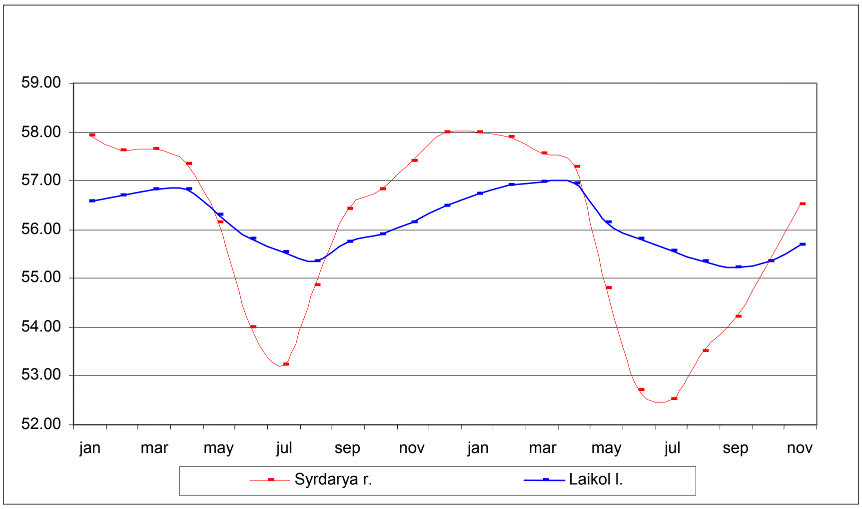


Figure 81 - Courses linking of the Syrdarya river levels at the section Zhasulan channel and elevation of the Laikol lake

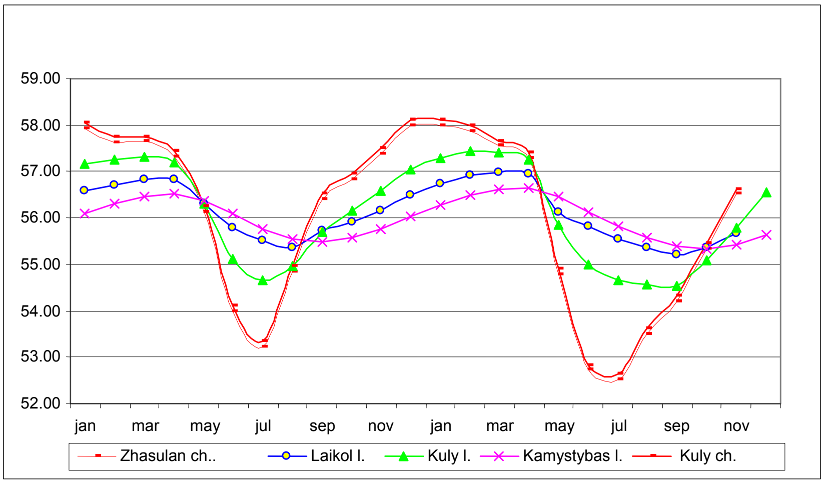


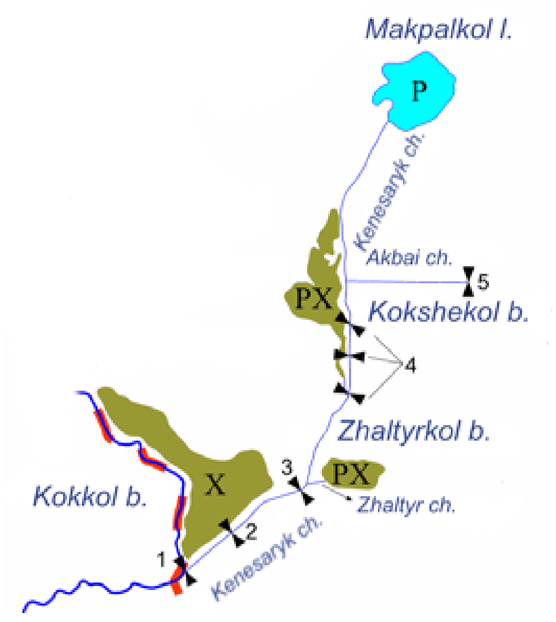
Figure 82 - Courses linking of the Syrdarya river levels at the sections Zhasulan, Keragar and Kuly channels and elevations of the Laikol, Kuly and Kamystybas lakes

6.6.3 Imitation results of the Kamystybas lakes system

Geographically the Kamystybas lakes system is located below of irrigation land. Type of feed is flooding by river water, partly with return water to the riverbed. At the present time water accumulation in the lakes systems is registered during autumn-winter seasons (October-March). Intensive level drawdown takes place in warm season (May-August). Maximal annual water level in the lakes ia registered in April, and minimal – In August-September. Governing factor of this phenomenon is higher evaporation from lakes surface in summer and water flow transformation of the Syrdarya river due to water intakes for irrigation during vegetation period and winter power discharge from the Toktogul reservoir. At the present time the regime of the lakes systems filling and discharging carries out by two fundamentally different schemes: «running» and «cycle». «Running» scheme assumes that a water object has a separate «entrance» for filling of the water body and «exit» for it discharging. Structure of the running lakes systems is formed usually as cascade-based principle. Representative of this scheme is Aksai-Kuandarya lakes system. Representative of the «cycle» scheme is part of the Kamystybas lakes system – third sub-system. It is filled-up by five channels during high-water period of the Syrdarya river, and discharged – low-water period. So, the flooding cycle of this lakes system is characterized by filling-up phase and discharge phase under reversible (alternating) regime of the flooding channels.

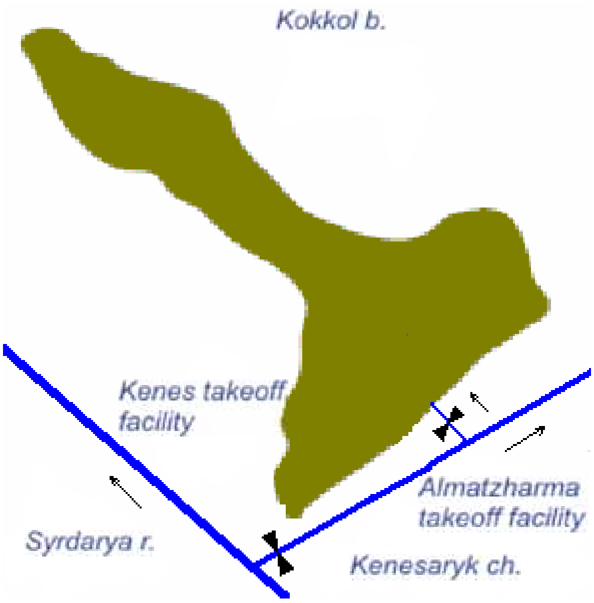
Stated winter flooding regime of the delta lakes systems is forced, caused by unnatural water regime of the Syrdarya river. This regime is contraindicative particularly for area flooding occupied by forests and bushes, unacceptable for musk-rat industry and ineffective for fish industry.

Imitation calculation has been carried out at one time with daily imitation by the following scheme:



- Calculation of water entry from the river to a raceway;
- Calculation water delivery by raceway (channel) to a lake and bog, and at the same time calculation of channel sections below water outlet;
- Change of lakes and bogs water balance;
- Coordination of water income from a channel with water entry to a lake (or entry water back from the lake to the channel and then to the river);
- Water mineralization change in a lake (bog).

Kenesaryk channel control water overflow from the Syrdarya river to the Makpalkol lake and Kokkol, Zhaltyrkol and Makpalkol bogs. Channel crest level – 56.87 m. Average bed width – 17 m. Maximum accepted flow value – 8.1 m^3/sec.



Kokkol bog belongs to Kamystybas lakes system and is an economic purpose object.

Economic purpose object is – water bodies and bogs with flood riverside lands with average depth 1.5-2.5 m, mineralization less 2.0-4.0 g/l, for getting construction and fuel reeds, for stock-breeding pastures and hay-fields, for swimming birds farming, melon growing and truck farming.

Bed level is 51.03 (BSS). Weighted average depth of the water body in 2005 was – 1.97 m. Weighted average depth of the water body in 2006 – 1.88 m. Area occupied by reed and grain crops is 50.40 km^2.

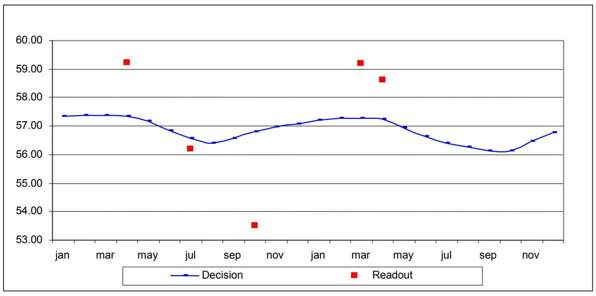


Figure 83 – Levels course of the Kokkol bog

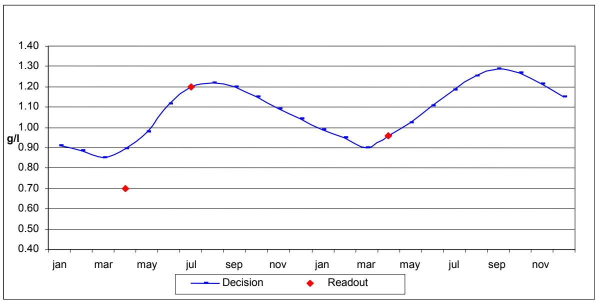


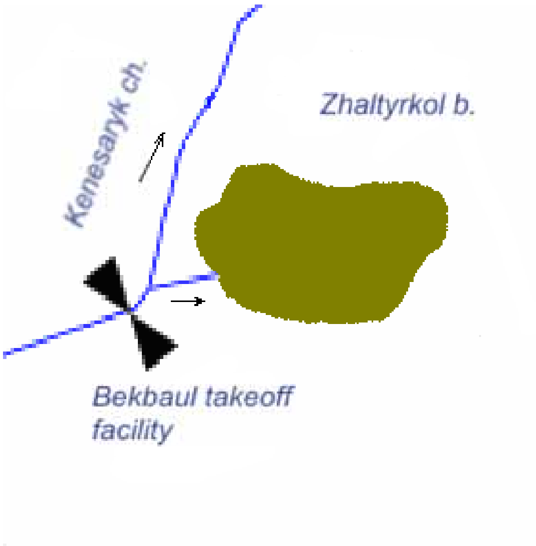
Figure 84 – Mineralization course of the Kokkol bog

Table 70

Month, year	Syrdarya river level	Channel water level	Water body level	Water discharge from Syrdarya river to Kenesaryk channel (m^3/sec)	Kenesaryk chanel water discharge near to Kokkol (m^3/sec)	Kenesaryk chanel water discharge to the bog (m^3/sec)	Kenesaryk chanel water discharge below Kokkol (m^3/sec)
2005							
FEB	59.59	58.03	57.39	8.10	7.29	0.31	6.98
MAR	59.61	58.03	57.38	8.10	7.29	0.29	7.00
APR	59.30	58.03	57.33	8.10	7.29	0.34	6.95
MAY	58.10	57.34	57.17	4.98	4.48	0.04	4.44
JUN	55.97	56.23	56.83	0.00	0.00	-0.90	0.90

JUL	55.20	56.23	56.55	0.00	0.00	-0.36	0.36
AUG	56.82	56.23	56.39	0.00	0.00	-0.13	0.13
SEP	58.38	57.59	56.57	6.12	5.50	1.61	3.89
OCT	58.79	57.96	56.79	7.78	7.00	1.66	5.34
NOV	59.36	58.03	56.96	8.10	7.29	1.25	6.04
DEC	59.97	58.03	57.09	8.10	7.29	0.92	6.37
2006							
JAN	59.97	58.03	57.19	8.10	7.29	0.69	6.60
FEB	59.85	58.03	57.26	8.10	7.29	0.53	6.76
MAR	59.52	58.03	57.27	8.10	7.29	0.46	6.83
APR	59.26	58.03	57.24	8.10	7.29	0.48	6.81
MAY	56.76	56.23	56.92	0.00	0.00	-1.07	1.07
JUN	54.69	56.23	56.64	0.00	0.00	-0.50	0.50
JUL	54.48	56.23	56.40	0.00	0.00	-0.17	0.17
AUG	55.46	56.23	56.26	0.00	0.00	-0.06	0.06
SEP	56.18	56.23	56.14	0.00	0.00	-0.01	0.01
OCT	57.31	56.63	56.13	1.78	1.60	0.27	1.33
NOV	58.48	57.68	56.48	6.52	5.87	1.92	3.95
DEC	59.66	58.03	56.78	8.10	7.29	1.81	5.48

Month, year	Water body level	Water body volume (mln.m^3)	Water surface area (km^2)	Balance of evaporation and precipitation (m^3/sec)	Mineralization, g/l
2005					
FEB	57.39	41.45	19.71	-0.01	0.89
MAR	57.38	41.21	19.63	0.39	0.85
APR	57.33	40.19	19.31	0.72	0.90
MAY	57.17	37.32	18.37	1.12	0.98
JUN	56.83	31.29	16.34	1.43	1.12
JUL	56.55	27.05	14.83	1.22	1.20
AUG	56.39	24.76	13.98	0.73	1.22
SEP	56.57	27.28	14.91	0.64	1.20
OCT	56.79	30.66	16.12	0.39	1.15
NOV	56.96	33.50	17.10	0.16	1.09
DEC	57.09	35.74	17.85	0.08	1.04
2006					
JAN	57.19	37.65	18.49	-0.03	0.99
FEB	57.26	38.96	18.91	-0.01	0.95
MAR	57.27	39.19	18.98	0.37	0.90
APR	57.24	38.58	18.79	0.71	0.96
MAY	56.92	32.93	16.91	1.04	1.02
JUN	56.64	28.35	15.30	1.27	1.11
JUL	56.40	24.89	14.03	1.13	1.19
AUG	56.26	22.91	13.27	0.68	1.25
SEP	56.14	21.43	12.70	0.56	1.29
OCT	56.13	21.30	12.64	0.32	1.27
NOV	56.48	25.92	14.41	0.13	1.21
DEC	56.78	30.57	16.09	0.07	1.15



Zhaltyrkol bog belongs to the Kamystybas lakes system and is fish and economic purpose object. *Fish purpose object is* water bodies with average depth 2.5-3.0 m, with mineralization less than 8-10 g/l, with spawning and feeding areas, with possible renewable natural fish resources of local types, and due to fish industry, i.e. artificial seeding and catching. Bed level is 55.18 (BSS).

Weighted average depth of the water body in 2005 was – 0.57 m. Weighted average depth of the water body in 2006 was – 0.48 m. Area occupied by reeds and grain crops is 84.48 km^2. Area occupied by tugai is – 11.52 km^2.

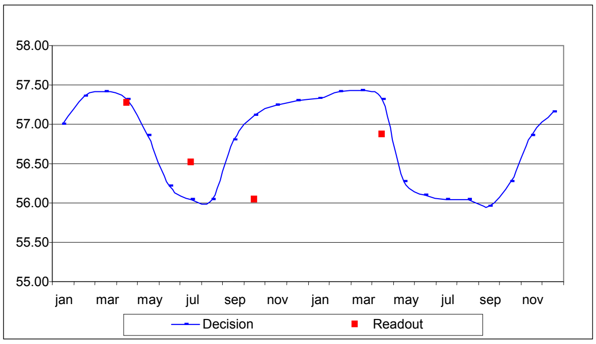


Figure 85 – Levels course of the Zhaltyrkol bog

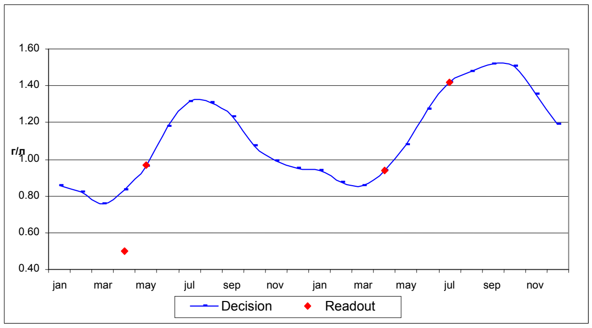
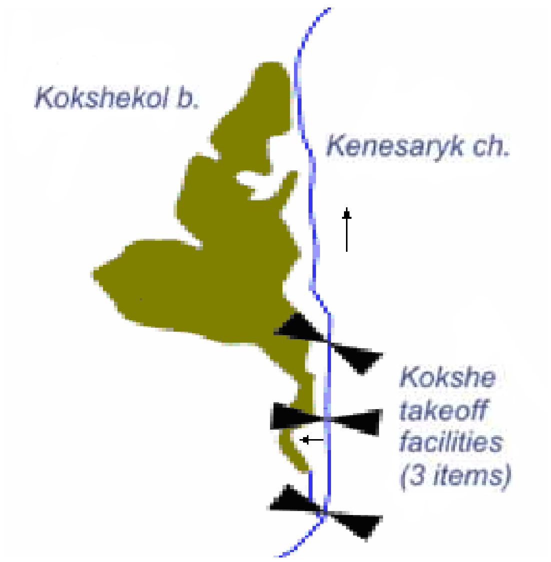


Figure 86 - Mineralization course of the Zhaltyrkol bog



Kokshekol bog belongs to the Kamystybas lakes system and is fish and economic purpose object. Bed level is 54.17 (BSS).

Weighted average depth of the water body in 2005 was – 0.50 m. Weighted average depth of the water body in 2006 was – 0.43 m. Area occupied by reeds and grain crops is 21.07 km^2.

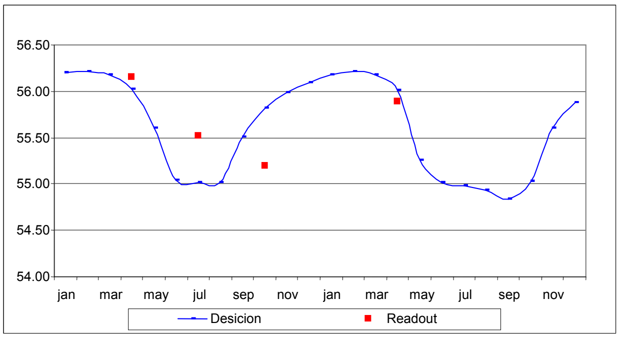
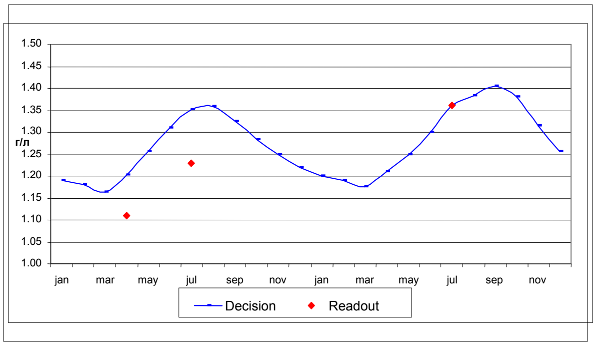
	

Figure 87 - Levels course of the Kokshekol bog	Figure 88 - Mineralization course of the Kokshekol bog

Makpalkol lake belongs to the Kamystybas lakes system and is fish purpose object. Bed level is 44.39 (BSS).

Weighted average depth of the water body in 2005 was – 3.26 m. Weighted average depth of the water body in 2006 was – 3.18 m. Area occupied by reeds is 3.17 km^2.

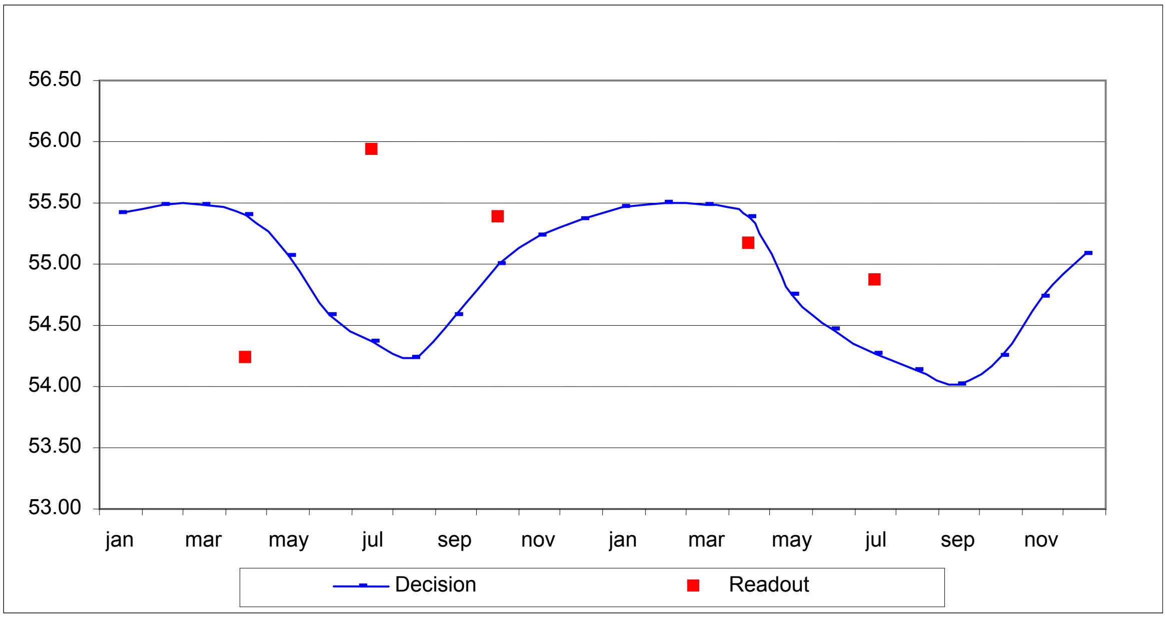


Figure 89 - Levels course of the Makpalkol lake

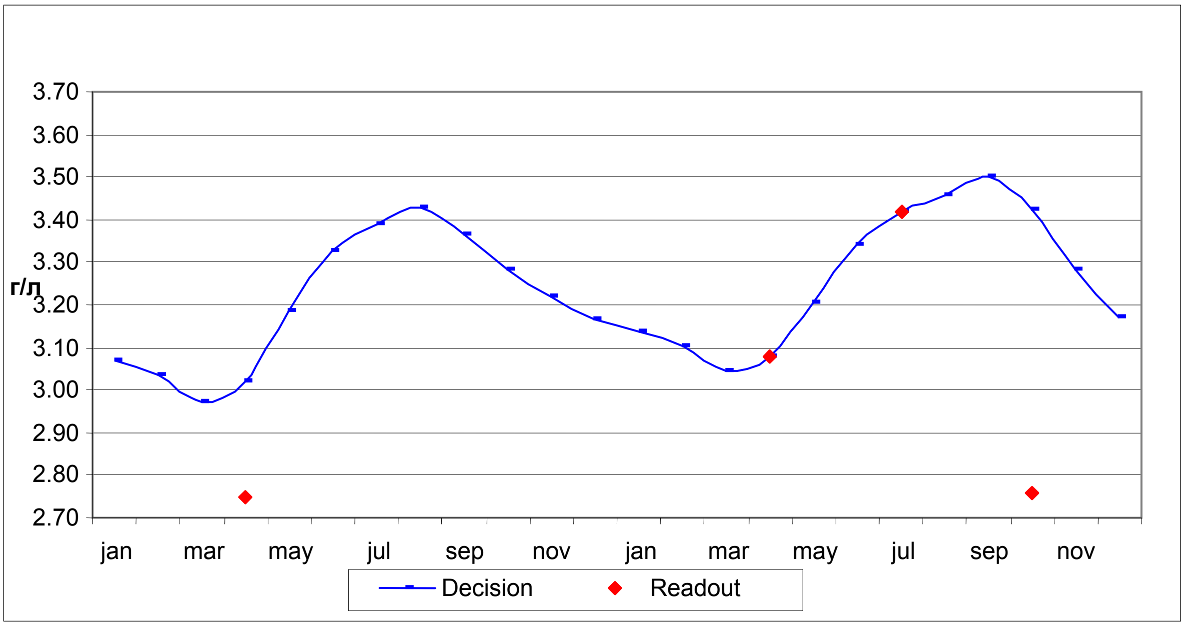
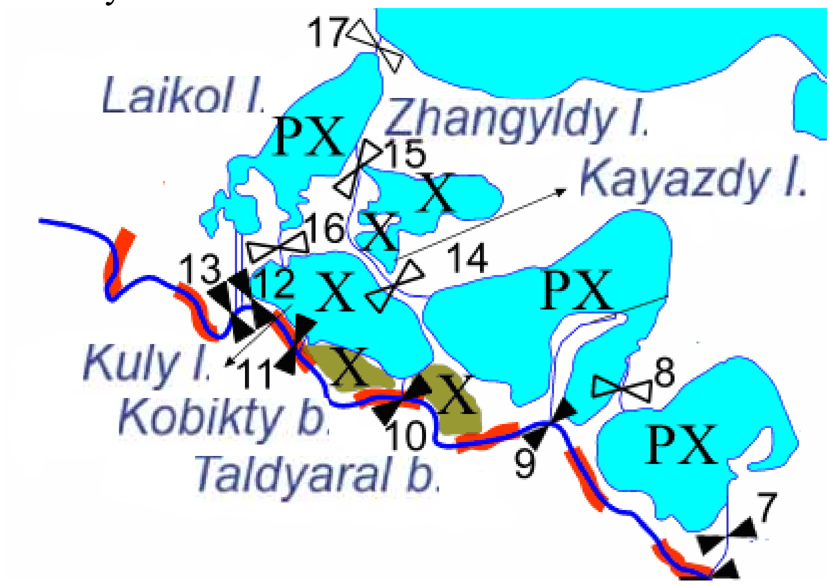


Figure 90 - Mineralization course of the Makpalkol lake

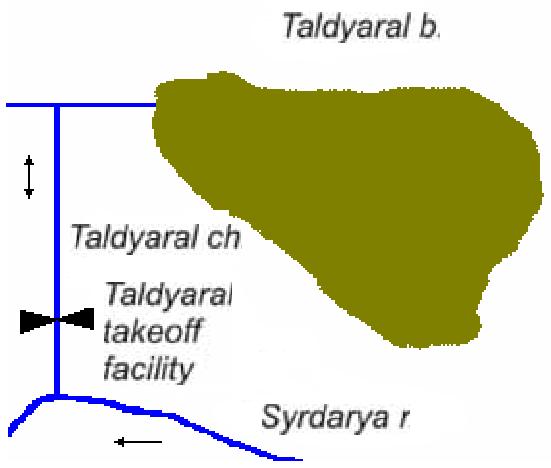
On the whole the sub-system, in spite of winter regime, is in satisfactory condition and water mineralization doesn't exceed of the permissible limits for fish industry.



The dynamic of the second sub-system:

Taldyaral bog belongs to the Kamystybas lakes system and is economic purpose object. Bed level is 54.73 (BSS).

Weighted average depth of the water body in 2005 was – 0.70 m. Weighted average depth of the water body in 2006 was – 0.53 m. Water surface area is 3.9 km^2. Area occupied by reeds is 4.07 km^2.



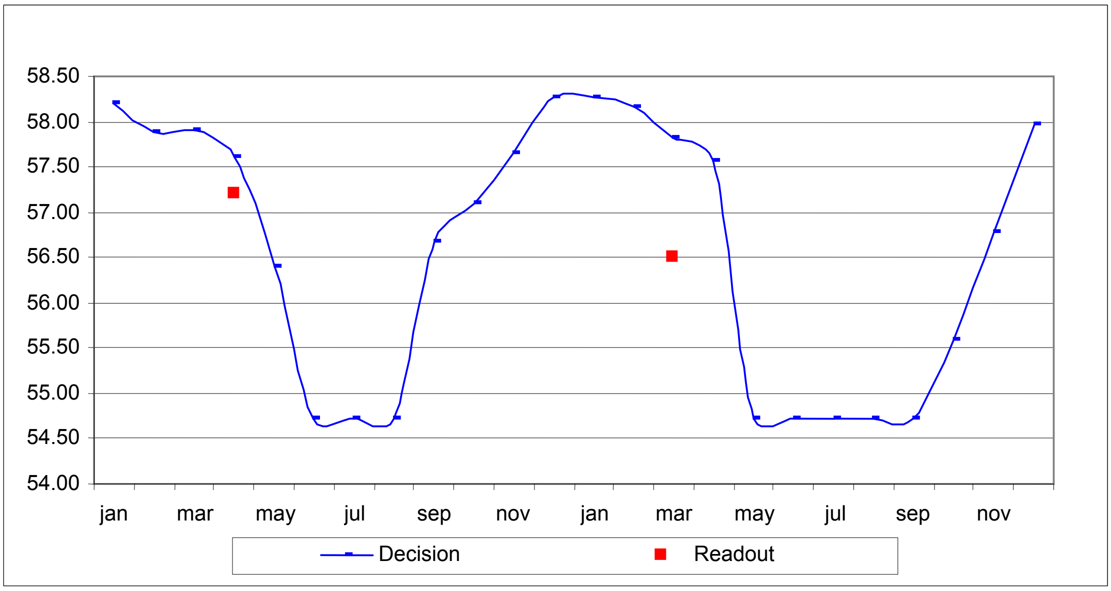


Figure 91 - Levels course of the Taldyaral bog

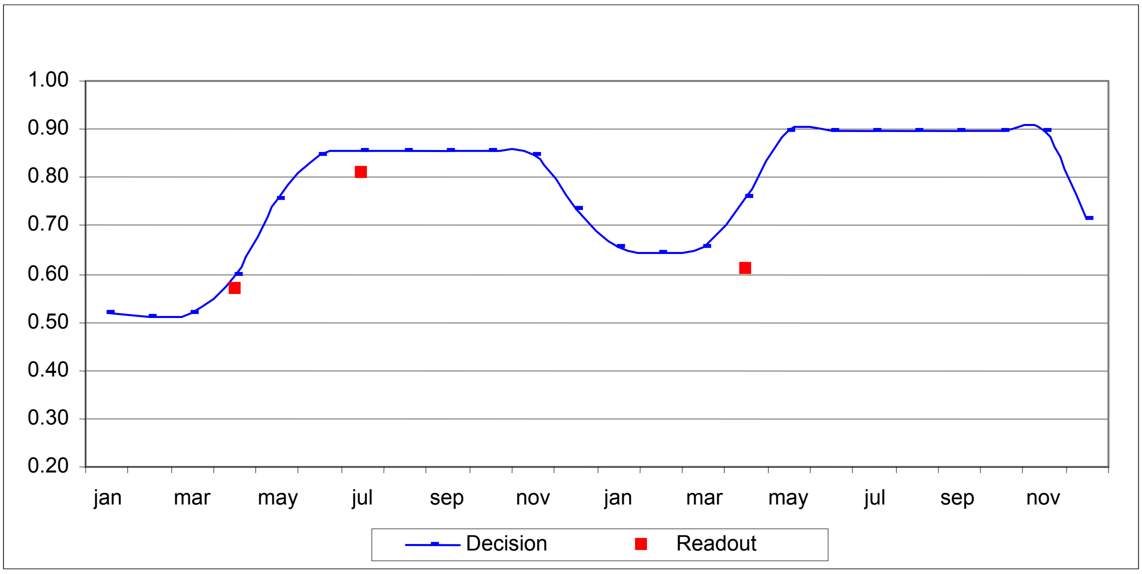


Figure 92 - Mineralization course of the Taldyaral bog

Kobykty bog belongs to the Kamystybas lakes system and is economic purpose object. Bed level is 53.86 (BSS).

Weighted average depth of the water body in 2005 was – 1.00 m. Weighted average depth of the water body in 2006 was – 0.77 m. Area occupied by reeds is 3.09 km^2.

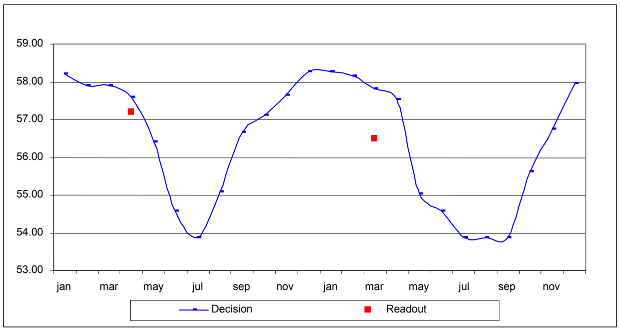


Figure 93 - Levels course of the Kobikty bog

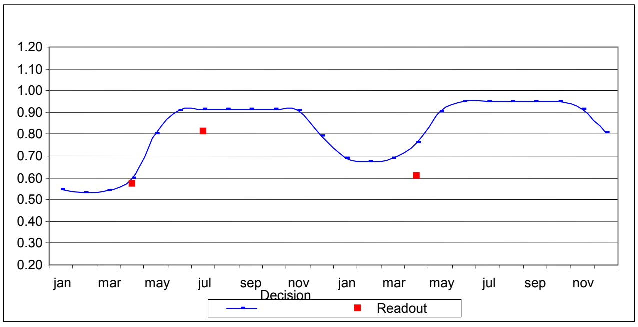
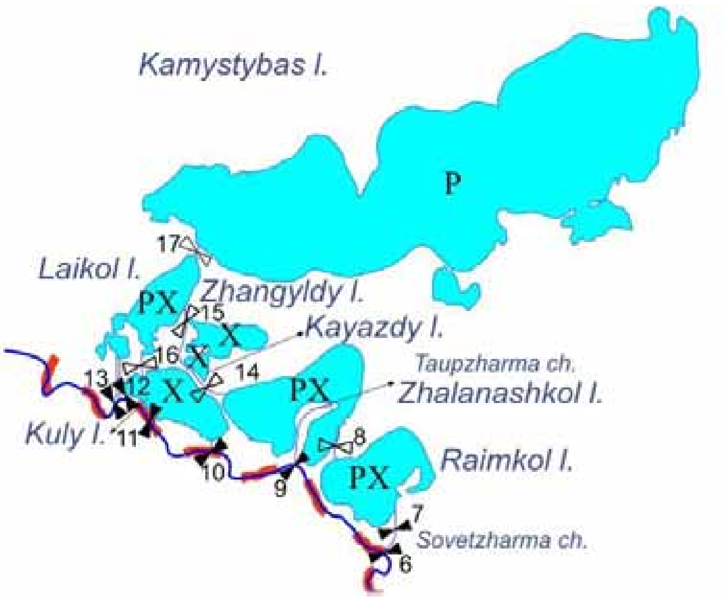
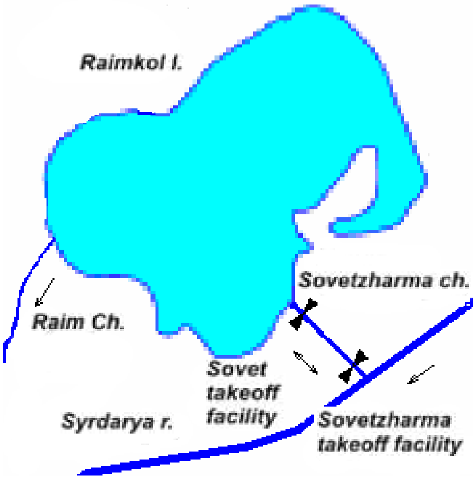


Figure 94 - Mineralization course of the Kobikty bog



This sub-system unsuitably to review as for guarantee water delivery. It is enough a minimal filling-up for supporting of these wetlands vitality.



The dynamic of the third sub-system:

Raimkol lake belongs to the Kamystybas lakes system and is fish and economic purpose object. Bed level is 53.24 (BSS).

Weighted average depth of the water body in 2005 was – 1.42 m. Weighted average depth of the water body in 2006 was – 1.19 m. Area occupied by reeds is 21.07 km^2.

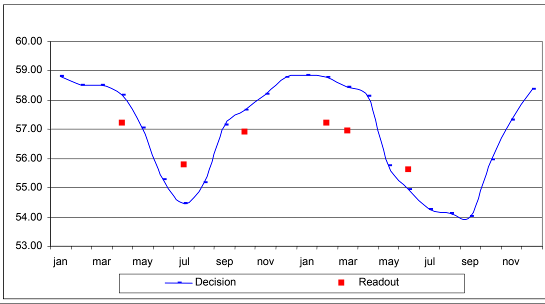


Figure 95 - Levels course of the Raimkol lake

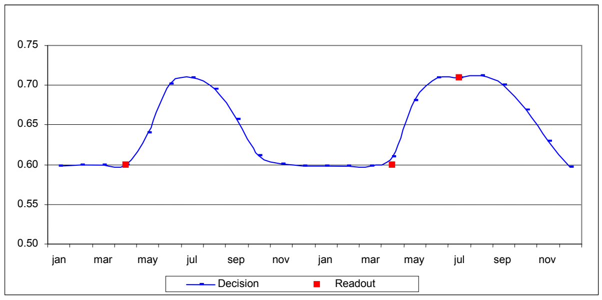
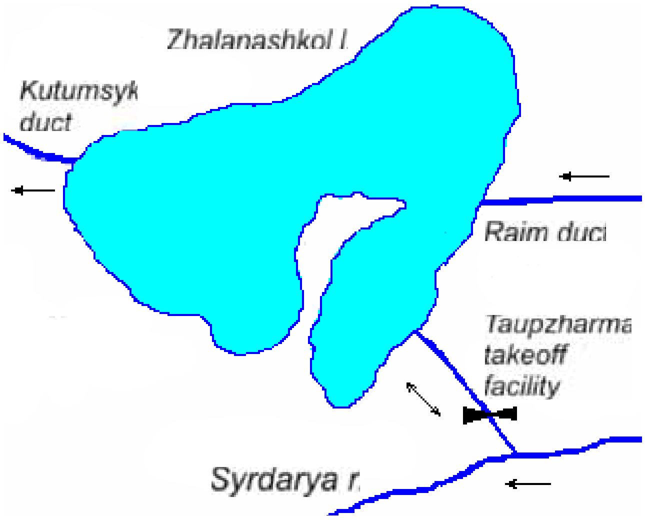


Figure 96 - Mineralization course of the Raimkol lake



Zhalanashkol lake belongs to the Kamystybas lakes system and is fish and economic purpose object. Bed level is 53.15 (BSS).

Weighted average depth of the water body in 2005 was – 1.18 m. Weighted average depth of the water body in 2006 was – 1.05 m. Area occupied by reeds is 18.88 km^2.

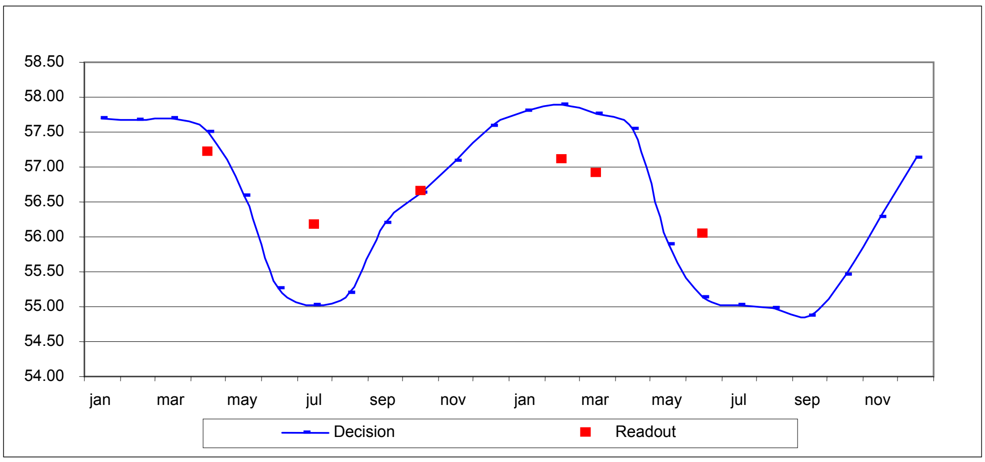


Figure 97 - Levels course of the Zhalanashkol lake

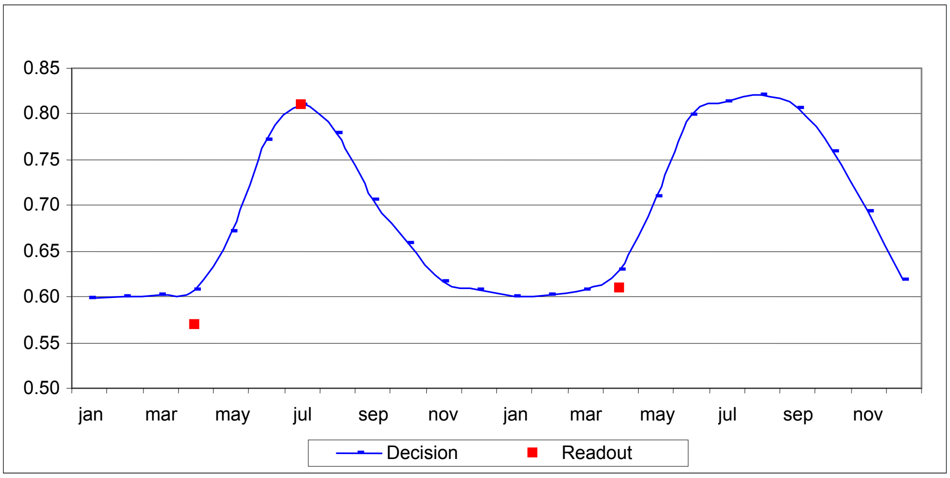
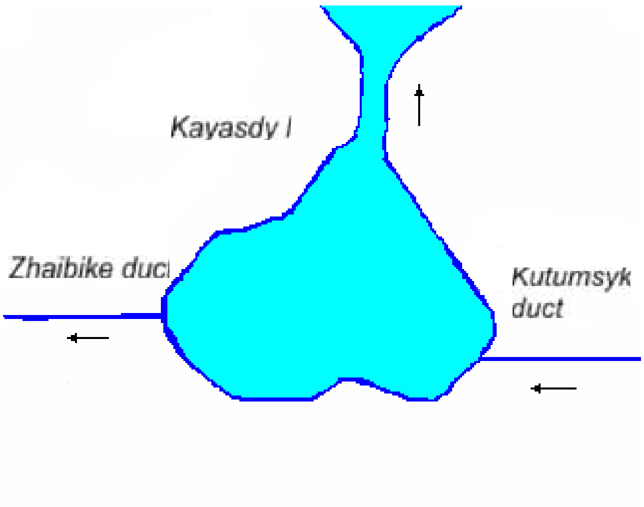


Figure 98 - Mineralization course of the Zhalanashkol lake



Kayazdy lake belongs to the Kamystybas lakes system and is economic purpose object. Bed level is 53.98 (BSS).

Area occupied by reeds is 4.33 km^2.

Zhyngyldy lake belongs to the Kamystybas lakes system and is economic purpose object. Bed level is 51.85 (BSS). Area occupied by reeds is 0.47 km2.

Because of true border between Kayazdy and Zhyngyldy lakes is missed the calculation had been made for united water area. Weighted average depth of the water body in 2005 was – 0.86 m. Weighted average depth of the water body in 2006 was – 0.78 m.

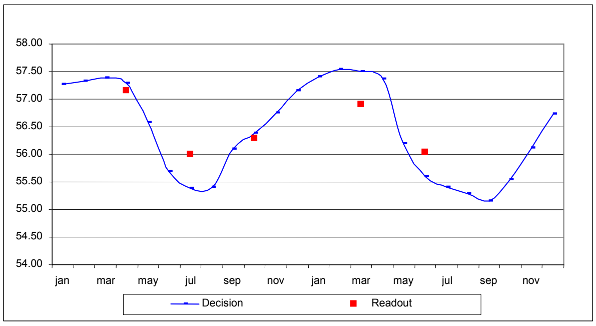


Figure 99 - Levels course of the Kayazdy-Zhyngyldy lake

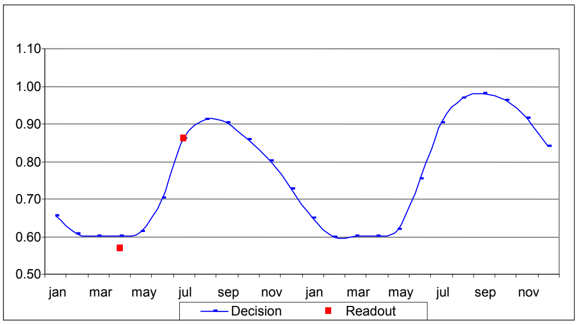
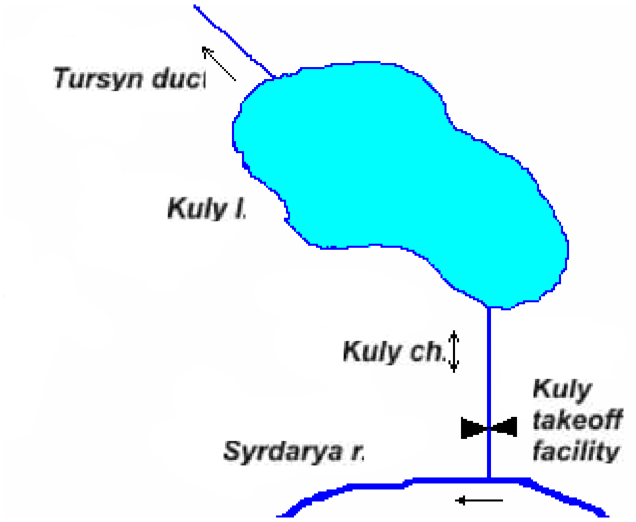


Figure 100 - Mineralization course of the Kayazdy-Zhyngyldy lake



Kuly lake is economic purpose object. Bed level is 52.61 (BSS).

Weighted average depth of the water body in 2005 was – 1.23 m. Weighted average depth of the water body in 2006 was – 1.11 m. Area occupied by reeds is 13.62 km^2.

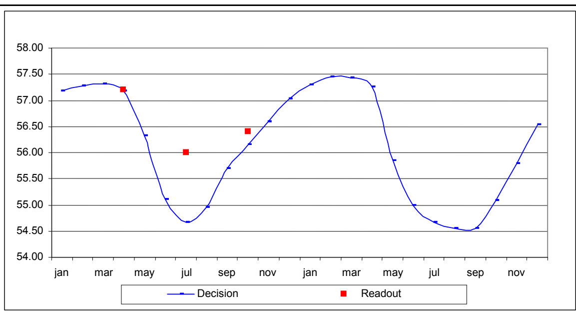


Figure 101 - Levels course of the Kuly lake

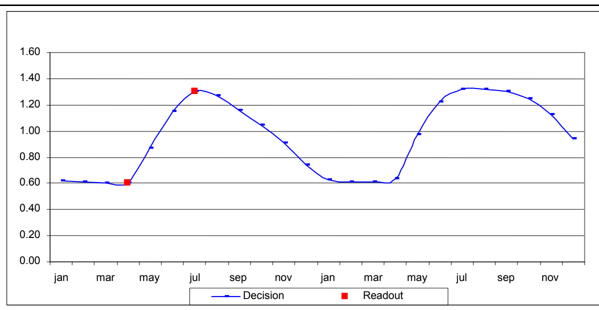


Figure 102 - Mineralization course of the Kuly lake

Laikol lake is fish and economic purpose object. Bed level is 48.78 (BSS).

Weighted average depth of the water body in 2005 was – 2.47 m. Weighted average depth of the water body in 2006 was – 2.43 m. Area occupied by reeds and grain crops is 14.13 km^2. Area occupied by tugai is 2.73 km^2.

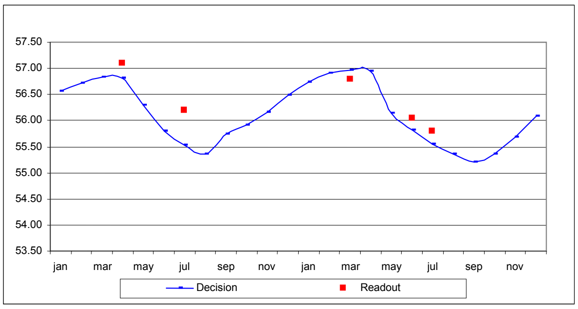


Figure 103 - Levels course of the Laikol lake

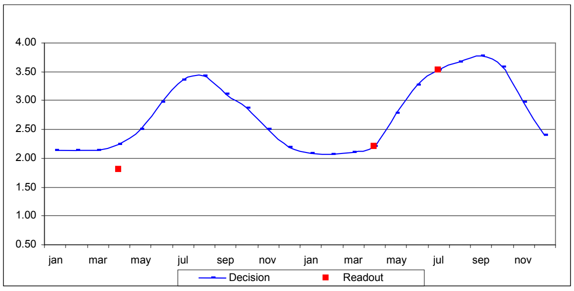
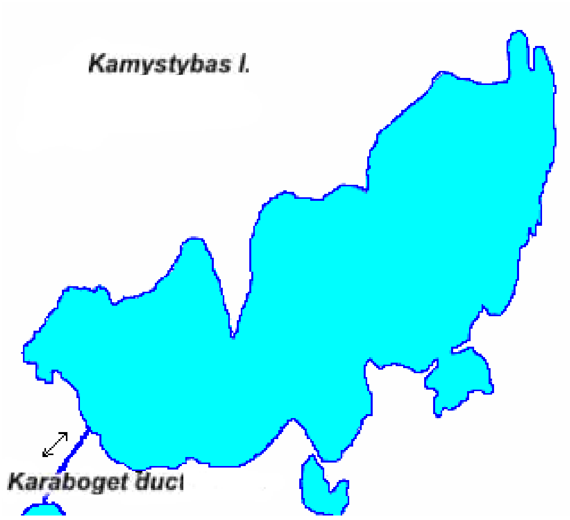


Figure 104 - Mineralization course of the Laikol lake

Kamystybas lake belongs to the Kamystybas lakes system and is fish purpose object. Bed level is 42.63 (BSS).

Weighted average depth of the water body in 2005 was – 4.46 m. Weighted average depth of the water body in 2006 was – 4.45 m. Area occupied by reeds is 31.76 km^2.



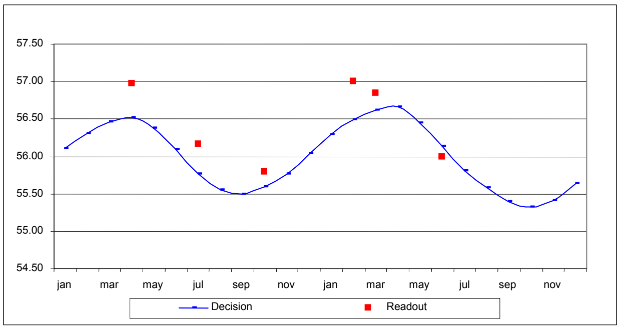


Figure 105 - Levels course of the Kamystybas lake

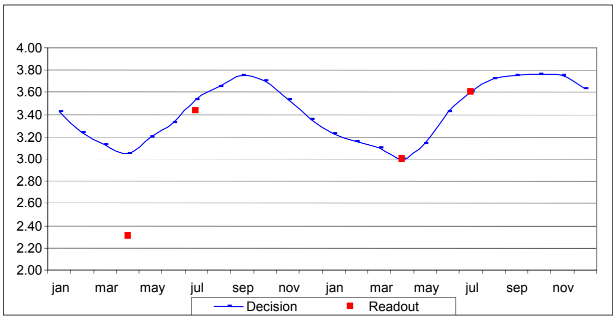


Figure 106 - Mineralization course of the Kamystybas lake

- 2005

Water intake: 444.4 mln.m^3;
Water discharge to the river: 191.8 mln.m^3;
Water losses for evaporation and evapotranspiration: 212.9 mln.m^3.

- 2006

Water intake: 333.7 mln.m^3;
Water discharge to the river: 233.1 mln.m^3;
Water losses for evaporation and evapotranspiration: 199.4 mln.m^3.

Hence, Kamystybas lakes system operates very ineffective – with large water discharge back to the river and even it discharges from its long-term water supply during high-water years.

6.6.4 Variants of recommended water level supporting

This section gives results of calculation of three variants for water level supporting. Any of the reviewed variants can exist without check facility on the river. The following hydraulic facilities were reviewed for construction:

- Amanotkel
- Raim

Numerical experiments were applied to the selected variants for the following water level in the river:

1. Amanotkel: minimal water level is raising up to 57.6 m.
   Interaction between the river and the system is happened in the all channels.
2. Raim: a) minimal water level is raising up to 59.1 m (variant №1). Lakes system feeds from Sovetzharma and Zhasulan channels.
   б) minimal water level is raising up to 59.1 m (variant №2). Lakes system feeds only from Sovetzharma channel.

Base of river level change within a year was data for 2005 and 2006 years for Kenesaryk cross-section with raise of minimal levels up to above mentioned sizes.

Impact of the Syrdarya river level raising up to minimal level 57.60 m in the Amanotkel hydraulic facility to the Kamystybas lakes system water balance

Table 71 – Raimkol lake

Month, year	Syrdarya river level at the section “Sovetzharma channel”	Raimkol water level	Sovetzharma channel water discharge from Syrdarya river (m^3/sec)	Raim river water discharge to Zhalanashkol (m^3/sec)	Water body volume (mln.m^3)	Water surface area (km^2)	Balance of evaporation and precipitation (m^3/sec)
2005							
JAN	58.91	58.76	8.43	7.70	60.60	32.92	0.01
FEB	58.59	58.48	3.23	6.99	51.83	29.66	0.00
MAR	58.61	58.46	7.79	7.43	51.08	29.38	-0.64
APR	58.30	58.14	4.87	6.76	42.44	25.97	-1.56
MAY	57.60	57.52	0.60	4.39	28.30	19.82	-1.67
JUN	57.60	57.50	6.30	4.44	27.82	19.59	-2.05
JUL	57.60	57.50	6.49	4.54	27.84	19.60	-1.94
AUG	57.60	57.53	5.85	4.46	28.33	19.83	-1.20
SEP	57.60	57.53	5.43	4.38	28.46	19.89	-1.00
OCT	57.79	57.70	7.18	5.38	31.92	21.47	-0.47
NOV	58.36	58.19	11.63	6.78	43.60	26.43	-0.19
DEC	58.97	58.72	13.69	7.58	59.28	32.45	-0.06
2006							
JAN	58.97	58.82	8.74	7.47	62.60	33.65	0.01
FEB	58.85	58.73	6.12	7.46	59.47	32.51	0.00
MAR	58.52	58.40	3.36	6.57	49.48	28.76	-0.64
APR	58.26	58.11	4.84	6.42	41.64	25.64	-1.55
MAY	57.60	57.52	0.82	4.27	28.30	19.82	-1.71
JUN	57.60	57.50	6.28	4.34	27.84	19.61	-2.13
JUL	57.60	57.50	6.42	4.40	27.89	19.63	-1.99
AUG	57.60	57.53	5.75	4.35	28.37	19.85	-1.22
SEP	57.60	57.53	5.38	4.33	28.47	19.90	-1.01
OCT	57.60	57.55	4.91	4.37	28.73	20.02	-0.44

NOV	57.60	57.55	4.56	4.35	28.87	20.08	-0.15
DEC	58.66	58.42	14.78	6.58	50.00	28.96	-0.05

Table 72 – Zhalanashkol lake

Month, year	Water level	Taupzharma channel water discharge from Syrdarya river (m^3/sec)	Raim river water discharge from Raimkol (m^3/sec)	Kutumsyk river water discharge to Kayazdy-Zhyngyldy (m^3/sec)	Water body volume (mln.m^3)	Water surface area (km^2)	Balance of evaporation and precipitation (m^3/sec)
2005							
JAN	58.47	0.65	7.70	7.06	80.24	45.26	0.01
FEB	58.23	-5.87	6.99	5.55	69.89	41.28	0.00
MAR	58.19	-2.52	7.43	4.69	68.19	40.61	-0.64
APR	57.91	-5.15	6.76	3.71	57.54	36.26	-1.56
MAY	57.59	-2.84	4.39	2.58	46.73	31.56	-1.67
JUN	57.54	1.61	4.44	2.62	45.20	30.87	-2.05
JUL	57.54	1.97	4.54	2.95	45.15	30.85	-1.94
AUG	57.58	1.37	4.46	3.21	46.51	31.46	-1.20
SEP	57.59	0.74	4.38	3.28	46.81	31.60	-1.00
OCT	57.62	-1.14	5.38	3.21	47.67	31.99	-0.47
NOV	57.94	1.80	6.78	3.94	58.62	36.71	-0.19
DEC	58.45	5.85	7.58	5.29	79.51	44.98	-0.06
2006							
JAN	58.54	-0.19	7.47	5.73	83.57	46.50	0.01
FEB	58.46	-4.19	7.46	4.89	79.79	45.09	0.00
MAR	58.18	-6.44	6.57	3.78	67.97	40.52	-0.64
APR	57.91	-5.76	6.42	2.74	57.36	36.18	-1.55
MAY	57.60	-3.24	4.27	1.87	46.95	31.66	-1.71
JUN	57.56	1.30	4.34	2.01	45.73	31.11	-2.13
JUL	57.56	1.62	4.40	2.38	45.73	31.11	-1.99
AUG	57.60	0.87	4.35	2.66	46.87	31.63	-1.22
SEP	57.60	0.20	4.33	2.75	46.99	31.68	-1.01
OCT	57.61	-0.89	4.37	2.68	47.26	31.80	-0.44
NOV	57.62	-1.47	4.35	2.49	47.63	31.97	-0.15
DEC	58.18	5.10	6.58	3.74	68.05	40.55	-0.05

Table 73 – Kayazdy-Zhyngyldy lake

Month, year	Water level	Kutumsyk river water discharge from Zhalanashkol (m^3/sec)	Zhaibike river water discharge to Laikol (m^3/sec)	Water body volume (mln.m^3)	Water surface area (km^2)	Balance of evaporation and precipitation (m^3/sec)
2005						
JAN	57.74	7.06	6.61	10.24	8.18	0.00
FEB	57.69	5.55	5.71	9.89	7.99	0.00
MAR	57.69	4.69	4.52	9.90	8.00	-0.16
APR	57.57	3.71	3.71	8.95	7.48	-0.37
MAY	57.38	2.58	2.52	7.57	6.69	-0.59
JUN	57.28	2.62	2.12	6.93	6.30	-0.76

JUL	57.23	2.95	2.40	6.63	6.12	-0.66
AUG	57.25	3.21	2.77	6.77	6.21	-0.39
SEP	57.26	3.28	2.94	6.82	6.24	-0.32
OCT	57.31	3.21	2.94	7.14	6.43	-0.14
NOV	57.49	3.94	3.39	8.39	7.16	-0.05
DEC	57.80	5.29	4.35	10.78	8.47	-0.01
2006						
JAN	57.94	5.73	5.25	12.03	9.11	0.00
FEB	57.96	4.89	4.81	12.21	9.20	0.00
MAR	57.84	3.78	4.02	11.10	8.63	-0.18
APR	57.69	2.74	2.85	9.87	7.98	-0.39
MAY	57.49	1.87	1.85	8.34	7.13	-0.61
JUN	57.38	2.01	1.52	7.61	6.71	-0.78
JUL	57.33	2.38	1.83	7.26	6.50	-0.68
AUG	57.34	2.66	2.23	7.33	6.55	-0.40
SEP	57.34	2.75	2.42	7.31	6.54	-0.33
OCT	57.37	2.68	2.44	7.54	6.67	-0.15
NOV	57.42	2.49	2.32	7.84	6.85	-0.05
DEC	57.69	3.74	2.93	9.89	7.99	-0.01

Table 74 – Kuly lake

Month, year	Water level	Kuly channel water discharge from Syrdarya river (m^3/sec)	Tursun river water discharge to Laikol lake (m^3/sec)	Water body volume (mln.m^3)	Water surface area (km^2)	Balance of evaporation and precipitation (m^3/sec)
2005						
JAN	57.60	2.05	0.89	30.31	18.21	0.01
FEB	57.62	0.93	0.84	30.51	18.29	0.00
MAR	57.60	1.01	0.69	30.29	18.20	-0.40
APR	57.47	0.60	0.50	27.99	17.27	-1.01
MAY	57.33	1.09	0.36	25.56	16.25	-1.67
JUN	57.17	1.44	0.28	23.08	15.18	-2.16
JUL	57.11	1.65	0.26	22.15	14.77	-1.75
AUG	57.16	1.65	0.33	22.97	15.14	-1.00
SEP	57.21	1.55	0.43	23.69	15.45	-0.84
OCT	57.30	1.42	0.51	25.14	16.07	-0.35
NOV	57.39	1.22	0.53	26.54	16.67	-0.13
DEC	57.63	2.21	0.54	30.79	18.40	-0.03
2006						
JAN	57.79	1.81	0.62	33.89	19.61	0.01
FEB	57.85	1.15	0.63	35.10	20.08	0.00
MAR	57.65	-0.73	0.40	31.10	18.52	-0.41
APR	57.52	0.28	0.20	28.73	17.57	-1.02
MAY	57.38	0.95	0.14	26.45	16.62	-1.69
JUN	57.23	1.33	0.11	23.97	15.57	-2.21
JUL	57.17	1.54	0.11	23.03	15.16	-1.79
AUG	57.22	1.54	0.19	23.87	15.53	-1.02
SEP	57.27	1.44	0.30	24.58	15.83	-0.86

OCT	57.36	1.29	0.39	26.00	16.44	-0.36
NOV	57.43	1.09	0.45	27.29	16.98	-0.13
DEC	57.57	1.44	0.48	29.69	17.96	-0.03

Table 75 – Laikol lake

Month, year	Water level	Zhasulan channel water discharge from Syrdarya river (m^3/sec)	Zhaibike river water discharge from Kayazdy-Zhyngyldy (m^3/sec)	Tursun river water discharge from Kuly (m^3/sec)	Karaboget river water discharge to Kamystybas (m^3/sec)	Water body volume (mln.m^3)	Water surface area (km^2)	Balance of evaporation and precipitation (m^3/sec)
2005								
JAN	57.16	6.26	6.61	0.89	12.94	35.33	12.64	0.00
FEB	57.22	3.99	5.71	0.84	10.20	36.12	12.83	0.00
MAR	57.28	3.81	4.52	0.69	8.43	36.79	12.99	-0.32
APR	57.25	3.52	3.71	0.50	6.95	36.45	12.91	-0.92
MAY	57.16	3.81	2.52	0.36	5.55	35.29	12.63	-1.58
JUN	57.04	4.28	2.12	0.28	5.09	33.86	12.29	-2.15
JUL	56.96	4.66	2.40	0.26	6.02	32.82	12.04	-1.69
AUG	56.95	4.83	2.77	0.33	7.08	32.74	12.02	-0.88
SEP	56.95	4.85	2.94	0.43	7.51	32.78	12.03	-0.70
OCT	57.01	4.73	2.94	0.51	7.65	33.47	12.20	-0.27
NOV	57.11	4.43	3.39	0.53	7.75	34.74	12.50	-0.10
DEC	57.31	6.03	4.35	0.54	9.91	37.30	13.11	-0.02
2006								
JAN	57.46	5.36	5.25	0.62	10.51	39.20	13.55	0.00
FEB	57.53	4.11	4.81	0.63	9.11	40.23	13.79	0.00
MAR	57.49	1.91	4.02	0.40	6.21	39.70	13.67	-0.33
APR	57.44	2.21	2.85	0.20	4.60	39.01	13.51	-0.93
MAY	57.34	2.78	1.85	0.14	3.72	37.59	13.18	-1.59
JUN	57.21	3.47	1.52	0.11	3.60	35.95	12.79	-2.15
JUL	57.11	3.98	1.83	0.11	4.70	34.73	12.50	-1.69
AUG	57.09	4.24	2.23	0.19	5.88	34.45	12.43	-0.89
SEP	57.08	4.32	2.42	0.30	6.40	34.31	12.40	-0.70
OCT	57.12	4.26	2.44	0.39	6.62	34.82	12.52	-0.27
NOV	57.18	4.04	2.32	0.45	6.40	35.60	12.71	-0.10
DEC	57.31	4.13	2.93	0.48	6.88	37.24	13.10	-0.02

Table 76 – Kamystybas lake

Month, year	Water level	Karaboget river water discharge from Laikol (m^3/sec)	Water body volume (mln.m^3)	Water surface area (km^2)	Balance of evaporation and precipitation (m^3/sec)
2005					
JAN	56.77	12.94	820.75	174.06	0.01
FEB	56.91	10.20	844.55	177.41	0.00
MAR	56.99	8.43	858.20	179.32	-0.64
APR	57.00	6.95	861.13	179.73	-1.56

MAY	56.94	5.55	850.20	178.20	-1.67
JUN	56.82	5.09	828.95	175.22	-2.05
JUL	56.71	6.02	809.12	172.41	-1.94
AUG	56.68	7.08	804.14	171.71	-1.20
SEP	56.68	7.51	803.66	171.64	-1.00
OCT	56.73	7.65	813.64	173.06	-0.47
NOV	56.83	7.75	829.70	175.33	-0.19
DEC	56.97	9.91	854.54	178.81	-0.06
2006					
JAN	57.12	10.51	881.94	182.61	0.01
FEB	57.23	9.11	903.20	185.53	0.00
MAR	57.27	6.21	910.76	186.57	-0.64
APR	57.26	4.60	907.36	186.10	-1.55
MAY	57.17	3.72	891.13	183.88	-1.71
JUN	57.03	3.60	865.71	180.36	-2.13
JUL	56.90	4.70	841.98	177.05	-1.99
AUG	56.85	5.88	833.50	175.86	-1.22
SEP	56.83	6.40	829.97	175.36	-1.01
OCT	56.87	6.62	837.08	176.36	-0.44
NOV	56.94	6.40	849.68	178.13	-0.15
DEC	57.03	6.88	866.65	180.49	-0.05

- 2005

  Water intake: 470.9 mln.m^3;
  Water discharge to the river: 73.1 mln.m^3;
  Water losses for evaporation and evapotranspiration: 317.7 mln.m^3.

- 2006

  Water intake: 395.8 mln.m^3;
  Water discharge to the river: 87.4 mln.m^3;
  Water losses for evaporation and evapotranspiration: 322.6 mln.m^3.

Impact of the level increasing of the Syrdarya river up to level 59.10 m at the section Sovetzharma channel to the water balance of the Kamystybas lakes system.

Table 77 – Raimkol lake

Month, year	Syrdarya river water level at the section "Sovetzharma channel"	Raimkol water level	Sovetzharma channel water discharge from Syrdarya river (m^3/sec)	Raim river water discharge to Zhalanashkol (m^3/sec)	Water body volume (mln.m^3)	Water surface area (km^2)	Balance of evaporation and precipitation (m^3/sec)
2005							
JAN	59.10	58.92	9.28	8.72	65.87	34.81	0.01
FEB	59.10	58.94	8.46	8.06	66.81	35.14	0.00
MAR	59.10	58.94	8.27	7.62	66.60	35.07	-0.73
APR	59.10	58.90	8.79	7.52	65.40	34.64	-1.75
MAY	59.10	58.83	10.02	8.03	62.82	33.72	-2.99
JUN	59.10	58.72	11.81	9.13	59.25	32.43	-4.10

JUL	59.10	58.67	13.09	10.16	57.68	31.86	-3.53
AUG	59.10	58.71	13.13	10.65	58.77	32.26	-2.06
SEP	59.10	58.74	12.64	10.47	59.93	32.68	-1.71
OCT	59.10	58.81	11.61	9.94	62.35	33.56	-0.73
NOV	59.10	58.87	10.37	9.32	64.34	34.27	-0.26
DEC	59.10	58.92	9.27	8.58	65.95	34.84	-0.06
2006							
JAN	59.10	58.95	8.30	7.84	67.16	35.26	0.01
FEB	59.10	58.98	7.56	7.24	67.92	35.53	0.00
MAR	59.10	58.97	7.46	6.85	67.60	35.41	-0.74
APR	59.10	58.93	8.10	6.85	66.33	34.97	-1.76
MAY	59.10	58.85	9.47	7.56	63.51	33.97	-3.00
JUN	59.10	58.74	11.48	8.86	59.84	32.65	-4.09
JUL	59.10	58.69	12.76	9.80	58.35	32.11	-3.53
AUG	59.10	58.72	12.80	10.34	59.37	32.48	-2.06
SEP	59.10	58.74	12.44	10.51	59.93	32.68	-1.71
OCT	59.10	58.79	11.82	10.44	61.62	33.29	-0.73
NOV	59.10	58.84	10.91	9.95	63.36	33.92	-0.26
DEC	59.10	58.89	9.88	9.17	65.04	34.51	-0.06

Table 78 – Zhalanashkol lake

Month, year	Water level	Raim river water discharge from Raimkol (m^3/sec)	Kutumsyk river water discharge to Kayazdy-Zhyngyldy (m^3/sec)	Water body volume (mln.m^3)	Water surface area (km^2)	Balance of evaporation and precipitation (m^3/sec)
2005						
JAN	58.15	8.72	7.01	66.55	39.95	0.01
FEB	58.23	8.06	6.69	69.76	41.23	0.00
MAR	58.25	7.62	6.32	70.80	41.63	-0.73
APR	58.20	7.52	6.06	68.83	40.86	-1.75
MAY	58.04	8.03	6.82	62.35	38.25	-2.99
JUN	57.82	9.13	7.76	54.25	34.86	-4.10
JUL	57.70	10.16	8.06	50.36	33.18	-3.53
AUG	57.72	10.65	8.41	50.85	33.39	-2.06
SEP	57.80	10.47	7.61	53.62	34.59	-1.71
OCT	57.92	9.94	7.47	57.99	36.45	-0.73
NOV	58.04	9.32	7.22	62.53	38.33	-0.26
DEC	58.16	8.58	6.69	67.24	40.23	-0.06
2006						
JAN	58.27	7.84	6.25	71.39	41.87	0.01
FEB	58.34	7.24	5.92	74.47	43.06	0.00
MAR	58.35	6.85	5.71	75.02	43.27	-0.74
APR	58.29	6.85	5.55	72.54	42.32	-1.76
MAY	58.08	7.56	7.14	64.02	38.93	-3.00
JUN	57.87	8.86	7.57	56.02	35.62	-4.09
JUL	57.76	9.80	7.75	52.11	33.94	-3.53
AUG	57.76	10.34	8.23	52.26	34.01	-2.06
SEP	57.77	10.51	8.67	52.58	34.14	-1.71
OCT	57.84	10.44	8.70	55.12	35.23	-0.73
NOV	57.96	9.95	8.00	59.32	37.00	-0.26

DEC	58.08	9.17	7.26	64.08	38.96	-0.06

Table 79 – Kayazdy-Zhyngyldy lake

Month, year	Water level	Kutumsyk river water discharge from Zhalanashkol (m^3/sec)	Zhaibike river water discharge to Laikol (m^3/sec)	Water body volume (mln.m^3)	Water surface area (km^2)	Balance of evaporation and precipitation (m^3/sec)
2005						
JAN	57.23	7.01	6.65	6.64	6.13	0.00
FEB	57.34	6.69	6.41	7.31	6.53	0.00
MAR	57.41	6.32	6.00	7.77	6.80	-0.14
APR	57.38	6.06	5.78	7.60	6.70	-0.35
MAY	57.10	6.82	6.96	5.87	5.64	-0.53
JUN	56.78	7.76	7.85	4.25	4.55	-0.56
JUL	56.64	8.06	7.89	3.63	4.10	-0.41
AUG	56.62	8.41	8.21	3.54	4.03	-0.23
SEP	56.80	7.61	7.07	4.34	4.62	-0.22
OCT	56.93	7.47	7.12	4.97	5.05	-0.11
NOV	57.09	7.22	6.83	5.84	5.63	-0.04
DEC	57.28	6.69	6.25	6.96	6.32	-0.01
2006						
JAN	57.43	6.25	5.89	7.92	6.89	0.00
FEB	57.53	5.92	5.60	8.67	7.32	0.00
MAR	57.56	5.71	5.47	8.90	7.45	-0.15
APR	57.52	5.55	5.31	8.60	7.28	-0.37
MAY	57.08	7.14	7.74	5.76	5.57	-0.50
JUN	56.87	7.57	7.48	4.65	4.83	-0.53
JUL	56.72	7.75	7.61	3.97	4.35	-0.40
AUG	56.67	8.23	8.08	3.75	4.19	-0.23
SEP	56.64	8.67	8.52	3.65	4.12	-0.19
OCT	56.72	8.70	8.48	3.96	4.34	-0.09
NOV	56.93	8.00	7.56	4.97	5.05	-0.04
DEC	57.14	7.26	6.81	6.12	5.80	-0.01

Table 80 – Kuly lake

Month, year	Water level	Tursun river water discharge to Laikol lake (m^3/sec)	Water body volume (mln.m^3)	Water surface area (km^2)	Balance of evaporation and precipitation (m^3/sec)
2005					
JAN	56.10	0.65	10.36	8.90	0.00
FEB	56.25	0.59	11.73	9.67	0.00
MAR	56.34	0.60	12.59	10.14	-0.26
APR	56.29	0.63	12.10	9.87	-0.82
MAY	56.03	0.39	9.73	8.54	-1.31
JUN	55.69	0.31	7.09	6.91	-1.36
JUL	55.53	0.39	6.04	6.21	-0.79
AUG	55.51	0.35	5.93	6.14	-0.39
SEP	55.63	0.66	6.72	6.67	-0.35
OCT	55.79	0.60	7.86	7.40	-0.16

NOV	55.97	0.60	9.22	8.23	-0.06
DEC	56.16	0.67	10.92	9.22	-0.02
2006					
JAN	56.34	0.67	12.66	10.17	0.00
FEB	56.48	0.63	14.14	10.95	0.00
MAR	56.55	0.57	14.88	11.33	-0.28
APR	56.49	0.58	14.20	10.98	-0.85
MAY	56.18	0.11	11.05	9.29	-1.32
JUN	55.85	0.21	8.25	7.65	-1.32
JUL	55.67	0.30	6.99	6.84	-0.78
AUG	55.62	0.26	6.65	6.62	-0.39
SEP	55.59	0.22	6.43	6.48	-0.31
OCT	55.64	0.28	6.77	6.70	-0.15
NOV	55.80	0.50	7.89	7.42	-0.05
DEC	56.00	0.64	9.50	8.40	-0.01

Table 81 – Laikol lake

Month, year	Water level	Zhaibike river water discharge from Kayazdy-Zhyngyldy (m^3/sec)	Tursun river water discharge from Kuly (m^3/sec)	Karaboget river water discharge to Kamystybas (m^3/sec)	Water body volume (mln.m^3)	Water surface area (km^2)	Balance of evaporation and precipitation (m^3/sec)
2005							
JAN	56.60	6.65	0.65	13.29	28.67	11.00	0.00
FEB	56.72	6.41	0.59	11.23	29.99	11.34	0.00
MAR	56.82	6.00	0.60	10.37	31.14	11.62	-0.29
APR	56.81	5.78	0.63	8.27	31.03	11.60	-0.89
MAY	56.44	6.96	0.39	1.00	26.97	10.56	-1.24
JUN	56.05	7.85	0.31	-2.12	23.08	9.52	-1.19
JUL	55.89	7.89	0.39	-1.43	21.58	9.10	-0.82
AUG	55.85	8.21	0.35	-0.15	21.17	8.99	-0.47
SEP	56.11	7.07	0.66	6.96	23.63	9.67	-0.48
OCT	56.24	7.12	0.60	9.26	24.95	10.03	-0.22
NOV	56.44	6.83	0.60	11.01	26.94	10.55	-0.08
DEC	56.67	6.25	0.67	12.76	29.50	11.21	-0.02
2006							
JAN	56.85	5.89	0.67	12.10	31.49	11.71	0.00
FEB	56.97	5.60	0.63	10.86	32.97	12.07	0.00
MAR	57.01	5.47	0.57	8.86	33.47	12.20	-0.30
APR	56.98	5.31	0.58	6.91	33.13	12.11	-0.90
MAY	56.37	7.74	0.11	-2.92	26.20	10.36	-1.03
JUN	56.16	7.48	0.21	-3.54	24.11	9.80	-1.05
JUL	55.99	7.61	0.30	-2.16	22.47	9.35	-0.75
AUG	55.90	8.08	0.26	-0.84	21.67	9.13	-0.45
SEP	55.86	8.52	0.22	-0.03	21.27	9.01	-0.38
OCT	55.93	8.48	0.28	1.85	21.90	9.19	-0.20
NOV	56.22	7.56	0.50	8.11	24.68	9.96	-0.08
DEC	56.49	6.81	0.64	12.13	27.52	10.71	-0.02

Table 82 – Kamystybas lake

Month, year	Water level	Karaboget river water discharge from Laikol (m^3/sec)	Water body volume ($mln.m^3$)	Water surface area (km^2)	Balance of evaporation and precipitation (m^3/sec)
2005					
JAN	56.20	13.29	725.22	160.28	0.01
FEB	56.36	11.23	751.41	164.12	0.00
MAR	56.48	10.37	770.62	166.90	-0.73
APR	56.52	8.27	777.62	167.91	-1.75
MAY	56.39	1.00	756.41	164.84	-2.99
JUN	56.17	-2.12	720.27	159.55	-4.10
JUL	55.95	-1.43	685.56	154.38	-3.53
AUG	55.82	-0.15	665.04	151.28	-2.06
SEP	55.82	6.96	665.95	151.42	-1.71
OCT	55.92	9.26	681.25	153.73	-0.73
NOV	56.08	11.01	705.84	157.41	-0.26
DEC	56.28	12.76	738.13	162.18	-0.06
2006					
JAN	56.47	12.10	769.65	166.76	0.01
FEB	56.63	10.86	794.99	170.40	0.00
MAR	56.71	8.86	810.03	172.54	-0.74
APR	56.73	6.91	813.27	173.00	-1.76
MAY	56.55	-2.92	781.59	168.48	-3.00
JUN	56.31	-3.54	742.06	162.75	-4.09
JUL	56.08	-2.16	705.44	157.35	-3.53
AUG	55.93	-0.84	683.00	154.00	-2.06
SEP	55.83	-0.03	666.45	151.50	-1.71
OCT	55.80	1.85	662.61	150.92	-0.73
NOV	55.91	8.11	679.98	153.54	-0.26
DEC	56.11	12.13	710.67	158.13	-0.06

Total water intake of the Kamystybas lakes system under increasing of the minimal level at the section Sovetzharma channel up to 59.1 m:

- 2005

Water intake: 322,5 $mln.m^3$;
Water discharge to the river: 0.0 $mln.m^3$;
Water losses for evaporation and evapotranspiration: 288,1 $mln.m^3$.

- 2006

Water intake: 313,1 $mln.m^3$;
Water discharge to the river: 0.0 $mln.m^3$;
Water losses for evaporation and evapotranspiration: 286,6 $mln.m^3$.

Impact of the level increasing of the Syrdarya river up to level 59.10 m at the section Sovetzharma channel to the water balance of the Kamystybas lakes system.

Table 83 – Raimkol lake

Month, year	Syrdarya river water level at the section “Sovetzharma channel”	Raimkol water level	Sovetzharma channel water discharge from Syrdarya river (m^3/sec)	Raim river water discharge to Zhalanashkol (m^3/sec)	Water body volume (mln.m^3)	Water surface area (km^2)	Balance of evaporation and precipitation (m^3/sec)
2005							
JAN	59.10	58.87	10.25	9.84	64.15	34.20	0.01
FEB	59.10	58.89	9.70	9.39	64.88	34.46	0.00
MAR	59.10	58.88	9.64	9.07	64.49	34.32	-0.72
APR	59.10	58.83	10.23	9.07	63.05	33.81	-1.73
MAY	59.10	58.76	11.42	9.44	60.53	32.90	-2.95
JUN	59.10	58.67	12.90	10.05	57.49	31.79	-4.07
JUL	59.10	58.64	13.78	10.58	56.63	31.47	-3.54
AUG	59.10	58.69	13.49	10.75	58.37	32.11	-2.07
SEP	59.10	58.73	12.80	10.61	59.52	32.53	-1.73
OCT	59.10	58.79	11.91	10.36	61.66	33.31	-0.73
NOV	59.10	58.84	10.86	9.92	63.36	33.92	-0.26
DEC	59.10	58.88	9.99	9.44	64.64	34.37	-0.06
2006							
JAN	59.10	58.91	9.31	8.97	65.56	34.70	0.01
FEB	59.10	58.93	8.81	8.56	66.15	34.90	0.00
MAR	59.10	58.91	8.84	8.29	65.67	34.74	-0.73
APR	59.10	58.87	9.50	8.35	64.20	34.22	-1.74
MAY	59.10	58.79	10.75	8.75	61.69	33.32	-2.97
JUN	59.10	58.70	12.29	9.40	58.67	32.22	-4.10
JUL	59.10	58.67	13.21	9.98	57.78	31.89	-3.57
AUG	59.10	58.73	12.93	10.19	59.45	32.51	-2.09
SEP	59.10	58.76	12.26	10.08	60.52	32.90	-1.75
OCT	59.10	58.82	11.38	9.86	62.57	33.63	-0.73
NOV	59.10	58.87	10.35	9.44	64.19	34.21	-0.26
DEC	59.10	58.90	9.50	8.98	65.37	34.63	-0.06

Table 84 – Zhalanashkol lake

Month, year	Water level	Raim river water discharge from Raimkol (m^3/sec)	Kutumsyk river water discharge to Kayazdy-Zhyngyldy (m^3/sec)	Water body volume (mln.m^3)	Water surface area (km^2)	Balance of evaporation and precipitation (m^3/sec)
2005						
JAN	57.98	9.84	8.75	60.15	37.35	0.01
FEB	58.04	9.39	8.44	62.35	38.25	0.00
MAR	58.05	9.07	8.13	62.59	38.35	-0.72
APR	57.99	9.07	7.83	60.29	37.40	-1.73
MAY	57.86	9.44	7.56	55.79	35.52	-2.95
JUN	57.71	10.05	7.43	50.49	33.23	-4.07
JUL	57.65	10.58	7.49	48.54	32.37	-3.54
AUG	57.71	10.75	7.79	50.52	33.25	-2.07

SEP	57.76	10.61	8.10	52.20	33.98	-1.73
OCT	57.86	10.36	8.27	55.63	35.45	-0.73
NOV	57.95	9.92	8.31	58.98	36.86	-0.26
DEC	58.03	9.44	8.18	62.05	38.13	-0.06
2006						
JAN	58.10	8.97	7.96	64.70	39.21	0.01
FEB	58.15	8.56	7.70	66.71	40.01	0.00
MAR	58.15	8.29	7.43	66.67	40.00	-0.73
APR	58.08	8.35	7.18	64.08	38.96	-1.74
MAY	57.96	8.75	6.95	59.26	36.98	-2.97
JUN	57.80	9.40	6.85	53.64	34.60	-4.10
JUL	57.74	9.98	6.93	51.42	33.64	-3.57
AUG	57.79	10.19	7.24	53.26	34.44	-2.09
SEP	57.83	10.08	7.57	54.84	35.12	-1.75
OCT	57.93	9.86	7.77	58.19	36.53	-0.73
NOV	58.02	9.44	7.84	61.48	37.90	-0.26
DEC	58.09	8.98	7.75	64.49	39.12	-0.06

Table 85 – Kayazdy-Zhyngyldy lake

Month, year	Water level	Kutumsyk river water discharge from Zhalanashkol (m^3/sec)	Zhaibike river water discharge to Laikol (m^3/sec)	Water body volume (mln.m^3)	Water surface area (km^2)	Balance of evaporation and precipitation (m^3/sec)
2005						
JAN	56.88	8.75	8.56	4.71	4.87	0.00
FEB	56.97	8.44	8.26	5.15	5.17	0.00
MAR	57.00	8.13	7.94	5.35	5.31	-0.12
APR	56.97	7.83	7.58	5.19	5.20	-0.31
MAY	56.87	7.56	7.23	4.68	4.85	-0.53
JUN	56.72	7.43	7.02	3.99	4.37	-0.69
JUL	56.64	7.49	7.08	3.65	4.11	-0.54
AUG	56.67	7.79	7.46	3.75	4.19	-0.29
SEP	56.69	8.10	7.81	3.86	4.27	-0.24
OCT	56.78	8.27	8.02	4.25	4.55	-0.10
NOV	56.88	8.31	8.09	4.71	4.87	-0.04
DEC	56.98	8.18	7.98	5.22	5.22	-0.01
2006						
JAN	57.07	7.96	7.76	5.73	5.55	0.00
FEB	57.15	7.70	7.51	6.16	5.83	0.00
MAR	57.18	7.43	7.24	6.32	5.93	-0.13
APR	57.14	7.18	6.94	6.09	5.79	-0.33
MAY	57.03	6.95	6.63	5.49	5.40	-0.55
JUN	56.88	6.85	6.45	4.70	4.87	-0.72
JUL	56.79	6.93	6.52	4.28	4.57	-0.56
AUG	56.80	7.24	6.90	4.35	4.62	-0.31
SEP	56.82	7.57	7.28	4.44	4.68	-0.25
OCT	56.90	7.77	7.52	4.81	4.95	-0.11
NOV	56.99	7.84	7.62	5.28	5.26	-0.04
DEC	57.09	7.75	7.54	5.79	5.59	-0.01

Table 86 – Kuly lake

Month, year	Water level	Tursun river water discharge from Laikol lake (m^3/sec)	Water body volume (mln.m^3)	Water surface area (km^2)	Balance of evaporation and precipitation (m^3/sec)
2005					
JAN	55.77	0.34	7.64	7.27	0.00
FEB	55.87	0.34	8.44	7.77	0.00
MAR	55.91	0.36	8.78	7.97	-0.23
APR	55.82	0.47	8.02	7.50	-0.77
MAY	55.62	0.70	6.63	6.61	-1.24
JUN	55.40	0.93	5.30	5.70	-1.46
JUL	55.36	0.93	5.07	5.53	-1.02
AUG	55.45	0.73	5.60	5.91	-0.52
SEP	55.51	0.57	5.96	6.15	-0.43
OCT	55.65	0.47	6.81	6.73	-0.14
NOV	55.77	0.40	7.67	7.28	-0.05
DEC	55.89	0.37	8.59	7.85	-0.01
2006					
JAN	56.01	0.36	9.52	8.41	0.00
FEB	56.10	0.35	10.35	8.89	0.00
MAR	56.13	0.36	10.64	9.06	-0.25
APR	56.04	0.45	9.78	8.57	-0.80
MAY	55.84	0.66	8.17	7.60	-1.28
JUN	55.61	0.88	6.60	6.59	-1.51
JUL	55.55	0.90	6.20	6.32	-1.05
AUG	55.63	0.73	6.68	6.64	-0.54
SEP	55.67	0.58	7.00	6.86	-0.45
OCT	55.79	0.48	7.84	7.39	-0.16
NOV	55.91	0.41	8.71	7.93	-0.06
DEC	56.02	0.38	9.65	8.49	-0.02

Table 87– Laikol lake

Month, year	Water level	Zhaibike river water discharge from Kayazdy-Zhyngyldy (m^3/sec)	Tursun river water discharge from Kuly (m^3/sec)	Karaboget river water discharge to Kamystybas (m^3/sec)	Water body volume (mln.m^3)	Water surface area (km^2)	Balance of evaporation and precipitation (m^3/sec)
2005							
JAN	56.11	8.56	0.34	7.75	23.63	9.67	0.00
FEB	56.22	8.26	0.34	7.46	24.67	9.95	0.00
MAR	56.28	7.94	0.36	7.07	25.29	10.12	-0.27
APR	56.27	7.58	0.47	6.29	25.23	10.10	-0.85
MAY	56.19	7.23	0.70	5.38	24.42	9.88	-1.47
JUN	56.05	7.02	0.93	4.64	23.06	9.51	-1.99
JUL	55.95	7.08	0.93	5.04	22.12	9.25	-1.48
AUG	55.95	7.46	0.73	6.01	22.08	9.24	-0.74
SEP	55.96	7.81	0.57	6.62	22.17	9.27	-0.58

OCT	56.03	8.02	0.47	7.07	22.88	9.47	-0.21
NOV	56.13	8.09	0.40	7.23	23.85	9.73	-0.07
DEC	56.24	7.98	0.37	7.16	24.96	10.03	-0.02
2006							
JAN	56.36	7.76	0.36	6.97	26.09	10.33	0.00
FEB	56.45	7.51	0.35	6.74	27.06	10.59	0.00
MAR	56.50	7.24	0.36	6.41	27.56	10.72	-0.28
APR	56.48	6.94	0.45	5.70	27.39	10.67	-0.86
MAY	56.39	6.63	0.66	4.85	26.44	10.42	-1.49
JUN	56.24	6.45	0.88	4.17	24.94	10.02	-2.00
JUL	56.13	6.52	0.90	4.55	23.87	9.73	-1.49
AUG	56.12	6.90	0.73	5.49	23.71	9.69	-0.75
SEP	56.12	7.28	0.58	6.11	23.71	9.69	-0.59
OCT	56.18	7.52	0.48	6.58	24.35	9.87	-0.22
NOV	56.28	7.62	0.41	6.77	25.26	10.11	-0.08
DEC	56.38	7.54	0.38	6.73	26.33	10.39	-0.02

Table 88 – Kamystybas lake

Month, year	Water level	Karaboget river water discharge from Laikol lake (m^3/sec)	Water body volume (mln.m^3)	Water surface area (km^2)	Balance of evaporation and precipitation (m^3/sec)
2005					
JAN	55.83	7.75	667.06	151.59	0.01
FEB	55.94	7.46	684.47	154.22	0.00
MAR	56.02	7.07	695.58	155.88	-0.72
APR	56.03	6.29	698.31	156.29	-1.73
MAY	55.98	5.38	689.39	154.96	-2.95
JUN	55.85	4.64	670.34	152.09	-4.07
JUL	55.73	5.04	652.02	149.30	-3.54
AUG	55.70	6.01	647.18	148.56	-2.07
SEP	55.70	6.62	646.96	148.53	-1.73
OCT	55.76	7.07	656.77	150.03	-0.73
NOV	55.86	7.23	671.96	152.33	-0.26
DEC	55.98	7.16	689.78	155.01	-0.06
2006					
JAN	56.09	6.97	708.01	157.73	0.01
FEB	56.19	6.74	723.74	160.06	0.00
MAR	56.25	6.41	732.89	161.41	-0.73
APR	56.26	5.70	733.79	161.54	-1.74
MAY	56.19	4.85	723.00	159.95	-2.97
JUN	56.06	4.17	702.18	156.87	-4.10
JUL	55.93	4.55	681.92	153.83	-3.57
AUG	55.88	5.49	675.27	152.83	-2.09
SEP	55.87	6.11	673.40	152.55	-1.75
OCT	55.93	6.58	681.72	153.80	-0.73
NOV	56.02	6.77	695.68	155.90	-0.26
DEC	56.12	6.73	712.37	158.38	-0.06

Total water intake of the Kamystybas lakes system under increasing of the minimal level at the section Zhasulan channel up to 57.6 m:

- 2005

Water intake: 348.5 mln.m^3;
Water discharge to the river: 0.0 mln.m^3;
Water losses for evaporation and evapotranspiration: 293.8 mln.m^3.

- 2006

Water intake: 328.5 mln.m^3;
Water discharge to the river: 0.0 mln.m^3;
Water losses for evaporation and evapotranspiration: 299.8 mln.m^3.

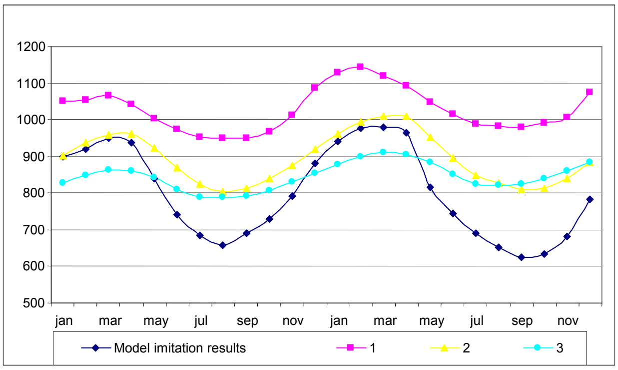


Figure 107 – Total water volume in the Kamystybas lakes system

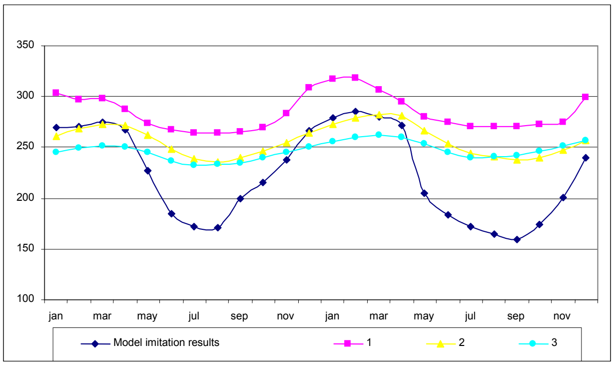


Figure 108 – Total area of the water bodies in the Kamystybas lakes system

Comparison of the curves in the Figures 107 and 108 shows that the most stable condition of the water bodies is under the variant with construction of the Amanotkel dam with level 57.6 m. At that the rate of water use in the basin is 0.67 – 0.81, that 25 - 35% higher than present one. Enough and largest stability of area supported by designed scheme can be received under backup of the system by Amanotkel hydraulic facility at the level 57.6. Complex of models has good reaction to the parameters change and that why can be used in calculations of different variants in future.

Nevertheless, on the whole, the received decision isn't optimal one because the system has enough big water discharge to the river. On purpose of supporting of standard mineralization level this regime is rather surplus. During getting all data on channels parameters, bathymetry elaboration for all overflows we can find more rational decision under which the discharge will not exceed 10 - 15 %.

Table 89 – Comparison table of the main parameters of the Kamystybas lakes system

Parameters	Model imitation results	Variants of recommended level supporting		
		1	**2**	**3**
2005				
Water intake, mln.m^3	444.4	470.9	322.5	348.5
Water discharge to the Syrdarya river, mln.m^3	191.8	73.1	0.0	0.0
Water losses for evaporation and evapotranspiration, mln.m^3	212.9	317.7	288.0	293.8

Water use coefficient	0.48	0.67	0.89	0.84
Average area of the lakes system, km^2	229.7	282.0	255.1	242.8
Average volume of he lakes system, $mln.m^3$	810.0	1009.5	886.0	826.0
2006				
Water intake, $mln.m^3$	333.7	395.8	313.1	328.6
Water discharge to the Syrdarya river, $mln.m^3$	233.1	87.4	0.0	0.0
Water losses for evaporation and evapotranspiration, $mln.m^3$	199.4	322.6	286.6	299.8
Water use coefficient	0.60	0.81	0.92	0.91
Average area of the lakes system, km^2	217.9	287.4	258.3	251.1
Average volume of he lakes system, $mln.m^3$	790.4	1047.7	903.3	865.5

Variants of recommended levels supporting:

1. Impact of the Syrdarya river level rises up to minimal level 57.60 m in the Amanotkel cross-section to the water balance of the Kamystybas lakes system.
2. Impact of minimal river level rises up to 59.1 m (variant №1). Lakes system feeds from Sovetzharma and Zhasulan channels.
3. Impact of minimal river level rises up to 59.1 m (variant №2). Lakes system feeds only from Sovetzharma channel.

6.6.5 Summary and proposals

Create of working model under lack of information is very complicated. Especially it touches to spatial tasks related with a dynamic of its movement. Nevertheless, the set task to get a complex of models which dynamic reflects all nascent interactions in the system have been created.

Transfer to piece-old-nature models system with one-day step and decision of several general tasks permitted with determinate level of approximation to get calculated results which had been showing a good nature reduction based on water level and mineralization and on fragmentary information submitted by the Hydrology research group. As a result, a preliminary lakes system movement for the different variants of main feed had been get.

Sufficiently sound opinion of the engineers, as showed the model, that the best variant for future is preliminary rehabilitation of the Amanotkel dam with level 57.6. By optimization we can receive the most rational technical decision in the presence of all necessary parameters under this variant in future.

The following consecutions of DSS-1 and DSS-2 establishment have been proposed:

DSS-1

✓ Assess long-term sequence of possible variants of water income to the delta in connection with possible flow changes in the river and its tributaries, and it is very important to determine and control of necessary parameters for winter water flow control;

✓ Determine appropriate dynamic of the Syrdarya river levels for all points of possible water intake;

- ✓ Include to the model precise parameters of all existing channels and hydraulic facilities, bathymetrical curves of the water bodies, and possible engineering parameters of the proposed (by Kazgiprovodhoz) variants of the hydraulic facilities for running of different sub-variants of the selected complexes;
- ✓ Carry out a first optimization by ratio changing of fitted levels of the hydraulic facilities on the river (Amanotkel and Raim) and water discharge through system (for Raim variant – through Sovetzharma and Taupzharma with cutting off Kuly and Zhasulan channels and without ones; for Amanotkel variant, and for other combinations of other channels), under maximum supporting of the fish production area and critical (one month) flooding of reed area, supplying and at the same time holding of water mineralization at the required limits;
- ✓ Carry out a second optimization after receiving of the data which can describe a relation between economic and operational parameters in accordance with function of maximum cumulative effect taking into account reduced expenses and dependences:

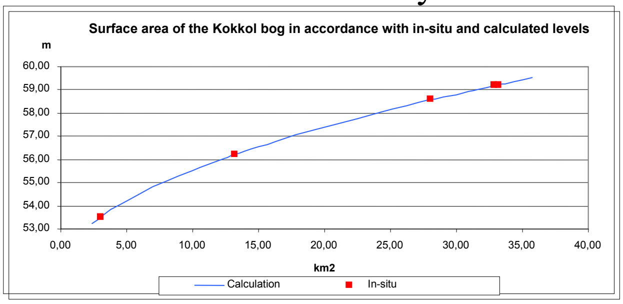
$E = f(w; w_n)$ – effectiveness as function of water delivery and water surface for the different variants;
$K = f(w)$ – quantitative function from water availability;
$E_{op} = f(w)$ – operating costs depending on value of delivery water.

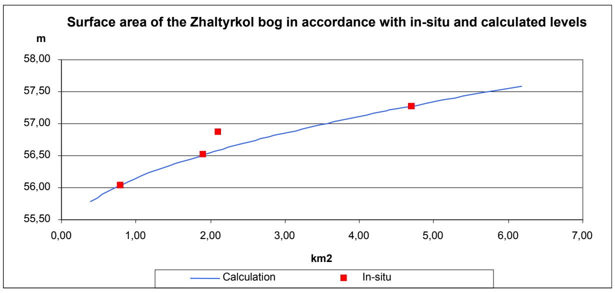
It is necessary to know the followings for the effectiveness function calculation:

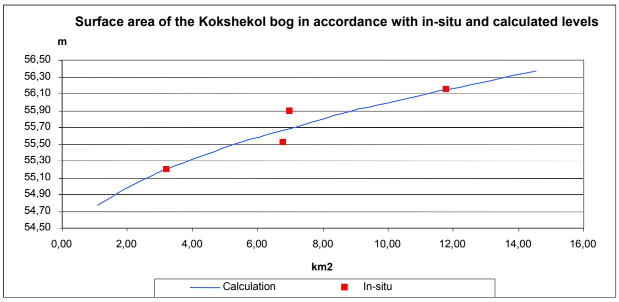
- value of fish and musk-rat production, using on depend of satisfaction degree of environmental needs;
- income from direct and additional products;
- facilities construction and reconstruction costs;
- expenses for power in depend of facilities type.

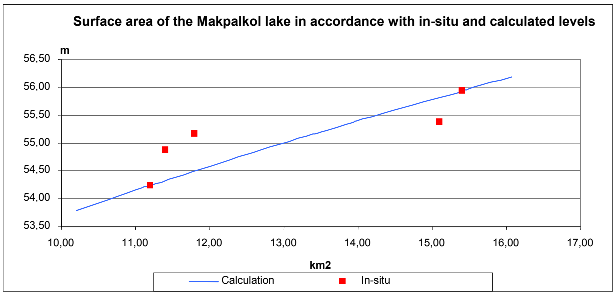
6.6.6 Comparative assessment of the calculated bathymetry with in-situ levels and areas measurements

First sub-system of the Kamystybas lakes system

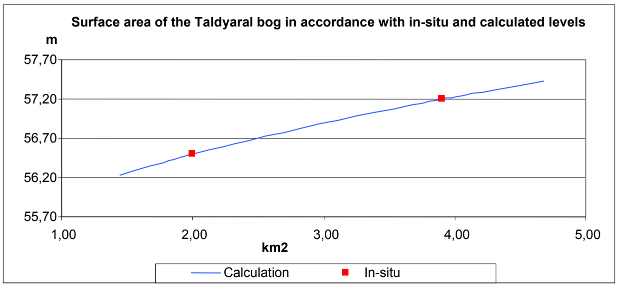


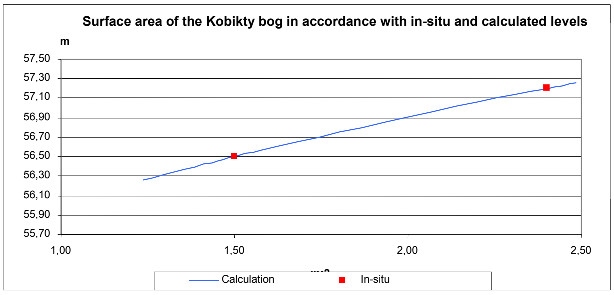




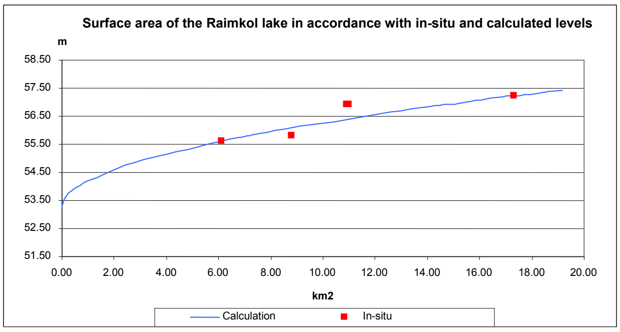


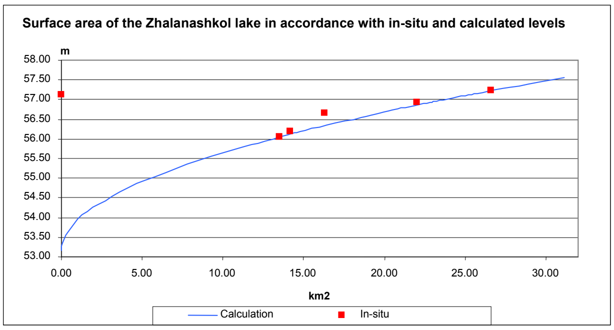
Second sub-system of the Kamystybas lakes system

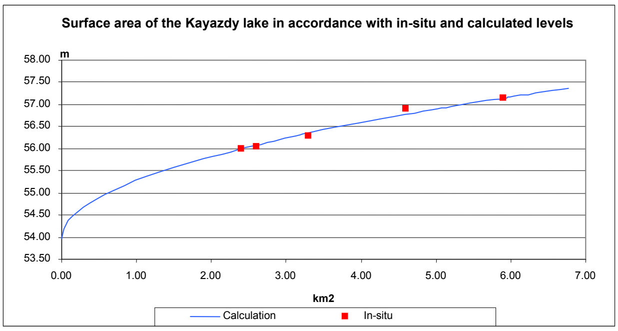


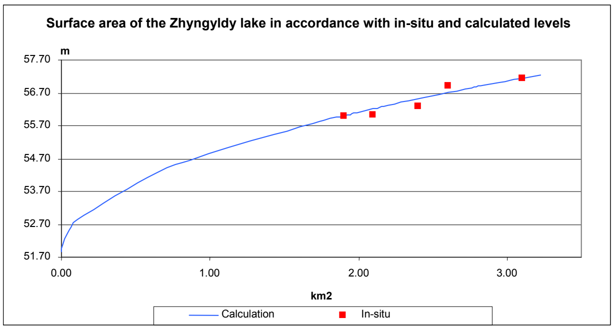


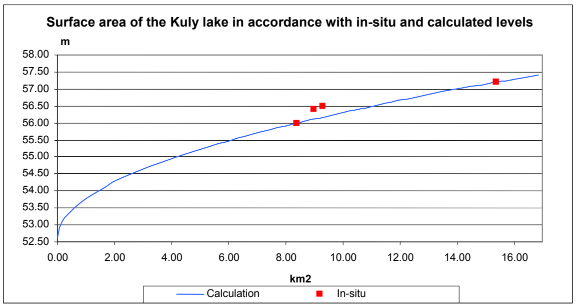
Third sub-system of the Kamystybas lakes system

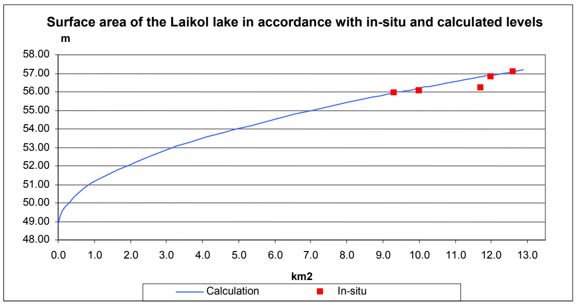


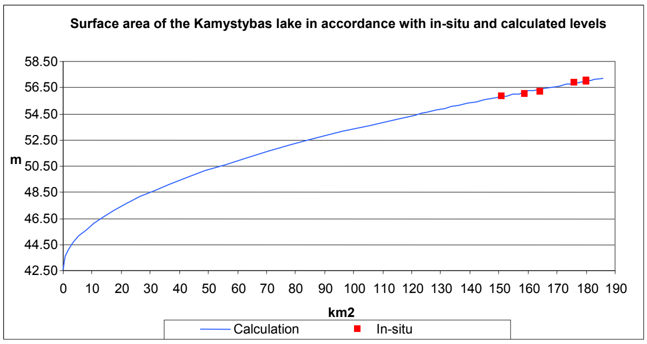



Surface area of the Kayazdy lake in accordance with in-situ and calculated levels
m
58.00
57.50
57.00
56.50
56.00
55.50
55.00
54.50
54.00
53.50
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00
km2
Calculation
In-situ


Surface area of the Zhyngyldy lake in accordance with in-situ and calculated levels
m
57.70
56.70
55.70
54.70
53.70
52.70
51.70
0.00 1.00 2.00 3.00
km2
Calculation
In-situ


Surface area of the Kuly lake in accordance with in-situ and calculated levels
m
58.00
57.50
57.00
56.50
56.00
55.50
55.00
54.50
54.00
53.50
53.00
52.50
0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00
km2
Calculation
In-situ


Surface area of the Laikol lake in accordance with in-situ and calculated levels
m
58.00
57.00
56.00
55.00
54.00
53.00
52.00
51.00
50.00
49.00
48.00
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0
km2
Calculation
In-situ


Surface area of the Kamystybas lake in accordance with in-situ and calculated levels
m
58.50
56.50
54.50
52.50
50.50
48.50
46.50
44.50
42.50
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190
km2
Calculation
In-situ

7. MAP MODELS AND GIS

Under the project it was created the digitization of the topographic map in scale 1: 200 000. Electronic version of the topographic map was created for the first time for this area in the adopted in Kazakhstan the Gauss-Kruger projection Krossovsky Spheroid.

Digital map data are presented as collection of the digital layers (20 layers) on hypsometry, hydrography, road network, settlements, infrastructures and etc., which organized on GIS technology. Digitization and accuracy control was carried out with using special software - Arc GIS 10.0.

Created electronic version of the topographic maps is corresponded to area conditions in 1962. Undoubtedly many mapping objects (roads, hydrographic network, water level of the sea, etc) greatly changed in comparison with present time. Electronic version of the topographic maps permits to amend the single layers in accordance with space pictures and results of the field study.

Based on project purposes, the additional data was transferred to this digital basis as a single layer on present hydrotechnical structures (channels, dams, etc) which was taken from updated the topographic base by Japanese experts in scale 1:100 000 (1995) and brought in correspondence with scale 1: 200 000.

Thereby, the electronic version permits to update the map, include new objects which have clear coordinate affixment on map, for example hydrostructures, dams, channels. It is important for modeling and exact map calculation by using software (area and length of the objects, etc).

The space pictures Landsat 7ETM+ and IRS are used for the analysis of the present conditions of the area, particularly the water bodies. These pictures show the different water years and season dynamic of the hydrology regime (2000 – spring, autumn; 2001 – spring, autumn; 2004 – spring, autumn; 2005 – spring). On purpose to meet with high-precision spatial data the space pictures were corrected with digital layers for the purpose to receive the high-precision spatial data with using Arc GIS 10.0 and ERDAS Imagine 8.6. Map layers organized in GIS technology. By combination of space pictures with electronic version of topographic base it permitted to:

- Receive the full insight of present conditions of the delta of the Syrdarya river;
- Estimate the high-precision water area for all lakes in dynamic, hayfields, tugai and etc by using the map-mask method;
- Analysis of the infrastructure objects, hayfields, and pastures in depend of surface water conditions by composition of the created thematic maps (soil, vegetation) on the base of the space.
- Identify the flooding and underflooding area in dynamic;
- Identify the most problem sites regarding water availability;
- Forecast the high water during the discharges, etc.

At the next stage the electronic version of the topographic map and it correction in accordance with space pictures will permit to:

- Design the water infrastructure with high-precision;
- Operative analyze of the spatial water distribution during the discharges and present conditions of the water infrastructures;
- Identify the present negative processes and occurrences;
- Monitor the conditions of the surface water and its interactions with soil-vegetation cover of the specific area;
- Monitor the Small Aral Sea filling-up dynamic and Big Aral Sea conditions;
- Planning and map updating regarding water-economy and other activities in the project area by using GIS technology;
- Make any map estimation (lakes and wetlands area, channels length, road and etc.);
- Assess the conditions and area of the forage fields (hayfields and pastures), and other lands;
- Forecast the different water consumption and other activities scenarios.

In addition to the topographic maps and space pictures it were developed the following thematic maps by using of GIS technology: soil, vegetation, hydrology, water management infrastructure map. All these maps were prepared in electronic version in scale 1:200 000.

Notional load of the map was developed based on field investigation. Each contour of the map has description of the phytocenosis and soil taking into accounts its diversity and spatial distribution of the main types on the project area. The points of field description were fixed through GPS. Vegetation description includes the floristic diversity and present status of the phytocenosis in depends on ecology conditions and, particularly, on water availability regime. Vegetation map shows the regularity of the spatial pattern of the present vegetation, and the legend shows the characteristics of the phytocenosis and its combination.

CONCLUSION

Since 1960, reduction of water entry to the Northern part of the Aral Sea Basin and fall of water level in the Aral Sea from +53 m up to +38 m have caused the desertification processes and degradation of the delta ecosystems of the Syrdarya river, and resulted in change of ecological, social and economical conditions in the lower reach.

Authors of the monograph have carried out for the first time complex study and investigations in the region on the following directions:

- hydrology regimes of the Syrdarya river, the Northern Aral Sea and lakes systems;
- biodiversity conditions and area desertification processes;
- water infrastructure;
- social status of the local people, economic status of Aralsk and Kazaly rayons of Kyzylorda Oblast;
- mathematical modeling of happened processes and identification optimal parameters of the suggested measures;
- GIS and map models forming.

Following the change of regime and flow quantity the water availability of the lakes systems in the delta and support of optimal water level in the Northern Aral Sea were highly difficult.

At that a negative role has played poor conditions and missing of the appropriate infrastructure for water flow control in the lower reach, which should support water-salt and level regimes of the lakes systems. Transformation of soil and vegetation cover happens exactly as a result of changes in a flow regime of the Syrdarya river and desertification of the Aral Sea.

Stated environmental requirement for flora and fauna, an arrangement of optimal hydrology regime for lakes systems and water-salt balance for rayons.

The Northern part of the Aral Sea and ecosystem of the Syrdarya river delta have been studied as independent and eligible beneficiary as water users which water requirements appropriately its area were identified taking into account common regional ecology, social and economic interests. Estimated capacity of flooding and water distribution channels and water control structures have been calculated with consideration of environmental requirements to botanic structure of the wetlands.

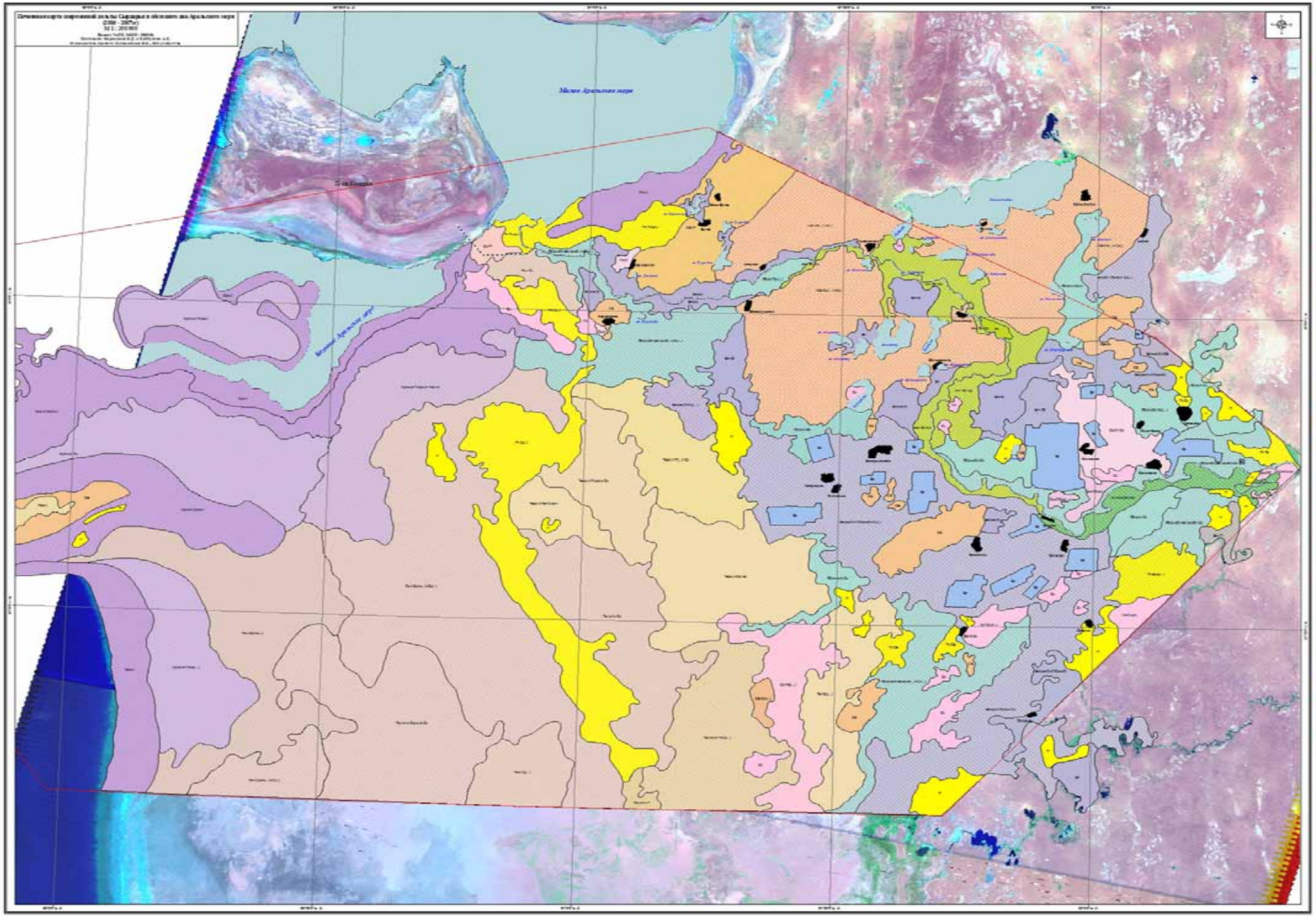
Based on research investigations and analysis of cumulative data, and early carried out studies, authors have proposed specific activities for delta arrangement by complex hydrotechnical structures that will guarantee stability water availability and save the most valuable lakes systems and lands, isolate waste strong salt water bodies and lands.

As a ecology stabilization of the region and save of the northern part of the Aral Sea it has been proposed a construction of Kokaral Dam with level +42 m for first stage, then the level will be led up to +45 m or + 46 m.

Based on GIS technology with resource to topographic maps and satellite photography at the first time it has been prepared thematic digital maps: soil, vegetation, hydrology, hydraulic infrastructure, which permit to track the ecology situation in the delta of the Syrdarya river and Northern part of the Aral Sea during the ensuing years.

It has been justified need for construction of Koksarai reregulating reservoir which improve conditions of water passing along the Syrdarya river in winter, decrease a risk of ice jam formation and thoroughly flooding of adjacent area of the river with settlements and hydraulic infrastructures.

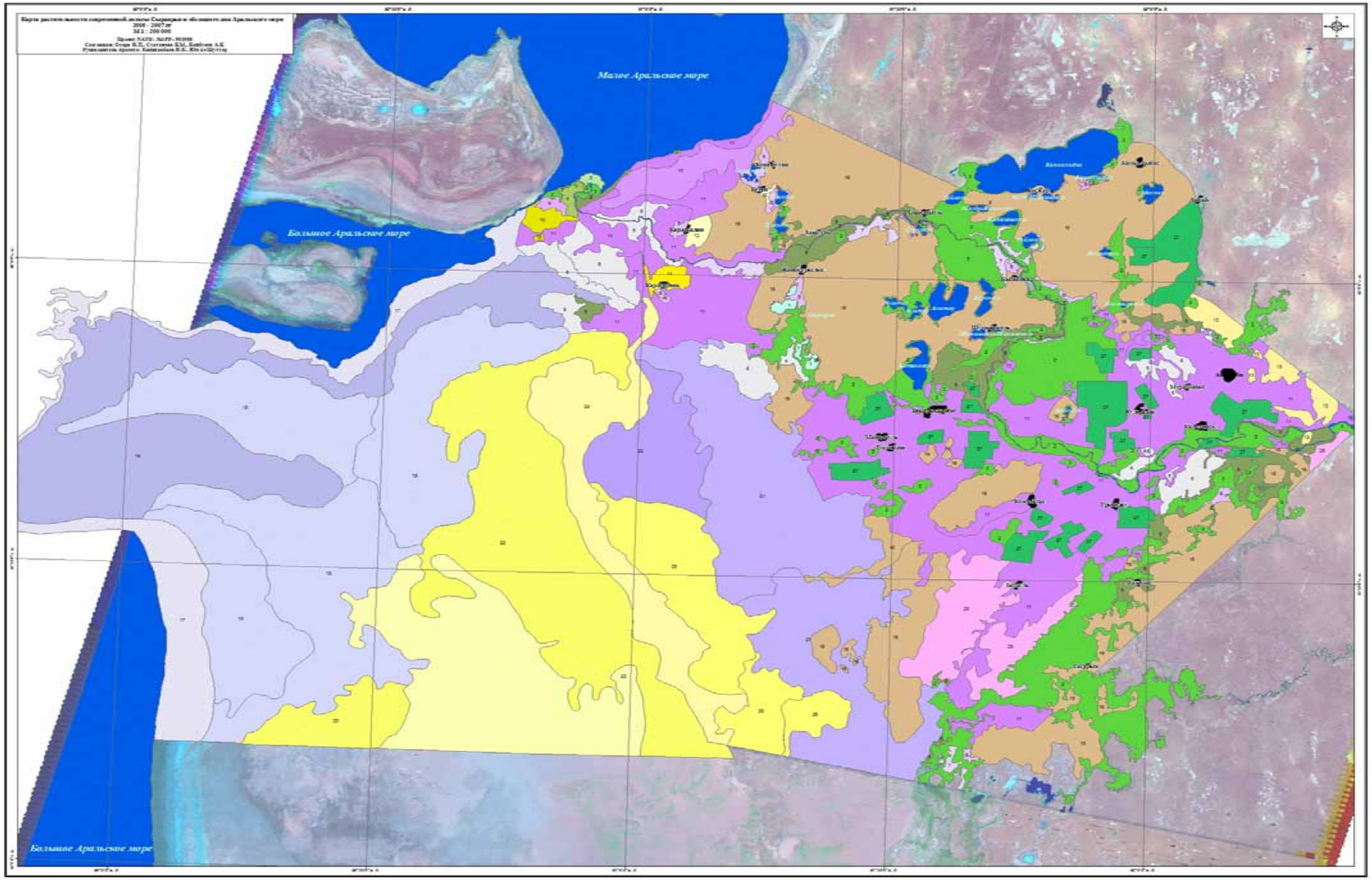
Calculated water consumption value and parameters of the wetlands in the delta of Syrdarya river are identical to the results of the DSS mathematical modeling.



Soil map of the present delta of the Syrdarya river and dried bed of the Aral Sea

Note – Legend to the Soil map of the present delta of the Syrdarya river and dried bed of the Aral Sea

	Grey-brown desert	Б	Marsh
Тв	Takyr-type	Бр	Rice - Marsh
Тв(ск)	Takyr-type shor	Пм	Seaside
Ал	Alluvial-meadow	Пм(ск)	Seaside shor
Ал(об)	Alluvial-meadow dried	Пм(п)	Seaside with blown sand cover
Ат	Alluvial-meadow tugai	Ск	Alkali
Лб	Marsh - meadow	Ск(л)	Alkali meadow
Лб(ск)	Marsh - meadow shor	Ск(с)	Alkali shor
Лб(об)	Marsh - meadow dried	Ск(от)	Alkali takyr
Лб(скоб)	Marsh - meadow shor dried	Ск(тв)	Alkali takyr-type
Лб(скоп)	Marsh - meadow shor desertificated	Ск(м)	Alkali march
Бл	Meadow - marsh	Ск(пм)	Alkali seaside
Бл(ск)	Meadow - marsh shor	Сн	Solonetz
Бл(об)	Meadow - marsh dried	П	Sand
Бл(скоб)	Meadow - marsh shor dried	Оз.	Lake
Бл(скоп)	Meadow - marsh shor desertificated		Settlement



Vegetation map of the present delta of the Syrdarya river and dried bed of the Aral Sea

Note – Legend to the Vegetation map of the present delta of the Syrdarya river and dried bed of the Aral Sea

I Gras bog (tangles of reed and hydrophytes on shallow water)

1 Shallow water bodies with water macrophytes

2 Tangles of long-rhizome grasses and grassy perennial plants here and there with sharing of water and air-to-water macrophytes

3 Solitary reed and tamarisk on sandbank and alluvial drifts without vegetation

II Tugai in combination with real and desertificated meadows

4 Oleaster-willow rarefied community with sharing of bushes and long-rhizome grasses with miscellaneous herbs by herb layer

5 Bushes community with annual-saltwort grasses by herb layer

III Meadow and bushes tangles (halophytic and desertificated)

6 Annual-saltwort grasses with halophytic grasses and club-rush comminities

7 Halophytic-bushe annual-saltwort grasses with halophytic miscellaneous herbs

8 Annual-saltwort-halophytic-bushe communities

9 Rarefied halophytic communities with domination of perennial grasses with annual saltwort

10 Complex of wormwood psammitic-phyto-bushe communities and shor alkali without vegetation in halophytic bushes frame

11 Complex of halopytic-bushe, annual-saltwort grasses, reed communities

IV Vegetation of grumous-hummock sands

12 Psammitic-phyto-bushe and ephemers, and tamarisk miscellaneous herbs

13 Ephemer-wormwood with psammitic-phyto bushes

14 Broken (barchan) sands with rarefied communities of shor types

15 Combination of anthropogenic-transformed without vegetation and psammitic-phyto-bushe, tamarisk with miscellaneous communities

V Zonal vegetation of residual hills

16 Semibushe wormwood with ephemers, ephemer types and sometimes bushes

VI Vegetation of the dried seabed

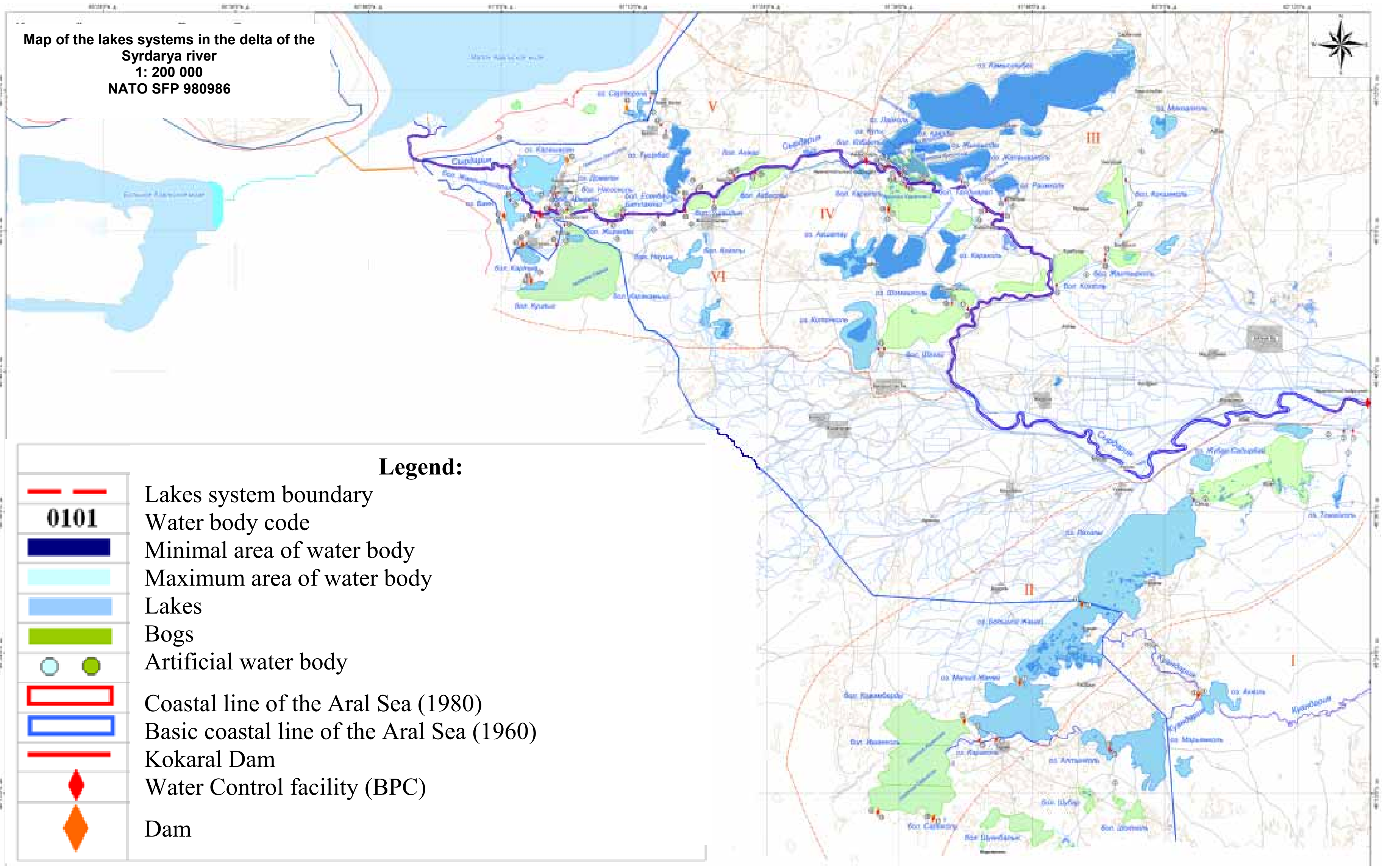
17 Solitary annual plants with area without vegetation on the alkali marches

18 Rarefied communities of annual plants on the alkali seaside

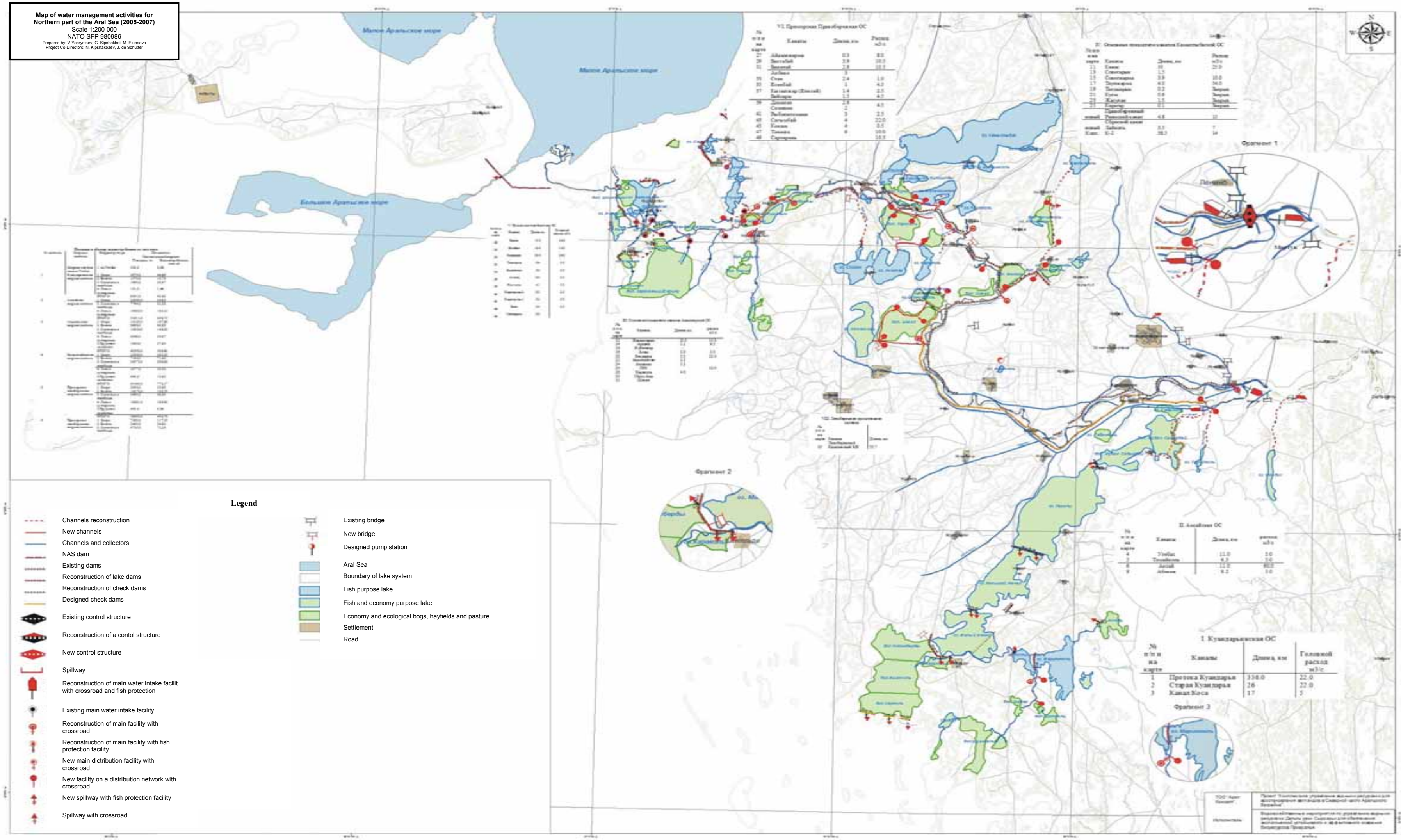
	19	Complex of halophytic-bushe, psammitic-phyto bushes and annual-saltwort communities on the alkali seaside and marches
	20	Complex of annual-saltwort, halophytic-bushe, biurgun communities and shor alkali without vegetation in sarsazan frame
	21	Combination of biurgun and halophytic-bushe communities and shor alkali without vegetation in sarsazan frame
	22	Combination of arrow painted grasses and tamarisk communities (class number 28)
	23	Communities with domination of arrow painted grasses
	24	Unfixed sands with solitary plants in combination with psammitic bushe communities
	25	Complex of psammitic-phyto-bushe, halopytic-bushe communities and unfixed sands
	26	Complex of rarefied halopytic-bushe, annual-saltwort communities and unfixed barchan sands

VII Vegetation of agricultural lands

	27	Agricultural fields, limans and fallow lands
	28	Rarefied vegetation on old-irrigation fields with repeated soil salinization



Map of the lakes systems in the delta of the Syrdarya river



Map of water management activities for Northern part of the Aral Sea