

Water-related Problems of Central Asia: Some Results of the (GIWA) International Water Assessment Program

This paper presents results of the research under the program Global International Waters Assessment (GIWA) for the Aral Sea basin (Subregion 24 of the GIWA program). These results show that the determining factor for the region is freshwater shortage and the main issue is modification of stream flow. According to GIWA assessment estimations, freshwater shortage is responsible for about 70% of the developmental problems in the region. The current economy is developing under conditions of increasing water deficiency. In spite of increasing efforts by the governments of the countries in the region, and by the international community, the situation in regard to water supply and economic objectives in the countries of central Asia remains tense and shows clear tendencies towards aggravation and conflict. The main causes for this sharpening of ecological and socioeconomic conditions in the region are analyzed, and measures to mitigate stress in transboundary water-resources use are presented.

INTRODUCTION

Rational use of water resources is one of the main components in present-day environmental management and sustainable development strategies at the national level. Problems of joint use of transboundary water resources more and more often lead to conflicts and are the subject of increasingly complicated interstate negotiations.

Under conditions of ever-increasing freshwater deficiency, a transition to basin principles for water resources management becomes more and more obvious, independent of whether the basin under consideration is situated on the territory of one or several states. In this respect, the countries of Central Asia are no exception. On the contrary, over the past decade the issue of water supply became increasingly aggravated. There are 2 main reasons for this increase in hostilities.

i) An orientation of the irrigated farming in the region toward production of water-consuming plants, i.e. cotton and rice. *ii)* The break-up of the Soviet Union, which was followed by the collapse of a once integrated and abstemious economic system, and to socioeconomic upheaval. An important role in the aggravation of the situation in the region was played by the rapid increase in population. The results of these changes were obvious both in a general economic decline and in a considerable reduction in agricultural production. Productivity of irrigated farming decreased from USD 1600 – 2000 to USD 500 – 900 ha⁻¹ and efficiency of usage of 1 m³ of irrigation water decreased from USD 0.18 – 0.25 to 0.03 – 0.10 (1).

The countries of the region which proclaimed their independence—Kazakhstan, Kyrgyzstan, Uzbekistan Tajikistan and Turkmenistan—were forced to solve the broad present-day state problems under conditions of the break-up of former economic relations, economic decline,

and transition to the new methods of economic management based on free-market practices.

The necessity to rely largely on their own resources predetermined the differences in strategies and rates of economic development of the countries in the region. Former priorities had to be reevaluated and the former rules for regional water resources management, based on priority for irrigated farming, lost their attractiveness and the states like Tajikistan and Kyrgyzstan, are now mainly interested in water resources use for electricity generation (1, 2). At the same time, there are reasons for the development of integration processes; the main reason being the problem of the rational use of water resources, which are transboundary in nature.

Even today the economies in the region are developing under conditions of increasing water deficiency (1, 3-6), The exploitation of groundwaters is easing the situation, but does not solve the problem of water resources as a whole. Even in Tajikistan, on territory where the overwhelming part of the Amudarya flow is formed and which seems to have excess water supplies, some regions still suffer from a water deficiency (7).

The problem of water in the region is a problem of paramount importance because all big rivers in 5 countries of the region; the Irtysh and Ishym in the east, the Chu, Talas, Syrdarya, and Amudarya in the south, the Ural in the west, and the Ishim and Tobol in the north are transboundary rivers. The largest, the Amudarya, and the Syrdarya flow across the borders of more than 3 countries. The most difficult situation is observed in Turkmenistan and Uzbekistan where 80 – 90% of the national economies depend on water resources coming from transboundary rivers that originate in neighboring states. Taking into account the prognosis for population growth, it is to be expected that the water supply problem will become even more complicated.

MATERIALS AND METHODS

Activities aimed at the identification of regional problems and their causes were carried out using GIWA methodology, and at different stages included the whole set of actions and estimations envisaged in the GIWA program.

Based on analyses of the available information we determined cause-and-effect relations for the main problems of the Aral Sea basin, and on this basis determined the key reasons for unfavorable changes in socioeconomic relations at national and international levels as well as unfavorable environmental effects.

The detailed assessment stage was preceded by the collection and generalization of information and materials from scientific publications, in regard to all the main aspects of regional problems. As a rule, within the framework of these activities,

additional research was carried out. This research led to more substantiated conclusions on the development of the situation in the region, which did not always coincide with the generally accepted point of view.

RESEARCH AND RESULTS

Natural Water Resources in the Aral Sea Basin

Table 1 shows the characteristics of surface river runoff resources in the Aral Sea basin. From the data in Table 1, it is obvious that the Amudarya basin has much greater runoff ($0.257 \text{ km}^3 \text{ km}^{-2} \text{ yr}^{-1}$ whereas in the Syrdarya basin it is $0.170 \text{ km}^3 \text{ km}^{-2} \text{ yr}^{-1}$). The fraction of the Amudarya runoff forming renewable water resources of the Aral Sea is 68%, whereas 62% of the annual Amudarya runoff forms in the Tajikistan territory. Table 1 does not take into account the Chu, and Talas runoff, which orographically belongs to the Aral Sea basin. Taking these waters into account, total water resources in the Aral Sea basin make up 121.6 km^3 (8, 9). When determining water balance within the Aral Sea basin it is expedient to take into account both results: 116.58 km^3 and 121.6 km^3 . About 43% of the Aral Sea basin resources are formed in Tajikistan territory and more than 24% in Kyrgyzstan territory. A considerable fraction of surface runoff resources (18.6%) is formed in Afghanistan and Iran.

Difficulties with water supply in the region are not only caused by the fact that the main rivers in the region are transboundary rivers, but also by the prevailing hydrological regimes, which are characterized by an extremely irregular territorial distribution of renewable water resources and a high degree of runoff variation from year to year. Most renewable surface water resources are formed in the mountains on the territory of Tajikistan and Kyrgyzstan and the main consumers of water resources are Uzbekistan, Turkmenistan, and Kazakhstan. The region is also characterized by strong variations in annual river runoff, the maximum volume of annual runoff is 1.5 – 2.5 times greater than the average annual runoff and minimum runoff volume for the period of measurements was 2.0 – 2.2 times less than the average annual runoff (3, 10, 11). Under the arid climate conditions and an increasing deficiency of water resources runoff variations are the main risk factors for agricultural irrigation.

Another important hydrological feature of the region is related to the dramatic reduction of glacier resources—by more than one third over the last 35 years. However, the runoff of the main rivers of the Aral Sea basin and Balkhash lake over the last 40 years has not changed (8, 12).

Groundwater resources

Total groundwater reserves in the region are estimated as $43.5 \text{ km}^3 \text{ yr}^{-1}$ (3). More than half of these reserves (58%) are located in the Amudarya basin. The total volume of approved groundwater resources in the Aral Sea basin is 17.0 km^3 , of which present-day net intake hardly exceeds $11.0 \text{ km}^3 \text{ yr}^{-1}$. In the Kazakhstan part of the Aral Sea basin the overwhelming amount of groundwater is used for drinking water (more than 68%), more than 40% of groundwater reserves are used for this purpose in Turkmenistan and Uzbekistan, whereas in Kyrgyzstan and Tajikistan the lion's share of accessible groundwater resources is used for farm irrigation; 59.4% and 69.5%, respectively.

Table 1. Mean annual river runoff in the Aral Sea basin, $\text{km}^3 \text{ yr}^{-1}$ (4).

Country	River basin		Aral Sea basin	
	Syrdarya	Amudarya	km^3	%
Kazakhstan	2.43	–	2.43	2.1
Kyrgyzstan	26.85	1.60	28.45	24.4
Tajikistan	1.00	49.58	50.58	43.4
Turkmenistan	–	1.55	1.55	1.3
Uzbekistan	6.17	5.06	11.22	9.6
Afghanistan and Iran	–	21.59	21.59	18.5
China	0.76	–	0.76	0.7
Total for the Aral Sea basin	37.20	79.38	116.58	100

Lakes and water-storage reservoirs

There are more than 5000 lakes in the Aral Sea basin, of which more than 4000 are situated in the Amudarya and Syrdarya basins. Most of the lakewater reserves are concentrated in the Amudarya basin (46 km^3); water reserves in the Syrdarya basin amount to 4 km^3 (9). Most of these lakes are small with a small amount of accumulated water, many of the plain's lakes dry out in extremely dry years.

The largest lake in the region is a high mountainous closed lake, Karakul, in the Eastern Pamirs, with a volume of more than 26 km^3 . Sarez lake, also situated in the Pamirs mountains, formed as the result of a tremendous landslide during the 1911 earthquake. The total lake volume is 17 km^3 . Sarez lake is the subject of constant attention not only by the government of Tajikistan but also by the world community. According to expert estimations, one cannot completely exclude the possibility of a breakthrough of the lake's dam. As a result, the area of more than 5000 km^2 and the population of more than 5 million people would be at risk (7). Within the plains of the Aral Sea basin the largest lakes are situated on the territory of Uzbekistan and, partially, Kazakhstan, in the lower and middle flow of the Amudarya and Syrdarya. These lakes were formed by drainage waters, most of which reaches them as drainage effluent from irrigated areas. The largest of such lakes are Aydar-Arnasay, whose mirror area is 30 km^2 , Sarykamysh (8 km^2), Sudochoye, and Parsankul (2 km^2 each). Aydar-Arnasay is situated in the Arnasay depression at the boundary between Kazakhstan and Uzbekistan; its total volume is about 30 km^3 . It was formed as a result of excess water discharge from Chardarya water reservoir (mainly due to winter water discharges from Tokhtogul water reservoir) and drainage waters from the irrigated fields of the Golodnaya steppe in Uzbekistan and Kazakhstan.

The total volume of water-storage reservoirs in the Aral Sea basin is over 74 km^3 . The largest water reservoirs of the region are Tokhtogul reservoir on the Naryn river in Kyrgyzstan, which has a total volume of 19.5 km^3 , and the Nurek water reservoir (total volume 10.5 km^3) on the Vakhsh river in Tajikistan. All large water-storage reservoirs are multipurpose water reservoirs, and are mainly used for power generation and irrigation. The 45 hydropower plants with a total capacity 34.5 GWh yr^{-1} were constructed on the major water-storage reservoirs. The largest being Nurek hydropower station on the Vakhsh river in Tajikistan (2700

MWh yr⁻¹) and Tokhtogul hydropower station (1200 MWh yr⁻¹) on the Naryn river in Kyrgyzstan (3).

In Uzbekistan, in addition to numerous ponds and small-capacity water-storage reservoirs used for irrigation, 50 rather large water-storage reservoirs with a total volume of 19 km³ have been constructed. The total volume of water-storage reservoirs constructed on the Syrdarya in Uzbekistan is 5 km³, and 29 water-storage reservoirs with a total capacity of 14 km³ have been built on the Amudarya. The largest water reservoirs are Charvak on the Charvak River near Tashkent, and Andizhan in Osh Valley on the Karadarya River.

Return waters

A considerable part of the available (accessible for use) water resources consists of return waters, i.e. drainage effluents from irrigated areas, industrial wastewaters, and municipal sewerage waters. Their average annual volume for the region is 32.4 km³. In the period from 1990 to 1999 this changed from 28.0 to 33.5 km³ (3). Some return waters are used repeatedly for irrigation purposes, some are discharged into rivers and natural sinks, e.g. Sarykamysh depression in the Amudarya lower reaches, Arnasay depression in the Syrdarya middle flow. More than 95% of the total volume of return waters is formed by drainage waters from irrigated fields, that is why return waters have high mineral content and are one of the main sources of pollution of surface and groundwaters in the region. About 60% of the total volume of return waters originates in Uzbekistan. On average about 11 km³ (36.8%) of return waters are discharged into natural landscape sinks and are practically eliminated from the national economy. The overwhelming part of these waters (85.8%) is formed by the drainage waters of the Amudarya basin.

The absence of explicit rules and regulations regarding use of return waters for irrigation farming has resulted in negative consequences, such as salinization of agricultural fields and reduced productivity, which have become very pronounced recently. A second problem directly connected with drainage and wastewater formation is the abrupt degradation of natural water quality, which refers both to surface and groundwaters. The total volume of heavily polluted drainage and wastewaters discharged to surface-water flows in the region amounts to about 15% of the annual volume of the natural river flow to the Aral Sea basin (3). Even now it is a serious hazard for water resources quality; mineralization has increased dramatically, and in some cases to a level which causes loss in ecological resources and in the economic use value of such water reservoirs. It is especially characteristic of these water reservoirs that collect drainage and wastewaters; there are hundreds of such water reservoirs in the lower reaches of the Amudarya and the Syrdarya.

Water Resources Usage

The system of water consumption in the zone of predominant usage of water resources is largely determined by the interests of irrigated farming, the GDP fraction of which is 50% (13). A sophisticated farm-to-farm and interfarm irrigation network with a total length of 316 000 km and a drainage system with a total length of more than 190 000 km (14) has been created in the region. A complex system for river flow regulation includes a large number of river and off-river water-storage reservoirs, controlled by 2 basin administrations; Syrdarya and Amudarya offices were organized before the

USSR collapse and were incorporated in the structure of Interstate Coordination Water Commission (ICWC) in 1992.

Estimations show that more than 90% of the total water resources are used for irrigation farming, the fraction of resources used being rather stable over time. During the period 1960 – 1999 the change in total volume of regional water resources used for farm irrigation was from 88.5% to 92.6% of (3).

The main water resources consumer is Uzbekistan: On average, during the years considered, Uzbekistan used about 54% of the total water resources, and in 1999 this use was about 60% of the total. Turkmenistan uses about 19% of the regional water resources. Irrigated areas in the Aral Sea basin grew rapidly from 4 510 000 ha in 1960 to 6 920 000 ha in 1980 and continued to increase, though at a slower pace, by the year 2000 (7 851 000 ha). Total water intake for irrigation had been rapidly increasing by the beginning of the 1980s, when it reached 120.7 km³ yr⁻¹ (4).

On the basis of official data (4), the water consumption situation in irrigated farming appears favorable; in spite of the increase in irrigated area the total water intake for agriculture decreased, from 106.4 km³ yr⁻¹ in 1990 to 94.7 km³ yr⁻¹ in 2000. This was achieved due to an anticipated decrease in water intake for irrigation. These positive trends in regional water economy were the result of a coordinated policy of water saving in the region and replacement of cotton for less water-consuming crops (mainly grain crops).

On the basis of the ratios of croppage and the corresponding irrigated areas, it can be concluded that from 1986 till 1999 crop capacity did not change; the observed changes in croppage are equal to the changes in irrigated areas. Thus, the technology for major crop growing remained unchanged, which is natural under conditions of abrupt economic decline in the post-Soviet period. With a high degree of certainty, water usage ha⁻¹ remained the same as that at the beginning of the 1980s. According to the estimates of one of the organizers of water-management systems in the region, R.A. Ginijatulin, water intake for irrigation increased from the 1980s till the end of the 20th century. Grain crops, from 300–400 m³ centner⁻¹ up to 400–700 m³ centner⁻¹; for rice, from 600–700 m³ centner⁻¹ to 1000–1700 m³ centner⁻¹; and for cotton, from 600–700 m³ centner⁻¹ to 900–1200 m³ centner⁻¹ (15, 16) (1 centner=100 kg).

Even if we accept that water intake ha⁻¹ of these crops remained at the same level as in the beginning of the 1980s, then taking into account the increase in the irrigated areas in the Aral Sea basin (not less than 700 000 ha by 2000), we can conclude that total water intake in irrigated farming had to increase compared to the corresponding water intake in 1986 by not less than 10 km³ and would be equal to 116 – 117 km³ by the 2000. This figure exceeds that for water intake obtained by generalization of the official data (3) by more than 20 km³, and approaches the volume of water consumption in all fields of economy at the beginning of the 1980s (more than 120 km³ yr⁻¹). Thus, total water intake will be more than 126 km³ yr⁻¹.

The increase in the irrigated areas in the low and middle Amudarya and Syrdarya flow did not provide an opportunity to halt the drop in water level in the Aral Sea or to preserve the Priaralje ecosystem. The ecological situation in the Priaralje territory was severely affected, especially in the Amudarya delta. Less than 10% of the total area of the delta lakes remains, and the once profitable fishing and musk-rat fishery has completely vanished (4).

Table 2. Present-day balance of surface (river) water resources in the Aral Sea basin.

No.	Components of surface water resource balance	Volume, km ³ yr ⁻¹
<i>Income</i>		
1.	Regional natural flow resources	116.6 – 121.6*
<i>Expenditures</i>		
2.	Total water intake, including Irrigation	119,0 – 120,0 109,0 – 110,0
3.	Unproductive flow losses, including water discharge into natural relief lowering, riverbed losses, losses on evaporation filtration from water-storage reservoirs	9.5 – 16.3
4.	Water supply to sustain ecosystems of Priaralje and the Aral Sea	5.5 – 13.5
5.	Total water intake	134.0 – 149.8
6.	Balance	-17.5 ÷ - 28.2

*This column presents two estimations of natural runoff regional resources by the data of ref. (4) and (9).

The situation is even more aggravated by deterioration of the water quality, due to effluent discharge from the irrigated fields to the riverbed. All these factors have led to rapid deterioration of the ecological conditions in Priaralje. In the Republic of Karakalpakstan, river water is unsuitable for drinking 10 months every year (mineralization increased to 2.5–2.8 g L⁻¹ solids). Water shortage and secondary soil salinity cause rapid decreases in the productive area of fields and, thus, the productivity of basic crops. As a result, the socioeconomic and ecological situations in Priaralje are threatened (3).

Evaluating the water balance for the Aral Sea, it is necessary to consider effective water-saving strategies that have been reached, due to the replacement of water-consuming crops. The total increase in the area under grain crops in the region was 875 000 ha during the period beginning early 1980 to the end of the 1990s. By the year 2000 total water consumption decreased by 8.5 km³ in the 4 countries studied.

In Turkmenistan, irrigated areas increased by 400 000 ha (16) during the period considered, and total additional water use for irrigation of these areas was not less than 2 km³.

According to our results, total water saving in the Aral Sea basin due to replacement of cotton and rice by grain and other crops could be 6.5 km³ by 2000. In this case, total water consumption for irrigation farming would be not less than 109–110 km³ and total water consumption in the Aral Sea region not less than 119–120 km³ (Table 2). This corresponds to a total water consumption in the region equal to that at the beginning of the 1980s (3).

On average, unproductive flow losses in the region, for the period 1990–1999, were estimated to be 9.5 to 16.3 km³ yr⁻¹ (3). Thus, total surface (river) water resources in the Aral Sea basin over a mean water year are 116.8–121.6 km³. Taking into account unproductive water losses the figures are only 100–107 km³, not taking into account the Chu and Talas runoff, and are 115–112 km³ if these waters are taken into account.

The Amudarya and the Syrdarya flows are characterized by high year-to-year variability, and depend on water content for any one year, the volume of natural river flow can differ from the average annual flow volumes. In high water years (5% flow probability) natural river flow resources can

exceed the average annual standard by almost 40% and reach 51.1 km³ yr⁻¹ in the Syrdarya basin and 109.6 km³ yr⁻¹ in the Amudarya basin. In low water years (95% of flow probability) water resources can be 13.6 km³ (about 37%) less than the standard in the Syrdarya basin and 20.7 km³ (26%) in the Amudarya basin (3).

Even if we accept that return waters volumes of 32–33 km³ are fully used to maintain a satisfactory economy and water supply as well as healthy ecosystems, for Priaralje and the Aral Sea, a surface runoff balance ranging from 5.0 to 14.6 km³ yr⁻¹ is necessary. Not taking into account the volume of return waters, water shortage in a mean water year will range from 17.4 to 28.2 km³ yr⁻¹ depending on the amount of nonproductive losses (Table 2). Thus, with a high degree of certainty, natural flow resources in the Aral Sea region are fully exhausted and the economy of the region is developing under conditions of ever-increasing water shortage. Even now overall usage of water resources in the Syrdarya basin amounts to 130–150% and in the Amudarya basin, 100–110% due to repeated usage of return waters (3).

Water shortage is especially noticeable in low-water years. As a result of unequal distribution of water shortage, the total damage caused by losses in irrigation farming can reach hundreds of millions USD. Thus, during the growing season of 2000, total damage to the Amudarya basin alone was about USD 260 million (17). The most aggravated situation with water-supply is observed in the lower reaches of the Syrdarya and Amudarya, with considerable losses to the economy of Uzbekistan and Kazakhstan.

Priority Concerns for Future Analysis

It is well known that the main reasons for the crisis in the region are unwise political decisions, mainly aimed at the development of water-dependent irrigation farming and the cultivation of water-consuming crops such as cotton and rice.

This situation was aggravated by an ineffective system of water-resource management at the All Union and Republican levels (18).

The result was an abrupt decrease in the natural runoff of the biggest rivers in the region; the Amudarya and Syrdarya,

which resulted in a rapid decrease in the waters of the Aral Sea. This process was accompanied by deterioration of landscapes, increasing desertification, secondary soil salinization, and frequent recurrence of atmospheric droughts and dust storms. The above processes led to severe degradation of both water and land ecosystems, and a reduction in biodiversity. These effects were most pronounced in the Priaraliye zone.

Taking the above into account at the Causal Chain Analysis stage, GIWA experts had no doubts as to the choice of priorities for analysis and estimation. The main priority for the GIWA Region-24 was “freshwater shortage”; a major issue being “modification of stream flow”. GIWA experts’ estimations indicated that the latter accounted for not less than 70% of the negative effects in the region over the last decades. The next important issue for the region is “pollution of existing supplies”, which is responsible for up to 30% of the degradation in the region.

Analysis of the available information, using GIWA methodology, shows that the direct reasons for freshwater shortage are increased water diversion (70%) and changes in return water (20%). The remaining 10% are ascribed to a “decrease in ice resources”. Thus, modification of stream flow became the main reason for rapid depletion of the Aral Sea and degradation of natural and agricultural systems and provoked aggravation of the socioeconomic situation, resulting in tense interstate relations. The latter due to joint usage of regional water resources.

Until 1991, the impact of the modification of stream flow on the environment was expressed in rapid depletion of the Aral Sea waters, progressive soil salinization, pollution of water sources, and degradation of water and land ecosystems, especially intensive in the territory of Priaralye. The most striking indicator of the influence of the modification of stream flow on the socioeconomic sphere is the deterioration of people’s health (most clearly pronounced in Priaralye), abrupt reduction in fishery and the fish-processing industry, pronounced reduction in the productivity of agricultural fields, and water usage in irrigation farming. According to GIWA experts’ 3 groups of factors are responsible for the development of the situation in the region:

- i) *Knowledge*: Faulty evaluation of projects and decisions made on economic and technical knowledge.
- ii) *Governance*: Unbalanced interests—biased towards agriculture/ infrastructure and environment not considered.
- iii) *Economic*: Lack of incentives to save water.

In the post-Soviet period negative processes and phenomena in nature and the socioeconomic spheres, caused by the impact of the modification of stream flow, continued and although from the mid-1990s onwards some improvement was observed in the health of the population in the area, the state of the environment and water-dependent sectors of the economy declined.

GIWA experts suggested the following reasons for the deterioration of the situation in the region:

- weak water management;
- inadequate integration of environmental concerns;
- lack of a clear water strategy;
- unclear legal framework;
- inadequate knowledge of current status of water resources;
- archaic irrigation practices linked to traditions and economic restraints;
- lack of incentives to save water;
- strong dependence on agriculture.

Identification of the Recommended Policy Option

The most glaring indicator of the modification of stream flow was abrupt drying up of the Aral Sea. The area of its mirror was reduced to less than half, as early as in 1986 the Sea itself divided into 2 independent water reservoirs—the Large and the Small Seas—and the water level in the Large Sea had decreased by 22 m by July 2002 (19). Modification of stream flow also led to an increasing water shortage, primarily in irrigation farming, and a deterioration of the water quality, of both surface- and groundwaters.

As early as the beginning of the 1980s total water consumption in the Aral Sea basin exceeded natural runoff resources. As shown in Table 2, not taking into account the volume of return waters, water shortage in a mean water year will range from 17.4 to 28.2 km³ yr⁻¹. Taking into account year-to-year runoff variability, one can anticipate that 50–60% of surface runoff is a threshold volume from the point of view of water sustainability in the region. Even now, all the countries in the region are in the critical zone for water usage with a high degree of dependence on climatic factors (20). Contemporary and projected population growth rates, indicate that the water supply situation will worsen over time.

Modification of stream flow also intensified desertification processes, resulting in a reduction of pasture productivity. Over the past 15 years, pasture productivity in Uzbekistan decreased by more than 20% and harvesting of dry mass for animals decreased from 2.4 to 1.8 centner ha⁻¹ (1 centner = 100 kg) (21).

A serious consequence of the increase in the area of salinized and oversalinized soils was the increase in the chemical and biological “aggressiveness” of air and water environments. As a result the financial costs of ecological deterioration exceeded annual estimated investments 2.8-fold (21). In these conditions it becomes more and more obvious that the problem of water resources management in the region is vitally important, the solution of which will affect not only sustainable ecologically-sound development of the region, but even the issues of ensuring national and regional security.

Significant Modification of Stream Flow Due to the Construction of Many Dams and an Irrigation Network

The main reason for the change in the natural runoff regime of the main rivers in the region was the rapid increase in the area irrigated and the corresponding increase in water resources usage for irrigation farming. During a relatively short time interval, from 1960 till 2000, irrigated areas almost doubled from 4 510 000 ha to 7 853 000 ha. As a result, already at the beginning of the 1980s, total water intake in the Aral Sea basin exceeded 120 km³ yr⁻¹ (3) and as our study showed has retained this level up to the present.

An important role was also played by the irrigation network, whose total length exceeds 500 000 km (14). It is not surprising that the natural runoff regime was preserved only within the runoff formation area, i.e. in the mountains. As one moves away from the mountains the runoff regime becomes more and more regulated and water delivery for economic and population reasons becomes more and more dependent on the advantages or disadvantages of water-management systems at all levels, from regional to local.

The creation of a great number of irrigation and power-generation water reservoirs in the region also contributed to

changes in runoff. Besides the numerous ponds and small capacity water reservoirs, more than 100 water reservoirs with total capacity of more than 74 km³ were created in the Aral Sea basin area. The very creation of such a large number of water reservoirs dramatically changed the natural river runoff regime. A forced switch in the operation of the main water reservoirs in Kyrgyzstan and Tajikistan from irrigation to power generation changed the regime of the Amudarya and Syrdarya rivers. As a result, winter floods became a frequent phenomena, and river runoff during the vegetation period was considerably reduced. This resulted in the reduction of the productivity of irrigated areas and increasing economic losses in irrigation farming in Uzbekistan and Kazakhstan, especially in low-water years. Certainly, the most aggravated water supply situation is observed in the lower reaches of the Syrdarya and Amudarya, yielding considerable losses to the economy of Uzbekistan and Kazakhstan.

Serious consequences of the change in the runoff regime of the main regional rivers were the unproductive water costs for filling natural reliefs, which in turn resulted in a reduction of pasture area. Thus, in the area of the Arnasay-Aidarkul water reservoir more than 2.5 million ha of pasture land were exempted from use (21).

The rapid increase in irrigated areas in the region hindered water-level stabilization in the Aral Sea and preservation of ecosystems in Priaralye. By year 2000, total annual runoff of the Amudarya near the estuary (Chatly-Samanbay measuring station) decreased almost 10-fold compared with that in 1970. As a result not more than 10% was left of the total area of delta lakes in the Amudarya lower reaches and the once profitable fishery and water-rat fishery industry disappeared.

The overwhelming majority of once numerous and biologically productive freshwater lakes in the delta of the Amudarya and Syrdarya have completely dried up or lost their economic value.

In 1960, fish catch in the Amudarya delta reached 225 200 centners, but in 2000 was only 11 000 centners. The water-rat population decreased from 1 130 000 to 1000 (22). From 1970 till 1999 the area of tugay forests in the Amudarya delta decreased 10-fold from 300 000 to 30 000 ha and attempts to restore natural forest failed (23). Desertification and degradation affected wildlife. In the Amudarya delta, besides the abrupt reduction in the water-rat population, 6 species and subspecies of fauna disappeared, more than 20 species became rare, and about 30 bird species disappeared. The situation was exacerbated by poor water quality, mainly caused by water leaching from irrigated areas. As a result, in early 1990 the socioeconomic and ecological situation in Priaralye had reached crisis level.

Significant Modification of Stream Flow Due to Change in Management of Water Resources

The former USSR system of centralized regional water resources management, including determination of water quotas for each of the countries in the region, has practically been retained, the only difference being that by the decision of the Heads of 5 countries (February, 1992) the functions of the USSR Ministry are entrusted to the Inter-State Coordination Water Commission (ICWC). However, everyday economic difficulties and the collapse of the power supply in Kyrgyzstan and Tajikistan has forced the governments of these countries to switch the use of the Tokhtogul and Nurek water-storage reservoir from irrigation to power generation.

This action dramatically changed the runoff regime of the Amudarya and Syrdarya rivers, resulting in huge economic losses in the agriculture of Uzbekistan and Kazakhstan, and became the subject of difficult interstate negotiations and agreements.

Alternative Policies

Retain present situation (no change)

If the present situation for water and land resources in the countries of the region continues, it will undoubtedly cause further degradation of the environment and aggravate the socioeconomic conditions. The effects will be most pronounced in the following ways:

Disappearance of the Aral Sea: Abrupt fall in the Aral Sea water level (22 m in the Big Sea by mid-2002) and the same pace of increase in water mineralization under invariable reduction in river water inflow leave no hope for the preservation of the Sea and its ecosystems. Under the conditions of increasing water shortage in the region, primarily caused by archaic water technology in irrigation farming, low efficiency of irrigation systems—which results in up to 50% water lost on the way to irrigated areas (16, 18)—and a rapid increase in the population, there is no hope for the Aral Sea. To achieve significant improvement in the Small Sea ecosystem, the project of Korakal separating dam construction at the confluence of the Small Sea to the Big Sea needs to succeed. During the period of dam existence, from August 1996 till April 1999, the water level in the Small Sea rose by 2.5 m, mean salinity decreased by 14.5%, and a vast freshwater zone was formed where freshwater creatures established (22). For some reasons, mainly economic, one can not rely upon the transfer of the part of Siberian river runoff, at least for the near future.

Significant Decrease in Biodiversity Especially in Delta Areas: Already at the beginning of the 1970s, because of the increase in water salinity, indigenous fish reproduction practically disappeared, which resulted in the loss of their fishery value. At present, with water salinity at 83–84‰ marine fauna are nearing extinction (24). The loss of marine populations and food in the delta waters make them poor in nutrition for fish and for some insectivorous birds in the water-swamp complex. The total number of birds of different species which relocated to the regions amounted to several hundred thousands.

If contemporary environment and socioeconomic tendencies continue we can also expect increases in desertification processes, further ecosystem degradation, and biodiversity loss, especially in the Priaralye zone.

Fast Reduction of Land and Water per capita: One of the most disturbing consequences of irrational usage of land and water resources was the degradation of arable lands. The main reasons for which are progressive soil salinity caused by irrational water usage and soil pollution from the excessive use of herbicides and fertilizers. Nowadays, of the 7.8 million irrigated ha in the Aral Sea basin more than 50% experience increased salinization. For the last 20 years, the area of salinized irrigated fields has grown to 56%, during the same period the humus concentration—the main source of soil fertility—decreased by no less than 40% (21). This has resulted in a considerable reduction of soil fertility and

increasingly less effective water usage for irrigation farming. Thus, in Uzbekistan moderately and strongly salinized soils are 60%, and in the central part of Fergana valley even 80% of the total irrigated area (18). More than 30% of the irrigated area in Tajikistan is salinized and up to 40% in Kyrgyzstan (25).

As a result of soil salinization and pollution since the beginning of the 1980s, productivity of the main agricultural products, grain crops, vegetable, cotton and berries has decreased. Even if soil salinization is relatively low, cotton productivity has been reduced by 50–60%; barley, by 30–40%; corn productivity, by 40–60%; and wheat, by 50–60% (26). The total reduction in crop yield from irrigated areas caused by soil salinization was 30% in Uzbekistan, 40% in Turkmenistan, 18% in Tajikistan, 30% in Kazakhstan, 20% in Kyrgyzstan (21).

An alarming socioeconomic factor in the region is the rapid reduction in irrigated areas and in the volume of consumed water per capita. According to the available data from 1960 till 2000 (3) water intake per capita in the Aral Sea basin decreased 1.7-fold from 4270 to 2530 m³ person⁻¹ yr⁻¹ and can decrease below health standards during the next 20 years, if the current rate of population growth continues.

The situation in regard to distribution of arable lands is no better: In spite of a considerable increase in the irrigated area, the rapid increase in population has resulted in a reduction in irrigated area by almost 2-fold: from 0.32 ha person⁻¹ to 0.18 ha person⁻¹ for the period from 1960 till 2000 (3). It has already reached a minimal critical level, below which it becomes impossible to grow the 120–130 kg of bread needed per individual per year (26). If the current rate of population growth continues, 4 of the 6 countries in the Aral Sea basin (besides Kazakhstan and Afghanistan), within the next 50 years, will reduce the irrigated area per capita to practically zero (20).

Growing pollution and human impact on the environment: According to GIWA experts environmental pollution, primarily pollution of water resources, is the next most important factor after modification of stream flow, leading to deterioration of conditions in the region. Pollution of surface and groundwaters is becoming more and more disturbing, and it is one of direct reasons for the poor health of the population. In fact, only the runoff formation zone, i.e. in mountain water, with rare exceptions, meets sanitary standards. As one moves away from the mountains, the quality of surface and groundwaters decreases and in the lower reaches of rivers and in the irrigation canals it is considered harmful to human health. Thus, mineralization of the Amudarya water increases from the 0.4–0.5 g L⁻¹ where the river leaves the mountains to 2.0 g L⁻¹ and more in the delta zone (27). The results of studies along the length of the Amudarya and Syrdarya, downstream from the mountains, show that copper, zinc, and hexavalent chromium concentrations exceed maximum permissible concentration (MPC). Along practically all the Amudarya flow, cases where phenols concentrations are above the MPC have been registered.

Results show that only 8% of water in the region, where observations of water quality were carried out, refer to the category of polluted and very polluted, but as much as 25% of the water is in the “red zone”, i.e. the boundary between

satisfactory and unsatisfactory water quality. About 44% of water supply in the region is in the category “moderately polluted” and only 23% is classified as clean and slightly polluted. The area with good water quality as a percentage of the whole territory of Uzbekistan is only 8.6%, 35.2% of the water is satisfactory quality, 44.0% unsatisfactory water quality, 5.25% water quality hazardous to health, and 7.2% very hazardous. Only 2.3% of the population live within areas with good water quality, more than 49% in areas with poor water quality, 2.3% in hazardous water quality areas, and 0.2% in extremely hazardous (27–29). More than 70% of the Amudarya territory within Uzbekistan has a water quality that is hazardous to health, and more than 10% of water is in the category extremely hazardous (29, 30).

The situation in Turkmenistan is no better. One can clearly observe the increase in water mineralization in the Karakum Canal valley. Water quality in Ashgabad is very poor, with sulfate concentrations of 1.5-fold above the MPC and nitrate concentrations several times higher than MPC, an indication of the presence of biological wastes (30). According to Japanese standards for drinking water, the Amudarya water cannot be used as drinking water at any time of the year (31).

From 30 to 66% of the total area of irrigated fields in the region are polluted, and often pollutant concentrations exceed the MPC 20–40-fold. Losses of agricultural products as a result of soil pollution are up to 30% in Uzbekistan and 20% in Kyrgyzstan and Tajikistan (18, 23, 32). The main reason for soil salinization, is high mineralization of the irrigation water; over the past 30 years, mineralization in the Amudarya basin has increased from 0.4–0.6 g L⁻¹ to 1.3–2.0 g L⁻¹ (18, 33).

Growing dependence of the countries of the region on import of food products: Food security in the region is reaching alarming proportions. Tajikistan provides only one fourth of its population with agricultural products grown in the country. Even now it has crossed the safe line and is in the group with poor African countries (26). If current rates of population growth are maintained, there will be a catastrophic reduction in arable lands by the mid-21st century (26).

A serious consequence of the irrational use of water resources in irrigation farming was an increase in the level of groundwaters and flooding of population areas. For example, in Khorezm oblast in Uzbekistan, areas with groundwater levels up to 1.5 m constitute 70% of the land, and in the lower reaches of the Zeravshan river more than 50% (21).

Thus, in spite of considerable efforts by the governments and the international community, the water-supply situation for the population and economic conditions in the countries of central Asia remains strained (34). The main reasons for this situation are:

- the transboundary nature of the major watershed basins in the region, which makes it impossible to solve the problems of rational water-resource use without interstate agreements;
- imperfections in the transboundary water-resource management systems based on principles of the centralized regulations of the Soviet period;
- low efficiency of irrigation canals and a limited material and technical base, which makes it practically impossible to carry out large-scale reconstruction of irrigation systems, most of which need major repairs or are completely

- destroyed;
- low income of peasant farmers and small agricultural enterprises, which does not allow the introduction of modern large-scale water-saving technologies in irrigation farming.

Aggravation of water-related situation due to the construction of new large water reservoirs and growth of irrigated areas: One of the major reasons for tension in the region lies in the tendency toward unilateral decisions and actions, which have gained popularity in recent years. This strategy may complicate the rather tense situation in regard to joint use of transboundary water resources.

Practically all the countries of the region intend to increase their irrigated areas. Thus, Tajikistan plans to increase its irrigated area by 700 000 ha in the near future, requiring additional water use of not less than $19 \text{ km}^3 \text{ yr}^{-1}$ from the Amudarya River. Tajikistan, having completed construction of the Ragon water-storage reservoir (capacity 10 km^3) intends to construct a number of water reservoirs, used for power generation (34). Turkmenistan is also planning to increase its irrigated areas by 450 000 ha, and in spite of arguments by Uzbek specialists has begun to create a lake (volume $5\text{--}6 \text{ km}^3$) in the Karakum desert, i.e. “Lake of Gold Century”. It is planning to use the accumulated water to irrigate between 700 000 and 1 million ha of desert pastures. Uzbek experts estimate that to maintain the level of this lake, it will be necessary to utilize an additional ca 10 km^3 of the Amudarya River water (34).

An important confounding factor is the necessity to take into account the interests of Afghanistan. Experts estimate that using the total water quota (10 of 19 km^3 of the Pyandzh runoff, according to the agreement signed by Afghanistan and the USSR in 1946) will considerably alter the runoff of Amudarya (34).

Inadequate knowledge about water resources development including prediction of changes, and as a result inadequate planning of water usage: One of the most important conditions for successful solutions to the problems of the region, is sufficient knowledge of natural processes dynamics, primarily in the runoff formation zone. Unfortunately, the situation in this respect is far from favorable. It is sufficient to note that the last water resources estimation was made some 40 years ago. Considerable changes have taken place in the runoff formation zone, and these changes affected the conditions and characteristics of runoff formation. In addition, there has been rapid degradation of glaciation (from 1965 to 1990 glaciation in the northern Tien Shan was decreasing at a rate of $0.8\% \text{ yr}^{-1}$ (35, 36)).

Mamytov (pers. comm.) estimated that during the period from the mid-1950s to the end of the 1980s, productivity of the high-mountain Tien Shan pastures decreased by not less than 40% due to overgrazing. Similar results were obtained by Abdulkhasimov et al. (21). This decrease suggests that water-physical soil properties changed and, hence, conditions of runoff formation. Processes of mountain geosystems degradation in the region became more pronounced after the dissolution of the USSR. In particular, the geosystems of the Pamirs deteriorated due to poverty and economic and fuel crises.

Floodplain forests were cut as were bushes and wormwood. Even under favorable conditions natural restoration is estimated to take from 30 to 60 years (37).

Unfortunately, studies in mountain areas using well-organized monitoring systems high-mountain monitoring stations, and regular expeditions, were more or less terminated with the collapse of the USSR. Moreover, during development of most of the projects related to the solution of water problems in the region, the problems of mountainous territories were seldom considered or only outdated information was taken into account.

The problem becomes even more acute in view of the anticipated climate-driven changes in water resources. Thus, according to predictions, water resources of the main watershed basins in Kazakhstan will decrease by at least 20–22%, droughts will increase, and grain crop productivity will decrease by 20–23%. There is a wide range of probable water-resource changes for the Aral Sea basin, according to 4 well-known scenarios of climate change; from positive values (GFDL model) to a decrease in the Syrdarya runoff by 25%, and the Amudarya runoff by 40% (8). Such a decrease in water resources will have serious consequences for the region. For the arid climate conditions of Central Asia, such reductions in water resources will necessitate considerable reconstruction of the whole water supply system. They may also provoke large-scale ecological catastrophes and negative socioeconomic consequences.

Thus, to leave the situation as it is at present would condemn the region to further deterioration of its socioeconomic base, aggravation of interstate relations due to joint use of transboundary water resources, and further environment degradation—especially rapid in the lower reaches of the main rivers and Priaralje.

Change of policy: Clearly understanding the implications of such development, governments are making efforts to solve regional problems, among which interstate use of regional water resources are given priority. Due to the activity of the Interstate Coordination Water Commission (ICWC) established in 1992, chaos has been avoided in regional water resources use and a possibility for a constructive dialogue on this problem has been provided. The results of ICWC activities and estimations and suggestions, prepared with ICWC participation, form the basis for numerous interstate agreements on the problems of water resources use. There are e.g. 25 agreements signed in the last decade on joint usage of the Syrdarya water resources.

In addition, an important role is played by the efforts of international organizations aimed at the solution of regional problems, among which water problems are foremost. Well-known projects of the World Bank, UNEP, UNESCO, UNDP, and a number of research and applied projects funded by INTAS, NATO, TACIS, INCO—COPERNICUS, have greatly contributed to our understanding of the situation at all levels from regional to local. Not only have solutions for several practical tasks, but also the strategies for sustainable development been developed. Some of those efforts did not have the expected effects. Real life turned out to be harder and stronger than the logic which encouraged governments and the international community to initiate joint actions aimed at solving regional problems and much of what was planned has not yet been done. About half of the projects carried out with financial and technical support from international organizations have failed (1).

Skepticism in the countries involved concerning efficiency of foreign participation in finding solutions for regional problems is based on the following:

- a predisposition of donor-countries to technical decisions, whose results very often do not meet expectations because technical decisions are not supported by legislative and political decisions (34);
- insufficient competence of the decision-making officials, which together with imperfections in the legislative base is one reason for the irrational use of funds allocated for the development of projects aimed at regional problem solutions;
- imperfection of financing systems for research funded both from the State budget and donor funds. The distributor of orders and their arbiter is usually a state organization, as a rule, a ministry. The tender system of order placement as used in the developed countries is rarely effective under current conditions. Fairness is very often lost to group interests, and the role played by official self-interest;
- insufficient use of local scientific potential in the solution of regional problems. Very often executors of scientific and scientific-technical projects including those done with donor money are so-called limited companies with rather doubtful reputations, whereas the experience of highly qualified scientists and specialists from research institutions where the main archives of practical data and knowledge on key problems of the region are concentrated remain unused;
- not always effective participation of foreign specialists in the development of projects financed by international organizations. Lack of interest in the final results of the work and insufficient knowledge of the local conditions hinder specialists' efforts to develop key aspects of international programs and projects.

The situation is also aggravated by regional issues, among which the most important are:

- imperfection in management systems at all levels, from regional to local;
- lack of clearly formulated water strategies in the countries of the region and, as a result, low efficiency of interstate agreements on joint water resources use;
- lack of a clearly formulated, mutually acceptable legislative base for interstate usage of water resources and as a result diametrically opposite visions of the perspective of cooperation in this field. Countries with dominant use of water resources insist on maintaining the quotas established in the Soviet period, whereas Kyrgyzstan and Tajikistan argue that the current water-sharing is unfair and are demanding payment for water delivered to countries downstream. This is unacceptable by Uzbekistan and Kazakhstan;
- lack of mutually acceptable water-sharing criteria. In the opinion of Uzbekistan, in order to follow the principle of fairness the main criteria of water resources division must be an equal water share per capita, with which other countries do not agree, especially Kyrgyzstan and Tajikistan.

The most pressing problem is water quotas. It is becoming more and more difficult to preserve quotas established in the Soviet period. The problem is so pressing that the International Crisis Group (ICG) experts state; “the problems of coordination of water and energy resources in the Central Asian region as a current source of tension are so important that they can be considered only less important than Islamic extremism” and the “struggle for water resources can only become more intensive if more effective mechanisms of

problem solution are not created” (34). It is also clear that the solution to this problem is to be sought not in the technical but in the political sphere, and requires development of a set of political and legislative decisions and measures that take into account not only interrelated problems of water-energy resources, but also the demographic, socioeconomic and ecological problems of the region.

As a measure to increase the efficiency of regional water resources management the creation of an interstate water-power generation consortium has been discussed. This consortium would have much broader powers than the ICWC. In the same vein, problems of economic integration of the countries in the region are under discussion. But the fact that each of the countries has demonstrated its intention to expand its irrigated areas or to construct new water reservoirs to satisfy its national needs, is evidence of an increase in disagreements rather than a means for constructive solutions to the problem of joint water resources use.

Thus, the problem of optimization of transboundary water resources usage in Central Asia remains complicated and shows a tendency to aggravation. The most likely solution to the problems is to be sought in political, not the technical sphere, and requires development of a package of legislative agreements based on the following principles:

- equal representation of the countries of the region in interstate agencies for water resources management, including basin administration. Nowadays, representatives from one country dominate the ICWC, and this is one of the reasons for most donor funds being directed to the solution of regional water use problems in Uzbekistan. In the interstate structures there are practically no representatives from the main water-users; i.e. farms and agricultural associations, there are no representatives of industry and scientific organizations;
- fairness when distributing water quotas and water and energy operations;
- obligatory compensation of mutual damage. It is possible to come to mutually acceptable and implemented decisions only if this principle is observed;
- taking into account environmental interests, as an equal consumer of water resources. In the conditions of the existing system of regional water resources management the interests of the environment are either taken into account last or ignored and decisions taken at the interstate level on stabilization of the crisis in Priaralje very often remain unfulfilled;
- equal access to information on the hydro-meteorological regime, volume of water consumption in each of the countries in the region;
- equal rights and responsibilities for the development of positive relations in the field of regional water resources use.

CONCLUSION AND RECOMMENDATIONS

In Central Asia, the problem of the rational use of transboundary water resources is the key to the welfare of the population and to the possibility for sustainable development of the national economies in the region.

During the last 40 years the water supply situation for populations and industry has deteriorated considerably for the following reasons:

- Predominant use of regional water resources (more than 90%) for irrigation farming and an orientation toward production of water-consuming crops: cotton and rice.

- Dissolution of the USSR and the processes which followed: e.g. the collapse of a formerly integrated economic system, a catastrophic decline in the economies of the countries of the region, social upheavals in extreme forms like the civil war in Tajikistan and conflicts in Uzbekistan and Kyrgyzstan.
- A substantiated switch in the priorities of water resources use in the upstream runoff zone (Tajikistan, Kyrgyzstan) from irrigation to power generation, which resulted in economic loss and significant deterioration of the ecological situation downstream, especially in Uzbekistan and Kazakhstan.
- Imperfection of water-resource management systems at all levels; from regional to local levels.
- High rates of population growth with related aggravation of food security and drinking water supply.

As early as the beginning of the 1980s, overall water consumption in the Aral Sea basin exceeded input from natural river water resources. In particular, according to our estimations the water sector of the economy turned out to be somewhat more difficult than previously thought, and information about successful and increasing water savings in irrigation farming do not fully correspond the true situation.

National Level

Development and enactment of national water strategies that do not contradict international water laws and the interests of the countries in the region. National strategies containing statements infringing the interests of neighbor countries will be an additional obstacle on the way to mutually acceptable agreements on the problem of joint usage of regional water resources.

Development of the system of political and legislative documents aimed at:

- strengthening water-users interests to increase water-use efficiency, primarily in irrigation farming;
- providing efficiency of water resources management at all levels from regional to local.

Stimulation and support of scientific research in the following fields:

- monitoring of desertification and landscape degradation dynamics in the area of predominant water resources use;
- optimization of land-use structures taking into account crop adequacy for natural soil fertility and agroclimatic conditions;
- adaptation of modern water-saving technologies in irrigation farming for conditions in Central Asian states;
- monitoring of soil contamination dynamics and agroclimatic conditions including remote-sensing methods;
- development of methods and agrotechnical techniques of restoration of salinized and highly contaminated soils;
- irrigation systems optimization, and improvement of their efficiency.

Special attention should be given to the research into organization of climate-driven dynamics of natural processes in the runoff formation zone, especially in the high-mountain areas (> 3000–3200 m a.s.l.). Glaciers and the overwhelming part of snow resources, the main sources of runoff formation, are concentrated here. Unfortunately, there are almost no observation data for these areas.

Regional Level

It is difficult not to agree with ICG recommendations for reorganization of the existing system of water resources management. Central here are the ICWC improvements by:

- providing equal representation of the countries of the region in the ICWC and participation of the representatives of main water users and nongovernmental organizations in taking decisions on water quotas and operational regime of water infrastructure;
- extension of the Commission's powers with inclusion into its terms of reference of responsibility to control observation of water quotas; right to impose sanctions against infringements of the above quotas; preparation of suggestions on integrated development of power industry and agriculture within the region;
- increase of control efficiency for implementation of coordinated decisions on water quotas and operational regime of the objects of water-power infrastructure;
- development and enactment of new legislative norms and rules, which exclude the possibility of the influence of local administration representatives on ICWC decisions and activities of its representatives;
- reorganization of basin administrations by providing equal representation for all the countries;
- introduction of market prices for land lots and water, taking into account the ecological status of the lots themselves and their surroundings, water quality and reliability of delivery to the consumer.

If these conditions are satisfied the degree of ecological violations and deterioration of the quality of life including inadequate management of water resources, will be expressed in objective terms (38). It will enable the use of economically viable mechanisms for the solution of inter-branch and interstate problems of regional water resources use.

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