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

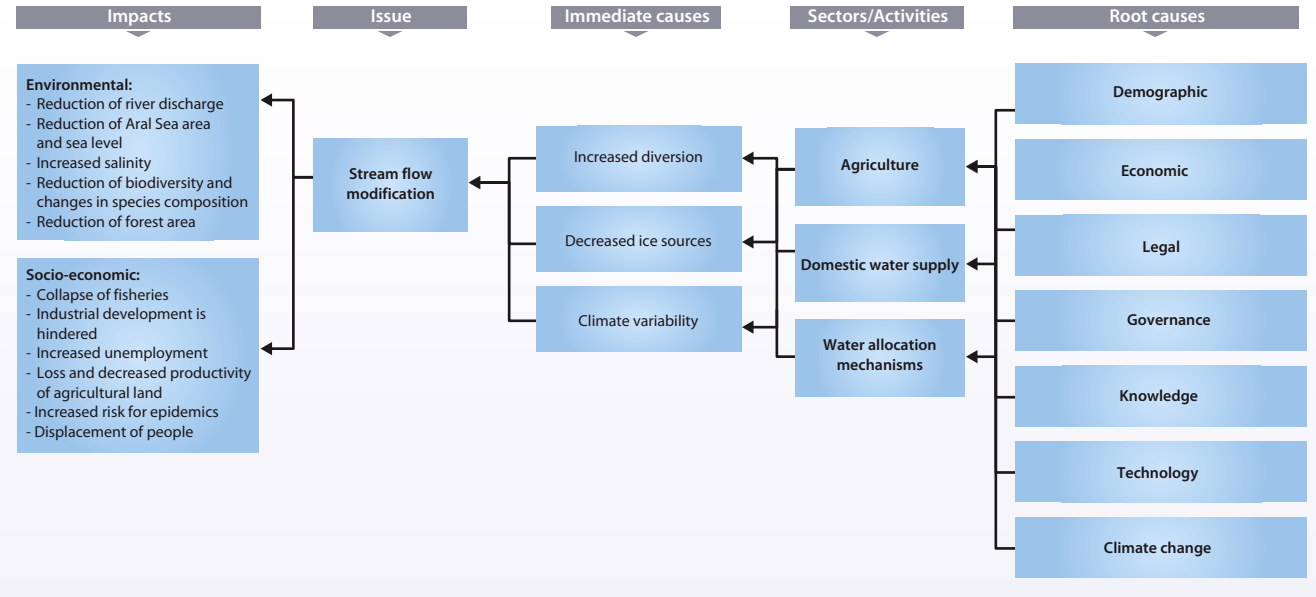

Figure 11 Causal chain analysis model for the Aral Sea region.

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.