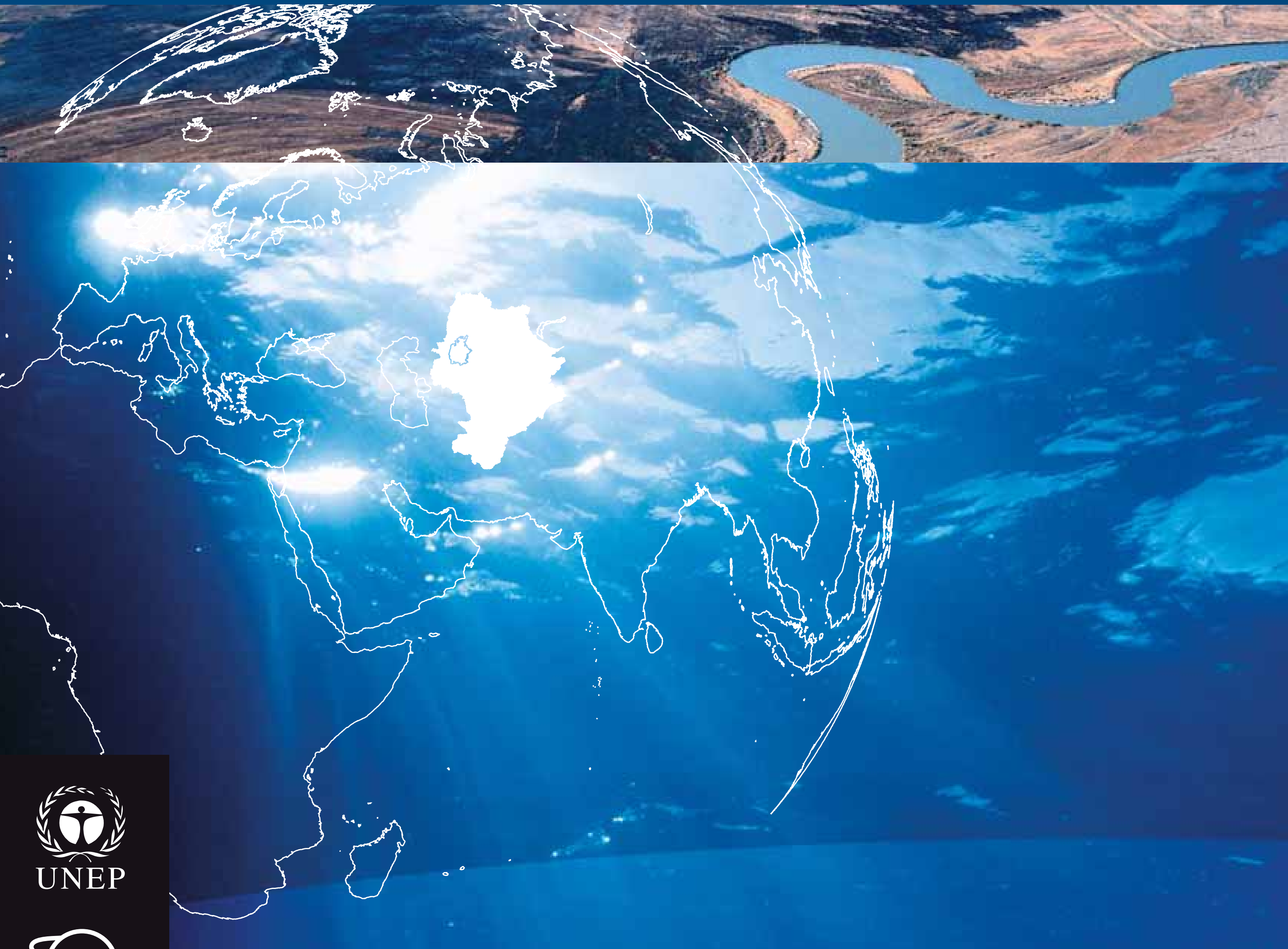
GIWA

Global International Waters Assessment



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Aral Sea

GIWA Regional assessment 24

Severskiy, I., Chervanyov, I., Ponomarenko, Y., Novikova, N.M., Miagkov, S.V., Rautalahti, E. and D. Daler

Global International Waters Assessment

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Global International Waters Assessment

Regional assessment 24
Aral Sea

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Preface

Water has always been the most limiting factor for the inhabitants of Central Asia. Historically, the countries of the region have adapted to the water scarce conditions through a legacy of sustainable water management that dates back several thousand years.

The Global International Waters Assessment (GIWA) of the Aral Sea Basin describes how since the 1960s water abstraction for economic activities, particularly irrigated farming, has become unsustainable and now exceeds the carrying capacity of the region's ecosystems. Insufficient water is allocated to the lower reaches of the region's rivers and the Aral Sea, which has resulted in an environmental catastrophe. The inhabitants of the region are now forced to survive under conditions of increasing water stress. Against this backdrop, poverty and poor health are rife throughout the region, from the Tajik mountains to the waterlogged wetlands of Karakalpakstan.

The assessment takes a holistic approach to analysing the transboundary environmental concerns of the region and in identifying the root causes behind these problems. Specialists of various environmental and socio-economic disciplines expressed the immanency of the situation and the need to take urgent action. Recent progress in addressing water management issues is also discussed in the report and various options are proposed to reverse the negative trends in the condition of the aquatic environment of the Aral Sea Basin.

Donors for over a decade have funded various initiatives aimed at resolving the causes of freshwater shortage in the region, but with limited progress realised. In fact, a sardonic proverb concludes that, "If all visiting experts had brought a bowl of water with them the Aral Sea would have been filled up again."

With the present global agenda set on achieving sustainable development and eradicating poverty, the countries of Central Asia must foremost address the root causes of its water problems. The UN International Decade for Action 2005–2015, Water for Life, was launched by the President of Tajikistan who also raised international awareness of the water crisis in Central Asia. In the forthcoming years water polices, aimed at achieving the Millennium Development Goals, will be implemented in all the countries of the region.

In this context the GIWA assessment serves as a useful tool for decision makers when exploring new mechanisms to resolve the situation. Complementary to the GIWA assessment, the Global Water Partnership (GWP) provides a neutral forum for regional stakeholders to discuss relevant water issues and formulate solutions through sustainable and equitable water management practices.

During the GWP Central Asia and Caucasus stakeholder conference in Bishkek, Kyrgyzstan, in January 2005, the outcomes of the GIWA assessment were presented and discussed by participants. While the global community may assist in catalysing change, restructuring the water agenda of Central Asia into a sustainable framework must be undertaken by regional policymakers.

Björn Guterstam

Network Officer

Global Water Partnership Secretariat, Stockholm

Executive summary

The Aral Sea Basin (GIWA region 24) is located in Central Asia and entirely or partially, covers Kazakhstan, Kyrgyzstan, Uzbekistan, Tajikistan, Turkmenistan, Afghanistan and Iran. The transboundary waters of the region are the Syrdarya and Amudarya rivers, which have a major hydrological impact on the Aral Sea Basin.

The GIWA Assessment evaluates the current status and the historical trends of each of the five predefined GIWA concerns i.e. freshwater shortage, pollution, habitat and community modification, unsustainable exploitation of fish and other living resources, global change, and their constituent issues. The assessment determined that freshwater shortage exerted the greatest impacts on the Aral Sea Basin. The effect of climate change on freshwater shortage has also been considered in this report.

Freshwater shortage is a fundamental problem for the countries of Central Asia which has led to the destruction of ecosystems in the Aral Sea and the degradation of terrestrial and aquatic ecosystems in Priaralye. As a result of freshwater shortages, the reuse of return waters in irrigated farming is becoming more frequent, resulting in heavy soil salinisation and the pollution of surface and underground waters. Consequently, poor quality drinking water is having severe health impacts on the population, particularly in Priaralye.

In the 1960s when the total population in five countries in the region (excluding Afghanistan and Iran) was approximately 15 million, more than 50% of the annual water yield of the Syrdarya and Amudarya rivers was used for economic purposes. Since the beginning of the 1980s the renewable water resources of the Syrdarya and Amudarya basins are fully exploited and the regional economy is developing under conditions of increasingly severe water shortages.

In view of this situation the concern of freshwater shortage, and more specifically the issue of stream flow modification, was prioritised for Causal chain analysis (CCA) and Policy options analysis (POA). The GIWA Task Team identified the following as immediate causes of modification of stream flow:

- Increased diversion;
- Decreased ice resources;
- Inter-annual climatic variability.

The main root causes of increased diversion stem from the regulation of rivers by reservoirs, which store huge volumes of water for irrigation and power generation. The collapse of the USSR triggered further problems for the region. The previously integrated economic system fragmented, and social and economic turmoil followed, e.g. civil war in Tajikistan (1992-1997). The quotas from the Soviet era have been maintained and they regulate water use to some degree. However, in recent years Kyrgyzstan and Tajikistan have persistently disputed the current system of quotas and demand that they be revised. There is insufficient coordination between upstream and downstream states regarding the allocation of water resources and a lack of mechanisms aimed at regulating the diversion of rivers. Conflicts between the various water users, particularly hydropower engineering and irrigation, remain unresolved.

The following were identified as root causes of freshwater shortage in the region:

Demographic: Increases in population have led to greater pressure on the water resources of the Aral Sea Basin.

Economic: The collapse of the economic system formed under Soviet rule, has led to a recession in the region and social upheavals. Consequently, investment in the agricultural sector reduced, which led to a decline in the productivity and the water efficiency of irrigation systems. Water users are not given economic incentives to conserve water resources and there is no common approach to economically evaluating water.

Legal: There is weak legislation regulating water management. A mutually acceptable legislative framework for interstate sharing of transboundary water resources is absent. The current water legislation was formulated during the Soviet period and is not appropriate under present-day conditions.

Governance: The transboundary nature of the major watershed basins in the region makes it impossible to solve the freshwater shortage concern without inter-state agreements. Many of the agreements made to date have not been implemented or adhered to by the countries of the region. For example, despite the governments signing agreements aimed at resolving the water management issues, all of the countries in the region intend to increase their irrigated areas. The transboundary water management system is inadequate as it is based on the principles of centralised regulation formed in the Soviet period. There is a lack of clearly formulated national water strategies and each country's is significantly different, adopting various approaches to addressing the problems of interstate use of water resources of transboundary basins management. The national strategies are not integrated at the regional level, for example, through a regional water strategy.

Knowledge: The lack of knowledge regarding the contemporary characteristics of the region's water resources and future climatically induced changes in freshwater availability, is severely hindering policy makers in making informed decisions in order to resolve water management issues.

Technology: Water resources are not being utilised efficiently due to irrigated agriculture employing outmoded technology. Economic constraints and the lack of economic incentives for farmers to save water, is preventing the adoption of water saving technologies.

Climatic variability: Freshwater shortage may become even more acute over the next few decades if as predicted, water resources in the region's major river basins reduce by 20-40%. However, some predictions show anthropogenic induced climate change to play a less significant role than was previously thought as there is evidence of a compensating mechanism in the formation of run-off which is maintaining the total volume of renewable water resources.

The current use of transboundary water resources in Central Asia is complex due to a range of demographic, socio-economic and ecological trends. In the post-Soviet period essential differences have been revealed concerning the approaches used by the countries within the region to the mutual use of regional water resources, especially regarding the principles and criteria of interstate water sharing and the legal and economic mechanisms of water use. In addition to the economic problems encountered during the transitional period from Soviet rule, coordination between the countries in the sharing of transboundary water resources and nature protection has also proved problematic. Despite efforts by the region's governments and the international community, the situation of water supply in Central Asian states remains critical. One of the main reasons for the lack of progress is the tendency of governments to take unilateral decisions and actions, which often exacerbate problems in other countries due to the transboundary nature of water resources.

A significant reduction in the volume of water resources used in human activities is unlikely in the region, at least in the immediate future. However, water management in the forthcoming decades can be based upon the modern volume of available water resources, as there is not believed to be significant reductions in freshwater availability as a result of climate changes. Despite the considerable reduction in glacial resources, the flow rates of the main rivers have remained relatively unaltered in recent decades, suggesting the existence of a compensating mechanism. It is believed that an inflow of freshwater from the melt-water of underground ice accumulates in the perennial permafrost. The area of perennial permafrost is many times greater than the area of present-day glaciers, and therefore even slight melting of the permafrost could compensate for the reduction in freshwater supply caused by the decline in the area of the glaciers. This has yet to be adequately researched by the scientific community, despite its importance when considering the influence of climate changes on freshwater resources.

Increased water abstraction may lead to an ecological disaster by the year 2010. The situation is so critical that this scenario may transpire if only one of the countries increases abstraction of surface waters. The success of interstate agreements on the sharing of water resources may be jeopardised by the current level of water use, the continued deterioration of water infrastructure and degradation of the environment. A prerequisite to resolving the freshwater shortage problem is a comprehensive knowledge of the hydrodynamics of the region.

The report highlights policy options which governments could implement and incorporate into strategic policies. The main recommendations are:

- The development and enactment of national water strategies that comply with international water law and take into account the interests of all the countries in the region. They should aim to increase the efficiency of water use, primarily in irrigated farming, and promote the conversion of water intensive crops, such as rice and cotton, to less water intensive crops.
- To broaden the understanding of socio-economic and environmental characteristics and their relationship with the water resources of the region.
- To initiate and support scientific research on water and the environmental and socio-economic problems of the region.

At the regional level, it is recommended that: i) the existing system of water resources management be reorganised; ii) a new multi-lateral water sharing agreement be created; and iii) water pricing systems be introduced.

The tasks deserving special attention by the region's governments and the international community are:

- The creation of an interstate body empowered to implement effective and conflict-free regional water resources management.
- The development of a system of mutually acceptable political and legislative decisions and measures in order to facilitate the equitable and sustainable use of the region's water resources.

Financial, technical and organisational support is required from international organisations in the:

- reconstruction and updating of irrigation systems to increase water efficiency;
- development of legislative principles and mechanisms for water use at all levels, and in the implementation of integrated water resources management principles, and,
- monitoring of the environment, particularly regarding climatically driven glaciosphere dynamics in the zone of run-off formation, where approximately 75% of the region's renewable water resources orginate.

These policy options are intended to considered by the international scientific community, local, regional and international decision-makers, funding bodies, and the general public, although at present, the latter is not sufficiently organised or powerful to act as a key stakeholder.

In conclusion, the water resources of transboundary basins in Central Asia are not optimally utilised, thus the freshwater shortage situation remains unresolved and continues to deteriorate. Progress in this area can be achieved through political rather than technical measures and firstly requires the development of legal agreements at the national, regional and international level.

Acknowledgements

This report presents the results of the Global International Waters Assessment of the Aral Sea Basin, GIWA region 24. The assessment has been carried out by a multidisciplinary team of international experts that included representatives from each riparian country. Regional scientific institutions, such as the Russian Academy of Science (RAS), Kazakhstan's Institute of Geography and Uzbekistan's Hydrometeorology Institute all contributed to the assessment. The results were discussed at the Regional Conference of GWP CACENA Stakeholders on the 17- 18th January 2005 in Bishkek and with the Committee for Water Resources of the Ministry of Agriculture of Kazakhstan, IFAS, the Ministry of Nature protection of Turkmenistan, and other local and regional authorities and executive bodies. The Environment Programme (CEP) was also consulted.

Abbreviations and acronyms

ASBP-1	First Aral Sea Basin Program
ASBP-2	Second Aral Sea Basin Program
CCA	Causal Chain Analysis
CDF	Comprehensive Development Framework
CIA	Central Intelligence Agency
CIS	Commonwealth of Independant States
CNR	Commission for National Reconciliation
DDT	Dichlorodiphenyltrichloroethane
FSU	Former Soviet Union
GDP	Gross Domestic Product
GEF	Global Environment Facility
GFDL	Geophysical Fluid Dynamics Laboratory.
GIWA	Global International Waters Assessment
GNP	Gross National Product
ICG	International Crisis Group
ICSD	International Commission on Sustainable Development
ICWC	Interstate Coordination Water Commission
IDA	International Development Association
IFAS	International Fund for saving the Aral Sea
IMF	International Monetary Fund
INTAS	The Interrnational Association for the Promotion of Co-operation with Scientists from the New Independent States (NIS) of the Former Soviet Union
IPPC	Intergovernmental Panel on Climate Change
IWP	Index of Water Pollution
IWRM	Integrated Water Resources Management
MAC	Maximum Allowable Concentration
NATO	North Atlantic Treaty Organisation
NPRS	National Poverty Reduction Strategy
SIC	Center of Scientific Information
SPECA	Special Programme for the Economies of Central Asia
SRC ICWC	Scientific-Research Center of Interstate Commission for Water Coordination of Central Asia
TACIS	Technical Assistance to the CIS
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USSR	Union of Soviet Socialist Republics
UTO	United Tajik Opposition
WTO	World Trade Organization

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Regional definition

This section describes the boundaries and the main physical and socio-economic characteristics of the region in order to define the area considered in the regional GIWA Assessment and to provide sufficient background information to establish the context within which the assessment was conducted.

Boundaries of the region

According to the GIWA regional boundaries, the Aral Sea region includes the territory of three closed water basins - the Aral Sea, Lake Balkhash and Lake Issyk Kul. Each of these basins has specific natural and socio-economic features which should be evaluated separately. This report focuses on the Aral Sea Basin exclusively, which is situated between 55°00' E and 78°20' E and 33°45' N and 51°45' N and has a total area of 2.7 million km^2 (2.4 million km^2 within the border of five former republics of the USSR) (Bortnik & Chistijaeva 1990) (Figure 1).

The Aral Sea Basin includes the basins of the Syrdarya and Amudarya rivers which flow into the Sea, and the Tedzhen and Murgabi rivers, the Karakum canal, and shallow rivers flowing from Kopet Dag and western Tien-Shan, as well as closed areas near these rivers and the Aral Sea (Figure 1). Administratively, the region entirely covers Uzbekistan and Tajikistan, some parts of Kazakhstan (the Kyzylorda and Shimkent regions and the southern part of the Aktyubinsk region), Kyrgyzstan (the Osh and Naryn regions), Turkmenistan (excluding the Krasnovodsk region), and part of northern Afghanistan and northeastern Iran. This assessment does not focus on the latter two countries and when the report discusses 'the five countries of the region' it does not include these, but is referring rather to the five former Soviet countries of the region.

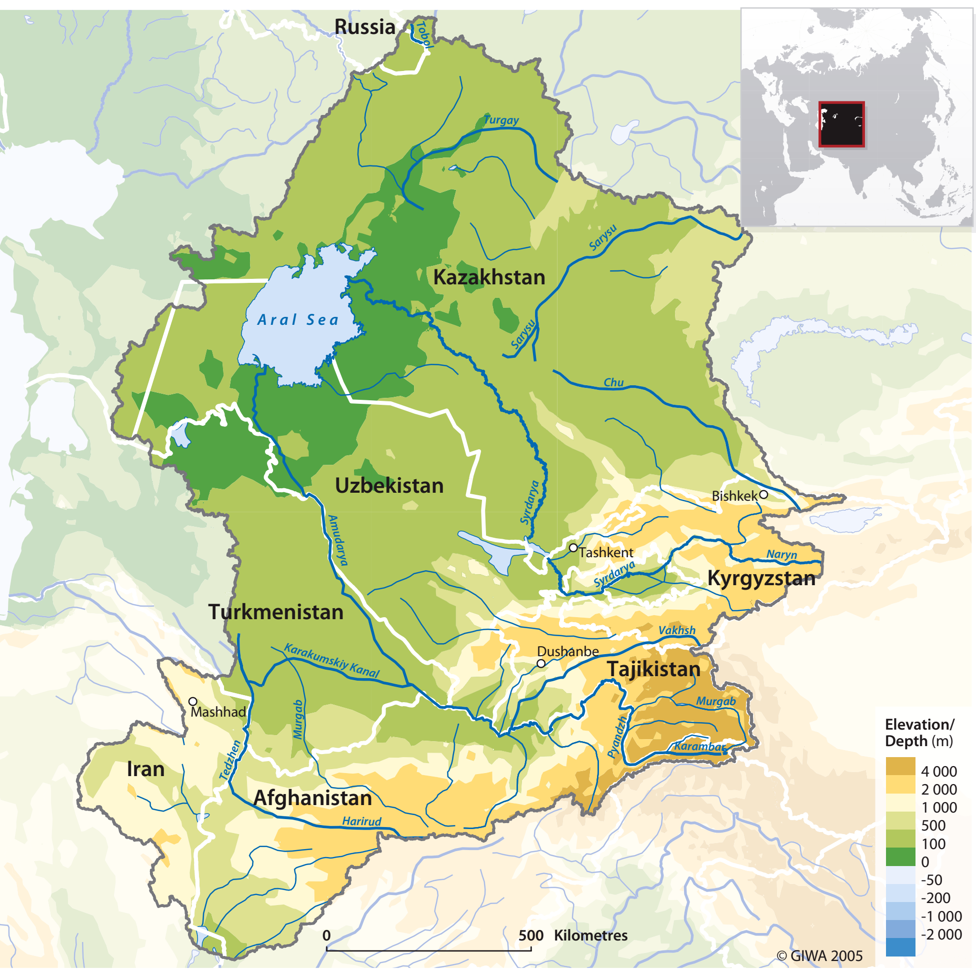

Figure 1 Boundaries of the Aral Sea region.

Physical characteristics

Geological composition and relief

The geological composition and relief form the lithogenic background of the geographical landscape. Figure 1 shows the main physio-geographical features of the Aral Sea region. The territory is heterogeneous in terms of its geology. The plain-lands belong to the Turanian plate of the Gercian platform, where a deep covering layer (more than 10 km thick) of Mesozoic and Cenozoic sediments lies upon highly rugose Paleozoic sediments.

The mountainous areas of the region (the Pamirs, Tien-Shan, Pamiro-Alay) comprise of newly formed rugose geological structures, which originate from the same plate formed in the Neogene period of the Cenozoic aeon. Continental neogene-quaternary sediments are found above this layer, which were formed by river processes and temporary water flows, as well as sea transgressions and aeolic (dust) processes.

The geological constitution has a significant impact on the relief and landscape of the territory. The relief of the territory can be divided into two types: plain and mountainous.

The plain relief is found in the Kazakh tableland (nipple-land) and Turanian lowland. The Kazakh nipple-land covers the northern part of the plain and is actually a peneplain (hilly, elevated plain), which in some places is occupied by low-lying residual mountains. It is generally 200-500 m high, but the residual mountains of Ulu-Tau are over 1 100 m in height.

The Turanian lowland is situated on the Turanian plateau, which has predominantly flat monotonous relief (-43 m in Sary-Kamysch depression), which rises to about 200 m above sea level (Sultan-Wis-Dag). This area contains alluvial and sea formed lowland plains, with benches and dry seabeds. It encompasses the southern areas of the plain territory. The arenaceous deserts Karakum, Kyzilkum and Muyunkum are characterised by aeolic sandhills and ridges. The elevated plateau of Usturt is located in the south of the region.

The Turanian lowland is bordered by the foothills of the Kopet-Dag mountains and Parapamize (in Turkmenistan). To the southeast of the territory, the catchment area is partially occupied by foothills and the high mountains of Pamirs, Pamiro-Alai and Tien Shan, which are covered by more than 800 mountain glaciers.

Soil and vegetation

The region is dominated by zonal semi-desert, semi-bush and desert dispersed bush and graminaceus vegetation (Figure 2). Semi-deserts and deserts cover approximately one third of the regions' surface.

The region contains the following soil and vegetation zones:

- Dry steppe with feather grass and tipchack vegetation, found upon the chestnut (brown) soils, which cover approximately one quarter of the territory (northern part);
- Semi-deserts with grass and shrubby vegetation, situated on lurid (dark brown) semi-desert soils;
- Deserts of the temperate climatic belt with grey and brown soils;
- Sands of semi-deserts and deserts with sporadic vegetation cover, which support a high diversity of plant species, but with limited soil cover. For example the Karakum desert hosts 827 species of higher plants. The area is characterised by the anthropogenic degradation of forests;
- Grey soils of semi-deserts where trees and perennial vegetation prevail. Desertification is observed and there has been degradation of steppes (grassy communities) as a result of agricultural activities, and the savannahs (complexes of trees and grassy vegetation) due to the salinisation of soils;
- Xerophytic forests and bushes of the foothills and low mountains, found upon brown and grey-brown soils;
- Wide-leaf forests situated upon mountainous grey and dark brown soils.

Figure 2 Vegetation types in the Aral Sea region.

Intrazonal soils are formed locally in river valleys and especially along broad deltas, and under "tugays" (periodically inundated forested areas). Permanent or periodically excessive humidification results in the growth of tugay forests and bushes on alluvial soils.

Land use

Central Asia's prosperity is strongly linked with the patterns of land use development. At present, the total area of potential arable land is 59 million ha, of which only 10 million ha are actually being cultivated (Table 1).

Table 1 Land resources of the Aral Sea Basin.

Country	Total area (ha)	Potential arable area (ha)	Arable area (ha)	Irrigated area (ha)
Kazakhstan*	34 440 000	23 872 400	1 658 800	786 200
Kyrgyzstan*	12 490 000	1 570 000	595 000	422 000
Tajikistan	14 310 000	1 571 000**	874 000	719 000
Turkmenistan	48 810 000	7 013 000	1 805 300	1 735 000
Uzbekistan	44 884 000	25 447 700	5 207 800	4 233 400
Aral Sea Basin	154 934 000	59 474 100	10 140 900	7 895 600

*Notes: *Territories within the Aral Sea Basin. ** Areas suitable for irrigation.*
(Source: FAO 1997)

Half of the cultivated land belongs to the oasis, where it is naturally drained and the soil is fertile. The rest of the potential arable land would require complex and costly development, including drainage, landscape modification and improvements in soil structure (SPECA 2004).

Biodiversity

Biodiversity in the region is determined by the plain, sub-mountain and mountain landscapes, as well as the considerable latitudinal extension of the region (almost 20° latitude). Mountain regions are characterised by altitudinal and horizontal zoning with a high level of heterogeneity caused by relief peculiarities. The highest numbers of endemic species are observed in the isolated habitats. The relatively homogeneous structure of the flat landscapes of the region becomes more complex closer towards the mountain areas. The regional flora includes 1200 species of anthophyta (flowering plants) and 560 species of woody vegetation, including 29 endemic species of Central Asia. The flora of the Aral Sea coast includes 423 species of plant (Novikova 2001).

Climate and climatic variability

Owing to the extreme remoteness of the region from the oceans, it has a distinct continental climate. It is not subject to the monsoons of Southern Asia as it is separated by high mountains, and it is seldom subject to cyclones from the west.

The radiation balance (kkal/ cm^2 annually) in the marine area of the Aral Sea averages as R=55.7. It is characterised in this region by an absolute predominance of turbulent flows of heat compared with the expenditures of heat from the transpiration of moisture, whereas on the majority of the earth's surface there is a reverse interrelationship between these two parameters.

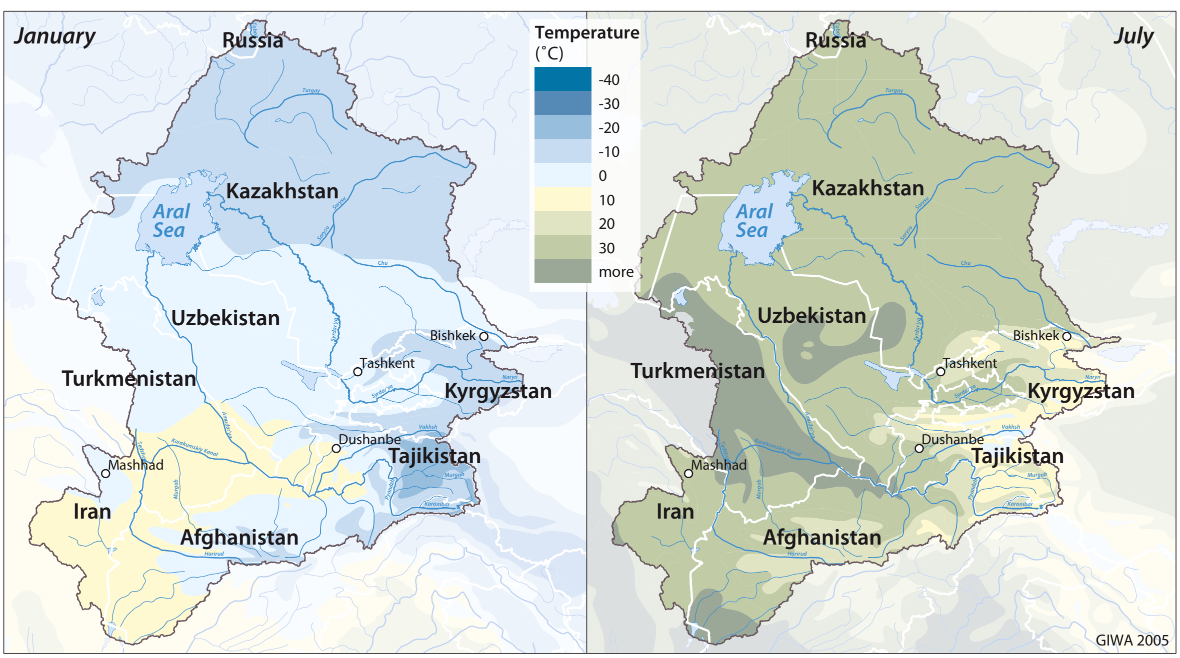

Figure 3 Mean air temperatures in January and July.

The region is characterised by large variations in temperature and precipitation (Figure 3 and 4). The aridity of the climate increases in the centre of the region. Annual precipitation ranges from 1 500-2 500 mm at the glacier belts of West Tien Shan and West Pamir, to 500-600 mm at the foothills, and to 150 mm at the latitude of the Aral Sea. To the north of this latitude, in Northern Kazakhstan, annual precipitation increases to between 250 and 350 mm.

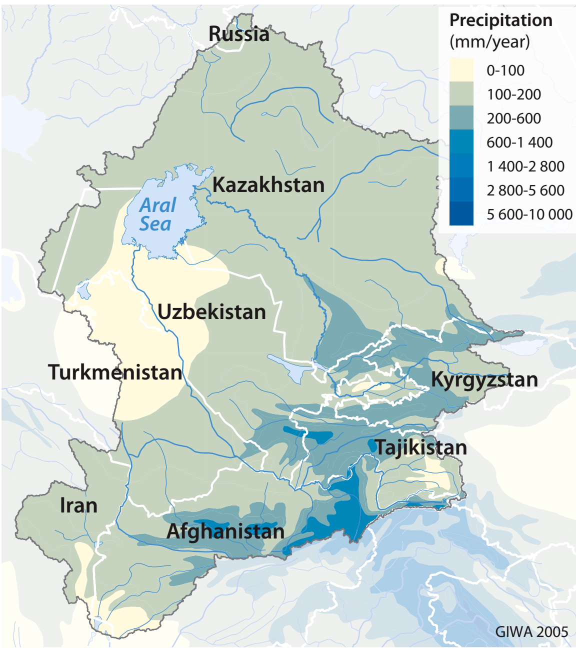

Figure 4 Annual precipitation in the Aral Sea region.

Hydrological characteristics

The term "water resources" in this region refers to the annual volume of river flow measured where headwaters leave the mountains for the lowlands and upstream of water intake structures used for irrigation. Table 2 shows the mean annual surface river run-off in the Aral Sea Basin. The Amudarya Basin receives far greater water in the area of run-off formation (0.256 km^3/km^2 per year compared to 0.170 km^3/km^2 per year in the Syrdarya Basin), with 62% of its annual river run-off formed on the territory of Tajikistan. The Aral Sea is supplied with 68% of its renewable water resources by the Amudarya Basin. It should be noted that table 2 does not take into account the run-off from the Chu and Talas rivers, which orographically belong to the Aral Sea Basin. Taking these waters into account, the total water resources in the Aral Sea Basin is 123.6 km^3 (Chub 2000).

Water supply in the region is not only affected by the modification of the main transboundary rivers in the region, but also by their hydrological regime, which is characterised by an extremely irregular

Table 2 Mean annual river run-off in the Aral Sea Basin.

Country	Annual river run-off (km^3)			Aral Sea Basin (%)
	Syrdarya Basin	Amudarya Basin	Aral Sea Basin	
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	0.756	-	0.756	0.7
Total for the Aral Sea Basin	37.20	79.38	116.58	100

(Source: Kipshakbayev & Sokolov 2002)

territorial distribution of renewable water resources and a high degree of variation in inter-annual run-off. About 43% of the Aral Sea Basin resources are formed in the territory of Tajikistan and more than 24% in the territory of Kyrgyzstan. A considerable fraction of surface run-off resources (18.6%) is also formed in the territories of Afghanistan and Iran (table 2). The main consumers of water resources, however, are Uzbekistan, Turkmenistan and Kazakhstan. The annual river run-off fluctuates between a maximum volume 1.5-2.5 times greater, and a minimum 2.0-2.2 times less, than the average annual run-off (Shultz 1965, Bolshakov 1974, Kipshaskbayev & Sokolov 2002). With an arid climate and increasingly deficient water resources such run-off variations present an extreme risk for irrigated farming.

Rivers

The majority of the Aral Sea region belongs to the basins of the two major rivers - the Amudarya and Syrdarya. The territory of the Tadjen, Murghab, Chu and Talas rivers orographically belong to the Aral Sea Basin but the waters are exploited for irrigation or are lost on the sub-mountain plain and do not reach the Aral Sea.

The mountainous areas play an important role in maintaining the ecological integrity and food security for the entire region. They only occupy about 20% of the total area of the Aral Sea Basin but are the source of approximately 75% of renewable water resources and contain freshwater resources within glaciers and underground ice; a reliable guarantee of stable river flow for the future.

The Aral Sea

Origins of civilisation and farming in the Aral Sea Basin can be traced back 2 000 years. Natural environmental variance and human activity have led to significant ecological changes in the Aral Sea Basin.

Prior to the 1960s, the Aral Sea comprised an area of 68 300 km², including a water surface area of 66 100 km² and islands of 2 200 km². The volume of seawater amounted to 1 066 km³ (Hurni et al. 2004, Bortnik & Chistjaeva 1990). The maximum depth of the Sea is 69 m, but depths of less than 30 m are common in a large proportion of the sea. The average sea level, meanwhile, fluctuates between 52 to 53 m. Mineralisation of the Aral Sea waters over the past 100 years of instrumental observations has varied within a range of 10-12 g/l (Glazovsky 1990 and 1995, Amirgaliev & Ismuchanov 2002).

Historically, the Sea has risen and fallen considerably. During the Quaternary period, variations in the level of the Aral Sea were as much as 36 m. In the first half of the twentieth century the variance in sea level did not exceed 1 m, and the ecological situation was quite stable up to the end of the 1950s. However, substantial variations have taken place during the last 40 years, and this report focuses on this time period.

Decreased river inflow since the early 1960s has changed the water budget of the Aral Sea. By 1990, the area of the Sea had decreased to 34 800 km² and its volume to 304 km³ (Glazovsky 1995), and since the end of the 1950s the level of the Sea had fallen by more than 22 m (Amirgaliev & Ismuchanov 2002). A significant proportion (about 33 000 km²) of the sea floor has dried up, the configuration of the shoreline has changed, and water mineralisation has increased from 10-12‰ in the 1930-1960s to 83-85‰ in 2002 (Amirgaliev & Ismuchanov 2002). Today the inland sea covers about half of its former area and its water volume has decreased by about 75%. As water mineralisation increased, the spawning sites of fish disappeared and the forage reserve depleted, which led to a decline in fish resources. Only five species of fish remain and nearly all limnoplankton and numerous haloplankton became extinct (Aladin 1999, Aladin & Kotov 1989, Aladin et al. 2001, Treshkin 2001).

Lakes

There are more than 5 000 lakes in the Aral Sea Basin, of which more than 4 000 are situated in the Amudarya and Syrdarya basins. Most of the lake water reserves are concentrated in the Amudarya Basin (46 km³), whereas water reserves in the Syrdarya Basin only amount to 4 km³ (Chub 2000&2002, Chub & Myagkov 2002). The majority of these lakes are of small area and limited volume, with many low-lying plain lakes drying out in extremely dry years.

Lake Karakul, a high-mountainous closed lake located in the Eastern Pamirs, is the largest lake in the region with a water volume of more than 26 km³. Lake Sarez was formed as the result of a tremendous landslide during an earthquake in 1911 and is also located in the Pamirs Mountains. The total lake volume is 17 km³. Lake Sarez is under constant observation by the government of Tajikistan and the international community due to the possibility that the lake's dam could burst, putting an area of more than 5 000 km² and over 5 million people at risk (Olimov 2001).

The largest lakes in the low-lying areas of the Aral Sea Basin are situated in Uzbekistan and partially in Kazakhstan, in the lower and middle reaches of the Amudarya and Syrdarya. The largest of them were formed by drainage waters, which today consist predominantly of drainage effluent from irrigated areas. The largest of these lakes are Aydarkul (surface area of 30 km²), Sarykamysh (8 km²), Sudochye and Parsankul (2 km² each). The first of the above-mentioned lakes is situated in the Arnarsay depression at the boundary between Kazakhstan and Uzbekistan; its total volume is about 30 km³. It was formed by the discharge of excess water 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 majority of the once numerous and biologically productive freshwater lakes in the delta of the Amudarya and Syrdarya have completely dried up or lost their economic value, constituting one of the most important and dramatic consequences of the irrational use of water resources in the Aral Sea Basin. It has caused the rapid degradation of the delta landscapes and an abrupt reduction in the biodiversity of aquatic and terrestrial ecosystems.

Water reservoirs

The total volume of water reservoirs in the Aral Sea Basin is over 74 km³ (Table 3). The largest is Tokhtogul reservoir, which has a total volume of 19.5 km³ and a useful volume of more than 14 km³. All of the large water reservoirs have multi-purposes, but are mainly used for power generation and irrigation. On the territory of Uzbekistan, in addition to numerous ponds and small-capacity water reservoirs used for irrigation, 50 relatively large reservoirs with a total volume of 19 km³ have been constructed.

A total of 45 hydropower plants with a total capacity of 34.5 GWh/year were constructed on the largest reservoirs. The Nurek hydropower station on the Vakhsh River in Tajikistan (2 700 MWh/year) and the Tokhtogul hydropower station (1 200 MWh/year) on the Naryn River in Kyrgyzstan are the largest (Kipshkbayev & Sokolov 2002, Duskayev 2000, Burlibayev et al. 2002, Mamatkanov 2001). Of all the countries of the Aral Sea Basin Tajikistan has the greatest hydroelectric potential of all the countries in the Aral Sea Basin - more than 52 000 GWh/year.

Table 3 Water reservoirs in the Aral Sea Basin.

Country	Water-storage reservoirs		Largest water-storage reservoirs		
	Number	Capacity (km³)	Name	Capacity (km³)	River
Kazakhstan	1	5.7	Chadarya	5.7	Syrdarya
Kyrgyzstan	13	23.5	Tokhtogul	19.5	Naryn (Syrdarya)
			Kirov	0.55	Talas
			Orto-Tokay	0.47	Chuy
Tajikistan	19	29.0	Nurek	10.5	Vakhsh
			Kayrakum	4.16	Syrdarya
			Nizhne-Kafirighan	0.9	Kafirnighan
Turkmenistan	18	2.86	Naue-Khan	0.88	Karakum canal
Uzbekistan	50	19.0	Charvak	1.99	Charvak (Syrdarya)
			Andizhan	1.90	Karadarya (Syrdarya)

(Source: Kipshkbayev & Sokolov 2002, Duskayev 2000, Burlibayev et al. 2002, Mamatkanov 2001)

According to estimations it is technically feasible to harness about half of this potential energy. Until now only about 4 GWh/year have been utilised.

Socio-economic characteristics

Demographic characteristics

Recent population growth figures may not be representative of future trends. There is likely to be a decline in population growth rates, but it is not known by how much and when this is to occur. In principle, smaller families will be desirable for the urban population, but for subsistence farmers it will remain attractive to have larger families, with more than 4 children. In any case, in the next 25 years the population of the region is predicted to grow due to the age structure of the present population.

Table 4 shows the ethnic breakdown of the population of each country in the Aral Sea Basin, excluding Afghanistan. There are three dominant ethnic groups in the region: Uzbeks, who account for more than 40% of the population, Kazakhs (16.8%) and Russians (13.4%). In the five countries of the region the indigenous population dominate, especially in Uzbekistan (80%) and Turkmenistan (77%). The highest percentage of small ethnic groups united in the table under the heading "Other" is registered in Kyrgyzstan (11.8%) and Kazakhstan (8%). These are the most ethnically diverse countries.

In general, the region is characterised by high population growth rates (except in Kazakhstan), a negative balance of migration and a high infant mortality rate. The demography of Kazakhstan differs from the other countries due to its low rate of population growth (0.1), the greatest negative balance of migration (-6.16 migrants/1 000 population) and the smallest percentage of the population living below the poverty line (26% as compared with 34-80% in other countries of the region).

Kazakhstan has the smallest percentage of young people (under 15 years old) in the region, accounting for only 26% of the population, whereas in the other countries of the region this figure ranges from 34 to 40%. Kazakhstan also has the highest proportion of the population that are older than 65 (7.5%) (Table 5). These factors combined with the lowest birth rate (17.83 births/1 000 population as compared with 26-32/1 000 in other countries) and the highest death rate in the region (10.69/1000 population in 2002) may induce social and economic problems in the near future. It is also worth noting that Kazakhstan

Table 4 Ethnic composition of the population.

State	Ethnic group (%)								
	Kazakh	Kyrgyz	Uzbek	Tajik	Turkmen	Russian	Ukrainian	German	Other
Kazakhstan	53.4	-	-	-	-	30.0	3.7	2.4	8.0
Kyrgyzstan	-	52.4	-	-	-	18.0	2.5	2.4	11.8
Uzbekistan	3.0	-	80.0	5.0	-	5.5	-	-	6.5
Tajikistan	-	-	25.0	64.9	-	3.5	-	-	6.6
Turkmenistan	2.0	-	9.2	-	77.0	6.7	-	-	5.1
Total	16.80	4.31	40.3	9.63	6.17	13.40	2.26	0.88	7.26

(Source: CIA 2002)

Table 5 Demographic characteristics.

Country	Population	Growth rate (%)	Migration rate (migrate/ 1 000)	Infant mortality rate (deaths/ 1 000)	Life expectancy at birth		Total health expenditure		Birth rate (births/1 000)	Death rate (deaths/ 1 000)	Age structure	
					Female	Male	Per capita (USD)	% of GDP			0-14 (%)	15-64 (%)
Kazakhstan	16 741 519	0.1	-6.16	58.95	69.01	58.02	211	3.7	17.93	10.69	26.0	66.5
Kyrgyzstan	4 822 166	1.45	-2.51	75.92	67.98	59.35	145	6.0	26.11	9.10	34.5	59.4
Uzbekistan	25 563 441	1.62	-1.94	71.72	67.60	60.38	86	3.7	26.09	7.98	35.5	59.8
Tajikistan	6 719 567	2.12	-3.27	114.77	67.46	61.24	29	2.5	32.99	8.51	40.4	54.9
Turkmenistan	4 688 963	1.84	-0.98	73.21	64.80	57.57	286	5.4	28.27	-	37.3	58.6
Total	58 435 656											

(Source: CIA 2002, World Bank 2002)

has a relatively high level of social welfare for its population, which is explained by the country having the greatest GDP/per capita (5 900 USD) in the region, the highest percentage of elderly people, and relatively high expenditure on health care (211 USD per capita) (Table 5). In contrast, Kyrgyzstan has the lowest percentage of elderly people in the region (less than 1%), which relates to the low level of social welfare. Tajikistan has the highest level of infant mortality (114.7deaths/1 000 live births), the highest birth rate (33.0/1 000 population), the lowest GDP (1 140 USD per capita), the greatest percentage of the population living below the poverty line and the highest unemployment rate - 20% compared with 7-10% in the other countries (Table 5).

Economic characteristics

Table 6 outlines the economic characteristics of the countries in the region. Unfortunately the data for Turkmenistan is not complete. Kazakhstan has undergone the most successful economic development; it has the highest GDP (98 billion USD), which is almost one third higher than that of Uzbekistan and more than ten times that of Tajikistan. The poorest economic situation can be found in Tajikistan. In general, the region has experienced positive economic tendencies in recent years. In Kazakhstan GDP growth has exceeded 6-7% over the last five years.

Kazakhstan

Kazakhstan, the largest of the former Soviet republics excluding Russia, is rich in fossil fuel resources and has plentiful supplies of other minerals and metals, including gold, iron ore, coal, chrome and zinc. It also has a thriving agricultural sector in the areas of livestock and grain production. There are vast areas of arable land. The agricultural and the industrial sectors' share of GDP is estimated at 15% and 30%, respectively. Kazakhstan's industrial sector relies on the extraction and processing of natural resources and also on a growing sector specialising in the construction of equipment, agricultural machinery and defence technology.

Kazakhstan has a relatively high standard of infrastructure and the contribution of the services sector to the GDP is 60%. The economy of Kazakhstan also has the highest real growth of GDP in the region (12.2% as compared with 3-10% in other countries), a positive export and import balance (2.3 billion USD), relatively low inflation (8.5%) and low unemployment (Table 6). Kazakhstan also has the lowest population percentage living below the poverty line. The ratio of the contribution of the industrial sector in comparison to the agricultural sector towards the formation of GDP is 3.0, which is 1.8-4.6 times higher than the corresponding ratio for the other countries in the region. In 2003 GDP increased by 9.2%, the share of industrial output increased by 8.7%, foreign trade by 8.3%, and investments into fixed assets by 17.2%. Deficiency of the budget in 2003 was less than 1% of GDP and real wages increased by 8.3%. The general five year growth of GDP in Kazakhstan meant that in 2003, GDP had increased by 6.3% compared to 1991.

The break-up of the USSR and the severe decline in demand for heavy industrial products from Kazakhstan resulted in the short-term collapse of the economy, with the steepest annual decline recorded in 1994. Between 1995 and 1997, the pace of economic reform and privatisation quickened, resulting in a substantial shifting of assets to the private sector. In 1993, Kazakhstan began a comprehensive structural reform programme aimed at moving towards a market economy which was internationally supported by bilateral and multilateral donors, including the World Bank and the International Monetary Fund (IMF).

Today, poverty in the country persists. In 2001, approximately 28% of the population were earning below the minimum subsistence level. A considerable proportion of the population has no access to potable water and suffers from the effects of pollution and environmental degradation.

In 2000 and 2001, Kazakhstan experienced economic growth due to its booming energy sector, economic reform, good harvests, and foreign investment. The opening of the Caspian Consortium pipeline in 2001, from western Kazakhstan's Tengiz oilfield to the Black Sea, substantially raised export capacity. The industrial policy in Kazakhstan is designed

Table 6 Economic characteristics of the Aral Sea countries.

State	Budget (million USD)	GDP					Population below poverty line (%)	Industrial production growth rate (%)	Export (million USD)	Import (million USD)	Inflation rate (%)	Unemployment rate (%)
		Purchasing power parity		Per capita	Agriculture (%)	Industry (%)						
		Total (billion USD)	Real growth rate (%)									
Kazakhstan	4 200	98.1	12.2	5 900	10	30	26.0	11.4	10 500	8 200	8,5	10.0
Kyrgyzstan	207	13.5	5.0	2 800	38	27	55.0	6.0	475	420	7.0	7.2 (1999)
Uzbekistan	4 000	62.0	3.0	2 500	33	24	-	3.5	2 800	2 500	23.0	10.0
Tajikistan	-	7.5	8.3	1 140	19	25	80.0	10.3	640	700	33.0	20.0
Turkmenistan	589	21.2	10.0	4 700	27	45	34.4	-	2 700	2 300	10.0	-

(Source: CIA 2002, World Bank 2002)

to direct the economy away from overdependence on the oil sector by developing light industry (CIA 2002). Inflation decreased from an annual rate of 29% in 1996 to only 6.4% in 2003. In 1996, GDP growth was estimated at 0.5%, compared to 9.2% in 2003.

Kyrgyzstan

Kyrgyzstan is a small mountainous country with an economy predominantly based on agriculture. The country has undergone an economic transformation following the dissolution of the Soviet Union. Cotton and wool constitute the main agricultural products and exports. Industrial exports include gold, mercury, uranium, and electricity. Kyrgyzstan has been one of the most progressive countries of the former Soviet Union in carrying out market reforms.

Policymakers have had difficulties dealing with the termination of budgetary support from Moscow, the disruption of the former Soviet Union's trade system and a large deterioration in the Kyrgyzstan Republic's terms of trade, primarily owing to large increases in import prices of oil and natural gas. By 1999, GNP had declined to 260 USD per capita, with severe declines in living standards.

Early reforms by the Government included the liberalisation of most prices, the creation of a national currency, the introduction of a liberal trade regime, and the elimination of most capital flows. Substantive progress in tightening fiscal policies followed in parallel with a successful reform of the financial sector, and monetary policy framework and instruments. In 1994, deposit and interest rates were liberalised, directed credits were discontinued, and domestic financing of the budget deficit was sharply curtailed.

On July 17, 1998, the Kyrgyz Republic successfully concluded World Trade Organization (WTO) accession negotiations, paving the way for the Kyrgyz Republic to become the 133rd and the first Commonwealth of Independent States member to join the WTO.

In 2001 inflation was lowered to an estimated 7%. Much of the government's stock enterprises have been sold. Production had severely declined since the break-up of the Soviet Union, but by 1995 production had begun to recover and increase. Growth increased from 2.1% in 1998 to 5% in 2000, and again 5% in 2001. Nevertheless, poverty remains acute: approximately 40% of the Kyrgyz population lives in poverty, with 51% and 41% of the population in 2001 living in poverty in rural and urban areas, respectively. In September 2002, the Government released the National Poverty Reduction Strategy (NPRS): 2003-2005, one element of the Comprehensive Development Framework (CDF) of the Kyrgyz Republic to the year 2010. Despite substantial international aid for development programmes in Kyrgyzstan over the past five years, poverty remains a significant issue in the country (UNDP 2003).

Recent economic development is beginning to show as a result of these measures. The rate of inflation declined from 1 000% in 1993 to 15% in 1997. Following a cumulative decline of approximately 51% in 1991-1995, GDP grew by 7% in 1996 and 1997, by 6.7% in 2003 and 7.1% in 2004 (ICWC 2004). After concerted efforts to attract private capital and interest to the mining sector, the Kumtor gold mine, the eighth largest in the world, began production in 1997 and achieved commercial levels in May 1997, adding 4% to GDP. Agriculture, the largest sector in the economy of Kyrgyzstan, accounted for 45% of GDP and for half of the total employment in 1997 (UNESCO 2000).

The production of most crops declined considerably between 1990 and 1995 but has begun to recover more recently. Livestock and wool production however, two of the mainstays of the rural economy, have declined severely and still remain depressed. Agro-industry faced crisis between 1990 and 1996, with annual production declining by over 90% for most commodities. In recent years state support has stimulated growth in the agrarian sector.

Government intervention in agricultural marketing has largely disappeared. The foreign trade regime and prices have been liberalised. Over 65% of the agro-business has been privatised and demonopolised.

However, the government and the international financial institutions have embarked on a comprehensive medium-term poverty reduction and economic growth strategy. In November 2001, with financial assurance from the Paris Club, the IMF Board approved a three-year 93 million USD Poverty Reduction and Growth Facility (CIA 2002).

Uzbekistan

Uzbekistan is a dry, landlocked country of which 11% of the territory consists of intensely cultivated, irrigated river valleys. More then 60% of its population live in densely populated rural communities. The country possesses significant economic potential with a well educated population and qualified labour force. Uzbekistan is rich in natural resources such as gold, natural gas, oil, coal and copper. It is the world's ninth largest producer of gold (with an annual output of approximately 60 tonnes) and is among the largest suppliers of natural gas (with an annual production of more then 50 billion m^3). In spite of its potential, Uzbekistan presently remains an underdeveloped country. Its GNP per capita was estimated at 350 USD in 1999.

Figure 5 Aerial view of meandering Syrdarya River.
(Photo: CORBIS)

More than 20% of Uzbekistan's GDP is generated in agriculture, which employs about 49% of the country's labour force. Primary commodities, such as cotton fibre, mining and energy products, account for about 75% of its merchandise exports; cotton alone accounts for 40% of exports. The cautious approach to reform, combined with a focus on developing self-reliance in energy and improving the mining and agricultural sectors including trade diversification (especially of cotton export), allowed Uzbekistan to avoid an output collapse recorded in many other former Soviet Union countries during the first years of independence. Uzbekistan's GDP declined by less than 145 USD in 1991-1993, compared with a former Soviet Union average of almost 40% (UNESCO 2000).

Uzbekistan has introduced some elements of a market system over the past decade (for example privatisation and capital markets). However, the government has opposed, to varying degrees, the following: trade liberalisation; currency convertibility and a unified exchange rate; full price liberalisation; the elimination of government interference into the key sectors of the economy (e.g. cotton production); and central bank independence.

In 1997 and during the first half of 1998 economic trends were mixed. In an effort to curb accelerating inflation and a widening current account deficit, the authorities started tightening fiscal policies at the beginning of 1997. As a result, macroeconomic performance began to improve again. According to official statistics, real GDP grew by 5.2% in 1997 and by 4.0% in the first half of 1998, while average monthly consumer price inflation fell to 2.1% in 1997 and to 1.7% in the first half of 1998. The IMF's estimates suggest that the GDP growth in 1997 may have been only 2.4%, while average monthly inflation was estimated at about 3.5%.

Uzbekistan is now the second largest cotton exporter, a large producer of gold and oil, and a regionally significant producer of chemicals and machinery. Following independence in 1991, the government sought to support its Soviet-like command economy with subsidies and tight controls on production and prices. The state continues to be a dominating influence in the economy and has so far failed to bring about necessary structural changes. The IMF suspended Uzbekistan's 185 million USD standby arrangement in late 1996 because of governmental steps that made impossible the fulfilment of a Fund contribution. Uzbekistan has responded to the negative external conditions generated by the Asian and Russian financial crises by emphasising import substitute industrialisation and tightening export and currency within its already closed economy. Economic policies that have repelled foreign investment are a major factor in the economy's stagnation. A growing debt burden, persistent inflation, and a poor business climate led to disappointing growth in 2001. However, in December 2001 the government voiced a renewed interest in economic reform, seeking advice from the IMF and other financial institutions (CIA 2002).

Tajikistan

The Republic of Tajikistan has inherited a developed infrastructure and a well-organised and varied industrial and agricultural basis from its former Soviet period. However, transition to the market type of economy has led to serious changes in the economic system and in the economic links between the countries of the region. As a result of conflict, economic stagnation, and changes in the structure of export and import, the level of industrial output dropped by 60%, a figure which only started recovering at the end of the 1990s. The agrarian sector plays a major role in the modern economy of Tajikistan, but the industrial sector is less significant. To stop the deterioration in economic conditions, the government introduced several reform measures in 1995, including fiscal retrenchment and price liberalisation, supported by an IMF Stand-by arrangement and an IDA rehabilitation credit in 1996. In the following two years the policy performance of Tajikistan was mixed, largely because of the renewed conflict and weak institutional capacity. Much of the reform agenda contained in the above credit was eroded or even reversed because of the conflict and the reform programme had been disrupted by mid-1997. The civil conflict diverted resources to defence and security purposes to the detriment of other essential needs, and at the same time revenues declined. As of June 1997, the fiscal deficit reached 10% of GDP, social safety net payments were eight months in arrears, inflation exceeded 60% and the currency depreciated rapidly. Recognising that the reversal of this situation required dramatic action in the areas of political and macroeconomic stability and structural reform, the government and the United Tajik Opposition (UTO) signed a Peace Agreement in July 1997. The Commission for National Reconciliation (CNR) was created as the focal point to foster national reconciliation.

The government, in consultation with the IMF and the World Bank, also moved quickly on the stabilisation and structural reform fronts and has made significant progress in achieving macroeconomic stability. Average monthly inflation for the first four months of 1998 was brought down to 1.3%, compared with over 20% per month in July 1997. Recent fiscal performance has also been impressive, with the fiscal deficit (on a cash basis) in the last quarter of 1997 narrowing to only 0.2% of GDP. During the first quarter of 1998, the deficit was 1.6% of GDP. Owing to the restored macroeconomic stability and the availability of external financing for cotton production, GDP grew by 1.7% in 1997; the first real growth since independence in 1991. The recovery has continued, with real GDP in the first quarter of 1998 estimated to be 1.3% over the corresponding period in 1997.

Tajikistan has the lowest GDP per capita among the 15 former Soviet republics, the highest unemployment in the region and 80% of the population lives below the poverty line. Tajikistan has a negative export-import balance and the highest inflation level. At the same time Tajikistan has one of the highest rates of GDP growth in the region (only Kazakhstan has greater GDP growth).

Cotton is the most important crop. Mineral resources, varied but limited, include silver, gold, uranium, and tungsten. Industry consists of a large aluminium plant, hydropower facilities, and small obsolete factories, mostly in light industry and food processing. The availability of hydroelectric power has influenced the pattern and structure of the industrial sector, with aluminium, chemicals and other energy-intensive industries as the sector's mainstays. The civil war (1992-1997) severely damaged the already weak economic infrastructure and caused a sharp decline in industrial and agricultural production. On independence in 1991, the collapse of the trade and payments system among former Soviet Union countries triggered a precipitous decline in output. As a result, national poverty increased, particularly in the more remote and war affected areas, with as much as 85% of the population considered poor. A large proportion of the labour force in Tajikistan (as high as 25%) and Kyrgyzstan depends on work abroad (particularly in Russia), remitting a significant volume of income to their home countries.

Tajikistan has experienced strong economic growth since 1997. Continued privatisation of medium and large state-owned enterprises will further increase productivity. Tajikistan's economic situation, however, remains fragile due to the uneven implementation of structural reforms, weak governance, and the burden of external debt. Servicing of the debt, owed principally to Russia and Uzbekistan, required as much as 50% of government revenues in 2002, thus limiting the nation's ability to address pressing development issues (CIA 2002).

Despite Tajikistan's current economic problems, the country has considerable potential for development. The population is well educated, the land is very fertile and the country has demonstrated a capacity to produce competitively for international markets. The country also has an established but idle industrial base with assets that can be deployed more efficiently and productively. This industrial base can serve as the basis for economic growth especially in the agriculture sector. The development of this potential will, however, depend on whether peace and security can be maintained throughout the country.

Turkmenistan

Turkmenistan is a largely desert country with intensive agriculture in irrigated oasis and huge hydrocarbon resources; the country has the fifth largest gas reserves in the world. The cornerstone of the Turkmenistan economy is energy. With 2.7 trillion m^3 in proven and probable gas reserves and additional indicative reserves estimated at 14 trillion m^3, Turkmenistan is the second largest natural gas producer in the former Soviet Union after the Russian Federation, and the fourth largest producer in the world. The country also has an estimated 1.1 billion tonnes of oil reserves (UNESCO 2000).

Turkmenistan has considerable potential for diversification into mineral resource-based industries. However, agriculture still predominates, accounting for 10% of GDP and 44% of employment. Turkmenistan is among the top 10 cotton producers in the world. Other major crops include grains, vegetables, and fruits. Natural gas, oil products and cotton account for 84% of exports. The main imports in 1997 were machinery and metalwork (43%), processed food (19%), industrial chemicals (11%) and non-food consumer products (11%). Real GDP declined by 30% in 1993-1995 and by 3% in 1996. In 1997, GDP fell a further 26%, reflecting the combined effect of deep declines in exports of gas (73%) and cotton fibre (52%), tempered by a 34% growth in the domestic sector buoyed by the increase in cotton and wheat production and a boom in the construction industry.

The underlying fiscal position has weakened markedly over the years, as budget deficits were avoided mainly through expenditure compression, implicit taxes and subsidies. Credit policy has been expansionary, with large directed credit programmes and enterprises facing lax budget constraints. Inflation averaged roughly 1 800% in 1994, 1 000% in 1995, 450% in 1996, and 20% in 1997. From 1993 to 1995, wage adjustments lagged far behind inflation, and real minimum monthly wages declined by an estimated 80%. During 1996-1997, a series of wage increases raised average real wages by 84%, but only to two-thirds of their 1994 levels. Per capita income (970 USD in 1995, 870 USD in 1996, 630 USD in 1997, and 690 USD in 1999) is now significantly below the Former Soviet Union (FSU) average.

Economic reforms have lagged in Turkmenistan compared to other FSU countries. In November 1993, Turkmenistan introduced its own currency, the manat, and established a dual exchange rate system with an official rate used for all transactions related to gas exports, and a commercial rate which was substantially higher. From 1995-1998, the government took some steps towards a market economy. It removed price controls on most consumer goods, privatised most micro or small enterprises and trade and catering establishments, and initiated a leasehold programme to transfer agricultural land to private farmers. It also made several attempts at unifying the exchange rate, the last in April 1998. However, little progress was made in macroeconomic stabilisation or structural reforms. The government has recently formulated a ten-year production and investment plan that includes large investments in infrastructure and energy financed by foreign direct investment and the fiscal budget.

One half of its irrigated land is used for cotton production, making it the world's tenth largest producer. Until the end of 1993, Turkmenistan had experienced less economic disruption than other former Soviet states because its economy received a boost from higher prices for oil and gas and a sharp increase in hard currency earnings. With an authoritarian ex-Communist regime in power and a tribally based social structure, Turkmenistan has taken a cautious approach to economic reform, hoping to use gas and cotton sales to sustain its inefficient economy. Privatisation goals remain limited. In 1998-2001, Turkmenistan suffered from the continued lack of adequate export routes for natural gas and from obligations on extensive short-term external debt. At the same time, total exports have risen sharply because of higher international oil and gas prices. Turkmenistan is the most closed, inward-oriented country in the region, relying heavily on its rich natural gas deposits. Turkmenistan economic statistics are state secrets, and other GDP and figures are subject to wide margins of error (CIA 2002). Turkmenistan has good long-term potential for development given its natural resource base. The large share of the gas sector in the country's GDP indicates that even a modest upturn in gas output would imply growth in GDP.

International programmes and agreements related to water

The sharing of transboundary water resources in Central Asia has become one of the main problems regarding the relations between the countries of the region since gaining independence. Acknowledging that regional water resources management is one of the most important issues for sustainable development, in 1992 Water Management bodies of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan signed an agreement on cooperation in the joint usage and protection of transboundary water resources. The parties agreed to coordinate their actions establish rules of water resources usage, to find joint solutions to ecological problems, and determined minimum sanitary conditions downstream. It was agreed not to alter the order of interstate water division and water quotas which existed under the USSR. In order to take coordinated decisions, the Interstate Coordination Water management Commission (ICWC) was established.

In March 1993, at the Kyzylorda conference on the Aral Sea, the heads of the states took the decision to organise the Interstate Council on the problems of the Aral Sea Basin. The ICWC with its associated divisions; the Center of Scientific Information (SIC) and the Basin's administration along the Amudarya and Syrdarya rivers, got the rank of organisations subordinate to the International Fund for saving the Aral Sea (IFAS) (Velmuradov 2003, Kipshakbaev 2004, Sarsembekov at al. 2004).

The International Commission on Sustainable Development (ICSD), organised under the IFAS, became responsible for the coordination and control of regional cooperation regarding environmental protection and sustainable development of Central Asian countries. This included the development of the main principles and criteria for passing legislative acts concerning the problems of the stabilisation and improvement of the environment (Esenov & Mamieva 2003, Dzhalavov 2003, Aslov 2003, Nurushev 2003).

A conceptual base for the improvement of water management and the ecological situation in the Aral Sea Basin was formulated in the joint declarations on the Aral Sea problems signed by the heads of Central Asian states in Kzyl Orda (1993), Nukus (1995), Almaty (1997), Ashgabat (1999), and Dushanbe (2002). These documents stress the necessity of normative-legal regulation of regional water resources management. These agreements became central to large-scale international programmes and projects on the Aral Sea problems, including those fulfilled with financial support of international funds and organisations. The most important projects include;

- A programme of concrete actions on the improvement of the ecological situation of the Aral Sea Basin (ASBP-1). The main priorities include the development of sustainable strategies of water resources management and the improvement of the methods of regional water resources management (Ryabtsev 2003, Aslov 2003).
- A GEF project entitled "Water and environmental management in the Aral Sea Basin", financed by the World Bank, and governments of the Netherlands, Sweden and Central Asian countries which focussed on the development of a national and regional water strategy, the improvement of dam safety, the monitoring of transboundary waters and the formation of public opinion promoting stability in Central Asia (Aslov 2003).
- Special United Nations programme on rational and effective use of energy and water resources of Central Asia (SPECA). Within the framework of this, a diagnostic report was developed on the concepts of strategy and regional cooperation on rational and effective usage of regional water and energy resources. These documents are oriented around the improvement of a normative-legal base, the creation of an economic mechanism of water usage, and cooperation in achieving stable development of Central Asian countries (Koimdodov 2003).
- "Programme on concrete actions on improvement of ecological and socio-economic situation in the Aral Sea Basin for the years 2003-2010" (ASBP-2). The priority issues of the programme were approved by the regional heads of states at the meeting in Dushanbe in October, 2002. The programme guides the countries on the: continual coordination of the mechanisms of water resources management; rehabilitation of water resources objects; improvement of the use of water and land resources; struggle against desertification and natural disasters; implementation of water saving measures; strengthening of the legal base of cooperation in the context of sustainable development; and the improvement of socio-economic conditions for the population of the Aral Sea Basin (Koimdodov 2003, Esenov & Mamieva 2003).

The governments of the Central Asian countries, IFAS, and its institutions ICWC and ICSD, and with the help of international aid, are taking steps to resolve the priority issues of water distribution, ecological safety and economic development, taking into account the interests of each country. The creation of water-energy, transport and food consortiums, a concept which was approved by the presidents of states and members of the organisation "the Central - Asian Cooperation" in the summer of 2004, aims to develop integration processes (ICWC 2004).

Assessment

Table 7 Scoring table for the Aral Sea region.

Assessment of GIWA concerns and issues according to scoring criteria (see Methodology chapter).

- 0 No known impact
- 1 Slight impact
- 2 Moderate impact
- 3 Severe impact

The arrow indicates the likely direction of future changes.

- ↗ Increased impact
- → No changes
- ↘ Decreased impact

Aral Sea	Environmental impacts	Economic impacts	Health impacts	Other community impacts	Overall Score**	Priority***
Freshwater shortage	3.0* ↗	3.0 →	2.8 →	2.3 ↗	2.9	1
Modification of stream flow	3					
Pollution of existing supplies	3					
Changes in the water table	3					
Pollution	2.4* →	2.4 →	2.8 →	2.3 →	2.5	2
Microbiological pollution	0					
Eutrophication	1					
Chemical	3					
Suspended solids	1					
Solid waste	2					
Thermal	1					
Radionuclide	1					
Spills	1					
Habitat and community modification	2.4* →	2.4 →	2.4 →	2.3 →	2.4	3
Loss of ecosystems	2					
Modification of ecosystems	3					
Unsustainable exploitation of fish	0* →	0 →	0 →	0 →	0	5
Overexploitation of fish	0					
Excessive by-catch and discards	0					
Destructive fishing practices	0					
Decreased viability of stock	0					
Impact on biological and genetic diversity	0					
Global change	1.0* →	1.0 →	1.0 →	1.0 →	1.0	4
Changes in hydrological cycle	0					
Sea level change	1					
Increased UV-B radiation	1					
Changes in ocean CO_2 source/sink function	0					

* This value represents an average weighted score of the environmental issues associated to the concern. For further details see Detailed scoring tables (Annex II).

** This value represents the overall score including environmental, socio-economic and likely future impacts. For further details see Detailed scoring tables (Annex II).

*** Priority refers to the ranking of GIWA concerns.

This section presents the results of the assessment of the impacts of each of the five predefined GIWA concerns i.e. Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources, Global change, and their constituent issues and the priorities identified during this process. The evaluation of severity of each issue adheres to a set of predefined criteria as provided in the chapter describing the GIWA methodology. In this section, the scoring of GIWA concerns and issues is presented in Table 7.

Freshwater shortage

The rational use of water resources is a major component of the present-day strategy of nature management and sustainable development. Problems associated with the sharing of transboundary water resources can provoke conflicts and are becoming the subject of increasingly complicated interstate negotiations. The rapid development of irrigated areas in the region has destabilised the water level of the Aral Sea and is jeopardising the preservation of ecosystems in Priaralye.

This situation is accompanied by poor water quality as a result of the discharge of drainage water from irrigated areas. Consequently in the early 1990s the socio-economic and ecological situation in Priaralye was assessed as critical.

The freshwater concern is inextricably linked with the other assessed concerns. In particular, habitat modification of the Aral Sea and the Syrdarya and Amurdarya river basins, and the resultant changes in abundance and distribution of biological resources was caused by the upstream modification of streams for the purposes of irrigated agricultural. Therefore to obtain a comprehensive understanding of the freshwater shortage concern, refer to the habitat modification concern.

Environmental impacts

Modification of stream flow

The most acute problem in the Aral Sea region is the irrational use of surface water resources. The volume of water consumed in the areas of the region where water is predominantly used is largely determined by the interests of irrigated farming, which accounts for 50% of GDP (Schultz 2002). A sophisticated farm-to-farm and inter-farm irrigation network of a total length of 316 000 km and a drainage system of a total length of more than 190 000 km have been constructed in the region (Duskayev 2000). A complex system of river flow regulation includes a large number of river and off-river water reservoirs, and is controlled by two basin administrations; the Syrdarya and the Amudarya offices which were established before the collapse of the USSR. These offices were incorporated into the Interstate Coordination Water Management Committee (ICWC) in 1992.

On the territory of Uzbekistan, in addition to numerous ponds and small-capacity water reservoirs used for irrigation, 50 relatively large reservoirs with a total volume of 19 km^3 have been constructed. The total volume of reservoirs constructed on the Syrdarya in Uzbekistan is 5 km^3, and 29 water-storage reservoirs with a total capacity of 14 km^3 have been built on the Amudarya. The largest water reservoirs are Charvak water reservoir on the Charvak River near Tashkent and Andizhan water reservoir in Osh valley on the Karadarya River. The existing reservoirs have a run-off control rate of 0.94 for the Syrdarya (i.e. close to its maximum), and 0.78 for the Amudarya, with capacity for further increases. Upstream flow regulation in the Amudarya Basin is provided by three main reservoirs, namely the Nurek and Baypasin on the Vakhsh River and the Tuyamuyun on the Amudarya, as well as by a network of river reservoirs and their associated canals. There are four river reservoirs on the Karakum Canal, two on the Amubuchara Canal and one on the Karshin Canal, which can hold a combined volume of 6 km^3 (SPECA 2004).

The greatest consumer of water resources is Uzbekistan which, on average, uses approximately 54% of the region's total water resources, a figure which rose to 60% in 1999. Turkmenistan uses about 19% of the regional water resources. The overwhelming proportion of river flow (almost 68%) is formed on the territory of Tajikistan and Kyrgyzstan, yet the main irrigated areas where most of the total river flow is used are located on the territories of Uzbekistan, Turkmenistan and, to a lesser extent, in Kazakhstan. It is estimated that more than 90% of total water resources are used by irrigated farming in these countries, and this percentage remains relatively consistent from one country to another, fluctuating between 88.5% and 92.6% (Kipshakbayev & Sokolov 2002).

Irrigated areas in the Aral Sea Basin grew from 4.51 million ha in 1960 to 6.92 million ha in 1980 and to 7.85 million ha in 2000. Accordingly, total water intake for irrigation rapidly increased and by the beginning of the 1980s had reached 120.7 km^3/year and overall water consumption in the Aral Sea Basin exceeded the available river water resources. Today, due to the use of return waters, the volume of water resources used exceeds available supplies; in the Syrdarya Basin 130-150% of available water resources are used and in the Amudarya Basin, 100-110% (Kipshakbayev & Sokolov 2002).

Naturally, the increase in water consumption, particularly in low-water years, has severely affected the numerous rivers in 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 and the largest of these, the Amudarya and the Syrdarya, cross the borders of three or more countries. In the Amudarya Basin the reduction in river flow following the construction of the Takhiatash and Tyuyamuyn reservoirs and the excessive use of water in irrigated areas has modified the delta and floodplain environment. By the year 2000 the total annual run-off of the Amudarya near the estuary (Chatly-Samanbay measuring station) had reduced by almost ten times in comparison with 1970. As a result, less than 10% of the total area of delta lakes in the Amudarya lower reaches remained, and the once profitable fishery and water rat fishery practically disappeared. Furthermore, some regions in Tajikistan suffer from water deficiency, despite being on the territory where the majority of the Amudarya flow is formed and which seems to have an excess of water resources (Olimov 2001).

The reduction in the flows of the Amudarya and Syrdarya rivers resulted in a decline in the water level of the Aral Sea and threatened the preservation of the Priaralye ecosystem (Kamalov 2002). The area of the Aral Sea has reduced more than two-fold. In 1986, the Sea divided into two independent water reservoirs-the Big and Small seas-and by July 2002 the water level in the Big Sea had decreased by 22 m (Zholdasova et al. 2002). The dramatic shrinkage of the Aral Sea since the 1960s is one of the greatest environmental catastrophes ever recorded. The salinity of the lake's waters has tripled, killing plant and animal life. In addition, the climate has been affected; both summer and winter temperatures have become more extreme. Plans have been made to use less water from the Amudarya and Syrdarya for irrigation in order that more can flow into the Aral, though these efforts may not be sufficient to save the Aral Sea.

The extreme degradation of the water and deltas of the Amudarya and Syrdarya and the multiple reductions in the area of delta lakes and swamp water areas caused a severe reduction in bio-diversity and a greater concentration of pollution in surface and groundwater supplies. The total area of lakes in the Amudarya delta reduced from 300 000 to 30 000 ha and water mineralisation increased to 20-25 g/l, which resulted in an abrupt reduction of fish and animal reproduction.

In 1960 fish catches in the Amudarya delta weighed a total of 22 520 tonnes compared with only 1 100 tonnes in 2000. Similarly, the water rat population decreased from 1 130 000 to 1 000 (Amirbekov et al. 2002). Between 1970 and 1999 the area of tugay forests in the Amudarya delta reduced ten times from 300 000 to 30 000 ha and no successful attempts were made to restore the natural forest (Bakhiev & Treshkin 2002). Desertification and the degradation of aquatic ecosystems has severely affected wildlife; in the Amudarya delta, besides a reduction in the water rat population, about 6 species and subspecies of fauna disappeared, more than 20 species became rare, and approximately 30 species of ornithofauna disappeared.

Pollution of existing supplies

A considerable part of available (accessible for use) water resources consist of return waters (drained effluents from irrigated areas, industrial wastewaters and municipal sewerage waters). Their average annual volume in the Aral Sea Basin is 32.4 km^3 which between 1990 and 1999 increased from 28 to 33.5 km^3 (Kipshakbayev & Sokolov 2002, Dzhalalov 2003). Some return waters are used repeatedly for irrigation, more than 51% of return flow is discharged into rivers and 31% into natural relief depressions. More than 95% of the total volume of return waters is formed by drainage waters from irrigated fields, which is the reason why return waters have high mineralisation and are one of the main sources of pollution of surface and groundwater in the region. About 60% of the total volume of return waters is formed in Uzbekistan.

Approximately 15% of surface water supplies in the Aral Sea Basin have been contaminated with polluted drainage and wastewaters (Kipshakbayev & Sokolov 2002). Today, it is severely affecting water quality; mineralisation has increased dramatically, and in some cases has diminished the ecological and economic functions of reservoirs. This is particularly true for the numerous water reservoirs that collect drainage and wastewaters in the lower reaches of the Amudarya and the Syrdarya. The largest of these are the Sarykamysh (with a volume of about 26 km^3) and the Aydar-Arnasay Lake (about 30 km^3) as well as the Dengizkul, Sudochye and the Solenoye lakes, each containing several million cubic meters of water. Most of them are stagnating and have high salinity levels. Subsequently they cannot be used for fishing, and flora and fauna are unable to survive (SPECA 2004).

The mineralisation of the Amudarya water increases from 0.4-0.5 g/l in mountain rivers, to 2.0 g/l or more in the deltas (Chembarisov & Lesnik 1995, Khasankhanova & Abdullaev 2001, Chembarisov et al. 2001a). According to research carried out along the Amudarya and Syrdarya rivers, copper, zinc and hexavalent chromium concentrations exceed the Maximum Allowable Concentration (MAC). Along almost the entire Amudarya River phenol concentrations exceed their MAC. Salinity has increased from 10 g/l to 40-50 g/l due to a lack of freshwater inflow to the rivers.

An average of 11 km^3 (36.8%) of return waters are discharged into natural depressions in the landscape and are subsequently not used for economic purposes. The overwhelming proportion of such waters (85.8%) is formed by the drainage waters of the Amudarya Basin. Drainage effluents from irrigated fields discharged into rivers are degrading riverbeds and deteriorating the water quality of the Amudarya. This is adversely affecting the ecology of Priaralye.

The waters of the rivers in the Aral Sea Basin as well as the Aral Sea itself are heavily polluted by salts and chemical pollutants discharged by the agricultural and industrial sectors. These issues are discussed further in the assessment of Pollution.

A major environmental problem facing the Aral Sea Basin is the increasing salinisation of irrigated areas which is reducing their productivity. Soil salinisation is occurring through the use of inadequate drainage systems. Following the collapse of the USSR, a programme of drainage reconstruction and development, and land melioration was significantly reduced, producing a ten-fold cutback in investment. This resulted in increased salinisation and the bogging of lands, and correspondingly a decline in land productivity (ICWC 2004). The high mineralisation of irrigation water is increasing salinisation; for the last 30 years mineralisation in the Amudarya Basin increased from 0.4-0.6 g/l to 1.3-2.0 g/l (Dmitriev 1995).

Between 1990 and 1999, the area of salinised soils increased in the Amudarya Basin from 1.16 to 1.82 million ha (by 57%), and from 0.34 to 0.61 million ha (by 79%) in the Syrdarya Basin. Between 30 and 66% of the total area of irrigated fields in the region are polluted, with concentrations sometimes exceeding the MAC by 20-40 times. The efficiency coefficient of drainage systems between 1990 and 2000 decreased by 30%, and if this trend continues, over 50% of the drainage systems in the region will be out of operation by the mid 21st century.

According to experts, inadequate drainage systems result in annual losses of about 1 billion USD (ICWC 2004). In some areas soil salinity and pollution has caused such a decrease in fertility that irrigation expenses quite often exceed profit and lead to a reduction in product quality (Glazovsky 1995).

The increase in salinised soils has necessitated the further use of water to wash the soils. In Uzbekistan alone it is necessary to wash up to 2 million ha of salinised soils annually, which requires up to 2 million m^3 of water per hectare. Annually, total water consumption for these purposes in the region ranges between 6 and 8 billion m^3. The process of improving the salinity of soils in irrigated areas would require considerable quantities of water. It is therefore imperative to implement such measures as soon as possible.

Changes in the water table

Total groundwater reserves in the region are estimated at 43.49 km^3 per year (Table 8), of which 25.1 km^3/year is found in the Amudarya Basin and 18.4 km^3/year in the Syrdarya Basin. Over half of total reserves (58%) are located in the Amudarya Basin. The total volume of approved groundwater intake in the Aral Sea Basin is 17.0 km^3, of which present-day net intake barely exceeds 11.0 km^3/year (Table 8). The greatest groundwater deposits are found in Uzbekistan and Tajikistan (more than 42% of regional reserves).

In the Kazakhstan area of the Aral Sea Basin the majority of groundwater is used for drinking water (more than 68%), compared with about 40% in Turkmenistan and Uzbekistan. In Kyrgyzstan and Tajikistan accessible groundwater resources are predominantly used for irrigated farming, 59.4% and 69.5% respectively.

Water logging and salinisation of soils has resulted in groundwater deterioration. Groundwater levels have changed significantly as a result of abstraction for anthropogenic activities. Declining water levels in the region's rivers and the Aral Sea have affected their ability to recharge groundwater supplies, resulting in a lowering of the water table by up to 50 cm per year on non-irrigated territories and in some regions by as much as 10-15 m.

On irrigated land, however, the groundwater levels have risen with consequential flooding of populated centres. For example, groundwater levels have increased by up to 1.5 m in 70% and over 50% of the total area of Khorezm oblast and in the lower reaches of the Zeravshan River respectively (Abdulkasimov et al. 2003). According to estimates, about 30% of the irrigation return waters in the upper watershed percolate through the soil to the water table. Some of this water eventually returns to the rivers as saline inflow, but much does not. In effect, much of the water from the Aral Sea has accumulated in the groundwater. As the groundwater is used for irrigation applications downstream, even regions that do not have a high water table are affected. Changes in the biota, unforeseen and often disregarded during the planning of projects, are associated with irrigation causing the water table to rise on an area of 3.23 million ha in the Aral Sea Basin.

Socio-economic impacts

Economic impacts

The freshwater shortage concern is severely impacting the regional economy. The poor quality and lack of freshwater is hindering industries in need of water for operations. In the Aral coastal zone economic activity has been suspended, which is additionally affecting inland industries. The rapid drying-up of the Aral Sea and the associated degradation of its marine ecosystem has led to the collapse of a previously well-developed fishery and fish processing industries. There has consequently been a dramatic decrease in available employment and income for the inhabitants of the Aral Sea region. Since the end of the 1980s in the Kyzylorda region of Kazakhstan and in Karakalpakstan of Uzbekistan, unemployment has been continuously increasing.

A serious consequence of the change in the run-off regime of the main regional rivers is that water is redirected away from pasture lands to fill

Table 8 Groundwater reserves in the Aral Sea Basin and their uses.

Country	Groundwater reserves (km^3/year)		Used 1999 (km^3)	Groundwater use (km^3/year)					
	Explored	Approved for usage		Drinking water supply	Industry	Irrigation	Vertical drainage	Experimental pumping	Other purposes
Kazakhstan	1.846	1.270	0.293	0.200	0.081	0	0	0	0.012
Kuyrgyzstan	1.595	0.632	0.244	0.043	0.056	0.145	0	0	0
Tajikistan	18.230	6.020	2.294	0.485	0.200	1.594	0	0	0.015
Turkmenistan	3.360	1.220	0.457	0.210	0.036	0.150	0.060	0.001	0
Uzbekistan	18.455	7.796	7.749	3.369	0.715	2.156	1.349	0.120	0.040
Total for the Aral Sea Basin	43.486	16.938	11.037	4.307	1.088	4.045	1.409	0.121	0.067

(Source: Kipshakbayev & Sokolov 2002, SPECA 2004)

lowland depressions, resulting in reduced pasture land. For example, in the area surrounding the Anasay-Aidarkul reservoir more than 2.5 million ha of pasture land has disappeared (Abdulkasimov et al. 2003). Furthermore, desertification resulting from freshwater shortages has also resulted in a reduction of pasture productivity. For the past 15 years pasture productivity in Uzbekistan has reduced by more than 20% and the harvesting of dry mass fed to animals has reduced from 2.4 to 1.8 centner/ha (Abdulkasimov et al. 2003).

A particularly alarming factor is the rapid reduction in the volume of water consumed per capita. According to available data (Kipshakbaev & Sokolov 2002), between 1960 and 2000 water intake per capita in the Aral Sea Basin reduced 1.7 times from 4 270 to 2 530 m^3/person and it may reduce to below sanitary standards within the next 20 years if the current rate of population growth continues.

A similar situation exists concerning the distribution of arable lands. Despite a considerable increase in irrigated areas, due to the rapid increase in population irrigated areas per capita reduced almost two-fold between 1960 and 2000 from 0.32 ha per person to 0.18 ha per person (Kipshakbaev & Sokolov 2002). This barely meets the required minimum level for the production of the daily human bread quota (Reteyum 2003). If the current rate of population growth is maintained, four out of five countries in the Aral Sea Basin (besides Kazakhstan and Afghanistan) will reduce the "irrigated area per capita" factor to practically zero over the next 50 years (Rodina 2002).

Water shortage and widespread secondary soil salinity cause a rapid reduction of usable fields and the productivity of agriculture. Thousands of hectares are drying up and becoming salinised. As a result, the current socio-economic and ecological situation in Priaralye is considered to be in crisis (Kamalov 2002). There have been severe economic losses for irrigated farming as a result of freshwater shortages. In the Amudarya Basin, economic losses were approximately 260 million USD in the harvest of 2000 (Sorokin 2002). The most severe situation regarding water supply is observed in the lower reaches of the Syrdarya and Amudarya, resulting in considerable economical losses in Uzbekistan and Kazakhstan.

Increasingly salinised and polluted soils have exacerbated the chemical and biological aggressiveness of the air and water environment. Chemical reagents and microorganisms in the air damage isolators of high-voltage transmission lines and salinised groundwater threatens building and construction foundations. As a result, financial expenses exceed estimated annual investments by 2.8 times (Abdulkasimov et al. 2003).

The most difficult situation is observed in Turkmenistan and Uzbekistan, where 80-90% of the national economy depends on the water resources supplied by transboundary rivers from neighbouring states. Currently the population of Uzbekistan is allocated less than 2 500 m^3 of water per person per year, falling short of sanitary standards. If predicted rates of population growth are realised, the situation will deteriorate substantially.

Health impacts

The health impacts of freshwater shortage are considered as severe, as water quality and quantity is directly associated with the spread of disease, especially of the central nervous system, the digestive tract, the vascular system, as well as infectious diseases and immunity deficiency. Health issues associated with the region's ecological crisis include the spread of anaemia, diminished thyroid function, and renal and liver diseases.

Although in general the health of the population in all five countries is relatively good, there has been a deterioration of epidemiological conditions in the region resulting in greater morbidity. Between 1995 and 2003 in Samarkand oblast (Uzbekistan) incidences of disease increased by a factor of 3, the incidence of blood circulation diseases among children increased by a factor of 5, and over the last 8 years the number of children suffering from anaemia increased by a factor of 4. In the Republic of Karakalpakstan, river water is unsuitable for drinking supply for 10 months a year (its mineralisation goes up to 2.5-2.8 g/l of solid residue).

As the Aral Sea recedes it leaves behind a harmful layer of chemical pesticides and natural salts which are blown by the wind into noxious dust storms, seriously affecting the health of the inhabitants of the area. It is estimated that 100 000 tonnes of salt and sand contaminated with pesticide residues are carried away each year by storms with increasing frequency and severity. Cancer and respiratory diseases have subsequently increased in prevalence as well as the rate of infant mortality.

The pollution of surface and groundwater is becoming increasingly alarming and is directly impacting the health of the population. Only water in the run-off formation zone in the mountains, with rare exceptions, meets sanitary standards. Further away from the mountains, the quality of surface and groundwater worsens abruptly and in the lower parts of the river and in the irrigation canals it is regarded as harmful for human health.

Food safety is becoming increasingly alarming due to the lack of potable water for the population located in the downstream sections of the rivers, and famine may occur in future (Rakhmonov 2003). Today, Tajikistan can only provide a quarter of the population with domestically grown agricultural products (Reteyum 2003). If current rates of population growth persist, by the middle of this century the country will experience a catastrophic reduction of arable land per capita, thus jeopardising food security (Rodina 2002).

Other social and community impacts

The sharing of transboundary water resources between the countries of the Aral Sea region can provoke conflicts. There have been increased expenses for deepening wells and pumping and for providing alternative water distribution. The region has witnessed a permanent decrease in agricultural efficiency (including grain crops, livestock, and aquatic crops). The fishing industry, which once employed thousands of people, has practically collapsed. The shores are barren and several villages and large towns, such as Aralsk and Moynoq which were located on the shore before 1960, are now stranded inland.

Due to the water shortage many local populations are choosing to migrate rather than tolerate the unfavourable conditions. There has been an estimated 100 000 people displaced due to the poor environmental conditions in the Aral Sea region. Despite efforts by the governments of the region and the international community, the issue of domestic and economic water supply remains serious and is frequently a subject of political conflict between the nations of the region.

Conclusion and future outlook

In the Aral Sea Basin the irrational use of transboundary water resources is the primary issue affecting the ecological health and socio-economic integrity of the region. Freshwater shortages are severely affecting the welfare of the population and this issue is impeding sustainable development in the countries of the region.

The most prominent impacts of the modification of stream flow and the pollution of existing water supplies are: the modification of riparian habitats; the reduction in agricultural and ecological bio-productivity; depleted fish stocks and a reduction in species diversity, including the extinction of a number of species; a deterioration in water quality of surface and groundwater; a reduction in the extent of wetlands; and the reduced capacity of rivers to transport sediments and disperse pollution. The water table has risen in irrigated areas due to recharge by polluted drainage water, but lowered in non-irrigated areas due to abstraction.

The freshwater shortage concern was assessed as severe, and it can be concluded that surface water resources in the Aral Sea region are fully exploited and the economy of the region is developing under conditions of ever increasing water shortages.

IMPACT Pollution

Many of the rivers in the Aral Sea Basin are contaminated, except in the area of run-off formation. Most pollution consists of various chemical contaminants. The index of water pollution (IWP) is a classification for the pollution levels in the region. The IWP not only takes into account whether the concentration of a substance exceeds Maximal Allowable Concentration (MAC), but also its danger to human health.

Environmental impacts

Microbiological pollution

Poor sanitary standards are evident in the settlements in the Amudarya and Syrdarya deltas. The standard treatment facilities (settling, coagulating, filtration, chlorination) do not offer adequate bacteria removal treatment and in 25-50% of samples the water does not meet national bacterial standards.

Chemical pollution

The excessive application of agro-chemicals has compromised the quality of surface and groundwater supplies. A large number of herbicides, pesticides, mineral fertilisers and defoliants are used every year in the production of cotton, with ecological, social and economic consequences for the region (Chembarisov 1998, Chembarisov & Lesnik 1995, Chembarisov et al. 2001a&b, National report 1998, Myagkov 1991a&b, Myagkov & Miagkova 1998, Isida et al. 1995, IFAS 2000). In the coastal zone surrounding Muinak City, pesticides are applied in quantities ten-fold the average for the former USSR countries, while the total use of pesticides in Uzbekistan exceed the standard level by six times.

The agro-chemicals not utilised by the plants and soil are washed away from the fields and into rivers via irrigation canals. By the end of the 1980s, more than 3 billion m^3 of water contaminated with agro-chemicals from the fields of Uzbekistan and Turkmenistan were discharged annually into the Amudarya River (Chub 2000).

A large amount of industrial and domestic wastes has been stored on the territory of the Central Asian countries over a long period of economic activity. The issue of their removal, storage and processing is becoming increasingly important as they are negatively affecting the environment.

The most polluting industries in Kyrgyzstan are the mining, tanning, cement, chemical, galvanising and textile industries. As the Republic does not have any special facilities to store and process harmful industrial waste, nor sites for their disposal, the industrial enterprises are obliged to store them on their territories.

Until recently, 70 mineral deposits were exploited on the territory of Tajikistan. The mining and processing industries extract huge amounts of mountain rocks and use only 3-10% of these as useful raw material. The rest is stored in tailing dumps and dump pits. Industrial wastes contain over 400 substances, some of them toxic. The main producers of toxic wastes are Tajik Aluminium Plant (TAP), the industrial association "Tajikchimprom," and other enterprises. There are 3 sites for toxic wastes in Turkmenistan: Mariinsk velayat "Karipaty", Lebap velayat "Zerger" and Dashhovuz velayat "Takhta". 1 350 tonnes of out-dated and prohibited chemical pesticides such as keltan, butiphos, metilethylchlorophos were disposed on these sites.

On the territory of Uzbekistan there are 43 enterprises with more than 80 storage sites for industrial wastes. They occupy about 22 000 ha, comparable in size to an administrative district. In Uzbekistan, 300 million m^3 of contaminated industrial wastes are produced annually, of which approximately 10% is discharged into water reservoirs without treatment. More than 25 billion tonnes of industrial wastes from mining enterprises, a considerable fraction of which is formed by toxic wastes from non-ferrous industries, have accumulated in the region.

As a result of these economic activities, the rivers of the Aral Sea Basin are generally highly polluted. However, the water quality of rivers in the mountainous regions of the Syrdarya and Amudarya basins is relatively good, though water in the high reaches of some mountainous rivers (e.g. the Pskem, the Chatcal, the Ugam) has a medium level of pollution and a satisfactory IWP (1-3).

Downstream of the mountains the level of river pollution intensifies. Although in some rivers and canals self-cleaning of the water is evident, the general situation of water quality in the Syrdarya Basin is poor and in the lower reaches of the rivers and canals the index of water quality is bad. Water quality is unsatisfactory and contains concentrations of phenols, copper, zinc and chromium higher than their MACs in the rivers of Ahangaran (below the Tuyamuyunskoe reservoir) and Karadarya (near the city of Andijan). Table 9 shows the water quality of the rivers in the Syrdarya Basin.

Table 9 Water pollution in Syrdarya River Basin.

River/channel	Location of the site of water quality assessment	Index of water pollution (IWP)
Syrdarya	5.0 km above the Keles river mouth	3.75
Naryn	0.2 km above the mouth	2.67
Karadarya	5.0 km below the dam of the Andijan reservoir	3.30
Northern Baghdad channel	0.5 km above the mouth	2.97
Tadjigen	0.2 km above the mouth	3.15
Ahangaran	0.5 km above the mouth	3.56
Kyzylcha	At the mouth	1.50
Karasu channel(northern banc)	3.0 km above the mouth	3.55
Chirchik	3.5 km above the mouth	3.81
Akbulak	At the mouth	2.09
Bozsu channel	At the mouth	3.79
Shuruzyac collector	At the mouth	3.03

(Source: Rubinova 2000)

The situation in the Amudarya Basin is no better. The discharge of drainage water results in the deposition of contaminants on the riverbeds. Consequently, mineralisation increases along the course of the River, from 0.7 g/l at the boundary of Turkmenistan and Uzbekistan to 1.7-2.0 g/l at the river delta (Table 10). Furthermore, the salinity of water also increases progressively along the course of the rivers in the Aral Sea Basin (Table 11).

Table 10 Salinity along the Amudarya River.

River	Salinity (g/l)
Upper Amudarya	0.71
Kelif	0.73
Kerki	0.84
Chardjou	0.91
Il'chik	0.98
Tuyamuyun	1.27
Nukus	1.69
Kizildjar	1.92

(Source: Rubinova 2000)

Table 11 Change in salinity along some rivers.

River	Upper river (g/l)	River mouth (g/l)
Amudarya	0.700	2.000
Surhandarya	0.385	1.500
Kashkadarya	0.270	2.500
Zaravshan	0.255	1.800
Karakum channel	0.700	0.900
Syrdarya	0.650	1.800
Naryn	0.250	0.500
Karadarya	0.345	0.520
Ahangaran	0.140	0.660
Chirchik	0.190	0.500

(Source: Rubinova 2000)

According to sanitary research the amount of chemical pollutants discharged every year into the Amudarya amounts to 300 tonnes of oil products, 1.35 million tonnes of sulphates, and 19 000 tonnes of surface-active substances. Similarly, 23 000 tonnes of oil products, 787 000 tonnes of sulphates, 925 000 tonnes of chlorides, 5 tonnes of phenols and 7 tonnes of surface active substances are discharged into the Syrdarya every year. In certain sections of the Amudarya (Temirbai) and the Syrdarya (Kyzylorda and Kazalinsk) mineralisation of water between the early 1930s and the late 1980s has increased by 2-3 times. In the Aral Sea, until the year 2000, mineralisation increased 5-6 times compared to the beginning of the 1960s. Today, the rate of mineralisation in the rivers is static. The mineralisation trends at the main sections of the Amudarya and Syrdarya basins during the last 6 decades are given in Table 12.

Table 12 Historical changes in salinity in some rivers in the Amudarya and Syrdarya basins.

River	Salinity (g/l)					
	1932-1950	1951-1960	1961-1970	1971-1980	1981-1990	1991-1999
Amudarya Basin						
Surkhandarya - Zhdanov - Manguzar	0.3-0.57	0.32-0.6	0.35-0.88	0.38-1.08	0.40-1.2	0.42-1.2
Amudarya - Kerki - Samanbai	0.5-0.51	0.51-0.52	0.57-0.64	0.59-0.75	0.57-1.2	0.57-1.2
Kashkadarya - Varganza -Karatikon	0.26-0.38	0.27-0.49	0.28-1.01	0.3-1.82	0.31-2.57	0.35-2.57
Zerafshan - Dupuli - Navoi	0.22-0.3	0.23-0.55	0.24-0.73	0.24-0.88	0.24-1.22	0.25-1.22
Syrdarya Basin						
Naryn - Toktogul - Uchkurgan	0.24-0.28	0.24-0.29	0.25-0.29	0.25-0.3	0.26-0.3	0.26-0.3
Karadarya - Uchtepe - Kampyrravat	0.3-0.48	0.31-0.49	0.32-0.5	0.35-0.52	0.40-0.53	0.42-0.53
Chirchik - Khodjikent - Chinaz	0.17-0.34	0.18-0.4	0.18-0.44	0.19-0.65	0.23-0.72	0.25-0.72
Angren - Turk - Soldatskoie	0.12-0.32	0.13-0.33	0.13-0.44	0.13-0.68	0.13-0.85	0.13-0.85
Syrdarya - Kal - Kyzylkishlak	0.4-0.42	0.45-0.59	0.62-1.03	1.04-1.2	1.1-1.25	1.12-1.26

(Source: Rubinova 2000)

In the region around the city of Nukus, the waters of the Amudarya River are contaminated with heavy metals, hexachloran, sodium and magnesium. At the section of Kyzylzhar, pesticides are 20-30 times the MAC and the water is classified as dangerous.

The discharge of wastewater causes a rapid deterioration in the ion composition of the river water. Thus, at the narrowing of the Kyzyldzhar River, concentrations of calcium ions increase by 240%, magnesium by 420%, hydrocarbons by 120%, sulphates by 620% as compared with the zone of run-off formation. One of the most polluted rivers is the Zeravshan. Mineralisation of water in this river increases from 0.27-0.30 g/l at the headwaters to 1.5-1.6 g/l at the estuary and concentrations of pesticides exceed the MAC by 5.8-6.2 times. High concentrations of antimony have also been detected which implies grave health implications for the population. Water in the lower section of the Zeravshan River is classified as dangerous. Over the past few years increases in concentrations of sulphate and chloride and magnesium and potassium have been recorded (Chub 2000).

According to research only 8% of water in Uzbekistan are categorised as polluted or very polluted, but 25% are moderately polluted, i.e. they are at the "red line" which determines a conventional boundary between satisfactory and unsatisfactory water quality. The water bodies in Uzbekistan have a total area of 173 600 km^2, of which 8.6% is classified as good quality water, 35.2% as satisfactory, and 44% as bad quality water. In addition, 5.2% of the country's water quality is classified as harmful for human health and in 7.2% very harmful. Only 2.3% of the population live within the area of good water quality, yet more than 49% live in the areas of bad water quality, 2.4% use harmful and 0.2% use very harmful water (Chembarisov et al. 2001a&b).

Fortunately, only background concentrations of heavy metals and oil products are observed in the majority of the region's rivers, and most pollution is concentrated around industrial and urban conglomerations. The discharge of heavy metal compounds, chlorine and organic pesticides into the Aral Sea has resulted in the mortality of game-fish, fish tumour diseases, and changes in cytogenetic parameters. In 1970 maximum levels of oil hydrocarbons were recorded in the Aral Sea. However, since 1978 recorded pollution from oil hydrocarbons has been within the national standards (Chembarisov et al. 2001a&b, Myagkov & Myagkova 1998, Bragin et al. 2001).

Solid waste

Billions of tonnes of solid industrial wastes have been stored in Kazakhstan. The non-ferrous industry was responsible for more than 5.2 billion tonnes of wastes, of which 4 billion tonnes are stored in the waste disposal sites of the mining industry, the ore-dressing industry more than 1.1 billion tonnes and metallurgical processing 105 million tonnes of waste.

Radionuclides

The level of radiation contamination in the region varies relatively little. The dosage rate of gamma radiation ranges between 5-25 mR/hour, with an average value of 14.4 mR/hour. The density of precipitation of beta-ionising radionuclides from the atmosphere ranges between 0.5 Bq/m^2 per day in Kazakhstan to 5.0 Bq/m^2 per day in Uzbekistan, the average value for the region was 2.6 Bq/m^2 per day (excluding Tajikistan).

Socio-economic impacts

Economic impact

Pollution is currently one of the most pressing issues in the region and its impact on the economy was assessed as severe. There is a lack of effective preventative measures to tackle the problem of pollution and its consequences. Pollution has had significant impacts on industrial development, competition and investment within the regional economy.

The economic impacts of pollution in the region include: increased expenses for animal protection; loss of economically important species; a decline in the productivity of agricultural land; and the cost of remediation programmes. Commercial fishing in the Aral Sea, which peaked in the 19th century when more than 40 000 tonnes of fish were caught annually, had almost ceased operations by the beginning of the 1980s as a result of increased water mineralisation and pollution (Glazovsky 1995, SPECA 2004).

One of the most alarming consequences of the irrational use of land and water resources is the degradation of arable lands. This has resulted primarily from increasing soil salinity and contamination due to the excessive application of herbicides and fertilisers. Nowadays, out of a total of 7.8 million ha of irrigated land in the Aral Sea Basin, more than 50% has experienced increased salinisation. In the last 20 years humus concentrations, the main factor determining soil fertility, has reduced by at least 40% (Abdulkasimov et al. 2003).

In Uzbekistan, moderately and severely salinised soils increased by more than 50% and by 80% in the irrigated areas of the Fergana valley (Glazovsky 1995). More than 30% of irrigated land is salinised in Tajikistan, up to 40% in Kyrgyzstan (Khamidov 2002) and in Turkmenistan as much as 95% (Yermolov 2003). As a result of soil salinisation and contamination, the productivity of the main agricultural products - grain crops, vegetables, cotton and berries - has decreased since the 1980s. Even with minimal soil salinisation, cotton productivity can decrease by 50-60%, barley by 30-40%, corn productivity by 40-60%, and wheat by 50-60% (Askarova 2002). Total reduction in crop yield from irrigated areas caused by soil salinisation was 30% in Uzbekistan, 40% in Turkmenistan, 18% in Tajikistan, 30% in Kazakhstan, and 20% in Kyrgyzstan (Abdulkasimov et al. 2003). In addition, the productive quality of irrigated lands in Central Asia is declining due to toxicants deposited by contaminated water being washed onto the low-lying areas of the region.

Health impacts

There has been an increase in the rate of morbidity and the spread of disease in the region. Populations residing within the coastal zone of Kazakhstan and Uzbekistan have experienced a permanent increase in respiratory, infectious and internal diseases (Khasankhanova & Abdullaev 2001).

The issue of deteriorating water quality is having a detrimental impact on the health of the population of the Aral Sea Basin. This is most prominent in the lower reaches of the Amudarya and the Syrdarya, especially in the ecologically unstable territory of Priaralye. Serious health problems concerning the population of Priaralye were registered at the end of the 1980s (Rudenko 1989). The mineralisation of drinking water was equal to 2-4 g/l and bacteria exceeded MAC by 5-10 times. By the end of the 1980s the health of the population in the region had reduced dramatically; 60% of the local population examined had serious health problems, 80% of pregnant women suffered from anaemia, and cases of infant mortality were 82 per 1000 children born alive (Glantz 1998; Rudenko 1989). The incidence of tuberculosis, mortality from infectious and parasite-caused diseases as well as infant mortality is much worse in Priaralye than in the rest of the region. From the 1970s to the 1980s the death rate in different areas of Priaralye increased by a factor of between 3 and 29 (Tsukatani 1998). In addition, pests are abundant in the desert zone of Priaralye and act as a vector for diseases. For example, in 1999, 4 cases of plague and two cases of Crimean gemmorogical fever were registered in Kyzylorda oblast (Tokmagambetova 2000).

A major factor causing the high level of morbidity is the mineralisation of drinking water and the high concentrations of chemical fertilisers, pesticides and defoliants introduced into cotton fields, such as the DDT, methyl mercaptophos, ostametyl, dutifos, milbex, hexachlorane, lenacil, and ronit (Ro-Neet), Yalan which are contaminating surface and groundwater supplies and the atmosphere.

Furthermore, the disinfection of drinking water using chlorine causes the formation of the highly hazardous organo-halogen compounds in concentrations that exceed local health standards 2-4 times. The genotoxicity of mother's milk, revealed in the urban areas of Nukus and Turtku, is likely connected with the use of chlorinated water.

These pollutants are also contaminating food products. As early as the mid 1980s pesticides, mineral fertilisers, various microorganisms and their toxic derivatives became the main pollutants of food products in Kazakhstan and particularly in Priaralye (Sharmanov 1998). Analysis of different fish species caught in the Syrdarya delta showed an increase in the concentrations of insecticides and heavy metals in their organs and tissues.

Increased concentrations of lead, cadmium and manganese have been found in children's organisms, resulting in considerable damage to the functions and structure of their cells. The number of people suffering from oncological diseases is increasing at an alarming rate. For example, in Kyzylorda oblast 800 people reportedly suffer from oncological diseases every year; primarily from oesophagus cancer (46.6 cases per 100,000 people) and stomach cancer (Tokmagambetova 2001). A significant correlation (0.80-0.99) between the salt composition of drinking water and the number of oncological oesophagus diseases has been established.

Poor quality drinking water is recognised as a major factor for the high morbidity rate in the region. This conclusion is supported by the data of figures 6 and 7, which show a correlation between the percentage of infant mortality and mortality from infectious diseases in Karakalpakstan and Khorezm oblast (data presented by the Public Health Ministry of Uzbekistan) and the disparity of water quality from the standards of Uzbekistan (Khasankhanova & Abdullaev 2001). A deviation in water quality from the standards by only 25% causes an increase in mortality from infectious diseases by 25 to 60 cases per 100 000 people (Figure 6). As the deviation from water quality standards increased from 20% to 80%, infant mortality increased from 18-20 to 50-55 per 1 000 live births (Figure 7).

In the majority of the Aral Sea Basin sanitary conditions are similar. For example, in Kyrgyzstan, where in general the ecological situation exceeds that of Priaralye, the sanitary-epidemiological situation is relatively poor. Every year more than 200 000 cases of infectious diseases are registered in this republic. The number of reported cases of acute intestinal infections (20.4% in 2000) and hepatitis (9.3%) is also very high, especially in the areas with an insufficiently developed central water supply network. The main reason for this situation is poor water quality, with drinking water receiving inadequate treatment. About 36% of water supply sources in the republic have inadequately wide sanitary protection zones, more than 8% of water supply receives no treatment and more than 60% of water does not pass preliminary disinfection. Overall 700 000 residents (1/6 of Kyrgyzstan's population) are not connected to the central water-pipe network. The unsatisfactory state of rural water-pipes obliges the population to use water from surface water reservoirs and irrigation systems (Vashneva & Peredkov 2001).

As a consequence, the incidence of acute intestinal diseases is very high in Kyrgyzstan. The sanitary-epidemiological situation in the Osh oblast is particularly alarming, due to it having the fewest number of houses with access to running water in Kyrgyzstan. The incidence of common intestinal diseases in Kyrgyzstan (382.2-637.7 per 100 000 people between 1990 and 1999) is often greater than that of Priaralye. During the last decade only in Kyzylorda oblast did cases increase more persistently than in Kyrgyzstan. Cases of enteric fever have been recorded in Kyrgyzstan and in 1998 there was an outbreak of enteric fever with 1 200 cases (Vashneva & Peredkov 2001).

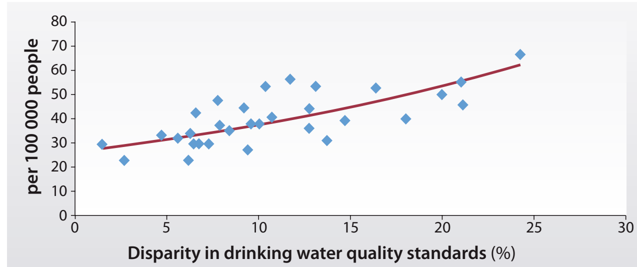

Figure 6 Correlation between mortality from infectious diseases (per 100 000 people) and a deviation of water quality from the accepted standards.
(Source: Khasankhanova & Abdullaev 2001)

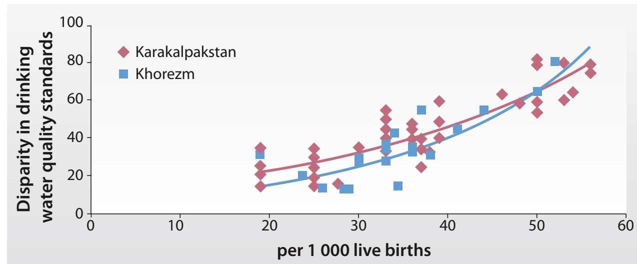

Figure 7 Correlation between infant mortality rate (per 1 000 live births) and a deviation of water quality from the accepted standards.
(Source: Khasankhanova & Abdullaev 2001)

The declining quality of the region's water resources has been a primary cause of the deterioration in the health status of the region, but socio-economic factors and the general degradation of the region's environment have also played an important role. Since the beginning of the 1990s, higher unemployment, a reduction in family income and associated poverty and unbalanced nutritional intake, combined with a degrading medical service have undoubtedly affected the health of the region's inhabitants.

Other social and community impacts

Many communities have lost the recreational and amenity value of their local environment due the reduction in species diversity. The social and cultural integrity of communities in the most affected areas has been threatened by the deterioration in the environmental quality of the region. Pollution has led to a loss of ecosystem services resulting in increased unemployment, greater prevalence of diseases and economic hardship. The quality of agricultural products, and subsequently their nutritional value, has been reduced. Governmental support has been required to assist the public and implement remediation measures.

Overall, other social and community impacts of pollution were assessed as moderate.

Conclusion and future outlook

Overall pollution was considered as severe. The issue of chemical pollution has the most devastating transboundary impacts. The excessive application of agro-chemicals is compromising water quality as drainage water from the irrigated fields is discharged into surface water and leaches into groundwater supplies, thus increasing mineralisation and salinity, particularly in the lower reaches of the rivers. Industrial, mining and domestic waste is inadequately disposed and contaminates aquatic ecosystems. Pollution is hindering economic development and increasing the prevalence of disease. Unless effective measures are established and adhered to, the extent of pollution in regional surface and groundwater is expected to increase in the future.

IMPACT Habitat and community modification

Large-scale irrigation projects, particularly for cotton production, have resulted in significant habitat modification, especially in the vicinity of the drying Aral Sea. The ecosystems of the Sea have been severely degraded, particularly those of the Syrdarya and Amurdarya river deltas. Habitat modification has been largely caused by the diversion of freshwater resources for irrigated farming and the pollution of existing water supplies, and therefore this concern needs to considered with the freshwater shortage concern.

Environmental impacts

The drying-up of the Aral Sea has resulted in: a more arid climate, with an intensification of desertification; increases in groundwater mineralisation and the salinisation of soils; greater wind blown salt and dust from the dried-up sea bottom; and a sharp reduction in biodiversity. The Syrdarya and Amurdarya deltas have suffered the greatest impacts. The area of natural lakes in the Amudarya and Syrdarya delta were reduced from 640 and 833 km^2 to 80 and 400 km^2, respectively. Alluvial-meadow and marsh-meadow soils were transformed into meadow-takyr and meadow-desert soils. Over 1 million ha of flood-lands have dried-up and the productivity of reeds have decreased by a factor of 30-35. The area of Tugai forests was reduced by almost 90% as a result of reduced water availability. Consequently, 18 species of higher plant were lost, and 54 species of higher plants are now threatened with extinction, including relict and endemic plants. The degradation of nesting sites resulted in a severe reduction in bird fauna in river deltas from 173 to 30 species (Amirgaliev & Ismukhanov 2002, Ashirbekov et al. 2002, Askarova 2002, Bakhiev & Treshkin 2002, IFAS 2000, Novikova 1999, Novikova et al. 2001).

Changes to the Aral Sea ecosystem

The reduction of the water inflow to the Aral Sea has resulted in irreversible changes to the Sea's hydrological and hydrochemical characteristics and its ecosystems. The changes in the saline balance have trebled the salinity, and subsequently transformed the Aral Sea into a biological desert.

The early 1980s witnessed great changes in water fauna. The freshwater and brackish water fauna, for example phytoplankton and zooplankton species, were replaced by more salt tolerant marine and haline species. There has been a four to five-fold reduction in microorganisms (bacteria and yeast) that inhabit the waters and saline sediments. The population and biomass of the phytoplankton decreased three to five-fold, and was replaced by diatom algae. The diversity of zooplankton was also impoverished, but its biomass remained at a similar level. Even more striking shifts were observed in the macro-zoobenthos. In the late 1970s, colonising marine species from adjacent saline waters practically replaced the indigenous species. 44 species existed in the benthos in 1970, 15 in 1978, and 32 in 1982. When the mean salinity of the sea exceeded 17‰, only 9 species remained from the native fauna (Aladin & Kotov 1989, Aladin et al. 2001).

The ichthyofauna of the Aral Sea has undergone considerable changes. The addition of colonising fish has increased the number of fish species from 20 to 34. Previously the dominant species were freshwater fish, including bream, sazan, vobla (Caspian roach) and harbel. The continuing salinisation of the sea has not favoured reproduction, resulting in decreased catches (except of pike, perch and chub). In the early 1960s the fish catch in the Aral Sea was 46 000 tonnes per year (over 15% of the total freshwater catches in the USSR), of which nearly 70% was large fish. By 1970 annual catches had fallen from 41 000 to 10 000 tonnes and in the early 1980s the total catch had fallen to 1 000 tonnes. Nowadays fishing has practically ceased altogether (Aladin 1999).

An increase in salinity to over 23‰ has led to the brackish water Caspian invertebrates dying out or retreating into the delta waters. The only survivors were the marine forms and salt-tolerant hydrobionts, which arrived in the Aral Sea from hypersaline waters. In recent decades the invertebrate fauna has consisted exclusively of colonising species, the majority of which have remained untouched due to the exhaustion of fish stocks. Today, salinity in the Big Aral Sea is nearly

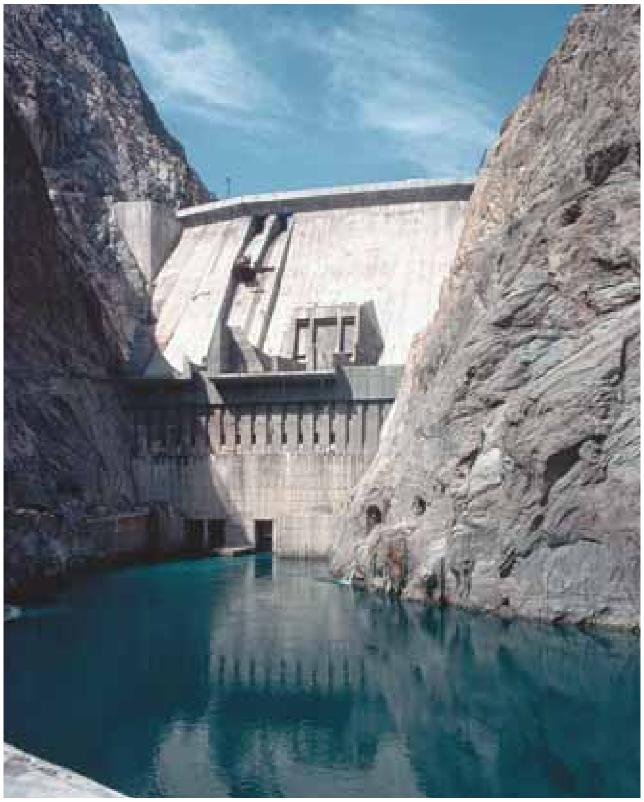

Figure 8 The Toktogul hydroelectric dam on the Naryn (Syrdarya) River, Kyrgyzstan.
(Photo: CORBIS)

63‰ and consequently very little is able to survive in these waters (Zholdasova 1999).

The drained tract of the Aral Sea Basin is characterised by a lower biodiversity in comparison with the coast. Among the plant species of the Aral Sea coast, 30 species are valuable fodder plants, there are more than 30 species of medicinal plants and 31 species of weed plants. More than 60 species of local flora are potential phytomeliorants for the dried coasts (Novikova 2001).

The area affected by irrigation practices is not restricted merely to the land which is actually irrigated but instead includes the feed source (the river), the reservoirs, the main and subsidiary canals, the man-made lakes (for accumulation of the collector-drainage waters) and the river valleys, deltas, and final lakes. All these components of irrigation cause significant changes in the region's terrestrial and aquatic ecosystems (Bakhiev & Treshkin 2002, Novikova 1999, Novikova et al. 2001, Treshkin 2001).

The development of irrigated agriculture in the Aral Sea Basin has replaced natural desert ecosystems of an area of 7.2 million ha with agricultural coenoses. To regulate water feed to the fields, reservoirs (Chardara on the Syrdarya River; Takhiatash and Tyuyamuyun on the Amudarya River) were created, inundating 277 000 ha of floodplain and desert ecosystems. Furthermore, canals were created, destroying 40 000 ha of the natural environment. The total length of the irrigation and drainage channels in Uzbekistan is 180 000 km. Thus, as a result of irrigation development over the last 30 years, approximately 4.5 million ha of natural ecosystems have been lost, with a total biological productivity of 5.4 million tonnes (including 1.8 million tonnes of useful products). The total biological production of the agro-coenoses on irrigated areas is 120 million tonnes, 10 million tonnes of useful production (Kuksa et al. 1991).

Changes in the biota, unforeseen and often disregarded during the planning of projects, are associated with raising the water table by irrigation. In removing the collector/drainage waters from the oases, 530 000 ha of desert ecosystems have undergone flooding, waterlogging and salinisation. Thus, as a result of the processes accompanying irrigation, salty solonchak-type ecosystems have developed on an area of 4.06 million ha, where weedy halophile mixed herbs and halophile shrubs and sub-shrubs dominate, with an impoverished diversity of fauna. Remembering that about half of the present irrigated lands have become saline and parts of them are not sown every year, the total area of anthropogenic solonchak systems approaches 5 million ha.

A change in the water balance of the rivers and increased water mineralisation has resulted in the loss of unique biocenosis and a number of endemic animal species. Until 1960 over 70 species of mammals and 319 species of birds inhabited the river deltas. Nowadays these numbers have been reduced to 32 species of mammals and 160 species of birds. In the low-lying areas of Syrdarya more than 100 000 ha of alluvial soils have become alkali soils and more than 500 000 ha of wetlands have dried up. This has resulted in the modification and destruction of 5-7 food sources for sheep, goats, horses and camels (Saiko 2000).

Changes to the wetland (tugai) ecosystem

Syrdarya delta

The ecological changes to the Syrdarya delta began slightly earlier than in the Amudarya delta. As early as the 1960s, the renewable water resources of the Syrdarya Basin were fully exploited, and in the 1970s this level was exceeded as return waters also began to be exploited. The further increase in river-water abstraction led to a reduction in flow in the lower reaches of the delta. In the late 1970s, only an average of 4% of the annual resources formed in the catchment area actually entered the Syrdarya delta. The summer-spring floods on the Syrdarya ceased as early as 1971. Simultaneously, there was a rapid fall in the level of the Aral Sea, which led to desertification on the delta plain. By 1978 approximately 114 000 ha of alluvial meadow soils had turned into solonchaks and 532 000 ha of marshy and meadow-marshy soils had dried out and 31 000 ha had become desert. Thus, 732 000 ha effectively went out of agricultural use. The productivity of the grass/mixed-herb and mixed-herb meadows was reduced to one-third of its former level (Bakhiev et al. 1987).

Formerly rich areas of hydrophile vegetation (hay and fodder areas) died on a large part of the delta. Total fodder resources fell from 1.5 to 0.5 million tonnes. The area of riparian woodland was halved, and the remaining was severely degraded and desertified. Desert species of plants and animals started to expand in the delta and floodplain, and impoverished desert ecosystems began to form (Novikova 1999). Colony-forming birds relocated away from the lower reaches of the Syrdarya.

Amudarya delta

The reduction in river flow following the construction of the Takhiatash and Tyuyamuyn reservoirs and the excessive use of water in irrigated areas has modified the delta and floodplain environment. The area occupied by plant communities found in the floodplain habitats only under annual spring-summer flood inundation was reduced from 35% to 8% and plant communities characteristic of periodically flooded habitats above the floodplain were reduced from 40 to 20%. At the same time, the number of communities associated with salinised and desertified parts of the floodplains and delta rose from 25 to 75% (Novikova 1999).

Vast reed thickets occupied more than 300 000 ha in the Amudarya delta. They were a rich habitat for bird fauna, inhabited by 21 species of waterfowl (including 11 nesting species, the Khivin pheasant, 9 species of waders, including spoonbills), several species of raptors and more than 10 species of passerine birds. Wild boar and reed cat were widespread and until the late 1930s the Central Asian tiger inhabited the flood plains. By the mid 1980s the area of reed thickets had reduced five-fold, and the green weight yield decreased from 30 000-40 000 kg/ha in the 1960s to 4 000-12 000 kg/ha in the 1980s. The populations of reed dwelling animals were considerably depleted. By the 1980s the wild boar population had declined almost six-fold (Kuksa et al. 1991).

In the maritime area of the delta, a large muskrat population inhabited lakes. In the early 1980s this whole network of lakes had dried up, putting an end to hunting and trade. The muskrat continued to be caught on a non-commercial scale until 1990 on Lakes Togus -Tore and Sudochye.

With the persisting and worsening aridity and desertification of the environment in the Amudarya river delta, the productivity of the meadow and pasture communities continues to decline in the current environmental conditions of the Aral Sea region.

Desertification in the delta is leading to the replacement of highly productive reed communities by mixed communities of low growing reed, annual *Salsola* spp., often by bushes of tamarix and in some places by *Karelinia caspica* and *Alhagi pseudalhai*. The yield of these communities does not exceed 400-500 kg/ha. By 1985 only 70 000 ha of watered reedy hay lands remained in the Amudarya delta. Commercially valuable reed areas can only be preserved by irrigation on the bottom of the drying up lakes and depressions between the streambeds for about 2 months a year.

The increasing aridity of the Amudarya floodplain and delta, and the practice of unsustainable forestry have threatened the existence of the unique riparian woodland ecosystems. In the early 1930s the riparian woodlands occupied 300 000 ha in the lower reaches of the River, but by 1986 this had been reduced to 33 000 ha. In 50 years their area within the lower reaches and Amudarya delta had decreased by nearly 90%. The degradation and loss of the riparian woodlands gained impetus in the late 1970s and 1980s. In 8 years (1978-1986) the area of riparian forests in the delta halved. The rate of mortality of the riparian woodland reached a "record" of 5 778 ha per year. Today these forests form less than 3% of the total forest resources of Karakalpakstan. Many of the stands that have persisted are now dieing, and illegal felling continues (Treshkin & Kuzmina 1993).

Floristically the Amudarya riparian forests are the richest ecosystem in Central Asia and include 567 species of higher plants, including 29 endemic species and many relict plants of the Tertiary geological period. Presently, the profound disruptions in habitat have led to the near extinction of 54 species of plants (in 46 genera and 26 families). Even by the end of the 1980s, white and yellow water-lilies, *Aldrovanda*, *Agropyrum repens*, and ferns no longer existed (Novikova 2001).

The number of mammals has declined. The Khangul-Bokhara deer, the typical inhabitant of the riparian woodlands, has virtually disappeared from the wild. Only about 10 semi-wild deer in the Baday-Tugai reserve survive today.

Environmental degradation has resulted in a reduction in the trophic potential for birds and mammals. The fish mortality in the Aral Sea and the impoverishment of food sources in the delta waters makes survival difficult for fish of higher trophic levels and insectivorous birds of the water-swamp ecosystem.

There was widespread migration of waterfowl and aquatic-swamp birds both within the Aral Sea region and further a field. As early as 1978, a complex of birds including thousands of red-legged and red-crested pochards and river ducks, whooper swans, spoonbills, cormorants and white and Dalmatian pelicans left the Syrdarya delta, which had lost its flooded areas, and migrated to the Turgai lakes, 350-400 km north. The total number of species which relocated amounted to several hundred thousand (Zaletaev 1989).

Socio-economic impacts

Economic impacts

The impacts caused by habitat and community modifications affect practically all economic sectors. Considering the significant and continual damage caused by this concern, and the high gravity of the consequences, economic impacts were assessed as severe.

Changes in vegetation caused a reduction in pasture productivity from 1.2 million to 600 000 tonnes, and the productivity of cereal mixed-grass meadows and mixed-grass meadows decreased three-fold. Commercial use of water-marsh areas has ceased completely (Kuksa et al. 1991).

Desertification led to a decline in the areas of hay and pastures and a reduction in their yields. Since 1960, the area of hay was reduced from 420 000 ha to 70 000-75 000 ha by the end of the 1980s. Along with this 6-fold reduction in area, the hay yield on the periodically watered areas fell from 1 500-4 000 to 300-1 600 kg/ha (dry plant weight) and to 70-80 kg/ha on the non-watered decertifying areas. Only a third of pastures in the Amudarya delta remained, falling from 348 000 to 120 000 ha, and pasture productivity fell from 100-1 400 to 50-500 kg/ha. The reason for the sharp fall in biological productivity of the meadow communities in the Amudarya delta was the reduction in water supply to the terrestrial ecosystems by 3-4 classes according to Ramenskii's scale, from moist-meadow to dry-steppe and desert (Novikova et al. 1998 & 2001).

In the Syrdarya Basin the commercial potential of the water-marsh areas was lost. In the 1950s the yield of muskrat skins was 70 000 to 230 000. In 1968 this figure was reduced to 9 000 skins, and by 1978 only 72. There is now no muskrat trade (Kuksa et al. 1990).

In the Aral Sea itself, salinisation has led to a severe decline in the fisheries. Fish catches fell from 46 000 tonnes in the early 1960s, to 10 000 tonnes in the 1970s and by the 1980s only 1 000 tonnes were landed. Today, the fisheries industry has practically collapsed (Aladin 1999).

Health impacts

Habitat and community modification has had detrimental effects on the health of the population. In areas where severe habitat modification has occurred, living conditions have deteriorated, and subsequently incidences of anaemia, diminished thyroid function, and renal and liver diseases has increased. The morbidity rate over the last 10-12 years has been permanently rising and this trend is predicted to continue. The decline in productivity of the regional ecosystems has reduced their nutritional value for humans, for example, from pasture lands and the fisheries. The health impacts associated with this concern were assessed as severe.

Other social and community impacts

The population of the region is now forced to survive upon poor quality and scarce food supplies. The ecosystems have lost their assimilate capacity for human activities, and it has become difficult to utilise alternative territorial resources without inflicting further environmental degradation. The employment structure has changed as individuals are forced to adopt alternative livelihood strategies due to the collapse of traditional industries, such as the fisheries. There has been a loss in the cultural and recreational value of the natural environment for the communities of the region. The impacts are occasional but long-term, and the degree of gravity is medium. Overall, other social and community impacts were assessed as severe.

Conclusion and future outlook

The modification of habitats has been severe in the Aral Sea region. However, it is primarily a function of freshwater shortage rather than a result of direct habitat modification by humans. For example, the loss and modification of the habitats associated with the Aral Sea and the river deltas is attributed to the reduction of stream flow as a result of water abstraction for irrigation purposes. This concern was therefore not selected as the region's priority concern despite its severe environmental and socio-economic impacts.

The intensity of anthropogenically induced desertification, secondary soil salinisation and destruction of the region's biodiversity, especially in Priaralye, has not decreased in recent years. Since the end of the 1980s no research has been carried out in the zones of run-off formation, and there is little information available on the degradation of mountain ecosystems (i.e. concerning reductions in the area of woodland vegetation and intensive erosion). Furthermore, the recreational amenity provided by the mountain regions is being developed; if this is not sufficiently regulated there may be ecological consequences. According to GIWA experts, besides developing a network of protected areas for conservation in all countries of the region, the rehabilitation of degraded ecosystems necessitates the establishment of national and regional ecological programmes aimed at evaluating ecosystem degradation and understanding the dynamics of natural processes in order to identify the impacts of development trends and future proposals.

IMPACT Unsustainable exploitation of fish and other living resources

The fishing industry has practically collapsed in the Aral Sea Basin. Annual fisheries production declined from 46 000 tonnes in the early 1960s to 1 000 tonnes in the 1980s and today very little fishing is practiced. There have also been significant changes in the taxonomic composition and diversity of fish species. For example, freshwater species have been replaced by more salt-tolerant marine and haline species. However, this has not been the result of the unsustainable exploitation of fish and other living resources, but resulted rather from the habitat and community modification concern. This in turn has been driven by the diversion of water for irrigated agriculture, which has prevented the sufficient allocation of water for the downstream habitats of fish and other aquatic organisms.

Environmental impacts

The former thriving ecosystem, which supported 24 game fish species, has been severely impoverished. Fish species included carp, grouper, sturgeon, salmon, met sheat-fish and sea-pike. The fishing industry was based primarily on the three fish species: bream, carp, and Aral dace. In the Aral Sea, the valuable fish species of sawyer and white-eye fish were fished near the coastal areas and in the lower reaches of the rivers. Changes in the saline structure of the Aral Sea and a loss of biota have resulted in the collapse of the fishing industry in the Sea by the year 2000, although some fishing still continues in the water bodies of the Syrdarya and Amudarya basins.

Since the mid-1970s members of the Aral department of Kazakhstan Scientific and Research Institute of Fisheries have conducted research into salt-affected fish species, including Caspian sturgeon, kurin salmon, azov and chernomor plaice-gloss and plaice-calcan. With its high ecological plasticity and ability to spawn in water with a salinity level of 17-60‰, the plaice-gloss has proven the most successful species to survive in the current physical conditions. Today, the plaice-gloss accounts for more than 30% of the total amount of fish caught in the Aral Sea.

Socio-economic impacts

Economic impacts

The decline in the fisheries has impacted the economy of the region due to the importance of the industry to many communities. The impact on the regional GDP from the collapse of the fishing industry can be assessed as medium to high. However, it should be noted that the economic impacts have been primarily a result of environmental changes rather than the overexploitation of fish.

Health impacts

This concern has limited direct affects on the health of the population, and there is consequently limited available data.

Other social and community impacts

Fishers surrounding the Aral Sea have been forced to migrate or change their livelihood strategy as the Sea receded. The communities have lost a valuable source of nutrition and income, in addition to the loss of many other ecosystem services. Consequently, the quality of life for these communities has been diminished.

Conclusion and future outlook

GIWA experts agreed that the concern of unsustainable exploitation of fish and other living resources is irrelevant and non-applicable to the region under the current freshwater shortage scenario.

The restoration of marine biota may be possible following the construction of the Kokaral Dam which will considerably raise the water level of the Small Sea. Opportunities to improve the ecological situation in the critical zone of Priaralye, as well as in the entire basin, are dependent on freshwater availability and the allocation of water. In order to rehabilitate the fisheries water needs to be equitably distributed, the sea level needs to be regulated and sufficient minimum discharges from the Amudarya and Syrdarya need to be maintained.

IMPACT Global change

Environmental impacts

Changes in the hydrological cycle

Variations in precipitation and temperatures

The recession of the Aral Sea has, to a certain extent, changed the climate of the Aral Sea region (Molostnova et al. 1987, Zolotokrylin &

Figure 9 Beached boat in a part of the Aral Sea which was once covered in water.
(Photo: SPL)

Tokarenko 1991, Zolotokrylin 2003). Summer and winter air temperatures at measuring stations near the shore have increased by 1.5-2.5°C and diurnal temperatures have increased by 0.5-3.3°C. At coastal stations the mean annual relative air humidity decreased by 23%, reaching 9% in spring and summer. The number of days the region experienced drought increased by 300%.

The annual cycle of precipitation has also changed. In 1959 maximum precipitation fell during February and March and the minimum in September, whereas between 1970 and 1979 the maximum was observed in April and the minimum in July. A three-fold increase in reflected solar radiation in the Aral area due to a seven-fold rise in the albedo of the area previously occupied by the Aral Sea has contributed to the increase in climate continentality (Kondratyev & Donchenko 1999). Although the drying of the Aral Sea and anthropogenically induced global warming have played roles in changing the climate, the temperature increases and changes in precipitation rates recorded over the last 40 years in Southern Priaralye are more likely a reflection of natural cyclic fluctuations in the climate (Zolotokrylin 2003).

According to estimations by the Intergovernmental Panel on Climate Change (IPPC), the mean global temperature of the atmosphere has increased by 0.3-0.6°C during the last century. This factor, together with rising trends in the concentration of CO_2 in the atmosphere, has led to conclusions that the climate, including that of Central Asia, will warm up significantly in the immediate decades resulting in further environmental changes (Chichasov & Shamen 1997, Eserkepova et al. 1996, Chub 2000).

According to predictions, the water resources in the main watersheds of Kazakhstan will reduce by at least 20-22%, droughts will increase in frequency, and the grain crop productivity will decrease by 20-23%. The scale of probable alterations in the availability of water resources in the Aral Sea Basin according to four established scenarios of climate changes is rather broad, ranging from positive values (GFDL model) to a decrease in the Syrdarya run-off by 25% and the Amudarya run-off by 40%. It is obvious that such a decrease in water resources will result in serious consequences for the countries of the region.

Contemporary and predicted changes in snow-ice and renewable water resources

In Central Asia melted snow and ice water contribute to the formation of renewable water resources. Therefore the evaluation of possible changes in water resources in the foreseeable future requires a reliable prediction of the changes in snow resources. According to analysis in Northern Tien Shan, over the last decades the average maximum snow-water equivalent (the main component of snow resources) has not changed (Pimankina 1998, Schröder & Sevrskiy 2004). Similar results were found by Artemjeva and Tsarev (2003) for Western Tien Shan and Gissaro-Alai. In addition, the volume of river run-off has also been consistent (Schröder & Sevrskiy 2004, Chub 2000).

The situation concerning the evaluation of the dynamics of ice resources is more complicated. Investigations (Shchetinnikov 1993, 1998, Shchetinnikov & Likhacheva 1994, Dikih 2001, Dikih et al. 2001, Vilesov & Uvarov 2001, Cherkasov 2002, Cherkasov et al. 2002, Durgerov et al. 1997, Glazirin & Kodoma 2003, Severskiy & Tokmagambetov 2004) confirm that the glacial systems of Central Asian mountains develop in the same direction and have similar rates of change. Therefore, over the last few decades the area of glaciers in different regions of Tien Shan, Gissaro-Alai, Pamirs and Dzhungarskiy Alatau has decreased at the average annual rate of 0.8-1.0% (Shchetinnikov 1993, Shchetinnikov & Likhacheva 1994, Dikih 2001, Cherkasov 2002, Severskiy & Tokmagambetov 2004). These results therefore suggest that contemporary and prognostic changes in ice resources of Central Asian mountains can be assessed using the example of a single representative area that has reliable information on its glacier dynamics. In Central Asia one such area is the Balkhash Lake Basin (southeast Kazakhstan and China). The state of the glaciers of this basin was analysed for 1956, 1972 (the Dzhungarskiy Glacier System), 1975 (the Zailiyskiy-Kungeiskiy Glacier System) and 1979, and 1990 (the Northern Slope of Zailiyskiy Alatau's glacier system).

According to the results of the comparative analysis the average annual rate of decrease in the glacier area on the northern slope of the Zailiyskiy Alatau was 0.92% between 1955 and 1990 and the decrease in the net glacier volume was 1.0%. As previously mentioned, ice resources of the Ili-Balkhash Lake Basin have decreased by more than 30%. The rate of glacier retreat has not remained constant over the last few decades. An increase of nearly 50% took place between 1975 and 1979, in comparison with the previous 20 years. The rates of glacier retreat has continued to increase, however not so sharply. Similar glacier characteristics were observed for the Jazgulem River Basin on the Western Pamir (Glazirin & Kodama 2003). Moreover, this is consistent with data from recent research (Batyrov & Yakovlev 2004). Glacial retreat in four large basins of Gissaro-Alai between 1980 and 2001 is half the rate of that over the period 1957-1979. Thus, the increasing rate of glacier retreat slowed between the mid 1970s and the early 1980s.

As the level of precipitation in the mountains of Central Asia has remained constant, there is a basis to assume that the reduction in the rate of glacier retreat can be attributed to the rise in air temperature. There is further evidence from long-term observations of the perennial permafrost in Zailiyskiy Alatau. According to this data, the temperature of the top layer of the perennial permafrost increased steadily during the 1970 and 1980s and has stabilised since the mid-1990s.

If glaciers continue to reduce in area and volume at the current rate, it can be assumed that by the middle of the 21st century the glaciers on the mountains of Central Asia will reduce by only one third and will not disappear by the end of the century as was previously expected (Cherkasov 2002, Dikih 2001, Glazirin 1996, Golodkovskaya 1982, Vilesov & Uvarov 2001). Taking into account the recurrence of the climatic cycles over the last 100 years in the region, there may be more favourable climatic conditions for glaciation in the future.

Changes in glaciation were confirmed by the results of the comparative analysis of photogrammetric surveys of the glaciers in the Small Almatinka River Basin carried out by German experts between 1958 and 1998. The thickness of ice on each glacier has been significantly reduced over most of their extent. For 40 years the thickness of the bottom layer of the Tuyuksu tang glacier, for example, has decreased by more than 45 m, and total losses of ice amounts to more than 40 million m^3 (Eber et al. 2005). A reduction in the thickness of the buried parts of glaciers is also typical.

Similarly, on the majority of the area of a zone of a feed of glaciers the mass balance of ice for the specified period was close to zero (changes have made from - 5 up to 5 m). Moreover, according to a survey of 1998 in a zone of a feed of all glaciers significant sites on the area where the mass balance for the specified period appeared positive. The common increment of thickness of ice (firn) in a zone of a feed of Tuyuksu glacier has made 15-25 m. Last circumstance in a combination to stability of norms of an atmospheric precipitation gives the basis to assume probability of forthcoming change of a sign on mass balance of glaciers with negative on positive.

The fact that despite a considerable reduction in glacier resources the flow rates of the main rivers have practically not changed in recent decades suggests that there is some compensating mechanism. One explanation is that water from the melting of underground ice has accumulated as perennial permafrost. The area covered by perennial permafrost in Central Asia is many times greater than the area of present-day glaciers (Gorbunov & Severskiy 1998, Gorbunov et al. 1997). Therefore even slight melting of the permafrost could compensate for the loss of water caused by the reduction in the region's glaciers. Until now this has not been considered by the scientific community and deserves further attention given the importance of freshwater availability on the ecology and socio-economic development of the region.

There are at least two pieces of evidence that suggest such a mechanism exists. According to the results of long-term geocryological studies carried out at the Zhusalykezen Pass (Northern Tien Shan, Zailiiskiy Alatau Range) between 1973 and 1996, the temperature of frozen grounds has increased significantly. Although there have been significant inter-annual fluctuations, in Northern Tien Shan there have been general trends of rising annual ground temperatures, increased depths of thawing and decreases in the thickness of the seasonally frozen layer (Gorbunov et al. 1997). The ground depth of seasonal thawing, measured in boreholes at the Zhusalykezen Pass, increased by over 1.1 m between 1973 and 1996 (Gorbunov et al. 1997). Thus, for the specified period melt waters from a 1.1 m thick layer of recently frozen ground may have contributed freshwater to the run-off in the Aral Sea Basin.

Isotope analysis used to study the genesis of water resources also gave evidence of a compensatory mechanism. According to the results of the study, 40-50% of water, and in some cases all of the water, in the lake-dam complexes of alpine areas of Kyrgyzstan (Top-Karagai, Tuyuk-Tor, Kashka-Suu) are comprised of melt-water from buried moraine ice (Tuzova 2002).

Socio-economic impacts

Since the 1960s, climatic variations have changed the community structure of flora and fauna in the region. A reduction in the biodiversity and quality of freshwater has been caused by increasing salinity. The greater aridity of the territory surrounding the Aral Sea has reduced agro-productivity and resulted in the loss of ecosystem services. Consequently, the employment structure has changed and there are fewer investment opportunities.

There is not sufficient evidence to suggest that global climate changes are responsible for all these impacts. There is no doubt that the primary factor responsible for the acute aggravation of the ecological and socio-economic situation in the Aral Sea Basin is freshwater shortage as a result of the modification of stream flow rather than a consequence of global climate changes.

There is no proof to suggest that there is a link between global changes and the health status of the region's population. There is cause to hope that the present upward trend in average annual air temperatures may start to reduce during this century and consequently improve the environmental conditions of the region.

Conclusion and future outlook

The impacts from the concern of global changes were assessed as slight. Present-day warming reflects a cyclic trend in the climate and the role of the anthropogenic component in this process is not believed to be as significant as often diagnosed. Hence, there is not enough evidence to rely on the predicted warming of between 2 and 6°C in the next few decades.

The conclusions differ considerably from contemporary and prognosis changes of climate and renewable water resources. Contrary to the established estimations which state that due to global warming, regional water resources will reduce by 20-40% in the near future (Chub 2000, SPECA 2004), there are grounds to argue that the volumes of river run-off will remain stable, at least over the next few decades.

Gradual air temperature increases are believed to be attributable to natural climatic changes. The glacier resources in the mountainous countries of Central Asia have reduced by more than one third during the last 30-35 years. Scientific explorations confirm that glacier resources in the Tien Shan Mountains have reduced over the past 30-40 years; by 0.92% in area and by 1% in volume annually (Severskiy & Tokmagambtov 2004). Experts predict that this process will continue for at least 100 years (Cherkasov 2002).

For the past 40 years the maximum snow storage (snow-water equivalent) volume has remained constant and the volume of river run-off has not changed significantly. The reduction in the area of glaciers has changed the inter-annual distribution of run-off, as it now contributes slightly less run-off during the vegetation period.

Despite a considerable reduction in glacier resources, the flow rates of the main rivers have remained relatively constant over the last few decades. One possibility for this could be that water inflow from underground melted ice accumulated in the perennial permafrost, which is now melting and contributing freshwater to the region's rivers. Until now this issue has not received scientific attention, but taking into account the extreme importance of probable changes in water resources as a reaction to climate changes, this aspect of the problem deserves particular consideration.

It has been forecasted that a significant diminution of water resources over the next few decades due to anthropogenic caused warming of the climate is unlikely. There are insufficient reasons to fear significant climate warming, a corresponding reduction in water resources or consequential economic losses.

Though this optimistic conclusion gives us the opportunity to predict the development of the situation in the near future, it does not make the problem less acute: water shortage in the region is one of the limiting factors of sustainable development. However, the water shortages are a result of the diversion of water for human activities rather than a reduction in the supply of freshwater resources. The transboundary nature of these regional water resources is one of the main premises for the development of international processes in Central Asia.

Priority concerns for further analysis

The GIWA concerns were prioritised in the following order:

1. Freshwater shortage
2 Pollution
3. Habitat and community modification
4. Global change
5. Unsustainlable exploitation of fish

Considering the above impacts, the GIWA experts concluded that freshwater shortage was the priority issue in the Aral Sea region, as it is driving the other environmental issues facing the region. The priority issue of freshwater shortage was identified as the modification of stream flow, which by GIWA Task Team estimations accounts for approximately 70% of the development of the concern. The second most important issue for the region is pollution of existing supplies, which, it is estimated, accounts for 30% of the development of the situation in the region.

There has been an abrupt decrease in the natural run-off of the largest rivers in the region - the Amudarya and Syrdarya - which resulted in the rapid drying up of the Aral Sea. This has led to severe habitat modification including deterioration of the landscape, intensive desertification, secondary soil salinisation, an increase in the extent of climate continentality and more frequent recurrence of droughts and dust storms. The above processes caused severe degradation of both water and land ecosystems and a reduction in biodiversity. The impacts are most pronounced in the Priaralye zone.

Causal chain analysis

This section aims to identify the root causes of the environmental and socio-economic impacts resulting from those issues and concerns that were prioritised during the assessment, so that appropriate policy interventions can be developed and focused where they will yield the greatest benefits for the region. In order to achieve this aim, the analysis involves a step-by-step process that identifies the most important causal links between the environmental and socio-economic impacts, their immediate causes, the human activities and economic sectors responsible and, finally, the root causes that determine the behaviour of those sectors. The GIWA Causal chain analysis also recognises that, within each region, there is often enormous variation in capacity and great social, cultural, political and environmental diversity. In order to ensure that the final outcomes of the GIWA are viable options for future remediation, the Causal chain analyses of the GIWA adopt relatively simple and practical analytical models and focus on specific sites within the region. For further details on the methodology, please refer to the GIWA methodology chapter.

Introduction

Freshwater shortage was selected as the priority concern for the Aral Sea region. The focus of the Causal chain analysis (CCA) is to determine the root causes of freshwater shortage in the region and, specifically, the prioritised GIWA issue of stream flow modification, so that the driving forces of the issues can be addressed by policy makers. The Causal chain analysis traces the cause-effect pathways associated with the freshwater shortage concern in the Aral Sea Basin from the socio-economic and environmental impacts back to the root causes. The analysis will consider the entire Aral Sea region due to the spatial scale of the region's freshwater shortage concern and the necessity to manage water resources at the regional level.

Causal chain analysis

Environmental and socio-economic impacts

For further detail of environmental and socio-economic impacts, please refer to the concerns of freshwater shortage and habitat and community modification in the Assessment section.

Environmental impacts include the following:

- By the year 2000 the discharge of the Amudarya had reduced almost ten-fold compared with 1970. As a result, less than 10% of the total area of delta lakes in the Amudarya lower reaches remains (Olimov 2001).
- The area of the Aral Sea has reduced more than two-fold and there has been a sharp decrease in sea level (by mid-2002 the Big Sea had decreased by 22 m).
- The salinity of the Sea's waters has tripled, killing plant and animal life.
- Summer and winter temperatures have become more extreme.
- A severe reduction in biodiversity and a greater concentration of pollution in surface and groundwater supplies.
- The total area of lakes in the Amudarya delta reduced from 300 000 to 30 000 ha and water mineralisation increased to 20-25 g/l, which resulted in an abrupt reduction in fish and animal reproduction.
- Between 1970 and 1999 the area of tugay forests in the Amudarya delta reduced ten times from 300 000 to 30 000 ha (Bakhiev & Treshkin 2002).
- Change in the taxonomic composition of aquatic ecosystems from brackish water species to more salt-tolerant species.

Socio-economic impacts include the following:

- The collapse of a previously well-developed fishery and fish processing industries.
- Industrial development is hindered by the lack and poor quality of freshwater.
- In the Aral coastal zone economic activity has ceased, also affecting inland industries.
- Unemployment has continuously increased.
- Loss and decreased productivity of agricultural and pasture land.
- Epidemiological conditions have deteriorated in the region resulting in greater morbidity.
- As the Aral Sea recedes, it leaves behind a harmful layer of chemical pesticides and natural salts which are blown by the wind into noxious dust storms, seriously affecting the health of the inhabitants of the area.
- An estimated 100 000 people have been displaced due to the poor environmental conditions in the Aral Sea region.

Immediate causes

According to GIWA experts, the following are the immediate causes of the modification of stream flow:

- Increased diversion;
- Reduction in ice resources;
- Inter-annual climate variability.

Increased diversion

The increased diversion of water to supply irrigated agriculture is the primary reason for the change in the regime of the region's major rivers. Between 1960 and 2000 the area of irrigated land increased almost two-fold, from 4.51 million ha to 7.85 million ha. Consequently, by the early 1980s total water intake from the Aral Sea Basin exceeded available water resources, with over 120 km^3 abstracted per year (Kipshakbaev & Sokolov 2002).

Today, there is an annual shortfall of water resources of approximately 17.0 km^3/year, and if the use of return waters is included the volume of consumed water resources actually exceeds available supplies; in the Syrdarya Basin 130-150% of available water resources are used and in the Amudarya Basin, 100-110% (Kipshakbayev & Sokolov 2002). Taking into account inter-annual run-off variability, an estimated 50-60% of surface run-off is a threshold volume in order to sustain current water use in the region. Water availability is at a critical level in all of the countries in the region, and they are highly dependent on climatic fluctuations to meet water demand (Rodina 2002). Irrigated land in the Aral Sea region is expected to increase in the immediate future and by 2020 could reach an estimated 8.4 million ha (Ruziev & Prichodko 2002). Thus, natural run-off resources in the Aral Sea region are fully exhausted and the economy of the region is developing under conditions of increasing water shortage.

The natural run-off regime has only been preserved within the run-off formation zone in the mountains. Further downstream the rivers become increasingly regulated due to water requirements by economic activities. Changes in water run-off have resulted from the construction of numerous water reservoirs for irrigation and power-generation. There are more than 100 water reservoirs with a total capacity of over 74 km^3 in the Aral Sea Basin and numerous ponds and small capacity water reservoirs. The largest are the Tokhtogul reservoir on the Naryn River, with a capacity of 19.5 km^3, Nurek reservoir on the Vakhsh River (10.5 km^3), Tuyamujun on the Amudarya River (7.3 km^3) and Charvak reservoir on the Syrdarya River (5.2 km^3). More recently there has been a switch in the function of the main water reservoirs in Kyrgyzstan and Tajikistan from irrigation to power generation, further altering the regime of the Amudarya and Syrdarya rivers.

Reduction in ice resources

During the last century the extent of glaciation declined on the Central Asian mountains (Pamir, Tien Shan, Gissaro-Alai, Dzhunghar Alatau). Between the 1950s and 1980s, the average annual rate of glacier retreat was approximately 0.9%, and the ice volume of glaciers reduced by more than a third. Contrary to expectations, this has not essentially affected the run-off characteristics of the main rivers in the region: the average run-off and its inter-annual fluctuations over the last 40-50 years have practically remained constant.

Observations of the Tuyuksu glacier (Northern Tien Shan) has shown that the proportion of thawed glacial waters in the total river run-off has gradually reduced, owing to the reduction in the area of glaciers. During the period of glacier retreat there was an increase in melt waters due to the increased thawing of ice in response to a warmer climate. The additional melt water was not enough to compensate for the reduction in glacial run-off due to the decline in the area of glaciers (Vilesov & Uvarov 2001). The dominant factor controlling the amount of glacial run-off was therefore found to be the reduction in glacier area rather than changes in glacial run-off caused by global warming.

The fact that despite the considerable reduction in glacial resources the flow rates of the main rivers have not altered significantly in recent decades suggests a compensating mechanism exists. It is believed that an inflow of freshwater from the melt-water of underground ice accumulates in the perennial permafrost. The area of perennial permafrost is many times greater than the area of present-day glaciers

Figure 10 Peaks rising from a glacier in the Pamirs, Tajikistan.
(Photo: CORBIS)

(Gorbunov et al. 1997, Gorbonov & Severskiy 1998), and therefore even a slight melting of the permafrost could compensate for the reduction in freshwater supply caused by the decline in the area of glaciers. As the area of perennial permafrost repeatedly exceeds the area of modern glaciation, and stocks of underground ice are comparable to the volume of glacial ice of glaciers, it is possible that even if the majority of glaciers disappear, it may not affect the availability of regional water resources, at least not in the forthcoming decades. This has not been adequately studied by the scientific community and is particularly important when considering the influence of climate changes on freshwater resources, particularly if average temperatures increase in the future.

Inter-annual climatic variability

Fluctuations in climatic conditions cause annual water resources to vary considerably. The Syrdarya River Basin has approximately 23.6 km^3 (63% of the average run-off) of water resources in scarce water years and 51.1 km^3 (137%) in abundant years. In the Amudarya River Basin annual water resources range from 58.6 km^3 (74%) to 109.6 km^3 (138%). Thus, in the Syrdarya River Basin there is essentially a more critical water situation; available freshwater resources in dry years are 37% below the long-term average, compared to 24% in the Amudarya River Basin. Irrigated agriculture in Uzbekistan, Turkmenistan and Kazakhstan is particularly affected by the water shortages. In extremely dry years there are severe economic losses. For example, in the year 2000 irrigated agriculture suffered economic losses of 77 million USD in Turkmenistan and 187 million USD in Uzbekistan (Sorokin 2002).

Root causes

Demographic

Increases in population have led to greater pressure on the natural resources of the Aral Sea Basin, including the water resources. The annual population growth rate is over 3%.

Economic

Collapse of Soviet economic mechanisms

Since the early 1990s the disintegration of the USSR and the pursuing collapse of its integrated economic system, the catastrophic decline in the economy of the countries of the region and associated social upheavals, for example the civil war in Tajikistan and conflicts in Uzbekistan and Kyrgyzstan, have not favoured regional cooperation and the equitable sharing of transboundary water resources.

The transition to a market economy was accompanied by an economic crisis in the region's agricultural sector and the collapse of economically powerful agricultural cooperatives. A subsequent lack of investment in agriculture has led to the deterioration of agricultural machinery, and irrigation and other water infrastructure. This has caused a decline in the water efficiency of irrigated farming and agricultural production. The productivity of irrigated farming decreased from 1 600-2 000 USD to 500-900 USD per ha and the efficiency of using 1 m^3 of irrigation water decreased from 0.18-0.25 USD to 0.03-0.10 USD (Duchovny 2002a&b).

Furthermore, the introduction of water saving technology has been impeded by the economic downtown in the agricultural sector. Despite efforts by the governments of the region and the international community this situation remains problematic.

Lack of economic incentives

There is a lack of economic mechanisms aimed at regulating water use, particularly in irrigated farming, which is a major obstacle in improving water resource management at all levels, local to regional. There are no economic incentives to conserve water resources. Currently irrigation farmers do not pay for the water they apply to their fields and consequently there is no incentive for them to employ irrigation systems that are more water efficient.

A joint approach to economically evaluating river water is absent in the region. There is no uniform understanding of even the most fundamental economic principles of river flow regulation, let alone questions of water pricing (Petrov & Leonidova 2003).

Overdependence on the agricultural sector

Agriculture, and more specifically irrigated farming, constitutes the largest proportion of GNP in Uzbekistan, Turkmenistan and Tajikistan. Development in most countries of the region is determined by the economic success of irrigated farming. Due to a long recession in the agricultural sector following the collapse of the Soviet Union, in the 1990s the governments of the region supported farmers through special programs. Productivity subsequently increased, especially in Kazakhstan, Uzbekistan and Turkmenistan, but the fundamental problems regarding the management of the region's water resources were not resolved.

Legal

Weak legislation

There is a lack of a clearly formulated and mutually accepted legislative framework for inter-state use of water resources. There is subsequently opposing national legislation which impedes regional cooperation in the management of water resources. The highly inefficient use of water by irrigated farming and unauthorised water diversion has been attributed, in part, to the weak legislative and regulatory system in the region. The absence of regulations governing the use of return water in irrigated farming has resulted in negative consequences, such as the salinisation of agricultural fields and a reduction in productivity.

Water rights

The current water legislation is in need of revision as it was formulated during the Soviet period and is inappropriate for present-day conditions. Countries abstracting the most water resources insist on maintaining the quotas established in the Soviet era and claim transboundary waters to be common property, whereas countries in the run-off formation zone, namely Kyrgyzstan and Tajikistan, argue that the quotas are unfair and demand payment for water which flows to the countries located downstream, which is categorically refused by Uzbekistan and Kazakhstan (SPECA 2004, Mazakhirov 2003, Babaev 2003). Uzbekistan maintains that, to achieve an equitable distribution, water resources should be allocated per capita. The other countries disagree with this proposal, especially Kyrgyzstan and Tajikistan. There are also discrepancies between countries on the joint usage of interstate facilities, such as power generation stations which were constructed in the Soviet era (Mambetov 2003, SPECA 2004).

There is no common legal approach among the countries of the region towards the allocation of transboundary water resources, though there is a general opinion that all actions concerning the use of regional water resources are to be based on the statement that it is necessary to keep the existing system concerning use of regional water resources, including quotas on water (Dzhalalov 2003). But it has been demonstrated worldwide that, even in areas with very high average precipitation rates, relations between countries concerning the sharing of transboundary water resources can be problematic (Petrov & Leonidiva 2003).

An alternative principle governing the rights of any state over the use of hydropower resources and its affect on other states is as follows: "A sovereign state has the right to establish any regime of river run-off regulation in accordance with its national interests on the territory of its water reservoirs. If the regime affects or contradicts the interests of any other state, the state-owner is obliged to change the regime in favour of the affected state and provide corresponding compensation" (Petrov & Leonidiva 2003).

Governance

Lack of integrated water management

The collapse of the Soviet Union required the reliance of the new independent states on their own resources for economic development.

Naturally, this has resulted in differing development strategies and rates of economic growth in the countries of the region. The governments also re-evaluated former priorities, including those for the management of water resources. States in the zone of run-off formation (e.g. Tajikistan and Kyrgyzstan) found it more economically attractive to use water resources for hydroelectricity generation (including export) rather than irrigated farming which had limited expansion prospects due the relief of the area (Duchovny 2002a&b, Sokolov 2001). Water use strategies have consequently diverged and cooperation between the various national water management institutions has become problematic.

Despite declarations by regional governments to coordinate water policies, there remains a tendency to take unilateral decisions and actions favouring national, rather than regional, interests. ICG experts have stated "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 will become more intensive unless more effective mechanisms to solve the problems are not created" (ICG 2002).

The decision to create a water-power generation consortium was made by the presidents of all Central Asian countries in 1997 and confirmed in July, 2003. Unfortunately, despite five years of efforts, there has been no success in establishing the consortium (Koimdodov 2003).

The regulations governing interstate water management are unsystematic, poorly coordinated, and often contradictory, impeding the implementation of water management systems (Petrov & Leonidiva 2003).

This situation, combined with unilateral and uncoordinated decisions and actions, is leading to significant changes in the hydrological regime of the region's transboundary rivers, thus demonstrating the ineffectiveness of the current system of interstate water allocation. This has led to complications in international relations in the region.

Expansion of irrigated farming

Despite the fact that the majority of regional water resources (more than 90%) are used for irrigated farming, particularly for the production of water intensive crops, such as cotton and rice, practically all countries in the region intend to increase their irrigated areas. Tajikistan is planning to increase its irrigated area by 700 000 ha in the near future, which will require an additional annual intake of more than 9 km^3 of water from the Amudarya River. Moreover, Tajikistan, following the construction of the Ragun water reservoir with a capacity of 10 km^3, intends to construct the Sangtudin reservoir and several other water reservoirs which will be mainly used for power generation (ICG 2002, Rakhmonov 2003). Turkmenistan also plans to increase its irrigated areas by 450 000 ha and create a lake with a volume of 5-6 km^3 in the Karakum desert called "Lake of the Gold Century". It plans to use the accumulated drainage water to irrigate between 700 000 and 1 million ha of desert pastures. According to estimates made by Uzbek experts, the maintenance of this lake will necessitate an additional intake of approximately 13.5 km^3 of Amudarya river water (ICG 2002). There are plans in Uzbekistan to construct 15 hydroelectric power stations and a long-term vision to construct a further 140 (ICWC 2004).

Inadequate and conflicting water use strategies

Inadequate political strategies have developed a water-dependent regional economy which is reliant on irrigated farming and the production of water intensive crops, i.e. cotton and rice. The conflict of interests regarding the use of water resources by the irrigation and power generation industries has not yet been resolved. At present, interrelations between these activities are regulated by the Syrdarya agreement of 17th March, 1998, which runs counter to the interests of the upstream countries (Petrov & Leonidova 2003).

Power resources were previously guaranteed to Krygyzstan and Tajikistan, but since the collapse of the USSR deliveries are only possible through interstate agreements, which are often not fully implemented. The discontinuation of power resources to Kyrgyzstan and Tajikistan and additional economic difficulties forced the governments of these countries to convert the Tokhtogul and Nurek reservoirs from irrigation to power generation. This action dramatically changed the hydrodynamics of the major rivers in the region, the Amudarya and Syrdarya, resulting in significant economic losses to the agricultural sector in Uzbekistan and Kazakhstan. This stimulated difficult interstate negotiations and agreements between the relevant nations.

The hydroelectric power stations operate at maximum capacity during the winter, when demand for electricity is greatest. Therefore, a greater volume of water is released during the winter from the reservoirs, resulting in a deficiency of water for irrigated agriculture during warmer periods of the year. This change in water use policy has resulted in the inefficient use of water resources, the degradation of downstream ecosystems, and dangerously high water levels in the lower reaches of the Syrdarya in the winter.

Despite annual agreements between the upstream and downstream nations regarding the release of water from the hydropower reservoirs on the Naryn-Syrdarya cascade, communities in Kyzylorda oblast in Kazakhstan are threatened by floods practically every year. This has necessitated regular consultations and negotiations between representatives and heads of the relevant states. For example, the release of water to the Arnasays' hollow was only increased when in the winter of 2004/2005 concern over the safety of the dam of the Shardara water reservoir was raised and there was intervention by the heads of the states of Kazakhstan and Uzbekistan.

There are plans for the further development of hydropower engineering in Tajikistan and Kyrgyzstan. Future projects include the construction of the Kambaratin hydropower station in Kyrghyzstan and the Sangtudin and Ragun hydroelectric power stations in Tajikistan. Kyrgyzstan plans to supply electricity to the CIS countries and Pakistan, and Tajikistan to Iran and other neighbouring countries. It is feared that the construction of new water reservoirs will further aggravate the conflict between the interests of hydropower and irrigation. At the same time, the introduction of new power capacities can promote economic integration between the countries of region and stimulate industrial growth, and subsequently reduce the dependence of the economy on water-intensive irrigated farming.

Following the collapse of the USSR, the countries on whose territory the headwaters originated became responsible for the maintenance of water distribution systems, including the large water reservoirs and channels. Tajikistan and Kyrgyzstan insist on shared participation in the funding of these systems.

Lack of compliance with inter-governmental agreements

The sharing of the regions transboundary water resources has become the subject of increasing interstate negotiations. Approximately 30 interstate agreements were negotiated concerning the distribution of the Amudarya River water. Unfortunately, political agreements have been difficult to implement in practice and are frequently disregarded. For example, an agreement between Kazakhstan, Kyrgyzstan and Uzbekistan on water discharges from the Tokhtagul and Shardarya reservoirs in the Syrdarya Basin was impractical. Winter floods in the lower reaches of the Syrdarya in November to January, 2003-2004 destroyed water regulatory structures and flooded some settlements in Kyzylorda oblast in Kazakhstan. In the post-Soviet period, an agreement was made to consider the Aral Sea as an independent (along with the states of the region) consumer of water resources. However, river discharges to the Sea were below the stipulated volume and in some years there was no inflow at all.

Afghanistan only utilises 10 km^3 of a total 19 km^3 of the Pyandzh run-off it was allocated in the agreement signed by Afghanistan and the USSR in 1946. If Afghanistan fulfils its quota, there will be considerable changes in the Amudarya run-off (ICG 2002).

Kazakhstan was the only Central Asian country to participate in the 1992 Helsinki water convention and the 1997 Convention on non-navigable river usage. Some items of the legislation of the countries contradict clauses of the above conventions. The national legislation of each of the Central Asian countries differ considerably and requires coordination, especially regarding transboundary river flows (Koimdodov 2003).

Approval of the Kyzylorda declaration of March 1993 required that all Central Asian states: recognise the system of regulation; improve water use discipline in the basin; develop corresponding interstate legal and normative documents envisaging regional principles of reimbursement of losses and damages as common problems for the region. However, practical results to these problems are yet to be seen, and only theoretical plans in the form of reports, presentations and proposals exist, which do not always correspond to each other in either content or principles (Ashirbekov & Zonn 2003).

The countries of the region have only succeeded in signing one agreement on the regulation of hydropower generation, the 1998 Bishkek agreement on the use of hydropower resources of the Syrdarya, with alterations and amendments according to the protocol of June 1999. A similar agreement on the Amudarya, which was prepared by Tajikistan in 1988 and presented to all other republics, has not yet been considered. Other regional agreements on water resources used for power generation including those prepared by SRC ICWC have also not been signed. The main agreements are:

- Agreement on the development of cooperation and differentiation of the functions of interstate organisations in protection, management and development of water resources in the Aral Sea Basin (1996);
- Agreement on joint usage of transboundary water resources (1996);
- Agreement on the organisational structure of joint control, protection and development of water resources in the Aral Sea Basin (1997);
- Agreement on cooperation in the joint usage of water objects, water resources and water facilities (1998);
- Agreement on information exchange and the creation of the Aral Sea Basin database on the transboundary water resources of the Aral Sea (1999).

Thus even the preparation and signing of joint agreements remains a contentious issue. Signed agreements often remain unfulfilled. In particular, Kazakhstan does not adhere to the agreement on the

Syrdarya regarding the mutual payment for changes in the operational regime of Kayrakkum water reservoir. Agreed quotas of electricity are supplied to Tajikistan by Uzbekistan, with some deviations from the agreement. In addition, Kazakhstan and Uzbekistan disregard their obligations stipulated by the agreement by not compensating Kyrgyzstan (Petrov & Leonodova 2003).

Inappropriate international support

The international community has inadequately contributed to solving the problems of the region (Mambetov 2003). Up to 50% of the projects initiated by donor countries have failed (Duchovny 2002a&b). The countries of the region doubt the efficiency of foreign participation on account of the following reasons:

- Predisposition of donor countries to adopt technical solutions, which often do not achieve their aims because they are not supported by legislative and political policies (ICG 2002);
- Irrational use of project funds;
- Incompetence of official decision making;
- Inadequately funded financing systems for research by the State Budget and donor funds;
- Insufficient use of local scientific resources in solving regional problems;
- Inappropriate foreign specialists employed by international projects who often lack an interest in the final results and have insufficient knowledge of local conditions.

Knowledge

Literacy in the former Soviet Union countries of Central Asia is among the highest in the world. Scientific human resources are of a high standard and infrastructure, such as laboratories, is well maintained. However, there is an extensive 'brain-drain' to other economic activities and countries. There are a limited number of young scientists, and institutions can only survive with foreign contracts (UNESCO 2000). Greater investment in the scientific capacity of the region may enable constructive solutions to the ecological and social problems.

There is a lack of knowledge regarding the natural dynamics of the region, particularly in the run-off formation zone, which is fundamental to solving the region's problems. The last estimation of total water resources was made 40 years ago. Since then, considerable changes have occurred in the run-off formation zone, including the depletion of glaciers, which have undoubtedly affected conditions of run-off formation.

The region lacks a common system for the collection and processing of real data on the hydrometeorological regime of the region and the water resources used. Such a system ceased operating following the collapse of the USSR and the newly independent states now have limited access to the monitoring data of the other nations in the region. Information officially presented by the countries of the region to form regional databases by the ICWC is limited and unreliable regarding the use of water resources (Ginijatullin 2002a&b, SPECA 2004).

Scientific investigations in the mountainous areas of the region through regular expeditions and mountain monitoring stations ceased with the collapse of the USSR. Moreover, at the planning stage of most water projects, changes in the hydrological regime of mountain territories are often not considered at all or out-of-date information on water resources is used, thus the real situation becomes less reliable every year.

The monitoring of the climatically-driven dynamics of the high-mountain belt glaciosphere (which includes glaciers, snow fields, ice mounds, snow cover, and underground ices above 3000-3200 m above sea level) deserves particular attention. It constitutes the region's glaciers and the majority of underground ice and snow resources, and therefore the main sources of renewable water resources. Unfortunately, the region's glaciosphere has not been comprehensively investigated.

An inadequate capacity to predict future water resource dynamics is resulting in poorly planned water use strategies. The current deficit in appropriate scientific studies has resulted in policy-makers lacking reliable information to make informed decisions regarding the conservation and allocation of water resources. However, warnings by scientists of environmental impacts were not heeded, when the governments decided to increase irrigated areas in the Aral Sea Basin (Glazovsky 1995).

Technology

The irrigation canals are highly outmoded and inefficient, resulting in the unproductive use of the region's scarce water resources; up to 50% of irrigation water is lost before reaching the fields (Ginijatullin 2002a & b, Glazovsky 1995). During the economic recession of the post-Soviet period water infrastructure was not sufficiently maintained. Following the collapse of collective farming (kolkhozes and sovkhozes) many irrigation canals which connected the various farms were not privatised and were poorly maintained. This is considered as one of the primary obstacles to a large scale introduction of modern irrigation techniques in the region. During this period hydraulic structures, water-distributing systems, and hydrological monitoring stations deteriorated.

Today, farmers lack the investment to update or adopt water saving technologies in irrigated farming. Large-scale reconstruction of irrigation systems is vital but not feasible due to economic constraints and the lack

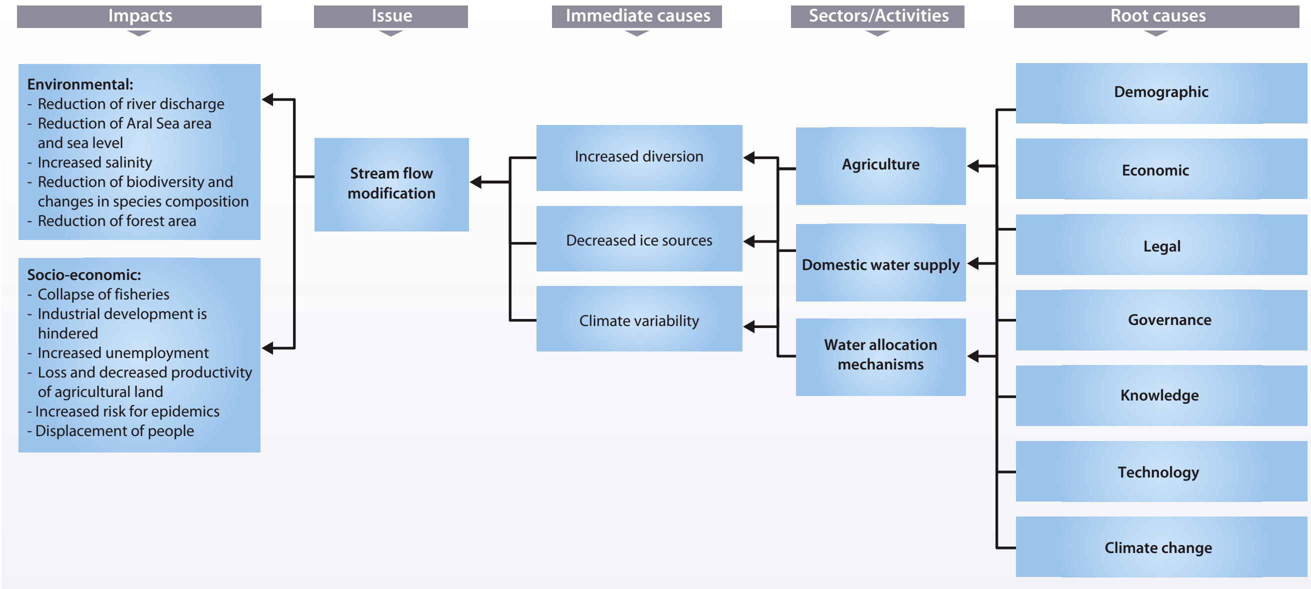

Figure 11 Causal chain analysis model for the Aral Sea region.

of technical human resources. In addition, there is a lack of awareness about the benefits of employing water efficient technologies.

Climate change

The problem of freshwater shortage may become even more acute over the next few decades if, as is predicted, water resources in the region's major river basins reduce by 20-40% (Chub 2000, SPECA 2004). Such a reduction in water resources will have severe ecological and socio-economic consequences unless drastic measures are taken to reduce the region's water requirements.

However, some predictions show that anthropogenic induced climate changes may play a less significant role than was previously thought; estimations of a 2-4°C rise in temperature in the near future cannot be relied upon (Severskiy 1999a&b, Kondratyev & Demchenko 1999, Kondratyev et al. 2001). The fact that run-off volumes have remained stable despite considerable reductions in glacier resources suggests the existence of a compensating mechanism in the formation of run-off. Such a mechanism may become increasingly active as underground ice melts as the result of a warmer climate and accumulates as permafrost.

Conclusions

The Causal chain analysis indicated the root causes that are driving the Freshwater shortage concern (Figure 11). According to GIWA experts, the majority of the root causes stem from the inadequate legislation that regulates water management. The transboundary nature of the major watershed basins in the region makes it impossible to solve the problems of rational water use without inter-state agreements. Many of the agreements made to date have not been implemented or are not strictly adhered to by the countries of the region.

The transboundary water management system is inadequate as it is based on the principles of centralised regulation formed in the Soviet period. There is a lack of clearly formulated water strategies in the countries of the region and the absence of a mutually acceptable legislative framework for interstate sharing of transboundary water resources.

The lack of knowledge regarding the dynamics of the region's water resources, primarily in the run-off formation zone, is severely hindering the capacity of policy makers to resolve the issues. Water resources are not being utilised efficiently due to the employment by irrigated agriculture of outmoded technology. Irrigation canals are inefficient and there is limited technical capacity in the region necessary to renovate or construct a new irrigation system. Economic constraints and the lack of economic incentives for farmers to save water are preventing the adoption of water saving technologies.

Policy options

This section aims to identify feasible policy options that target key components identified in the Causal chain analysis in order to minimise future impacts on the transboundary aquatic environment. Recommended policy options were identified through a pragmatic process that evaluated a wide range of potential policy options proposed by regional experts and key political actors according to a number of criteria that were appropriate for the institutional context, such as political and social acceptability, costs and benefits and capacity for implementation. The policy options presented in the report require additional detailed analysis that is beyond the scope of the GIWA and, as a consequence, they are not formal recommendations to governments but rather contributions to broader policy processes in the region.

Definition of the problem

The situation in the sphere of water management remains both regionally and locally contentious. There is no regionally accepted water strategy or effective regional agreements to provide a regulatory framework for the allocation and conservation of river water. The current interstate status of regional water resources and water management infrastructure has not been defined (Mambetov 2003, Nazirov 2003, Nurushev 2003).

Despite considerable efforts by the governments of the region and the international community, the freshwater shortage situation remains critical and is adversely affecting the socio-economic development (ICG 2002) and ecological integrity of the Aral Sea region.

Following the breakdown of the Soviet Union, the five Aral Sea Basin states (excluding Iran and Afghanistan) came to an agreement on the principles of water sharing and in 1992 established the Interstate Water Commission, ICWC. The results of the Commission's activities and recommendations formed the basis of numerous interstate agreements on the use of water resources, including 25 agreements on joint usage and annual agreements on joint usage of the Syrdarya resources for power generation.

International organisations have attempted to resolve the regional problems, primarily those concerning water. Projects executed/sponsored by the World Bank, UNEP, UNESCO, UNDP as well as a number of research and applied projects funded by INTAS, NATO, TACIS, INCO-COPERNICUS, MACCARTUR have contributed to the understanding of the situation in the region, suggested solutions, and implemented projects with an aim of achieving sustainable development. However, the countries of the region have expressed doubt towards the efficiency of foreign participation, as outlined in the Causal chain analysis.

The actual situation in the region was far more severe than was first envisaged by the region's governments and the international community. Consequently, much of what was planned in the region has not been fulfilled: approximately half the projects which had international financial and technical support have failed (Duchovny 2002a&b).

In the Aral Sea, significant improvements to the Small Sea ecosystem are likely with the construction of the Korakal dam between the Small Sea and the Big Sea. As a result, between 1996 and 1999 the water level of the Small Sea rose by 2.5 m, mean salinity reduced by 14.5%, and a vast freshwater zone formed where freshwater creatures reappeared (Amirbekov at al. 2002).

The transferral of water from Siberian rivers to the Aral Sea Basin is seen as one solution to the freshwater shortage concern in the Aral Sea Basin. A project developed in the early 1980s redirected water from the Ob River via a channel running through the Turgai deflection to Central Asia. However, in 1986 due to pressure from scientists and the public, the project was suspended but has been reactivated in recent years. In Russia, certain ambiguities surround the validity of this project for ecological and economic reasons. According to GIWA experts, the region should not rely upon the transfer of water from Siberian rivers but rather should maximise the efficiency of using the region's available water supplies.

Policy options

The policy options need to address the freshwater shortage concern through the development of political and legislative measures. The principles of inter-state water allocation in the region were formulated by the SPECA-Programme and presented in a report entitled 'Strengthening cooperation for the rational and efficient use of water and energy resources in Central Asia (SPECA 2004). As determined in this report, water will be allocated among Central Asian states according to the following principles:

- Water resources subject to allocation are summed up in each transboundary river basin as per the agreed list of basins;
- Each state retains the right to use its territorial water resources within its agreed quotas;
- Quotas are adjusted on the basis of mutually acceptable criteria and procedures are addressed in intergovernmental agreements;
- The long-term and seasonal flow regulation of transboundary rivers by storage reservoirs used for irrigation and power generation are subject to agreement. The filling and discharge schedules for storage reservoirs are established to ensure integrated use of water and energy resources and to meet environmental requirements;
- The schedules governing water intake and discharge at facilities on transboundary rivers and in water-management systems supplying water to neighbouring countries and capable of having transboundary impacts are subject to agreement;
- Water use should not lead to a significant deterioration in water quality in transboundary river basins, and pollutant concentrations should not exceed agreed limits.

The complexity of the freshwater shortage concern and the danger of its spontaneous development are recognised by all relevant parties and efforts to solve this problem continue. In order to increase the efficiency of regional water management there have been discussions on the creation of an interstate water-power generation consortium, with much wider powers than the ICWC.

Although the countries of the region have demonstrated a commitment to solving the freshwater shortage concern, the fact that each of the countries of the region intend to expand their irrigated areas or to construct new water reservoirs to satisfy their own needs indicates an exacerbation of the problem with likely disagreements regarding the sharing of transboundary water resources.

Thus, the problem of sharing transboundary water resources in Central Asia remains complicated. The solution to this problem requires the development of legislative agreements based on the following principles:

- Equal representation of the countries of the region in inter-state agencies responsible for water management, including basin administration. In the interstate management institutions there are practically no representatives from the main water users, i.e. farming and water user associations, industrial and scientific organisations;
- Fairness when allocating water quotas and in the regulation of stream flow;

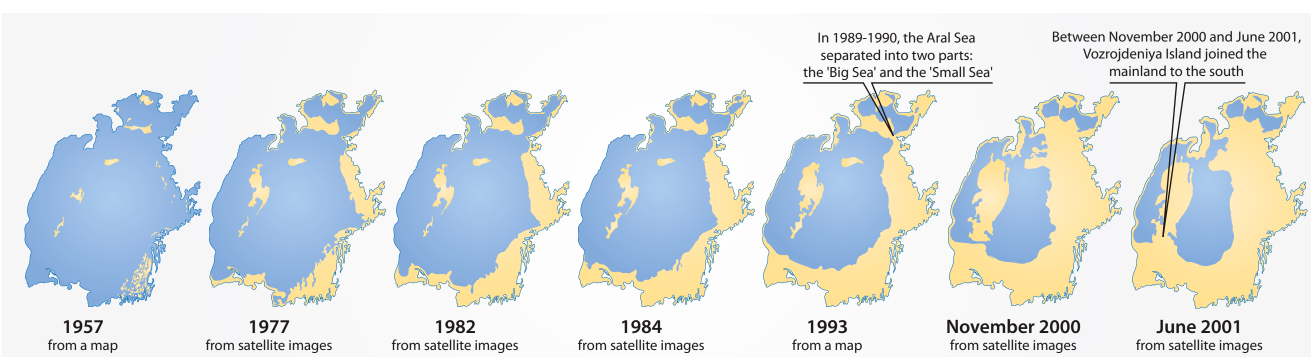

Figure 12 Changes in surface area of the Aral Sea.
(Source: UNEP 2002)

- Obligatory compensation for mutual damage. It is only possible to come to mutually acceptable decisions if this principle is observed;
- Consider ecosystems as an equal consumer of water resources to human uses. Under the existing system of regional water resources management the interests of the environment are considered last or not at all;
- Equal access to information on the hydrometerorological dynamics of all countries in the Aral Sea Basin, including the volume and regime of each country's water abstraction.

Recommended policy options

National level

Governance

- Revision and enactment of national water strategies, based on the principles laid down in the IWRM. These should be established in accordance with international water law and take into account the interests of all the countries in the region;
- The governments of each country should recognise the importance of interstate (regional) agreements over national legislation and regulations regarding the use of water resources;
- Creation of water user associations with an aim to improve water efficiency, particularly amongst farmers;
- Participation of water users' associations in the decision making process;
- Enhance administrative and legal mechanisms for regulating water use;
- Increase the administrative and legal responsibility of water users for inefficient use of water, particularly in irrigated farming.

Knowledge

Initiate and support scientific research in the following fields:

- Monitor natural processes in the run-off formation zone, primarily in the high-mountain belt, where the majority of renewable water resources are formed;
- Develop environmental approaches to water resource management;
- Monitor desertification and landscape degradation dynamics in the zone where the water is predominantly consumed;
- Assess available water and energy resources, forecast future demand.

Technology

- Optimise the productivity of agricultural land by assessing the appropriateness of crops for the agro-climatic conditions;
- Adapt water saving technologies for irrigated farming to the specific physical conditions of the Aral Sea region;
- Monitor the soil contamination dynamics and agro-climatic conditions, including through the application of remote sensing;
- Develop technical methods and techniques for the rehabilitation of salinised and highly contaminated soils;
- Increase the efficiency of irrigation systems.

Regional level

Governance

- Revise the interstate legislative framework regarding the sharing and equitable use of the Aral Sea Basin transboundary waters;
- Develop a regional strategy for the integrated management of water and power resources, including the allocation of water quotas and the coordinated control and enforcement of the established water regime based on the IWRM principles;
- Formulate and ratify regional agreements which require shared participation of the countries situated in both the zone of predominant water resource usage and in the run-off formation zone in the management and funding of maintenance of the major water distribution systems;
- Each country should adhere more strictly to the obligations they made when ratifying agreements aimed at addressing the freshwater shortage issues of the region;
- Develop legal procedures for the implementation of the 'polluter pays' principle;
- Create regional databases on the distribution, availability and use of water resources;
- Reform existing, or create new, interstate organisations with sufficient authority to enable the efficient and unbiased governance of regional water and power resources of the Aral Sea Basin.

A solution to this problem is to reform the ICWC by:

- Providing equal representation of all the countries in the ICWC;
- Extend the Commission's mandate to include interstate water and power generation issues;
- Strengthen the enforcement capacity of agreements regarding water quotas and the operation of reservoirs;
- Implement new legislative norms and rules, which express the authority and independence of the ICWC.

Economic

- Introduce market prices for water, taking into account the ecological health, water quality and the reliability of its delivery to the consumer. The loss in ecosystem services and the cost of protecting and rehabilitating ecosystems should be economically evaluated and considered in the pricing system (Khristoforov 2001). This will encourage a more efficient use of water by human activities.

- Develop and introduce economic mechanisms for the regulation of land-water use, protection and improvement in water quality (Babaev 2003, Sarsembekov at al. 2004, Kipshakbaev 2004).

Conclusion

The transboundary nature of the major basins in the region makes it impossible to solve the freshwater shortage concern without the implementation of inter-state agreements. The adoption of the IWRM principles constitutes the most viable option for the region. A significant obstacle in achieving the integrated management of regional water resources is the lack of a regional organisation with the authority to facilitate effective and conflict-free management, taking into account the interests of all the countries in the region. A successful solution to this problem necessitates the development of a legislative framework which ensures the equitable use of water resources, whilst preventing unilateral actions capable of changing the hydrological regime of the region. Despite regional disagreements regarding water resources, all of the countries in the region understand the necessity of interstate cooperation in resolving the freshwater shortage issues.

Conclusions and recommendations

The Aral Sea Basin contains the territories of six countries, Kazakhstan, Kyrgyzstan, Uzbekistan, Tajikistan, Turkmenistan, and Afghanistan. The priority concern of the region is that of freshwater shortage. The water deficiency became apparent in the early 1960s when the population in five countries of the region (excluding Afghanistan and Iran) was approximately 15 million. In this period more than 50% of the annual water yield of the Syrdarya and Amudarya river basins was used for human activities. However, since the beginning of the 1980s practically all renewable water resources are being used, predominantly for irrigation, and the regional economy is developing under conditions of increasing freshwater shortages. This scenario has arisen from two main factors, firstly, the rapid increase in the region's population and, secondly, by the orientation of the regional economy towards irrigated agriculture.

Accordingly, GIWA experts selected freshwater shortage as the priority concern, and specifically the issue of modification of stream flow. Pollution, and most importantly pollution of existing water supplies, was identified as the second most significant concern.

The Causal chain analysis (CCA) aimed to identify the root causes behind freshwater shortage to serve as a foundation for the selection of policy options. The immediate causes of the modification of Stream flow were defined as the following:

- Increased diversion;
- Decreased ice resources;
- Inter-annual climatic variability.

The root causes behind freshwater shortages were identified to serve as a foundation for the selection of policy options. The collapse of the USSR led to the fragmentation of the previously integrated economic system, which was followed by social and economic turmoil. Investment in the agricultural sector reduced due to economic recession in the region, which led to a decline in agro-productivity and the water efficiency of irrigation systems. Outmoded and inefficient irrigation technology continues to be employed, and the continued economic difficulties and the lack of fiscal incentives for farmers to save water prevents the adoption of water saving technologies.

Water use is controlled by weak legislation and the region lacks a mutually acceptable legislative framework for interstate sharing of transboundary water resources. The current water legislation was formulated during the Soviet period and is not appropriate under the present-day conditions. The transboundary nature of the major watershed basins in the region makes it impossible to solve the Freshwater shortage concern without inter-state agreements. Many past agreements have not been implemented or the countries have not fulfilled their obligations. Governments lack clearly formulated national water strategies and management is not integrated at the regional level. Contrary to governmental efforts to resolve the water management problems, all of the countries in the region intend to increase their irrigated areas.

Freshwater shortage may become even more acute over the next few decades if, as is predicted, water resources in the region's major river basins reduce by 20-40%. However, some predictions show that anthropogenic induced climate change may play a less significant role than was previously thought due to evidence of a compensating mechanism in the formation of run-off which is maintaining the total volume of renewable water resources. Thus, further research is needed regarding the dynamics of the region's water resources, primarily in the run-off formation zone, as policy makers cannot make informed decisions without accurate predictions of future renewable water resources.

Experience of the countries in the region cooperating in the management of transboundary water resources in the post-Soviet period has revealed essential differences in their approaches to resolving key issues. This is particularly true for the equitable use of regional water resources, in defining the principles and criteria for interstate water sharing, and in establishing legal and economic mechanisms for water use. Economic pressures experienced during the transitional period from Soviet rule, common to all countries in the region, has predetermined not only difficulties in achieving coordinated solutions, but has led to failures in the implementation of accepted interstate agreements and obligations at the national level. Despite the efforts of the region's governments and the international community, the situation of water supply in Central Asia remains critical and is anticipated to increase in severity. The tendencies of nations in the region to take unilateral decisions and actions is provoking political conflicts, and thus complicating and hindering the resolution of the situation to the mutual benefit of all states.

By the year 2010, the escalating water abstraction in the region is predicted to result in an ecological disaster. The situation is so critical that the situation could escalate to a crisis if only one of the countries increases water abstraction from surface supplies. Thus the equitable use of transboundary water resources in Central Asia remains problematic and is likely to worsen in future.

Progress in this area can be achieved through political rather than solely technical means and requires development of a package of legal agreements at the national, regional and international level. The following policy options are recommended as a priority:

- Reconstruction and more efficient operation of irrigation systems;
- Development of legislative principles and mechanisms for water use;
- Support of research projects to develop monitoring databases, water saving technologies and techniques to rehabilitate salinised lands;
- Development of a central water supply system and medical service for the population, especially in ecological crisis zones;
- Institutional and legislative support for water user associations and the creation of a legislative framework which facilitates participation of stakeholders in water management at all levels - from regional to local;
- Consideration of the specific environmental conditions of the region in the adoption of progressive water technologies for irrigated farming.

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Annexes

Annex I
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Annex II
Detailed scoring tables

I: Freshwater shortage

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
1. Modification of stream flow	3	N/a	Freshwater shortage	2.9
2. Pollution of existing supplies	3	N/a		
3. Changes in the water table	3	N/a		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large (0 1 2 3)	N/a	N/a
Degree of impact (cost, output changes etc.)	Minimum – Severe (0 1 2 3)	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	N/a	N/a
Weight average score for Economic impacts		**3.0**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large (0 1 2 3)	N/a	N/a
Degree of severity	Minimum – Severe (0 1 2 3)	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	N/a	N/a
Weight average score for Health impacts		**2.8**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large (0 1 2 3)	N/a	N/a
Degree of severity	Minimum – Severe (0 1 2 3)	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	N/a	N/a
Weight average score for Other social and community impacts		**2.3**	

N/a = Not applied

II: Pollution

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
4. Microbiological	0	N/a	Pollution	2.5
5. Eutrophication	1	N/a		
6. Chemical	3	N/a		
7. Suspended solids	1	N/a		
8. Solid wastes	2	N/a		
9. Thermal	1	N/a		
10. Radionuclides	1	N/a		
11. Spills	1	N/a		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large (0 1 2 3)	N/a	N/a
Degree of impact (cost, output changes etc.)	Minimum – Severe (0 1 2 3)	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	N/a	N/a
Weight average score for Economic impacts		**2.4**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large (0 1 2 3)	N/a	N/a
Degree of severity	Minimum – Severe (0 1 2 3)	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	N/a	N/a
Weight average score for Health impacts		**2.8**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large (0 1 2 3)	N/a	N/a
Degree of severity	Minimum – Severe (0 1 2 3)	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	N/a	N/a
Weight average score for Other social and community impacts		**2.3**	

N/a = Not applied

III: Habitat and community modification

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
12. Loss of ecosystems	2	N/a	Habitat and community modification	2.4
13. Modification of ecosystems or ecotones, including community structure and/or species composition	3	N/a		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Economic impacts		**2.4**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of severity	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Health impacts		**2.4**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of severity	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Other social and community impacts		**2.3**	

N/a = Not applied

IV: Unsustainable exploitation of fish and other living resources

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
14. Overexploitation	0	N/a	Unsustainable exploitation of fish	0
15. Excessive by-catch and discards	0	N/a		
16. Destructive fishing practices	0	N/a		
17. Decreased viability of stock through pollution and disease	0	N/a		
18. Impact on biological and genetic diversity	0	N/a		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Economic impacts		**0**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of severity	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Health impacts		**0**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of severity	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Other social and community impacts		**0**	

N/a = Not applied

V: Global change

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
19. Changes in the hydrological cycle	0	N/a	Global change	1.0
20. Sea level change	1	N/a		
21. Increased UV-B radiation as a result of ozone depletion	1	N/a		
22. Changes in ocean CO_2 source/sink function	0	N/a		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Economic impacts		**1.0**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of severity	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Health impacts		**1.0**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of severity	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Other social and community impacts		**1.0**	

N/a = Not applied

Comparative environmental and socio-economic impacts of each GIWA concern

Concern	Types of impacts								Overall score	Rank
	Environmental score		Economic score		Human health score		Social and community score			
	Present (a)	Future (b)	Present (a)	Future (b)	Present (a)	Future (b)	Present (a)	Future (b)		
Freshwater shortage	3.0	3.0	3.0	3.0	2.8	3.0	2.3	3.0	2.9	1
Pollution	2.4	3.0	2.4	2.0	2.8	3.0	2.3	2.0	2.5	2
Habitat and community modification	2.4	2.4	2.4	2.4	2.4	2.4	2.3	2.4	2.4	3
Unsustainable exploitation of fish and other living resources	0	0	0	0	0	0	0	0	0	5
Global change	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	4

Annex III
List of important water-related projects

Projects action in the region

- Aral Sea Basin Capacity Development Project (1996 - ongoing) http://www.resource.nl/uk/projecten
- Aral Sea Basin Project (financing by The World Bank and The Ministry for Foreign Affairs of Finland.) Duration 1995-1997
- Aral Sea Geographic Information System http://www.dfd.dlr.de/
- Environment in Central Asia 2000. Region environmental report on the Aral Sea Basin http://www.grida.no/aral/aralsea/index.htm
- The Aral Sea Area Programme (ASAP) http://www.msf.org/aralsea/
- Aral Sea sustainable water management 1993
- Water and Environmental Management Project of the Aral Sea Basin Programme (World Bank September 1998 - June 2003) http://www4.worldbank.org/sprojects/

The Global International Waters Assessment

This report presents the results of the Global International Waters Assessment (GIWA) of the transboundary waters of the Aral Sea region. This and the subsequent chapter offer a background that describes the impetus behind the establishment of GIWA, its objectives and how the GIWA was implemented.

The need for a global international waters assessment

Globally, people are becoming increasingly aware of the degradation of the world's water bodies. Disasters from floods and droughts, frequently reported in the media, are considered to be linked with ongoing global climate change (IPCC 2001), accidents involving large ships pollute public beaches and threaten marine life and almost every commercial fish stock is exploited beyond sustainable limits - it is estimated that the global stocks of large predatory fish have declined to less that 10% of pre-industrial fishing levels (Myers & Worm 2003). Further, more than 1 billion people worldwide lack access to safe drinking water and 2 billion people lack proper sanitation which causes approximately 4 billion cases of diarrhoea each year and results in the death of 2.2 million people, mostly children younger than five (WHO-UNICEF 2002). Moreover, freshwater and marine habitats are destroyed by infrastructure developments, dams, roads, ports and human settlements (Brinson & Malvárez 2002, Kennish 2002). As a consequence, there is growing public concern regarding the declining quality and quantity of the world's aquatic resources because of human activities, which has resulted in mounting pressure on governments and decision makers to institute new and innovative policies to manage those resources in a sustainable way ensuring their availability for future generations.

Adequately managing the world's aquatic resources for the benefit of all is, for a variety of reasons, a very complex task. The liquid state of the most of the world's water means that, without the construction of reservoirs, dams and canals it is free to flow wherever the laws of nature dictate. Water is, therefore, a vector transporting not only a wide variety of valuable resources but also problems from one area to another. The effluents emanating from environmentally destructive activities in upstream drainage areas are propagated downstream and can affect other areas considerable distances away. In the case of transboundary river basins, such as the Nile, Amazon and Niger, the impacts are transported across national borders and can be observed in the numerous countries situated within their catchments. In the case of large oceanic currents, the impacts can even be propagated between continents (AMAP 1998). Therefore, the inextricable linkages within and between both freshwater and marine environments dictates that management of aquatic resources ought to be implemented through a drainage basin approach.

In addition, there is growing appreciation of the incongruence between the transboundary nature of many aquatic resources and the traditional introspective nationally focused approaches to managing those resources. Water, unlike laws and management plans, does not respect national borders and, as a consequence, if future management of water and aquatic resources is to be successful, then a shift in focus towards international cooperation and intergovernmental agreements is required (UN 1972). Furthermore, the complexity of managing the world's water resources is exacerbated by the dependence of a great variety of domestic and industrial activities on those resources. As a consequence, cross-sectoral multidisciplinary approaches that integrate environmental, socio-economic and development aspects into management must be adopted. Unfortunately however, the scientific information or capacity within each discipline is often not available or is inadequately translated for use by managers, decision makers and policy developers. These inadequacies constitute a serious impediment to the implementation of urgently needed innovative policies.

Continual assessment of the prevailing and future threats to aquatic ecosystems and their implications for human populations is essential if governments and decision makers are going to be able to make strategic policy and management decisions that promote the sustainable use of those resources and respond to the growing concerns of the general public. Although many assessments of aquatic resources are being conducted by local, national, regional and international bodies, past assessments have often concentrated on specific themes, such as biodiversity or persistent toxic substances, or have focused only on marine or freshwaters. A globally coherent, drainage basin based assessment that embraces the inextricable links between transboundary freshwater and marine systems, and between environmental and societal issues, has never been conducted previously.

International call for action

The need for a holistic assessment of transboundary waters in order to respond to growing public concerns and provide advice to governments and decision makers regarding the management of aquatic resources was recognised by several international bodies focusing on the global environment. In particular, the Global Environment Facility (GEF) observed that the International Waters (IW) component of the GEF suffered from the lack of a global assessment which made it difficult to prioritise international water projects, particularly considering the inadequate understanding of the nature and root causes of environmental problems. In 1996, at its fourth meeting in Nairobi, the GEF Scientific and Technical Advisory Panel (STAP), noted that: *"Lack of an International Waters Assessment comparable with that of the IPCC, the Global Biodiversity Assessment, and the Stratospheric Ozone Assessment, was a unique and serious impediment to the implementation of the International Waters Component of the GEF"*.

The urgent need for an assessment of the causes of environmental degradation was also highlighted at the UN Special Session on the Environment (UNGASS) in 1997, where commitments were made regarding the work of the UN Commission on Sustainable Development (UNCSD) on freshwater in 1998 and seas in 1999. Also in 1997, two international Declarations, the Potomac Declaration: Towards enhanced ocean security into the third millennium, and the Stockholm Statement on interaction of land activities, freshwater and enclosed seas, specifically emphasised the need for an investigation of the root causes of degradation of the transboundary aquatic environment and options for addressing them. These processes led to the development of the Global International Waters Assessment (GIWA) that would be implemented by the United Nations Environment Programme (UNEP) in conjunction with the University of Kalmar, Sweden, on behalf of the GEF. The GIWA was inaugurated in Kalmar in October 1999 by the Executive Director of UNEP, Dr. Klaus Töpfer, and the late Swedish Minister of the Environment, Kjell Larsson. On this occasion Dr. Töpfer stated: *"GIWA is the framework of UNEP´s global water assessment strategy and will enable us to record and report on critical water resources for the planet for consideration of sustainable development management practices as part of our responsibilities under Agenda 21 agreements of the Rio conference"*.

The importance of the GIWA has been further underpinned by the UN Millennium Development Goals adopted by the UN General Assembly in 2000 and the Declaration from the World Summit on Sustainable

The Global Environment Facility (GEF)

The Global Environment Facility forges international co-operation and finances actions to address six critical threats to the global environment: biodiversity loss, climate change, degradation of international waters, ozone depletion, land degradation, and persistent organic pollutants (POPs).

The overall strategic thrust of GEF-funded international waters activities is to meet the incremental costs of: (a) assisting groups of countries to better understand the environmental concerns of their international waters and work collaboratively to address them; (b) building the capacity of existing institutions to utilise a more comprehensive approach for addressing transboundary water-related environmental concerns; and (c) implementing measures that address the priority transboundary environmental concerns. The goal is to assist countries to utilise the full range of technical, economic, financial, regulatory, and institutional measures needed to operationalise sustainable development strategies for international waters.

United Nations Environment Programme (UNEP)

United Nations Environment Programme, established in 1972, is the voice for the environment within the United Nations system. The mission of UNEP is to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

UNEP work encompasses:

- Assessing global, regional and national environmental conditions and trends;
- Developing international and national environmental instruments;
- Strengthening institutions for the wise management of the environment;
- Facilitating the transfer of knowledge and technology for sustainable development;
- Encouraging new partnerships and mind-sets within civil society and the private sector.

University of Kalmar

University of Kalmar hosts the GIWA Co-ordination Office and provides scientific advice and administrative and technical assistance to GIWA. University of Kalmar is situated on the coast of the Baltic Sea. The city has a long tradition of higher education; teachers and marine officers have been educated in Kalmar since the middle of the 19th century. Today, natural science is a priority area which gives Kalmar a unique educational and research profile compared with other smaller universities in Sweden. Of particular relevance for GIWA is the established research in aquatic and environmental science. Issues linked to the concept of sustainable development are implemented by the research programme Natural Resources Management and Agenda 21 Research School.

Since its establishment GIWA has grown to become an integral part of University activities. The GIWA Co-ordination office and GIWA Core team are located at the Kalmarsund Laboratory, the university centre for water-related research. Senior scientists appointed by the University are actively involved in the GIWA peer-review and steering groups. As a result of the cooperation the University can offer courses and seminars related to GIWA objectives and international water issues.

Development in 2002. The development goals aimed to halve the proportion of people without access to safe drinking water and basic sanitation by the year 2015 (United Nations Millennium Declaration 2000). The WSSD also calls for integrated management of land, water and living resources (WSSD 2002) and, by 2010, the Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem should be implemented by all countries that are party to the declaration (FAO 2001).

The conceptual framework and objectives

Considering the general decline in the condition of the world's aquatic resources and the internationally recognised need for a globally coherent assessment of transboundary waters, the primary objectives of the GIWA are:

- To provide a prioritising mechanism that allows the GEF to focus their resources so that they are used in the most cost effective manner to achieve significant environmental benefits, at national, regional and global levels; and
- To highlight areas in which governments can develop and implement strategic policies to reduce environmental degradation and improve the management of aquatic resources.

In order to meet these objectives and address some of the current inadequacies in international aquatic resources management, the GIWA has incorporated four essential elements into its design:

- A broad transboundary approach that generates a truly regional perspective through the incorporation of expertise and existing information from all nations in the region and the assessment of all factors that influence the aquatic resources of the region;
- A drainage basin approach integrating freshwater and marine systems;
- A multidisciplinary approach integrating environmental and socio-economic information and expertise; and
- A coherent assessment that enables global comparison of the results.

The GIWA builds on previous assessments implemented within the GEF International Waters portfolio but has developed and adopted a broader definition of transboundary waters to include factors that influence the quality and quantity of global aquatic resources. For example, due to globalisation and international trade, the market for penaeid shrimps has widened and the prices soared. This, in turn, has encouraged entrepreneurs in South East Asia to expand aquaculture resulting in the large-scale deforestation of mangroves for ponds (Primavera 1997). Within the GIWA, these "non-hydrological" factors constitute as large a transboundary influence as more traditionally recognised problems, such as the construction of dams that regulate the flow of water into a neighbouring country, and are considered equally important. In addition, the GIWA recognises the importance of hydrological units that would not normally be considered transboundary but exert a significant influence on transboundary waters, such as the Yangtze River in China which discharges into the East China Sea (Daoji & Daler 2004) and the Volga River in Russia which is largely responsible for the condition of the Caspian Sea (Barannik et al. 2004). Furthermore, the GIWA is a truly regional assessment that has incorporated data from a wide range of sources and included expert knowledge and information from a wide range of sectors and from each country in the region. Therefore, the transboundary concept adopted by the GIWA extends to include impacts caused by globalisation, international trade, demographic changes and technological advances and recognises the need for international cooperation to address them.

International waters and transboundary issues

The term "international waters", as used for the purposes of the GEF Operational Strategy, includes the oceans, large marine ecosystems, enclosed or semi-enclosed seas and estuaries, as well as rivers, lakes, groundwater systems, and wetlands with transboundary drainage basins or common borders. The water-related ecosystems associated with these waters are considered integral parts of the systems.

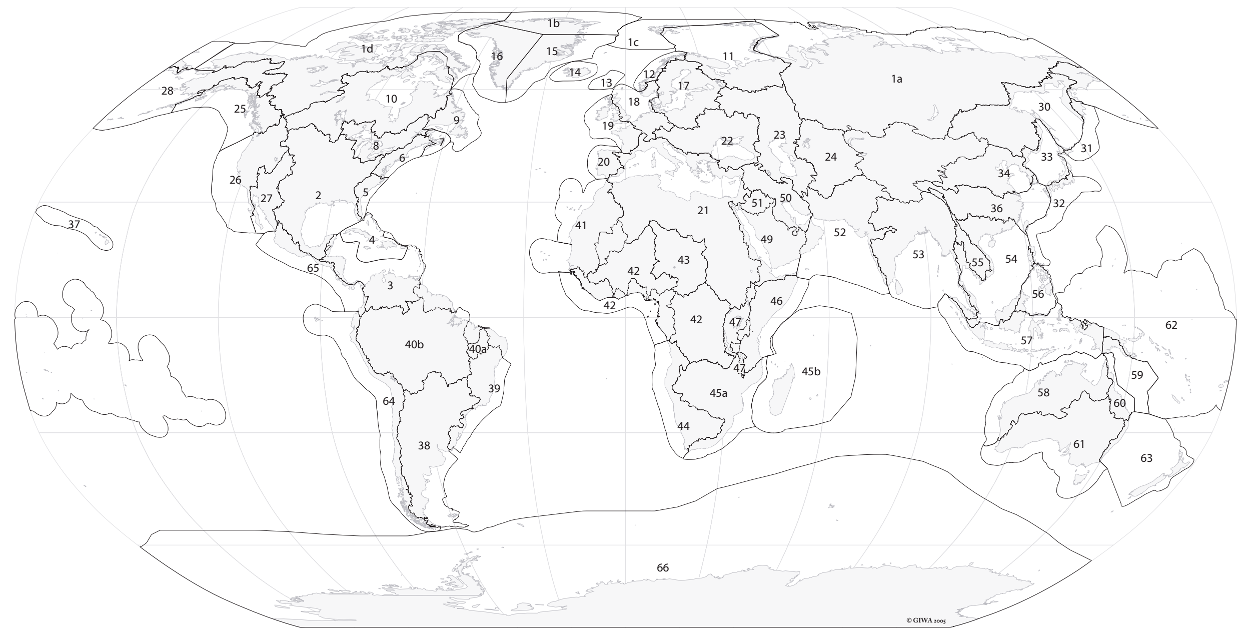
The term "transboundary issues" is used to describe the threats to the aquatic environment linked to globalisation, international trade, demographic changes and technological advancement, threats that are additional to those created through transboundary movement of water. Single country policies and actions are inadequate in order to cope with these challenges and this makes them transboundary in nature.

The international waters area includes numerous international conventions, treaties, and agreements. The architecture of marine agreements is especially complex, and a large number of bilateral and multilateral agreements exist for transboundary freshwater basins. Related conventions and agreements in other areas increase the complexity. These initiatives provide a new opportunity for cooperating nations to link many different programmes and instruments into regional comprehensive approaches to address international waters.

The organisational structure and implementation of the GIWA

The scale of the assessment

Initially, the scope of the GIWA was confined to transboundary waters in areas that included countries eligible to receive funds from the GEF. However, it was recognised that a truly global perspective would only be achieved if industrialised, GEF-ineligible regions of the world were also assessed. Financial resources to assess the GEF-eligible countries were obtained primarily from the GEF (68%), the Swedish International Development Cooperation Agency (Sida) (18%), and the Finnish Department for International Development Cooperation (FINNIDA)



1a Russian Arctic (4 LMEs)
1b Arctic Greenland (LME)
1c Arctic European/Atlantic
1d Arctic North American
2 Gulf of Mexico (LME)
3 Caribbean Sea (LME)
4 Caribbean Islands (LME)
5 Southeast Shelf (LME)
6 Northeast Shelf (LME)
7 Scotian Shelf (LME)
8 Gulf of St Lawrence
9 Newfoundland Shelf (LME)
10 Baffin Bay, Labrador Sea, Canadian Archipelago
11 Barents Sea (LME)
12 Norwegian Sea (LME)
13 Faroe plateau
14 Iceland Shelf (LME)
15 East Greenland Shelf (LME)
16 West Greenland Shelf (LME)
17 Baltic Sea (LME)
18 North Sea (LME)
19 Celtic-Biscay Shelf (LME)
20 Iberian Coastal Sea (LME)
21 North Africa and Nile River Basin (LME)
22 Black Sea (LME)
23 Caspian Sea
24 Aral Sea
25 Gulf of Alaska (LME)
26 California Current (LME)
27 Gulf of California (LME)
28 Bering Sea (LME)
30 Sea of Okhotsk (LME)
31 Oyashio Current (LME)
32 Kuroshio Current (LME)
33 Sea of Japan (LME)
34 Yellow Sea (LME)
36 East China Sea (LME)
37 Hawaiian Archipelago (LME)
38 Patagonian Shelf (LME)
39 Brazil Current (LME)
40a Northeast Brazil Shelf (2 LMEs)
40b Amazon
41 Canary Current (LME)
42 Guinea Current (LME)
43 Lake Chad
44 Benguela Current (LME)
45a Agulhas Current (LME)
45b Indian Ocean Islands
46 Somali Coastal Current (LME)
47 East African Rift Valley Lakes
49 Red Sea and Gulf of Aden (LME)
50 Euphrates and Tigris River Basin
51 Jordan
52 Arabian Sea (LME)
53 Bay of Bengal
54 South China Sea (2 LMEs)
55 Mekong River
56 Sulu-Celebes Sea (LME)
57 Indonesian Seas (LME)
58 North Australian Shelf (LME)
59 Coral Sea Basin
60 Great Barrier Reef (LME)
61 Great Australian Bight
62 Pacific Islands
63 Tasman Sea
64 Humboldt Current (LME)
65 Eastern Equatorial Pacific (LME)
66 Antarctic (LME)

Figure 1 The 66 transboundary regions assessed within the GIWA project.

(10%). Other contributions were made by Kalmar Municipality, the University of Kalmar and the Norwegian Government. The assessment of regions ineligible for GEF funds was conducted by various international and national organisations as in-kind contributions to the GIWA.

In order to be consistent with the transboundary nature of many of the world's aquatic resources and the focus of the GIWA, the geographical units being assessed have been designed according to the watersheds of discrete hydrographic systems rather than political borders (Figure 1). The geographic units of the assessment were determined during the preparatory phase of the project and resulted in the division of the world into 66 regions defined by the entire area of one or more catchments areas that drains into a single designated marine system. These marine systems often correspond to Large Marine Ecosystems (LMEs) (Sherman 1994, IOC 2002).

Considering the objectives of the GIWA and the elements incorporated into its design, a new methodology for the implementation of the assessment was developed during the initial phase of the project. The methodology focuses on five major environmental concerns which constitute the foundation of the GIWA assessment; Freshwater shortage, Pollution, Habitat and community modification, Overexploitation of fish and other living resources, and Global change. The GIWA methodology is outlined in the following chapter.

Large Marine Ecocsystems (LMEs)

Large Marine Ecosystems (LMEs) are regions of ocean space encompassing coastal areas from river basins and estuaries to the seaward boundaries of continental shelves and the outer margin of the major current systems. They are relatively large regions on the order of 200 000 km^2 or greater, characterised by distinct: (1) bathymetry, (2) hydrography, (3) productivity, and (4) trophically dependent populations.

The Large Marine Ecosystems strategy is a global effort for the assessment and management of international coastal waters. It developed in direct response to a declaration at the 1992 Rio Summit. As part of the strategy, the World Conservation Union (IUCN) and National Oceanic and Atmospheric Administration (NOAA) have joined in an action program to assist developing countries in planning and implementing an ecosystem-based strategy that is focused on LMEs as the principal assessment and management units for coastal ocean resources. The LME concept is also adopted by GEF that recommends the use of LMEs and their contributing freshwater basins as the geographic area for integrating changes in sectoral economic activities.

The global network

In each of the 66 regions, the assessment is conducted by a team of local experts that is headed by a Focal Point (Figure 2). The Focal Point can be an individual, institution or organisation that has been selected on the basis of their scientific reputation and experience implementing international assessment projects. The Focal Point is responsible for assembling members of the team and ensuring that it has the necessary expertise and experience in a variety of environmental and socio-economic disciplines to successfully conduct the regional assessment. The selection of team members is one of the most critical elements for the success of GIWA and, in order to ensure that the most relevant information is incorporated into the assessment, team members were selected from a wide variety of institutions such as

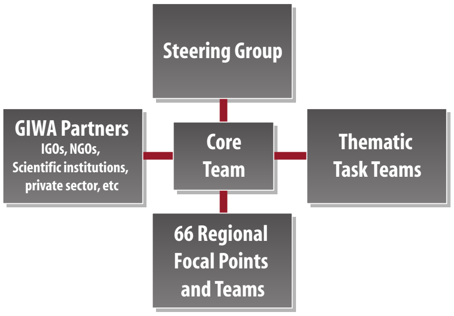


Figure 2 The organisation of the GIWA project.

universities, research institutes, government agencies, and the private sector. In addition, in order to ensure that the assessment produces a truly regional perspective, the teams should include representatives from each country that shares the region.

In total, more than 1 000 experts have contributed to the implementation of the GIWA illustrating that the GIWA is a participatory exercise that relies on regional expertise. This participatory approach is essential because it instils a sense of local ownership of the project, which ensures the credibility of the findings and moreover, it has created a global network of experts and institutions that can collaborate and exchange experiences and expertise to help mitigate the continued degradation of the world's aquatic resources.

GIWA Regional reports

The GIWA was established in response to growing concern among the general public regarding the quality of the world's aquatic resources and the recognition of governments and the international community concerning the absence of a globally coherent international waters assessment. However, because a holistic, region-by-region, assessment of the condition of the world's transboundary water resources had never been undertaken, a methodology guiding the implementation of such an assessment did not exist. Therefore, in order to implement the GIWA, a new methodology that adopted a multidisciplinary, multi-sectoral, multi-national approach was developed and is now available for the implementation of future international assessments of aquatic resources.

UNEP Water Policy and Strategy

The primary goals of the UNEP water policy and strategy are:

(a) Achieving greater global understanding of freshwater, coastal and marine environments by conducting environmental assessments in priority areas;

(b) Raising awareness of the importance and consequences of unsustainable water use;

(c) Supporting the efforts of Governments in the preparation and implementation of integrated management of freshwater systems and their related coastal and marine environments;

(d) Providing support for the preparation of integrated management plans and programmes for aquatic environmental hot spots, based on the assessment results;

(e) Promoting the application by stakeholders of precautionary, preventive and anticipatory approaches.

The GIWA is comprised of a logical sequence of four integrated components. The first stage of the GIWA is called Scaling and is a process by which the geographic area examined in the assessment is defined and all the transboundary waters within that area are identified. Once the geographic scale of the assessment has been defined, the assessment teams conduct a process known as Scoping in which the magnitude of environmental and associated socio-economic impacts of Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources, and Global change is assessed in order to identify and prioritise the concerns that require the most urgent intervention. The assessment of these predefined concerns incorporates the best available information and the knowledge and experience of the multidisciplinary, multi-national assessment teams formed in each region. Once the priority concerns have been identified, the root causes of these concerns are identified during the third component of the GIWA, Causal chain analysis. The root causes are determined through a sequential process that identifies, in turn, the most significant immediate causes followed by the economic sectors that are primarily responsible for the immediate causes and finally, the societal root causes. At each stage in the Causal chain analysis, the most significant contributors are identified through an analysis of the best available information which is augmented by the expertise of the assessment team. The final component of the GIWA is the development of Policy options that focus on mitigating the impacts of the root causes identified by the Causal chain analysis.

The results of the GIWA assessment in each region are reported in regional reports that are published by UNEP. These reports are designed to provide a brief physical and socio-economic description of the most important features of the region against which the results of the assessment can be cast. The remaining sections of the report present the results of each stage of the assessment in an easily digestible form. Each regional report is reviewed by at least two independent external reviewers in order to ensure the scientific validity and applicability of each report. The 66 regional assessments of the GIWA will serve UNEP as an essential complement to the UNEP Water Policy and Strategy and UNEP's activities in the hydrosphere.

Global International Waters Assessment

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The GIWA methodology

The specific objectives of the GIWA were to conduct a holistic and globally comparable assessment of the world's transboundary aquatic resources that incorporated both environmental and socio-economic factors and recognised the inextricable links between freshwater and marine environments, in order to enable the GEF to focus their resources and to provide guidance and advice to governments and decision makers. The coalition of all these elements into a single coherent methodology that produces an assessment that achieves each of these objectives had not previously been done and posed a significant challenge.

The integration of each of these elements into the GIWA methodology was achieved through an iterative process guided by a specially convened Methods task team that was comprised of a number of international assessment and water experts. Before the final version of the methodology was adopted, preliminary versions underwent an extensive external peer review and were subjected to preliminary testing in selected regions. Advice obtained from the Methods task team and other international experts and the lessons learnt from preliminary testing were incorporated into the final version that was used to conduct each of the GIWA regional assessments.

Considering the enormous differences between regions in terms of the quality, quantity and availability of data, socio-economic setting and environmental conditions, the achievement of global comparability required an innovative approach. This was facilitated by focusing the assessment on the impacts of five pre-defined concerns namely; Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources and Global change, in transboundary waters. Considering the diverse range of elements encompassed by each concern, assessing the magnitude of the impacts caused by these concerns was facilitated by evaluating the impacts of 22 specific issues that were grouped within these concerns (see Table 1).

The assessment integrates environmental and socio-economic data from each country in the region to determine the severity of the impacts of each of the five concerns and their constituent issues on the entire region. The integration of this information was facilitated by implementing the assessment during two participatory workshops that typically involved 10 to 15 environmental and socio-economic experts from each country in the region. During these workshops, the regional teams performed preliminary analyses based on the collective knowledge and experience of these local experts. The results of these analyses were substantiated with the best available information to be presented in a regional report.

Table 1 Pre-defined GIWA concerns and their constituent issues addressed within the assessment.

Environmental issues	Major concerns
1. Modification of stream flow 2. Pollution of existing supplies 3. Changes in the water table	**I Freshwater shortage**
4. Microbiological 5. Eutrophication 6. Chemical 7. Suspended solids 8. Solid wastes 9. Thermal 10. Radionuclide 11. Spills	**II Pollution**
12. Loss of ecosystems 13. Modification of ecosystems or ecotones, including community structure and/or species composition	**III Habitat and community modification**
14. Overexploitation 15. Excessive by-catch and discards 16. Destructive fishing practices 17. Decreased viability of stock through pollution and disease 18. Impact on biological and genetic diversity	**IV Unsustainable exploitation of fish and other living resources**
19. Changes in hydrological cycle 20. Sea level change 21. Increased uv-b radiation as a result of ozone depletion 22. Changes in ocean CO_2 source/sink function	**V Global change**

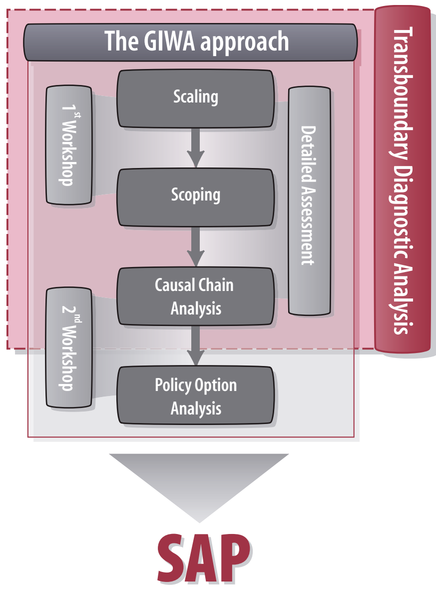

Figure 1 Illustration of the relationship between the GIWA approach and other projects implemented within the GEF International Waters (IW) portfolio.

The GIWA is a logical contiguous process that defines the geographic region to be assessed, identifies and prioritises particularly problems based on the magnitude of their impacts on the environment and human societies in the region, determines the root causes of those problems and, finally, assesses various policy options that addresses those root causes in order to reverse negative trends in the condition of the aquatic environment. These four steps, referred to as Scaling, Scoping, Causal chain analysis and Policy options analysis, are summarised below and are described in their entirety in two volumes: *GIWA Methodology Stage 1: Scaling and Scoping*; and *GIWA Methodology: Detailed Assessment, Causal Chain Analysis and Policy Options Analysis*. Generally, the components of the GIWA methodology are aligned with the framework adopted by the GEF for Transboundary Diagnostic Analyses (TDAs) and Strategic Action Programmes (SAPs) (Figure 1) and assume a broad spectrum of transboundary influences in addition to those associated with the physical movement of water across national borders.

Scaling – Defining the geographic extent of the region

Scaling is the first stage of the assessment and is the process by which the geographic scale of the assessment is defined. In order to facilitate the implementation of the GIWA, the globe was divided during the design phase of the project into 66 contiguous regions. Considering the transboundary nature of many aquatic resources and the transboundary focus of the GIWA, the boundaries of the regions did not comply with political boundaries but were instead, generally defined by a large but discrete drainage basin that also included the coastal marine waters into which the basin discharges. In many cases, the marine areas examined during the assessment coincided with the Large Marine Ecosystems (LMEs) defined by the US National Atmospheric and Oceanographic Administration (NOAA). As a consequence, scaling should be a relatively straight-forward task that involves the inspection of the boundaries that were proposed for the region during the preparatory phase of GIWA to ensure that they are appropriate and that there are no important overlaps or gaps with neighbouring regions. When the proposed boundaries were found to be inadequate, the boundaries of the region were revised according to the recommendations of experts from both within the region and from adjacent regions so as to ensure that any changes did not result in the exclusion of areas from the GIWA. Once the regional boundary was defined, regional teams identified all the transboundary elements of the aquatic environment within the region and determined if these elements could be assessed as a single coherent aquatic system or if there were two or more independent systems that should be assessed separately.

Scoping – Assessing the GIWA concerns

Scoping is an assessment of the severity of environmental and socio-economic impacts caused by each of the five pre-defined GIWA concerns and their constituent issues (Table 1). It is not designed to provide an exhaustive review of water-related problems that exist within each region, but rather it is a mechanism to identify the most urgent problems in the region and prioritise those for remedial actions. The priorities determined by Scoping are therefore one of the main outputs of the GIWA project.

Focusing the assessment on pre-defined concerns and issues ensured the comparability of the results between different regions. In addition, to ensure the long-term applicability of the options that are developed to mitigate these problems, Scoping not only assesses the current impacts of these concerns and issues but also the probable future impacts according to the "most likely scenario" which considered demographic, economic, technological and other relevant changes that will potentially influence the aquatic environment within the region by 2020.

The magnitude of the impacts caused by each issue on the environment and socio-economic indicators was assessed over the entire region using the best available information from a wide range of sources and the knowledge and experience of the each of the experts comprising the regional team. In order to enhance the comparability of the assessment between different regions and remove biases in the assessment caused by different perceptions of and ways to communicate the severity of impacts caused by particular issues, the results were distilled and reported as standardised scores according to the following four point scale:

- 0 = no known impact
- 1 = slight impact
- 2 = moderate impact
- 3 = severe impact

The attributes of each score for each issue were described by a detailed set of pre-defined criteria that were used to guide experts in reporting the results of the assessment. For example, the criterion for assigning a score of 3 to the issue Loss of ecosystems or ecotones is: "*Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by >30% during the last 2-3 decades.*" The full list of criteria is presented at the end of the chapter, Table 5a-e. Although the scoring inevitably includes an arbitrary component, the use of predefined criteria facilitates comparison of impacts on a global scale and also encouraged consensus of opinion among experts.

The trade-off associated with assessing the impacts of each concern and their constituent issues at the scale of the entire region is that spatial resolution was sometimes low. Although the assessment provides a score indicating the severity of impacts of a particular issue or concern on the entire region, it does not mean that the entire region suffers the impacts of that problem. For example, eutrophication could be identified as a severe problem in a region, but this does not imply that all waters in the region suffer from severe eutrophication. It simply means that when the degree of eutrophication, the size of the area affected, the socio-economic impacts and the number of people affected is considered, the magnitude of the overall impacts meets the criteria defining a severe problem and that a regional action should be initiated in order to mitigate the impacts of the problem.

When each issue has been scored, it was weighted according to the relative contribution it made to the overall environmental impacts of the concern and a weighted average score for each of the five concerns was calculated (Table 2). Of course, if each issue was deemed to make equal contributions, then the score describing the overall impacts of the concern was simply the arithmetic mean of the scores allocated to each issue within the concern. In addition, the socio-economic impacts of each of the five major concerns were assessed for the entire region. The socio-economic impacts were grouped into three categories; Economic impacts, Health impacts and Other social and community impacts (Table 3). For each category, an evaluation of the size, degree and frequency of the impact was performed and, once completed, a weighted average score describing the overall socio-economic impacts of each concern was calculated in the same manner as the overall environmental score.

Table 2 Example of environmental impact assessment of Freshwater shortage.

Environmental issues	Score	Weight %	Environmental concerns	Weight averaged score
1. Modification of stream flow	1	20	Freshwater shortage	1.50
2. Pollution of existing supplies	2	50		
3. Changes in the water table	1	30		

Table 3 Example of Health impacts assessment linked to one of the GIWA concerns.

Criteria for Health impacts	Raw score	Score	Weight %
Number of people affected	Very small – Very large 0 1 2 3	2	50
Degree of severity	Minimum – Severe 0 1 2 3	2	30
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	20
Weight average score for Health impacts		**2**	

After all 22 issues and associated socio-economic impacts have been scored, weighted and averaged, the magnitude of likely future changes in the environmental and socio-economic impacts of each of the five concerns on the entire region is assessed according to the most likely scenario which describes the demographic, economic, technological and other relevant changes that might influence the aquatic environment within the region by 2020.

In order to prioritise among GIWA concerns within the region and identify those that will be subjected to causal chain and policy options analysis in the subsequent stages of the GIWA, the present and future scores of the environmental and socio-economic impacts of each concern are tabulated and an overall score calculated. In the example presented in Table 4, the scoping assessment indicated that concern III, Habitat and community modification, was the priority concern in this region. The outcome of this mathematic process was reconciled against the knowledge of experts and the best available information in order to ensure the validity of the conclusion.

In some cases however, this process and the subsequent participatory discussion did not yield consensus among the regional experts regarding the ranking of priorities. As a consequence, further analysis was required. In such cases, expert teams continued by assessing the relative importance of present and potential future impacts and assign weights to each. Afterwards, the teams assign weights indicating the relative contribution made by environmental and socio-economic factors to the overall impacts of the concern. The weighted average score for each concern is then recalculated taking into account

Table 4 Example of comparative environmental and socio-economic impacts of each major concern, presently and likely in year 2020.

Concern	Types of impacts								Overall score
	Environmental score		Economic score		Human health score		Social and community score		
	Present (a)	Future (b)	Present (c)	Future (d)	Present (e)	Future (f)	Present (g)	Future (h)	
Freshwater shortage	1.3	2.3	2.7	2.8	2.6	3.0	1.8	2.2	**2.3**
Pollution	1.5	2.0	2.0	2.3	1.8	2.3	2.0	2.3	**2.0**
Habitat and community modification	2.0	3.0	2.4	3.0	2.4	2.8	2.3	2.7	**2.6**
Unsustainable exploitation of fish and other living resources	1.8	2.2	2.0	2.1	2.0	2.1	2.4	2.5	**2.1**
Global change	0.8	1.0	1.5	1.7	1.5	1.5	1.0	1.0	**1.2**

the relative contributions of both present and future impacts and environmental and socio-economic factors. The outcome of these additional analyses was subjected to further discussion to identify overall priorities for the region.

Finally, the assessment recognises that each of the five GIWA concerns are not discrete but often interact. For example, pollution can destroy aquatic habitats that are essential for fish reproduction which, in turn, can cause declines in fish stocks and subsequent overexploitation. Once teams have ranked each of the concerns and determined the priorities for the region, the links between the concerns are highlighted in order to identify places where strategic interventions could be applied to yield the greatest benefits for the environment and human societies in the region.

Causal chain analysis

Causal Chain Analysis (CCA) traces the cause-effect pathways from the socio-economic and environmental impacts back to their root causes. The GIWA CCA aims to identify the most important causes of each concern prioritised during the scoping assessment in order to direct policy measures at the most appropriate target in order to prevent further degradation of the regional aquatic environment.

Root causes are not always easy to identify because they are often spatially or temporally separated from the actual problems they cause. The GIWA CCA was developed to help identify and understand the root causes of environmental and socio-economic problems in international waters and is conducted by identifying the human activities that cause the problem and then the factors that determine the ways in which these activities are undertaken. However, because there is no universal theory describing how root causes interact to create natural resource management problems and due to the great variation of local circumstances under which the methodology will be applied, the GIWA CCA is not a rigidly structured assessment but should be regarded as a framework to guide the analysis, rather than as a set of detailed instructions. Secondly, in an ideal setting, a causal chain would be produced by a multidisciplinary group of specialists that would statistically examine each successive cause and study its links to the problem and to other causes. However, this approach (even if feasible) would use far more resources and time than those available to GIWA[1]. For this reason, it has been necessary to develop a relatively simple and practical analytical model for gathering information to assemble meaningful causal chains.

Conceptual model

A causal chain is a series of statements that link the causes of a problem with its effects. Recognising the great diversity of local settings and the resulting difficulty in developing broadly applicable policy strategies, the GIWA CCA focuses on a particular system and then only on those issues that were prioritised during the scoping assessment. The starting point of a particular causal chain is one of the issues selected during the Scaling and Scoping stages and its related environmental and socio-economic impacts. The next element in the GIWA chain is the immediate cause; defined as the physical, biological or chemical variable that produces the GIWA issue. For example, for the issue of eutrophication the immediate causes may be, inter alia:

- Enhanced nutrient inputs;
- Increased recycling/mobilisation;
- Trapping of nutrients (e.g. in river impoundments);
- Run-off and stormwaters

Once the relevant immediate cause(s) for the particular system has (have) been identified, the sectors of human activity that contribute most significantly to the immediate cause have to be determined. Assuming that the most important immediate cause in our example had been increased nutrient concentrations, then it is logical that the most likely sources of those nutrients would be the agricultural, urban or industrial sectors. After identifying the sectors that are primarily

[1] This does not mean that the methodology ignores statistical or quantitative studies; as has already been pointed out, the available evidence that justifies the assumption of causal links should be provided in the assessment.

responsible for the immediate causes, the root causes acting on those sectors must be determined. For example, if agriculture was found to be primarily responsible for the increased nutrient concentrations, the root causes could potentially be:

- Economic (e.g. subsidies to fertilisers and agricultural products);
- Legal (e.g. inadequate regulation);
- Failures in governance (e.g. poor enforcement); or
- Technology or knowledge related (e.g. lack of affordable substitutes for fertilisers or lack of knowledge as to their application).

Once the most relevant root causes have been identified, an explanation, which includes available data and information, of how they are responsible for the primary environmental and socio-economic problems in the region should be provided.

Policy option analysis

Despite considerable effort of many Governments and other organisations to address transboundary water problems, the evidence indicates that there is still much to be done in this endeavour. An important characteristic of GIWA's Policy Option Analysis (POA) is that its recommendations are firmly based on a better understanding of the root causes of the problems. Freshwater scarcity, water pollution, overexploitation of living resources and habitat destruction are very complex phenomena. Policy options that are grounded on a better understanding of these phenomena will contribute to create more effective societal responses to the extremely complex water related transboundary problems. The core of POA in the assessment consists of two tasks:

Construct policy options

Policy options are simply different courses of action, which are not always mutually exclusive, to solve or mitigate environmental and socio-economic problems in the region. Although a multitude of different policy options could be constructed to address each root cause identified in the CCA, only those few policy options that have the greatest likelihood of success were analysed in the GIWA.

Select and apply the criteria on which the policy options will be evaluated

Although there are many criteria that could be used to evaluate any policy option, GIWA focuses on:

- Effectiveness (certainty of result)
- Efficiency (maximisation of net benefits)
- Equity (fairness of distributional impacts)
- Practical criteria (political acceptability, implementation feasibility).

The policy options recommended by the GIWA are only contributions to the larger policy process and, as such, the GIWA methodology developed to test the performance of various options under the different circumstances has been kept simple and broadly applicable.

Global International Waters Assessment

Table 5a: Scoring criteria for environmental impacts of Freshwater shortage

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 1: Modification of stream flow "An increase or decrease in the discharge of streams and rivers as a result of human interventions on a local/regional scale (see Issue 19 for flow alterations resulting from global change) over the last 3-4 decades."	■ No evidence of modification of stream flow.	■ There is a measurably changing trend in annual river discharge at gauging stations in a major river or tributary (basin > 40 000 km^2); or ■ There is a measurable decrease in the area of wetlands (other than as a consequence of conversion or embankment construction); or ■ There is a measurable change in the interannual mean salinity of estuaries or coastal lagoons and/or change in the mean position of estuarine salt wedge or mixing zone; or ■ Change in the occurrence of exceptional discharges (e.g. due to upstream damming.	■ Significant downward or upward trend (more than 20% of the long term mean) in annual discharges in a major river or tributary draining a basin of >250 000 km^2; or ■ Loss of >20% of flood plain or deltaic wetlands through causes other than conversion or artificial embankments; or ■ Significant loss of riparian vegetation (e.g. trees, flood plain vegetation); or ■ Significant saline intrusion into previously freshwater rivers or lagoons.	■ Annual discharge of a river altered by more than 50% of long term mean; or ■ Loss of >50% of riparian or deltaic wetlands over a period of not less than 40 years (through causes other than conversion or artificial embankment); or ■ Significant increased siltation or erosion due to changing in flow regime (other than normal fluctuations in flood plain rivers); or ■ Loss of one or more anadromous or catadromous fish species for reasons other than physical barriers to migration, pollution or overfishing.
Issue 2: Pollution of existing supplies "Pollution of surface and ground fresh waters supplies as a result of point or diffuse sources"	■ No evidence of pollution of surface and ground waters.	■ Any monitored water in the region does not meet WHO or national drinking water criteria, other than for natural reasons; or ■ There have been reports of one or more fish kills in the system due to pollution within the past five years.	■ Water supplies does not meet WHO or national drinking water standards in more than 30% of the region; or ■ There are one or more reports of fish kills due to pollution in any river draining a basin of >250 000 km^2 .	■ River draining more than 10% of the basin have suffered polysaprobic conditions, no longer support fish, or have suffered severe oxygen depletion ■ Severe pollution of other sources of freshwater (e.g. groundwater)
Issue 3: Changes in the water table "Changes in aquifers as a direct or indirect consequence of human activity"	■ No evidence that abstraction of water from aquifers exceeds natural replenishment.	■ Several wells have been deepened because of excessive aquifer draw-down; or ■ Several springs have dried up; or ■ Several wells show some salinisation.	■ Clear evidence of declining base flow in rivers in semi-arid areas; or ■ Loss of plant species in the past decade, that depend on the presence of ground water; or ■ Wells have been deepened over areas of hundreds of km^2;or ■ Salinisation over significant areas of the region.	■ Aquifers are suffering salinisation over regional scale; or ■ Perennial springs have dried up over regionally significant areas; or ■ Some aquifers have become exhausted

Table 5b: Scoring criteria for environmental impacts of Pollution

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 4: Microbiological pollution "The adverse effects of microbial constituents of human sewage released to water bodies."	■ Normal incidence of bacterial related gastroenteric disorders in fisheries product consumers and no fisheries closures or advisories.	■ There is minor increase in incidence of bacterial related gastroenteric disorders in fisheries product consumers but no fisheries closures or advisories.	■ Public health authorities aware of marked increase in the incidence of bacterial related gastroenteric disorders in fisheries product consumers; or ■ There are limited area closures or advisories reducing the exploitation or marketability of fisheries products.	■ There are large closure areas or very restrictive advisories affecting the marketability of fisheries products; or ■ There exists widespread public or tourist awareness of hazards resulting in major reductions in the exploitation or marketability of fisheries products.
Issue 5: Eutrophication "Artificially enhanced primary productivity in receiving water basins related to the increased availability or supply of nutrients, including cultural eutrophication in lakes."	■ No visible effects on the abundance and distributions of natural living resource distributions in the area; and ■ No increased frequency of hypoxia[1] or fish mortality events or harmful algal blooms associated with enhanced primary production; and ■ No evidence of periodically reduced dissolved oxygen or fish and zoobenthos mortality; and ■ No evident abnormality in the frequency of algal blooms.	■ Increased abundance of epiphytic algae; or ■ A statistically significant trend in decreased water transparency associated with algal production as compared with long-term (>20 year) data sets; or ■ Measurable shallowing of the depth range of macrophytes.	■ Increased filamentous algal production resulting in algal mats; or ■ Medium frequency (up to once per year) of large-scale hypoxia and/or fish and zoobenthos mortality events and/or harmful algal blooms.	■ High frequency (>1 event per year), or intensity, or large areas of periodic hypoxic conditions, or high frequencies of fish and zoobenthos mortality events or harmful algal blooms; or ■ Significant changes in the littoral community; or ■ Presence of hydrogen sulphide in historically well oxygenated areas.

Issue 6: Chemical pollution "The adverse effects of chemical contaminants released to standing or marine water bodies as a result of human activities. Chemical contaminants are here defined as compounds that are toxic or persistent or bioaccumulating."	■ No known or historical levels of chemical contaminants except background levels of naturally occurring substances; and ■ No fisheries closures or advisories due to chemical pollution; and ■ No incidence of fisheries product tainting; and ■ No unusual fish mortality events. If there is no available data use the following criteria: ■ No use of pesticides; and ■ No sources of dioxins and furans; and ■ No regional use of PCBs; and ■ No bleached kraft pulp mills using chlorine bleaching; and ■ No use or sources of other contaminants.	■ Some chemical contaminants are detectable but below threshold limits defined for the country or region; or ■ Restricted area advisories regarding chemical contamination of fisheries products. If there is no available data use the following criteria: ■ Some use of pesticides in small areas; or ■ Presence of small sources of dioxins or furans (e.g., small incineration plants or bleached kraft/pulp mills using chlorine); or ■ Some previous and existing use of PCBs and limited amounts of PCB-containing wastes but not in amounts invoking local concerns; or ■ Presence of other contaminants.	■ Some chemical contaminants are above threshold limits defined for the country or region; or ■ Large area advisories by public health authorities concerning fisheries product contamination but without associated catch restrictions or closures; or ■ High mortalities of aquatic species near outfalls. If there is no available data use the following criteria: ■ Large-scale use of pesticides in agriculture and forestry; or ■ Presence of major sources of dioxins or furans such as large municipal or industrial incinerators or large bleached kraft pulp mills; or ■ Considerable quantities of waste PCBs in the area with inadequate regulation or has invoked some public concerns; or ■ Presence of considerable quantities of other contaminants.	■ Chemical contaminants are above threshold limits defined for the country or region; and ■ Public health and public awareness of fisheries contamination problems with associated reductions in the marketability of such products either through the imposition of limited advisories or by area closures of fisheries; or ■ Large-scale mortalities of aquatic species. If there is no available data use the following criteria: ■ Indications of health effects resulting from use of pesticides; or ■ Known emissions of dioxins or furans from incinerators or chlorine bleaching of pulp; or ■ Known contamination of the environment or foodstuffs by PCBs; or ■ Known contamination of the environment or foodstuffs by other contaminants.
Issue 7: Suspended solids "The adverse effects of modified rates of release of suspended particulate matter to water bodies resulting from human activities"	■ No visible reduction in water transparency; and ■ No evidence of turbidity plumes or increased siltation; and ■ No evidence of progressive riverbank, beach, other coastal or deltaic erosion.	■ Evidently increased or reduced turbidity in streams and/or receiving riverine and marine environments but without major changes in associated sedimentation or erosion rates, mortality or diversity of flora and fauna; or ■ Some evidence of changes in benthic or pelagic biodiversity in some areas due to sediment blanketing or increased turbidity.	■ Markedly increased or reduced turbidity in small areas of streams and/or receiving riverine and marine environments; or ■ Extensive evidence of changes in sedimentation or erosion rates; or ■ Changes in benthic or pelagic biodiversity in areas due to sediment blanketing or increased turbidity.	■ Major changes in turbidity over wide or ecologically significant areas resulting in markedly changed biodiversity or mortality in benthic species due to excessive sedimentation with or without concomitant changes in the nature of deposited sediments (i.e., grain-size composition/redox); or ■ Major change in pelagic biodiversity or mortality due to excessive turbidity.
Issue 8: Solid wastes "Adverse effects associated with the introduction of solid waste materials into water bodies or their environs."	■ No noticeable interference with trawling activities; and ■ No noticeable interference with the recreational use of beaches due to litter; and ■ No reported entanglement of aquatic organisms with debris.	■ Some evidence of marine-derived litter on beaches; or ■ Occasional recovery of solid wastes through trawling activities; but ■ Without noticeable interference with trawling and recreational activities in coastal areas.	■ Widespread litter on beaches giving rise to public concerns regarding the recreational use of beaches; or ■ High frequencies of benthic litter recovery and interference with trawling activities; or ■ Frequent reports of entanglement/suffocation of species by litter.	■ Incidence of litter on beaches sufficient to deter the public from recreational activities; or ■ Trawling activities untenable because of benthic litter and gear entanglement; or ■ Widespread entanglement and/or suffocation of aquatic species by litter.
Issue 9: Thermal "The adverse effects of the release of aqueous effluents at temperatures exceeding ambient temperature in the receiving water body."	■ No thermal discharges or evidence of thermal effluent effects.	■ Presence of thermal discharges but without noticeable effects beyond the mixing zone and no significant interference with migration of species.	■ Presence of thermal discharges with large mixing zones having reduced productivity or altered biodiversity; or ■ Evidence of reduced migration of species due to thermal plume.	■ Presence of thermal discharges with large mixing zones with associated mortalities, substantially reduced productivity or noticeable changes in biodiversity; or ■ Marked reduction in the migration of species due to thermal plumes.
Issue 10: Radionuclide "The adverse effects of the release of radioactive contaminants and wastes into the aquatic environment from human activities."	■ No radionuclide discharges or nuclear activities in the region.	■ Minor releases or fallout of radionuclides but with well regulated or well-managed conditions complying with the Basic Safety Standards.	■ Minor releases or fallout of radionuclides under poorly regulated conditions that do not provide an adequate basis for public health assurance or the protection of aquatic organisms but without situations or levels likely to warrant large scale intervention by a national or international authority.	■ Substantial releases or fallout of radionuclides resulting in excessive exposures to humans or animals in relation to those recommended under the Basic Safety Standards; or ■ Some indication of situations or exposures warranting intervention by a national or international authority.
Issue 11: Spills "The adverse effects of accidental episodic releases of contaminants and materials to the aquatic environment as a result of human activities."	■ No evidence of present or previous spills of hazardous material; or ■ No evidence of increased aquatic or avian species mortality due to spills.	■ Some evidence of minor spills of hazardous materials in small areas with insignificant small-scale adverse effects one aquatic or avian species.	■ Evidence of widespread contamination by hazardous or aesthetically displeasing materials assumed to be from spillage (e.g. oil slicks) but with limited evidence of widespread adverse effects on resources or amenities; or ■ Some evidence of aquatic or avian species mortality through increased presence of contaminated or poisoned carcasses on beaches.	■ Widespread contamination by hazardous or aesthetically displeasing materials from frequent spills resulting in major interference with aquatic resource exploitation or coastal recreational amenities; or ■ Significant mortality of aquatic or avian species as evidenced by large numbers of contaminated carcasses on beaches.

Table 5c: Scoring criteria for environmental impacts of Habitat and community modification

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 12: Loss of ecosystems or ecotones "The complete destruction of aquatic habitats. For the purpose of GIWA methodology, recent loss will be measured as a loss of pre-defined habitats over the last 2-3 decades."	■ There is no evidence of loss of ecosystems or habitats.	■ There are indications of fragmentation of at least one of the habitats.	■ Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by up to 30 % during the last 2-3 decades.	■ Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by >30% during the last 2-3 decades.
Issue 13: Modification of ecosystems or ecotones, including community structure and/or species composition "Modification of pre-defined habitats in terms of extinction of native species, occurrence of introduced species and changing in ecosystem function and services over the last 2-3 decades."	■ No evidence of change in species complement due to species extinction or introduction; and ■ No changing in ecosystem function and services.	■ Evidence of change in species complement due to species extinction or introduction	■ Evidence of change in species complement due to species extinction or introduction; and ■ Evidence of change in population structure or change in functional group composition or structure	■ Evidence of change in species complement due to species extinction or introduction; and ■ Evidence of change in population structure or change in functional group composition or structure; and ■ Evidence of change in ecosystem services[2].

[2] Constanza, R. et al. (1997). The value of the world ecosystem services and natural capital, Nature 387:253-260.

Table 5d: Scoring criteria for environmental impacts of Unsustainable exploitation of fish and other living resources

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 14: Overexploitation "The capture of fish, shellfish or marine invertebrates at a level that exceeds the maximum sustainable yield of the stock."	■ No harvesting exists catching fish (with commercial gear for sale or subsistence).	■ Commercial harvesting exists but there is no evidence of over-exploitation.	■ One stock is exploited beyond MSY (maximum sustainable yield) or is outside safe biological limits.	■ More than one stock is exploited beyond MSY or is outside safe biological limits.
Issue 15: Excessive by-catch and discards "By-catch refers to the incidental capture of fish or other animals that are not the target of the fisheries. Discards refers to dead fish or other animals that are returned to the sea."	■ Current harvesting practices show no evidence of excessive by-catch and/or discards.	■ Up to 30% of the fisheries yield (by weight) consists of by-catch and/or discards.	■ 30-60% of the fisheries yield consists of by-catch and/or discards.	■ Over 60% of the fisheries yield is by-catch and/or discards; or ■ Noticeable incidence of capture of endangered species.
Issue 16: Destructive fishing practices "Fishing practices that are deemed to produce significant harm to marine, lacustrine or coastal habitats and communities."	■ No evidence of habitat destruction due to fisheries practices.	■ Habitat destruction resulting in changes in distribution of fish or shellfish stocks; or ■ Trawling of any one area of the seabed is occurring less than once per year.	■ Habitat destruction resulting in moderate reduction of stocks or moderate changes of the environment; or ■ Trawling of any one area of the seabed is occurring 1-10 times per year; or ■ Incidental use of explosives or poisons for fishing.	■ Habitat destruction resulting in complete collapse of a stock or far reaching changes in the environment; or ■ Trawling of any one area of the seabed is occurring more than 10 times per year; or ■ Widespread use of explosives or poisons for fishing.
Issue 17: Decreased viability of stocks through contamination and disease "Contamination or diseases of feral (wild) stocks of fish or invertebrates that are a direct or indirect consequence of human action."	■ No evidence of increased incidence of fish or shellfish diseases.	■ Increased reports of diseases without major impacts on the stock.	■ Declining populations of one or more species as a result of diseases or contamination.	■ Collapse of stocks as a result of diseases or contamination.
Issue 18: Impact on biological and genetic diversity "Changes in genetic and species diversity of aquatic environments resulting from the introduction of alien or genetically modified species as an intentional or unintentional result of human activities including aquaculture and restocking."	■ No evidence of deliberate or accidental introductions of alien species; and ■ No evidence of deliberate or accidental introductions of alien stocks; and ■ No evidence of deliberate or accidental introductions of genetically modified species.	■ Alien species introduced intentionally or accidentally without major changes in the community structure; or ■ Alien stocks introduced intentionally or accidentally without major changes in the community structure; or ■ Genetically modified species introduced intentionally or accidentally without major changes in the community structure.	■ Measurable decline in the population of native species or local stocks as a result of introductions (intentional or accidental); or ■ Some changes in the genetic composition of stocks (e.g. as a result of escapes from aquaculture replacing the wild stock).	■ Extinction of native species or local stocks as a result of introductions (intentional or accidental); or ■ Major changes (>20%) in the genetic composition of stocks (e.g. as a result of escapes from aquaculture replacing the wild stock).

Table 5e: Scoring criteria for environmental impacts of Global change

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 19: Changes in hydrological cycle and ocean circulation "Changes in the local/regional water balance and changes in ocean and coastal circulation or current regime over the last 2-3 decades arising from the wider problem of global change including ENSO."	■ No evidence of changes in hydrological cycle and ocean/coastal current due to global change.	■ Change in hydrological cycles due to global change causing changes in the distribution and density of riparian terrestrial or aquatic plants without influencing overall levels of productivity; or ■ Some evidence of changes in ocean or coastal currents due to global change but without a strong effect on ecosystem diversity or productivity.	■ Significant trend in changing terrestrial or sea ice cover (by comparison with a long-term time series) without major downstream effects on river/ocean circulation or biological diversity; or ■ Extreme events such as flood and drought are increasing; or ■ Aquatic productivity has been altered as a result of global phenomena such as ENSO events.	■ Loss of an entire habitat through desiccation or submergence as a result of global change; or ■ Change in the tree or lichen lines; or ■ Major impacts on habitats or biodiversity as the result of increasing frequency of extreme events; or ■ Changing in ocean or coastal currents or upwelling regimes such that plant or animal populations are unable to recover to their historical or stable levels; or ■ Significant changes in thermohaline circulation.
Issue 20: Sea level change "Changes in the last 2-3 decades in the annual/seasonal mean sea level as a result of global change."	■ No evidence of sea level change.	■ Some evidences of sea level change without major loss of populations of organisms.	■ Changed pattern of coastal erosion due to sea level rise has became evident; or ■ Increase in coastal flooding events partly attributed to sea-level rise or changing prevailing atmospheric forcing such as atmospheric pressure or wind field (other than storm surges).	■ Major loss of coastal land areas due to sea-level change or sea-level induced erosion; or ■ Major loss of coastal or intertidal populations due to sea-level change or sea level induced erosion.
Issue 21: Increased UV-B radiation as a result of ozone depletion "Increased UV-B flux as a result polar ozone depletion over the last 2-3 decades."	■ No evidence of increasing effects of UV/B radiation on marine or freshwater organisms.	■ Some measurable effects of UV/B radiation on behavior or appearance of some aquatic species without affecting the viability of the population.	■ Aquatic community structure is measurably altered as a consequence of UV/B radiation; or ■ One or more aquatic populations are declining.	■ Measured/assessed effects of UV/B irradiation are leading to massive loss of aquatic communities or a significant change in biological diversity.
Issue 22: Changes in ocean CO_2 source/sink function "Changes in the capacity of aquatic systems, ocean as well as freshwater, to generate or absorb atmospheric CO_2 as a direct or indirect consequence of global change over the last 2-3 decades."	■ No measurable or assessed changes in CO_2 source/sink function of aquatic system.	■ Some reasonable suspicions that current global change is impacting the aquatic system sufficiently to alter its source/sink function for CO_2.	■ Some evidences that the impacts of global change have altered the source/sink function for CO_2 of aquatic systems in the region by at least 10%.	■ Evidences that the changes in source/sink function of the aquatic systems in the region are sufficient to cause measurable change in global CO_2 balance.

GIWA

The Global International Waters Assessment (GIWA) is a holistic, globally comparable assessment of all the world's transboundary waters that recognises the inextricable links between freshwater and coastal marine environment and integrates environmental and socio-economic information to determine the impacts of a broad suite of influences on the world's aquatic environment.

Broad Transboundary Approach

The GIWA not only assesses the problems caused by human activities manifested by the physical movement of transboundary waters, but also the impacts of other non-hydrological influences that determine how humans use transboundary waters.

Regional Assessment – Global Perspective

The GIWA provides a global perspective of the world's transboundary waters by assessing 66 regions that encompass all major drainage basins and adjacent large marine ecosystems. The GIWA Assessment of each region incorporates information and expertise from all countries sharing the transboundary water resources.

Global Comparability

In each region, the assessment focuses on 5 broad concerns that are comprised of 22 specific water related issues.

Integration of Information and Ecosystems

The GIWA recognises the inextricable links between freshwater and coastal marine environment and assesses them together as one integrated unit.

The GIWA recognises that the integration of socio-economic and environmental information and expertise is essential to obtain a holistic picture of the interactions between the environmental and societal aspects of transboundary waters.

Priorities, Root Causes and Options for the Future

The GIWA indicates priority concerns in each region, determines their societal root causes and develops options to mitigate the impacts of those concerns in the future.

This Report

This report presents the results of the GIWA assessment of the Aral Sea, a land-locked sea in Central Asia. Practically all renewable water resources in the region are being used, predominantly for irrigation, and the regional economy is developing under conditions of increasing freshwater shortages. Freshwater shortage, and more specifically the issue of modification of stream flow was assessed to be of the highest priority. The past and present status and future prospects are discussed, and the transboundary issues are traced back to their root causes. The use of outmoded and inefficient irrigation technology, the continued economic difficulties and weak legislation for water use are major root causes in this region. Policy options have been recommended to mitigate environmental and socio-economic impacts and to secure the region's future prosperity.

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