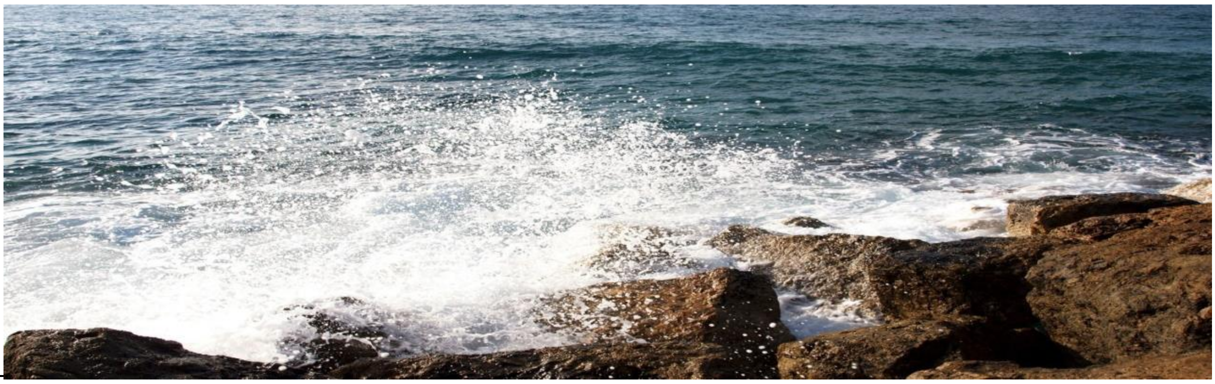
Introduction

Dear friends! My future colleagues! More than 60 years ago, when my coevals and I were entering the institutes of higher education related to water resources management and land reclamation, your parents, may be, were not born yet or "were knee-high to a duck.[1]" It was the epoch of creating gigantic infrastructure for water resources management, when all mass media including newspapers, magazines and radio were informing about achieved successes in this field of activity. At that time, the first mass TV-sets "KVN-49", having small screens with magnifying lenses in front of them, only started to appear in our homes. However, our more experienced colleagues' tales have compensated lack of television information. During the practical training, they have visited the Kakhovskaya HPS, Kanevskaya HPS, Farkhad HPS, Volzhskaya HPS, Votkinskaya HPS and many other hydropower plants or the Karakum Canal and were impressed by grandiose scales of these construction sites. With great pride and their superiority over us - young inexperienced students - they were demonstrating photos (made by primitive cameras of such brands as Leica, Zenith, or FED[2]) that were proving their labor participation.

We took pride in our participation in creative works for the future. In the course of our training, we have studied scores of engineering subjects: descriptive geometry, theoretical mechanics, geodesy, theory of filtration etc. Due to such a curriculum, we have imagined ourselves as servants of holy and miraculous exact sciences, whose name - engineers - has demonstrated the belonging to designing of motors, pumps, and technical calculations or, in brief, to the engineering in contrast to humanitarian and economic sciences, which we considered as good-for-nothing talks! We doughtily studied mathematics by the textbook written by L. Lourie and A. Vinogradov, hydrology by the textbook written by A. Ogievsky, hydraulics by the textbook written by R. Chugaev and M. Chortousov, hydraulic facilities by the textbook written by E. Zamarin. At the same time, we were discussing with aplomb the prospects of great construction projects in hoping that it will last our time.



[1] Being a little child
[2] This camera was made at the factory named after Felix Edmundovich Dzerzhinsky (FED)

For our age, there were sufficient number of projects encompassing construction of unique irrigation and drainage canals, pumping station cascades that were the largest all over the world and development of hundreds of thousands of hectares of virgin lands. However, at the same time, we had to rethink the content and subject directions of our specialty. Today for developing the water sector, it is necessary to apply the combination of technical and agricultural knowledge with using achievements of economic, social, legal, environmental and even political sciences. It needs to be mentioned that already at the beginning of 20th century - long before our work in this economic sector – Russian scientists who studied the problems of irrigation in the desert zone of Central Asia have come to conclusion that hydraulic engineers should think wider going beyond technical sciences. One of outstanding hydraulic engineers, researchers and practitioners in Central Asia, Professor Georgy Rizenkampf wrote in his preface to the book "Towards a new Golodnaya Steppe Irrigation Project":

"Restoring life in this desert burned by the sun and reviving dead lands are the task of engineers-irrigators. An engineer-irrigator can formally consider his mission as completed after constructing a water intake structure for diverting water from a river, network of irrigation canals with life-giving water that is covered a whole area under development and regulators for well-timed water supply to each colonist. However, the tasks of irrigation systems' builders are more complicated.

The irrigation network is "a canvas on which life will be embroidered"; *and in the process of its creation, it is necessary to see all the aspects of future life very clearly. Developing an irrigation system should not be the end in itself because it is only part of an integrated whole - revival of the desert, with which the irrigation system must be inherently linked, forming the main assignments for engineers-irrigators.*

… A key requirement is to provide the most rational organization of all aspects of life rather than only focusing on the construction of irrigation networks, as well as achieving the maximum effect as a whole rather than in separate details. Among general technical and economic requirements, first, it is necessary to satisfy those that lead to better organization of all life.

It needs not only to design an irrigation system but also to draw up a plan for developing an area under consideration, including the scheme of roads, sites for industrial and market centers and the most rational sources of energy in order to supply future factories and workshops, as well as to prove that the designed irrigation system is inherently linked with future arrangement of life and is a well-designed part of the integrated whole."[3]

[3] G. Rizenkampf, Towards a new Golodnaya Steppe Irrigation Project, Part 1, published by the Main Water Department in Central Asia, Leningrad, 1930

Georgy K. Rizenkampf is Russian hydraulic engineer who participated in designing almost all major hydraulic structures in our country before World War II and founder of the Scientific-Research Institute of Land Reclamation.

G. K. Rizenkampf was born in Tiflis in 1886. After graduating from the Tiflis non-classical secondary school[4], he was enrolled, on the competition base, to the Petersburg Institute of Railway Engineers, the Faculty of Waterways. During his studies, he has undergone practical training in Europe. In 1909, he was awarded with the special hydraulic engineering award for his capstone project. After a short-duration service in the Caucasus Department of Railways, G.K. Rizenkampf began working in the Reclamation Department of the Ministry of Agriculture. In 1912, he became the manager of survey works for the irrigation project in the Golodnaya Steppe in Turkestan. In 1915, he prepared the irrigation project based on integrated water resources use - for irrigation and power generation.

After the 1917 Revolution, K.G. Rizenkampf has taught at universities and participated in drafting the Electrification Plan in Central Asia. Thanks to his petition in 1921, the Scientific-Research Institute of Land Reclamation was established in Petrograd, which later was reformed into the All-Union Scientific-Research Institute of Hydraulic Engineering (VNIIG) named after B.E. Vedeneev. This institute has become the first organization in the country for developing the scientific foundations of designing irrigation and drainage systems and hydraulic structures. Outstanding scientists in the field of hydraulics and hydraulic engineering were invited for work in the new institute. In 1921, G.K. Rizenkampf was appointed as Professor at the Department of Land Reclamation of the Petrograd Polytechnic Institute.

During his work in this institution, G.K. Rizenkampf has prepared many publications concerning irrigation, as well as carried out the expert examination of the new irrigation project in Golodnaya Steppe and projects “Land Reclamation of the Neva Estuary and Flood Protection of Leningrad” and “Land Reclamation in Colchis Lowland.” In 1929, G.K. Rizenkampf, like many other engineers, was arrested on charges of sabotage and anti-Soviet activities. About three years, he worked as a designer at the construction site of the White Sea-Baltic Canal. Following the grant of parole in 1932, he was appointed as the technical director of the Special Hydraulic Engineering Department in Moscow, where he was involved in developing the scheme "Big Volga." G.K. Rizenkampf was Chief Engineer of this project. In recent years of his creative activity, G.K. Rizenkampf worked on the Manych Sea Way Project and was the consultant on the construction of hydraulic structures on the Kura River (Caucasus). In 1942, G.K. Rizenkampf was again arrested, and then he died in prison on 30 May 1943. He was posthumously rehabilitated in 1956.

[4] In Russia until1917: a secondary school where natural and exact sciences dominated in the curricula

As mentioned in the book «Out of water ...»[5] published by the IWMI, in the 20th century, the epoch of domination of an engineering approach in developing the water sector that prevailed in the practice and governmental decisions in colonial and developed countries has come to the end. The 20th century was the witness of culmination of so-called "hydraulic mission" - the golden age of engineering approaches, which has left the great inheritance including more than 50,000 large and small dams, and 280 millions of hectares of irrigated lands that produce a most part of food and power.

Today, our specialty's scope has expanded even more. In fact, the water profession's range is a whole life, with all its features, interrelations, and known and undiscovered regularities, because the water predestines the existence and activity of man and life itself on Earth, in all its diversity, as well as is the basis and driving force of living environment. It is difficult to find a natural phenomenon or human activity, wherever water does make an impact or is not used. Think about it, look around, and you will make sure that this is the absolute truth. Since the morning, when you wake up and are ready to start the working day or go to a university, the water gives you the opportunity to freshen up yourselves and to cheer up by a cup of coffee or fragrant green tea. Water refreshes morning air that surrounds you on the way to a place of work or training. All day long, water accompanies you in all production processes, in the process of training or during meetings. Your contact with water becomes still more pleasant while on vacation, relaxation, distant walking and travels. When you rush to the mountains for skiing or sledding, you are also surrounded by water, only in the solid state in the form of snow, which covers hillsides and provides slip to your winter equipment. You can make certain of the universality of water by looking around and analyzing your observations. This book a task of which is to prepare you to altruistic, boundless and sincere service water - thereby to humanity and nature - can help you in this!

[5] Chartres, C. and Varma, S. Out of water. From Abundance to Scarcity and How to Solve the World's Water Problems FT Press (USA), 2010.

Chapter 1.The Role of Water in Human Life and Life of Planet. The Water Cycle in Nature

At first sight, water is an elementary simple substance consisting of two simple chemical elements - hydrogen and oxygen. However, even without any complex organic compounds - multivalent and multi-molecular components - water by itself performs complicated functions in nature, living beings, production complexes - industrial and agricultural, households and municipal services.

In our world there is not another substance having so diverse properties necessary for man in his all-round activity. Water is equally important for environment, in which we live. We often hear the slogan “Water is Life.” However, water represents much more than simply life because this is we ourselves. Two-thirds of a human body consist of water, which circulates through a well-developed hydraulic system inside our organism. For the normal vital activity, each of us needs to replenish this system in amounts of one and a half or two liters of water a day. Water is really the basis for activity of our organism, because only with the help of water every organ of a human body can carry out its destined functions. Water is involved in the digestive process and promotes not only move of food through the gastrointestinal tract, at the same time it dissolves the nutrients under the process of converting food into a source of internal energy. No wonder that the Russian proverb says: "A dry spoon tears up a mouth!" Moisture moistens oxygen during respiration. Water carries nutrients and oxygen to every cell of our body; it is a kind of conveyor of minerals, glucose, and vitamins distributing them very evenly and in purposeful manner between each such a cell, as needed. Our blood consists of water on 92% and represents a solution, which is composed very carefully and predetermines a normal or diseased state of our organism. When hemoconcentration takes place under the influence of various stresses that are perceived and transmitted through nerve receptors a person begins to suffer from hypertension, which is a "fashionable" disease in our stressed century, and then the doctors prescribe different thrombolytics for injection into the bloodstream in order to dilute the blood. Water helps to all organs of our body to absorb substances necessary for them, while this process has a peculiar nature for every organ. At the same time, all organs dump their refuse, toxins and waste products outward through a complex drainage system of a human being in the form of urine and feces.

The sensational news from the world of cardiology: just one glass of water before going to bed will save you from a stroke! It is so simple, but most importantly cheap!

We could avoid many health problems now in case of adhering the proper drinking regime in our childhood. Everyone is aware the value of drinking water, however it is important not only to drink plenty of fluids but also a time when you drink a cherished glass of water. Find out when you need to drink water with the maximum benefit for your organism!

1. *Please, drink two glasses of water immediately after waking up - in this way you can help to your internal organs launch their more intensive work. Active metabolic processes are impossible without water, therefore moistening of your organism is necessary since the morning.*
2. *To improve digestion, drink a glass of water 30 minutes before meals.*
3. *If you are going to take a bath, be sure to drink a glass of water before this procedure. This will reduce your blood pressure that is especially useful for people who are prone to hypertension.*
4. *A glass of water drunk in the evening may prevent heart problems and protect against stroke. If you drink water before going to bed, you save yourself from one more annoying trouble - night cramps. Scientists have found that dehydration is the cause of nocturnal muscle cramps. It is especially important to drink water before going to bed for people in old age - this will help their heart to cope with a load much better; at the same time, nocturnal cardiac arrhythmias and other problems will be not so probable. Water is the best and cheapest medicine!*

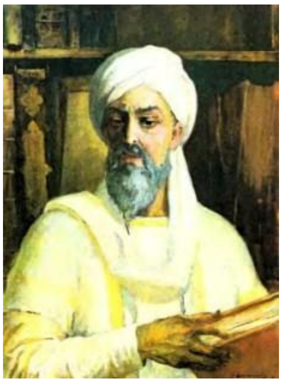
Human urine, like water in irrigation canals or rivers, has its permissible limits of composition of substances unnecessary for a human being. According to their concentration, doctors can determine whether a person is healthy or his “drainage system” needs repair and intensifying of the work of “organism’s filters” – kidneys, or purifying of “the natural settler” - gall-bladder from stones. In hot weather, your sweat cools your body due to evaporation from a skin surface. This aqueous regulator of your body temperature is acting based on the same principles, which your parents use to cool a ground in front of your house by watering it during the summer scorching heat, in order to sleep well in a fresh environment.

Bones consist of water on 22%, and the content of liquid in muscles exceeds 75%. A lubrication action of liquid is especially important for joints in order to prevent their abrasion because of huge distances that a human being overcomes during his life. Moreover, a human brain consists of water on 75%, and its dehydration leads to dizziness and headaches.

It turns out that our great ancestor Abu Ali Ibn Sina who is known in the world as Avicenna knew about the great role of water in affecting the human longevity. He considered "desiccation of an organism" as one of the most significant factors of aging. Modern science confirms this fact - an amount of water in our organism is reduced with our age. This leads to the inspissation of blood and lymph as well as to decreasing the elasticity of skin and muscles, headaches, pains in joints and so on. So what to do?

The answer is simple - it is necessary to moisturize our organism, saturating it with moisture, i.e. to drink water. However when, how and what water? As you know, water is the basis of our body. At the same time, water is a carrier of information and energy. A large amount of water is also needed for transferring energy within the body. Many energy healing practices, especially such as the Theta-Healing, are possible only under a sufficient amount of water in a body. Main thing, water records any information - both bad and good. When you use bad language near the water, it will record negative information, but when you give to listen good music or talk to her words of love, it will record positive information. Only positively charged water is useful for health! Yoga recommends drinking water in the morning, but water should be warm about 40 degrees rather than cold water. According to Tibetan medicine, water has beneficial effects on the nervous system - allows you to relieve stress and reduce the anxiety and depression. There is a famous recipe - after a stressful situation, it is necessary to sip a glass of hot water - and you immediately become much easier, and the body is able to “dissolve” your stress without harm to itself. We want to draw your attention to the fact that those people who are drinking hot water in the morning have very few wrinkles!

Avicenna



Abu Ali Ibn Sina (Avicenna) was born in 980 in Afshan Village near Bukhara City. Known the month of his birth according to Muslim chronology - Safar, which corresponds to the second half of August and early September. The boy was given a name - Hussein. Hussein studied Arabic, and already in ten years old, he knew the Koran by heart. The boy also studied arithmetic and Islamic jurisprudence - Fiqh. Later Hussein was studying geometry, astronomy and other sciences, after that he was interested in medicine.

At the age of 17 years, Avicenna was already a well-known doctor in Bukhara and was invited to the court of Nuh ibn Mansur. The philosophical book "Studies on moral forces," was written by Hussein when he was 17 years old, and the book "Almadzkmul" (Collected works), which sets out the ideas of rhetoric, poetics and other sciences, was written when the scientist was 21 years old.

In 1005, Avicenna moved to Khorezm, where he met with the great mathematician and astronomer Al-Beruni and other scientists. In Khorezm he became known as "the prince of physicians." In 1008, after the renunciation of Avicenna to enter the service of Sultan Mahmud of Ghazni, his prosperous life gave way to years of wandering in the Khorasan and Tabaristan. Seven years later, Avicenna went to Jurjan (Gorgan), then to other cities in Khorasan and Iran. In Gorgan, he started to write the famous multivolume encyclopedia "Canon of Medicine". Since 1015 until 1024, Avicenna lived in Hamadan City. For the successful treatment of the Emir Shams al-Dawla, he was appointed as the Vizier, but sometimes he was in disfavor of Emir and even was confined in the prison (zindan), where he has also written several books. Since 1024, Ibn Sina (Avicenna) was living in Isfahan, where the Ruler Adud Al-Dawla has created all the conditions for his scientific work.

Avicenna left the huge legacy: the multivolume encyclopedia "Canon of Medicine", many books on logic, physics, mathematics and other sciences. According to scientists, Ibn Sina wrote more than 450 books, of which about 240 survived up to our time. Creative work of Ibn Sina was of great importance for developing literature, not only for Central Asia but also for the entire East. Besides numerous poems of philosophical and lyrical content that come down to us, eight poems (Urdzhuza) are devoted to medicine. Ibn Sina (Avicenna) died on June 24, 1037. Outstanding scientist was buried in Hamadan near the city wall, and 8 months later, his remains were moved in Isfahan and buried in the mausoleum of Al ad-Daula.

Similarly to a human body, the existence of every living organisms is not possible without water, because water is the medium for advancing chemical reactions, which are the basis for forming organic matter, as well as the driving force behind the development and nutrition of plants. Plant tissues consist of water on 96-98% in algae, somewhat smaller up to 95% in salads, onions, tomatoes and cucumbers, on 40-55% in wood of a tree trunk, and on 12-14% in cereals. In accordance with K.A. Timiryazev, water performs a large set of functions, in fact, determining living processes in plants. Water permeates the entire plant body and creates the unity of all plant cells, where it is presented in vacuoles and protoplasm, starting from the root hairs that extract water from soil to a final leaf area where it evaporates. Water in plant cells has a high degree of tension, second only to mercury, with the result that nutrient saps are moving through plant tissues and absorbing nutrients, simultaneously dissolving them and creating the medium for biochemical processes. Water is involved in forming protein mass and is actively involved in metabolism: under photosynthesis, it supplies the electrons, and when breathing creates the hydrolysis process and, at the same time, forms the medium for membranous processes of metabolism. Like the blood transports substances in the bodies of humans and animals, water is a major carrier of substances in plants. Finally, water is the main heat regulator that protects the tissues from overheating or temperature drop due to a high heat capacity, as well as provides heat transmission.

A mechanism of plant transpiration, which, in fact, represents simply a constant upward current of water from root hairs towards the evaporating surface of leaves, is of particular interest. Its movement takes place due to the difference of water potential gradients in soil and atmosphere, which is supported by the suction force of transpiration leaf cells. The larger leaf area, the higher transpiration, the easier absorption of carbon dioxide from the atmosphere as well as the higher level the assimilation of solar radiation and evaporation through leaf stomata. At that, a balance between the evaporation rate of leaves and water flow from the root system must be constantly maintained. Epidermis - a layer of the outer living cortical cells of plants - is the main respiration organ of plants, which has stomata with the closable cells containing chloroplasts. Stomatal clefts are opening at light and closing in dark; therefore, photosynthesis stops at night (see Fig 1.1).

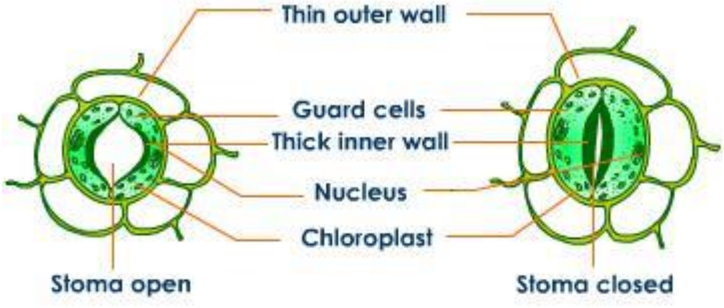


Figure 1.1 Two states of stomatal clefts

Under moisture deficit or when temperature threshold is exceeded (for example, 35 degrees Celsius for cotton), a similar phenomenon when the stomata are closed takes place; and the plants preserve moisture. Transpiration reaches its maximum before the onset of maximum daily temperatures. At noon, due to high temperatures and low air humidity, moisture deficit increases, and stomata are closed; the transpiration rate decreases, but it is rising later in the early evening hours. Another mechanism for water conservation, which is used by plants, is a selective growth of roots. Under the conditions of soil moisture deficit, the plant roots move forward to the wetter soil layers due to the influence of moisture gradient. In this regard, the asymmetrical arrangement of the roots around or near a moistener inside the soil or in an area around a dripper in case of drip irrigation is quite indicative. Inside the plants there is a kind of "tubular" system conductive in the vertical direction, which is presented by tracheids - the elongated, tapering cells up to 12 cm long, which function under the influence of diffusion, which, in turn, is amplified by transpiration of leaves.[6] It is no coincidence the following expression of Leonardo de Vinci:

Magic power was given to water to
become the blood of life on Earth!

Just as the water system of a man - the blood vessels, intestine, ureter and other organs of our complex organism - ensures various functions that allow us to move, think, eat, enjoy life and grow, there is the **water cycle** on Earth, which supports the existence of the earth's biosphere and nature as a whole. The water cycle in nature or, otherwise speaking, the hydrological cycle, represents the process of water circulation that goes on in the biosphere on the permanent basis. It consists of evaporation of water, vapor transport by air currents with following condensation into clouds and forming precipitation, their falling out on the ground and water surfaces, including the oceans, collection of them into streams and rivers, and return of water into the receiving basins and the World Ocean. There are several types of the water cycle in nature:

1) The big or the world water cycle, when water vapor formed over the surface of oceans is carried by the wind over continents, falls on their surface in the form of precipitation, and returns to the ocean through the watersheds, brooks, tributaries and rivers and underground water in the form of runoff. In the framework of this process, the water quality is changing: under evaporation, salty seawater becomes fresh, and polluted water is purified.

[6] I. Gringoff, A. Kleshenko, Fundamentals of Agricultural Meteorology, published by Rosgidromet, Volume 1, 2011, 126 – 148 pages

However, according as water is moving back to the ocean and in the process of its use, the water absorbs different substances and becomes contaminated, because a catchment system is also being the receiver of chemical and organic substances that fall into water.

2) The small or oceanic water cycle, when water vapor formed above the ocean surface, is condensed and falls as precipitation into the ocean again.

3) The inland water cycle, when water that is evaporated over the land surface falls on land as precipitation again. In case of the inland water cycle, the subsurface structure of the earth is very important because in addition to artesian aquifers there is movement of ground water, which provides a natural drainage of the land, carrying out harmful salts from the active layer of soil and ensuring its desalination. However, if a natural drainage capacity is insufficient, the man is obliged to enhance the drainage capacity using artificial drains, which play the role of “land’s veins.” At the same time, if natural rainfall is not enough for growing vegetation, the man builds irrigation canals, systems of sprinkling and drip irrigation, which are the “arteries” of the earth, its capillaries that distribute water to each plant. Besides, the vegetation cover itself plays a role of a respiratory apparatus of the earth and simultaneously its digestive tract, ensuring the growth and development of the biomass of grasses, crops, forests and shrubs, as well as vegetation of grasslands and steppe landscapes. As evidenced by the works of our great contemporary, Turkmen researcher of deserts with the worldwide reputation Agajan G. Babaev, even in the desert, life exists at the expense of scanty rainfall and condensation of moisture under transition from the heat of the day to the overnight coolness and vice versa.

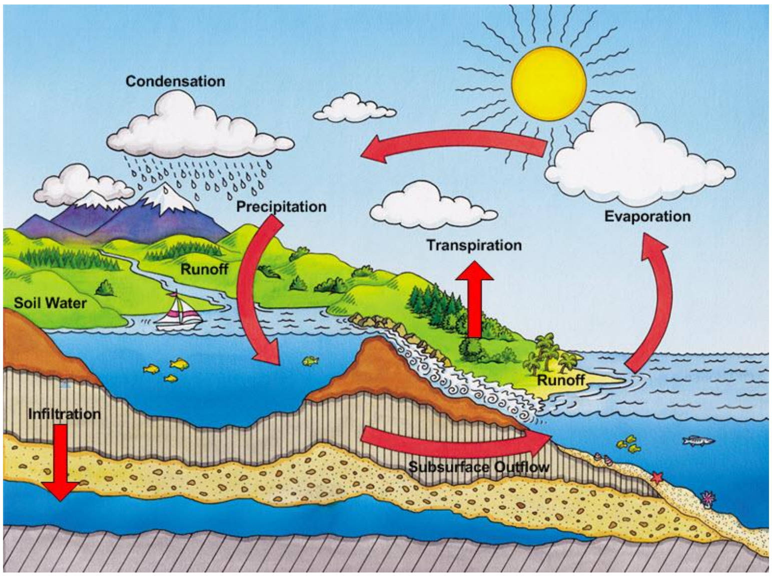


Figure 1.2 The hydrological cycle - water cycle in nature[7]

[7] http://picstopin.com

Finally, in all three types of water cycle, precipitation reaches the World Ocean, excluding inland basins such as the Aral Sea basin. Seas and oceans are losing more water due to evaporation than they obtain with precipitation owing to moisture transfer from the oceans towards the dry land; and the reverse situation is observed on the dry land. Water is continuously circulated around the globe, and its total quantity remains unchanged.

The water cycle is driven by solar energy. The Sun heats water in the oceans and seas, and it evaporates, converting into water vapor. A parallel process takes place on the dry land: water evaporates from the surface of the Earth heated by the Sun or evaporates by plants as a result of transpiration. In the process of advection, water vapor is moved together with air masses until the moment when eventually reaches the low temperature zone. Due to cooling the moisture condensation takes place in clouds. The clouds continue to move together with air masses, while condensed water droplets are mixed therein, stick together and grow in size. As a result, the water falls down as precipitation onto the dry land or ocean surface. Some precipitation falls in the form of snow, hail or sleet, and can build up in ice caps and glaciers, which store frozen water from several months to tens of thousands of years.

However, even in such a physical state (solid water), a negligible interchange by water between ice and the atmosphere takes place due to sublimation. At the time when in the deposition zone, the temperature is increased, the process of ice melt begins, and water is actively released from these sources. A greater part of water is returned from the atmosphere in the form of rain. A part of precipitation is intercepted by leaves of plants not reaching the ground surface. Once on the dry land, water flows over the land surface in the form of rivers moving to the oceans. Some of this water sinks into the ground as a result of infiltration and penetrates deep into the ground, replenishing groundwater aquifers, which also accumulate fresh water for a long time. In much the same way as water moves on the ground surface, water masses' movement exists also beneath the ground surface, and water is moving changing its location. Under certain conditions, groundwater is discharging to the ground surface in the form of springs and artesian wells (discharge of groundwater). This kind of water, as well as a small part of water, which has infiltrated into the ground, but not reached an aquifer, is returning back into surface water bodies and the ocean [8].

All of this huge mass of water, which is involved in the water cycle and formation of static and dynamic reserves exists in three physical states: solid, liquid and gas. The total volume of water mass is estimated at $1.533*10^6$ cubic kilometers[9], a most part of which (96.4%) is salt water of the seas and oceans, and a less part is fresh water of lakes, rivers, glaciers, groundwater and water vapor. By the way, underground and ground water is also mostly brackish.

[8] The water cycle in nature http://vodavodoy.ru/krugovorot-vodyi-v-prirode/

[9] The water cycle in a changing climate, University of Nottingham, 7 WWF, 15 p.

The volume of glaciers makes up 1.86% of the total water mass on the Earth, ground water - 1.68%, surface water - so-called renewable waters - only a little more than 0.02%. Fresh water in the liquid state amounts to 10,633,450 cubic kilometers in all types of water bodies (rivers, lakes, wetlands, groundwater). An aquatic shell of the Earth that is represented by the combination of all kinds of waters is called the hydrosphere. The constant exchange of water in its various forms between the hydrosphere, atmosphere and Earth's surface due to the processes of evaporation, movement of water vapor in the atmosphere, its condensing in the atmosphere, precipitation and runoff, is characterized by certain rates of replenish/renewal or full recovery for various components of the hydrosphere (see Table 1).

A rate of transferring various kinds of water variates over a wide range, and at the same time, a duration of periods for replenishing water volumes is also different. It is changed from a few hours up to tens of thousands of years. Water belonging to living organisms is recovered during a few hours. This is the most active form of water exchange. The period of renewing the water reserves in ice masses at the polar latitudes amounts to about 9 700 years.

The total volume of water on the Earth was adjusted up to 1533*10^6 cubic kilometers based on measurements in 2013.

Table 1.1

A renewal rate of various components of the hydrosphere

Physical medium	**Average time of renewal**
Oceans	3,200 years
Glaciers	from 5 to 1000 years
Seasonal snow cover	from 2 to 6 months
Soil layer	from 1 to 2 months
Groundwater	from 100 to 200 years
Ground water (aquafers)	10,000 years
Lakes	from 15 to 17 years
Rivers	from 17 to 19 days
Atmosphere	10 days

Fresh water is unevenly distributed on the Earth - the abundance in the tropics and subtropics, and water deficit and drought in steppes, and especially in desert arears, waterlogging in the northern latitudes. Landforms, intensity of solar radiation, various intensity of precipitation and evaporation, transferring of moisture by airflows are forming this uneven moisture distribution in space, which is also enhanced by seasonal and long-term fluctuations in the intensity of these phenomena, predetermining the instability of their indicators.

“The Kitchen of Weather”[10] in the form of a combination of solar radiation, activity of oceans and seas, winds and other factors creates permanent changes in inflow and outflow of water in the biosphere, day after day, within each alternating season, and between dry and wet periods of each year. Let us consider Central Asia. Average rainfall for this region is 270 - 300 mm per year, but it ranges from 750-800 mm in the mountains to 100 mm or even less in the Aral Sea area. In addition, there is the daily, ten-day and monthly variability of basic elements of the water balance - inflow of water with precipitation and loss of water due to evaporation from the soil surface and transpiration by plants. Although climate changes remain highly uncertain, they tend to aggravate the unevenness, making the arid zones even drier and increasing the humidity in the already humid regions. Moreover, precipitation is concentrated in the shorter but more intense showers. Reaction to the change in the Earth energy balance, caused by man-made emissions of greenhouse gases (the most common is carbon dioxide CO_2) contributes to rising the air temperature.

[10] "Kitchen of Weather" on our planet is the entire Earth's atmosphere that interacts with the surface of oceans and continents

The hydrological cycle plays the key role in these changes due to transporting thermal energy from the ground surface to the atmosphere and from the tropics to the poles at the expense of evapotranspiration and following condensation of water vapor, as well as affecting adsorption and reflected radiation owing to influence of shading by clouds and water evaporation. At a relatively low temperature, water vapor condenses and falls as rain. Thus, a contribution of climate changes in the hydrological cycle is formed.

Water is the creator of weather! Water evaporates from the oceans' surface and is transported through the atmosphere from the subtropics, where the maximum evaporation takes place, along the equator and towards the middle latitudes. Evaporation is especially intensive in the subtropical regions during the summer monsoons. This transporting of moisture, along with the rise of humid air in the mountains or over a warm Earth's surface, involving the water that evaporates from the earth's surface, defines the integrated composition of precipitation. An amount of precipitation here is sufficiently large, which increases the potential of forming underground aquifers.

An effect of climate change on the hydrological cycle is expected to grow at mid- to high latitudes and vice versa to decrease in dry and sub-tropical regions. Changes in the equatorial and monsoon regions are quite uncertain. A combination of more intense but less frequent rains will cause the growth of potential evapotranspiration, and respectively decreasing of soil moisture, and reduction in yields. Although the regional distribution of rainfalls is extremely uncertain, but nonetheless, the rigorous scientific works indicate that the greenhouse effect will impact on the water security globally and especially in the most arid regions due to increased fluctuations in the amount of precipitation and surface runoff.

It is known that the most common stereotype of prediction reduces to that the higher the temperature, the evaporation and transpiration become more intense. However, last studying and simulating the water consumption and behavior of different plants show that a temperature increase may be useful since it would result in reducing the growing season duration and even in decreasing water demand of individual plants. However, we will tell about these aspects later in the section "Water and Climate Change."

Chapter 2. Socio-economic and Environmental Value of Water. Water Resources Management and Its Role in Territorial Development

From time immemorial, a man strived to water. From time immemorial, the proximity to water sources was a key factor in placement of settlements and towns. Rivers such as the Nile, Euphrates, Tigris, Indus, Amu Darya and many others created the possibility for agricultural activity and trade, contributing to the development of civilization, an essential element of which was construction of water supply facilities. Romans were among the first nations who gave the world the majestic waterworks such as aqueducts and inverted siphons. Today, all the major cities and capitals of the world are located on the riverbanks, which are not only sources of water but also remarkable elements of the urban landscape.

You could make sure that water is the basis of our natural geosphere and that water is involved as an important element in the formation of the life cycle of man, plants, and living beings. Water is one of the creators of weather and is therefore an essential component of all nature and moreover the foundation of natural potential of our planet as a whole and its individual regions, zones, continents, specific areas and territories. At the same time, depending on the availability of water, various water bodies (rivers, lakes, groundwater, glaciers, etc.) and other natural elements: land with its soil and geomorphological features, climate, mineral resources, flora and fauna, creates a certain spatial areal and its **natural potential** with its geographical features.

Components of the natural potential by themselves are in strong mutual dependence of one another, either in the form of regularities of formation, or as a function of changes.

For example, as we had an opportunity to make sure the water forms climate, but also climate effects water resources, their distribution and characteristics of interacting water, soils and flora (evaporation, transpiration, infiltration, erosion, etc.) (see Fig. 2.1). Water was involved and continues to be involved in the creation of age-old reserves of mineral resources, their accumulation, dissolution, transformation, etc. Water, by force of its flows and currents, transports primary rocks and forms the alluvial, proluvial and other deposits that are transformed into the surroundings for water flows.

Water directly predetermines the character of fauna (hydrophilic, waterfowl or species adapted to arid conditions), but to a greater extent it predetermines the features of spreading the fauna of birds, mammals, reptiles, insects, etc. Interaction with many elements of natural potential in the most cases is based on the primary influence of water and response reaction to these actions of waters and other elements of the noosphere and biosphere.

Natural processes have dominated in developing our planet during many millennia until the appearance of man - Homo sapiens. Now, the science is ever-more moving away from the Darwinian evolutionary theory of appearing man, assuming the appearance of our ancestors from outer space or manifestation of "super intellect" in a manner, which is unknown for us yet. The humanity has presumably appeared several thousand years ago (about 8000 years ago according to the teachings of Judaism and Buddhism). According to the definition of V. Vernadsky, from this moment the noosphere of Earth has already started to form as a combination of nature and society - a community of people with their various manifestations of human nature and exceptional mental and intellectual abilities in comparing with other species of wildlife, initiating a new stage in the interaction of man and nature. Exactly human nature with its commitment to continuous improving and expanding mental outlook, with mastering of the wisdom bestowed by God, with the developed or developing thought process, and with penetration into nature has created the **human potential**. This potential is enriched along with developing the social processes, but at the same time, creating its inner destructing forces - manifestations of cupidity, selfishness, and mercenary behavior. Along with the progress, these negative factors of development interfered into the environment and sphere of development. By adapting of the nature to their own comfortable existence, people step by step created and used a variety of tools and devices in order to ensure their livelihoods, facilitate their existence and reduce the dependence on nature, which contributed to emerging of the **production potential** of humanity. At the beginning, there were a stick, plow and hoe, then a shovel and potter's wheel, later manufactories, workshops, factories and large production facilities, and now multinational corporations and other large associations of business entities. Alternatively, maybe, aliens have at once imported their technology, means of production and management methods to Earth? In contrast to natural, human and production potential, replacing petty trade for purchase and sale and appearance of money have created one more, non-material potential of humanity - **financial potential**. At the first stages of its development, the financial potential reflected a real ratio of costs and benefits derived from other potentials. However, at present, most likely, the financial potential is used for distorting the real values and costs of human society as the mechanism of “hidden” management of social, political and economic development.

Exactly from this point of view, it is necessary to consider the currency exchange as "one-sided game", as a result of which, in fact, estimates of all economic life and production are formed with respect to the "bubble index" - a market value of US dollar.

Until the value of each national currency was tied to gold reserves, value of existing fixed assets and natural potential, which ensured the currency values, this value was more or less objective. As soon as a national currency has been tied to stock values and “jumping” values, which are determined by the need in a particular currency (rather than by real backing of a currency!), the epoch of objective financial estimates has come to the end. This fact must be taken into consideration under assigning prices and carrying out assessments at the national level, trying as much as possible to avoid the influence of global factors and price approaches[11].

Water plays different roles in developing the production potential. Firstly, as a specific chemical or physical element, it serves as constituent part of the new products. As component, water is used in production of concrete, mortar and various compositions. It is the technological component of all types of dyeing industries, metallurgy, and mining of oil, gas and coal. Water is the source of energy for hydropower plants, water mills, siphon installations, hydro-cyclones and serves as a means of transporting ships with their cargoes and some goods by using hydrotransport. The special sector of dredging works is busy in cleaning up riverbeds and large waterbodies from sediments. There are methods of waterjet cutting of hard rocks and hydraulic mining of minerals (so-called flotation). Finally, extinguishing fires is carried out using high-pressure jetting installations. A completely dry production, which would not require water could be met very rare. Even such an “anhydrous” goods as a car requires 400 cubic meters of water for its production!

Usage of water in all kinds of production processes can be followed by partial consumption of water or without irrevocable consumption (hydropower, shipping, and cooling).

Water plays an equally important role in forming the financial potential. Firstly, water resources production, abstraction, distribution and use are associated with large capital investments and operating costs. At present, the formation of one cubic meter of water resources under regulation of river flow is estimated from 20 cents to 1 US dollar. Desalination of seawater costs from 45 cents to 1.5 US dollars per cubic meter. Saving water resources under introducing new irrigation techniques costs from 30 cents/m3 to USD 5 per m3.

[11] The approach in terms of price dynamics

Parameter	Nature potential →					
Climate		◙	◙		◙	◙
Water resources	◙		◙	◙	◙	◙
Land resources	●	◙		◙	◙	◙
Mineral resources		●	●			
Flora						◙
Fauna	◙	●	◙		◙	
	Climate	Water resources	Land resources	Mineral resources	Flora	Fauna

Figure 2.1 Block of nature potential

Figure 2.2 Farkhad Hydropower Plant

The water management complex is a complicated combination of water facilities, organizations and water users. In the framework of this complex, there are quite versatile financial interrelations: amortization of water facilities and funds for their renovation, reconstruction and modernization; payment for water supply; payment for water as a resource; formation of profits and taxes as a result of water management activity, various types of subsidies and penalties. In some countries (Australia, USA, Chile) the water market was established owing to occurrence of competitive water consumers. All this forms the financial potential of the water sector (if there is an objective evaluation of the cost factors of costs and benefits), which is determined depending on the state policy and its effectiveness. However, in general, the financial potential must ensure the sustainability of water supply, take into account an increase in the cost of water resources formation and, at the same time, initiate the renewal of water infrastructure. Given the key role of water in life activity of the humanity, it becomes understandable why, especially in recent years, the international financial institutions pay so much attention to investing in the water sector in developing countries. Nevertheless, on the example of Israel, you can see that the state can create the sustainable financial potential, even in case of limited water resources.

Thus, **production** and **financial** potentials are derived from **natural** and **human potentials**.

However, their development is put into effect at the expense of moving nonrenewable resources of nature into the production and financial potentials, as well as the use of renewable natural and human resources.

Developing the production potential feeds off also the financial potential, but at the same time the accumulated financial potential enhances and develops capabilities of the production potential for multiplying its capacity. In a similar manner, the human, financial and production potentials should support each other and simultaneously ensure the stability in use and recovery of renewable natural and human resources and compensate the natural potential when it comes to nonrenewable resources. If all these potentials are developing in such proportions that provide a mutual overlapping, i.e. they create a positive balance in accumulating their capacities then the capability for recovering is also maintained in the framework of each potential. Thus, in the frames of natural potential, living organisms themselves adapt to existing or variable natural conditions. At the same time, in the frames of human potential, a man develops himself and his fellow tribesmen. In the frames of production potential, one kind of economic activity generates another one, and money makes money in the framework of financial potential.

Within the territorial units (zones, countries or regions), export and import of the human potential (migration of labor force and "brain drain") and financial potential (loans, credits, donors' grants, and outflow of funds by legal and illegal ways) are quite important. The production potential may be also imported or exported by means of exporting raw materials and semi-manufactured goods and importing equipment, transport means, etc. Even the natural potential, especially water, can be imported or exported through redistributing water resources or exporting and acclimatization of flora and fauna.

Sustainable human development is based on the abilities of man to support a balance of four potentials and their abilities for self-recovering.

The success is guaranteed due to the following factors:

- Limitlessness of the technical progress and intellectual abilities of man;
- Some thresholds for reproduction in the production potential and renewal capabilities of resources;
- Clear-cut understanding of the system of links and interaction of these potentials as well as the limits of their use;
- Aspiration of achieving the potential productivity per unit of natural resources and building-up of the efficiency on the basis of dynamic development; and
- Presence of the obligatory universal regulations, postulates and rules for maintaining the policy that can and has to provide rational use of all four potentials, on behalf of not only some regions, nations, but also the human community as a whole.

We have already identified the components of the natural potential and a role of water. Let us consider the production potential now. This includes a population size and its dynamics - population growth, life expectancy, mortality, health status, and welfare.

From the standpoint of "The UN Millennium Ecosystem Assessment,"[12] there are five dimensions of human well-being:

- **Basic Material for a Good Life** - adequate income, household assets, food, water, shelter, and access to the necessary benefits and education;
- **Human Health -** favorable physical environment, hygiene, access to health care and the primary prevention system[13];
- **Good Social Relations –** the ability to realize aesthetic and recreational values, express cultural and spiritual values, develop institutional linkages that create social capital, show mutual respect, have good gender and family relations, and have the ability to help others and provide for their children;
- **Security -** in relation to natural and anthropogenic events (floods, floods, droughts, wars, disasters), as well as life in a predictable and controlled environment; and
- **Freedom and Choice**.

If we look at these five dimensions of human well-being, they are all dependent on water. This is sustainable water supply in the required amounts (according to Dr. Peter H. Gleick - the minimum basic water requirement just for cooking, cleaning, drinking, bathing and simple sanitation is 50 liters per person per day), provision of food, access to clean and constantly supplied water, prevention of water extrema, etc. Moreover, without water it is almost impossible to ensure such manifestations of the human potential, in the best sense of the term, as a healthy way of life, observance of traditions, education, culture, religion views, science and the aesthetic perception of life, nature and society. From this point of view, the ethics in water use, which is particularly notable in the traditions of our peoples, should be included in the agenda. It should be noted that water consumption per capita is much more in developed countries than in developing ones. For example, according to M. Barlow[14], an average water consumption per a family consisting of three persons amounts 500 cubic meters a year in comparing with the optimal norm of 300 cubic meters (350 liters per day per person).

[12] Chapter 5.2 Dimensions of Human Well-Being, UN Millennium Ecosystem Assessment, 2003
[13] the first level of health care, designed to prevent the occurrence of disease and promote health
[14] M. Barlow and T. Clarke, Blue Gold: The Fight to Stop the Corporate Theft of the World's Water, New York: The New Press, 2002

Our generation, which grew in the period of great construction works of water infrastructure, was a witness and, at times, participant of such events, when any construction of water facilities, especially large-scale construction works, resulted in new populated territories, large industrial conglomerates, new cities and settlements. Bekabat City, two large plants for the production of cement, as well as the metallurgical works were built around the firstborn of Uzbek hydropower sector - Farkhad Hydropower Plant, which was constructed in the difficult years of the World War II for supplying electric energy generated using water of the Syrdarya River.

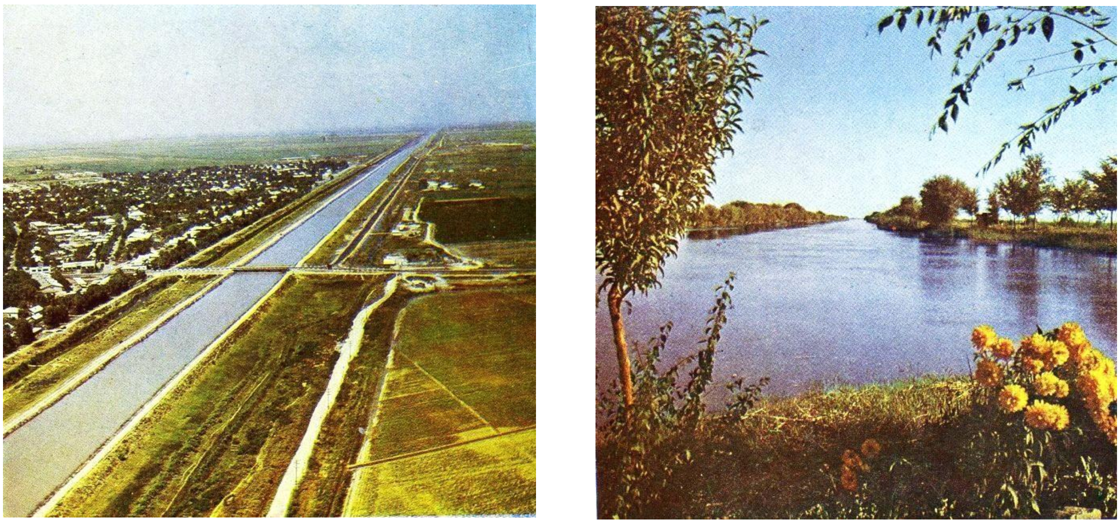


Figure 2.3 The South Golodnostepsky Canal[15]

Similarly, the settlement for construction workers of the Kairakum HPS and reservoir on the Syrdarya River has transformed into Kairakum City with the carpet factory known throughout all Central Asia, with repair enterprises, as well as the beautiful recreational area. Integrated construction of water facilities and desert land development in the Golodnaya Steppe on territories of Kazakh SSR, Tajik SSR and Uzbek SSR in the period since 1956 to 1978 has become the stimulus for comprehensive socio-economic development in the region. Later on, using the experience gained in the Golodnaya Steppe, similar virgin land development was undertaken all over Central Asia - in the Karshi Steppe and Jizak Steppe in Uzbekistan, Kyzyl-Kum area in Kazakhstan, and lands adjacent to the Karakum Canal in Turkmenistan. At the same time, every regional development project based on irrigation of lands also tackles a number of socio-economic and environmental tasks. For instance, the irrigation project in the Golodnaya Steppe has included constructing the intense road network with total length more than two thousands of kilometers, 1.5 km of high-tension electric mains, more than 700 km of communication lines, 700 km of water mains, 560 km of gas mains, and thousands of kilometers of irrigation and drainage canals. Creating the local modern industrial base and infrastructure was one of critical components of the production and construction complex.

[15] Encyclopedia "Irrigation of Uzbekistan", Volume 2, The Current State and Prospects of Irrigation Development in the Syrdarya Basin. (1975)

More than 20 large industrial enterprises located in the cities Yangiyer, Djizak, Bekobod, and Pakhtakor were built over these years of construction and development. They produce reinforced concrete canalets 6 m long (up to 75,000 pieces per year), non-load-bearing wall elements of lime concrete (to up 100,000 m3 a year), gypsum-rolling partitions (400,000 m2 per year) and a number of other products.

Since 1956 until 1975, more than 2 million m2 of housing, as well as objects of cultural and community purpose: school buildings - nearly for 25,000 students, nursery schools - for 10,000 children, hospitals for 1000 hospital beds, clubs and cinemas for 22,000 seats, cafeterias and teahouses for 8,000 visitors, shops - 426 jobs, public bathhouses - for 1,030 visitors, etc. were built in the state farms and towns in Golodnaya Steppe.

Akop A. Sarkisov

(1907.15.XII to1971.26.VII)

The Lenin Prize Winner. Statesman. Project Manager of the Chirchik HPS cascade. Project Manager of the Farkhad HPS. Deputy Director of Department of Central Committee of the Communist Party of Uzbek SSR. Director of «Glavsredazirsovhozstroy» under the Ministry of Land Reclamation and Water Resources of Uzbek SSR (1957 to1971). He has made a great contribution to the promotion and development of the Golodnaya Steppe. He was awarded by the state awards. Place of Burial: Memorial Cemetery “Chigatay.”

Forty-six new cotton-growing, horticultural, winegrowing and other farms have been established in the steppe. Dozens of cotton-storing centers, four cotton-cleaning plant, large bases for processing of raw materials, fertilizer warehouses and many other facilities were built. Agricultural production was diversified - animal husbandry, sericulture, horticulture, viticulture, melon-growing were put in farming practice in addition to cotton growing. Dreams of Professor G. Rizenkampf about better life organization under developing virgin land were at last implemented. The great merit in successful implementing this project belongs to the developers and managers of construction works A. Sarkisov, E. Ozersky, D. Tersitsky, I. Nizamov, A.Tairov and many others who were working under direct supporting by the leader of the republic Sh. Rashidov.

Let us consider a role, which this very complicated water management project plays in social and environmental development of this region. When we started this project in the Golodnaya Steppe, its population was about 1.5-2 thousand herdsmen who pastured flocks of sheep and herds of camels on the vast desert expanses, driving them away in the winter closer to the mountains, where they could take refuge from the terrible frosts - up to 35 degrees below zero. Now, more than half a million people live on the territory of two administrative districts of Uzbekistan, two administrative districts of South Kazakhstan and one administrative district of Tajikistan in the former desert. They are descendants of settlers from the densely populated areas of the Fergana Valley and Zerafshan Valley, where nowadays the population density reaches 600 people per square kilometer. Moreover, it would be much more! Soils in the Golodnaya Steppe were naturally salt-affected and were not able to provide to local inhabitants anything, except for camel thorn (*Alhagi canescens*), which is suitable only for feeding camels and sheep. Now, after construction of artificial drainage and leaching operations, these lands ensure food, income, and living environment for millions of people, creating a continuous green area from the Syrdarya up to the spurs of the Turkestan Range! In the year of completing project works, 15 years later from the beginning of the project, the annual national income from agricultural activity on irrigated lands has reached one billion rubles allowing provide high rates of return of investments (1.7 billion rubles).

I've been thinking how to demonstrate you (our future leaders and experts who will solve the future water problems) the importance of water for social development avoiding boring routine figures. Fortunately, a very interesting report[16] prepared by the L. William Seidman Research Institute, located in the Arizona State that is a partner of the Arizona State University has got in my hands. This report deals with the importance of the Colorado River for life in seven southwestern states of the USA: Arizona, Utah, Wyoming, Nevada, New Mexico, Colorado and much of Southern California. Why was I interested in this report? Still in Soviet times, our research institute SANIIRI, which at that time was the leading institution in studying irrigation and land reclamation in the country, has received a government assignment to organize cooperation with the California Department of US Bureau of Reclamation and the US Salinity Laboratory at Riverside.

[16]Professor Tim James, Dr. Anthony Evans, Eva Madly, and Cary Kelly L William: The Economic Importance of the Colorado River to the Basin Region, Final Report, December 18, 2014, Seidman Research Institute, W. P. Carey School of Business, Arizona State University

Figure 2.4 The Syrdarya River

Two co-managers of this program were appointed (Dr. J. Maletic from the US Bureau of Reclamation and your obedient servant on behalf of SANIIRI), and the teams of executors were determined (Prof. Shilfgard, Prof. Raats, and drainage specialist Dr. Ox were included in the team on the part of the US Bureau of Reclamation).

A main reason for selecting both our organizations was the likeness of problems in the Colorado and Syrdarya river basins (these rivers have similar length and flow rates), namely: transboundary allocation of water resources (in our country between the republics, in the USA - between states), salinity control, and the need in water saving. US Specialists presented us the Colorado River Effective Management Program, and we presented them the program "Water Conservation" by the example of the irrigation project in the Golodnaya Steppe.

Information on the Colorado River Basin should be interesting for you, because and now this river basin faces new problems similar to our ones that have arisen already during last 20 years: acute water scarcity, competition between sectors of irrigation and hydropower, and the problems of dying delta, which can be rehabilitated. With the permission of the authors of abovementioned report, I allow myself to consider its main provisions that can answer on the question in the heading of this section.

Figure 2.5 The Colorado River

The Colorado River Basin

The Colorado River has a length of 1,450 miles. Its headwaters are in the Central Rocky Mountains of north central Colorado. The river is flowing in the south-western direction, crossing the Colorado Plateau to Lake Mead, where it turns south towards. Before entering Mexico in the Colorado Desert most of its waters are diverted into the Imperial Valley of Southern California. In Mexico, its course forms the boundary between Sonora and Baja California before entering the Gulf of California. The river is controlled by the large number of waterworks, reservoirs and dams, and its waters are extensively used for water supply of 40 million people, as well as for irrigation and energy generation. As a result, over last years of the last century, the river water did not reach the mouth, over a length more than 100 miles, and did not discharge into the Gulf. However, in the historical past, the river has brought 16.3 million acre feet of water (20.1 cubic kilometers) into the Gulf, and, according to data of the US Bureau of Reclamation, even now supplies with water 22 federally-recognized residence arears of Indian tribes, 7 national nature reserves, 11 national parks and four recreation areas.

River Basin Management is based on a large number of compacts, federal laws, court decisions and decrees, contracts, and regulatory guidelines that constitute “the Colorado River Compact" (water allocation rules) signed by all seven states that use the river’s water. The compact is a 1922 agreement, which is in force up to now and divides the river basin into two areas, the Upper Division (comprising Colorado, New Mexico, Utah and Wyoming) and the Lower Division (Nevada, Arizona and California).

Water is distributed by 7,500,000 acre feet (9.3 km3) between the Upper Division and Lower Division (see Table 2.1). In addition to this, 1,440,000 acre feet (1.776 km3)/year of Colorado River water is allocated to Mexico, pursuant to the treaty between the USA and Mexico signed February 3, 1944.

Table 2.1

Current Colorado River Apportionment by State

GEOGRAPHY	WATER APPORTIONMENT, Million Acre Feet (MAF)
Upper Basin Allocation	7.5
Colorado	*3.9*
New Mexico	*0.85*
Utah	*1.7*
Wyoming	*1.0*
Lower Basin Allocation	7.5
Arizona	2.8
California	*4.4*[17]
Nevada	0.3

Source: The United States Bureau of Reclamation (USBR) (2008)

This study examines the importance of the Colorado River for the socio-economic development of seven states, which the river supplies with water. In other words, what would happen in the development of these states, in case of the non-availability of Colorado River water for one full year? Amount of water that is received directly from the river, and its share regarding the total water consumption (in percent) are given in Table 2.2.

[17] An additional 50,000 acre-feet is allocated to Arizona from the Upper Basin apportionment

Table 2.2

Estimated Annual Water Consumption, and Percent Sourced from Colorado River, by Geography

GEOGRAPHY	AGRICULTURAL		MUNICIPAL & INDUSTRIAL	
	Total Requirement, MAF	Percent Sourced from Colorado River	Total Requirement, MAF	Percent Sourced from Colorado River
Arizona	2.20	49%	1.98	41%
Colorado	6.13	31%	1.25	41%
Nevada	0	0%	0.37	79%
New Mexico	0.72	15%	0.30	60%
California	3.52	92%	4.17	37%
Utah	2.04	22%	0.84	34%
Wyoming	1.95	20%	0.15	70%
Entire Basin Region	16.56	43%	9.05	41%

Source: The USBR (2012)

This assessment was conducted according to the following indicators:

- **Gross State Product (GSP)** represents the dollar value of all goods and services produced for final demand in a state; it includes all the intermediate income that is included in the price of the final product. It also includes the sum of all compensations to the employed population from an employer (salary, bonuses, revenue, insurance and pension payments, income from property and the proceeds from its sale), indirect taxes on business.
- **Employment** is a count of full- and part-time jobs for one full year.
- **Labor income** includes employee compensation (wages and benefits) and proprietor income.

Calculations are made for one year for each of the states. The estimated total economic impacts of Colorado River water loss by Basin Region geography for one full calendar year is estimated in Table. 2.3.

Outcomes of the estimate indicate that the non-availability of Colorado River water for one full year results in declining the total gross state product by 1.434 billion dollars, the number of employees by 16 million people out of 115.6 million in the country, including 14 million jobs in the private sector!

Table 2.3

Estimated Total Economic Impacts of Colorado River Water Loss by Geography

GEOGRAPHY	GROSS STATE PRODUCT, Billions USD in 2014	EMPLOYMENT, Jobs Years[18]	LABOR INCOME, Billions USD in 2014
Arizona	185.01	2,147,770	107.80
Colorado	188.95	2,147,141	115.97
Nevada	115.39	1,417,283	70.57
New Mexico	59.76	771,618	34.17
California	657.45	7,046,110	406.58
Utah	69.79	969,735	43.30
Wyoming	21.67	284,276	13.18

Source: The USBR

The biggest shortfall in total GSP occur in the following economic sectors:

- ✓ Real Estate and Rental - USD 174.3 billion;
- ✓ Healthcare and Social Services - USD148.6 billion;
- ✓ Finance and Insurance - USD 137.1 billion;
- ✓ Professional, Scientific and Technical Services - USD 130.6 billion; and
- ✓ Retail Trade – USD 96.2 billion.

The annual losses to GSP resulting from the non-availability of Colorado River water range from 49.5% to 87.4%, dependent on the geography studied: in Arizona - 59.9%; Colorado - 88.8%; Nevada - 88.4%; New Mexico - 56,8%; South California - 54.9%; Utah - 49.8%; Wyoming - 62.3%. Thus, the entire American West, giving nearly 45% of US national income, without water Colorado would lose half of its national wealth and 16 million jobs.

[18] A job year is equivalent to one person having a full-time job for exactly one year.

The Syrdarya River Basin

Let us see on the situation in the similar Syrdarya River Basin. The Syrdarya River is the second largest river in Central Asia, having the total length of 2,212 kilometers and a mean annual runoff of 37.6 km3. The river originates in the Tian Shan Mountains in Kyrgyzstan and eastern Uzbekistan and is formed on the basis of two chief tributaries - Naryn River and Karadarya River, as well as in its middle course has a number of other tributaries: Chirchik River, Akhangaran River, Arys River, and Keles River. After passing through the territories of Kyrgyzstan, Uzbekistan, Tajikistan and Kazakhstan, it flows into the northern remnants of the Aral Sea - so-called the Northern Sea. The river is of great importance for all four countries of the region, in the first place as a source of irrigation for more than 2 million hectares, as well as a source of water supply, hydropower generation, fishery, and being a significant component of ecosystems in these countries. The river supplies with water three regions of Kyrgyzstan (Batken, Jalalabad and Osh), a significant part of the Sogd Province in Tajikistan and the six provinces in Uzbekistan (Andijan, Namangan, Fergana in the Fergana Valley, Tashkent, Djizak and Syrdarya provinces in the lower reaches), as well as two provinces in Kazakhstan - Kzyl-Orda and South Kazakhstan. Thus, the Syrdarya River is comparable in size to the Colorado River and plays an equally important role in the livelihood of all the above provinces.

On the analogy with the economic indicators of the Colorado River, the similar indicators concerning the importance of river water for development of the provinces that use water of the Syrdarya and small rivers of this river basin, which are located in close conjunction with its catchment area are given below.

Although, in absolute values, a share of the Colorado River is 40 times greater than the Syrdarya River, but in the percentage ratio, a share of the Syrdarya in formation of the national income in twelve provinces is much higher than that of the Colorado River. A difference in absolute values can be explained by the disparity in the size of the national incomes and their structures in the basins of Colorado and Syrdarya rivers. In the first case, it is more than 40,000 dollars per capita, while in the second case, the national income amounts to 2000 dollars per capita, on average. However, the role in the employment is approximately the same - in the Colorado River Basin 16 million people, and in the Syrdarya River Basin - about 10 million people.

It should be borne in mind that with growing the water productivity, on the one hand, and an increase in the gross national product per capita, on the other hand, the comparative figures of influence of each river on the socio-economic development will converge under calculating per unit of water used.

In recent years (2010-2015), an extreme situation is in California due to drought that takes place year after year. An Interagency Task Force on Drought Control under the leadership of Governor of this State was established to implement the coordinated program of current and future actions. In 2014, 160,000 hectares of irrigated land were not sown with crops, resulting to the damage in billion dollars. The focus is directed on the broad exchange of information between stakeholders, starting from data of the forecast of climatic and hydrological parameters up to demonstration of water conservation techniques and offers of manufacturers of drip irrigation systems and equipment for fine-dispersed sprinkling.

The Syrdarya River Basin has experienced severe drought in 2008, when the water supply was about 78% of planned parameters, and in some summer ten-day periods dropped up to 50%. The agricultural sector has also lost about a billion dollars, taking into account related sectors. Nevertheless, the introduction of integrated water resources management in the Fergana Valley over the area of 130,000 hectares allowed overcoming drought without economical losses due to preparing to the water shortage by applying the developed technological and organizational methods

Table 2.4

Estimating a share of the transboundary Syrdarya River Basin water in forming GDP (data of the SIC ICWC, Tsay E.)

Geography	Total water intake (actual) MCM[19]	Incl. for irrigation MCM	Water intake from local sources MCM	Water intake of TBW[20] MCM	Share of TBW %	GDP B$[21]	Share of GDP based on local sources B$	Share of GDP based on, млрд. USD	Gross output of agriculture B$	Incl. plant growing output B$
Kazakhstan: Kzyl-Orda and South Kazakhstan Provinces	7,529.1	5,943.73	984.3	6,544.8	87	18.8	2.444	16.356	1.41	0.79
Kyrgyzstan: Batken, Jalalabad and Osh Provinces	3,232.5	2,912.72	1,694.5	1,538.0	47	1.49	0.79	0.7	1.25	0.61
Sogdy Province of Tajikistan	4,872.8	3,120.3	1,374.5	3,498.3	71.8	1.66	0.47	1.19	0.631	0.407
Six provinces of Uzbekistan	25,521.7	19,127.3	3,886.0	21,635.7	84.8	21.58	3.286	18.295	4.61	2.54
Total	**411,56.1**	**31,104.1**	**7,939.3**	**332,168.0**	**80.8**	**43.53**	**6.99**	**36.54**	**7.90**	**4.35**

[19] MCM – million cubic meters
[20] Transboundary waters
[21] B$ - billion US dollars

Chapter 3. Role of Water in Developing the Civilization

The term "civilization" means the stage in the development of human society that is characterized by the existence of social formations, cities, writing and other similar traits, for example, such as a money exchange. This stage was presumably the next one after the savagery and barbarism. Later this concept and its development gained its own theoretical basis that is characterized by a wide variety of trends, each of which tries to give a justification as to the global principles of building the human society and its individual directions. The modern view on the criteria that distinguish civilization from the barbarism stage, defines them as:

- The ***system of economic relations*** based on differentiation of labor - the horizontal differentiation (professional and sectoral specialization) and the vertical differentiation (social stratification).
- ***Means of production*** (including the living labor), which are controlled by the ruling class that is performing centralization and redistribution of a surplus product withdrawn from the primary producers through dues or taxes, as well as through the use of labor for implementing public works.
- The ***presence of an exchange network*** controlled by market relations or the state, instead of direct exchange of products and services.
- The ***political structure***, in which the social class that concentrates in their hands the executive and administrative functions dominates. A tribal organization based on parentage and kinship is replaced by the power of the ruling class, which rests on forcing. The state that provides a system of social and class relations and the unity of territory, is the basis of civilizing political system.

Forming the Central-Asian civilization, the first mentioning of which can be found in travel notes of the Chinese traveler Zhang Qian, who mentioned some events in the tenth century BC and his own epoch (the second century BC) was based on irrigated agriculture and well-considered use of the hydrographic network in Central Asia. The works of Strabo[22] with description of trade routes from India to Girkania[23] along the great rivers in Central Asia (their ancient names - *Ôxos* and *Jaxartes* in Greek) also attest this fact. References are also found in Vedic literature and in Chapter 21 of the book of the Prophet Ezekiel, which coincide with the descriptions of Herodotus (see Bekchurin, 1950; Konshin, 1883; and Solovyev, 1989). These descriptions of the river network in Central Asia note the Amu-Darya under the name of Vedi-Darya.

[22] Strabo (63BC?- 24AD?), Greek geographer and historian, born in Amasya, Pontus (now in Turkey)

[23] Gerkania corresponds to modern Gorgan City (Iran) located near the Caspian Sea

This river originates in the mountain ridges “Charaiti” (Tian Shan) and flows towards the “Zahra Kosha” (the Caspian Sea), replenishing along its way by water of tributaries such as the Chu River (running through the Buam Canyon), Zeravshan River ("Soghd"), Murgab River ("Mug") and Tejen River (“Herirud”). A territory between Syrdarya and Amudarya rivers was the site of placing ancient settlements of Aryan tribes that were engaged into agriculture and practiced Zoroastrianism.

The social structure of people originated in ancient times and changed in accordance with the development of productive forces and the need to adapt to changes in the environment including changes of the hydrographic network. In accordance with the works of the prominent historian and researcher of this region S. Tolstov *“...in Central Asia, the society went through many political reforms from the ancient closed communities towards the slave-owning system and centralized state”* (Tolstov, 1948). Further, he added: “*These are just those features which Marx and Engels considered as most essential pre-requisites for the flowering of irrigation.*”

In the article “The British Rule in India” published on June 10, 1853, Karl Marx wrote: “*The elementary need for joint and economical use of water, which in the West stimulated private entrepreneurs to team up into the associations on a voluntary basis as in Flanders and Italy; in the East, where civilization was at the lower level and where territories are too large to allow calling the associations into being on a voluntary basis, this has required interference by consolidating forces of the government. Therefore, organizing community-based works became the leading economic function that had to be implemented by all Asian governments.*” (Marx, 1969). In his letter to Karl Marx dated June 6, 1853, F. Engels wrote: “*Here, farming is based on man-made irrigation, and irrigation is already a business of communities, provinces and central government.*” In the same articles and letters, Marx and Engels clearly show us the causes for collapsing ancient Oriental cultures that were based on irrigation.

“*This system of artificial land reclamation that depends on a strong government, and will immediately fall into decay if neglected by this central authority. This explains why today we can find large areas of, at present, we see vast barren and deserted land that were previously excellently cultivated irrigated areas, such as, Palmyra,*[24] *Petra, the ruins in Yemen, and large areas in Egypt, Persia, and Hindustan. In the same manner, it is possible to explain the fact that only one ruinous war was able to depopulate any country for many follow-up centuries and destroy its civilization at all.*”

[24] An ancient city in central Syria: said to have been built by Solomon.

We know that already thousands of years before the present day there were ancient settlements - cities Shash, Bukhara, Andijan, Soghd, Urgench, Khiva, Kokand, as well as the statehood, religious and cultural unity, advanced trade and class society, which were quite clearly-cut structured.

It is no coincidence that the need in water management and agricultural development gave impetus to development of earth science and astronomy, as well as the foundations of mathematics. All the world knows the names of those who have enriched scientific knowledge: Rayhan Muhammad ibn Ahmad al-Biruni, Abu Ali Ibn Sino, Al-Khwarizmi, Ahmad Al-Fargoni and many others. Thus, the development of water management contributed to the rise of science and predetermined the progress and flourishing of the Oriental civilization based on irrigated agriculture.

We use the term "civilization" as meant in "the level of social development and material culture that was reached by a particular socio-economic formation" (Bongard-Levin, 1989). Our goal is to demonstrate the interaction of man with water resources in our region by means of describing the dependence on water, water management techniques and struggle for water resources. In so doing, we proceed from the fact that water has always been a driving force behind social and economic development, and therefore the settlements always situated near a water source, facilitating water supply and creating of the natural communication ways and protection from assaults. However, the peculiarity of our region consists in the need in adaption of farming to the instability of natural water availability promoting the progress in agricultural sector and requiring the constant mobilization of public forces, improvement of production relations, and developing means of production.

Under achieving and developing its specific kind of oriental civilization related to irrigation, Central Asia has overcome the huge historical way from the primitive society of Keltiminar culture, which covers the period between 5500 and 3500 years ago to the modern stage of development. In 1939, Academician S. Tolstov has discovered the first traces of this culture close to Urgench in the Amudarya delta. This site[25] was inhabited at the turn of fourth and third millennium BC. In total, eighteen sites of Keltiminar culture have been discovered only in Uzbekistan. All of them were united by common features in manufacturing of pottery and first primitive instruments for agricultural labor and in constructing the settlements, where a large-sized family community (up to 100 people) lived. Similar sites of Keltiminar culture out of the territory of Central Asia are dated on one or two thousands of years later; and this fact conforms that Central Asia was the starting point for developing the oriental civilization that then spread northwards (Tolstov, 1948).

[25] Place of settlement of the Stone Age people

Irrigated agriculture was practiced on most favorable areas in accordance with their natural and geographical conditions, namely in the foothills valleys and in flood plains or the deltas of large lowland rivers. In Central Asia, this fact can be confirmed by reference to the cultural heritage of farming communities in the Geoksur oasis (4000 BC), floodplain of Mohan-Darya (the beginning of the second millennium BC) and ancient Khorezm (middle of the second millennium BC).

Turkmenistan was the cradle of irrigated agriculture in Central Asia. Here, twenty seven small rivers flow down over the northern slopes of the Kopet Dagh Range. They created the conditions for a settled life in the Akhal-Teke and Atrek oases.

Using small barrages, farmers created a man-made micro-relief for irrigating their fields. There was no the need to build any special structures for flooding fields since it was sufficient to construct small embankments along the fields' edges to retain water for a spell. Such a rather primitive techniques of water application initiated the development irrigation.

The origination of ancient irrigation techniques in South Turkmenistan and its spread throughout Central Asia are a consequence of rather favorable conditions for developing irrigation (ample coniferous forests and brooks on the slopes of the Kopet Dagh, fertile soils, climate that was milder than today), as well as proximity to the centers of ancient civilization in Mesopotamia, Asia Minor and India. The settled-farming culture, which has originated here and which is called the Annu culture is represented by rather large ancient settlements (for example, Namazga Tepe) that were surrounded by irrigated fields with a quite diverse set of crops, which have already being cultivated using copper-bronzed farming tools. Another community of ancient farmers existed in the Fergana valley. This was the Chust culture that was similar to the Late Annu culture. Excavations in Kuchuk Tepe and Saopali Tepe provide evidence that primeval-agricultural settlements with quite highly-developed farming systems existed at these locations from the end of the third millennium BC (Gafurov, 1989).

After the Keltiminar culture, new cultures such as Tazabag-Yab and Amir-Abad cultures that were discovered and studied by academician S. Tolstov have originated in the Amudarya delta (Khorezm Region). Farmers began to use horses as draft animals, ploughs and hoes for tillage and construction of irrigation canals. The irrigation canals with a length of a few kilometers can be referred to that time.

In the first millennium BC known as the beginning of the Iron Age, the new epoch in developing irrigated farming and irrigation systems has begun and it means, inherently, the beginning of irrigation civilization. Iron tools such as spades, hoes and ploughshare played a revolutionary role in driving technical equipping of agriculture.

Even the hardest soils could not resist to agricultural tools made of iron. Iron tools allowed extending the area of agricultural production, helping in construction of deep and wide irrigation canals and clearing woodland plots for crop cultivation. Primitive mining industry for extracting iron ore and processing industry with manufacturing of iron tools have emerged in the Fergana Valley.

Due to the high rates of population growth and handicraft industry development, demand for agricultural output was growing year to year. At the same time, emergence of city-states, as well as more large states such as ancient Khorezm, created more possibilities for expanding and technical upgrading irrigation systems. The period from the fourth century BC to the first century BC was the golden age for development of ancient irrigation. During that period, there were drastic changes in irrigation technologies that provided improving both water intake facilities and configuration of main irrigation canals. The extent of irrigation canals drastically increased, reaching hundreds of kilometers. Many small local irrigation systems were united into larger irrigation systems.

Archaeological studies show that in the fourth century BC the irrigated area in some places of lower reaches of the Amudarya, Syrdarya and Zeravshan rivers exceeds the current irrigated area several times. In the first century BC, the total irrigation area in the lower reaches of the Zeravshan and Kashkadarya rivers amounted to about 600,000 hectares, exceeding the present-day irrigated area in this region two times. In the lower reaches of the Amudarya and Syrdarya rivers, the area with developed irrigation network was four times larger than it is at the present time. This also means that the water withdrawals from these rivers were most likely larger than at the present time (Dingelshtadt 1893).

In the Iron Age, irrigation development started advancing from the piedmont areas towards the alluvial and deltaic plains of the rivers Amudarya, Syrdarya and Zeravshan. The first large canals, diverting water directly from the main streams of rivers rather than from their branches were built here. Headworks were built of stone and mortar, for example, Ak-Darya hydroscheme on the Zeravshan River. Large-scale agricultural development on the vast deltaic plains was in progress. The irrigation canal in Bazar-Kala (the Right-Bank Khorezm) was 40 m wide and more than one kilometer long.

The need for protecting the interests of irrigation scheme owners and building the required large irrigation systems prompted the development of oriental authoritarian forms of governance in Central Asian states, when only one strong personality made decisions and was responsible for the welfare of his country. In this way, the state in Central Asia became the entity with absolute powers for decision making on tackling water problems and the responsibility for sustainable water supply for irrigation, as well as establishing and defending the water rights of the population.

The state has being built on the basis of absolute power, and its principal responsibilities consisted in solving water issues, mobilizing the population for implementing public works, collecting taxes, and defending own territory. Private ownership of land was impossible. A ruler was the supreme owner of all the land.

Emergence and development of ancient towns was closely related to construction of main irrigation canals. Sometimes, these towns grew up around the headworks due to the need to guard the water, but more often irrigation systems were built near existing major settlements, the population of which usually initiated the construction of water infrastructure. In this way, irrigated oases that supplied agricultural products to urban inhabitants were created around ancient towns, and water was supplied through irrigation canals to these towns for satisfying the needs of the urban population. Over time, these territories was transforming into developed self-dependent states.

From time immemorial, the principal oases (the centers and zones of ancient irrigation systems) emerged along the large rivers and their tributaries and existed owing to the natural regime of seasonal flooding or artificial irrigation. They emerged as if threaded on the branches of these rivers.

Such a situation can be observed in the Samarkand and Bukhara oases located in the irrigated valley of the Zeravshan River, in the Tashkent oasis located in the Chirchik River Valley, , in the Fergana and Khujand oases located along the middle reach of the Syrdarya River, in the Surkhandarya oasis located along the upper reach of Surkhandarya River and in the Khorezm oasis located in the lower reaches of the Amudarya River. It is difficult to determine the accurate dates for the beginning of forming these and other oases. However, information contained in Chinese sources (from 1149 BC), Xenophon's writings and in the great work of Herodotus "The History" provides evidences of large-scale irrigation development in this area in the first millennium BC. Herodotus wrote that the north-eastern part of the ancient Persian Empire, its two satrapies (Turkestan) were inhabited by Bactrians, Khorezmians and Saranians (Soghdians). They paid taxes to Persia in the amount from 600 to 300 talents of silver, this is on 200 talents more than the prosperous Egypt paid at that time (Herodotus 1969).

Sogdiana and Shash undoubtedly were the largest oases at that time. Sogdiana was a separate economic entity located between the Zeravshan and Kashkadarya rivers. In the fourth and fifth centuries AD, some Arabic travelers have written about the Zeravshan Valley as about the earthly paradise. The Greek historians Aristobul and Strabo testified that the Zeravshan River originates from the vast Zeravshan Glacier (now the Fedchenko Glacier), which is located 3,000 m above sea level and has huge reserves of fresh water. A river stream disappears among desert sands, not reaching the Amudarya River (approximately 30 km). The Zeravshan River has never lost its value as a source of life and well-being.

The Sogdiana oasis stretches far away into the steppe as an emerald tape of green orchards and fields. Two of the most famous cities of Central Asia – Bukhara and Samarkand – are located in this oasis. On the south, the Sogdiana bordered with the Kashkadarya oasis, which was the creature of human hands. The Eskyangar Canal 100 km long was built in this location still in the fifth century BC. The canal has existed for over a thousand years and supported in good condition by the local population; and after reconstruction it is in operation even now (see Figure 3.1).

Historical data provides evidence that at the beginning of the first millennium BC, the Kesh State (in Greek documents, Nautaka) was established in the Kashkadarya Valley near the foothills of the Hissar Ridge, and the Nakhsab State (in Greek documents, Xenippa) has occupied lands in the middle and lower reaches of the Kashkadarya River. Several ancient settlements, which later became cities, emerged along this canal, including Tallaktepa, Erkurgan, Elkendepe, Kesh, Chirakchi, and Kitab.

When the depletion of water resources of this canal system became evident, it was decided to build a link it with the Dargom Canal in the Samarkand oasis. Construction of this connective channel has resulted in the development of a chain of new villages, fortified farmsteads and castles, as well as a line of outposts.

Figure 3.1 The Eskyangar Canal at present time (2010)

This water infrastructure is evidence of the wise and purposeful policies of well-organized states, the main function of which consisted in developing and maintaining the irrigation systems in good condition.

A quite advanced governmental system was established in Sogdiana over the period from the fifth to fourth centuries BC. Ancient Afrosiab, which later became known as Marakand, although according to Chinese sources it was called Kann, was the capital of this independent state (at present Samarkand). The state encouraged construction of these settlements, turning some of them into the control posts near the headworks of large irrigation systems that served for water flow control and distribution. For example, the fortified post at Varagsar where water diversions into the Dargom Canal, water levels and quality were monitored has become the key site. This fortified post was important for protecting the dam and headworks of this canal, which supplied with water all irrigated fields around Samarkand.

The state has also established the system of strict control over accounting water use. Books with records of water supply and water use in the Zeravshan oasis were kept up to present day. A water volume was measured in ravaks[26] (a local unit of volume where one ravak consists of 40 kuraks). One kurak was sufficient for irrigating a plot in 5 tanabs (about 120 hectares) of the cropped area.

The first project of inter-basin water transfer from the Zarafshan River Basin into the Sanzar River Basin through the Isky-Tuya-Tartar Canal was implemented in the more later period. The main feature of this canal, which exists and at present is the absolutely uniform gradient over its entire length.

The Tashkent oasis was another important ancient center of irrigated farming in Central Asia. Archaeologists have discovered 97 ancient settlements, 13 of which can be referred to urbanized areas. Kanka, which covered 150 hectares, was the biggest city and the economic center of the Tashkent oasis. A mainstay of economy in this oasis was settled farming based on irrigation with a developed network of canals, dams and small water reservoirs. The Chirchik River was the most significant water source for irrigation in the Tashkent oasis, and some 42 main canals diverted water from this river. V. Masalsky (1913) wrote: “Some of these ariqs of ancient origin look like rather big rivers measured by water abundance and length.” He described such irrigation canals as Boz-Su, Zakh and Salar. At present, it is known for certain that these canals were constructed in the first century AD. The Zakh Canal was 20 km long with numerous barrages and laterals in the shape of ariqs. It delivered water for all irrigated areas east of Tashkent. The Pargostepe Fortress was built at its head section for guarding water, and there was a whole system of outposts at its laterals. Constructing the Salar Canal has initiated creating the Salar-Karasu-Jun irrigation system, which facilitated forming a whole cluster of agricultural settlements.

The first information about Tashkent is contained in ancient eastern chronicles from the second century BC, where the city is mentioned under the name “Uni.”

[26] *ravaks* = 40 *kurags;* 1 *kurag* = 2 *toks*; 1 *tok* = 4 *choraks*; and 1 *chorak* = 2 *nimchas; etc.*

This city is described as located on the territory belonging to the Kanguy State. Shash, the ancient name of Tashkent oasis, was mentioned in the records of the king Shapur I dated 262 year AD. According to the transcription in Chinese sources its name is written as Shi, in Arabic sources as Shash, and in Turkic sources as Tash. In the second century BC, the urban settlement Shash-Tepe had established on the bank of the Jun River, and thus the history of Tashkent started.

Archaeological excavations in ancient oases allowed dating the stages of creating irrigation systems. For example, in the Surkhandarya oasis (Sapaliter), remnants of ancient irrigation systems are dated by the second millennium BC, and in the Fergana oasis (Chust and Dalverzin) from the end of the second millennium BC. In 1968, archaeological excavations of large irrigation canals in the Murgab oasis were undertaken by V.M. Masson, who described the two large Guni-Yab and Gati-Akor canals (55 and 36 km long, 5 and 8 m wide, and 2–3 m deep respectively). Still today, we can discover ancient irrigation canals in oases that are dated from the time of the flourishing period of the Kushan Dynasty (since the 1st century BC to around 230 AD).

Detailed archaeological surveys over vast areas have shown that over the Kushan Period, practically all the basic areas in Central Asia were ameliorated for the purposes of agricultural production. Construction of the Zang Canal in the Surkhandarya oasis, canals Zakh, Bozsu and Salar in the Tashkent oasis, canals Eskyangar and Dargom in the Samarkand oasis, and canals Shahrood and Ramitanrood in the Bukhara oasis is dated back to the abovementioned period; and some of them remain in use until the present time. According to Bartold (we quote the book of Andrianov, 1969), the total area under irrigation in these oases in ancient times was approximately 3.5 to 3.8 million hectares.

However, no more than 10-15% of this land was in actual use at any one time. Several research works are devoted to irrigation in the Samarkand oasis and adjacent regions (see, for example, Bekchurin, 1950), in which one can find the description of natural, political and economic conditions that existed in the oases around the time of the Kushan Dynasty.

Samarkand was really the cultural and economic center of Central Asia at that period. The ancient Greeks were very impressed by Sogdiana, and in Greek literature we find the following description: "*Samarkand, I do not know another place all over the world where a bird's eye view would be so pleasant. The city is located on the right bank of the Soghd River and [Sogdiana] stretches out from the Bukhara border up to the Buttan border. Its size is impressive and can be measured by eight days of travel along green fields and orchards. Flourishing orchards are surrounded by canals with permanent running water; and houses are located among meadows, fields, and ponds … Sogdiana is the most fertile land among all God-given countries. The best trees and fruits grow here and ditches with flowing waters are crossing all homesteads.*

It is very seldom when a street or a house does not have a canal with flowing waters.” "*Houzes*" - widely-distributed ponds, in which the water is accumulated for daily use and creating microclimate in settlements astonished the imagination of travelers.

Figure 3.2 Laby-Hauz in Bukhara

Water is the great mentor. In Central Asia, the water stimulated asserting the supremacy of laws, norms and social moral over individualism, egoism and greed for money.

The moral codes governing relations in the triangle “humans - land - water” are rooted in the attitude towards water. Water stimulated establishing of the unified moral laws that accord to its purity and sacred status. In Central Asia, water became not only a material but also moral value. Stealing water, for example, was completely out of the question, and everybody knew from childhood the saying: “Who steals water once, remains a thief for life.” A community could forgive a theft of property or cattle but never a theft of water; the label of “water thief” (*suv ogri*) was anchored not only to a thief himself but also to his family and descendants.

Religion played a leading role in forming the water cult by presenting water as God’s creation and turning the worship of water into an ideology. Religious dogmas were transformed into the public conscience, and religious canons have become the principles and rules of water use.

The Holy Scripture "Avesta," which represents the collection of sacred texts of Zoroastrianism, comprising preaching and legal regulations, prayers, psalms and hymns devoted to deities has become the prominent source for idolization of water in Central Asia. This ancient religion emerged five centuries before Christianity. In 1857, the German historian H. Weber expressed the view that Zoroastrianism arose in the middle of the fifth century BC in lands located between the Caspian Sea and the Amudarya River.

Earth, heaven, fire and water are considered to be the sacred creations of Ahura Mazda. The earth and water are also considered as living creatures that produce the cereals and trees that provide food for people and the grasses that provide forage for cows and horses. Water was declared holy entity that has to be protected against pollution by sewage. Water in creeks and rivers could only be used for drinking and irrigation, bathing was forbidden, and even wade in a river was forbidden (a river could be crossed only over a bridge). Magi were vigilant guardians and tireless monitors of executing these sacred instructions. Water that falls on the Earth's surface in the form of rain and snow, as well as mountain brooks were considered as holy entities. According to the Avesta, the rivers are holy and divine entities. They were glorified in hymns and sacred myths. In line with the Zoroastrian cosmography, the rivers are flowing not only over the Earth but also in Heaven, generating rainfalls. The Avesta laid the foundation for water deification and for attitude to water as a divine creature, which remains even today at nations in Central Asia as an important constituent of public consciousness.

A care about water unifies the states and nations. In 630 AD, at times of travels of the Chinese Buddhist monk and pilgrim Hsuan Tsang (600–664), the Maverannakhr represented the politically disintegrated state that was split into many small and independent domains, but from an economic point of view, they constituted a single whole with trading towns, irrigated fields, and irrigation canals. One part of the community was busy in trading, and another part was involved in farming. However, all of them, regardless of their economic activity, were supervising for water condition and monitored the condition of irrigation canals, jointly solving any water problems. The rulers of these domains knew one firm truth: "*if you would like peace and prosperity, you should take proper care of joint water use*" (Bartold, 1966).

They also knew it is impossible to maintain irrigation systems properly without the participation of all nation. In the ninth and tenth centuries AD, the maintenance of dams on the Zeravshan River and different parts of the irrigation system was entrusted to the inhabitants of separate blocks of houses, settlements or city districts. In return, for looking after the irrigation system, inhabitants were exempted from land tax or, for adherents of other faiths, from capitation tax (*jiziya*). In Central Asia, the word "*paykal*", which means the daily sequence of water use, dates from this period.

Islam, which supplanted the doctrine of Avesta in the 8th century AD has played its historic role in developing the irrigation culture in Central Asia. Arabs highly appriciated natural conditions of Central Asia, and they made energetic efforts for transforming this region into a base for supplying different goods to the Caliphate and into a source of enrichment. They catched the main idea that consisted in the fact that regional development should rely on expanding irrigation areas and construction of water infrastructure. The Caliphate has allocated considerable funds for irrigation works and, at that, made good use of considerable local knowledge and their own great experience of constructing irrigation canals in the valleys of the Tigris and Euphrates rivers. The Caliph Mutasid (833–842) personally contributed a large amount of his own money for constructing the large canal in Tashkent, which remained in operation for more than 900 years until the eighteenth century.

In Central Asia, Arabs faced the challenge of regulating the land and water relations. Here, quite developed irrigation systems were put in practice, but the rules governing water use were absent, due to lack of the legal framework, which could regulate water resources use. All rules of water relations were mainly grounded on customs and traditions, and this often resulted in disputes and conflicts that were harmful to economic activity. In the reign of *Abdallakh Ibn-Takhir* (830–844), the ruler of Khorasan, there was a dispute concerning use of karez and ariqs in Bukhara; and it was decided to apply to faqihs for making legal decision. However, the legal regulations that could resolve this problem were absent. There appeared the need in convening all the experts of fiqh in Khorasan and granting them the mandate to draft guidelines on water use with the participation of scholars-theologians from Iraq. A water code (*"The Book on Ariqs"*) was written, and this code became the guide for regulating land and water relations in Central Asia for many centuries. Unfortunately, the text has not survived to our time, but all its regulations were reflected in the Sharia, showing their importance for developing irrigation in the Muslim world. In 1924, a special issue of the journal "Bulletin of Irrigation" was devoted to the water legislation under the title "The Collection of Muslim Regulations (Sharia) for Water and Land Use," with quoting 205 instructions which covered key problems of water and land use. The most frequently used laws and regulations of Sharia have been translated into local languages, as well as were orally transmitted from generation to generation turning into the oral rules referred to as the Adat. The following regulations were included into the Adat[27]:

[27] The word "odat" literally means habit, custom or tradition. Rules and provisions of the Odat in the legal sense are regulations of the customary law

1. ***The recognition of waters in rivers and lakes as the community property.***
2. ***A ban on sale of land without water.***
3. ***In the event of water scarcity, water has to be allocated in the fair and equitable manner (proportional to a irrigated area).***
4. ***Water allocation into ariqs should be proportional to their command areas, taking into account a sequence of water supply.***
5. ***Participation (in the form of personal labour or supply of building materials) of each water user in implementing socially necessary works related to the construction, repairing and cleaning of canals and water regulators.***
6. ***Cultivation of hydrophilous crops (for example, rice) should be coordinated within a community, and, in case of water deficit, limitation of a cultivated area should be considered or obtaining consent of all downstream water users that depend on water supply from the canal.***
7. ***When constructing an ariq that crosses the land of another person, any damage should be paid for.***

Conscience, a certain order of doing things, rules and word of God became the fundamentals of the Odat. Its instructions were subject to unquestioning execution. Mirabs *("chief of water")* were appointed in the field to ensure proper implementation of the Sharia's regulations. General supervision was entrusted to the Imam (*a priest from the local mosque*). A mirab ensured the correct water distribution, settled disputes, and was responsible for water supply on the territory under his control.

Water has the highest moral value in Central Asia. The attitude to water, based on the recognition of its importance for life and its divine blessing, has been reflected in the culture of everyday life, literary works, philosophical treatises, myths and legends. Water does not endure the amorality, material egoism, mercenary motives or malice The outstanding oriental poets always appreciated heroic deeds for the sake of water. For example, this idea was incarnated in the poem "Farkhad and Shirin" written by the great Uzbek poet Alisher Navoi who was the Grand Vizier at the court of Hussayn Bayqarah, representative of the Timurid Dynasty in Herat. This poem glorified the feat of Farhad, who dammed the river and directed water to the fields suffered from drought for the sake of his love to Shirin. His image was captured in the sculpture of Farkhad at the dam foot of the Charvak hydropower plant on the Chirchik River.

Figure 3.3 Sculpture of Farkhad at the dam of Charvak HPS

A unity of man, water and earth, which was forming the way of thinking, norms of behavior, lifestyle and ethics has become the basis for Central Asian civilization. Water resources and man-made irrigation systems were the basis for life of nations in Central Asia and the source of their well-being, providing the formation of special production relations that have become the base of Asian way of production and development. Development of irrigation systems and continuous extension of agricultural land to meet the needs of a rapidly growing population were possible only for collective formations united by the state. The first states in Central Asia emerged, first of all, because of the need to establish a proper system of water resources management. The governance of Irrigated farming and upkeeping a regular army were the key functions of states that originated here. A state played a role of the chief national *mirab* (irrigator). The Quran states that the Earth is the property of Allah, and a sultan (sovereign) is his shade on the Earth and an executor of his will. Therefore, the sultan is the owner of water and land. Private ownership of land and water was unallowable. While in the West, private ownership of land and fixed assets formed the basis for legal and productive relations, and private property was considered as an inviolable right; in the East, water and land resources were the sovereign's property. In times of the caliphate, land was a property of caliph and could be distributed among land users into rent only on behalf of the caliph. In this region, large-scale irrigation has reached its apogee in the period between the seventh century BC and fifteenth century AD. This period corresponds to the stage of development and achievement of the golden age in civilization dynamics in accordance with all characteristics that were mentioned at the beginning of this section.

Large-scale irrigation requires well-organized management of considerable water volumes and involves the use huge manpower resources both for the operation and maintenance of irrigation systems and for agricultural production. At that point, many historians (I. Marcwart, V. Bartold, V. Ranov and others) consider that this system could exist only because there was a powerful state, which would have the necessary resources to organize its operation and maintenance. Such states as Margiana and Bactria with large urban settlements, such as Marakanda (Samarkand), Bukhara, Urgench, Shash (Tashkent) and Urus-Shana (Ura-Tepe) were formed and were developing in Central Asia just at that period. Religious dogmas and regulations were the ideological basis of this civilization, and the driving force for progress was the development of sciences related in varying degrees to water. The ancient school of scientists and irrigators has combined knowledge of mathematics, cartography, astronomy, hydraulics and other sciences. The creation of the lunisolar calendar of 12 lunar months of 30 days with five extra days at the end of a year may date back to that same period. Studying the natural seasonal cycles was needed for the proper application of irrigation and required knowledge of meteorology, astronomy and other sciences. Abu Abdulloh Mohammad Ibn Musa al-Khorezmi, in his famous book "Al-Jabr va-al-Mifuqabilah" wrote that this knowledge was necessary for various calculations and also for measuring land plots, canals, etc.

By applying traditional methods in irrigation and water use, the mankind was accumulating knowledge, especially in agriculture. Knowledge of the trajectory and periodicity of stars' movement, as well as of climatic and weather phenomena was used for assessing land use options. All this has led to introducing the systems of water management and irrigated farming based on knowledge of astronomy, meteorology, pedology and many other scientific fields. It is not by mere chance that in Central Asia in the eighth century, the basics of algebra (*Al-Jabr*) and the use of algorithms (*al-Khorithm*) were developed by the mathematicians of that period, such as Al-Khorezmi and Abu Ali al-Husayn ibn Abdullah ibn Sina. Thus, the Central Asian irrigation civilization emerged and encompassed the entire region approximately a millennium BC, further it developed and improved right until the 17th century AD and went into decline in the mid-19th century. However, its foundations and traditions have laid down in a basis for a new irrigation civilization that began to develop after the colonization of Turkestan by the Russian Empire, which has not changed the class structure of society and, therefore, has little influenced on the essence of civilization itself. Its final transformation took place in the Soviet era, when the class structure of society and production relations were changed owing to the nationalization of basic means of production and rights on land and water. At the peak of its development (the second half of the 20th century), the new civilization has provided the high technical level of basic means of production on the basis of the socialist system of production relations, but at the same time, the succession of traditional and religious attitude to nature and water was lost, on some extent, that resulted in the significant environmental losses.

Now, we are at the stage of development of a new oriental-market civilization, when water management and irrigation have lost their priority in the economic and social development, but kept the high level of dependence from governance, development, protection, condition and use of water resources, and this dependence rapidly grows in the environment of increasing water scarcity. As regards production relations, this civilization has to be based on the high-developed and diversified economic structure and on the institutional and legal principles of democratic society, using all the most valuable things from the legacy of both socialistic production relations and Islamic traditions of water use.

However, as a result of the consumer behavior and monetarist nature of our society, the future development can come into a blind alley, both in the global and regional scale. As predicted by the Club of Rome in 1972 in its report “The Limits to Growth,” the modern human and economic development has exhausted its possibilities and came to the border of continuous crises: economic, military, political, natural and human. How to explain that 1per cent of the population has the same wealth as half the global population? *According to other reports, 300 richest families in the world possess such means that and 3 billion people at the bottom have.*

Under the conditions of unrestrained pursuit of goods, wealth and luxury, the stratification of society, anger of the poor and the hungry, squandering of human and financial capital are increasing. The world is constantly on the verge of large and small conflicts.

Humanity needs in decisive moving the civilization to a new level of reducing consumption based on the estimate of well-being that takes into account the needs of the human society and ecosystems. Interesting reference points are the Buddhist principles (Bhutan's' gross national happiness index). In this case, it is necessary to refuse from the western level of consumption with its continuous linear growth, and to use the wise and comprehensive approaches, anti-Western traditions and practice.

It is necessary to draw attention to a special role of elaborating a new ideology of surviving humanity that will base on the priorities of saving nature in combination with very effective use of all its resources, as well as production, financial and human potentials. At that, intense development of science and knowledge, free exchange of knowledge and aspiration to collaboration and peaceful co-existence should be the basis for surviving of human society. The opportunities for realizing this approach will be considered in the following sections.

Chapter 4. What future awaits us in the water sector?

Forecasts of the World Water Assessment Program (WWAP), as well as the reports of UNESCO, UN-Water and World Water Council (for example, "Managing Water under Uncertainty and Risk," The United Nations World Water Development Report 4, 2012), which were prepared for the 6th World Water Forum and edited for the 7th World Water Forum try to attract attention to risk trends that nowadays are formed in the world. They all are analyzing the risks related to environmental, climatic, economic and, first of all, political restrictions, which are constantly arising in the turbulent present-day world.

Studying the advanced experience of countries, which survive under conditions of water scarcity gives us confidence that the water will suffice for mankind in case of the rational governance of water resources and their management in strict adherence to the international water law and its strengthening in a global scale! A publication of the National Intelligence Council "GLOBAL TRENDS 2030: ALTERNATIVE WORLDS" notes that, right now, more than one billion people live under conditions of water stress and only 15 percent of population will have the secure water supply in the future. It is supposed that water problems will increase in the future: demand for food is set to rise by more than 35 percent by 2030, at the same time, annual global water requirements will reach 6,900 billion cubic meters (bcm) in 2030, 40 percent above current sustainable water supplies. Agriculture, which accounts for approximately 3,100 bcm, or just under 70 percent of global water withdrawals today, will require 4,500 bcm without efficiency gains. By 2030, nearly half the world's population will live in areas with severe water stress. Water may become a more significant source of contention than energy or minerals out to 2030 at both the intrastate and interstate levels. The main belt of water stress covers the USA, Mexico, North Africa, the Middle East, Central Asia and South Asia, as well as Northern China[28] (Fig. 4.1)

[28] Global trends 2030, National Intelligence Council, 2012, ISBN 978-1-929667-21-5, 165 pages, NY

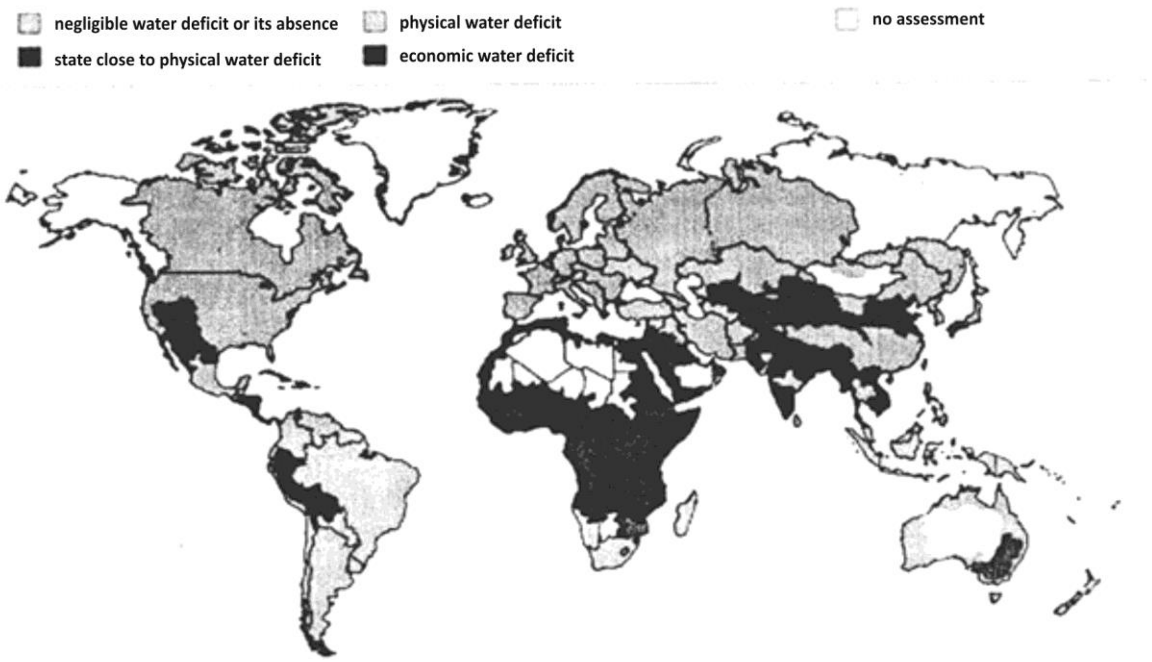


Figure 4.1 Zones of physical and economic water deficit

Forthcoming risks

The impact of climate change on water resources and water consumption

Current projections of forming surface water resources do not give preference to any decrease or increase in the volume of natural water resources. A great concern is expressed regarding the incremental melting of glaciers with subsequent reduction in feeding of rivers' flow. Present water resources depletion is primarily related to human activities. Reducing forest areas, desertification and, most importantly, water pollution by untreated discharges are main restrictions for the possibilities of water use. The shrinkage of the Aral Sea has its "brothers in misfortune" in all continents: Mono Lake, and Salten Sea in the United States, lakes Chad and Victoria in Africa, Dead Sea in Israel, and Lake Sevan in Armenia (www.cawater-info.net) - this is not a complete list of environmental disasters related to water. And how many rivers that were before full-flowing and clean now have become gutters in their lower reaches.

Climate change manifests itself primarily in increasing water demand due to higher temperatures and more frequent extreme events (droughts and floods), as well as increasing the non-uniformity in territorial distribution of available water. Just over 700 m3 per year of water resources per capita is a world mean value.

At the same time, in Israel, Jordan, Libya, Qatar, as well as in more than 30 other countries located in the areas with arid climate, water consumption amounts to less than 300 m3 per capita (www.fao.faostat). Three countries: Brazil, Canada and Russia have a dozen or more thousand cubic meters of water per capita, and it is assumed that a spatial unevenness will increase. However, in case of Russia, 60% of its water resources are concentrated in Siberia, where production activity is underdeveloped, but the south regions of this country - especially Krasnodar, Stavropol, North Caucasus, Rostov regions, middle and lower reaches of the Volga suffer from periodic droughts. Rivers flowing to the north, particularly major Siberian rivers in Russia - the Yenisei River and Ob River, – may to a certain extent increase their runoff and accordingly increase their influence on melting the ice cap of the North Pole. This phenomenon is of great concern is not in Russia or the CIS countries, but mainly in European countries that may be significantly affected by releasing ice from the pole and an increase in inflow of meltwater into the ocean that, to some extent, will cause a gradual rise of the water level in the Atlantic Ocean and relevant influence on the Gulf Stream. This ultimately can affect the European coast's mesoclimate. At the same time, under the influence of current rise of temperatures, the aridity will increase in the South of Russia, Ukraine, and in the same way in whole Central Asia.

An increase in water consumption will be the main threat for the future both under the influence of climatic features and especially due to the population pressure. According to FAO data, the quantities of additional water resources needed to meet the growing requirements of mankind in food and utility services will make up 40 % of the present level by the mid-century (Muller, 2011). This is understandable when you consider that today more than 1 billion people lack the access to safe drinking water and 2 billion people to sanitation, and 870 million people are starving! To meet their needs of current population plus 2-2.5 billion new inhabitants of our planet it is necessary to add almost 3000 km3 of waters to those volumes, which now are withdrawn from water sources. This means that humanity will encroach on those 9000 km3, which are today kept for supporting the natural ecological value of water. Therefore, the areas with lower water supply are doomed to growing the water deficit regardless of the increase or decrease in surface water volumes. Moreover, the southern regions are more exposed to population pressures, both through natural growth and thanks to more intense migration last decades in search of jobs and more favorable living conditions.

At the same time, only 30% of the available land fund that is equipped with irrigation networks (6.2 mln. ha) are being irrigated in Russia (at present just 2.5 million ha are in use). More than one million of irrigated land is not irrigated in Ukraine, and little less irrigated land in Kazakhstan. After the collapse of the socialist block, the total area of unused irrigated land in Eastern Europe and the CIS has exceeded 11 million hectares. A reason consists in the termination of subsidies for maintaining and operation of sprinkling irrigation systems.

Poor water management is a major disease of mankind. Until recently, water management was somewhere at the background in most countries, even in the United States. It is typical that in this country, which is like a flagship of the world, the absolute threshold of water consumption has been reached in many river basins such as the Colorado, Sacramento, and San Joaquin. In the USA, 42 percent of river length is estimated as being in poor condition due to contamination. Water supply over 70 percent of the country is at risk (the Pacific Institute, 2013). Russia, like most countries with transition economy, meanwhile stays aside from developing the deliberate state policy in water management issues. While the principle of river basin management was accepted everywhere, lack of the clear-cut program of governing the river basins, deficit financing of government programs related to water management (current funding the water sector in Russia is a hundred times less than the water sector's budget of Russia until 1990) are the evidences of management system degradation. Major accidents both at the Sayano-Shushenskaya HPS and in the Kuban region confirm this fact. In contrast, in 1970, the European Union launched a huge work to establish the order in water governance, which in 2001 led to developing the Water Framework Directive and its introduction in all countries of the European Union.

Although its implementation also meets big difficulties and the planned timeline of successful achieving the reliable condition of water bodies (2015) was not achieved, the European Union aims at strengthening the water governance and its monitoring. The state of water governance and management in Central Asia is somewhat better than in Russia, because here the people and especially farmers are well aware of the price of water, but the required level of good water governance and management was not still reached.

It must be emphasized that until the end of the last century water governance was very often mixed with water management. Meanwhile, these are completely different though closely related concepts. Water governance means the framework and rules that define a set of political, legal, institutional, financial and social regulations as well as mechanisms of incentives, while water management is responsible for their implementation, detailization and use with the purpose of formation, supply, distribution, management and protection of water resources and water facilities.

Hydroegoism that is more and more developing in the world is a very dangerous phenomenon, which is based on specific management principles, with which we must combat by all available means. Until recently, until the world was not trapped of an unprecedented race of competition for oil and gas, nobody believed in hydropower as the priority sector of water resources use.

The priority was given to integrated, multi-sectoral use of water resources and flow regulation by reservoirs in the interests of all water users. In this case, the most efficient use of each cubic meter of water takes place. Taking into consideration that hydropower plants are the most profitable users of natural water, unfortunately the equalization of electric power and organic fuels is becoming more and more prevalent.

If you compare a cost of electricity with costs of gas, gasoline, kerosene, etc., then the desire of many donors and national corporations to organize the maximum utilization of hydropower resources through construction of large, small and medium-sized hydropower plants, often without regard for the requirements of downstream countries, becomes clear. At the same time, if we take into account that a cost of winter electricity is much higher than a cost of summer electricity, then the desire of HPS's employees to increase generation of hydroelectric power in winter becomes quite understandable, leading to a substantial economic damage in downstream countries. Therefore, in winter we observe floods on the rivers with hydropower potential, but in summer they dry up.

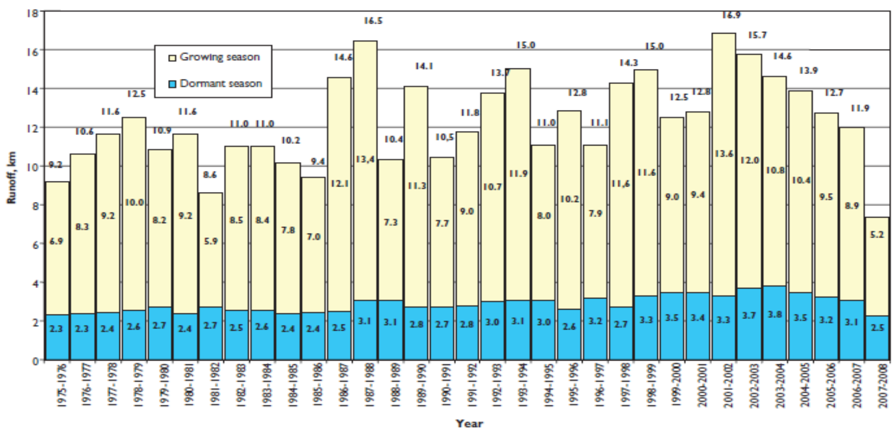
A typical example is changes in the flow regime of the Syrdarya River after gaining the independence by Central Asian republics. Although the state commission's act on commissioning the Toktogul Hydroscheme clearly determines that the dam was built for the long-term regulation of river flow in the interests of irrigation, and at the same time, generating of hydropower can be allowed only by use of water releases for irrigation, since 1994, the regime of water releases from the reservoir was changed (Figure 4.2).

Although the natural flow of this river remains unchanged regarding the ratio of summer and winter flows, since 1994 and especially after 1998, the ratio of winter and summer water releases has increased twice due to reducing summer water releases.

Therefore, one of the fundamental tasks to meet water supply needs (utilities, irrigated land, and nature itself) is to develop such procedures of the international water law and the ethical code of water use and management, under which such phenomena will become intolerant. This is possible and rational, since in such countries as Canada, the United States, as well as in the EU, the water agencies are busy in managing the use of water resources rather than the sectoral departments. These agencies sell water to hydropower plants that execute water releases, the regime of which is consistent with the requirements of all water users on the river.

Thus, the search for additional sources of water and increasing the productivity of using available water resources should withstand to these threats and destabilizing factors. However, it is obvious that under the current unpredictability of these changes, the orientation of tools and mechanisms of water use on rational using available waters is the most expedient approach.

Inflow into the Toktogul Reservoir over the period of 1975 to 2008



Water releases from the Togtogul Reservoir

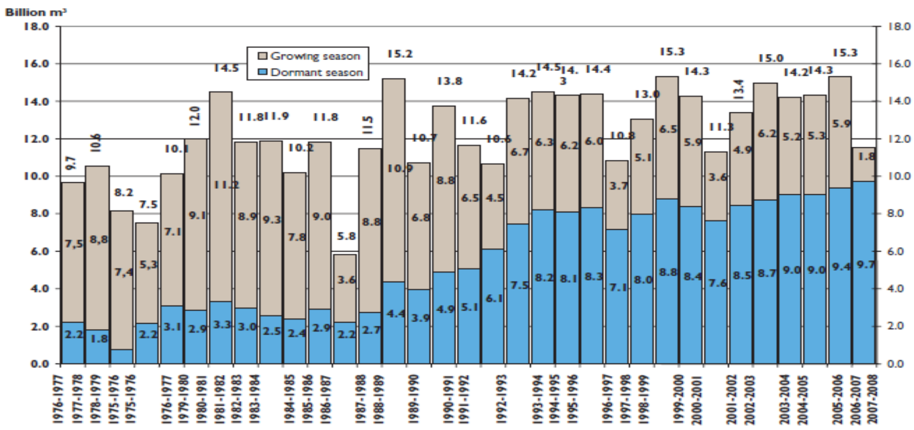


Figure 4.2 Studies in the Syrdarya River Basin (2002 -2008)[29]

[29] V. Dukhovny, J. de Schutter, Water in Central Asia: Past, Present, Future, CRC Press/Balkema, 2011, 410 p.

Mechanisms of surviving under water deficit

Bringing the order into water management by transition towards integrated water resources management (IWRM). IWRM allows reducing a water resources deficit at the expanse of water management within hydrological boundaries, public participation, integration of science and production, accounting the interests of different economic sectors (*horizontal integration*), integration of hierarchical levels of water management and liquidation of organizational losses at their junctions (*vertical integration*), as well as use of other water sources. Such an approach was applied and is applying in Spain, Italy and France during centuries. IWRM is based on several cornerstone principles set out in Chapter 7.

Involving into use more than 11 million hectares of land earlier irrigated by the sprinkler machines over the whole space of the former block of socialistic states, that have transformed into fallow land or rainfed land because of the loss of government subsidies. Four million hectares in Russia, 1,1 million ha in Ukraine and the same amount of land in Kazakhstan are the areas where require rehabilitation of large massifs of sprinkling irrigation. They existed in Russia and Kazakhstan, and now they require not only rehabilitation, but also in replacement with more efficient methods of irrigation (for example, mist irrigation systems and ground sprinkling) that have been successfully used worldwide.

Comprehensive developing the systems of water saving and increasing land productivity. The problem of water saving requires constant attention, preparation and approval at the governmental level of the national plans for the water sector, aimed at introducing the "green economy" and simultaneously at providing the employment of the rural population, and increasing output capacity of not only each hectare of land, but also every drop of water. The first priority is to create a network of agricultural and reclamation knowledge centers, which are designed to monitor continuously the state of land, water use, and be ready at any moment to assist a farmer or water user. This provides impulse for growing land and water productivity, since today due to transition to a market economy, people who have money rather than people who know the principles and methods of irrigated agriculture have come to management of land and water resources. They need the assistance to become the masters of land.

Figure 4.3 The SCADA system at the waterworks

Developing the greenhouses is an important measure for water saving. Those who had been in Spain, Holland, and Italy could see a bird's-eye the huge white areas under glass (protected ground), which provide high-quality agricultural products and, at the same time, large agricultural income in these countries. Here, the water productivity exceeds that, which is achieved under the conditions of outdoor growing several times. Analysis of developing the production in greenhouses in fifty leading countries all over the world, graciously presented by prof. S.R. Ibatulin, shows that in these countries the specific indicator makes up one hectare of greenhouses per1000 people, and in China even 2.3 ha! We are pleased to note that growing crops in greenhouses, especially vegetables, is increasingly developing in all countries of Central Asia, in southern Russia and the Caucasus.

Establishing an efficient and well-controlled system of water governance and management. A prototype of future water management can be the water sector in Israel - for arid areas, the water sector in the Netherlands - for the coastal zone and humid arears, and the water sector in Switzerland - for the temperate landscapes with intensive urbanization. A deep respect for water as the basis of natural complex, which need to save and multiply, accounting its huge ethical, cultural and moral potential, is typical for these countries. Natural and human systems in these countries are closely intertwined, as if they are woven into each other and tightly fit together like a puzzles in the children's games. In all these countries, there is the strictly developed and supported system of centralized water governance "top down", which determines the order of distribution, limitation and monitoring of water resources, and their use under managing water resources "bottom-up" with the wide involvement of all stakeholders.

An order of financing and motivation of both water users and water organizations in water saving established by the state ensures the sufficiency of funds for the maintenance, improvement and development of water infrastructure with share holding of the state, based on the widespread principles - "user pays" and "polluter pays", while they should pay more if they more pollute water sources or use limit-exceeding water volumes. All irrigation and drainage systems comply with the highest technical standards, equipped with automation, "on-line" control, and systems of forecasting and disaster warning. In terms of water productivity they approach potential water productivity!

Involvement of marginal water is a huge reserve in term of involving additional water sources. Usage of treated drainage and waste water must be put in practice following the example of the Middle East, where more than 50% of all available water resources are formed at the wastewater treatment plant with coarse and fine water filtering, which are then transported through large water conduits to meet the irrigation requirements and, to a much lesser extent, municipal and drinking needs. However, it should be borne in mind that the involvement of additional water resources based with using the wastewaters is expensive enjoyment, since the cost of water treatment amounts to 15-50 cents per cubic meter. Taking in account the fact that the productivity of irrigated agriculture in the majority of countries with economies in transition does not exceed 10 cents per cubic meter of water, it can be asserted that the modern water treatment methods can only be applied where there is a high water productivity. Under our conditions, the methods of partial treatment of wastewater and drainage water need to be applied, which purify marginal waters only from very harmful substances, but leave inert or even advantageous substances such as gypsum, which is a structure-forming substance for many soils.

A survival strategy and real execution of the rigid plans of water management is the necessary condition for overcoming current “illnesses” and “frozen” (with following reducing) of water intake scopes. China - the country with 20% of the world population - feeds and gives to drink his people, having only 12% of world's land resources and 9% of world's water resources. Within the framework of the single state, the planning of water management in the USSR was being drafted for the next 25-50 years as "The long-term Integrated Water Sector Development Schemes" at the national level and for large river basins. After establishing the CIS, neither in Russia nor in other independent states are not engaged in forecasting of water resources development by the state authorities, mainly focusing on the scenario "keeping current trends." Being prepared documents, which would schedule milestones of the future water consumption and satisfaction of these needs, are like the just published "Prospects of Land Reclamation Development in the Russian Federation." This document can be hardly accepted even for the next time horizon, since it does not contain any assessment of either current or future production, water reserves or land resources' condition.

The high technical standard of future water management systems is based on two components:

Full accounting all kinds of waters, their constant control in the on-line mode with the help of automatic control systems and data acquisition (SCADA), starting from main water sources in the river basins until to the last water outlet, including ground water (water intake wells, springs, etc.).

Water accounting should be accompanied with developing the dense network of weather stations for registering and transmitting data to end-users and water organizations, allowing them adjusting water consumption, operational regimes and water allocation plans. SCADA systems are used at present, for instance, in the BWO “Syrdarya” in Central Asia, for almost 10 years, ensuring the high accuracy of water measurement and water supply (± 2%) at sufficiently small costs.

A ring-shaped connection of water sources or transferring water from one river basin into others in order to smooth the existing and growing inequality in water availability of different zones in various periods with water surplus or deficit. China gives the example of behavior, which should become the ordinary phenomenon both inside countries and at the international level when all necessary environmental requirements to conservation of water bodies should observed in spite of their territorial location. Such an approach allows avoiding failures in water supply even in dramatically dry years in some regions at the expense of zones with higher water availability. I am sure that the project of a partial redistribution of Siberian rivers’ water, over which we have worked during the Soviet time, could smooth the water shortage over dry years in the Central Asian republics.

Certain strict rules should be worked out at the UN level regarding the procedures and conditions of the interstate systems' work. In general, the United Nations has already undertaken the first steps for global regulation of water resources use and protection: two global water conventions were put in force (the UN Convention on the Law of the Non-Navigational Uses of International Watercourses and the UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes), as well as the coordinating body “UN-Water” was established.

The next step has to be strengthening the international water law, tightening the international control over its execution and, maybe, even creating the special Water Security Council. Globally, this body will strictly watch for the states’ attitude to water resource, as a guarantee for the humanity’s existence, for the infringement of human rights to water for drinking and necessary food, and the implementation of measures to achieve potential water productivity and conservation of water potential in all places.

Water supply and water consumption in urban and rural areas for the benefit of drinking and utility needs will be provided on the basis of established regional standards for water quality and quantity, as a prerequisite for functioning of the residential zones. All needs of technical systems will be met at the expense of using insufficiently treated waste water with permitted quality or slightly saline waters. In each house and each apartment, water meters will show a water quota for each day and until the end of month, and if water users exceed over the approved water limits, they should pay a penalty. "Green roofs" with planting of plants on the roofs of buildings will be widespread.

A key consumer of water - irrigated farming will undergo a radical transformation.

Open irrigation canals that deliver and distribute water will disappear in the world, as in some countries of the Middle East, and all the water for irrigation will be transported through closed water conduits - pressure pipelines or free-flow pipelines, in which losses for evaporation and seepage are reduced to zero. Irrigated fields will turn into the automated production sites controlled depending on the weather parameters, which will be represented by several types depending on topographic and geological conditions. Irrigation in greenhouses and on protected ground (ground under coverage) using micro-irrigation systems[30] has already occupied 100-percent of farming land in Qatar and large areas in Spain, France and other countries. All these irrigation methods are certainly much more expensive than gravity systems of furrow irrigation, but they allow, firstly, improving irrigation efficiency from 0.6-0.65 to 0.85-0.92, that is, to increase it by 30% and, secondly, drastically reducing evaporation from the ground surface, focusing all water consumption for covering the plant transpiration.

Improving the water use system will require the same land drainage improvement. Since land, drains are “earth veins” in case of low natural outflow of ground water or waterlogged conditions, land drainage systems, including collector-drains, will be closed (subsurface land drainage). A dense observation network equipped with sensors that show a depth of groundwater table, which can be read out from the space, as well as observation manholes on subsurface drains and collector-drains equipped with similar sensors, will be under the constant observation of Hydro-Geological & Reclamation Services using the automated monitoring systems. Based on monitoring data, appropriate departments of the water sector and land reclamation services will evaluate the drainage system efficiency, soil salinity risks and water-and-salt balance, as well as will develop the guidelines to water users concerning brackish water use and preventive measures for the drainage network.

[30] Micro-irrigation refers to low-pressure irrigation systems that spray, mist, sprinkle or drip

An entire network of water infrastructure and drainage facilities together with its reclaimed land becomes the complicated natural-and-technogeneous system that is coordinated by means of monitoring, supervision and advice services. Such a system requires maintenance support in order to ensure long-term sustainable operation, resistance against natural and anthropogenic changes, high efficiency and maintainability, as well as some margin of safety. At the same time, it is particularly important to provide availability of proper personnel, its selection and training that should correspond to the technical level of this system with understanding relationships of its components, and impacts on the natural and socio-economic situation and its future changes. The professionalism of irrigators should again be raised up to the high level, providing the universal coverage of knowledge, decent wage, prestige and respect to this important profession, that it had previously possessed.

In ancient times, ***mirabs*** (irrigators) were the first viziers of oriental rulers rather than financiers!

Today, skilled water professionals are in explicit deficit, and graduates of the institutes of higher education related to water management prefer to be engaged into commercial business. The decision of the Russian Government on eliminating the only educational institution for training specialists for water resources management - the Moscow State University of Environmental Engineering is typical in this respect. Is not this political shortsightedness of those who prepared such a decision? At the same time, taking into account the new challenges (information and distance technologies, Nano technologies and their refraction for water sector's purposes), strengthening the scientific capacity of both academic and applied science, is the mandatory prerogative of future well-being.

It should be noted that the destructive tendencies in relation to the bodies of water governance and management that originated in our country as an attempt to destroy the water sector that was being one of the "elephants", on which the former country has rested, was not stopped in countries emerged from the crucible of former communist bloc. The power of water sector was virtually adequate to the power of Defense Department, and was able to accomplish great deeds both at the federal and republican levels. Elimination of the USSR Ministry of Water Resources was the beginning of liquidation of the Soviet Union, expertly managed from abroad. The inertia of institutional neglecting concerning the basics of water management and irrigated agriculture leads to constant organizational changes in the governance of the water sector, which merges with different governance bodies of other sectoral departments (agriculture, energy or the environment). Due to each of such reorganization, the governance of the water sector and ensuring sectoral progress have become increasingly difficult, since the personnel and functions fall outside the scope of management and control.

Unfortunately, economists, seeking to reduce government expenses do not understand that damage from losses of the controllability of the water sector and its knowledge potential is not comparable with the supposed savings, which can be received at the budget level. When considering this problem, I usually refer all "decision-makers" to the experience of the USA, Canada, Holland, and India, where the governance bodies of the water sector and irrigation are in action without reorganization a hundred years or more. For example, the US Bureau of Reclamation, US Army Corps of Engineers, etc., were established in accordance with the National Reclamation Act of 1902!

Our vision would be quite incomplete if we could not discuss *improving the condition of our watercourses - rivers, irrigation and drainage canals, as well as reservoirs and lakes*. There are a great number of countries in the world with countless bodies of water where people feel the greatness of aquatic nature, its dignity, holiness, purity and beauty. Japan, Korea, the Netherlands, Switzerland, Canada have restored their rivers including their biological productivity and greatness along with an amazing attraction, freshness and diversity of riverside zones. These values of water are maintained and multiplied by society and state jointly.

It is desirable to see the same picture over the whole space in the Eastern Europe, Caucasus and Central Asia!

Is it possible to realize our assumptions? Is it possible to achieve the general water availability while preserving water for future generations? Of course, this is possible if humanity will be able to overcome unbridled desire of some to wealth, when most of the population is poor. If humanity will be able to overcome the gap between word and deed, when those who proclaim beautiful slogans counteract to real cooperation. There is a sufficient amount of water in the world in order to feed all and give to drink to all, in case of improving the water systems in accordance with our assumptions; existing technical and financial resources are sufficient for implementing these improvements. We need in understanding, good will and peace, as well as in joint creativity of all starting from the international platforms and organizations, via national political circles up to local authorities and end-users. I want completing this section by the colorful description of "the eighth wonder of the world" that was created in the desert at the end of the twentieth century, as an example of the limitless possibilities of people, which are armed with the desire to achieve the well-being of their people and have the power and means to turn this dream into reality.

So: The eighth wonder of the world – The Great Man-Made River in Libya![31]

[31] Khvorova E. Revival of desert. 25.06.2015. http://erazvitie.org/article/ozhivivshij_pustynju.

This is the largest engineering project of the modernity, thanks to which inhabitants of Libya have access to drinking water and are able to settle in areas where previously no one had ever lived. Now, 6.5 million cubic meters of fresh water used also for developing agriculture in the region run through subsurface water conduits every day.

Figure 4.4 Transportation of precast sections of the water conduit

In 1953, the Nubian Sandstone Aquifer System was explored by British geologists in the course of geophysical prospecting of oil deposits. As ascertained by scientists, fresh water has accumulated underground at that period of time when the fertile savannas irrigated by frequent heavy rains extended over the territory of the modern Sahara. The freshwater bearing strata is confined by the layer of firm ferruginous sandstone 100 to 500 meters thick. Most of this water was accumulated over the period of 38,000 to 14,000 years ago, although some aquifers were formed relatively recently - about five thousand years BC. Three thousand years ago, Earth's climate has dramatically changed, and the territory of modern Sahara has turned into the desert, but water, which has percolated into the ground for thousands of years, has been accumulated in underground water-bearing horizons.

The Nubian Sandstone Aquifer System is located in the eastern part of the Sahara Desert covering more than two million square kilometers and includes 11 large underground water reservoirs. A Libyan territory is covered over four of them. Besides Libya, several African countries including northwestern Sudan, northeastern Chad, and most of Egypt are sharing the Nubian Sandstone Aquifer System.

After discovering the huge reserves of fresh water, many projects of constructing the irrigation systems have immediately appeared. However, the idea was realized much later, and only thanks to the efforts of the Government of Libya. This project involved the construction of water pipeline for delivering water from underground aquifer into industrial and more populated part of Libya (from south to north). In October 1983, the Project Management Office was established, and funding the project was started. By the start of construction, a total cost of this project was estimated at $ 25 billion, and the planned implementation period amounted to not less than 25 years.

Five phases of the project implementation was provided for: Phase I - construction of the plant for manufacturing pipes and the water conduit 1,200 km long with a daily delivery of two million cubic meters of water to Benghazi and Sirte; Phase II - bringing the water conduit to Tripoli and maintenance of its daily supply capacity of one million cubic meters of water; Phase III - the completion of constructing the water conduit from the oasis of Kufra to Benghazi; Phases IV and V - the construction of the western branch line of water conduit up to the city of Tobruk, and the connection of all branch lines of water conduit into the single system near the city of Sirte. A total length of the buried artificial river is close to four thousand kilometers. In the process of construction, a volume of excavation works amounted to 155 million cubic meters -12 times more than constructing the Assuan Dam. The used materials would be sufficient for the construction of sixteen Cheops pyramids. In addition to water conduits and aqueducts, the system embraces more than 1,300 water intake wells, most of which have a depth of over 500 meters. A total depth of all water intake wells is 70 times greater than the height of Mount Everest. Main water conduit branches were mounted of precast circular sections 7.5 meters long, 4 meters in diameter and weighing more than 80 tons (up to 83 tons). Each of 530,000 precast sections could easily serve as a tunnel section for the subway.

Out of the trunk pipelines, the water enters into the tanks with a storing capacity of 4 to 24 million cubic meters that were constructed near the towns, and they serve the sources of water supply of cities and towns. Fresh water enters the water supply system from underground aquifers located in the south of this country, and is supplied to the settlements that are mainly concentrated near the coast of Mediterranean Sea, including the major cities of Libya - Tripoli, Benghazi, and Sirte.

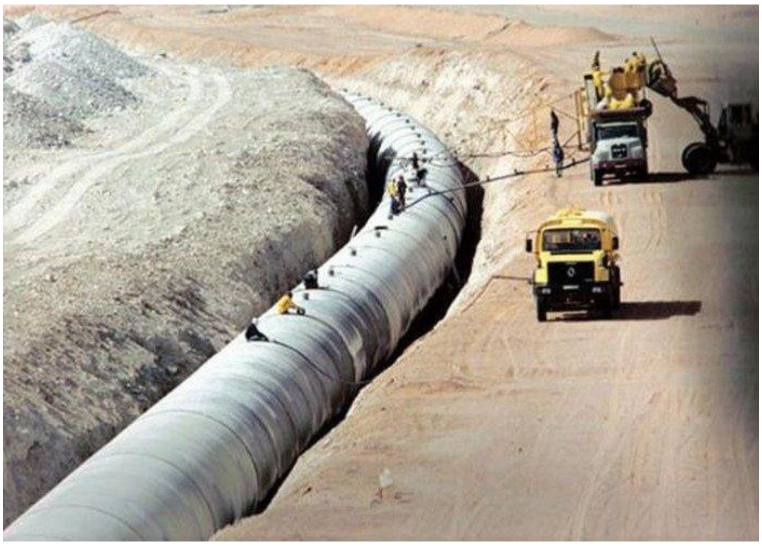


Figure 4.5 Construction of the water conduit is in progress

Actual construction began on August 28, 1984, when a cornerstone for this project was laid. A cost of the first phase of this project was estimated at $ 5 billion. Construction in Libya of a unique, first in the world, plant for manufacturing precast sections with the really gigantic diameter was realized by experts on modern technologies from South Korean. The specialists representing the world's leading companies from the USA, Turkey, UK, Japan and Germany arrived to the country. 3,700 kilometers of roads, which allowed moving the heavy machinery and equipment for laying gigantic precast pipes were built. In 1989, water entered the reservoirs Ajdabiya and Grand Omar Muktar, and in 1991, the Great Al Gardabiya Reservoir. The first and greatest section of Great Man-Made River was officially opened in August 1991 - the beginning of water supplying to such large cities as Benghazi and Sirte. Already in August 1996, regular water supply has been began into the capital of Libya - Tripoli. Finally, government of Libya has spent $33 billion for creating the eighth wonder of the world, and the financing was carried out without the international loans and IMF support. The Libyan Government did not collect payment for water from the population, recognizing the right to water as a basic human right.

The government has also tried not only to procure nothing for the project activity in the countries of "the first world," but also to produce everything needed domestically. All materials used for the project were locally produced and the plant that was built in El Burayka manufactured more than half a million of pipeline sections 4 m in diameter of prestressed concrete.

Figure 4.6 Circles of life in the desert

Prior to construction of the water supply system, the desert occupied 96% of the Libyan territory, and the areas suitable for human life amounted to only 4% of the whole land resources. It was planned to supply water for irrigation of 155,000 hectares after full implementing the project. By 2011, it was possible to start supplying 6.5 million cubic meters of fresh water to the cities of Libya, providing potable water to 4.5 million people. At that, 70% of supplied water was consumed in the agricultural sector, 28% for needs of population, and the rest for industrial purposes. However, the government's goal consisted not only in providing the population with fresh water, but also in reducing the dependence of Libya on imported food, and in the future, in ensuring complete own food production in the country.

With the development of water supply, large farms have been built for the production of wheat, oats, corn and barley, which were previously only imported. Thanks to sprinkling machines connected to the irrigation network, man-made oases and green fields from a few hundred meters up to three kilometers in diameter were created in this arid country.

Fields, which appeared thanks to the Great Man-Made River, are clearly visible from space: on satellite images, they are in the form of bright green circles scattered in the midst of grey-yellow desert areas (see the satellite image: cultivated fields near the Kufra oasis).

Figure 4.7 The cultivated fields

At the same time, the measures have been taken to encourage Libyans for relocation into farms that were created in the desert in the South of this country. However, not all local people has being willingly resettled, preferring to live in the northern coastal areas.

Therefore, the government has addressed to the Egyptian peasants with an invitation to move to Libya for job. After all, Libya has the population of only 6 million people, while in Egypt more than 80 million people, living mainly along the Nile. The water conduits also allowed organizing the resting places for people and animals in the Sahara along the caravan ways and watering places for camels (ditches with water).

Libya has even started to supply water to neighboring Egypt.

Figure 4.8 A field is irrigated by the center pivot irrigation system

In comparison with the Soviet irrigation projects implemented in Central Asia with the purpose of irrigating cotton fields, the Great Man-made River Project had a number of fundamental differences.

Firstly, the tremendous aquifer was used as a water source for irrigation of agricultural land in Libya instead of the surface water source, which is relatively small in comparing with the water volumes withdrawn.

Secondly, in Libya water losses were excluded in the process of water delivery, since water is supplied through the closed water conduit that excludes water evaporation. The created water conduit, without this shortcoming, has become an advanced water supply system for arid regions.

When Libyan Revolutionary Leader Colonel Muammar Gaddafi was just starting this project, he became the target of constant ridicule from Western media. However, 20 years later, in one of rare publications devoted to the success of this project, the National Geographic Magazine has recognized it as the epoch-making project. Since 1990, the UNESCO has become to render aid in training and support of engineers and technicians who were involved to this project. Colonel Gaddafi called the water project as "the most powerful answer to America, which accuses Libya in supporting terrorism, saying that no matter what else we are able."

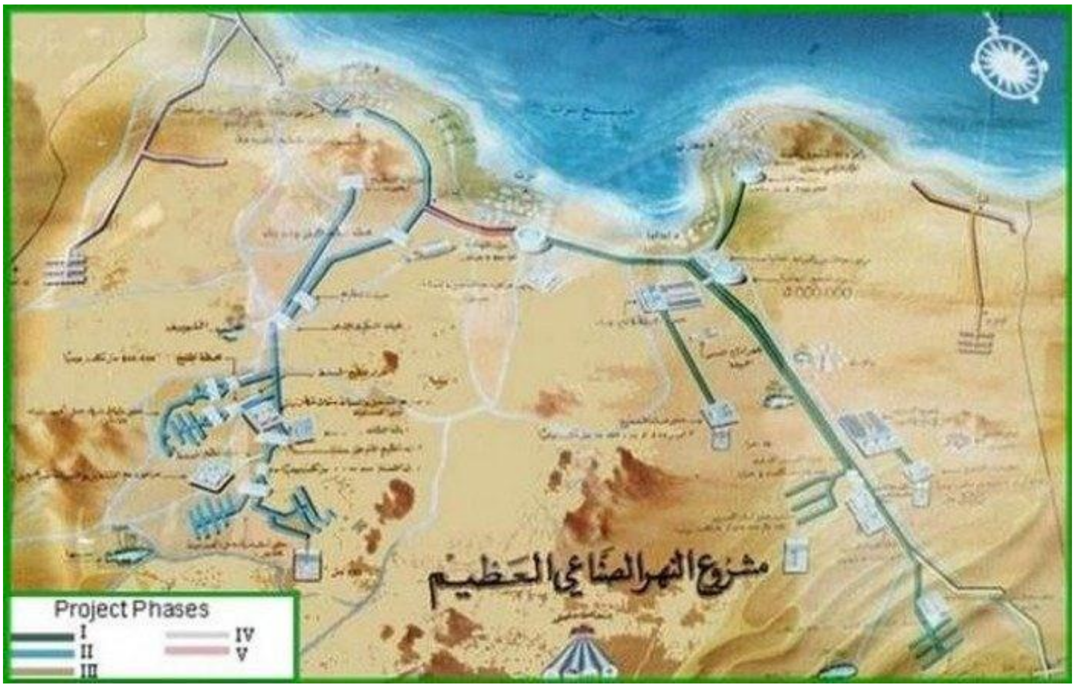


Figure 4.9 The layout of water conduits' routes

Figure 4.10 Water came to the desert!

Prior to putting the water conduit into operation, the cost of a desalinated seawater purchased by Libya was $3.75 per cubic meter. Construction of its own water supply system has enabled Libya completely excluding the water import dependency.

At that, the sum of all the costs for production and transportation of one cubic meter of water amounted to US35 cents, which is 11 times cheaper for Libyan government (before the war) than in the past. This is comparable to the cost of cold tap water in Russian cities. For comparison, the cost of water in European countries is about two Euro.

In this sense, the value of Libyan water reserves is much higher than the value of reserves of all its oil fields. Then, the proven oil reserves in Libya amount to 5.1 billion tones and their cost is about $ 2 trillion at the current price of $400 per ton. Let us compare these figures with the cost of water: even on the basis of a minimum of 35 cents per cubic meter, the Libyan water reserves are estimated in $10-15 trillion (accounting a total cost of water in the Nubian aquifer of $55 trillion), that is, 5-7 times exceed the cost of the whole Libyan oil reserves. If to start the export the bottled water, this amount will increase many times.

In addition to political risks indicated above, the Great Man-Made River Project had at least two uncertainties. This is the first large project of this kind, therefore no one could not predict with reliable accuracy what will happen when the aquifers will start to deplete. Some experts voiced fears that the whole system simply collapses under its own weight into the formed voids, which would entail the large-scale sinkhole collapse on the territory of several African countries. On the other hand, it was not clear what would happen with the existing natural oases, because many of them were initially fed off thanks to aquifers. Today, at least, drying up of one natural lake in the Libyan oasis of Kufra is associated with over-exploitation of aquifers. However, anyway, at this moment the Libyan man-made river is one of the most complicated, most expensive and large engineering projects carried out by mankind, that grew out of the dream of a single person to "make the desert green as the flag of the Libyan Jamahiriya."

Today's satellite images show that after the bloody US-European aggression, round-fields in Libya now again quickly turn into a desert ...

Eternal glory to the creators of this miracle, and the great disgrace to its destroyers!

Chapter 5. IWRM - Experience and Prospects

In first chapters of this book, we have demonstrated all the diversity of water resources and their role in the socio-economic development of mankind and nature conservation, as well as in the progress or degradation of our contemporary society. I am sure that now you understand as far as the duties of water managers are honorable as well as the great responsibility that falls on your shoulders if you decide to dress "the mantle of water religion's priest." Our ancestors have understood this liability long ago and established the procedure of electing mirabs, which took place once a year during the feast devoted to the beginning of a year (Navruz). Only the most honest, fair, strong and respected members of society could be admitted to this position.

The concept of **Integrated Water Resources Management** (IWRM) emerged relatively recently in the second half of the twentieth century, although the integration essence of water, per se, originated and evolved along with progress in developing the human society. This phenomenon is reflected in ties of water, in its use, its influence, in its growing and increasingly diverse application and ... in its scarcity and significance. Water has always been the multi-functional matter, and rather an entity that has been closely associated with the Earth, with a landscape, passing through which water brings life and changes it, making land more fertile and productive. Due to moisturizing dry air in deserts and steppes by the morning dew or spring rains, water injects new life and freshness into all living things, which, not long ago, have suffered from heat. Being used in a variety of production processes, water intrudes into the broad spectrum of economic sectors, requiring from them accounting peculiarities of its application, storage, cleaning and protection. Water, which is originated in the mountains and flows down to the foothills, rushes into the vast valleys and crosses the boundaries of various natural areas, integrates various natural conditions and different but neighboring geographical zones, transferring the alien elements into neighboring areas. Crossing the administrative boundaries of districts, provinces and countries, water unites them by the single notion - transboundary neighbors. Water is **the great integrator**, uniting all living things in nature by an impulse of growth and life, whole abiotic environment by the generality of use and limitedness of resources, and everything on the planet by the unity of the global water volume, which is in the constant hydrological cycle on the Earth. Water is necessary for all, and at the same time the water needs in everything, including a great number of people, both users and managers, lawyers, financiers, engineers, economists, ecologists, hydrologists and others. Therefore, water does not tolerate a narrow approach, it requires cooperation and coordination - interpersonal, interdisciplinary, inter-professional, inter-state and even intercontinental.

This integration role has predetermined the current need in IWRM!

At the same time, there is a visible separation in the world regarding water use, water management and water supply for various needs. This fragmentation is caused not only by natural and administrative boundaries, sectoral and professional priorities, as well as ambitions that are enhanced by political confrontation, personal and group interests, multiplied by commercialism and distorted notions about the welfare and happiness of man and his family. All this discreteness of society and state governance took place over all the centuries and in all social formations, stressing the reality of favorite slogan of all class societies - "Divide and rule!" At the same time, in the second half of the last century due to growing the scale of globalization and practical destruction of the socialist world (the only possible equitable society), it gained so much hypertrophied extent and form that the world has entered the period of permanent crisis. Under these conditions, IWRM should be put forward to the world scene as the approach that opposes to current trends, in the name of protecting water, but with far-reaching objectives and prospects.

In the environment of water professionals and environmentalists, the understanding of IWRM and its recognition as a possible way of transforming water management were emerged at the end of the first half of the twentieth century. From this point of view, it is necessary to consider the development of a number of integrated programs, such as the Tennessee River Program in the United States and establishing the Hydrographic Confederations in Spain by the Royal Decree of 5 March 1926. Finally, elaborating the complex method of irrigation and land development in Central Asia by the example of Golodnaya, Karshi, Djizak steppes and other massifs of irrigated land in the light of implementing the schemes of development and use of water resources of the Amu Darya River and Syr Darya River, was the most comprehensive approximation to the modern IWRM principles under other name. Since the International Conference on Water and Environment (Dublin, 1992), IWRM acquires worldwide recognition not only as an approach to create a global fundamentals for governance and development of water resources, but also as a certain leverage of affecting the entire social, economic, ecological, and political environment related to water resources. The decision adopted at the Sustainable Development Summit (Johannesburg, 2002) to prepare the National Integrated Water Resources and Water Efficiency Plans by 2005 was the next step already as the guideline for implementing IWRM principles. This guideline was mostly executed by the EU Member States in accordance with the European Water Framework Directive. Among Central Asian countries, only Kazakhstan has prepared the draft plan in 2005 with the UNDP technical assistance, but it was not realized, although the plan was approved by the Government Decree.

Bibliography concerning IWRM contains thousands of publications in this area, but in most cases, we deal with the academic articles that represent visions of their authors regarding the implementation of IWRM, attempts to attach some real water management practice to the trendy direction or reasoning of non-professionals around this approach. However, unfortunately, very little actual practice in water management can be called "really integrated management."

There appeared views regarding the insolvency of IWRM and the need in replacing it with an adaptive water management in the framework of adaptation to the changeable environment and mobile social conditions. The main reason for this perception of IWRM is that the real practice of IWRM with complete realization of IWRM principles is absent, and fragmented implementation, in fact, brings us back to the water management practice, in opposition to which the present understanding of IWRM originated. There are two definitions of IWRM, describing the fundamental role of IWRM. The Global Water Partnership defines IWRM as "*the process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.*" (TEC Background Paper No 4, 2000). We define IWRM as "*a management system, based on considering different kinds of water resources (surface water, groundwater and return water) within their hydrological limits, that links the interests of different economic sectors and hierarchical levels of water use, that involves all stakeholders in the decision-making process and promotes effective use of water, land and other natural resources to the meet requirements of ecosystems and human society under conditions of a sustainable water supply.*"[32]

The fundamental difference in these two formulations consists in the following: IWRM is the **system** or **process.** A possibility of partial implementation of IWRM lies in the understanding of IWRM by its propagandist and agitator - the Global Water Partnership, which imposes the idea that IWRM is the process. If this is the process then it does not matter where its beginning and what should be the end, and any elements of this process are creating an outward appearance of IWRM, despite the fact that they correspond to only 10 or 50 percent of works required for forming the whole system. A typical example in this regard is presented in the paper of the UN Economic Commission for Europe (UNECE, G. Roll), which defined the establishment of IWRM as forming the basin approach.[33] The desired functions are defined as water use regulation, ensuring proper operation of water infrastructure, availability of permits for special water use, information transparency and protection of ecosystems.

[32] Integrated Water Resources Management: from the Theory to Real Practice. Lessons learnt in Central Asia, Tashkent, 2008, Edited by V. Dukhovny, 363 p.

[33]Gulnara.Roll, Transboundary Water management in Eastern Europe, Caucasia and Central Asia, Pepsi Center for Transboundary cooperation, 37 papers, 2012

Other works (e.g., Olii Vaaris, and others) consider presence of vertical and horizontal coordination and linkages as the basis for IWRM[34].

Meanwhile, IWRM, as the management system, may be considered as complete system or, at least, advanced system, if all eight basic IWRM components listed below were determined and achieved (or work is underway in this direction):

- Water resources management and water delivery to consumers are based on the hydrographic principles;
- Public participation in the planning, implementation, monitoring and financing of water management activities;
- Equitable use of all types of water based on water accounting;
- Cross-sectoral coordination (horizontal integration) and coordination of all hierarchical levels of water governance (vertical integration);
- Focus on water saving and water productivity increase;
- Ensuring financial and economic sustainability;
- Satisfying the environment requirements; and
- Adequacy of information support.

A clear reconciliation of these components is needed to ensure the IWRM system as a whole. Therefore, water management based on hydrographic (or river basin) principles ensures overcoming the administrative hydro-egoism, which gives full control over water allocation to the local authorities (regional, district), which are guided by the rule “self comes first”." On the other hand, public participation in water governance opposes this negative phenomenon and, at the same time, prevents the hegemony of professional water allocation, which can arise in the absence of control by the public. A well-established accounting of all types of water, combined with the openness and transparency of information on an amount of water received and consumed, creates a platform for evaluating the practice of water supply and realization by each user his right to receive the due volume of water and taking action in case of its violation. Coordinated participation of representatives of all sectoral and generally single-type water users in the process of planning and monitoring water delivery and use should prevent excessive water use at the expense of a partner or competitor. At the same time, coordination of all water flows in the irrigation system and water withdrawal schedules by water users can prevent from unproductive organizational water losses at points of transferring the responsibility of different hierarchical levels of water management. Planning based on the water supply standards, which correspond to the modern technological level, and accounting environmental needs allow avoiding the wasteful orientation of water users and water management organizations on creating some their own reserves to the detriment of partners or nature.

[34] Olii Vaaris, K.Enckell, M.Keskinen, Integrated water resources management: horizontal and vertical explorations and the “water in all policies” approach, International Journal of water resources Development, 2014, http://www.tandfonline.com/loi/cijw20

Finally, sufficient funding, in accordance with the cost estimates, and its rational distribution between state water management organizations, water users, other stakeholders and local authorities should ensure a normal material support for functioning and development of the irrigation systems.

How should one understand IWRM, what are its focus, components, scope?

A main goal of IWRM, as was defined in our previous works[35], is to control the balance "water resources - water demand" in the whole system and in any moment of time for achieving positive impacts (Figure 5.1). Support of this dynamic balance is based on monitoring two directions in forming the water management situation: water supply management and coordination of water requirements, with using the appropriate institutional structures and technological tools. At that, impacts on all aspects of water sector's activity are first of all determined by the following:

- Water governance, which defines the rules for water allocation and use, as well as mechanisms of creating incentives. The Global Water Partnership defines "water governance" as a set of political, social, economic and administrative mechanisms that should regulate water resources development and management at the local level (and not only, but across the entire water management hierarchy);
- Integrated water resources management that is responsible for implementing these rules, their detailing and applying in the process of water allocation, regulation and protection in the framework of water sector's activity and related activities (agricultural, economic, financial, construction, institutional, procurement, etc.) that are constituents of the IWRM system, including organization of rational water use.

[35] Integrated Water Resources Management: from the Theory to Real Practice. Lessons learnt in Central Asia, Tashkent, 2008, Edited by V. Dukhovny, 363 p.

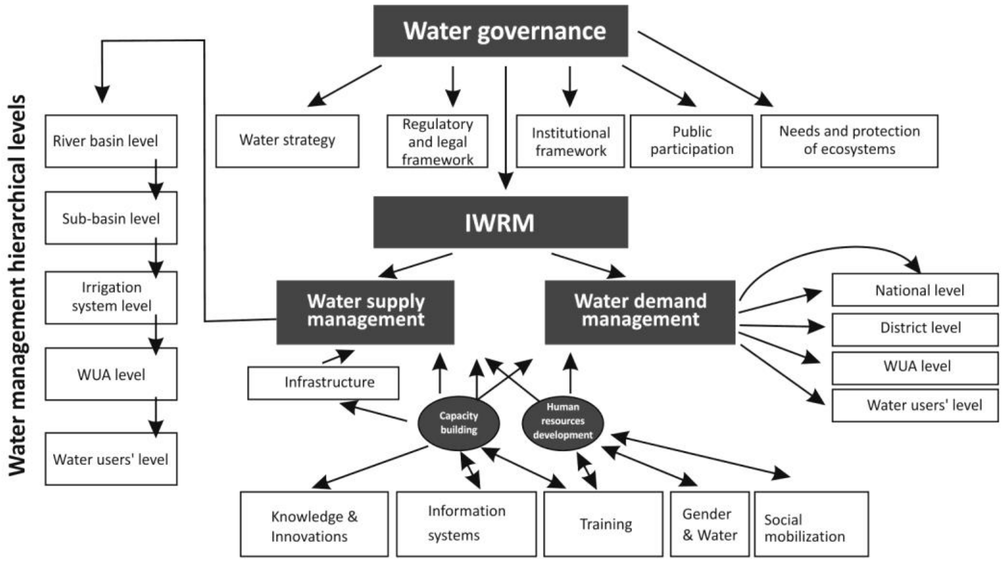


Figure 5.1 Governance, management and capacity building for IWRM

- Capacity building and human resources development, which include the introduction of innovations, information systems, selection and training of personnel and water users, social mobilization and gender equality are occupied a special place. This also includes promotion of promising young professionals; familiarization with advanced technologies and experience; as well as development of professional ethics of attitude to water, and responsibility when making water management decisions. The basis for the successful implementation of IWRM is "**GOVERNANCE**", which has its own specifics at all levels of the vertical water management hierarchy and determines the following:

    - the water policy expressed in the water strategy or concept paper;
    - the legislative framework, including various by-laws and the system for regulating interrelations;
    - the institutional framework based on legal regulations and coordination of both the water management hierarchical levels (vertical integration) and all economic sectors (horizontal integration);
    - procedures of participating all water users and other stakeholders both in water governance and in water resources management, financing, planning and development; and
    - observing the environment requirements, responsibility for water resources protection and sanctions for violating the order of water use, as well as preventive measures for conserving and developing water resources.

Developing of all these mechanisms and tools of “**GOVERNANCE**” allows implementing IWRM, which should be considered in coordination of two directions of water resources management – *managing of water supply and O&M of water infrastructure* and *water demand management*.

Elaborating the holistic approach does not, in any way, mean that IWRM should be formed under the auspices of a single organization. This is practically impossible, because the comprehensive building of IWRM is facing with an exorbitant number of stakeholders, ties, relationships, factors, consequences, sources of water and their consumers inside and outside the water sector.

Integration of water resources management does not at all mean the existence of the only organization that manages everything being as a single management body. Integration implies adherence to common canons and unified principles for achieving clearly established goals when various organizations are well aware of their obligations regarding the common goal, are independent but are functioning under conditions of precise coordination. Each task area should be linked with partners (horizontal integration) by means of the well-distributed areas of their specialized responsibility, as well as according to the balance of masses (water or another resource) across the entire water management hierarchy (vertical integration).

At the same time, all these tasks are solved by both the state water management bodies, and their public partners that are controlling the correspondence of actions of professional bureaucrats to the public interests and their basic indicators (equality, stability, and efficiency). A coordinating body that has resources and distributes them within its powers exists at each level of the water management hierarchy. At the lowest level (end-users and their associations), public participation is simultaneously a guarantor of meeting the needs of man and nature. Differentiation of responsibilities, centralization of efforts and actions, specification of outputs for each direction are being integrated in the framework of a single plan or program that should be in the field of vision of a general governing body that is established as the Coordination Council. The system should be based on distributing the set of components between governance and management, and management itself is subdivided into two components: water supply management and demand management (or water requirements).

Direct management of water supply (top-down) and ensuring sustainable water delivery in accordance with the requirements of consumers and the environment should be put together in the hands of the coordination structure that responds for timely and qualitative supply of required water volumes from a water source to water users (or their associations).

This organization can be specializing for specific economic sectors (for example, separately for irrigated agriculture and potable water supply) or be unified, such as in Israel, where water supply to all water users, irrespective of their sectoral affiliation, is carried out by a single organization "Mekharot." Water supply can be organized from the national, centralized and even transboundary water sources or local water sources (intake wells, small rivers, pumping stations, drainage water); moreover, combined water sources can be used. Operation and maintenance of centralized or combined water supply systems are more complicated in comparing with a stand-alone water supply system, but usually they are more profit-proved.

Proceeding from the task of ensuring the potential or economically-justified level of water productivity, water demand management should be based on a management system "bottom-up" (water users → WUAs → the Canal Administration).

This area of activity, although it refers mainly to the level of water users (both agricultural and communal water users), must be under the control and guidance of the coordination body under the umbrella of local authority having the powers to coordinate operation of all types of water infrastructure for satisfying the needs of end-users.

In addition to representatives of agrochemical, procurement and financial services, the coordinating body in the form of a District Water and Land Commission should include representatives of grass-roots water management organizations responsible for public and state water management and water supply (WUAs, Hydrogeological & Reclamation Service, etc.). This segment of IWRM has the specific set of tools, such as:

- Definition of technically-justified norms of water use that correspond to the modern technological level of advanced methods of water use, which is adopted as a basis for rationing and financial calculations for consuming water. A standard of water consumption for each type of production, for exceeding of which a water user is penalized, is established. Such a practice exists in Israel, in the west of the USA and in a number of other countries.
- Intake structures of all water users should be equipped with water meters, possibly partly at the expanse of water users.

- A common commitment of water users taking water from single source regarding water saving should be promoted. This can be achieved by uniting water users in certain communities (mahalla communities, commune of urban quarter, a union of farmers on a certain irrigation canal). Such an approach was applied on the Sokoluk Canal in the Osh Oblast (Kyrgyzstan), where a size of farmers' plots did not exceed 0.5 hectares along each intra-farm canal and where the installation of water meters at each inlet, as well as accounting water at these structures were quite difficult. The decision was found by means of introducing the collective responsibility for water supply of all water users on each distribution canal, joint payment for water delivery and, accordingly, its joint use under the leadership of "aryk-aksakals" (elected managers of irrigation canals).

- In the irrigated agriculture sector, introducing the knowledge transfer system and advisory services to WUAs and farmers (agricultural extension services), aimed at mobilizing all reserves in land use, is of great importance. Here, it is most expedient to use a certain system of interaction between scientific-research institutions, universities and innovation centers based on using the methodology of programming of crop yields. This methodology[36] involves estimating the levels of crop productivity and accounting all the factors that affect the potential productivity of crops under specific conditions. On the basis of analyzing the implementation of each agricultural procedure or deficit of crop development factors, actual crop loss is estimated. Measures for improving long-term soil fertility, technological enhancing of the current agro-technical and ameliorative processes, as well as organizational measures for reducing crop losses are considered. This methodology that is accessible for specialists is also based on fields certification (passport system), drafting technological maps and forecasting weather conditions that it is necessary for making recommendations on the irrigation schedule, number and depth of water applications. Another problem consists in the following: Whether achieving potential crop productivity is economically advantageous or not? Farmer's business planning should answer on this question.

The proposed technology for increasing the productivity of land and water in the framework of IWRM was successfully applied by Sh. Mukhamedzhanov and his team in several projects carried out by SIC ICWC in the Ferghana Valley using various organizational forms of implementation: WUAs in Uzbekistan, NGOs in Tajikistan and special advisory organizations in Kyrgyzstan.

[36] V.A. Dukhovniy, S.A. Nerozin, G.V. Stulina, G.F. Solodkiy. Programming of crop yields (The systems approach as applied to land reclamation), SIC ICWC,Tashkent, 2015

At present, this technology includes establishing a weather station in each WUA with a permanent recording weather parameters and preparation of local forecasts with the purpose of adjusting the schedule of water applications and disseminating this information through mobile communication to farmers. Such an approach allowed increasing the agricultural water productivity[37] by 25-40 percent under reducing total water consumption by 10 percent as minimum.

It is clear that the variety of natural conditions and economic and political circumstances in various regions and zones, as well as the diversity of influencing specific water factors on the environment require a linkage of IWRM to local conditions in the process of planning the introduction of IWRM. This also applies to selection of scope, priorities, institutional structure and sequence of works under introducing IWRM.

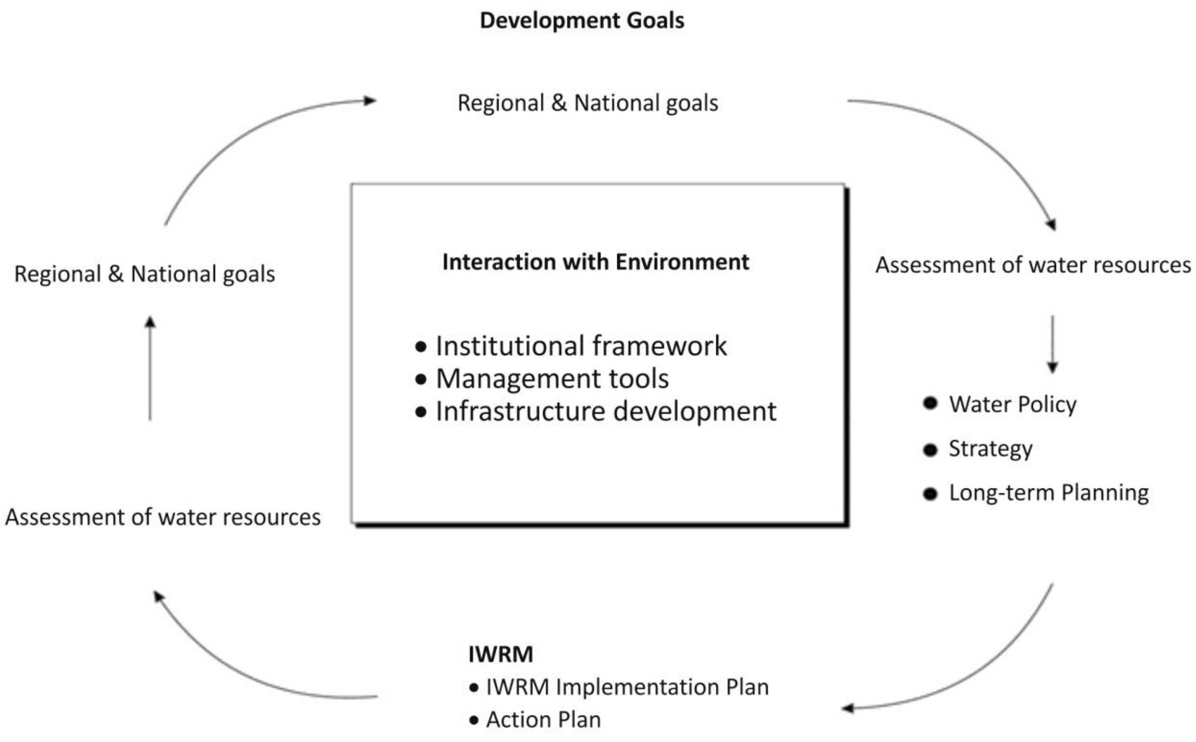


Figure 5.2 The IWRM Planning Cyclogram

[37] the term **water productivity** is used exclusively to denote the amount or value of product over volume of diverted **water** (FAO definition)

A certain cyclic process can be recommended here, which allows taking into account all this diversity on the assumption of following IWRM principles, as well as availability of its eight components, elaboration of governance tools, management itself, capacity building and IWRM vision (Fig. 5.2).

The process is initiated by defining the regional and national goals that are oriented for a period of 10-25 years and include ensuring the sustainability of water development and water supply in the face of destabilizing factors (climate change, population growth, socio-economic situation, possible changes in the intentions of neighboring states - in our case, the possibility of increasing the water intake by Afghanistan, which lays claim to additional 6 km3 of water in the upper and middle reaches of the Amu Darya River). Based on the estimated water resources by periods and national interests, the main directions of water policy for a country or river basin are being developed. At the same time, a long-term strategy of linking resources and needs, taking into account their average indicators and possible deviations (extremes) and the predictable parameters is being drafted under broad participation of stakeholders. These documents form the basis for developing the IWRM Implementation Plan and the corresponding National Action Plan. The IWRM Implementation Plan defines the institutional structure responsible for water management activity, necessary national, sectoral and local tools, as well as the infrastructure development program. The National Action Plan already includes the specific timetable for works, activities, actions that ensure executing the IWRM Implementation Plan. Further actions include monitoring and supervision over implementation actions and corresponding adjustment of both actions themselves and supporting activities.

One of the most successful projects on introducing IWRM is the IWRM-Ferghana Project that was implemented in the Fergana Valley on an area of 130,000 hectares of irrigated land, which are covering territories in Kyrgyzstan, Tajikistan and Uzbekistan. To confirm the success of this project, we refer to the following assessment made in the report of Canadian researchers in 2009[38]:

"IWRM Actions: Improved management of water resources based on IWRM principles emphasized higher program efficiency and more equitable watershed-based benefits. IWRM capacity building within river basin management among river commissions, provinces, municipalities, companies and water user associations were highlighted in the program. Program included demonstration of bottom-up approaches and increases in yields and water productivity by up to 30%. The Swiss Agency for Development and Cooperation assisted the Interstate Commission for Water Coordination in the implementation.

[38] D.Roy, B.Oborne, H.D.Veneva, IWRM in Canada, IISD, Agreefood Canada, 2009, 80 pages

Impacts: The project mainly addresses the possibilities for saving water, improving agricultural productivity, organizing water administrations, promotion and institutional build-up of Water Users' Associations (WUA) and the improvement of water allocation mechanisms among the users and among the three countries.

The program has resulted in a partnership among all water management actors across Fergana Valley. Safe drinking water is now provided to 28 villages with a population of 80,000 people and 320 ecological sanitation toilets have been constructed on a cost-sharing basis. Waterborne diseases have decreased by more than 60 per cent on average and infant mortality has been almost eradicated in all villages, despite prevailing poverty. Twenty-eight water committees have been created to operate and maintain water systems efficiently with more than 30 per cent participation by women. This has resulted in the expansion of improved irrigation practices; innovative solutions for irrigation canal management and sustainable water user associations; and sustainable financing at canal, water user association and farm levels.

The inception phase of the Integrated Water Resources Management Project in the Ferghana Valley started in September 2001. During this phase, a detailed analysis was carried out of the legal, institutional, economic-financial and managerial issues, as well as an analysis and evaluation of earlier experiences, methodologies and systems developed by other donors and regional and state organizations in the water management sector.

The major achievements of the project during Phase II include an increased awareness amongst policy makers about the principles of IWRM; improved water distribution along canals; a demonstration of a bottom-up approach; a demonstration of potential for increasing yields and water productivity by up to 30 percent.

Phase III of the project has triggered considerable changes in governance and management across the water hierarchy, and has gained acceptance in all three countries of the hydrological water distribution. Its activities were aimed at improved efficiency of modern governance policies, management procedures and institutional arrangements introduced at the national, regional and local levels during the previous phases. The project also focuses on expanding improved irrigation management practices and strengthening co-operation with other IWRM projects in the region.

The main results of this phase are the adoption of innovative solutions for irrigated canal management and sustainable water user associations, as well as introduction of effective methods for sustainable financing of the system at the canal, WUA and farm level. These accomplishments have been acknowledged in an external review of the project.

Phase IV of the project will concentrate on strengthening the achievements of the previous phases and addressing the gaps and challenges identified by the external review of the project, through consolidation and scaled-up experience, together with the new, innovative institutional arrangements achieved during Phase III.

Lessons: While significant emphasis was laid on management practices and technology, governance issues surrounding water management in the region were considered to be key to resolving the regional water issues.

Institutional capacity building for IWRM, education and awareness generation, as well as monitoring of impacts, was used to develop collective action plans and implementation schedules. Improved management procedures, governance policies, strengthened cooperation and the overall acceptance of IWRM goals and methods are key factors in the success of this program."

A detailed analysis of baseline data and ongoing monitoring - not only of water resources parameters, but also of related institutional, financial, economic and management issues - have led to the overall success of this project.

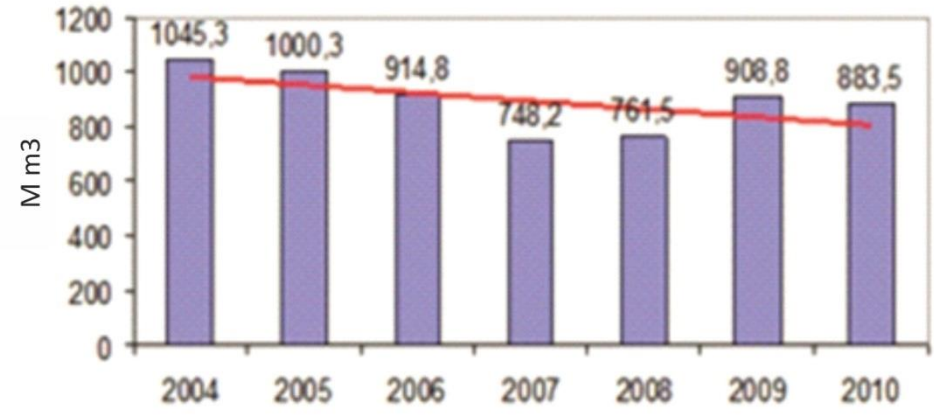


Figure 5.3 Total water withdrawal into the South Fergana Canal (in the growing season: April to September)

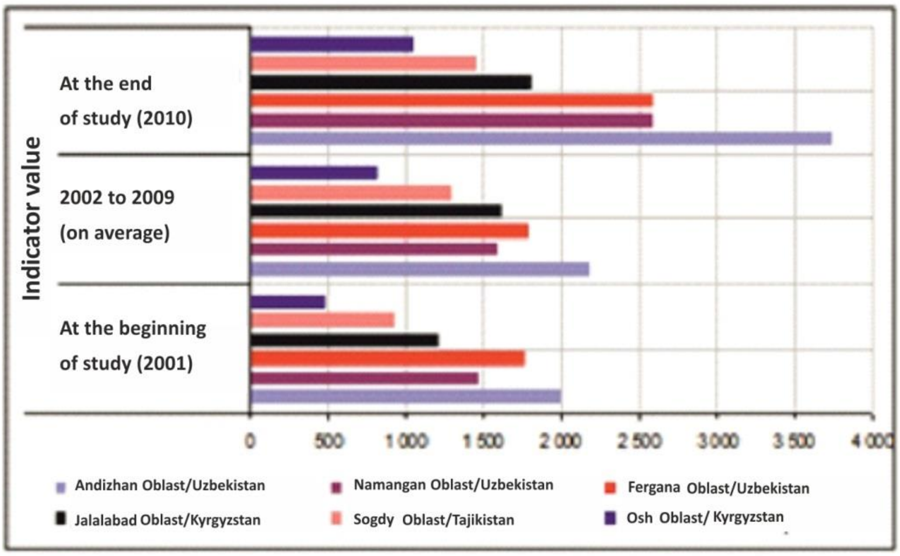


Figure 5.4 Dynamics of crop yields in the Fergana Valley

The project team has managed to sharply reduce the total water intake into the irrigation system with the increase in specific crop yield and productivity of the entire water management complex (Fig. 5.3, 5.4).

This experience allowed drawing very interesting conclusions. IWRM, to a lesser degree, is based on technical and engineering solutions, although they are used in IWRM as various tools, calculation methods, mechanisms of analysis and forecasting. A main thing in IWRM consists in organizational, economic, social and political mechanisms. Development and introduction of these mechanisms are a painstaking work that is a little intrinsic to engineering specialists and, as a whole, is a part of management, not so much economics as in the sphere of economic and social relations, as well as management of human relations and public consciousness. All water management actions affect the interests of many people, primarily water consumers and water users, as well as the caretakers of water in various professional hypostasis, and through these two categories, water management penetrates into the sphere, if not of the interests then the influence of the government and parliamentary bodies. The latter must demonstrate that they are protecting the interests of their citizens and simultaneously are concerned about state benefits (since water requires costs and solves the social and economic problems). On the other hand, water has an influence upon the environment, which is also the responsibility area of these categories of decision-makers, and deeply affects the needs of local authorities, ordinary people, as well as the needs of industry, recreation, services sphere, etc. A probability of arising conflict situations exists in all these interrelationships and interdependencies.

Sometimes, we deal with a gap in time of water releases from the reservoirs that creates contradictions between the needs and possibilities of water supply to water users from different economic sectors (for example, hydropower and agriculture). In case of limited water resources there are contradictions between water consumption in the economic sectors and the needs of nature, as well as between stakeholders that incur different costs and receives various benefits due to water use. A probability of arising conflict situations is growing due to an ample quantity of participants and their opinions concerning the water allocation process, as well as because of the presence of interests, which are not related to water management but reflect existed interrelations of these stakeholders regarding other aspects. Therefore, integrated water resources management requires the maximal openness, transparency, full information awareness “bottom-up” and “top-down” and, especially important, well-reasoned approaches to planning joint measures, criteria of water use, as well as attracting different categories of stakeholders to the equitable participation in the decision-making process. At the same time, it is very important to provide a constant motivation for integration, organization of integration events such as the round tables, iterative trainings, demonstration of mutual benefits from cooperation and also losses due to confrontation or disintegration.

In this regard, when implementing IWRM in the Ferghana Valley and its subsequent expansion in Uzbekistan, the special staff for social mobilization (**social mobilizers)** was widely used.

They disseminated information on the subjects that represent interest for various stakeholders in regards to their benefits, if they would decide to be integrated in different associations or their losses if they would act as individualists.

At the same time, social mobilizers should be able uniting people in the affinity groups encouraging activity of the community of like-minded persons in contrast to modern trends of domination of self-interest, greed and individualism. Social mobilizers together with water professionals must convince water users and employees of the grassroots level of water management hierarchy that the proposed direction on introducing IWRM corresponds to their interests in respect to future sustainable water use. Our experience of water management in dry years i.e. under conditions close to the expected water deficit conditions demonstrates the relevancy of such an approach in the best manner. After overcoming the water shortage of 2008 without loss of crop yield, the number of supporters of IWRM in the Fergana Valley has considerably increased.

Another mandatory element of IWRM implementation is the creation of a team of like-minded people - **initiators, organizers and supporters of IWRM** that deeply understand its mechanisms, benefits and prospects.

The presence of such enthusiasts and convinced supporters in the Government and at the grassroots level is the key factor for the successful promotion of IWRM at all levels of coordination. Finally, one more institutional body - **the National Coordination Council on Introducing IWRM** should incorporate the representatives of various interested ministries, as its active members, and has to assist in speeding up the coordination of inter-agency interests and ties.

Chapter 6. Water and Ecology

As was mentioned in Chapter 1, water is the most important and determinative component of nature, without which it cannot exist. At the same time, nothing is subject to such abrupt variations, even in a natural state, like water. Let us consider, for example, such an indicator as a flow rate in rivers and streams. Fluctuations in flow rates are determined by the variation coefficient, i.e. deviation of observed flow rates from the average annual, average monthly and even daily ones. A water source that is characterized by a constant water flow can be found very rarely. This feature is inherent to only regulated river flows or discharges from lakes or underground aquifers that weakly prone to fluctuations of water levels and the overall water balance of a water body. However, this value fluctuates over a wide range for the majority of natural watercourses. For example, let us consider the Syrdarya River Basin. The graph of its average annual flow rates for the period from 1912 to 2015 is given in Fig. 6.1. As can be seen, while an average annual runoff amounts to 37.6 km3, a range of annual runoff varies from 18.3 km3 in the driest 2000 year to 64 km3 in the catastrophically wet 1969 year, which brought many troubles for nature and society. During the year, the runoff also ranges from a minimum in winter or summer low water to a maximum in spring and early summer, caused by melting snow and glaciers (Fig. 6.2).

Natural fluctuations in precipitation cause corresponding fluctuations in groundwater levels, inflow into rivers, flow of artesian wells, amounts of water evaporation and transpiration. It should be noted that nature itself has created a number of natural structures for stabilizing these natural fluctuations. For example, lakes perform very important functions related to stabilizing flow rates and accumulating suspended solids.

The famous Lake Baikal can be used as the example (Fig. 8.3). Hundreds of rivers flowing down from the Barguzin and Sayan mountain ridges fall into this lake, and only single Angara River, which has the minimal variation coefficient of its flow rates flows out.

At the same time, the water outflowing from the Lake Baikal is one of the most transparent in the world. Prior to the construction of the Irkutsk HPS, standing on the bridge across the Angara River in Irkutsk City, we could see small stones at its bottom at a depth of 7 meters below the water surface! In the spring, water clarity in the lake itself was measured using the Secchi Method (a depth of dipping a Secchi disk amounted to 40 meters)![39]

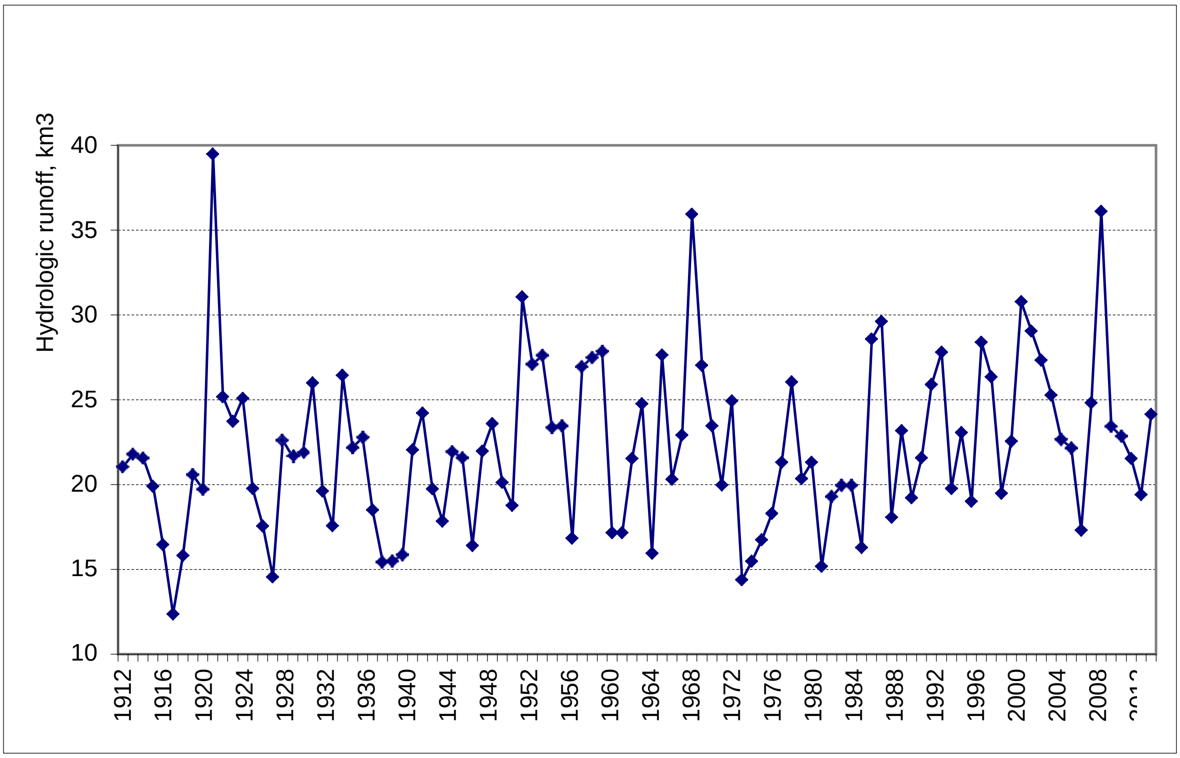


Figure 6.1 The mean annual runoff of the Syrdarya River (formed by main tributaries Naryn, Karadarya and Chirchik with Akhangaran) from 1911 to 2015

[39] A Secchi disk is an 8-inch diameter disk with alternating black and white quadrants that is lowered into the water column until it can no longer be seen from the surface. A depth at which the disk disappears is a function of the lake turbidity.

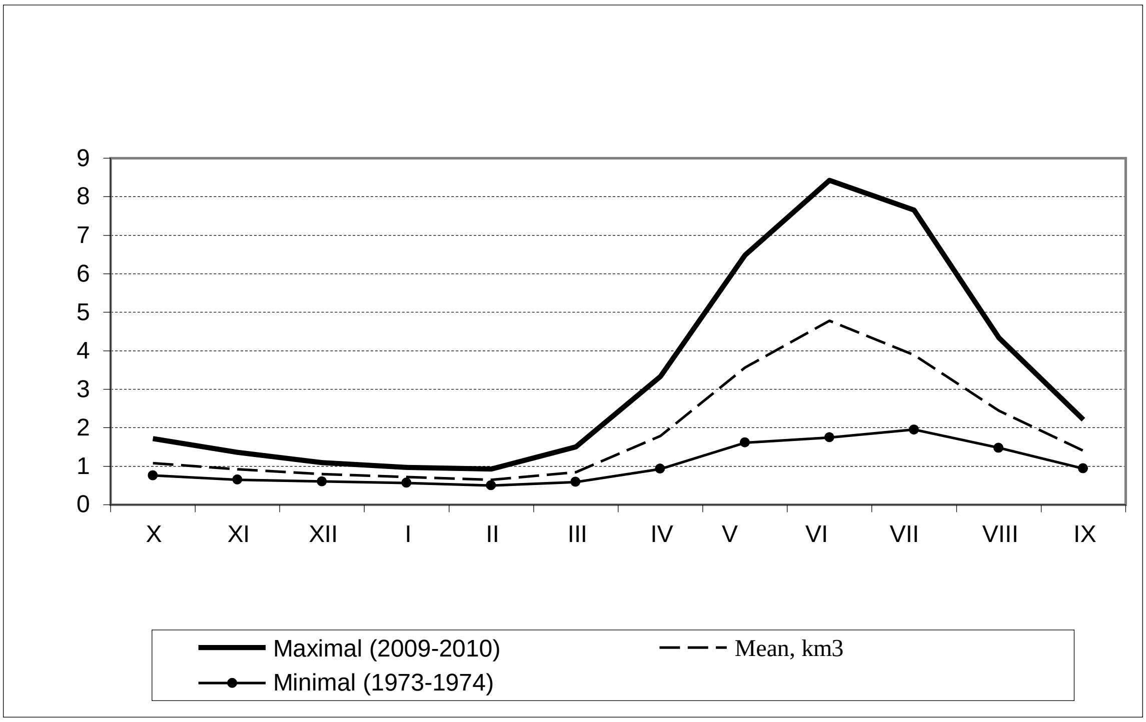


Figure 6.2 Total runoff of three rivers (Naryn, Karadarya and Chirchik) (1950-2014)

Another type of natural stabilizing water bodies is wetlands that intercept part of river flows in the mouths of rivers and create a more or less uniform water regime due to the large wet and flood areas that they form. The Convention on Wetlands of International Importance (called the Ramsar Convention) requires its Parties to strictly safeguard the stability of a water balance of such water bodies. Aquifers (artesian basins), as well as river flood plains with dead channels and oxbow lakes, which perceive river floods during high water are performing the same function. Forested slopes of catchments, which intercept flood runoff and mudflows with the help of vegetation and direct them to groundwater or rivers, but with a reduced erosion capacity play an important role in this respect.

Figure 6.3 Lake Baikal

Our task is not only to maintain this stabilizing capacity of natural water objects, but also to build up this natural potential, supporting ability of nature to survive. A dry bottom of the Aral Sea is a typical example in this respect. Due to the catastrophic anthropogenic disturbance of the runoff of two rivers, the Amudarya and the Syrdarya, which was used up, to a large extent, on developing irrigation in Central Asia, the Aral Sea, the fourth largest natural lake in the world, has decreased by almost 40 times in volume and more than 10 times in area.

A huge new desert, which the people called “Aral-Kum" has arisen at place of the former sea. The government of Uzbekistan organized afforestation on a dried bottom of 250,000 hectares in area for a decade with the aim of combating against dispersing of sand and other particles by wind action from the dry sea bottom over the area in a radius of 300-400 km.

According to SIC ICWC data, in 2009, due to this activity and development of the process of self-overgrowing, the area of afforestation amounted to almost half a million hectares or nearly was doubled (increased by 240.000 hectares).

By the way, on the example of the Aral Sea, one can see the most striking case of a destructive human intervention in the natural balance, which led to the disappearance of this huge water body, where the fish yield exceeded 40,000 tons a year. Until 1960, prior to the intensive withdrawal of water from the rivers feeding the sea, the water level in the Aral Sea was changing insignificantly.

A sea level fluctuated over a range of between 53.1 and 51.7 m + BSL, that is less than 2 meters for two hundred years, providing navigation, development of tugai forests in the delta over an area of more than 1.2 million hectares, migration of waterfowl, as well as significant softening the climate over millions of hectares of surrounding drylands. With the beginning of intensive development of irrigation in Uzbekistan and other Central Asian republics, the inflow to the Aral Sea was constantly declining to the point when in 1980 to 1983 a river flow in the estuaries of the Amudarya and Syrdarya has practically ceased. After the independence of the Central Asian republics, the situation improved somewhat - the inflow to the Aral Sea was resumed, but its magnitude could not compensate for the evaporation from the surface of remnants of the sea. Gradually, the vast sea was divided into three water bodies (Fig. 6.4): the North Sea that is fed by the Syrdarya River, Eastern Sea - entirely dependent on inflow from the Amudarya River, and Western Sea is a deep-water reservoir fed by groundwater inflow and rainfalls.

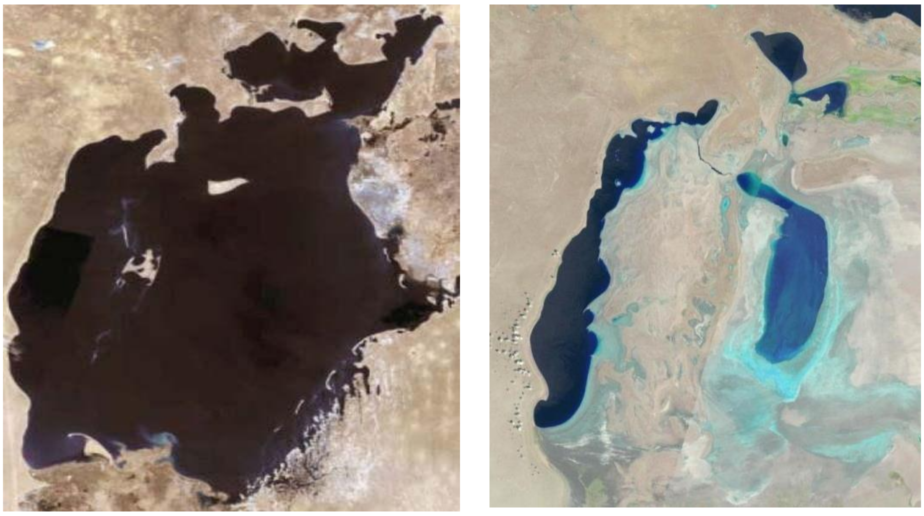


Figure 6.4 The Aral Sea in 1973 and nowadays[40]

For the sake of objectivity, it should be noted that the 20th century passed under the flag of a dramatic change in the attitude of man to nature. In the middle of last century, starting since the 1930s, predatory using of the natural potential prevailed throughout the world. The main slogan was "We cannot wait for mercies from nature - taking them is our task.[41]" It seems that humanity has decided to demonstrate the weakness of natural ties in the face of the increased power of industrialization. The large projects of "remodeling" nature objects throughout the world can be referred exactly to that period.

[40] http://www.cawater-info.net/aral/data/satellite.htm

[41] The words of the famous Russian biologist I. Michurin

In the 1970s, recovery of sight has begun under the influence of established environmental organizations, as well as the frightening forecasts of the Club of Rome and other global predictors. In the 1980s, essential measures were taken for limiting the harmful impacts of human society on nature and even restoring the natural balance. This practice is continuing even now in the form of global activities for mitigating destruction of the ozone layer and reducing the rate of temperature increase, including the measures of the IUCN (International Union for Conservation of Nature) on attracting attention to the protection of water bodies. However, as the saying goes, "It is too late to drink Borjomi[42]when your liver has already collapsed." More than 30 percent of water bodies in the world are polluted, and in addition to the Aral Sea there are more than a dozen closed water bodies on the globe that are subjected to a catastrophic decrease in water volume (Mono Lake, Pyramid Lake, and Salton Sea in the USA, lakes Victoria and Chad in Africa), which are included into the present-day agenda. For the same reason - an increase in water withdrawals from rivers feeding water bodies and sea asturias, a marine "desertification" of the Gulf of Mexico, the San Francisco Bay and many others takes place.

Today, we try to build up the mutual relations between nature and man based on maintaining the balance of water inflow and its consumption or evaporation. In this respect, constant decreasing the specific water intakes for irrigation in Central Asia in the Aral Sea basin is the typical trend (Fig. 6.5). Specific water intakes for irrigation have decreased from 17,000 m3/ha up to10,500 m3/ha. In case of understanding these trends at more earlier stages, it would be possible to stabilize the Aral Sea in a reduced size at the elevations of about 40 to 42 m + BSL. For achieving this purpose, it would be sufficient limiting the irrigation area at the level of 7 million hectares (20% less than today) and applying the irrigation schedules, which are used today.

Thus, we came to conclusion that water is an essential element of the natural potential. However, water is also an important element of the ecosystem. According to the Convention on Biological Diversity, that was opened for signature on July 5, 1992 in Rio de Janeiro and enacted on December 29, 1993: "*The ecosystem means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.*"

[42] Borjomi is a natural mineral bicarbonate-sodium water used for the prevention and treatment of diseases of the digestive system, liver and metabolism.

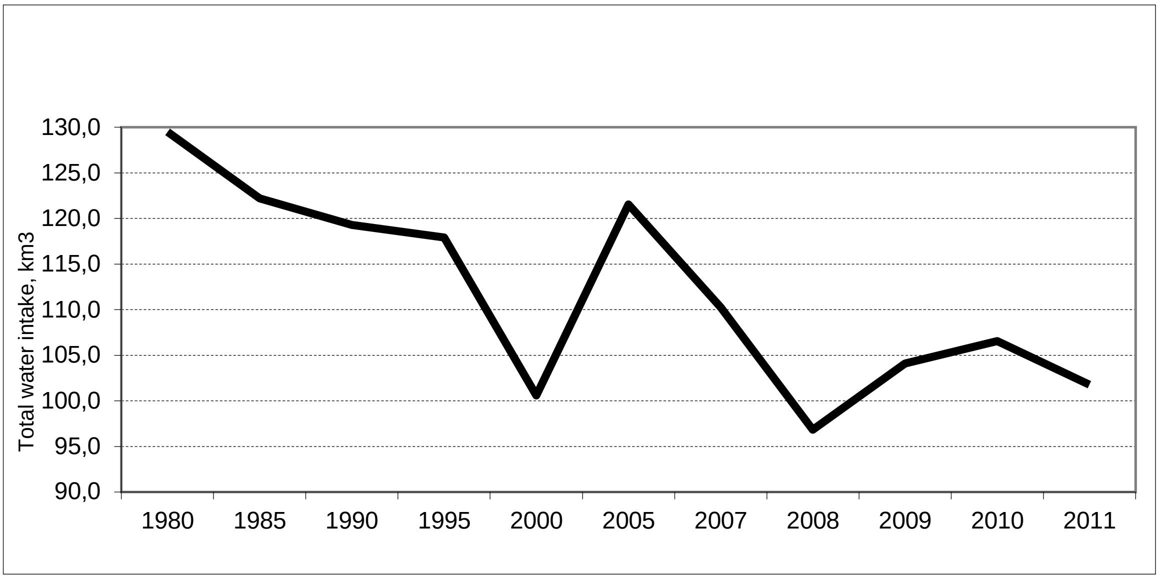


Figure 6.5 Reducing total water intake in countries of the Aral Sea basin since 1980

The UN Millennium Ecosystem Assessment (2005) has considered ten categories of ecosystems: Urban, Dryland, and Polar Systems; Inland Water and Mountain Systems; Marine, Coastal, and Island Systems; and Forest and Cultivated Systems. The World Wide Fund for Nature (WWF) defines the concept "ecoregion." This concept implies a part of the ecosystem that is characterized by a stable composition of natural elements (and in some ecosystems also anthropogenic ones) and a certain fluctuation in the ranges that determine the features of its functioning. With reference to the WWF, the IUCN (2014) defines an ecoregion as "*a relatively large unit of land (or water) containing a distinct assemblage of natural communities and species with boundaries that approximate the original extent of natural communities prior to major land-use change.*"

In our conditions, an ecoregion of the Aral Sea with its wetlands, as well as an ecoregion of closed lakes formed by drainage water disposal (Lake Dengizkul in Bukhara Region, Lake Arnasai, Lake Aydar and others) can be considered as particular ecoregions associated with water. In such ecoregions, inflow and water discharge are the basis for sustainable existence of fauna, flora and microorganisms. When using such lakes, one must bear in mind that in the absence of outflow and under the influence of evaporation, the water salinity gradually grows and turns them into fruitless water bodies with developing stagnation phenomena. To a certain extent, this applies to wetlands, which definitely need in a stable inflow of water and managed flow-through.

An ecoregion of forest massifs is very important. The forest massifs, usually located in mountainous and foothill areas, are characterized by a significant potential water retention capacity and also play an important role in supporting water quality in brooks, river tributaries and, eventually, rivers.

The crown, which consists of the leaves and branches at the top of trees, plays an important role in filtering dust and other particles from the air. It also reduces the impact of raindrops on the soil below, thereby reducing soil erosion on the slopes. At the same time, forests facilitate deep percolation of water into the underground layers and aquifers and serve as absorbers of certain harmful substances due to their root activity. In addition, forests serve as a smoothing regulator during peak rainfalls, reducing the intensity of water inflow to water sources and peak flow rates in the rivers. That is why huge efforts should be undertaken to preserve forests on the catchment areas. There, where they were previously destroyed, intensive afforestation is required.

Discharges of return water into rivers or subterranean horizons as a result of human activities has a very harmful effect on the rivers, especially if these discharges of untreated or insufficiently treated effluents coincide with the water withdrawals from rivers. In these cases, different pollutants appear in the rivers, a content of which does not allow using water for certain purposes. Disposal of drainage water into the rivers exerts the same harmful effect. On the one hand, it seems that the water resources are preserved, and a good thing is done (a kind of circulating water supply) but, on the other hand, salts and harmful substances that are contained in drainage waters make worse a water quality in the rivers.

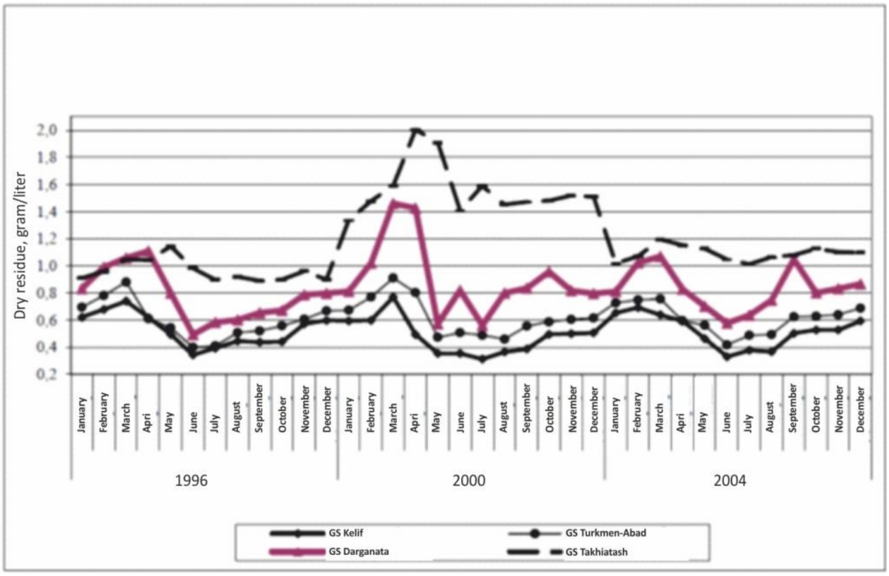


Figure 6.6 Dynamics of monthly values of dry residue in water at gauging stations on the Amudarya River

Fig. 6.6 presents a typical example of the impact of drainage water on the water quality in the Amu Darya River. As can be seen, a water salinity, gradually increasing from the upper reaches to the mouth, rises from 0.2-0.3 g/l to 0.9, and sometimes up to 1.8 g/l. It should be borne in mind that in the low water period a degree of water salinity is greater than at the high water. Water quality management in rivers is organized based on accounting these factors. Based on the consideration of the balance of inflow of salts (and harmful substances) from the drainage canals and the hydrograph of drainage discharges, it is possible to estimate when drainage water disposal into a river could be permissible. This is done based on assessing the dissolving capacity of river flow, assuming periodic discharges of drainage water from the drainage canals at a time when the resultant water quality according to a salt content does not exceed 1.0 g/l. In other periods of time, drainage water is disposed into the accumulating channels that run parallel to the river. Such a scheme of partial disposal of drainage water outside the river was developed for the Amu Darya River and, in case of its implementation, such an approach would preserve the water quality in the river and, at the same time, save up to 6 km3 of water resources with an acceptable level of water quality.

Our models for river basin management (or management of an irrigation canal's command area) distinguish so-called zones of planning (ZoP), which correspond to watersheds with their specific features of landscape and take into consideration administrative boundaries, according to which the state statistics on all economic and social indicators is performed. It should be noted that these are not just certain parts of the river basin, which, like leaves of a tree (similar organization of water distribution scheme), receive water from a river. They differ in their characteristics of the natural environment and, first of all, the landscapes with their topography. Namely, the topography, soils and hydrogeological conditions determine the required water flow for supplying a zone of planning and simultaneously characterize an interaction of the landscape with water resources, distribution of water within the landscape, discharge of drainage and groundwater into a river or, vice versa, feeding groundwater on the surrounding lands from a single water source. It should be borne in mind that every human activity in the catchment area has a corresponding cumulative effect on surface waters and groundwater, replenishing and polluting both. Thus, an interaction of a river and the ZoP takes place - the river supplies the ZoP with water, usually there are one or several points of water intake, the water is distributed over the surface of the ZoP and has a certain effect on the quality of return water, discharge points and volume of discharged water. Replenish of the moisture balance in the command area is one of the manifestations of ecosystem services.

In general, support of the ecosystem services is one of the most important directions, according to which the water management practice should develop. The term "ecosystem services" should be understood as the benefits people obtain from ecosystems. The IUCN distinguishes four categories of ecosystem services:

- ***Provisioning services*** consist of all the products obtained from ecosystems: bottled or tap water, food, genetic resources, demineralization of water, biochemical products, etc.;
- ***Regulating Services*** are the benefits obtained from regulating ecosystem processes, including regulation of watercourse regimes, water erosion control, land salinization control, cleaning water from pollution, adaptation to climate change, protecting against natural catastrophic phenomena (floods and droughts);
- ***Cultural Services*** are the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences (waterfalls, water landscapes, rainbows), including: educational values, cultural diversity (sceneries, walks along water objects, emotional satisfaction, enjoyment of water procedures - shower, bathhouse, ritual ablution), sports use (water competitions, swimming, regattas, jumps from springboards) and water tourism;
- ***Supporting Services*** are necessary for the production of all other ecosystem services. They differ from provisioning, regulating, and cultural services in that their impacts on people are either indirect or occur over a very long time, for example, cleaning channels and reservoirs, work on the forecast of hydrological phenomena, hydro-meteorological and climatic services, maintaining a certain stability in water supply, protection of deltas and waterways, etc.

The sustainability of environmental water services depends on two main factors of water well-being: preservation of an invariable amount of water that mankind can use for its own needs and maintaining development of nature, as well as preserving water quality that is suitable for various needs.

River deltas are a certain element of the aquatic systems that have great ecological value. The deltas and their constituent wetlands, which we mentioned above, are of great importance as habitats for wild animals (birds, reptiles, predators) and are natural filters of river waters. Being the terminal point of many open watercourses, wetlands serve as huge natural filters of river waters, absorbing a large volume of influents. In the USA, the Law on Deltas, which regulates the conservation and restoration of more than 40 million acres (16 million hectares) of coastal and inland wetlands in the country was adopted in 2009.

Figure 6.7 The Lake Sudoche

The US Government allocated more than $2 billion for restoring the world's largest and internationally recognized subtropical wetland “Everglades”, covering an area of 17,600 square kilometers in South Florida and related to the Gulf of Mexico.[43] In Central Asia, the deltaic systems live in degradation due to a drastic decrease in the inflow of water from the main rivers. Nevertheless, the Governments of Kazakhstan and Uzbekistan paid much attention to the preservation of wetlands in the deltas of Syrdarya and Amudarya rivers. In 2003, the GEF pilot project “Restoration of the Lake Sudoche Wetlands” was implemented in Uzbekistan in the Amudarya delta, and since 2004 to 2008, the similar project was realized for recovering the Kamyshlybash Lake System in the Syrdarya delta in Kazakhstan. At present, these restorative works are being built up beneficially effecting flora and fauna in these ecosystems.

We paid enough attention to the quantitative indicators of water resources on the planet and in its individual zones. Now, let's take a closer look at the problem of water quality, since the qualitative indicators of water resources play an important role for the system "water and ecology." Unfortunately, the current state of water resources quality and preservation of water quality are far from unsatisfactory. If we turn to the WWDP[44] analytical data that was published ahead of the 5th World Water Forum, then we will see that the water deficit in the world is aggravated by the fact that 30 percent of the world's surface water resources have unacceptable quality according to various indicators and cannot be used without cleaning for human needs.

[43] Restoring the Everglades returning water to the wetland. Water 21 p. 17-19, October 2013
[44] the World Water Development Program

Even developed and advanced Europe has managed to pollute its waters with various ingredients (more than 60% of water sources) to such a degree that the European Union had to develop a special European Water Framework Directive (EWFD), according to which all European countries are committed to bring their water sources up to the level of necessary maximum permissible concentration (MPC) by 2015. Unfortunately, this goal turned out to be unfulfilled, and the European Union extended the deadline for implementation of the EWFD until 2022. At the same time, there are examples of organized joint actions of a number of countries that have restored water quality in rivers. The most convincing indicator of the acceptability of surface water quality is the presence of biogeocenosis, primarily the fish population. Due to the discharges of various chemicals into the Rhine, the river from its upper reaches, starting on the territory of Switzerland, was so polluted that a sturgeon and, most importantly, Atlantic salmon disappeared from the waters of the Rhine River. This condition was noted back in 1936, when the troubled government created "the Salmon Commission." Its actions have been ineffective for a long time, especially during the economic recession of the 1930s, and then during the Second World War, but cooperation in this direction resumed in the 1950s. As a result, many schemes, proposals and draft decisions were developed. In 1976, the Rhine Commission adopted the program for water quality restoration in the Rhine River to such an extent that allows reviving the salmon and creating the conditions of its breeding in the river, and organized signing the Convention on the protection of the Rhine against pollution from chlorides and the separate convention against chemical pollutants. In the framework of this program, Switzerland, France, Germany, Belgium and the Netherlands jointly carried out a huge work to prevent discharges of untreated sewage into the river. The Convention on the Protection of the Rhine, signed in 1998, has allowed completing the organizational structure for observance of the river flow regime and operating it in such a way that it acts as a model for the whole Europe, especially after the catastrophic incident at the AG in Berne in 1986, when thousands of cubic meters of contaminated waters were discharged into the Rhine. Consequently, hundreds of enterprises located along the river have built sewage treatment plants or switched to a closed cycle of water supply without discharges into the river, as a result of which already in 2005 the salmon population was restored along 50% of the river's length.

Another noteworthy example of the joint work of the United States and Canada, in which a dozen states and provinces participated (2 Canadian provinces and 8 US States), is the project for improving the water quality of the largest aquatic system in North America - the Great Lakes Basin (Figure 6.8). In the early 20th century, due to the development of industrialization and the growth of cities in this basin along water bodies, thousands of large enterprises of steelmaking, aluminum-smelting, paper and chemical industries have grown up. Discharges of these industries into water bodies and directly into local depressions and valleys, along with the chemicalization of agriculture, have led to the disappearance of many aboriginal fish species, replacing them with specimens untypical for local conditions.

Given that the basin is a source of potable water for 36 million people living on its territory, as well as a significant deterioration of water quality, which led to the need of reconstructing and enhancing a variety of water treatment facilities throughout the Great Lakes Basin, in 1955, a detailed survey of the largest sources of water pollution was conducted. Based on this survey, all 10 states and provinces and two national governments signed the Convention on Great Lakes Fisheries as well as, in 1978, the Agreement between the United States of America and Canada on Great Lakes Water Quality was signed. For implementing this Agreement and planned activities, the special office was established under the International Joint Commission (IJC), on the initiative of which, in 1978, 1983 and 1987, amendments to the Agreement were adopted for enhancing the ecosystem approach in the basin. This office was responsible for monitoring and coordinating the actions of all government organizations in the provinces and US states to incorporate the provisions of the Agreement into federal and state legislation in the form of a special legal mechanism. In addition, the IJC is organizing, twice a year, the meetings of all representatives of interested states, governments and local organizations in the form of conferences, where the implementation of five-year programs that are systematically approved by the Commission are discussed. NGOs, which have the right to require the Commission permission on participation in the conference with the submission of certain claims on maintaining ecosystems or insufficient effective implementation of programs are actively involved in this work. As a result of all this activity, the stringent regime for regulating water bodies and procedures for their operation and coordination have been introduced for the whole basin, which is an actual example of achieving the required quality of water and its conservation for future generations.

It is necessary to emphasize a great role of the two-year forums of all stakeholders, which gather up to two thousand participants and provides such an environment that "everyone can be heard." The secret of successful implementing this agreement consists in the coverage not only four main lakes: Michigan, Erie, Great and Huron, but also all "streams, rivers, lakes, man-made canals and other water bodies in the basin, including all tributaries and groundwater." In 2012, another supplement was incorporated to the agreement, which emphasized the relationship of air, water, land and living organisms, including people, within the drainage basin of the Great Lakes and the San Lawrence River. The new agreement on the water quality of the Great Lakes, which entered into force in 2013, has enhanced commitments of the International Joint Commission on progress in improving water quality and public awareness. The Commission has the right checking the information of local governments, assessing the effectiveness of ongoing activities in relation to the intended program and making recommendations on implementing commitments or even to their toughening. These two examples show that humanity, which has committed a certain predatory attitude to the ecological state of water bodies, is in a position to organize the restoration of aquatic ecosystems if the government and society pay some attention to this problem.

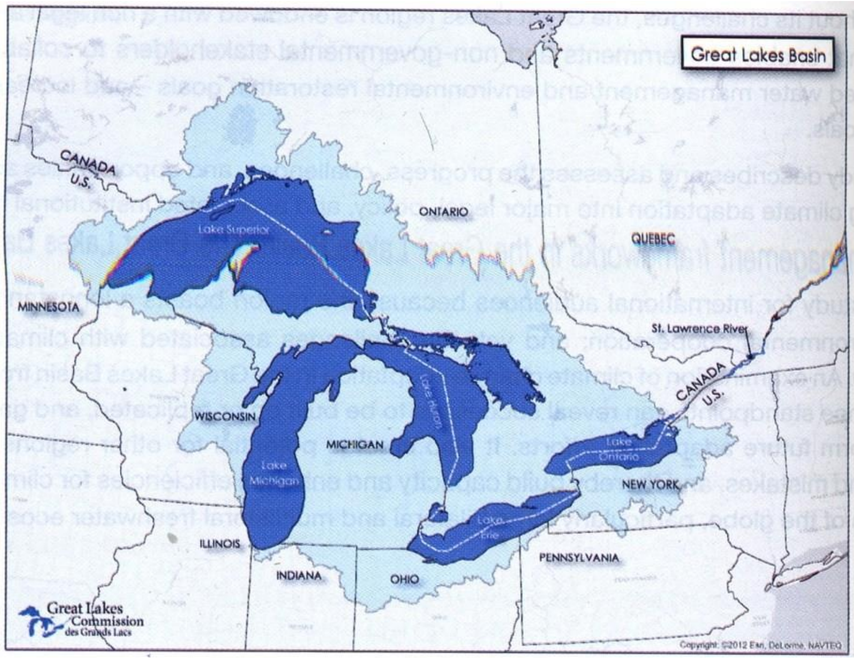


Figure 6.8 The Great Lakes Basin

In 1992, humanity started to see clearly in relation to problems of water quality and prevention of depleting water sources that was reflected in adopting the Convention on the Protection and Use of Transboundary Watercourses and International Lakes, which gained the global significance and spread in 2015, and which obliges the Parties to undertake all appropriate measures:

a. *"To prevent, control and reduce pollution of waters causing or likely to cause transboundary impact;*

b. *To ensure that transboundary waters are used with the aim of ecologically sound and rational water management, conservation of water resources and environmental protection;*

c. *To ensure that transboundary waters are used in a reasonable and equitable way, taking into particular account their transboundary character, in the case of activities which cause or are likely to cause transboundary impact;*

d. *To ensure conservation and, where necessary, restoration of ecosystems*."

We are talking about maintaining the quality of water within the range of required parameters. However, what is the most required composition of water? It is clear that a simple chemical compound (H_2O) is not the water we consume. The water that we use contains certain impurities giving it the taste and feeling of appropriateness, to which we have accustomed.

If we take absolutely pure water obtained from the melting of snow, ice, or after absolute demineralization, in spite of all its purity, it does not have a necessary taste and aesthetic qualities, therefore we cannot quench our thirst with such a water.

The so-called "Epiphany water", which is used for spattering with sanctified water in churches, is also absolutely tasteless. Water is considered suitable for using under food cooking and drinking, when it meets the requirements for the content of impurities and minerals in accordance with the so-called "maximum permissible concentration" (MPC) of each chemical or physical element, and in this respect the following criteria of water quality were accepted:

- ***Hygienic criterion*** that takes into account the toxicological, epidemiological and radioactive safety of water and the availability of favorable properties for human health;
- ***Fishery criterion*** that takes into account the suitability of water for habitat of commercial fish and aquatic organisms;
- ***Ecological criterion*** that takes into account the conditions of normal and stable functioning the aquatic ecosystem; and
- ***Economic criterion*** that takes into account the profitability of water use of a water body.[45]

Different approaches are used in various countries for specifying an integral characteristic of water pollution. In most CIS countries, the water quality classes are used as indicators of the integrated assessment of the surface waters quality by hydro-chemical indicators, that are evaluated by the "Water Pollution Index" (WPI) according to the instructions of the State Hydro-meteorological Service (Order No. 250-1163 dated 22.09.1986):

Quality Class	Characteristic of Water Quality	WPI
I	Very clean	<= 02
II	Clean	> 0.2-1
III	Moderate polluted	1-2
IV	Polluted	2-4
V	Dirty	4-6
VI	Very dirty	6-10
VII	Extreme Dirty	> 10

[45] www.glossary.ru/cgi-bin/gl_sch2-cgi

In case of surface water, the calculation of the "Water Pollution Index" (WPI) is carried out for each point (measuring alignment) using the following formula:

$$WPI = (\sum_{1}^{6}(Ci/MPC)/6)$$

where: C_i - a mean annual value of i-indicator; MPC - maximum permissible concentration of pollutant; “6” - a strictly specified number of indicators taken for calculation, including, compulsorily, dissolved oxygen and BOD_5.

Apart from dissolved oxygen and BOD_5, six components taken for the calculation involves those that have the highest relative concentrations (Ci/MPCi ratio). For oxygen, this ratio is in the reverse order (MPC/C_i). For representing water quality in the form of a single assessment, the indicators are selected regardless the limiting feature of harmfulness; at equal concentrations, preference is given to substances that have a toxicological sign of harmfulness. When calculating the WPI, the number of values used to determine mean annual concentrations should be at least five. For rivers, the WPI value that was calculated according to above formula is adjusted with a correction equal to the ratio of the average runoff for an estimated year to the average long-term runoff. The table below gives examples of MPC for pollutants and values of HC and EHC.

Examples of MPC, High Contamination (HC) and Extreme High Contamination (EHC) contamination of water bodies (http://www.eco.nw.ru/lib/data/08/3/030308.htm)

Indicator	Type of water body	Limiting requirements for water body	MPC	HC *)	EHC *)
Abs. content of dissolved O_2, mg/l Winter Summer	Fishery	General requirements	 4 6	 <3 <3	 <3 <3
Relative content of dissolved O_2, %	Fishery	General requirements	70	-	-
BOD_5, mg/l **)	Fishery	General requirements	2	>15	>60
pH	Fishery	General requirements	6.5-8.5	-	-
Ammonium nitrogen	Fishery	Toxicological requirements	0.39	>3.9	>39
Nitrate nitrogen	Fishery	Toxicological-hygienic	1	>10	>100

Indicator	Type of water body	Limiting requirements for water body	MPC	HC *)	EHC *)
Nitrite nitrogen	Fishery	Toxicological requirements	0.02	>0.2	>2.0
Magnesium, Mg	Fishery	Toxicological-hygienic	40	>400	>4000
Chloride, Cl	Fishery	Toxicological-hygienic	300	>3000	>30000
Sulphate, SO_4	Fishery	Toxicological-hygienic	100	>1000	>10000
Sodium, Na	Fishery	Toxicological-hygienic	120	>1200	>12000
Potassium, К	Fishery	Toxicological-hygienic	50	>500	>5000
Calcium, Ca	Fishery	Toxicological-hygienic	180	>1800	>18000
Salinity, mg	Sanitary-domestic	General requirements	1000	>10000	>100000
Phenol	Fishery	Fishery requirements	0.001	>0.03	>0.1
Oil products	Fishery	Fishery requirements	0.05	>1.5	>5.0
Synthetic Detergents	Fishery	Toxicological requirements	0.1	>1.0	>10
Copper, Cu	Fishery	Toxicological requirements	0.001	>0.03	>0.1
Nickel, Ni	Fishery	Toxicological requirements	0.01	>0.01	>1.0
Manganese, Mn	Fishery	Toxicological requirements	0.01	>0.01	>1.0
Lead, Pb	Sanitary-domestic	Toxicological-hygienic	0.03	>0.30	>3.0
Mercury, Hg	Sanitary-domestic	Toxicological-hygienic	0.0005	>0.005	>0.05
Cadmium, Cd	Sanitary-domestic	Toxicological-hygienic	0.001	>0.01	>0.1
Zinc, Zn	Fishery	Toxicological requirements	0.01	>0.1	>1.0
Pesticides	Fishery	Toxicological requirements	-	>0.001	>0.01

Note:
*) Criteria of HC and EHC were established by the State Committee for Hydrometeorology;
**) MPC for BOD_5 was taken as approximately 70% of the MPC for BOD_{total}.

There are classifications of water quality according to the presence of zooplankton, saprobionticity (the ability of organisms to live at a high concentration of organic substances in the medium), degree of chemical contamination for 3 years, hydro-biological indicators, and other indicators (V. Shabanov, V. Markin).[46] It is known that natural water in rivers and groundwater are not a pure H_2O compound. Water, even without the influence of man, circulates in nature and, having a large dissolving capacity, adsorbs chemical substances of that medium in which it moves. The formation of water quality occurs under the influence of natural processes, and this state is called as "background water quality," and a composition of substances contained in such a water as “background pollution.” It is different for various parts of the noosphere, because it is determined by the variety of precipitation and soils, through which water penetrates into a subsoil layer and from there into the groundwater.

In the process of infiltration through soil layers, water is enriched with chemical compounds from residues of decayed and preserved organic substances, plant debris, and also products of their processing by microorganisms contained in the soil. After percolation into deeper ground horizons with following discharging, water becomes saturated with chemical compounds of soluble rocks, through which it is moving, as well as is mixing with deeper artesian water that often has higher salinity and contains both useful and harmful minerals. In the process of discharging of groundwater into riverbeds or water inflow into rivers and other water sources across the land surface, in addition to vegetable residues, the water captures erosion products (silt, clay suspension, finely dusty particles), which in general are forming its quality. Therefore, even in the natural state, water can be drunk and used for hygienic purposes very limited, usually from wells excavated in well-permeable pebble rocks, karizes and springs. In most cases, people use water after a thorough multi-step cleaning and treatment (chlorination, ozonation and other methods).

On the one hand, owing to a human interference, development of industry and widespread urban development, especially the growth of large cities - megalopolises, the demand for water of a certain quality, adapted to the requirements of each type of water use has dramatically grown, but, on the other hand, a degree and diversity of water pollution noticeably increased. Sewage systems of cities and settlements, as well as certain types of industry, especially chemical, paper, food, aluminum, steel industry and others are being especially notable for this respect. Currently, more than 2 billion people use sewerage based on untreated or under-treated wastewater, despite the goal set in the UN Millennium Development Goals - to provide modern sanitation systems to all people.

[46] http://library.timacad.ru/files/svobodny_dostup/monografii_i_stati/metodika_ekologo_-_vodohozyaystvennoy_ocenki_vodnyh_obektov./2568.pdf.

The barrages and dams constructed on rivers that slow flow velocities leads to water eutrophication. Agriculture creates dispersed sources of pollution on broad areas, from which pollutants enter a body of water. Surface runoff from farms, for example, is a dispersed source of pollution, carrying animal wastes, fertilizers, pesticides, and silt into nearby rivers.

There are no universal methods for complex water purification from all the contaminants contained in it. Therefore, the process of water purification is multistage and the set of equipment must be selected for each specific case according to the results of water analyses. Moreover, it should be borne in mind that water treatment facilities are high-tech, expensive devices, a product of the development of high technology, so installation and maintenance of this equipment requires a high level of personnel training. 100-percent use of wastewater after full treatment is practiced in Israel, Singapore, and Hong Kong, where all return waters are cleaned and used differentially, depending on the degree of purification - for technical needs or for irrigation.

A very important mean of reducing the pollution of used water are water protection zones along rivers, irrigation canals, around water intake facilities and large hydroschemes. Another component of water resources protection is the reduction of leaks from sewage pipelines, as well as from water supply systems passing near sewage discharges.

Transition to a closed water supply cycle of industrial enterprises, when their demand for process water is met through the purification of their own sewage with recharging only that amount of water, which is irretrievably lost due to evaporation, is applied among other ways of preserving the quality of used waters. The legislation concerning wastewater treatment is available in all countries with a different degree of specification and severity. For example, the requirement of complying with the necessary amounts of environmental water releases for conservation of natural water objects presents in the Water Codes of Great Britain, Bolivia and Ecuador.

Several possible approaches to specifying the necessary flow rates sanitary water releases are available:

- no less than a minimum observed discharge at this section of the river in each time intervals;
- taking into account the specific conditions of fishery activity that meet the requirements of fish productivity;
- no less than 10% of a mean annual flow rate (the EU rule);
- to prevent damage of a delta and sea area (the Great Britain); and

- maintaining the self-cleaning ability of the river (Convention on the Protection of the Rhine).

It should be noted that compliance with environmental water releases is a legal norm adopted at the international level. The decision of the arbitration court made in 2013 regarding the implementation of the Indus Waters Treaty signed by Pakistan and India in 1960 has attested this fact. Maintaining a minimum river flow rate during the operation of the HPS was recognized as a customary rule of the international law that means its mandatory performance by all states.[47]

For the Amudarya and Syrdarya rivers in Central Asia, the magnitudes of sanitary water releases have been established based on scientific researches and agreed by the Regional Working Group in the framework of the "The Basic Provisions for the Development of the Regional Water Management Strategy in the Aral Sea Basin" (4.5 km3 for the Amudarya delta and 3.2 km3 for the Syrdarya delta respectively). However, these quantitative parameters were not included in any interstate agreements. Nevertheless, after independence of Central Asian republic, these quantitative parameters are maintained over many years, excepting very dry years. In addition, for a number of main irrigation canals in the Amudarya lower reaches (Khorezm Oblast of Uzbekistan and Turkmenistan), which are supplying water for household needs due to absence of other water supply sources the quantitative parameters of sanitary water releases in the winter period have been established.

A special type of regulating services is the land degradation control caused by water erosion, desertification and salinization. This work represents a special range of activities, primarily ground and remote monitoring, capabilities of which have now greatly increased due to the constant development of methods and instruments for space imagery. Three types of agencies in each country bear responsibility for monitoring and land degradation control: agencies responsible for nature protection, Hydro-meteorological services, and water management organizations. At that, direct responsibilities to combat these phenomena are mainly entrusted to the Ministries of Water Resources and Agriculture or National Agencies (Committees) for Water Resources. At the regional level, these responsibilities are performed by the Regional Hydrogeological & Reclamation Services under Oblvodkhozes48or the Basin Water Management Departments.

[47] Partial Award issued by the Court on 18 February 2013, http://www.pca-pa.org/showpageb106.html?pag_id=1392
[48] The Oblast Water Management Office; Oblast – an administrative unit in former Soviet Union that includes several administrative districts.

Chapter 7. Is Water a Limiting Factor? No, the Driving Force of Development

Reading the chapter "Role of Water in Developing the Civilization" you could make sure that since the ancient times, man, in his quest to use water, protect himself from water, manage water was forced to unite with his kind into certain communities. He studied water features, regularities of water movement, identified those water qualities and properties, which could be of benefit to people and could be used for their various needs. You have come in science and water management practice, when almost all of these problems and issues (but not all!) have been studied and described in many books, papers and project reports on the basis of those world technologies and ideas, which exist at the moment. You have to deepen this knowledge and understanding in the light of new ideas, new scientific and institutional solutions, new technologies that were unknown to our generation, and the time presents them into the disposal of your generation - take and use!!! Based on such an approach, you have the opportunity never to consider the lack of sufficient water quantity or its deficit as a limiting factor for development.

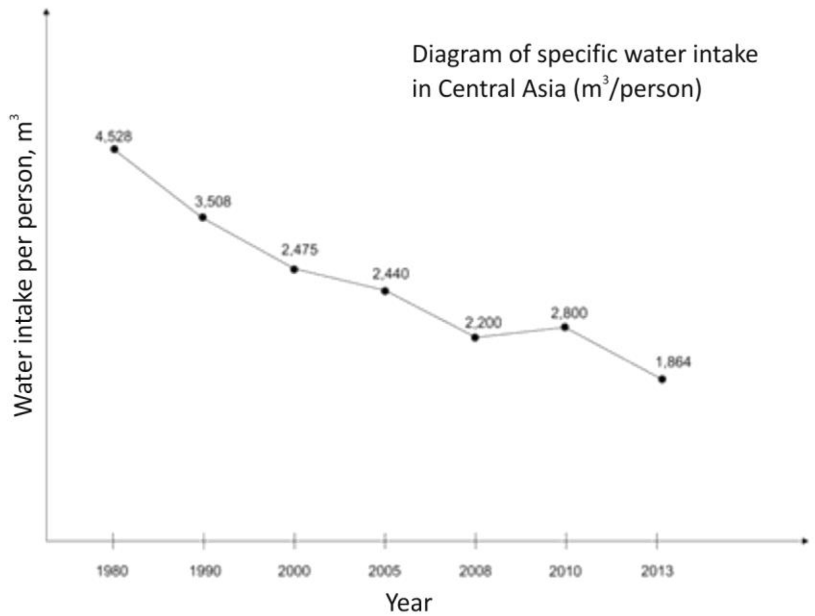


Figure 7.1 The diagram of specific water intake per capita a year (Data of the Analytical Report) www.cawater-info.net/analytika

At present, an average water consumption per capita is changed over a fairly large range. Its value depends not only upon the availability of water resources in local water sources, climatic features and amount of precipitation, but also, and even in a greater degree, the sectoral development and perfection of technological solutions. However, the public policy in relation to water use is the most important factor. Countries located in the arid zone consume much more water than countries that are located in the areas with humid climate. Agriculture, especially in the irrigation zone, consumes much more water than industry and communal services. In general, about 70 percent of all water consumed by humanity is used for irrigation (more than 90 percent in our Central Asian region), without the consumption of ecosystems. An average world consumption of water (surface water and groundwater) amounts to 700 cubic meters per capita a year, but in our region, a specific water consumption has approached 2000 cubic meters, due to predominantly agricultural water consumption. Constant changes in specific water consumption is a typical phenomenon, primarily due to the population growth and changes in national water policy and technological innovations (Fig. 7.1). At the same time, there are a large number of countries in the world that are forced to develop their economy against a background of a specific water consumption less than 500 cubic meters a year. Namely, the practice of these countries shows that absolute water famine does not threaten humanity, because the water deficit forces these countries to carry out significant political, organizational and technological transformations, as a result of which water deficit turns into a factor of progress.

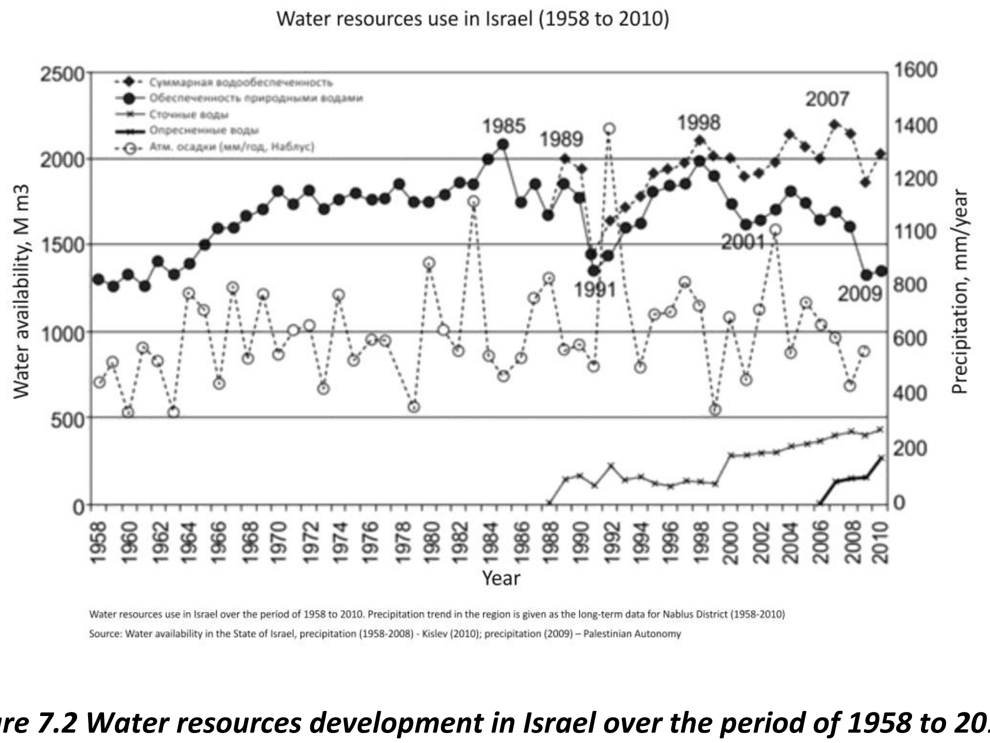


***Figure 7.2 Water resources development in Israel over the period of 1958 to 2010*[28]**

Dynamics of water resources development in Israel is an excellent example from this point of view. The country is located in the semi-arid climate zone with fluctuations in precipitation over the past 60 years over the range of 350 mm to more than 1000 mm a year. Natural water resources of the country, consisting of surface runoff of the Jordan River that is accumulated in Lake Tiberias (Kenereth) and water reserves in coastal and inland aquifers, which are used together with Jordan and Palestine, amount to 1550-1600 million cubic meters a year, on average. Figure 7.2 shows fluctuations in water availability in Israel since 1958 until 2010. At the time of Israel formation, the population amounted to 0, 873 million people that consumed 523.8 million cubic meter of water a year or about 600 cubic meter per capita a year. At the first stage, until 1972, the country chose the way of increasing water intake in proportion to the growth of population and water demand.

However, already in 1972, Israel has adopted a revolutionary decision in the history of irrigation and created drip irrigation systems that changed not only the method of supplying water to plants but also introduced a new technology in crop production that was disseminated around the world. At the same time, the national focus shifted to self-provision of food products - the agricultural production was reoriented on producing only high-value types of crops when importing mainly cheaper cereal crops. Import of grain and corn has become the decision that stabilized agricultural water consumption in 1985 at the level of 1500 million cubic meter with a subsequent decline to one billion cubic meter in 1990.

The maximum water abstraction in 1985 to 1213 million m3 from aquifer and 865 million m3 from surface water sources - led to the intrusion of seawater into the coastal aquifer. Concerns of the government and public regarding this environmental deterioration, along with the reduction of water reserves in Lake Tiberias, resulted in a number of government decisions to tighten the water policy, increase water tariffs and, simultaneously, to commission the first wastewater treatment plants and use treated waters for irrigation in the Negev Desert. In 1997, a special commission was established to reform the water sector.

For the first time, the issue of mass seawater desalination was considered as a promising solution of water problems in Israel along with water conservation, transport of water from Turkey (pipeline or by tankers) and other solutions. Since the priority was given to enhancing water saving in the sectors of irrigation and communal services, the cost of which was determined at the rate of 0.05 $/m3 for irrigation water and 0.15 $/m3 for communal services, the issue of seawater desalination was postponed until time when the reserves for using own waters would be exhausted, but was put in the agenda of technological developments.

Simultaneously, all water sources in the country (underground and surface) were united in a single network - the National Water Carrier of Israel under operation of the Mekorot Water Company[49], which is uniting all water supply systems into a single pipeline network with the high level of efficiency and automation. The Mekorot Water Company has initiated the processing of all municipal wastewater; and already since 1988, the use of all wastewater was being increased in the country.

If come back to Fig. 7.1, it shows that the national maximum water consumption of 2,200 million m3 was achieved in 2007, while covering the demand at the expanse of natural water resources amounted to 1,700 million m3. A deficit was compensated at the expense of 400 million cubic meters of wastewater used after treatment by the Dan Region Wastewater Treatment Plant, known in Israel as Shafdan, but most importantly - almost 200 million cubic meters of desalinated seawater. This was preceded by a long way of political disputes and decisions, technological improvements and establishing the strict state discipline of water use. Since 1999, the Israeli Water Commission, supported by the Ministry of Infrastructure, has launched the intensive company for developing the seawater desalinization projects, against which the Ministry of Finance resisted. As a result of the announced tender, it turned out that the proposed price of desalination was 0.5-0.6 dollars per cubic meter, which was commensurate with the costs of providing water saving in other water use sectors. In 2006, the first seawater desalting plant with a capacity of 100 million m3/year was put into operation, and the adoption of a new supplement to the Water Law in the same year has facilitated its activity.

At the same time, the official recognition of the natural complex as a water consumer, whose water requirements must be met, meant the need to increase the supply of treated wastewater to replenish aquifers. In accordance with the Long-Term Master Plan, it was necessary to increase the volumes of seawater desalinization as well.

In 2007, another seawater desalting plant with a capacity of 35 million m3/year was put into operation. Moreover, the seawater desalting plant with a capacity of 100 million m3/year in Hadera (2010) and two additional seawater desalting plants in Sorek and Ashdod (2013) have increased the total desalting capacity up to 500 million m3/year. This allowed Israel to conclude the agreement with Jordan and Palestine on supplying 50 million m3 of water a year in addition to the current natural flow of the Jordan River! One of the main factors of the sustainable water system in Israel is the economic principles of developing the tariffs that cover the recognized costs of various types of water supply and create the incentives for the effective use of water resources in all sectors of the economy.

[49] MEKOROT (Heb. "Sources") WATER COMPANY started to implement the the National Water Carrier Project in 1953.

At that, all financial regulation focuses on the growth of tariffs to cover the growing water consumption, but with differentiation depending on the quantity, quality and destination of water use. The existing procedure for determining the cost of water production, transportation, distribution, and development of new infrastructure also regulates the size of profits, inter-sector and state subsidies. All this is based on the highest discipline of water use, water accounting and payments for water supply. It should be borne in mind that tariffs, which are formed in the framework of the existing two-stage payment system, are quite high. When consuming less than 3.5 m3 of water per person a month (110 liters per day), a consumer pays 2.4 dollars per cubic meter, and if this consuming rate is exceeded - 4 dollars per cubic meter[50].

Using the example of water development in Israel, it becomes clear that thanks to the concentration of political and public efforts, based on the development of advanced technologies in irrigated agriculture, purification of sewage waters and seawater desalination, the country has ensured meeting the water demands of all economic sectors, municipal water users and ecosystems. Despite the population growth in 4 times compared with 1960 and the increase in gross national product by 44 times, the total consumption of natural water resources remained at the level that was fifty years ago with the consumption of all types of water and natural waters - 263 and 166 m3/capita, respectively!

Figure 7.3 Drip irrigation and a wheat field in Israel with crop yield of 8 ton/ha

[50] M.Gilmont, Decoupling dependence on natural water: flexibility in the regulation and allocation water in Israel, Water Policy 16 (2014)79 -101. Y.Shevah (2014), Adaptation to water scarcity and regional cooperation - in the Middle East, in Ahuja S (edit), Comprehensive Water quality and purification, vol1, pp 40 -70, USA, Elsevier.

Qatar has presented another striking example.

Qatar, being a small country on the Arabian Peninsula with a population of 1.7 million people and possessing only 65,000 hectares of cultivated land, has set the goal of providing itself with food products, most of which is now imported. All the water that is supplied for irrigation (3.8 million m3 per day or 100 million m3 per year) is desalinated seawater.

To feed the population of this country it is necessary, first of all, to train those who will be engaged in this activity. Dozens of colleges, universities and training centers were established in the country with the participation of the largest American universities. Oil and gas companies such as Shell, Exxon Mobil, Total S.A., General Electric and other companies are financing the University of Carnegie, Georgetown University, Texas University, Cornell University, etc. that are involved in training activity. The Qatar Science and Technology Park, which is the center of interaction between industry and academic science and provides constant technological progress, was created thanks to their efforts and support.

The lack of sources of water suitable for use does not frighten the Qatari people. Water is a by-product obtained under pumping out of oil and gas. Each barrel of oil is accompanied by 3-4 barrels of water, which need to be removed, but can be used.

The widespread use of this water for livestock and irrigation has become the first postulate of solving the food problem. The second postulate is the use of solar energy, both in greenhouses, and generally for obtaining clean electricity. Electric energy is generated on huge "solar fields" occupying the area in many hectares. Desalination in the process of oil and gas water treatment is the subject of research works in the framework of the Qatar Science and Technology Park aimed at reducing the cost of desalination and ensuring the environmental safety. The cost of desalination does not exceed half a dollar per cubic meter of water. The program also includes the production of liquid soluble fertilizers, construction of greenhouses on huge areas, as well as complete processing of output in order to eliminate the import of foodstuffs, which now constitute 90% of all food products. The program also focuses on the local diet. One of the components of this program is financial sustainability. This includes subsidizing agricultural production, including irrigation. Each of 1,340 farmers constantly reports to the state on implementing cultivation technology and their financial condition based on openness, transparency and trust. Each farmer receives financial assistance based on two conditions: preventing the increase in prices for products in excess of the established limits and ensuring the necessary level of reproduction for a long period, taking into account the formation of capital.

One could add to the experience of these countries the water situation in Jordan, Palestine, Burundi and other 18 countries that survive when water consumption is less than 500 cubic meters per capita a year. This practice of water-scarce countries categorically rejects the so-called indicators of water stress, proposed by the famous Swedish hydrologist Malin Falkenmark in 1989, when a country with the potential of supplying 1,700 m3 per capita a year or less is evaluated as a country "of water stress." Countries with water reserves less than 1,000 m3 per capita a year are considered as countries of "absolute water shortage." According to data of the UN-Water, this category will include countries with a total population of 1.8 billion people by 2025. Two thirds of the world's population will be referred into the category "water-stress countries" by that time, but the creatively developing countries are not obliged to do as these indicators dictate!

Chapter 8. Climate Change and Water

Nur al-Hussein, the Queen of Jordan, at the opening of the Islamic Conference "**Islam, Faith and Climate Change,**" held in Amman in August 2015, made a policy statement that largely reflects the opinion of all progressive humanity about the climate change on our planet:

«*Many have pointed out that we are the first generation to have hard evidence of the enormous damage that humanity is causing to natural ecosystems, and probably the last that can truly do something about it.*»

Climate change over the past decades has drawn attention of all mankind to its manifestations, its supposed consequences and the need for measures both to reduce its intensity and, if possible, to decrease its influence through adaptation measures. Although all the "roots" and causal relationships of the observed phenomenon have not been finally revealed, science has succeeded in forcing public opinion and decision makers to understand that the "Sword of Damocles", generated by an unreasonable anthropogenic pressure, is hanging over the world and can be rejected again only by joint actions of all mankind. Following the recommendations of the United Nations Framework Convention on Climate Change of 1992, adopted in Rio de Janeiro, the international organizations such as WMO, UNESCO, and UNEP created, with using data of national meteorological services, the Global Climate Observing System. It is located on stationary ground, floating, aviation and space surveillance facilities.

This system made possible to accurately reflect the current state of climate that is characterized by widespread global warming of climate, which is confirmed by temperature changes, decrease in the area of sea ice and the cap of the Arctic, melting of glaciers and increase in the level of the world's oceans. On a global scale, the warming manifested itself during the period 1910 to 1945, in the following 30 years a slight cooling was observed, and after 1976 a sharper increase in temperatures was registered (Fig. 8.1). The global temperature increase amounted to 0.75°C during the last century, and by regions: 1.29°C for Russia, up to 1.5°C in three arid countries in Central Asia (Kazakhstan, Turkmenistan and Uzbekistan), and 1.0°C for Kyrgyzstan and Tajikistan. Analysis of mean values for Central Asia indicates a large number of significant changes in the direction of warming. The most significant warming over this territory was recorded in April, in June, in November and December. In these months, at most meteorological stations, a meaningful increase in the average monthly air temperature was observed (from 50.2% to 92.3%). A meaningful decrease in average monthly values was noted relatively rare (from 7.7% to 19.8%), mainly in autumn months of the year.

Thus, it can be concluded even based on the analysis of an average monthly temperature series that there was a statistically significant warming in Central Asia. Standard deviations of mean monthly temperatures have insignificantly changed due to the high natural variability of air temperature. Analysis of changes in the maximum temperatures has shown the presence of upward trends in most months. It is interesting to note that in summer and autumn, the trend towards an increase in minimum temperatures is more visible than in case of maximum temperatures, at the same time, a decrease in maximum temperatures was recorded at a fairly large number of stations in summer. In the last decade, the winter months have put the greatest contribution to warming. For example, the average air temperature over the winter season for the10-year period was higher than the base norm practically throughout the whole territory, and in some areas, the excess was 1.2-1.5°C.

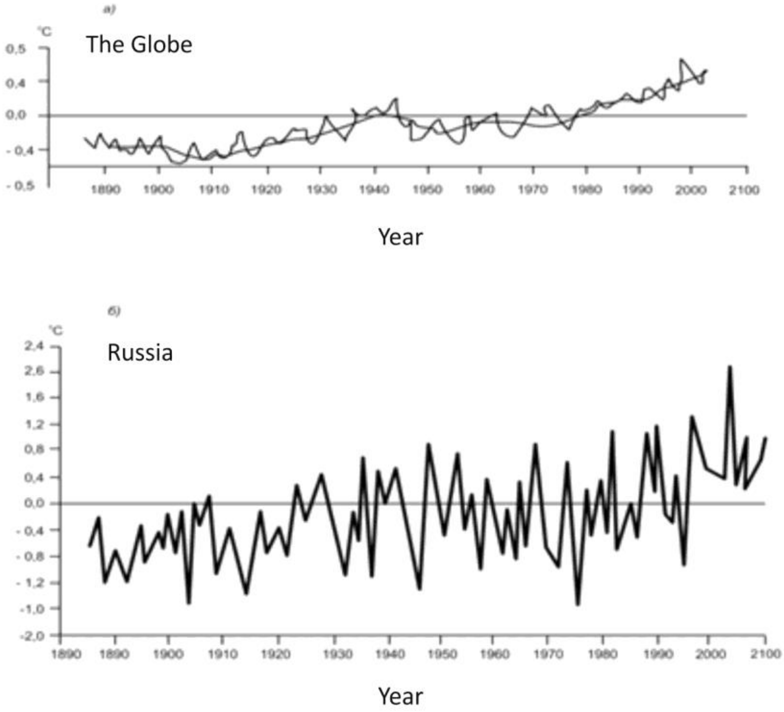


Figure 8.1 Temperature trends in the 20th and 21st centuries

Theoretically, a temperature growth should be accompanied by a slight increase in precipitation. Observation records on annual precipitation amounts have confirmed this relation for the plain areas in the period after 1961. For foothill and mountainous terrains, a presence of separate areas of increasing or decreasing precipitation is typical. During the summer period, an amount of precipitation did not practically change. The variability and intensity of precipitation is increasing in many districts of Central Asia. Such an increased unevenness in time, when heavy rains alternate with droughts, may negatively affect the regional terrain, since this intensifies soil erosion.

Moreover, in summer, similar precipitation does not provide the necessary soil moisture, since water is not able promptly to infiltrate through topsoil and some of water simply flows down over the land surface, and a high air temperature favors its intensive evaporation. As a rule, a significant increase in air temperature with a decrease or inessential increase in the amount of precipitation leads to enhancing the aridity of climate over the plain areas of deserts and semi-deserts.

Another indisputable consequence of climate change is a change in river runoff. Although according to the absolute magnitude of river runoff, changes can hardly be considered as significant for the Syrdarya River, but the frequency of wet years with a probability of 25% and less increased by 1.4 times, and especially wet years with a probability of 10% and less by almost 2 times.

A slightly different situation in the Amudarya river basin, where a river runoff was on 1.5% less than an average annual runoff for the previous 40 years, but almost coincides with an average annual runoff for the entire observed period. A frequency of dry and wet years has increased in the Amudarya river basin. A frequency of dry years (with a probability of 75% or higher) has increased by 1.3 times, wet years with a probability of 25% and less by 1.2 times, and especially wet years with a probability of 10% or less by 2.5 times. A "depth" of extremely dry years (i.e. the deviation of an average runoff in dry years from an average runoff over the whole period) has increased by 1.5 times.

Thus, in recent years, not only the number of abounding in water years (for all rivers) and years with shortages of water (for the Amudarya River) but also the amplitude of deviations from the mean values has increased. Our estimating fluctuations in available water resources and water consumption in the CAKIR basin (Chirchik-Akhangaran-Keles Irrigation District), according to scenarios for future development (in the next 25 years), indicates the possibility of even more significant fluctuations in available water resources, which under various scenarios may differ from the baseline values (2005) by ± 40%. Some researchers, and especially high-ranking officials in the countries of upper watersheds, are linking their fears and negative runoff forecasts with possible melting of glaciers.

Without deepening in details concerning disagreements on this issue, one can send off anybody who wants to familiarize the brochure "Climate Change - Tragedy or Reality?" that is published by the SIC ICWC[51]. It reflects the views of both sides – so-called "panic-stricken" geographers and "glaciologists-sceptics." An opinion of the "skeptics" is based on the fact that field observations of runoff cannot specify clear relationships between the volume of glaciers and runoff for the entire past period. Amudarya runoff has not decreased in recent years, although the volume of glaciers has decreased.

The latest studies of the GFZ German Research Centre for Geosciences for the Naryn River basin, based on the regional climate model REMO, have shown seasonal variation rather than reducing runoff, since an increase by 400 million m3 in the spring-autumn period is compensated by decrease in 398 million m3 in the summer time.

It should be noted that the current climate changes that took place in the 20th century and continue today are negligible in comparing with the huge changes occurring under the influence of shifting Global Warming and Cooling Cycles on the Earth. The evidence of these fluctuations is the change in the world ocean level, which during the glacial period of the Earth, known as the Little Ice Age, which ended in the 19th century, was much lower.

[51] Available at http://www.cawater-info.net/library/rus/climatechange15.pdf

According to the US Geological Survey (USGS FS-002-00), the last ice maximum took place 20 thousand years ago, and the ocean level was by 125 m lower than the existing level. We live in the Holocene Era, which began 10 thousand years ago. Judging by the fact that in the previous epoch, the ocean level was 3-20 meters higher than the current one, the climate warming and, accordingly, melting of glaciers, the Arctic polar cap, Greenland ice sheet occurred earlier as well.

Long-term climate changes are caused by variations in solar radiation, position of the Earth's orbit and its axis, changes in the reflectivity of land and ocean surface, content of CO_2 in the atmosphere and many other factors that have their own oscillation cycles. As a result of their distinct combinations, the complicated trends that are not yielded to predicting the options for climate dynamics are being created. That is why there are different approaches to assessing climate change and its causes among scientists around the world.

At present, the increase in concentration of greenhouse gases in the atmosphere is considered as the main factor for climate change, and, therefore, the great efforts of humanity are focused on minimizing the releases of harmful substances into the atmosphere in the process of burning fuel, decomposition of livestock waste and other organic wastes. Another direction of controlling the concentration of greenhouse gases is the restoration of forests previously destroyed by people, including through forest fires, because the forest cover recycles CO_2 and reduces the negative human impacts on nature.

Over the past decades, the United Nations (UN) has taken a number of significant efforts to organize universal actions for reducing anthropogenic impacts: the Marrakesh Climate Change Conference, Montreal Protocol on Substances that Deplete the Ozone Layer, Paris Climate Change Conference and adoption of the Paris Agreement on Climate Change. In general, all of them have recognized the existence of real threats related to climate change and the need for emergency measures to reduce its impact. It is assumed that reducing emissions will allow keeping an increase in the Earth's temperature no exceeding 2^oC above the pre-industrial level.

Such a solidarity of both developed and developing countries and unity of humanism forces in fighting against destruction of nature and development of irrevocable processes that can cause a cumulative effect of disastrous consequences command respect.

It should be borne in mind those quite influential groups of climatologists (K.Y. Kondratev, Kh.I. Abdusamatov, B.I. Berry, and Academician A. Tishkov) are considering an anthropogenic origin of climatic warming as quite disputable.

They believe that the current trends of maximum temperatures reflect the end of period of natural climate warming and suggest a possible beginning of the period of climate cooling in the second half of the 21st century. A lack of accurate forecasts of future changes makes an assessment of possible positive or negative effects of climate change quite uncertain. Today, we can only talk about the relatively short-term trend, in comparing with the geological cycles on the Earth, and the need to adapt to its possible inertial development during the next 15-20 years at the most.

Nevertheless, the decisions adopted in the framework of the Paris Agreement and joint actions in any case should be considered as a positive step on the way of reducing the anthropogenic pressure on nature, even if they are aimed at overcoming a relatively short-term trend in comparison with the geological cycles. As mentioned above, considering the impact of current climate change on water resources and irrigated agriculture, we can confidently speak only about four types of consequences:

- increase in evaporation and, correspondingly, growth of water consumption due to rising temperatures;
- modification of natural climatic resources;
- possible (but ambiguous) changes in the river runoff in an absolute value, both in the direction of increasing and decreasing; and
- frequency and amplitude of extremal fluctuations of river runoff (as the most important effect).

Consideration of these expected changes allows developing necessary adaptation measures.

Increase in atmospheric temperature can affect the productivity of crops both positively and negatively.

Table 8.1

Effects of climatic factors (classification made by the authors)

Climatic parameter	Effect	Evaluation
Air temperature	Increase in a duration of the growing season.	+
	Earlier sowing time.	+
	Change in conditions for germination, phenological development phases and growth.	±
	Extreme high temperatures suspend physiological processes.	–
Air humidity	Evaporation rate modification.	–
	Changes in the conditions of moisture-heat exchange, necessary for each specific crop, improving the growth.	+
Precipitation	Soil moisture and air humidity creates a natural moistening, conditions for plant growth.	+
	Heavy showers can be a hindrance to shoots and agricultural works - crust formation on topsoil and rotting of the roots.	–
Air temperature, air humidity and precipitation	Increase in plant evapotranspiration.	+
	Changes in the processes of soil salinization.	–
Concentration of CO_2	Changes in the intensity of photosynthesis.	–
	Changes in forming biomass and crop productivity.	+

Due to warming in Central Asia, the altitudinal and latitudinal climatic zones are shifting. The boundaries between the dry tropical zone and temperate climate zone will shift north by 150-200 km, and boundaries between the rainfed farming zone and semi-rainfed agricultural zone by 50-100 km. Figure 8.2 shows that boundaries of shifting over the established limits (3, 5, 10, 12, and 15^{0}C) for Tashkent Oblast go down to mean annual values in Kashkadarya Oblast. This means that the dates of sowing of different crops are shifted towards earlier ones, and, in turn, it means an earlier beginning of the growing season. Thus, it can be stated with certain confidence that with the climate change, Tashkent Oblast located further north acquires the climatic features of the southern Kashkadarya Oblast.

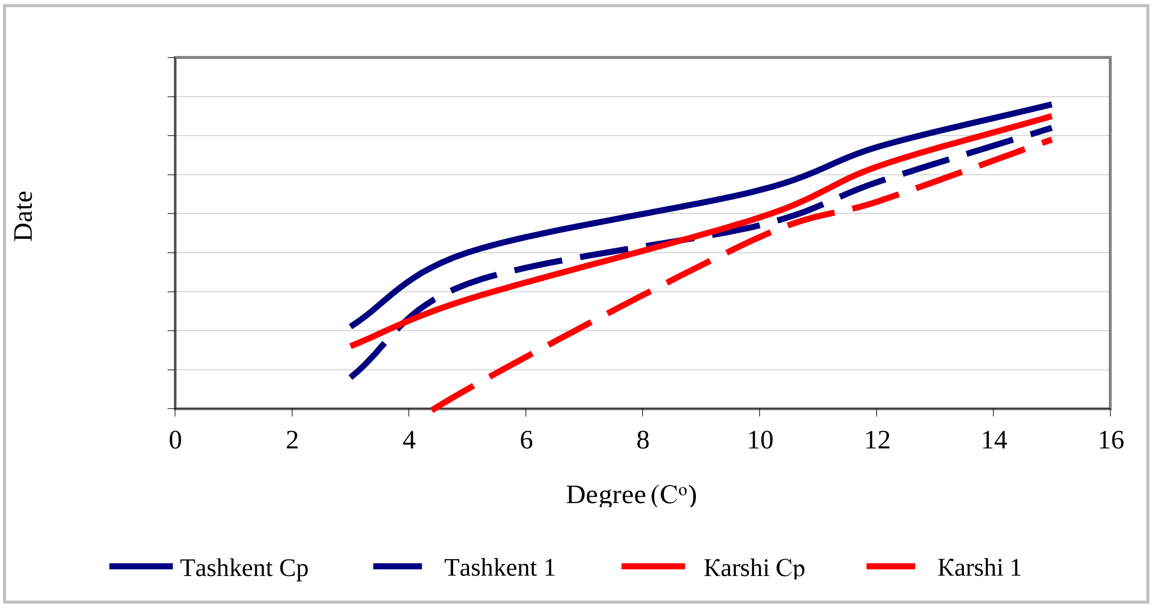


Figure 8.2 Shifting temperature values over the established limits (Cp – modern conditions, 1 – under conditions of climate change) according to the weather stations in Tashkent and Kashkadaya oblasts (in spring)

Figure 8.3 demonstrates that with climate change the autumn temperatures when shifting over limits specified for Tashkent Oblast are higher than the mean annual autumn temperatures in Kashkadarya Oblast. This shift in dates makes up 7 to 17 days. It means that with climate change the vegetation season ends later. Throughout the irrigated area of the region, a difference in dates when the temperature shifting over the established limits of 10, 15, 20^{o}C, in spring and autumn, amounts to 15-30 days on average. Climate change forces the agricultural specialists to revise the management principles under growing crops, especially cotton. In conditions of increasing air temperature and air humidity, the entire process chain must undergo some modification.

A main factor influencing the rate of plant development is the thermal conditions, the characteristic indicator of which is an average daily air temperature. A change in the phenological phases of plant development occurs when a necessary sum of effective temperatures is reached.

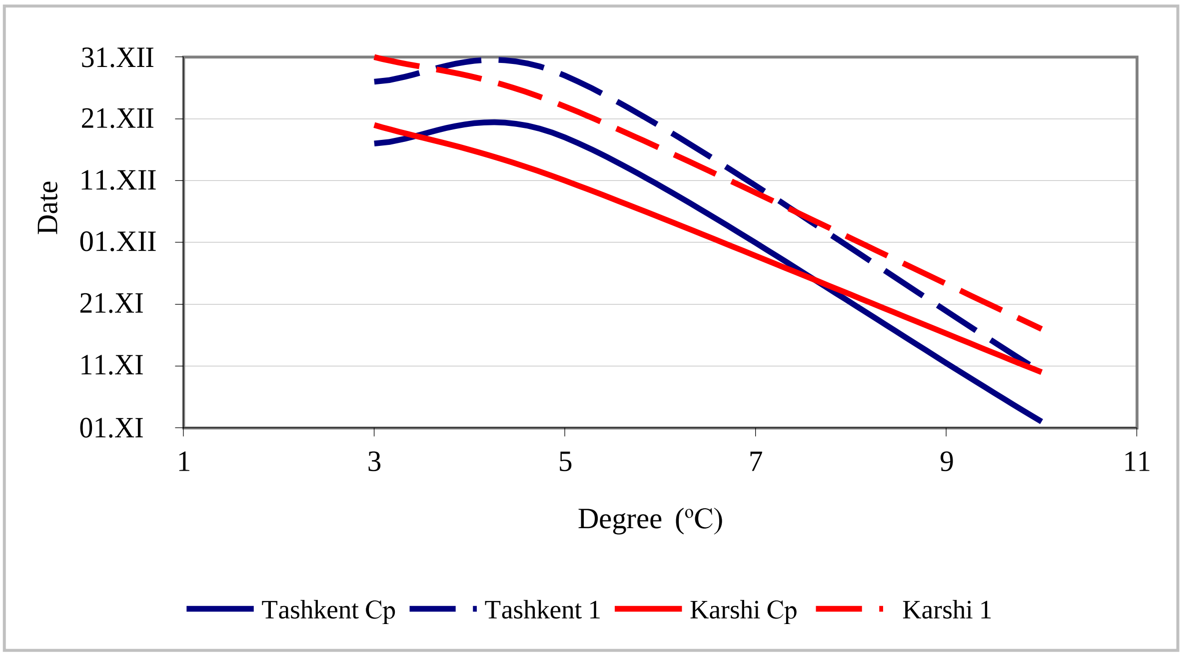


Figure 8.3 Shifting temperature values over the established limits (Cp – modern conditions, 1 – under conditions of climate change) according to the weather stations in Tashkent and Kashkadaya oblasts (in autumn)

An increase in temperature, as mentioned above, provides a longer vegetation season, while under the influence of climate change and modified agrometeorological conditions, a shift in the dates and rates of developing agricultural crops take place (reducing duration of phenological phases).

The latest research of G.V. Stulina and G.F. Solodkiy[52] in the Ferghana Valley and their comparison with the results of forecasts concerning temperature increase in the frame of three different climatic scenarios show a significant increase in the sum of effective temperatures and, accordingly, reducing the growing season duration (Table 8.2 and Fig. 8.4).

[52] Agricultural Sciences, 6, 834-847. http://dx.doi.org/10.4236/as.2015.68081

Table 8. 2

The sum of effective temperatures in different scenarios in comparison with the base period of 1961 to 1990

Year	> 5°C			> 10°C			> 15°C		
	A2	B2	REMO	A2	B2	REMO	A2	B2	REMO
2030	7-10%	10-15%	6%	7-13%	7-13%	8%	10-15%	10-15%	11%
2050	14-19%	14-19%	17%	15-20%	15-20%	23%	20-30%	20-30%	33%
2080	24-30%	21-27%	30%	24-29%	30-35%	40%	30-50%	30-50%	58%

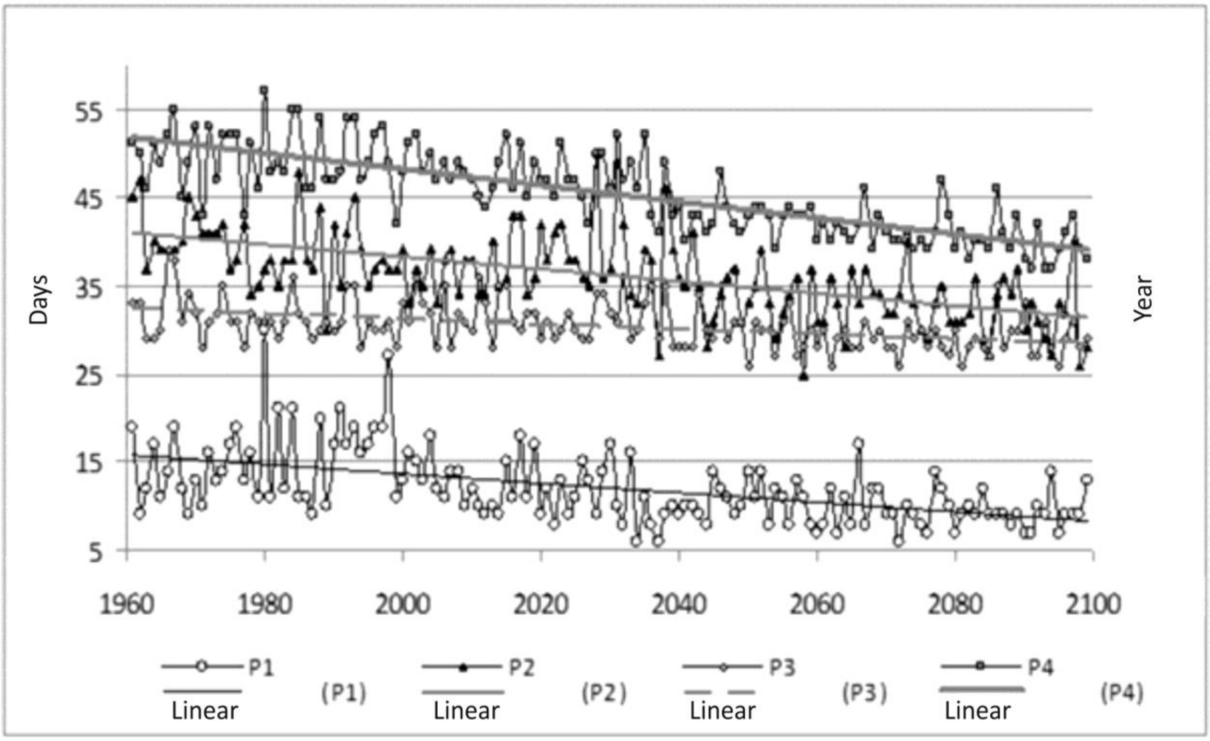


Figure 8.4 Dynamics of the cotton phenological phases' duration with temperature growth by the end of this century

These studies reveal not only the possibility of extending the period of crop cultivation, but also demonstrate the opportunities for reducing the irrigation water requirements due to reducing the number of days required for growing each crop. Despite the negative effect of higher temperatures (over 35°C), at which, as we showed in Chapter 1 above, cotton growth is inhibited, it is expected decreasing the evapotranspiration on 500 m3/ha by 2050.

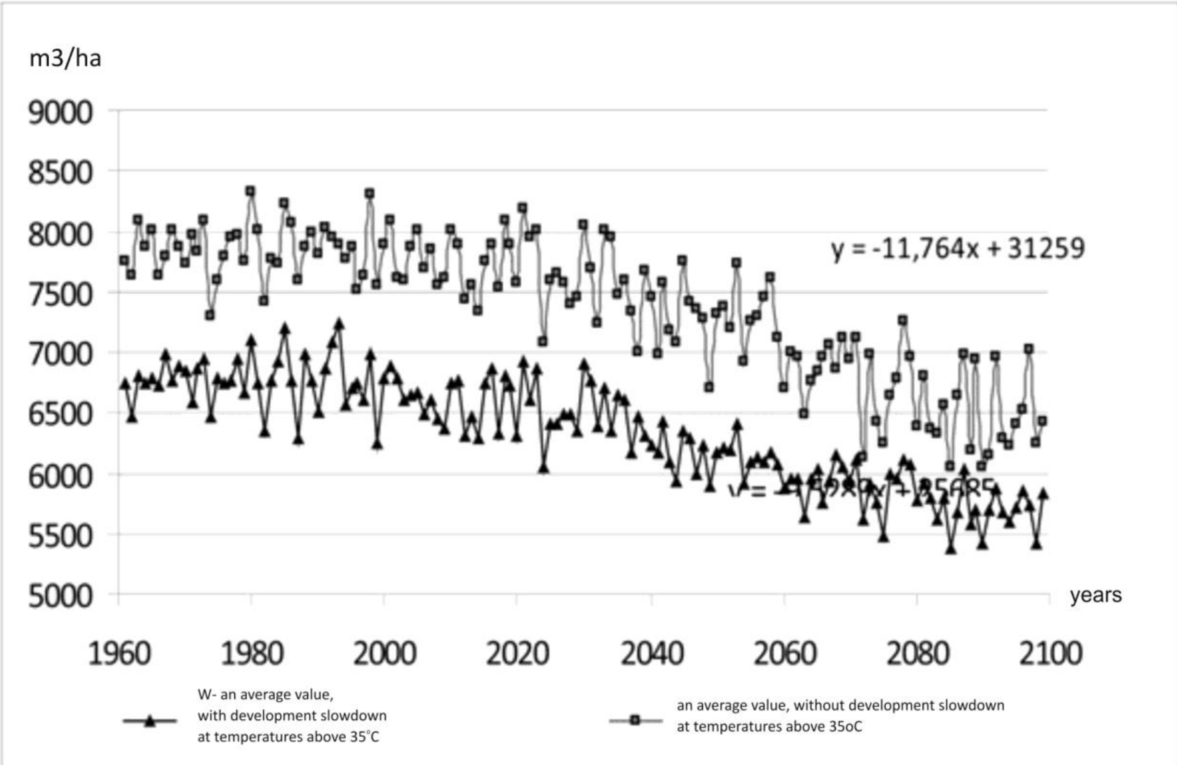


Figure 8.5 Reducing irrigation water requirement of cotton under the influence of shortening the vegetation season with/without taking into account a slowdown of cotton development at temperatures higher than 35°C

An elongation of the period for crop cultivation and reducing the growing season of a main crop considerably broaden the possibilities for growing double crops, in particular, various leguminous crops such as mung beans, peas, beans, which simultaneously produce nitrogen, due to the presence of nodule bacteria that assimilate nitrogen from air and improve soil fertility (Fig. 8.6).

Figure 8.6 Nodule-forming bacteria (azotobacter) on the field of interplanting pea crops[53]

It should be noted that the realization of this possibility is related to a new stage of improving the advisory services (*agricultural extension service*) for farmers and their associations by means of equipping their command areas with a network of weather stations (one station per 10,000 - 12,000 hectares) and organizing a constant adjustment of water consumption and plans of water delivery based on data on current climatic conditions recorded at these weather stations. Models for these adjustments have been developed and can be used on the basis of water requirement calculation (the REQWAT Model), data on the current agronomical and climatic situation, as well as weather forecasting. Outcomes of predictive calculations and recommendations to each farmer regarding each crop can be transmitted to farmers through mobile communication. Such an approach promises great water savings and simultaneously cost savings on crop growing. The main direction of adaptation to temperature rise, possible decrease in precipitation and increase in the frequency of extreme water events is water saving and introducing IWRM (Integrated Water Resources Management). The water saving system involves a wide range of measures that can be conditionally called as technological ones:

- optimization of the land reclamation practice using advanced drainage systems and water application techniques;
- agronomical techniques that enhance soil fertility;
- introducing advanced irrigation methods;
- establishing the system of planning water allocation and water use;

[53] Pilot plot of Dr. G. Stulina in the Fergana Valley

- reducing water losses based on coordination of activity at different levels of water management hierarchy (*water losses due to maladjustment between current water requirements and water supply practice; weakness of information mechanism for coordination, etc*.) and enhancing reliability and timeliness of water supply;

ensuring an appropriate level of monitoring of water supply and drainage water disposal with enhancing the validity of water accounting; and

- a more precise definition of water consumption norms and irrigation water requirements.

Our numerous experiments both in the framework of individual projects and on pilot plots have shown a quite wide range of possible water saving that, however, requires various and sufficiently large capital investments. The synthesis report, prepared by Dr. M. Khorst[54], demonstrates the considerable opportunities for selecting the most acceptable technological processes and design methods coordinated with cost indicators. The following two figures show the comparative values of water saving at two levels of the irrigation system efficiency - 0.77 corresponding to the current condition of the irrigation system, and 0.90 corresponding to the prospective condition of the irrigation systems.

The corresponding specific investments for introducing various types of water conservation systems are shown in Fig 8.9. At present, the introduction of capital-intensive water-saving systems of stationary sprinkling, drip irrigation and subsoil irrigation is unprofitable for farms when growing cotton but very profitable when growing gardens, grapes, vegetables and similar crops. Our recommendations on developing advanced irrigation techniques are based on such an approach.

[54] Horst M.G., Systematization of water conservation methods based on the experience of countries and previous project studies, Document prepared for discussion of the ICWC Working Group, 2015, 26 pages

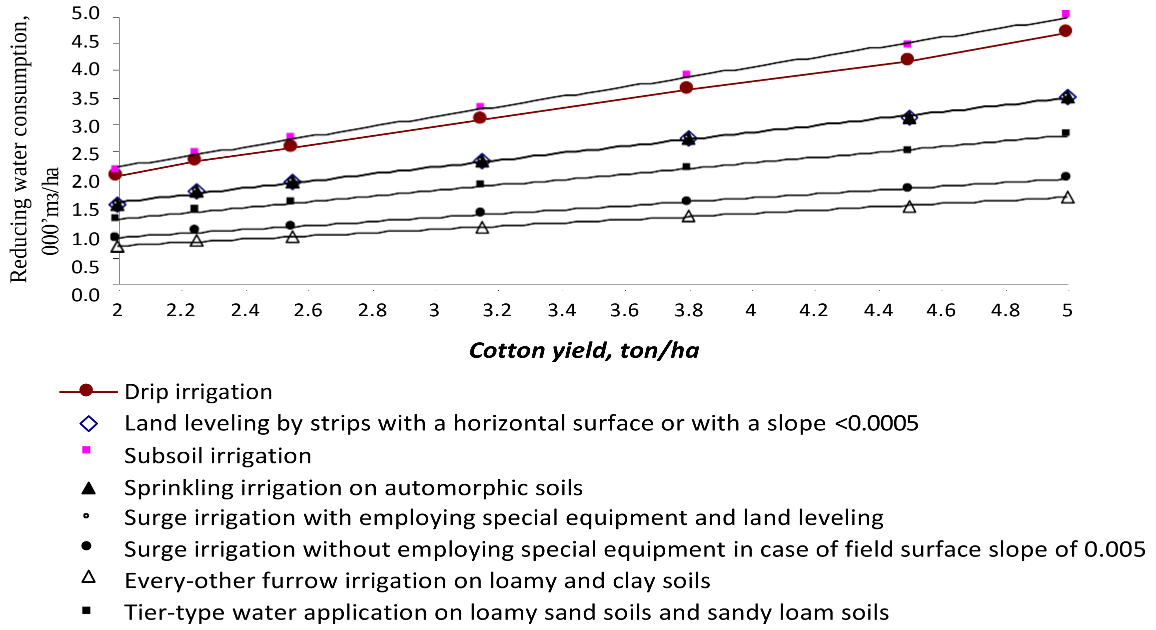


Figure 8.7 Water-saving indicators at the inlet to a farm (Irrigation System Efficiency = 90%)

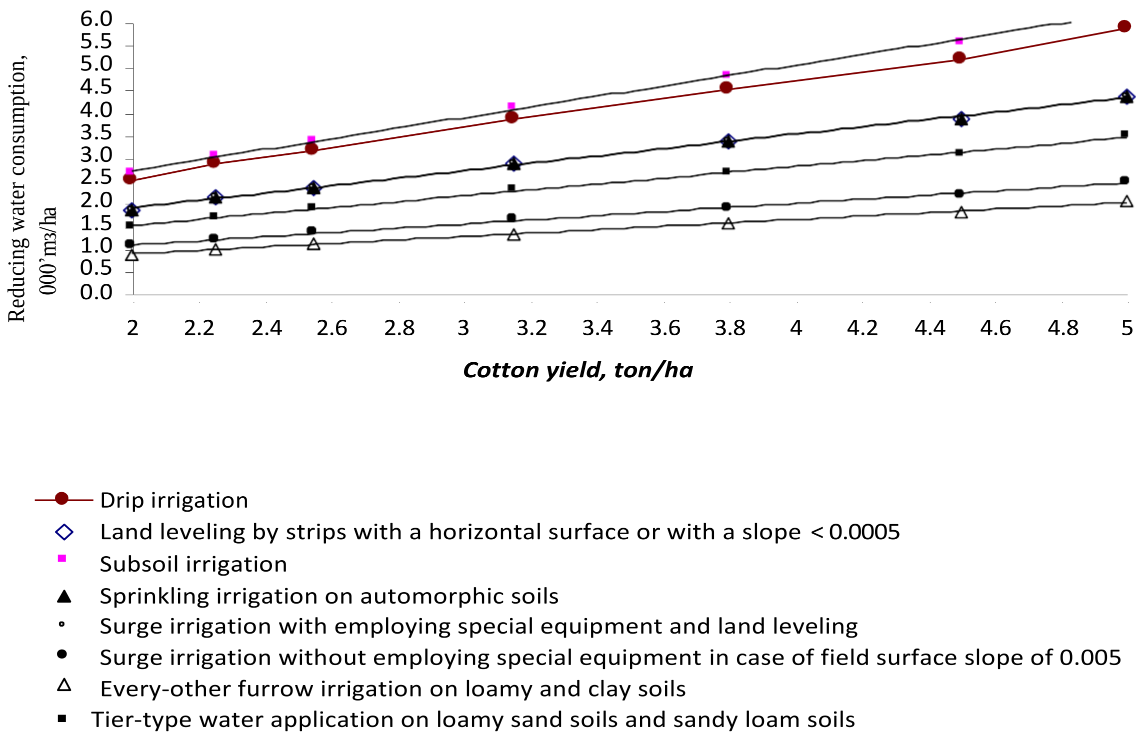


Figure 8.8 Water-saving indicators at the inlet to a farm (Irrigation System Efficiency = 77%)

Another promising direction for overcoming observed variations of water availability is the use of IWRM mechanisms (see Chapter 5). Forestalling the presentation of this system, nevertheless, we want to demonstrate its effectiveness in overcoming an essential water shortage in the Syrdarya River Basin in 2008. During the implementation of IWRM in the Ferghana Valley, we managed to organize the activity of all levels of the water management hierarchy including water users aimed at water-saving in such a manner that farms with the total irrigated area of 130,000 ha in three countries (Kyrgyzstan, Tajikistan and Uzbekistan) have come through 2007 and 2008 dry years without any complications. Although water supply has reduced by 21-25%, the agricultural output did not decrease at all.

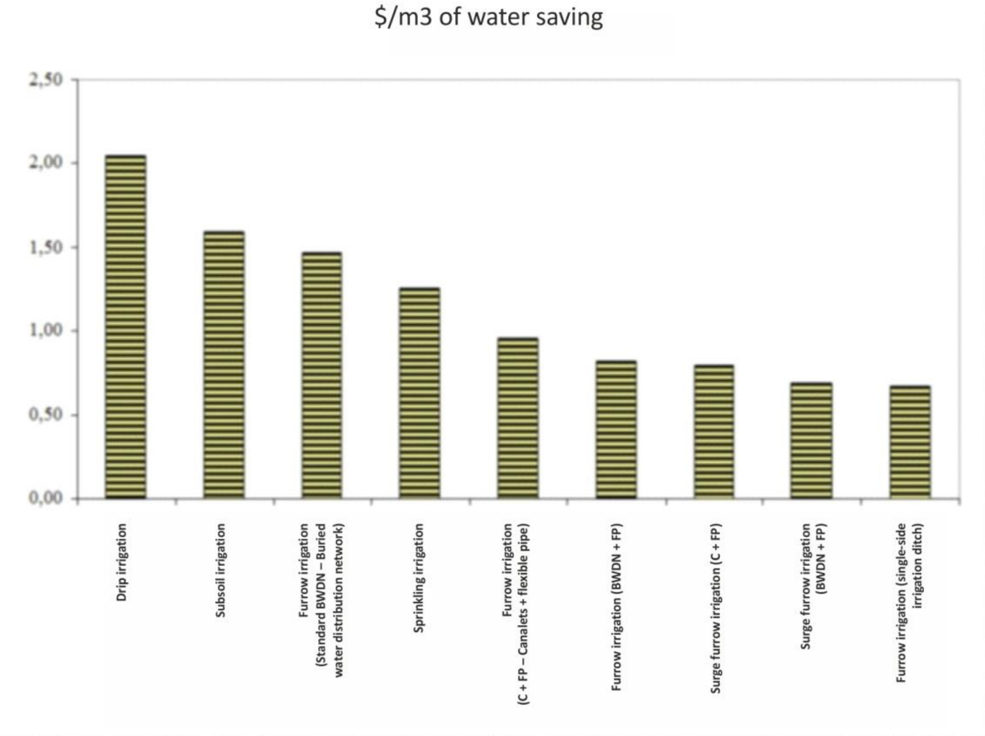


Figure 8.9 Investments required for receiving one cubic meter of water savings

The key tools were the following: revision of irrigation water requirements and irrigation schedules based on the adjusted water requirement zoning; organization of strict water accounting in the process of conveying water from the Canal Administration to WUAs, and from WUAs to farmers as well as public participation and appropriate activity of the Councils of Canal Water Users and Public Water and Land Commissions under the District Hakimiyats.

Particular attention was paid to the efficient irrigation schemes and techniques, as well as the rational technology of growing crops based on the recommendations of agricultural extension service. Along with abovementioned, in the water users' arsenal has contained utilizing drainage water, mostly slightly brackish water, as well as drought-resistant varieties of crops and double crops with azotobacter. The leading factor was the distinct planning of water delivery schedule, including a water rotation.

Finally, the third major technological measure to overcome the risks associated with climate change, namely, the increase in the frequency and amplitude of extreme water events due to variations in river runoff is the multiannual regulation of river runoff, the essence of which consists in the accumulation of river runoff in water storage reservoirs in wet years and planned water releases in dry years. Unfortunately, this is the very understandable and accessible measure related to the integrated use of water storage reservoirs and their cascades is becoming less feasible since they are often used with the priority of hydropower commercial interests. Power engineering specialists proceed from the purely market principle: accumulated water must be turned into electricity, and the faster this will be done the more rapidly profit will be put to turnover. From a financial point of view, this provision cannot provoke objections, excepting the profit that water users in the sectors of irrigation and water supply (as well as nature) will not receive if next year's or next years of shortage of water, which could be prevented, will occur. This provision should be provided for in the rules and procedures for managing cascades of water reservoirs, especially since they all were designed for the seasonal regulation of river runoff in the irrigation regime; and the Toktogul Reservoir is the storage reservoir of multiannual regulation.

Chapter 9. Water, Food and Energy Nexus – Innovation or Imitation?

This section was included in the prepared book because of the undeservedly wide dissemination of the fashionable notion "nexus." In its essence, it is devoted to one of the mandatory components of IWRM, which we have already considered in the chapter concerning IWRM – coordination of inter-sectoral interests of water users (horizontal links).

However, the modern lovers of new terms that are not so much discovering new knowledge, as are causing confusion over the existing clear notions, which were sufficiently proven by time and have received general recognition, and thereby they are creating the appearance of innovation activity.

For instance, the UN Economic Commission for Europe has prepared a collection of essays, in which this problem is examined using the example of three river basins: Sava, Syrdarya and Drina. Here, the nexus is considered as an opportunity for inter-sectoral integration, as a mean for supporting "green development," in order to enhance the resource use efficiency and for greater policy coherence. On the eve of the Bonn Conference, the “nexus” ideology was developed by the Stockholm Environmental Institute, which has presented the vision of improving the water, energy and food security based on a “nexus” approach that integrates management and governance across sectors and scales.

“*New approaches are needed, given that the overall costs of inaction are generally higher than those of pro-active adaptation, as the cases of climate change and biodiversity protection or land degradation demonstrate. More integrated policy- and decision-making that account for external costs across sectors, space or time (e.g. carbon leakage) will have to complement conventional approaches aimed at only improving sectoral resource productivity. This can lead to improved overall resource use efficiency, sustainable resource management and equitable benefit sharing. Because policy changes are often outpaced by the accelerated development, institutions need to be flexible, adaptive, and enabled to cooperate with institutions representing other sectors. In some cases new institutions may be required. Existing integrated frameworks, such as Integrated Water Resources Management (IWRM) or Integrated Natural Resources Management (INRM) need to be revisited in order to better resonate with requirements across various sectors. IWRM needs to evolve towards partnerships with water-using sectors whose policies and strategies are governed by many factors outside the water sector. There is a need for a coordinated and harmonized nexus knowledge-base and database indicators and metrics that cover all relevant spatial and temporal scales and planning horizons. Full life-cycle analyses across the nexus are also needed.”*[55] The main task consists in the enhancement of interrelationships between the economic sectors in time and space, reducing negative economic, social and environmental effects, obtaining additional income and guaranteeing the people's right to water and food. This approach should reduce competition and achieve synergy between sectors.

Based on the results of the 2011 Bonn Conference devoted this issue, the UNECE together with the German Federal Ministry for Economic Cooperation and Development, the International Food Policy Research Institute, the World Wildlife Fund and the World Economic Forum launched an on-line platform dedicated to this issue. It is typical that the text of this on-line platform opens with the following message: “*Coordination between water, energy, food and the environment fails due to difficulties at the national level, but the complexity is increasing much in*

[55] Hoff Holder, 2011, Understanding of Nexus. Background paper for Bonn Conference, The water, food and energy nexus/ SEI. Stockholm

transboundary basins where the influence spreads from one country to another.”

Statement of question of equating water, food and energy, per se, is wrongful - in my view, because a difference in their importance and the possibility of obtaining an alternative or replacing each of these pillars of human existence and development is too big. All people perfectly understand that there is no the substitute for water in all aspects of human life, and nothing can replace the functions of water in supporting the natural equilibrium and developing ecosystems. Confirmation of the significance of water is the current attempts by space agencies to prove the existence of life on the planet Mars. Attempts to find evidence of the presence or past existence of water on this planet are the single criterion for such a possibility.

Water is very important and significant component for food production, but the food problem is solved not only at the expense of water use, that is, through irrigated agriculture, fish farming, and aquaculture. Indeed, a share of food obtained based on water use reaches 50% of the total volume of gross demand, but in the future, due to the population growth and change in the diet to better meet the needs of the population this share will increase. According to the WESS-2013 (World Economic and Social Survey 2013), until 2050, investment needs for primary agriculture and its downstream industries to meet these needs will amount to USD 200 billion a year, mainly for the development and modernization of irrigation and aquaculture. Because the opportunities for intensification of other types of food production are limited. Therefore, the importance of food security is truly paramount, that is to a certain extent emphasized by the presence of almost one billion malnourished and starving in the world, according to FAO data, and also by the expected their increase due to population growth. Clarification of the term "vital human needs" given in the "Interpretative Statement," which accompanies the text of the 1997 UN Watercourses Convention, is quite valuable.

It notes that “*In determining “vital human needs,” special attention is to be paid to providing sufficient water to sustain human life, including both drinking water and water required for production of food in order to prevent starvation.*”

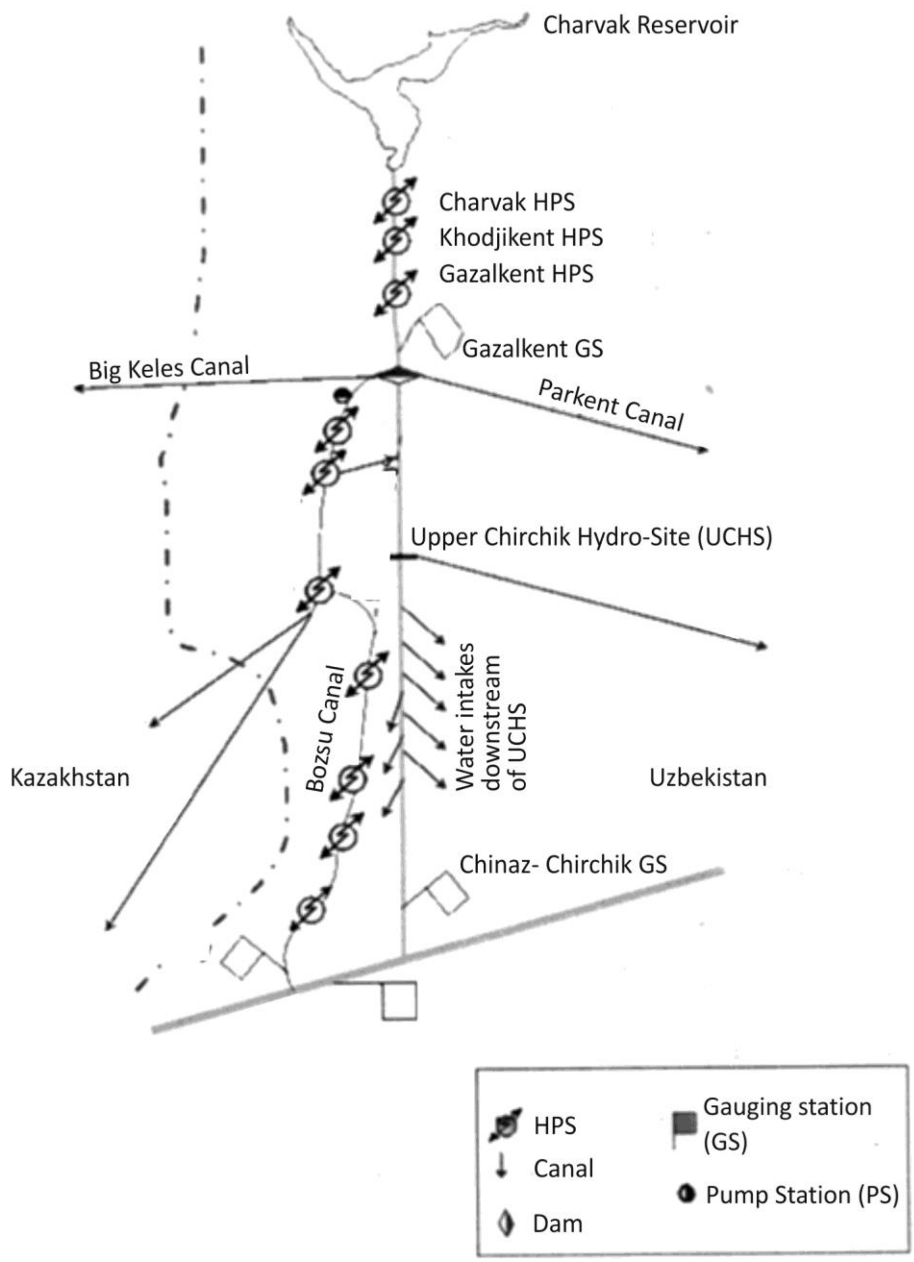


Figure 9.1 Scheme of the Chirchik-Bozsu HPS Cascade

As for power engineering, there are many methods of obtaining energy without using surface water sources (solar, wind, nuclear, tidal energy, etc.) or generation of hydropower, as by-product, without harm to other water use sectors, including ecosystems.

For instance, the development of small hydropower, which is based on using the flow of water without the construction of water storage reservoirs - the so-called derivational hydropower plants that practically do not change the river runoff and are not competitors to any other type of water use. An excellent example of such water use is the construction in the 1920-30s of the cascade of Chirchik and Bozsu hydropower stations in the Chirchik River Basin, which successfully operates for almost a century without creating any interference to other water users in the basin (Fig.9.1).

Moreover, all methods of generating electricity, including hydropower, are commercial activities that are subject to market laws. Water for human life and water for nature are not objects of bargaining, commerce, competition, and although water has value, price, production and maintenance costs, all this does not turn water into a commodity.

In general, the term "nexus," as a projection of the links between water, nature, food security and energy, represents rather misty notion, which misleads the public. The word "nexus" means not just a link or link chain, as interpreted in some publications, this word denotes a central link, hub, point or place where different things or ideas intersect.

Box 9.1

A nexus is a central link or connection. If you happen to be at the *nexus* of something, you are right in the middle of it, like standing in the middle of an intersection.

Nexus entered English during the seventeenth century from the Latin word *nectere*, meaning "to bind or tie." People tend to use this word to describe the point where different things or ideas come together or intersect. In the field of cell biology, a *nexus* refers to "a specialized area of the cell membrane involved in intercellular communication and adhesion," and implies that the *nexus* of a cell facilitates communication among the various parts and allows it to work properly.

Source: http://www.vocabulary.com/dictionary/nexus

In the above formulation presented by the Stockholm Ecological Institute, we see that this word has a meaning of any domain, in which all water use sectors are functioning. After incorporating themselves in the "nexus," some sectoral water users think that their sector is the center of water use. From this point of view, water itself is the "nexus" rather than any types of water use. The use of water for different purposes and by different sectors should be linked based on the principles of integrated water resources management, reasoning from the priority of use and the possibility for replacement, as it follows from the international water law.

Moreover, the authors of this approach themselves speak about the need to improve and revise IWRM in the direction of inter-sectoral coordination. Everyone understands the importance of linking inter-sectoral interests in the use of water resources that represents one of the seven characters or components of IWRM. It is not clear why it was necessary to single out this character in a separate direction of water management and to call it by the term that was unknown in water management practice heretofore, and which everyone can understand in his own way. In the UNECE collection of essays, which was already mentioned, the author of the presentation, Professor Mark Howells proposes to put the issues of hydropower and electricity shortage as a top priority in the Syrdarya River Basin. This meets the expectations of the country that produces electricity, but immediately comes into conflict with the needs of countries, for which water for irrigation, water supply and nature is a priority.

The search for consensus between sectors that use and consume water and, accordingly, the priorities related to water issues in riparian countries is conducted many years, and its goal is not to establish a "nexus," but seeks consensus among partners. This is also highlighted by Articles 5 and 7 of the UN Convention on the Law of Non-Navigational Uses of International Watercourses. The tools of this consensus are the Integrated Water Resources Use and Protection Schemes for the River Basins (IWRUP Schemes) or Master River Basin Plans, which assess the outlook on the basis of comparison of interests and needs and their socio-economic assessment. Applying the modeling methods allows comparing the alternatives and, using the Pareto method, establishing the limits for individual economic sectors and corresponding countries in the use of water for the future. At that, the vital human needs in drinking and food, as well as requirements of nature are taken as priorities. Such an approach is consistent with the requirements of sustainable development goals. The hydropower sector with its commercial interests and their variations in contrast to water supply for cities and settlements, as well as agricultural irrigation is not a criterion of sustainable development. A typical example is the operating mode of the Toktogul Reservoir over the period of wet years (2003 to 2006), when for the sake of commercial benefits the owners of the Naryn HPS Cascade released water in volumes much more than the possible 12.2 km3 per year needed to ensure over-year regulation of river runoff. As a result, in the following period of dry years (2007 to 20080, only the dead volume of water in the reservoir was maintained. In addition, Kazakhstan was subjected to man-made floods in the delta with an annual damage of US$15 million, which could be avoided under implementing the adopted recommendations (the Naryn Cascade Operation Rules that were developed by the Interstate and Inter-sectoral Working Groups established for the Syrdarya River Basin). Mark Berkman presented an interesting overview of attempts to use the "nexus" as a tool for bridging the gap between water requirements and water supply in the USA.[56]

[56] The electricity - water nexus: is a crisis imminent‖, Water Policy 17 (2015) 1163 -1175

Attempts to cover the water deficit using available surface and groundwater resources in the country failed and forced to seek other ways for covering the deficit at the expense of reusing waste water, cleaning them and only partially by water saving and energy conservation, that is, the ways, on which the "nexus approach" pins its main hopes.

The fact that the "nexus" itself does not **ensure** the tools and mechanisms for achieving consensus, is evident from the **proceedings** of the Mekong Regional Conference **held** in September 2014 at **the** Ubon Ratchathani University in Thailand. **F**or **demonstrating this fact, we use** the report "How the water-energy-food "nexus" in Asia affects real lives."[57]

"Dr. Dipak Gyawali of the Nepal Academy of Science and Technology highlighted how food, water and energy are running into each other's' limits in a relationship of what he called "entwined predicaments." He also pointed out that whilst at the family-level, these resources have always and necessarily been nexused in order to survive, associated expert knowledge has become fragmented and siloed. As a result, at scales above that of the family, the food, water and energy sectors have produced problems for each other. Dr. Gyawali explained that in part, there are institutional origins to this fragmentation, as government agencies responsible for food, water and energy seek to defend and expand their turf, and they have limited incentive for collaboration and integration despite some policy attempts to do so. In the Mekong River Basin, the energy sector considers the construction of dams as a priority, and the food problem is assessed by the extent to which a particular project affects it. In this regard, he asked whether the nexus will be able to do integration in a better way."

The participants of this conference came to conclusions that the concept of "nexus" refers to the relationship of forces of various organizations representing economic sectors, but it affects the lower level of stakeholders more negatively, because it is based on the priority of large consumers and their property rights. Without the common understanding and collaborative relation, the nexus cannot exist. The lessons learnt in Thailand shows that the infringement of one or another sector accompanies such multi-purpose projects. They initially lead to the need for compensation, which is determined partly and not always fully implemented, and that serves as a source of protests. An example of the Pak Mun Dam, where the value of electricity produced at this site was much less than the losses of fishermen was presented. Moreover, the dam design did not take into account the possibility of water abstraction for irrigation that results in pumping irrigation. There is a similar example for the Rasi Salai Dam. Wetlands, which supplied the local population with rice, fodders for cattle and medicinal plants, as well as sweet potatoes were drained up due to filling the

[57]Middleton C., How the water-energy-food "nexus" in Asia affects real lives. Center for Social Development Studies, 2015

reservoir. A loss of incomes very negatively affect the well-being of local community.

Finding of a consensus between these three sectors is not a technical or purely economic issue, it is a social problem. Hence, the question arises - what is primary: IWRM or "nexus," under which the authors, in fact, imply only one of the defining components of IWRM? Obviously, as it has been shown, IWRM and particularly the "nexus" approach itself that was taken out of context of the general understanding of IWRM, does not provide those results, which the authors expect from this approach.

Achieving inter-sectoral linkages, in addition to the aforementioned methods of comparative socio-economic modeling combined with the water management models (see, for example, the Aral Sea Basin Model, at www.asbmm.uz/index/php/), schemes and plans for long-term planning and analytical comparison of various options for sectoral use requires the involvement of various both national and basin or regional tools. These include, in the first place, the following:

- ✓ establishing the inter-sector and interstate working groups and their joint work on seeking the solutions most acceptable for all stakeholders;
- ✓ involving a wide range of stakeholders in the process of discussing possible solutions and their adopting;
- ✓ a set of measures for reducing the specific consumption of water and energy and increasing their productivity, along with measures to increase the productivity of land resources;
- ✓ introduction of the automated systems of water metering to reduce unaccounted organizational water losses;
- ✓ development of joint river basin knowledge bases and databases aimed at achieving inter-sectoral and interstate consensus, etc.; and
- ✓ the participation of countries and sectors in the full range of IWRM activities that fosters integration aspirations among all participants of its implementation process (it is the very important aspect).

However, the main precondition consists in the presence of political will among all countries for seeking a consensus and ensure transparency of the organizational and political measures being implemented, as well as the existence of trust to each other.

At the same time, the "nexus", in that form as its proponents recommend its use, can be a useful approach if it is viewed as a reflection of existing links in the triangle "water - food - energy" and search of the ways for possible consideration of feasible interaction.

They are numerous and diverse. If we consider the link "water - energy", then besides the participation of water component in the exploration, extraction, processing and purification of organic fuel, water is obtained as a by-product in the process of petroleum purification - 1 liter of water for every 4 liters of petroleum. Water is used to grow biofuel components and when they are converted into real fuel. Hydropower creates specific needs in water, and in addition, pumped-storage units require additional amounts of water. Reservoirs for hydropower plants facilitate eutrophication of water bodies. In turn, the power industry needs water for cooling, transport, distribution and frequency control. The water desalination processes are related to large electricity consumption.

An even greater amount of electricity is needed for the operation of pumping stations that lift huge amounts of water to great heights, such as the Karshi cascade of pumping stations with a flow rate of 250 m3/sec and a height of water lifting of 180 meters. Thousands of vertical drainage wells are pumping groundwater from various depths to maintain the optimal groundwater table. At the same time, water and energy have much in common, for example, in creating the welfare of the population as the decisive elements of the quality of life, as decisive factors in economic production, whose deficits restrain development.

Both are key factors of production capacity and economic competition. Their development and exploitation are quite capital-intensive, and they can therefore compete both within each economic sector and between these sectors. They also represent high-tech specialized areas that require a high educational level of personnel, and its high responsibility under control of social (public) institutions, despite the professional specificity.

Irrigation, although involved in the production of 45% of world food, consumes 70% of the world's water resources. It is also the largest polluter of surface waters and groundwater. At the same time, it consumes a large amount of energy, especially modern methods of water application: sprinkling or drip irrigation. Especially energy-intensive irrigation by underground waters is widespread in India, where investments in energy supply of water wells and transfer pumping stations make up almost 30% of irrigation investments and where the national government via states' budgets subsidizes up to 50% of farmers' costs for power. Fertilizers, which increase the land resources productivity through enhancing soil fertility, are produced based on the hydrolysis process that requires a large consumption of energy. Fertilizers application adversely affects the quality of water sources due to discharging return water from the fields. All technological processes related to preparing fields for crops, cultivation, primary and subsequent processing of output require a lot of water and consumption of different types of energy. The use of wastewater and brackish seawater for irrigation is the process that also requires a lot of energy. These are high technological and capital intensive processes that could compete with water and energy sectors in terms of necessary knowledge, labor potential, and capital intensity.

Thus, the triangle "water - food - energy" has the right to exist, taking into account the specifics of development and functioning. Above all, there is always a certain priority of water use for need of man and nature, and it is also possible the priority of one of leading sectors that is determined by the specifics of national development within national river basins or by the consensus between neighboring countries in transboundary river basins.

Chapter 10. Transboundary watercourses – peculiarities of their management[58]

As we saw in the chapter devoted to IWRM, water resources management itself is a rather complex process even within a single country. This is due to the fact that water resources management is carried out at several levels of the water management hierarchy. It is of a multi-sectoral nature and subject to strict linkage and coordination, in order to avoid duplication and overlapping in the decision-making process related to development and management, and avoidance of water losses at the junction of isolated institutional units and unnecessary costs, accordingly, as well as loss of physical and financial resources. At the national level, these issues can be easier linked by governmental decisions and regulation that are based on the same directivity and principles, and by the appropriate coordination mechanism in the form of the unified state body for water policy or governance or the National Water Council.

In conditions where river basins are used by two or more countries, the situation becomes more complicated. Transboundary (or international) watercourses represent any surface water bodies or groundwater, which designate or cross the borders between two or more states, as well as are located on such boundaries. According to recent estimates of the UNEP, there are 283 transboundary river basins worldwide, which are shared by 151 countries.[59] Almost half of the terrestrial parts of the globe is served by these watercourses. The procedures of interacting the countries on such water bodies is specified, as a rule, by the agreements between them, which differ in great variety according to both the purposes of cooperation and the conditions and organizational forms of their interaction. Information exchange agreements usually represent the initial form of their interaction, but they are very important, as they forms the basis for building

[58] The chapter was written together with Dr. D. Ziganshina

[59] UNEP-DHI and UNEP (2016). *Transboundary River Basins: Status and Trends*. United Nations Environment Programme (UNEP), Nairobi.

up trust between riparian countries.

Such agreements, for example, were signed between Kazakhstan and China regarding the Irtysh River, as well as between Germany and Czech Republic regarding the Elbe River. The Agreement on Lake Victoria is devoted to the joint conducting the scientific researches of biological and hydrological processes. A more advanced form of information exchange is the systems of joint flood prevention and forecasting, similar to those that were established by Hungary, Romania, Slovakia and Ukraine in the Tisza River Basin. Financing granted by Hungary, the model developed by Slovakia and data presented by all countries allowed creating the interstate forecast and early warning system that has shown its worth during a number of floods, enabling to reduce losses for all participating countries, especially Ukraine. The Agreement on the Danube River provides for the procedures for interaction of riparian countries in case of extreme water events.

The most comprehensive agreement on shared waters was signed between the United States and Canada in 1909. The history of this treaty dates back to 1903, when the United States and Canada established the International Joint Commission to resolve possible disagreements over the use of border rivers and develop common rules for their use. In 1907, the Commission prepared a draft agreement, which during the negotiation process was transformed into the 1909 Boundary Waters Treaty, devoted to the joint management and rules of cooperation between the United States and Canada with respect to the boundary waters.

The treaty establishes not only a clear and understandable definition of "boundary waters" but also the rules for joint navigation on these rivers and access to their waters. The treaty involves measures and conditions to limit impacts on the boundary waters and gives the International Joint Commission (IJC) powers to lay restrictions in order that the use of water and its pollution in one country could not harm another country. Neither Party can use or divert the volumes of water that can change the natural runoff without the authorization of the IJC. *“An International Joint Commission of the United States and Canada is composed of six commissioners, three on the part of the United States appointed by the President thereof, and three on the part of the United Kingdom appointed by His Majesty on the recommendation of the Governor in Council of the Dominion of Canada.”* At that, any proposals of Parties are jointly considered. To a certain extent, the IJC is the supra-state organ in its nature in terms of the full powers and responsibilities of its governing bodies. The IJC reports for the Governments of the United States and Canada on special issues requiring resolution should be based on "the best available science and be free of political prejudices." The treaty provided for a parity system of financing all activities and responsibility for preventing transboundary pollution. In 1996, at the meeting of the commissioners - members of the Joint Board of the International Joint Commission -

with members of the Interstate Coordination Water Commission of Central Asia, they unanimously noted that such a text of the Treaty would never have been signed in the current political conditions.

The reason is that the treaty gives the commissioners of the IJC great independence not only from local authorities, but also from federal governments.

A major study by the IJC set the stage for the coordinated development of water resources in the Columbia River basin. Principles recommended by the IJC for sharing flood control and electric power benefits also helped the two federal governments negotiate the 1961 Columbia River Treaty. Developing and operating the dams in a coordinated manner produced greater benefits for both countries. The Treaty has come in force in 1964. The Treaty has defined the rules for establishing a regime for river flow regulation for the purposes of protecting against flood and electricity generation. A degree of fairness of water distribution in the Columbia River Basin is estimated by the equality in meeting economic interest of both countries, as well as compensation to the Canadian Party for the lost electricity. It is noteworthy that, although the Treaty of 1964 does not directly regulate maintaining aquatic ecosystems and water releases for fish, the Parties are always seeking opportunities to meet these needs.

The Treaty requires the annual drafting the "Mandatory Operational Plan" for Canadian storage reservoirs with the purpose of achieving optimum energy generation indicators and flood protection in Canada and the United States. This allows the authorized bodies of both countries to propose the more favorable regimes, which provide, in addition to electricity generation and flood protection, protection of fish, recreation activity and other benefits. At present, both Parties are considering the possibility of amending the 1964 Columbia River Treaty to take into account the changing needs, including the maintenance of ecosystem functions, climate change, as well as the interests of indigenous peoples.

It is very important that the IJC ensures public participation in the decision-making process on water management and affecting environmental issues. For example, the Commission has recommended the Governments of the Parties take into account the public needs in jobs in the framework of the Great Lakes Water Quality Agreement.

Although mankind is facing with use of shared water resources by two or more countries for thousands of years, until the early 1960s, there was no the universal document that would systematize basic principles and norms of the international law with regard to the use of transboundary waters. The International Law Association, established in 1954, has undertaken the first attempt to codify the norms of international water law that had been developed by that time.

A reason for starting this work was a series of serious international disputes, which arose after 1945, in particular, between India and Pakistan concerning the Indus River, between Egypt and Sudan concerning the Nile River, between Israel and its neighbors concerning the Jordan River, and which have mainly emerged from the contradictions between countries located in upper reaches and lower reaches. After working over twelve years, the Committee on the Use of Waters of International Rivers established in the framework of the Association, later known as the River Committee, has managed to formulate the first recommendations in this direction, which were agreed upon by the Association in 1966 and entitled "Helsinki Rules" (“*The Helsinki Rules on the Uses of the Waters of International Rivers*"). Their value cannot be underestimated, since they for the first time systematized the customary norms of international water law, and their content was clearer and more specific in some issues than the content of subsequent international documents. First of all, this applies to the notion of "an international drainage basin" that is a geographical area extending over two or more States determined by the watershed limits of the system of waters, including surface and underground waters, flowing into a common terminus. Detailed recommendations aimed at implementing various articles of these rules, in particular, the model rules concerning a conciliation commission that is appointed for the resolution of disputes or guidelines for establishing the international commissions in the field of water resources are also of great importance.

The Helsinki Rules laid the foundation for many bilateral and multilateral agreements, including development of two global water conventions: the UN Convention on the Law of the Non-navigational Uses of International Watercourses (New York, 1997) and already mentioned the UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes" (Helsinki, 1992).

The first Convention was adopted by the UN General Assembly on 21 May 1997 and entered into force on 17 August 2014. The UNECE Convention was adopted by the Senior Advisers on the Environment and Water Problems of the Governments of the UNECE Region on 17-18 March 1992 and entered into force on 6 October 1996. After 17 years from its entry into force, the UNECE Convention has acquired the global nature, and any UN member state can join it. As a result, the world community of transboundary water users and water consumers has received general rules for their actions and should commensurate their agreements and treaties, and most importantly their own behavior, with this international water code.

These documents provide for clear rights and responsibilities of states, how to organize their activity focusing on the possibility of joint, fair and equitable use of shared waters. No matter how these waters are called: transboundary water resources, international watercourses, shared waters or some another term, these conventions specify the general procedures for users of such waters.

And the essence of conventions lies in the main message - do no harm to your neighbor, use the water on your own territory so that water use and nature in neighboring transboundary countries are not affected. Both Conventions, to some extent, complement each other - the UN Convention focuses more on planning events, specifying the procedures for planned measures and provisions for organizing cooperation. The second Convention is more focused on observing the environmental rules under interaction with countries in transboundary drainage basins. A particular strength of the UNECE Water Convention consists in the presence of a strong and developed institutional mechanism to support countries in the implementation of its provisions and their development, which includes the Meeting of the Parties, the working and subsidiary bodies and expert groups, the Compliance Committee, etc. This institutional basis is conditioned by a framework nature of the Convention, which provides for that the general principles and norms contained therein should be specified and detailed in the form of various recommendations, guidelines and other tools of so-called "soft" law. Such a collective forum, where all stakeholders can exchange their views, experiences and problems, is an important platform allowing to clarify all ambiguities in the application of international law norms. Moreover, as shown in the review of recent decades' trends, developing and strengthening modern international law take place mainly at such platforms, where representatives of countries, the general public, sectoral ministries and experts can jointly work.

Both documents have three general provisions:

- commitment to cooperate;
- obligation “do no harm”; and
- obligation of reasonable and equitable use of water (or watercourses).

It is understood that these general provisions should be specified and detailed in the agreements on individual watercourses. However, despite the fact that almost a third of the an international drainage basins should be managed in the framework of interstate agreements, only less than a dozen basins fall under treaties and other regulatory instruments, which contain strict and clear rules for managing and using water in such difficult conditions. A significant part of the treaties suffers from the lack of a well-founded regulation for reservoir operation regimes, compliance with ecological water releases, allocation of water under ordinary and extreme conditions, terms of financing and economic relations, especially reparation of damages, as well as for dispute resolution.

Such a state of affairs creates a certain instability in the water security, because there are opportunities to “bypass” disputable or not always exact provisions of existing legal documents. It should be noted that the negotiations on transboundary waters and, accordingly, preparation, signing, and approval of the agreements on transboundary waters at the parliamentary level are very complicated procedures. “*The main problems in managing these shared resources are rooted in the differences between riparian countries in terms of socio-economic development, water use objectives, political orientation, and administrative and management capacities to nationally manage water.*”[60] This process, like all relationships concerning international watercourses, has a very emotional nature, because it is always a convenient occasion for manifestation and demonstration of both nationalist tendencies, as well as views and approaches based on realities and understanding of the necessity and inevitability of collaboration and search for consensus. This is especially evident with the arrival of new national representatives into the inter-state organization established for transboundary waters management, because every new national leader or chief of water management organization, at first, tries to demonstrate that he loves his homeland more than his predecessors. Add to this the situation in parliamentary circles, where tendencies of protecting the national interests, as they understand these interests, always predominate over the aspirations of rational decision-making aimed at enhancing inter-state cooperation. Many deputies, unfortunately, do not always understand the subtleties of water policy and management, but often seek to demonstrate a commitment to protecting national sovereignty and interests, not in the general human sense, but based on personal momentary interests. Sometimes, the media, which use the slightest excuse to pressurize the situation and create "tempest in a tea cup," are playing a negative role in water issues. All water relationships are always on the verge of mutually exclusive interests, which are easily portrayed as “grains of conflict.”

From water allocation and maintaining flow regimes on large rivers up to the distribution of water through a small canal, the competition in terms of quantity, quality, "allocation" or operational regime always takes place. However, this stresses the need in creating a platform for discussion, search for mutually acceptable solutions and joint implementation of necessary measures. Adherents of the theory of conflicts and analysts in the field of water relations (*A. Wolf, M. Zeitoun, M. Patrick and others*) stick this position. They emphasize that "*a conflict does not block the opportunity for solving problems, but on the contrary a conflict or the likelihood of its occurrence make us seek a lasting solution to the problem.*"

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[60] Dan Tarlock, Promoting effective water management cooperation among riparian nations, GWP TEC Background papers, No21, 2015, page11.

In their daily practice, water professionals constantly resolve conflict situations. We must put ourselves at a place of our opponent and try to find solutions, considering positions of both sides. However, one must be frank: counter-interests at the interstate level, especially inter-sector ones, are developing into an international confrontation, when ambitious aspirations prevail over reason. This is especially true for situations where commercial interests are combining with the desire for economic and political dominance of some countries over others, as in the case with the lop-sided development of the countries in the upper catchment areas with a high energy potential, when the aspirations to obtain significant benefits from the use of hydropower potential contradict the principles of justice and rationality, as well as the rule "do no harm." The question arises: where are the “roots” of such a behavior? Let's try to understand this issue.

a) The international water law does not provide clear prescriptions for the use and management of individual transboundary watercourses, but provides the basis for peaceful interaction and outlines permissible behavior, which is differently interpreted by various countries. For example, each country interprets the fundamental principle of international water law "fair and reasonable use" in its own way, whereas it would be more productive and constructive to come to a joint decision, which is fair and reasonable for any given international watercourse, taking into account all relevant circumstances and factors.
b) A role of geopolitical hegemons in these issues is largely negative. Since the moment of voting in 1997, the United States and China reject the UN Convention on the Law of the Non-Navigational Uses of International Watercourses. In addition, by all their actions, China, in respect of water resources of the rivers Mekong and Irtysh, and the USA, to a lesser extent, regarding water resources that they are sharing with Mexico demonstrate the priority of their own interests. Moreover, the world leaders openly support this kind of behavior of their wards: the USA - Tajikistan and Ethiopia; China - India.
c) The commercialization of water bodies and hegemony of monetary interests, which are now prevalent in the world, especially in Asia and Latin America, dramatically reduces the possibility of a fair and efficient use of water in the interests of riparian countries and nature. Owners of hydropower facilities strive to receive their profit as much as possible and as quickly as possible. In these conditions, there can be practically no question of long-term regulation of river runoff as a means of overcoming effects of climate change and associated increase in extreme water events. At all times, the ownership and management of dams and water storage reservoirs on a river have given the key to water resources of the entire river. Pinning of own position on the river by individual countries based on commercial interests, loans or agreements with countries located out of the river basin allows ignoring the interests of neighbors. Management should be joint and neutral, regardless of commercial interests.

The experience of the United States and Canada gives the only correct decision - to separate the owners of water storage reservoirs from the owners of hydropower plants; and, moreover, the owners of hydropower plants should pay to the owners of water storage reservoirs for the volumes of water releases and never have the right to dictate the regime of these water releases. They are established by water organizations in agreement with all stakeholders of the river basin.

d) The role of donors and International Financial Institutions can be positive: the Indus Waters Treaty (1960) concluded between Pakistan and India under the World Bank's pressure, patronage and guarantees is a good example. The Asian Development Bank adheres to a fairly objective line in its operational guidelines and affirms loan terms, only when the project construction is coordinated between riparian countries. Previously, the World Bank has also adhered to this line of loaning, but likely that a new commercial paradigm has become to determine the current approach of the World Bank that supports constructing large hydropower plants, even if there are categorical objections of riparian countries. This can be traced in the new Bank's strategy adopted in July 2013 and participation in the construction of a power transmission lines from large disputable hydropower plants in Ethiopia, Kyrgyzstan and Tajikistan. At the same time, some donors, which support opponents of the Water Convention, unreasonably oppose to the idea of cooperation. Often, international donors' principles go counter to the international water law. Such a flirtation in the style of "double standards" is astonished by its inconsequence and is counterproductive in general!

e) Another "root of evil" is the counteraction to the exchange of information and creating the basin knowledge bases. Although some success in this direction has been achieved in Europe due to the implementation of the European Water Directive, but, in general, a rule exists: those who want to become hydro-hegemons hinder the open exchange of information, especially on-line, or, in the last resort, provide pre-adjusted data. Creating barriers for the open and transparent exchange of information between countries on snow storage in the mountains or for exchanging data of monitoring at gauging stations does not allow organizing the effective water resources management. Such a behavior of some countries should be seen as a threat to the future survival of mankind and severely suppressed at the global level through UN instruments and mechanisms.

Free access to information should be regarded as a "litmus test" for the readiness of countries, governments, and individual agencies to cooperate. Ensuring cooperation, which should be supported by a number of procedures and mechanisms of interaction between riparian countries is considered as one of the most important provisions in the international water law.

We approached the most fundamental issue that specifies the degree and nature of cooperation, interaction and joint participation in the management and governance of transboundary waters use, which is largely determined by the availability and effective operation of joint bodies.

Available documents on founding the joint international organizations do not define in the rigid manner how they should formulate their goals and objectives, and only are advisory in nature. The guidance on establishing the international water resources administration, an attachment to the Helsinki Rules[61], recommends to determine the validity period of such an organization, its form, decision-making procedure, governing body, composition and representation of riparian countries in the organization, ownership and operated facilities, powers and responsibility.

It is very important to have a clear definition of the scope of activities, boundaries of responsibilities and linkages with national stakeholders, as well as well-defined functions. They may include the exchange of hydrological, technical and/or socio-economic data, which can be accessed in the common services or in each country; advisory, coordination, planning and regulatory functions; inspection, monitoring, co-management and conflict resolution. A mandatory condition for functioning of such administrations is clear definition of sources and procedure of financing, equal or some other order of representation and a degree of participation of riparian countries in such bodies.

[61] Guidelines for establishment of international water resources administration, in the International Law of Water Resources, by Slavko Bogdanovich, Kluwer Law International, 2001, page 257.

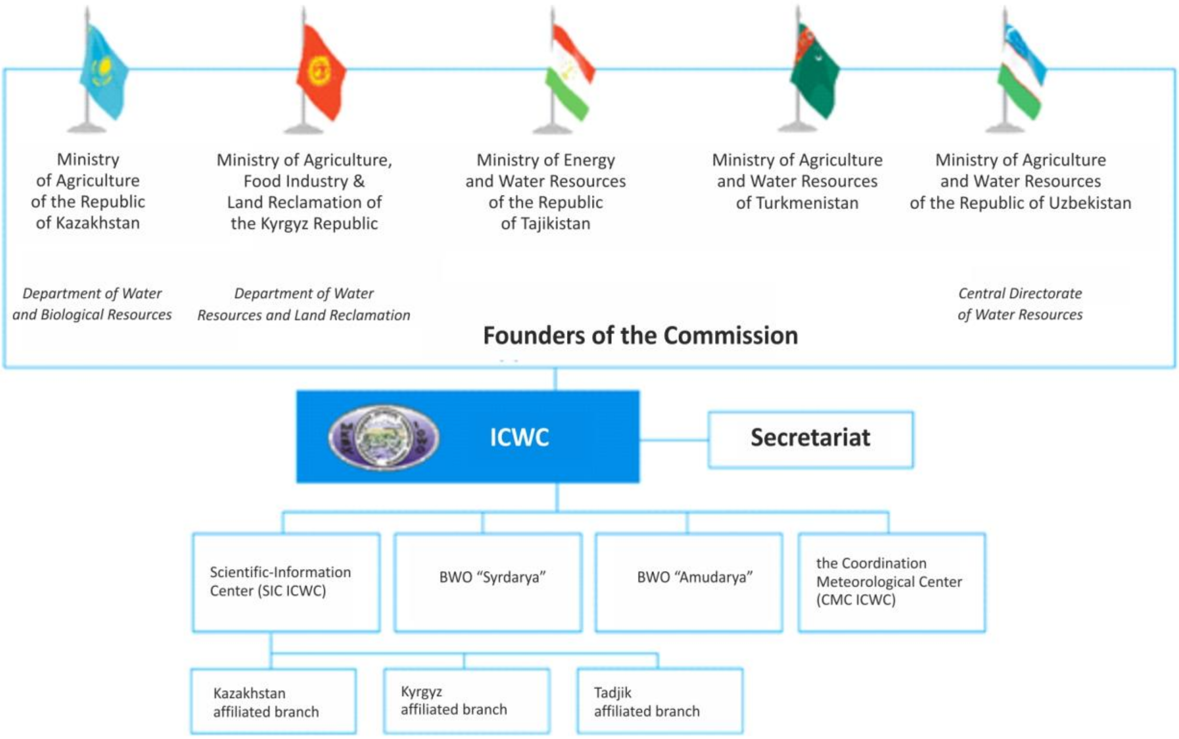


Figure 10.1 The organizational structure of the Interstate Coordination Water Commission of Central Asia

A degree of centralization can be quite different - from the Commission, which will be busy in only informing the participants about the planned or proposed actions and exchanging information within a limited scale (for example, activity of the Kazakh-Chinese Commission until recently) towards the Commission or Committee that assumes full or partial responsibility for management and development of transboundary waters.

Five Central Asian countries (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan) have undertaken just such an attempt in 1992 after collapsing the Soviet Union, when they immediately decided to establish the Interstate Coordination Water Commission (ICWC) of Central Asia.

By inertia and in accordance with governance principles of the single federative state, the attempt was made to entrust most of the powers on joint water resources management in the Aral Sea Basin to the commission that was established based on the Agreement of March 18, 1992, being signed 5 months after the independence.

The Agreement stipulated not only the democratic nature of the relationship, the equal participation of the water departments of each country with one vote under decision-making regardless of a size of water withdrawal and financial contribution, as well as the condition of "consensus" for making any decisions, but also a wide range of activities from planning, operational management to implementation of monitoring and regulatory functions aimed at the long-term development of water resources. At the first stage, during the initial decade of cooperation, the Commission fulfilled its tasks, ensuring conflict-free management, distribution and monitoring of the basin's water resources, despite the presence of dramatically dry years and disastrous wet years. Moreover, the ICWC has initiated establishing the higher level bodies for interaction of riparian countries in the field of water resources management and sustainable development, such as the Interstate Council for the Aral Sea, which subsequently merged with the International Fund for the Aral Sea (Fig. 10.1). The Commission and its executive bodies have developed certain procedures for planning and distribution of water resources on transboundary watercourses based on river runoff forecasts, taking into account the water allocation limits. The presence of two inter-republican basin administrations (BWO “Amudarya” and BWO “Syrdarya”) with trained personnel, premises and some necessary equipment at the moment of the independence has substantially facilitated arrangement of Commission’s activity.

The procedures for reporting, daily and ten-day operational analysis, as well as constant monitoring of the interstate water sources were developed. Over last 25 years, the Commission is working on continuing basis and in unified manner, addressing the issues of annual and seasonal water allocation, operational water resources management, and exchange of information.

Establishing the higher-level organ has provided the political platform for regional cooperation and, at the same time, initiated creating the separate regional bodies in the form of specialized agencies, covering sustainable development (the Interstate Commission on Sustainable Development (ICSD) that integrates environmental agencies and water protection organizations), hydro-meteorological services (the Regional Centre for Hydrometeorology), mountain landscapes, etc.

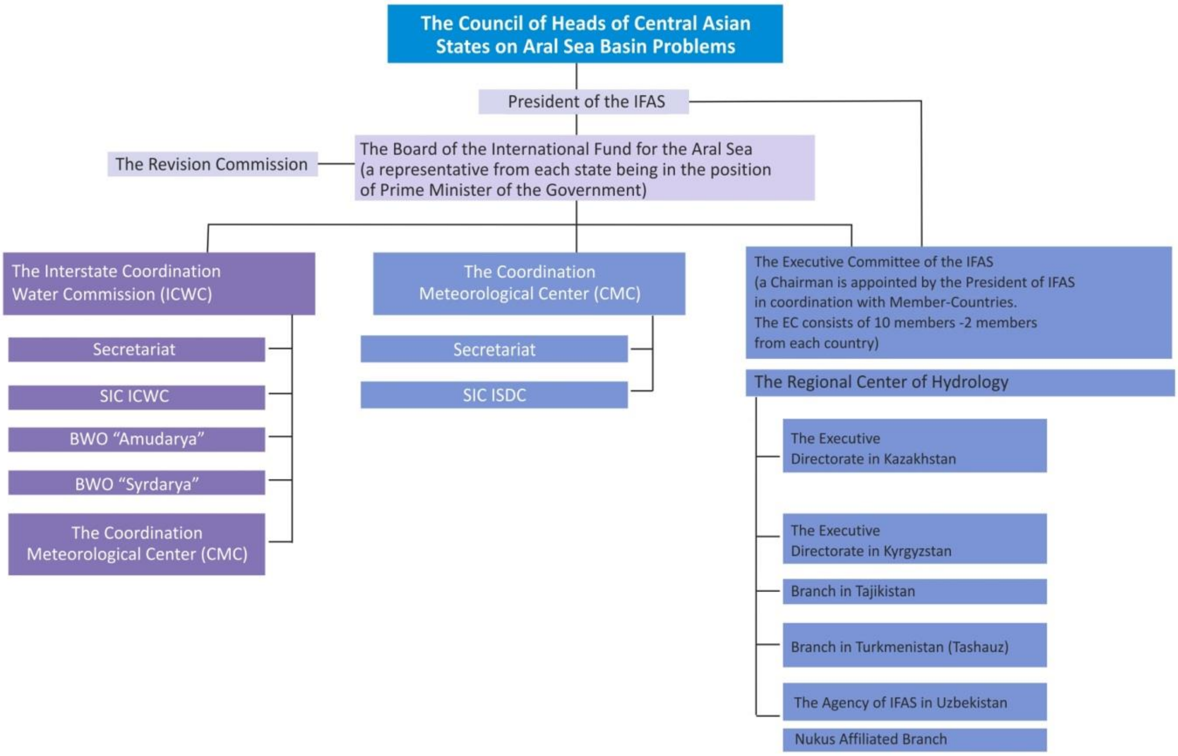


Figure 10.2 The IFAS organizational chart

In addition, on the initiative of international donors, the Regional Environmental Center was established, which, in fact, is the agency acting in parallel to the ICSD. Such an approach, taking into account an inadequate mechanism of coordination, only makes more complex the issues of long-term development, leads to dissipation of resources due to overlapping of functions and, simultaneously, triggers bilateral actions owing to arising centrifugal tendencies.

In these conditions, the ICWC activity, especially related to prospective development, has become more complicated. Since, riparian countries could not avoid frictions and growing contradictions in subsequent years due to both the changed political and socio-economic situation and owing to the shortcomings of the established legal framework.

Figure 10.3 One of the meetings of the Interstate Coordination Water Commission

The unclear formulation and insufficient coordination of the mechanisms for implementing the provisions of signed agreements, their inconsistency with requirements of the joint administration and, most importantly, differences in the national priorities and, consequently, in future investments have led to the current state of transboundary cooperation in the Aral Sea Basin, which leaves much to be desired.

The most important condition for successful cooperation is the political will of riparian countries located in one river basin and their desire to develop the cooperation in order to achieve the mutually beneficial compromises and to follow the jointly adopted decisions. It is very important to support constant attention and follow the spirit of signed agreements, main provisions of which are coordinated at the highest level, so that a feeling that any Party is avoiding cooperation will not arise. In water relations between riparian countries, it is very important to throw “fuelwood on a fire” of the water cooperation policy on the constant basis.

These can be joint decisions for water-saving, improvement of water quality, synchronized actions to improve an accuracy of water accounting, assistance in addressing inadequate water availability or flood prevention, etc.

At the same time, nothing is such a conducive motive for rejection of partners from each other as attempts to gain one's own benefit at the expense of the partner or unpunctuality in implementing the agreed decisions or even boycott of the disputable issues' discussion. Therefore, it is necessary to support and cherish collaboration of riparian countries.

The world practice presents us an excellent example of a high-level partnership between countries, based on an exclusive ethic of water use and respect for the needs of partners and nature. We have repeatedly pointed out the experience of the International Joint Commission of the United States and Canada. At the end of 2014, the Governments of the United States and Canada have jointly approved the Plan 2014 as the preferred option for regulating Lake Ontario-St. Lawrence River water levels and flows. This plan has become the result of 14-year scientific study with public engagement conducted by both Parties with involving the provinces of Quebec and Ontario and the State of New York. Based on studying the experience of 50-year operation of the entire water complex, it was exposed that the work sequence in accordance with the Plan of 1958 has resulted in damage of the lake shoreline and degradation of 26,000 hectares of wetlands. Joint researches of the two countries, for which USD 20 million were spent, have provided an opportunity to involve in the discussion of the problem all stakeholders in the river basin, including municipal officials, representatives of native nations, shipping companies, fishermen, as well as representatives of recreation, cultural, tourist, ecological and economic sectors. As a result, the Plan 2014 has received general support, and was approved at the level of federal governments of both countries.[62] In contrast to the current practice of the Rogun HPS Construction Project, when only one country that is interested in the construction project, and the hired external designers have participated in expert assessment without involving representatives of potentially affected countries, in case of the Plan 2014, the joint comprehensive examination and approval were implemented.

As mentioned above, one of the key tools is a set of **legal instruments** that define the obligations of Parties, procedure of their interaction, clear indicating on rights, list/parameters of mutual services and information. It may be agreements, protocols, memoranda, rules and procedures that are agreed upon and signed by all stakeholders. It is important in order that these documents could be substantiated as thoroughly as possible, and taken into consideration all the possible situations, not only in the ordinary conditions but also in emergency situations that may arise in the process of water resources management due to the variability of hydrological, climatic and economic conditions.

[62] Report to the Governments of Canada and the United States by the International Joint Commission, 2014, Washington, Ottawa

The more accurately predicted and thought out possible situations, the more likely it is that pre-determined solutions and prepared **procedures** and **rules** will be used in the real circumstance. It is important to have a well-developed system of measures and actions in the form of certain guidelines for making systemic decisions to avoid spontaneous actions of executors, when there is not much time for thinking, but it is necessary to act promptly.

In the context of a tried-and-true system, which ensures confidence in its sustainability, even actions of an employee of little experience cannot lead to catastrophic errors. A number of severe accidents, like at the Sayano-Shushenskaya HPS, underscores the urgent need in clear operational rules for extreme situations, as well as their imitation in the training process to rise the readiness level of personnel for actions in case of accidents. The next tool that can and should provide joint preparation of various documents, decisions, plans and programs is the **formation and activity of working groups** involving the representatives of national and basin stakeholders and creating a sense of implication of all participants in the process of preparing the responsible decisions or joint projects and measures. This is especially useful in case of continuous work of the same representatives, since it allows providing consensus and understanding of the partner's problems in the process of joint seeking solutions. An excellent example is the exceptionally fruitful activity of working groups under the International Joint Commission of the United States and Canada, which we described above, when it addresses the issue of collateral use of the Columbia River's waters or develops the new agreements on the water quality in the Great Lakes.

Information exchange, establishing joint information systems and their accessibility to users, while ensuring the transparency of data collection and formation, are the indicators of cooperation extent and serve to its enhancing. This concerns information on the flow regimes of watercourses, their regulation and compliance with the planned and agreed water allocation plans, as well as monitoring water use so that partners can become convinced that each contracting party complies with the requirements of fairness and validity of its practice and does not infringe on the interests of other party. This provision extends to the forecasting service and analytical reports that help to find solutions in difficult water management situations. An information system can consist of various thematic databases and knowledge bases of general use, as for example, the information system of ICWC "CA Water-Info," which serves a huge number of quite different users - from water professionals to scientists and even popular mass media. Up to 10,000 users visit regularly this regional information system on the Internet that emphasizes its popularity and informativeness. Currently, GIS maps and remote sensing imagery are accompanying electronic text information.

According to the experience of the Central Asian region, an important tool for cooperation is the basin or regional training system, which allows collectively developing common approaches, joint understanding of problems, and reaching a consensus in the process of training activities. Thanks to the method of iterative training, when participants from different riparian countries sit at the round table, discuss the examples of best practices and commensurate them with their tasks, this approach allows everyone being included in a joint discussion of pressing and future problems. This gives them an opportunity to understand each other's requirements and positions and develop joint solutions that are acceptable to all. Those who study together will work together, and will never interfere and harm each other.

The same, if no more, consolidated influence exerts joint implementing **the regional projects, which contributes to long-term interaction of partners in the framework of specific practical actions** and facilitates synchronized implementation of activities aimed at increasing the efficiency of water resources use or improving the water resources management, or introducing innovative approaches. This creates an orientation to the same criteria, common goals and objectives and helps to fulfill them in spite of a certain competition in the interests. In such conditions, as in no other, a team spirit is formed. We were the participants, and not only eyewitness, of such a joint work in a number of projects but it was especially successful, as mentioned earlier, in the IWRM project in the Fergana Valley. Here, we have managed not only jointly to develop principles of integrated water resources management adapted to local conditions, but also to implement them, having achieved water resources savings of 200 million cubic meters per year on the territory of four provinces of Kyrgyzstan, Tajikistan and Uzbekistan. In the process of implementation, there was a constant exchange of experience and results between the republican and regional organizations, which also contributed to an increase in mutual understanding.

Finally, another important tool is **participation in financing** of the interstate bodies and interstate events. It is important to achieve fair participation of partners in joint costs corresponding to their share of using transboundary waters, their interests or claims to benefits. Using the example of ICWC activity in Central Asia, one can see that this tool is very delicate. A predominant contribution of Uzbekistan and Kazakhstan, based on the largest share of transboundary water use, led to the deployment of most regional organizations in these countries, and hence to criticism from other countries regarding uneven placement of these agencies. At the same time, the direct contribution of two countries located in the zone of runoff formation to financing of the basin bodies was insignificant, if not to say zero, although they constantly express displeasure with equal participation in all ICWC decisions. These very sensitive issues require a balanced approach and especially its careful execution.

The entire previous text of this chapter is mainly devoted to surface water, although many of the above provisions apply to transboundary aquifers. Such a situation was primarily caused by the much smaller practice of interstate relations regarding groundwater, frankly speaking, the reluctance of many countries to consider groundwater as shared with other countries, although, in fact, their aquifers are of transboundary nature. This fact has reflected in the quantity of available agreements between countries concerning groundwater use, which currently does not exceed one dozen, including agreements that deal with both surface and groundwater.

The decision of the UN General Assembly, at its 63rd session, with recommendation to riparian countries to use the legal instrument on transboundary aquifers that was developed by the UN International Law Commission in 2008 and finalized in 2011, gave some impetus to developing the practice in applying the international law concerning these waters.

Of course, the ascertainment of boundaries and useful groundwater resources of transboundary aquifers is more difficult task than in case of surface waters, because a more precise definition of dynamics and origin of groundwater, bearing in mind their replenishment on the territory of each state, requires the multi-year exploration using complicated geophysical methods. An assessment of dynamics of qualitative indicators, their role in ecological equilibrium and possibility of obtaining alternative solutions, taking into account interactions with surface waters, is the more difficult task. In the future, this section of international water law should be additionally elaborated taking into account the technical aspects and practical law enforcement.

In conclusion of this chapter, it is necessary to focus on the inevitability of cooperation on transboundary waters. Cooperation is gaining in the special importance due to the present circumstances related to quite unpredictable future because of climate change, growing needs owing to population growth and changing social welfare, as well as financial and geopolitical instability. Proceeding from this, on the one hand, the orientation to immediate one-sided benefits can turn into great losses in the future, and, on the other hand, mutually beneficial decisions that enhance the interaction effect can always be found in co-operation and collaboration.

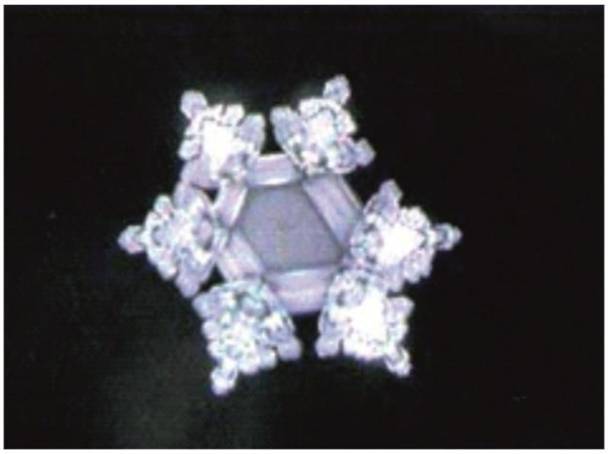
Chapter 11. Water and Ethics

What is ethics? There are many definitions, but one thing is clear: it is one of the forms of social consciousness, the system of moral principles regulating human behavior, including cultural development and the relations between man and nature.

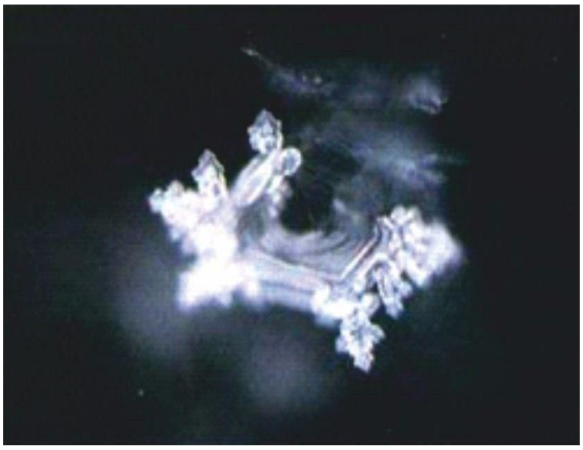
Prior to the beginning of industrialization and global human impacts on the environment, the main ethical direction was represented by the rules of human moral behavior, human mutual relations, rules of social and family relations, aimed at preserving humanity in God's world. With the development of production, business and financial relations, the corresponding ethical norms within these spheres of activity have received “a start in life.” Issues of the relations with nature were almost not considered, because human intervention in nature was insignificant.

Religion, which always represented a set of ethical rules, basically did not concern the rules of human behavior in relation to nature in general, and water in particular. Nevertheless, as noted in Chapter 3, the oriental religions, primarily Zoroastrianism and Islam were an exception. Given that they originated in the arid zone, they have recognized not only the unique role of water and obligated to keep it clean, but also developed certain rules for water use, which have not lost their relevance even now.

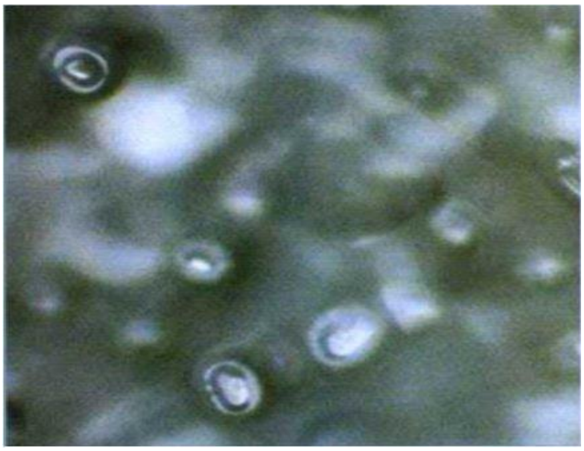
For example, one can mention the requirement of equality in water delivery, determining a sequence of water use on irrigated land from the end of irrigation canal, inadmissibility of refusing to give drinking water to a traveler or a caravan of wanderers in and so on. Shintoists (a special faith in Japan), who, since ancient times, already knew about the unique feature of water - its memory and demanded to preserve it, behaved toward water most reverently, as an element of the deity. Indeed, one of the most unusual and mysterious properties of water is its ability to remember and store any positive or negative information. Water has a cluster structure. There are a lot of clusters combinations: beautiful, harmonious, destroyed, and ugly. Words, thoughts, feelings have meaning and are themselves information. What this information carries: good or evil; creation or destruction. This phenomenon, although the Japanese knew about it for a long time, was investigated and described again by Japanese scientists in the second half of the 20th century. Below you can see the photos of different structure of water depending on information that was "heard" by the fluid.



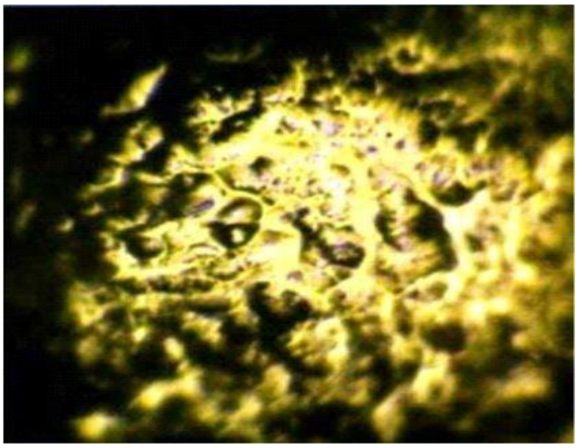
Water from a holy source near Lake Chuzenjiko



The same water treated with chlorine



Tap water from London



Tap water from Bangkok

Figure 11.1 Pictures of different water structure

Let's compare - the water from holy sources looks like an image of precious stones, and at the same time, the water treated with chlorine or utilitarian tap water in general has the form of torn figures with an unpleasant configuration and color. Understanding of the sanctity of water, its uniqueness and necessity refers to it with particular attention as to a subject that must be preserved for the sustainable existence of life on the Earth, and not just for the production of some kind of goods and satisfying people's vital needs, has created the need for absolutely new ethical rules, especially taking into account great threats that appeared for the future of water caused by the peculiarities of modern society, its stratification - catastrophic poverty at one end, and unrestrained striving for profit on another one.

Drastically increased opportunities of scientific foresight and analysis of emerging global trends have made it possible to draw a picture of tremendous degradation of the natural complex and, primarily, of water resources, which threatens the future survival of mankind. In this respect, it is necessary to note the special importance of the scientific forecasts of the famous Club of Rome (1960-1980), which predicted the loss of almost half of humanity by the second half of the 21st century, while maintaining the existing selfish tendencies in the development of society and the economy. Such a situation has required a change in ethics, to some extent, which is already happening.

Several global events have initiated this process, primarily, the United Nations Conference on the Environment of 1972, as well as activity of the World Commission on Environment and Development (WCED) under the chairmanship of the Prime Minister of Norway Gro Harlem Brundtland. Considering causes of the critical ecological situation in the world and finding ways to eliminate them were adopted as the basis for WCRM activity. The main conclusion of the Commission consists in the need to achieve sustainable socio-economic development, in conditions of which decisions at all levels would be made with full consideration of environmental factors. Survival and further existence of mankind determine the world, development and state of the environment. The slogan of this Commission: *"We do not inherit the Earth from our ancestors; we borrow it from our children!"* has become the basis of modern ethics in relation to nature and, consequently, to water.

The World Water Council, UNESCO, the International Water Association and the World Commission on the Ethics of Scientific Knowledge and Technology, established with their participation, have made a great contribution to developing the principles of water ethics.

Issues of water ethics are closely related to development of the law. The water law has existed since ancient times in the form of Ancient Egyptian Water Regulation (3400-2650 B.C.), Mesopotamian Water Regulation (the Hammarubi Code, 2492 B.C.) and later on Romanesque Water Law (753 B.C. to 565 A.D.).[63]

However, in recent decades, the right of human to water has gone the way from a norm of moral and ethical content towards the legal norm enshrined in national laws of many countries and in the international documents. There are a number of UN documents that allow talking about international protection of the population's rights to water.

In particular, General Comment No. 15 on the right to water, adopted in 2002 by the UN Committee on Economic, Social and Cultural Rights, determines the following "*The human right to water entitles everyone to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses.*

[63] Caponera, Dante A. Principles of water law and administration, Balkema, 1992, Roterdam, 260 pages

An adequate amount of safe water is necessary to prevent death from dehydration, to reduce the risk of water-related disease and to provide for consumption, cooking, personal and domestic hygienic requirements.” In one of the basic documents of the international water law of the UN Convention "On the Law to Non-navigational Uses of Transboundary Watercourses" (1997), Article 10.2 provides for the following “*In the event of a conflict between uses of an international watercourse, it shall be resolved with reference to articles 5 to 7, with special regard being given to the requirements of vital human needs.”* The Statement of Understanding annexed to the 1997 Convention clarifies that “*sufficient water to sustain human life, including both drinking water and water required for the production of food in order to prevent starvation.”*

Nevertheless, a vast distance has to be overcome from the proclamation of the right to water to its real realization. On this way, not only national legislation that determines the guarantees of water rights for all the above-mentioned needs at the national, provincial and local government level needs to be developed, but, most importantly, the mechanisms for its implementation must be elaborated, including rules for equitable water distribution, responsibilities for transferring water to each other at different levels of the water management hierarchy, financial support for these rights, the corresponding obligations of water users and water supply authorities. Compliance with these mutual obligations is one of the most important life-supporting signs of ethics.

As we saw in the previous chapter, elaboration and complying with the rules for using **transboundary** water resources are especially important for the realization of water rights.

Here, we are again faced with an ethical question - the reasonable and equitable use of such waters. The fact is that with regard to the use of all natural resources, there is a provision on the territorial sovereignty of their use. As applied to water, this provision is interpreted by many politicians, as a full right to use all water resources that are formed on the territory of any country in its own interests. But then, there arises a conflict with both above-mentioned conventions. Unfortunately, the comments on international conventions do not give clear recommendations on how to understand the terms "reasonable" and "equitable" use of water. From the standpoint of "absolute sovereignty", any use of waters that are formed within the national borders will be considered by the country as " reasonable water use." However, "equitable" use should be evaluated by neighboring riparian countries, to what extent they are satisfied with the decision of the initiating party.

On the other hand, the criterion of equitable use should be based on another provision of the abovementioned conventions - the obligation “not cause damage.”

Let's consider the situation related to regulating runoff of such rivers as Amudarya and Syrdarya after the independence, the countries of upper catchment - Kyrgyzstan and Tajikistan - have changed the regime of flow regulation from the summer option, mainly in the interests of irrigation, as was envisaged in the project documents of the Soviet period, to the winter option in the interests of self-sufficiency in electricity. As a result, in summer, the countries located downstream do not receive 3.5-4 cubic kilometers of water in the Amudarya river basin and 3-6 cubic kilometers of water the Syrdarya river basin respectively. From the positions of upstream countries, such a change is "reasonable" and "equitable." However, from the positions of downstream countries, this decision is unfair, since available water resources for use in the interests of irrigation have considerably reduced. The task of modern jurisprudence is to develop objective criteria for "reasonable" and "equitable" water use. Thus, the requirement of an equitable and reasonable approach to water based on the international water law is also an element of water ethics.

In general, despite understanding the sanctity and uniqueness of water as a source of life and development by all individuals and organizations involved in water resources management and use, the practical actions of each entity are determined by its vital interests, current tasks or even the necessity of solving problems with least costs. Here, the pressing tasks come into conflict with future requirements, which can be solved only on the basis of a culture of relations between individuals that are restricted by certain ethical rules. As shown in Chapter 2, already in the first millennium of our era, our predecessors developed such provisions, especially in Moslem countries where they were expressed in ayahs.

Today, in order to strictly follow the norms of this well-deserved attitude to water, it is necessary to elaborate the industrial, agrarian, and municipal rules of water use in detail, as well as strict regulations for water resources management and allocation. However, it is even more important to cultivate understanding the value of each drop of water in all citizens of our planet since childhood. In this regard, one says that it is possible to assess a culture of man according to his reaction on water flowing from an open tap of a water riser on the street. A gentleman will turn off a tap, a carefree man will ignore this fact, and slacker will turn on it much more! Therefore, it is necessary to learn every person that all taps, when they are not in use, should be closed; and when they are used they should be opened for the minimum necessary flow rate. Unfortunately, little attention is paid to this issue in children's institutions and at schools, if at all. In 2003, with the assistance of one donor, we received a small grant and together with the Ministry of Education of Uzbekistan organized a survey of education programs for secondary schools in the republic. It turned out that they did not contain a word about water-saving and careful attitude to water. But just this generation, which is now going to school in the first class, will live and will start to work 15 years from now, when in Central Asia water supply per capita will be one and a half times less!

Due to the lack of ethical rules for the use of water in various countries, attempts have been made to establish departmental or even international ethical rules or water codes. For example, the rules of the UNESCO Sub-Commission on the Ethics of Fresh Water, which has proclaimed the following principles[64]:

"Human dignity, for there is no life without water and those to whom it is denied are denied life.

Participation, for all individuals, especially the poor, must be involved in water planning and management with gender and poverty issues recognized in fostering this process.

Solidarity, for water continually confronts humans with their upstream and downstream interdependence, and initiatives for integrated water management may be seen as a direct response to this realization.

Human equality, for all persons ought to be provided with what is needed on an equitable basis.

Common good, because by almost everyone's definition water is a common good, and without proper water management human potential and dignity diminishes.

Stewardship, for protection and careful use of water resources is needed for intergenerational and intra-generational equity and promotes the sustainable use of life-enabling ecosystems.

Transparency and universal access to information, for if data is not accessible in a form that can be understood, there will be an opportunity for one interested party to take advantage of others.

Inclusiveness, for water management policies must address the interests of all who live in water catchment areas. Minority interests must be protected as well as those of the poor and other disadvantaged sectors. In the past few years the concept of Integrated Water resources Management (IWRM) has been also used for propagating equitable, economically sound and environmentally sustainable management of water resources.

Empowerment, or the requirement to facilitate participation in planning and management means much more than to allow an opportunity for consultation. Best ethical practice will enable stakeholders to influence management.

[64] World Commission on the Ethics of Science and Technology (COMEST) and the International Hydrology Programme (IHP). 2004. Best Ethical Practice in Water Use. UNESCO: Paris

Water management is fundamentally a question of social and environmental justice based on three essential concepts: equity, fairness and access between and across generations.”

The UNESCO Universal Declaration of Bioethics and Human Rights (UDBHR), adopted by all UNESCO members in 2005, called upon all countries to more formally capture ethical standards for environmental and water applications, in particular for the implementation of Article 2 of the Declaration, which provides for:

“*g. to safeguard and promote the interests of the present and future generations;*
h. to underline the importance of biodiversity and its conservation as a common concern of human kind.”

Another example of such ethical status for water management organizations is the World Pact for Better Basin Management of the International Network of Basin Organizations, adopted at the 6th World Water Forum in 2012, which, inter alia, made commitments:

- *“supporting processes of sustainable, integrated, joint and participative management of water resources and environments organized on the appropriate scale of local, national or transboundary basins according to the case;*
- *organizing dialogue with the stakeholders recognized in our basins and their effective participation, to achieve a truly shared vision of the future, to identify the necessary agreements on priorities and the resources to mobilize, coordinate initiatives and projects, analyze the results;*
- *based on a prior assessment, facilitating the agreement of the various stakeholders on a "shared vision" of the future of their basin and developing, through dialogue and transparency, management plans or basin master plans for setting out the goals to be achieved in the medium and long term;*
- *developing successive action and investment plans that meet the economic, social and environmental priorities of the basins, set out in the management plans, and establishing mechanisms for evaluating their results while using suited performance indicators;*
- *making better use of water and ensure low consumption of this scarce resource by better control of the demand, encouraging more efficient uses, and according to the case, the use of unconventional resources, the reuse of treated wastewater or artificial recharge of aquifers for sustainable development in particular;*

- *better taking into account the significance of ecosystems and of their services in planning decisions for the development and management of our river basins; and*
- *organizing in each basin, in cooperation with the major data producers and managers, harmonized data collection as part of Integrated Information Systems, which are permanent, reliable, representative, inter-operable and easily accessible, allowing a precise vision of the encountered situations and their evolution."*

A certain manifestation of developing water ethics is the formulation of sectoral ethical rules, such as the rules for manufacturers of bottled water adopted by the World Health Organization (WHO) on 24-26 April 2006 in Baltimore, USA (162 participants of the International Symposium from 25 countries), together with specialists of the International Water Association and the largest manufacturers of equipment for water treatment and desalination of water.

Recognition of "precautionary principle" and "the need to prevent adverse effects of the scientific and technological progress on humans" finds understanding and recognition among representatives of large business, although with great difficulty.

As the above examples show, the principles of professional ethics specific to specialists of water supply and irrigated agriculture sectors should reflect the responsibility of water professionals for the continuity of water delivery, sustainability and quality of water supply and water conservation, because these aspects of professional activity directly affect a significant number of served population. A high responsibility rests with professionals who provide access to information and prevention of natural disasters (floods, mudflows, droughts, breakthroughs and accidents at water facilities, etc.).

Table 11.1

Basic principles of the Code of Ethics for members of the International Bottled Water Association

Basic principles:	
1	*Manufacturers of bottled water respect the principles of sustainable development and understand the importance of long-term preservation of water quality in the water sources.*
2	*As far as possible, manufacturers of bottled water engage themselves to developing the communities, on territories of which they take water, including improvement of environmental objects;*
3	*Manufacturers of bottled water undertake to cooperate with municipal authorities and neighboring communities, involving them in expert examination and training to this activity;*
4	*Manufacturers of bottled water carefully monitor compliance with all environmental standards that are regulated by the government and other authorities*
5	*Manufacturers of bottled water pay much attention water resources management, because they consider it as the important element of sustainable development of the state.*

A degree of professional unity, mutual understanding and mutual assistance among water professionals is quite high. There have been cases where colleagues from the neighboring regions have come to assist under emergencies on canals, rivers and water infrastructure, without any instructions from their own leaders.

A high level of water partnership at the interstate level has existed earlier as well, when we shared our experience with water professionals from the developing countries in Africa, Latin America and Asia. It remains at a high level and now, for example, our Scientific-Information Center has organized an open exchange of knowledge through the portal: **www.cawater.info.net**, which is daily used by up to 10,000 visitors from all over the world. Here, we observe a manifestation of professional ethics, based on principles, which consist of general and specialized provisions. General provisions are based on the universal norms of morality and provide for:

a. professional solidarity, which sometimes grows into corporativity;
b. special understanding of duty and honor; and
c. a special form of responsibility based on the object and importance of activity;

Thus, **water ethics** that is the most important condition for survival of mankind on the cusp of growing water crisis, should serve as an internal compass for each participant of water resources management and use in its daily activity. Moreover, **water ethics** is the yardstick, using which decision-makers should evaluate their decisions relating to water resources use, management, protection, development and planning.

Let's summarize - what are the main tools of **water ethics**?

The most important tool is ***consciousness*** and ***understanding*** of the uniqueness of water, its role in preserving, surviving and the future of mankind, in protecting nature and its living creatures, in satisfying the needs of noosphere.

Religion plays an essential role in preserving water, as one of four basics of life on our planet created by God. All ancient nations treated the water as a shrine. Each religion involves a ritual washing. Hindus plunge into waters of the sacred river Ganges and believe that the water contains energy of the cosmos. Ancient Jews had to wash their hands before praying. In each yard there was a reservoir, serving to collect rainwater, which was considered "alive." In Egypt, there was a holiday dedicated to the day when the Nile River overflowed its banks. The ancient Greeks revered the God of the seas Poseidon and built temples in honor of him. The Romans solemnly celebrated the day of the god Fontalia and decorated water bodies with flowers in his honor. Muslims have many rituals associated with ablution. The Prophet himself said that purity is already half the faith. Since ancient times, Christianity also considers water as the holy essence. No church rite passes without a ritual, when a priest besprinkles the believers with holy water.

Regardless of the specifics of religion, this is an ideological tool of ethics, its moral foundation and spiritual thread that permeates and unites not only the pressing water problems, but also the water of the future, water forever - now, and ever, and unto ages of ages![65]

Education is the next important tool that should enter life of every inhabitant of our planet and give him a purposeful understanding of the water significance, role of water, its links, and its influence.

[65] et nunc et semper, et in saecula saeculorum

Along with the basic set of elementary knowledge (an excellent example is the education of children and youth in Japan, where, as I say, “since they were knee-high to a grasshopper”, children are taught a deep respect for water, they learn how to protect waterways and clean the water protection zones of rivers) should be the attitude development in the human environment, mentoring, especially by efforts of the older generation, permanent on-site training and industrial training, which includes learning the rules and regulations for optimal water use and water management!

Culture, with all the variety of its directions (literature, art, cinema, folk art) and with its unique works of art that touch on moral and sensory perceptions of people, has always emphasized the aesthetic significance of water. The current development of information resources for cultural exchange makes it possible to disseminate the images of water among a large number of people, pushing them to altruistic service to nature and water in order to preserve it by joint efforts.

We have already stressed the role of **law** as a tool of water ethics. Water issues permeate the legislation of all countries, but it is indisputable with a different degree of accounting a specific role of water and its importance in life of humans, nature protection, equitable and reasonable distribution of water. It can say that the right to water for drinking and hygiene needs is proclaimed in many constitutions and laws, but the right to water for ecosystems and for food production is not adequately outlined. Moreover, the mechanism for implementing laws must be strengthened everywhere, with some exceptions.

Particular attention should be paid to the international water law, in which the presence of certain contradictions between the sovereign rights of countries to use natural resources on their territory and the need for equitable use of water resources over the whole catchment area, create the possibility of actions that contradict the ethics of water use.

At last, two more instruments of water ethics, which we have not yet considered.

The problem of different approaches to the right to water depending on **gender** is a very delicate and sensitive tool in terms of moral relations in society. A difference in specific biological characteristics of men and women is clear for all. However, the representatives of two gender groups differ often by their position in society.

A woman is, first and foremost, a mother, who cares about preserving her family, upbringing children, food, hygiene, health, and finally the future.

Nevertheless, in spite of her tense and responsible burden, a woman has less access to sources of finance and food, as well as to education, distribution of benefits and different levels of public governance. All these differences are sharply manifested themselves in relation to water. In this case, a woman is, first of all, a consumer and getter, who use 65-80% of water in her household, and often becomes a fighter for the purity and quality of water. In rural areas, a woman not only delivers water from wells or a river, but also cultivates and irrigates those homestead plots that ensure most of income of a subsistence farming of the family.

At the same time, women suffer from unequal access to water, as can be clearly seen from the documents of gender survey conducted by the SIC ICWC and GWP for a decade both in the Fergana Valley, and selectively in all the eight countries of the Caucasus and Central Asia (Dr. G. Stulina, 2003, 2011). A solution of problems of gender relations and rational water resources management boils down to the following: providing women with equal rights in access to water management, distribution and use. Another side of a medal is to take into account the gender peculiarities of women in water use and their role in social life.

At that, we must proceed from the fact that the upbringing of future generations and care for healthy our descendants is impossible without the use of clean water suitable for humans. Therefore, ensuring this need of women and their role in the family - not only in your own families, but in the whole sphere of your activity - is the responsibility of the water sector in general and every water professional in particular. Such an approach will be your response to your mother's care for you, as well as will be your care for all mothers on our planet. Because the attitude of mothers to their children is identical throughout the world and variates only due to different economic and social opportunities.

Activity on involving women in solving the water problems is multifaceted and presents many opportunities. First of all, it is necessary to include the issues of gender relations related to water resources into the Action Plans of water management organizations. Further, taking into account the national circumstances of each country and based on surveys conducted, it needs to define to what extent the present situation violates the equality of rights of women and men, and also does not meet the female requirements concerning labor relations, access to water, hygiene and maternity.

It is advisable to find out whether there are gender aspects in the national legislation related to the rights to water and water use as well as, if necessary, to initiate the necessary changes in the legislation and domestic practice. It is very important to organize a women's movement joining efforts for protecting their rights and promoting their participation in activity of local and national governmental bodies.

Access of women to education in the field of water resources management should be complemented by a special training on such subjects as rational water use and water saving, especially in connection with the occurrence of women-farm managers.

Our experience confirms great activity of women when they are involved in establishing non-governmental organizations, such as the River Basin Council, Canal Water Users Union, WUAs and others.

Finally, one of the main tools of water ethics is **trust**.

Trust is the basis for water relations, especially for interstate water cooperation.

1. Regardless who you are – a manager of water agency, hydrologist or specialist in modeling or informatics, trust provides the basis that can facilitate establishing the platform for stable relations, operation of which is very important for all levels of water cooperation - interstate, inter-regional, within the command area of irrigation canal or a WUA.
2. Water resources management, especially, if they are scarce or, on the contrary, are catastrophically redundant, is always a coordination and balancing of various interests. Such a situation is called as “conflict” in the foreign professional literature. Our understanding of the term "conflict" is rather different; in our view, the term “conflict” means a threshold level for growing political and economic tensions, confrontation, struggle for one's own interests, and even wars. Water resources management rarely faces such conflicts. The resolution of the ICWC jubilee conference in April 2007, dedicated to the 15th anniversary of our organization, has stated that, despite the increased droughts and floods, as a consequence of climate change, the ICWC confidently overcame these extreme events, preventing the conflicts between riparian countries. Of course, an extremely dry 2008 year has changed something in this respect. However, on the whole, we settle opposite interests related to water resources use every day and every ten-day and avoid conflicts in our understanding.
3. So, trust. According to Sophocles, this is the “*glue*” of human relations. Loss of trust breeds suspicion and hostility, this is difficult to forget. People do not believe to said words, do not believe in promises, therefore, it is impossible to build joint actions while there is distrust. We are firmly sure that trust plays a critical role in social relations like cooperation, coordination, collaboration and joint activity.

Individual trust is characterized as a willingness to feel confidence, faith in a human being, expecting from him actions of a personality, feeling his righteous roots, as the basis of his origin or early child development.

Institutional trust is a confidence in future interaction, which is based on certain rules and norms implemented by organizations-partners. Such trust is usually generated by a long-term joint activity and partnership, where relationships are tested by time and, what is very important, by mercantile interests (by money).

Collective or clannish trust is based on certain unwritten codes of relationships within such communities. Those who lost their trust have being usually banished from such closed communities. Trust between masons, within criminal groups, within informal associations, where so-called "code of honor" is intra-group regulations for their behavior can be a model. Very interesting informal relations often could be established between people united by common interests in the business.

Trust is a faith of individuals and their desire to cooperate on the basis of words, actions and decisions.[66] The level of trust is determined by an individual consistency of interaction, situational solidarity and history of relationship. The durability of historical solidarity that arose in the struggle against enemies or in the process of overcoming certain obstacles creates a reliable ground for trust. However, it is not eternal, for example, modern relations between Russia and Ukraine show that external and internal forces aimed at destroying the friendship and trust can play a decisive role. Therefore, please, preserve the historical bases of trust and friendship!

Trust can be based on and, most often, arises in consequence of professional and personal relations. Given, in the past, these relations were focused on solving certain tasks, they can be anchored if there suddenly arises the need to achieve goals that lie outside of former relations. There arises a so-called social-emotional confidential relationship, which is based on overcoming certain tensions or interdependencies.

Estimated trust is based on the confidence in a line of partner's conduct and his guarantee of fulfilling promises. This can be also based on the understanding that failure of obligations can have serious consequences for a partner. On the other hand, such a trust can be confirmed by the hope that the preservation of trust can repeatedly benefit both sides in the future. Finally, the desire to maintain a reputation not only in the opinion of a partner, but also in the opinion of others related to you and your partner, your friends and associates is of no small importance. It is very important to preserve the "image of an honest partner." From this point of view, a short-term profit at the expense of loss of reputation can in the subsequent turn to the big losses. Diplomats use the notion of "maintaining a reputation", and it should be supported by not one-shot actions, but systematically as relations of friends. "*Two hands are always needed for applause!*"

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[66] Trust in sociology and psychology - open, positive relationships between people, containing confidence in the decency and goodwill of another person with whom the trustee is in some way or another.

Reasonable trust consists in a clear understanding the expected relations and intentions. The parties usually help each other and treat with respect the wishes and intentions of another party. Such trust allows the parties to act as a united front on the basis of a common position in relation to other entities. Each of the parties, defending own interests, protects the interests of a partner as own ones. Applying the collective identification (single name, slogan or brand), association of fellow-countrymen, creation of joint products, contribution to common values facilitate forming of this type of trust. All types of components that facilitate strengthening the trust can be observed in SIC ICWC activity - work in the framework of shared projects, elaborating common products (for example, "CAREWIB") and conducting joint trainings. Such a constancy in relations promotes understanding the needs, abilities, decisions and interests of partners. There arises an opportunity to imagine ourselves at the place of a partner and to assume a possible line of his behavior. Applying a common identification facilitates the involvement of different values of each partner in creating a unified product of common worth.

Usually these collective relations are supplemented by personal relations. An example of such a symbiosis can serve a chorus, where everyone performs his own part, but participates in creating a general sound that gives added value to the partnership.

Trust passes the test of time. We live in a complicated world under impacting of external and internal factors. We can influence on some factors but not on all. As a result, the various, often unforeseen, situations are created that can put relations under attack or strengthen them. We need our mind, patience and ability to understand the position of another person. The period of "perestroika" and wild business after collapse of the USSR was fraught with a loss of confidence and ideals, as well as disappointment in authorities. In the course of my work, I had many occasions to check people, their moral qualities and possibility to trust them. Up to now, I was disappointed only in 5 persons. You need to learn how to forgive little mistakes, but you must not forgive meanness!

Trust is tested in many ways.

Often, the essence of people manifests itself in various deeds like the Janus-faced. Different contexts and situations can reveal the deeply ingrained traits and intentions that can destroy the former image. Different human traits can manifest themselves in various conditions. Therefore, the old German saying states: "*Trust is good, but control is better*" or "*Trust but verify!*" Such an approach is very important for a manager.

Usually, in its subconscious basis, trust assumes the following:

- personal predisposition of given human character regarding the trust, openness, friendliness and firmness of opinion;
- psychological orientation motivated by emotional support and moral principles;
- the human stereotype: "*A good name is sooner lost than won!*"; and
- relationship experience.

All these positions must be borne in mind to support and preserve a partner or even be able to caution him against actions that can cause losses.

Criteria for verifying the trust:

- ✓ a partner follows the agreed rules (in writing or orally);
- ✓ a partner acts according to the expected behavior;
- ✓ a partner respects the timing ("*Punctuality is the politeness of kings*");
- ✓ a partner exactly fulfills the agreed obligations in the process of works; and
- ✓ a partner exactly follows the financial arrangements ("*greed did him in!*").

Fundamentals for strengthening the trust:

- Common interests;
- Shared goals and objectives;
- Joint response on different situations;
- Demonstrating the integration of actions; and
- Communication in all conditions (even if "cracks" in relations occur)!

Trust is an important tool in overcoming conflicts

- In case of arising "cracks" in the mutual trust, try to assess what threatens to both parties in the future and how the situation can affect activity of your organization, joint business, etc.
- Analyze what is more profitable to gain benefits today, but lose the trust or lose benefits today, but keep the mutual trust.
- Try to clarify what unites with the partner, and what separates. Explain each other what is more valuable for both, especially at the threshold of the future.
- Try to find an entity (a person or organization) that enjoys the authority of your partner and try to use it as a moderator for confidence-building.

- Try to find solutions that are opposed to those which facilitated arising of distrust and which can suit a partner to a greater extent.
- Initiators of arising mistrust should be publicly declared and, if possible, convicted. Try to avoid the presence of intriguers in your business environment!

Our ability to react to requests and obligatoriness are no less important as the tools of trust.

We often do not pay attention to the fact that our partners are inviting us somewhere, and we, under every pretext, begin a long chain of excuses: "*the bosses do not allow*", "*I have other plans*", "*I'm very busy!*" etc.

It is necessary to remember: "*the echo responds to the call!*"

When we need to invite someone for negotiations, we should expect the same line of behavior on the part of partners. This is very important for the future!

For example, you have undertaken obligations in your aspiration to persuade your partner to make concessions, have persuaded and forgotten. When time passed, the partner can recall these obligations that were not fulfilled - you turned out to be untenable! That is the first step towards losing the trust.

In our water management business, we must proceed from the fact that we are tied for centuries! Water has tightly bound our interests, opportunities and future in spite of existing borders. Therefore, we cannot survive without trust.

As the first step towards building the trust, we must understand what are our needs, what waits for us in the future, and what our alternatives. I want to note that earlier we solved most of issues orally based on the confident negotiations, often without protocols, decisions and even receipts. The atmosphere of general trust has ruled the roost, without being burdened by various financial interests. A word had a considerable weight! I am proud that having lived a long life, I was never being a liar during the long way of labor activity and hardship!

Now, as was shown above in the chapter "Water and civilization", the world stands on the threshold of difficult choice - to reject the previous paradigm of consumer development and create a new rational and resource-saving civilization.

The current approach of the G20 and other world leaders that focuses on the momentary solving economic problems by covering the needs at the expenses of the resources of nature and future generations should be rejected.

It is necessary to review the requirements that have arisen owing to the progress of technologies in general in society, and to develop a mechanism for self-restraint, ranging from the level of governments up to an individual person. It is required to change the behavior of people and establish limitations that will be difficult to overcome for those who have just begun to learn the "fruits" of consumption and imaginary well-being. It is necessary to take aim at such consumption levels as in China and India, which can create a new way of life, which differs sharply from the western one. For this purpose, the reformative leadership is needed as never before.

In anticipation of a real collapse of opportunities, weakness of the public sector as a result of an ideological failure owing to market fundamentalism being practiced over the past decades should be overcome, and the world should be redirected towards self-regulating the market, limiting consumption and ensuring survival, taking into account broad public interests.

To this end, it is necessary to increase public awareness and mobilize the public to exercise public control over the discipline of accounting natural resources use in the private and public sector, with a view to achieving sustainable development and a more equitable sharing of benefits.

Chapter 12. Water Security

In the preface to «Water Security for Better Lives» (2013 г.), Secretary-General of the Organization for Economic Co-Operation and Development (OECD) Angel Gurria prognosticates: "*Water security is one of the defining challenges of our time. By the middle of the next century, over 40% of the global population will live under sever water stress. As global population increases, so will tensions among different water users.*

This challenging outlook on water security, together with an increased severity in floods and droughts brought about by climate change, is an urgent call for better managing water risks, including water shortages, excesses, pollution and other risks to freshwater systems (river, lakes, and aquifers). The key lies in adopting an approach based on knowing, targeting and managing water risks."

Proceeding from such an approach, a modern specialist in the field of water management, entering his professional life (starting since studentship), should understand that he assumes a great responsibility - to be a conductor of such water resources management and use, which resists water-related risk, and actively participate in this management practice.

A young specialist should equip himself with modern knowledge and adjust himself to fighting against the routine of water management practice that characterizes the current inertia of government and water management agencies in their reluctance to move away from the trend of "preserving existing trends" (business as usual). Moreover, he should take charge of movement of society aimed at overcoming water-related risks. Risk management and water safety require the sufficient capability of local specialists to manage water-related hazards not only in normal conditions, as we were trained 60 years ago. They should learn the rules of water management under a certain level of risk of water scarcity or, conversely, its excess, taking into account the variability in water availability, deterioration of water quality and many other extreme abnormalities that must be analyzed by a water professional in a systemic manner.

What do we mean by water security? This is the state of national water resources, water management and use, under which:

- all water users and water consumers in a country, region or district are provided with water of suitable quality in sufficient quantities and at the right time for all needs (communal water supply, irrigation, energy production and nature), now and for the future;
- the population, economic entities and natural objects are safely protected from harmful effects of waters;
- the population has access to information on possible changes in water management conditions and is prepared to overcome deviations from the normal water management situation in case of extreme events.

The current generation of water experts should master not only the experience and knowledge accumulated by many years of previous practice and scientific research, but also:

- understand in detail <u>what kind of risk</u> can be associated with extreme water events and their affects and help a wide range of people - preferably representatives of all population groups - to be aware about these risks and be prepared for their various impacts;
- <u>risk management</u> means to envisage its occurrence, prevent it using sufficient measures and prepare for it and, on the basis of this preparation, gain benefits owing to preventing possible damages. Moreover, water professionals should create conditions when water risk does not cause a risk related to food security, energy supply, nature, etc.;

- control over risks means that in case of extreme events it is necessary to have the possibility for using their consequences, for example, an increase in temperature due to climate change for reducing the duration of growing season; or for restricting extreme impacts of floods by redistributing the excess of water for creating water reserves in water scarce areas at the expense of water discharged from reservoirs in advance.

It should bear in mind that we entered an era of great uncertainty and high risks due to climate change, demographic pressure and growing environmental requirements, as well as we face other challenges including political, social, market and financial risks.

Water risks, which are the antithesis of water security, are manifested in several fundamental forms. These are natural floods, droughts, typhoons, as well as reduction in precipitation, glacier-fed and groundwater runoff due to climate change. However, there are also anthropogenic risks due to improper human intervention in the hydrological processes - pollution of river water, transformations of riverbeds, flow rates and regimes owing to construction of various water infrastructure, siltation of water bodies, phenomenon of "*deigish*" (catastrophic riverbank caving) and much more. All possible manifestations of risks pose a threat to water security and are closely related to other issues of security - national or regional security: public, food, energy, climate.[67] At first glance, it is difficult to single out what of these types of security is primary and what is secondary: the natural variations in precipitation and runoff or climate change and the growing demographic and economic burden. Because all these phenomena are closely related, and besides, political factors such as the priority of national interests or cooperation on transboundary waters are imposed on them, as well as the preparedness of society for extreme water-related events.

All aspects of security have a different stability, depending on the combination of risk components and intensity of their impacts. For example, if floods, catastrophic riverbank caving and typhoons are of occasional and periodic occurrence at certain periods of time then deterioration of water quality and, especially, droughts, can be either periodic or permanent event. Among these phenomena, water scarcity is the most widespread and increasing threat to the future survival of mankind. What is a reason? Everyone understands that the population growth, increase in its food demand and economic, communal, energy needs in the conditions of limited water resources, an amount of which are still diminishing due to climate change, lead to **a constant reduction of available water resources per capita**.

[67] M. Zeitoun, The web of sustainable water security, in "Water security, principles, perspectives and practices, Earthcan, Routledge, 2013, 357 pages , New York, London"

Let us trace the dynamics of this indicator in Central Asia over the short period of time since 1960. In just 50 years - half a century – its quantitative indicator has decreased three times. And what threatens us in the future? We need to know the prospects for the nearest 25-30 years, in order that countries of this region could take measures for establishing the system of water security that requires huge investments and considerable terms of construction works. According to the forecast made by SIC ICWC using the ASBmm model, in 2050, in case of the most optimal variant regarding available water resources in the region, water consumption per capita will amount to 1,400 cubic meter per year or by 60% less than now. It is also necessary to keep in mind the extent of uncertainty. A risk and uncertainty should be considered together for assessing investments into water infrastructure. There are two variants of assessment: the first one – searching of a risk management option to ensure an acceptable level of risk. The second variant consists in optimization focusing on solutions where each additional dollar invested will bring the maximum additional benefit, for example, increasing hydropower generation or reducing losses owing to water-related disasters as a difference between losses with/without investments. Both approaches are based on optimization of combining additional economic benefits due to productive use of water and reducing economic losses owing to destructive effects of water-related disasters. To this end, the cost-benefit analysis is a scientific method for determining optimal solutions. These estimates will be especially efficient if they will take into account not only direct, but also indirect social and environmental costs and benefits, as well as related effects, for example, increasing employment or income due to processing primary products. For river basins or large-scale regional projects, it is necessary to have a set of competitive project proposals that show all effects and investments in an integrated manner.

Water security issues are of the special importance for transboundary river basins. The former Prime Minister of Norway, Mrs. Gro Harlem Brutland, in her foreword to the book "The Global Water Crisis: Addressing an Urgent Security Issue" very correctly emphasized: *“The contemporary understanding of water security concerns also makes it clear that broader principles must be incorporated into transboundary treaties if such agreements are to remain relevant in changing hydrological scenarios*.

These principles include: integration of surface and groundwater interactions with land use planning and water management; ecosystem protection; public and private sector involvement; collaborative, multi-level governance; and the need for adaptability and flexibility in the management of shared waters. If we are able to balance our needs for water availability and quality in terms of nature, agriculture, populations and development, many other needs, including achieving sustainability, may very well fall into place. Thus, we see that moving quickly to manage water more carefully will generate greater global benefits in and of itself, while at the same time allowing us to imagine a future in which a water crisis does not exist.”

One of the key factors in the inadequate reaction of authorities and society to water-related risks is poor awareness of stakeholders concerning these risks, lack of knowledge about the possibilities for reducing them and insufficient response of the governments. The following symptoms are typical for this situation:

- a weakness of the service for hydro-meteorological forecasts, and inadequate system of agro-climatic observations in terms of area coverage and measurement frequency;
- disuse of modern RM methods (remote measurements) and forecasts of climatic phenomena based on radar observations;
- poor equipment of the hydrological service for measurements and forecasts, and inadequate scientific provision for developing measures to adapt to situations of higher risk and reduce their effects; and
- lack of access to information sources for stakeholders.

These are the most common causes leading to unpreparedness for extreme events.

Meanwhile, modern science has quite impressive information in order to convince decision makers to make water security their indispensable priority for protecting their peoples and their future. According to the report of Oxford University (D. Grey, et al.)[68], supported by the GWP and OECD, the cost of "***water insecurity***" amounts to the world $500 billion a year, including damage of urban property of $120 billion and irrigated agriculture of $94 billion. In this report, water security is estimated by a magnitude of actual economic risks expressed in relative losses of the national income in three main areas of water scarcity:

- water shortage in agriculture;
- loss of property value due to floods and typhoons; and
- unsatisfactory water supply and sanitation.

According to the ranking based on the first indicator, China occupies the first place in the rating followed by Pakistan and India; Uzbekistan occupies the 8th place in the rating, the USA - the 9th place, and Afghanistan - 10th place.

According to the second indicator, India occupies the first place in the rating followed by China, the same situation is observed under ranking according to the third indicator. It is interesting that the Russia Federation occupies the 9th place!

The impact of water risk on the global well-being can be clearly seen from the data of 2010, the drought of 2010-2011 in Russia, China and Argentina, while Canada, Brazil, Pakistan and Austria were subjected to floods, led to a fall in the reserves of grain and sugar and doubling the prices of these products at the world market.

[68] "Securing water, sustainable growth", Report of the GWP/OECD Task Force of Water Security, University of Oxford 2015.

During the same period (2011), flooding in Thailand resulted in the death of 884 people, destroyed 1.5 million houses, destroyed 25% of rice crops and 7,500 industrial plants, being caused a total loss of $46 billion! In the face of such challenges, water security should be among the first priorities under tackling national and global problems! For the first time, the Global Risks Report 2014[69] highlights the water crisis as the Risk No 1 for business in the coming 10 years. Such a situation is the result of the world nation's inability to ensure access to water everywhere, sustainability and good quality water supply in sufficient quantities for producing economic goods and services.

Risk control

The simplest, but probably the most expensive approach to risk management is to create large margins either in a carrying capacity of waterways or in creating water storage reservoirs, or in a design of protective structures that exceed all possible effects of high-risk events (floods, droughts, hurricanes, rising water levels, etc.). However, the creation of large margins requires large water-related investments, which is not always admissible for water users, states or organizations responsible for water security. There are many examples of high-quality capital water infrastructure in the world, which ensure stable operation in case of disastrous water events due to their unique design, being monuments and work of engineering art.

Ancient civilizations that constructed their settlements and towns along a river have placed the most important buildings at higher elevations (for example, churches and cathedrals in England) and established the special system of emergency information and warning about floods such as a "long ear" in Central Asia or "flame signals" in Egypt. The subsequent development, related to the progress of civilization was marked by the construction of intensive protective structures, ring-type dams, channels with switching flow directions, etc.

Hereinafter, we will present several examples of risk management by the engineering means that are typical for the entire XIX and XX centuries, when water management was primarily perceived as construction of waterworks. A classic example of ensuring water security in areas of increased risk of marine floods due to wave surges is the practice of Holland and its polders. During several centuries, a system of flood walls (dams or embankments), transfer pumping stations, which use wind engines, connecting and diverting canals were built. At that, the system of public participation in allocating costs for security measures and early warning was ultimately supplemented by a huge complex of state systems based on preventing and stopping inflow of water masses into polders, as well as exclusively openwork arched structures in order to stop the surging waves in the mouths of the Meuse and Rhine rivers.

[69] Presented at the World Economic Forum

Figure 12.1 Polders in the Netherlands

No less grandiose structures for protecting the Neva River mouth were built at the end of the past century - beginning of the XXI century. It is known that St. Petersburg, and later Leningrad, were repeatedly subjected to catastrophic floods that have the same origin - a surge wave at the Neva River mouth. In a short period of time, less than a day, a water level in the river and the system of canals has increased by 4-5 meters, flooding a significant part of the city and even the Peter and Paul Fortress, and this fact reflected in many outstanding works of literature ("The Bronze Horseman", Pushkin A.S., "The Princess Tarakanova", Yu. Miloslavsky) and in fine arts. Although the design of protective structures in the mouths of the Meuse and Neva rivers is identical in principle (two arched legs that are floatingly moved towards a place of their interlocking and subsequently are put on the apron by filling them with water), their dimensions differ considerably - a weight of one arch leg of the gate in St. Petersburg exceeds 46,000 tons!

Along with infrastructure measures for risk control, in some countries the preference is given to methods of improving an accuracy of forecasting the flow rates and flow regime, equipping river and canal facilities with SCADA systems with simultaneous granting the forecasting software. A typical example is the experience of South Korea, which created a radar monitoring system for rainfall throughout the country, including part of North Korea. This system supported by modeling of climatic and hydrological indicators is characterized by a high accuracy of forecasts of the forthcoming extreme events.

Being included in the national system of emergencies, this complex constantly informs the population of countries exposed to floods or droughts about the impending danger.

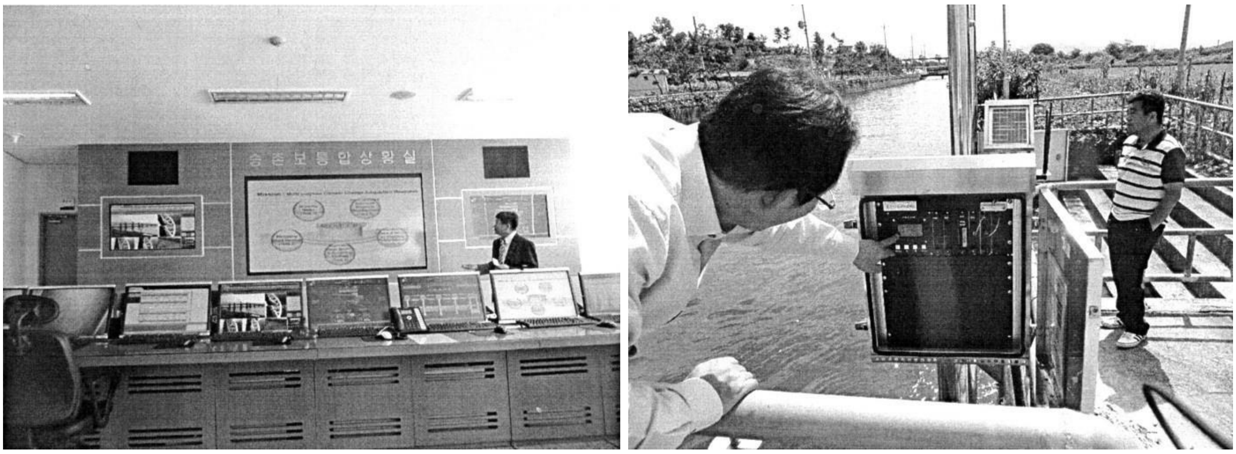

Figure 12.2 The Smart Water Grid in South Korea

The Government of Israel presents one more example of solving the problem of water security in another region of the world with extremely scarce water resources - the Middle East. The growing population and, correspondingly, increased demand for water resulted in decrease in the available water resources up to 250 m3 per capita a year in the Jordan Valley (Israel, Jordan, Palestine). As a result of considering several options for water supply in these countries, a variant of seawater desalination was adopted based on construction of several large water-desalinating plants along the Mediterranean Sea coast, having created the water desalination industry during the short period (5 years) with a production capacity of each plant equaling 100 million m3 a year or even more. As a result, not only the current water requirements of population, irrigation and industry, but also the needs for environment were met; and in 2013, for the first time, Israel has released 50 million m3 of water to the mainstream of the Jordan River by the agreement with Jordan and Palestine!

All three of the above examples can be considered as the model practice of preventive measures to reduce (or complete reduce) the risk of water scarcity and their implementation at the expense of the state budget.

A magnitude of permissible risks plays a significant role in risk management. For example, when designing large dams, the estimated probability of exceeding the maximum water flow during floods is equal to 0.001 (once per thousand years).

Houses and main roads are designed taking into account a flood probability of once over 100 years, while ordinary roads are designed with a flood probability of once over 10 years. A flood probability of once over 100 years was accepted for New York; for London and Shanghai - once over 500 years, and for Amsterdam - once over 10,000 years!

This is a reflection of one of the eternal rules for risk management - selecting the most reliable and acceptable degree of risk in coordination with the cost of possible damage or cost of preventive or protective measures. At the same time, it is very important to select the optimal variant of capital investments in risk prevention based on the consideration of costs due to expected damage vis-a-vis costs for its prevention. This supposedly simple technical and economic task always faces, first, the problem of correct definition of damage, depending on the expected frequency of extreme events and their intensity, and secondly with an assessment of the expected social and environmental consequences that often exceed direct economic losses. A typical example is the consequences of Hurricane Katherine for the south of the United States - the delta of Mississippi River, as well as New Orleans and its environs. Ten years before the hurricane, the expected costs for engineering protection of this area against floods was estimated to be less than $1 billion, but the US Congress rejected them. The actual direct damage amounted to $40 billion (?!), but taking into account the social and environmental consequences about $108 billion.[70]

Risk management

For risk management, first of all, it is necessary to have information and a mechanism for coordinating the interests of stakeholders through inter-sectoral and interstate negotiations, as well as the existence of risks control mechanisms and a permanent executive body for emergencies. It is particularly important to have comprehensive information on transboundary watercourses due to its multifaceted nature that determines a risk level, taking into consideration the presence of numerous distributed sources of this information that are often poorly linked. At the same time, the fragmentation and poor coordination of information about different stimulatory sources of water-related disasters (causes of impacts) are also playing an important role.

Let us consider the case study when a threatening flood situation is expected in the river basin with complex (multilateral) water use, based on forecasts of precipitation and river runoff, and on the basis of analogs of climatic and hydrological information. For instance, the state body, most often, the Ministry of Emergencies announces so-called flood warning or storm warning. In this case, the plan of envisaged activities should include:

[70] http://en.wikipedia.org/wiki/Hurricane_Katrina

- Specifying the parameters of expected flood, such as total inflow, rate of increase in intensity, duration, time of flood recession and spreading volumes;
- Pre-emptying existing water storage reservoirs and preparing them for intake of flood water; specifying their availability and marginal capacity if an expected maximum inflow will be exceeded;
- Identifying a storage capacity of former river-beds (dead channels) and forebays as a receiving volume for part of flood water;
- Drafting the plan of distributing and passing a part of flood water through the irrigation and drainage networks in order to gain time for cutting the flood peak values; and

- Managing water storage reservoirs and mudflow-storage reservoirs on tributaries to prevent additional inflow from the lateral catchments to the mainstream.

Please, specify what components of this plan does not correspond to the interests of an owner of water infrastructure. Of course, this runs counter to the interests of hydropower scheme's owners who, first of all, care about water reserves in the water storage reservoirs for generating a necessary amount of electricity. If, in the critical situation, a hydropower scheme will follow their interests for obtaining, say, a maximal immediate benefit, this can lead to large additional flood loads. Such uncoordinated actions are especially dangerous in the time of winter operational regimes of reservoir cascades. The ice regime of riverbeds requires a certain increase in flow within a riverbed in such a way that the process of freezing the river from the surface and near its banks is forming an ice pipe, a pass-through capacity of which must correspond to a maximum allowable values of river flow in winter. For example, in the lower course of the Syrdarya River downstream of the Chardara reservoir, such an ice pipe should be formed by a gradual increase in river flow up to 600-650 m3/s in the process of its freezing. If administrations of the Toktogul cascade or the Karakum, or Charvak reservoirs do not observe the coordinated regime of winter water releases, then a risk of overflowing the Chardara depression and water releases, which exceed values required for forming an ice pipe becomes quite probable. In this case, a water flow over the surface of ice can cause the formation of ice jams and heaping up an ice dam, which will cause a catastrophic flooding of adjacent areas. Such a phenomenon has repeatedly occurred during the first years of the Tuyamuyun reservoir operation, causing the necessity of bombarding these ice dams on the Amudarya River, until the required experience in managing the winter water releases regime has been accumulated.

No less dangerous effects can be initiated by uncoordinated actions in case of expected droughts, when instead of accumulating the maximum possible water volumes in the reservoirs; water releases take place in the winter period.

For example, up to several cubic kilometers of water were released from the Nurek Reservoir, aggravating the consequences of catastrophic dry years (2000-2001, and 2007-2008).

A key tool for risk management is the development of a strategic plan to overcome floods, droughts or other water-related disasters. As an example of a successful approach to drafting the flood management strategies can serve the "Strategic Flood Management», (*SFM*) developed as the guideline document.[71] It is based on the following:

- ***Influencing the source of flood waters:***
    - *through storage at or close to a source (in-land water bodies and lagoons, reservoirs, groundwater recharge, bogs, marshes, fens, sustainable urban drainage systems) and land management;*
- ***Influencing the pathway of flood waters:***
    - *through morphological, debris and vegetation management, wetland and washland creation as well as permanent and temporary structural defenses, pumps and barriers.*
- ***Influencing the water receivers' capacity:***
    - *through the flood water planning and distribution system*;
    - *through protective dams and bund walls*;
    - *through water evacuation, for example, a deliberate breakthrough of a dam;*
    - *through raising awareness and preparedness of people and business and early warning system;*

through providing post-event recovery systems.

- ***Influencing future climate change;***
- ***Influencing demographic change;***

Ten "golden rules" of the flood management system:

[71] Sayers, Paul Paul, Galloway, Gerry et al., *Strategic flood management: ten 'golden rules' to guide a sound approach.* International Journal of River Basin Management, 13 (2). pp. 137-151. ISSN 1571-5124

1) "*Accept that absolute protection is not possible and plan for exceedance. Structural protection provides protection against more frequent lower consequence events but often provides limited protection from low-frequency, high-consequence events. Through an acceptance of residual risks, and that some degree of failure is almost inevitable, a focus is placed upon building resilience into all aspects of the planning process.*"

2) *"Promote some flooding as desirable. Floodplains provide a fertile area for agriculture and a variety of ecosystem goods and services to society, including natural flood storage.*"

3) *"Base decisions on an understanding of risk and uncertainty. The SFM process is iterative and adaptive, taking into account better information as it is developed and not waiting for what is likely to be unattainable information before proceeding to the next step."*

4) "*Recognize that the future will be different from the past. Climate change, demographic change, changes in the condition of structures and other societal changes mean that planning processes that focus on a future that resembles the present are no longer acceptable.*"

5) "*Do not rely on a single measure, but implement a portfolio of responses."*

6) *"Utilize limited resources efficiently and fairly to reduce risk."*

7) *"Be clear on responsibilities for governance and action. The role of governments, businesses, and other organizations including the affected communities and individuals must be clearly defined."*

8) *"Communicate risk and uncertainty effectively and widely."*

9) *"Promote stakeholder participation in the decision-making process."*

10) *"Reflect local context and integrate with other planning processes."*

Glossary

Advection (from the Latin "advection" - delivery) movement of air in the horizontal direction with transferring along with it its properties: temperature, humidity and others. In this sense, one can say, for example, about advection of heat and cold. Advection of cold and warm, dry and moist air masses plays an important role in meteorological processes and thus affects the weather conditions.

Aqueduct (from Latin aqua - water and duco - supply) is a hydraulic structure in the form of a bridge that is constructed to convey water over an obstacle, such as a ravine or valley and could also be used for agriculture. Aqueducts sufficient in width could also be used by ships (a water bridge).

Acclimatizer is a machine added by the Genetics mod. It is used to adjust the temperature and humidity tolerance of a Bee up to the maximum of +5 or change the type of flower a bee seeks.

Hydrocyclone (centrifugal separator) - apparatus designed to purify water from sediment, sludge. The principle of action of hydrocyclones is based on the separation of particles of the solid phase in a rotating flow of liquid.

Inverted siphon (from Dutch "duiker", came to Russian through German, Düker - "siphon") - a pressure pipeline section laid under the channel of the river (canal), along the slopes or the bottom of the deep valley (ravine), under the road located in the depression. Inverted siphon are used in water supply, sewerage, irrigation, etc.

Ingredient is an integral part of some complex compound or mixture present in the finished product in its original or modified form.

Infiltration - the penetration of atmospheric and surface water into the soil.

Cluster is a group of the same or similar elements gathered or occurring closely together, which can be regarded as an independent unit or complex possessing certain properties.

Condensation - the transition of a gas or vapor to a liquid or solid state either by cooling or by being subjected to increased pressure (the inverse process is called sublimation). When water vapor cools in the atmosphere, it condenses into tiny drops of water, which form clouds. A maximum temperature, below which condensation takes place, is called "critical."

Noosphere is the sphere of human thought; the sphere of interaction between society and nature, in which human activity based on intellect becomes the determining factor of development (this sphere is also denoted by the terms "anthroposphere" or "biotechnosphere"). The noosphere is supposedly a new, higher stage in the evolution of the biosphere, emergence of which is associated with the development of a society that has a profound effect on natural processes. According to V.I. Vernadsky, "in the biosphere there is a great geological, perhaps, cosmic power whose planetary influence is usually not taken into account in the ideas about the cosmos ...

This force is the human thought, aspiring and organized will of man as a social being."

Saprobionts are organisms that live in waters polluted by organic substances (mainly, aerobic and anaerobic bacteria), which can be used for biological water treatment.

Siphon – in a narrower sense, the word refers particularly to a tube in an inverted 'U' shape ("automatic pipe-pump"), which causes a liquid to flow upward, above the surface of a reservoir, with no pump, but powered by the fall of the liquid as it flows down the tube under the pull of gravity, then discharging at a level lower than the surface of the reservoir from which it came.

Sublimation is the phase transition of a substance directly from the solid to the gas phase without passing through the intermediate liquid phase. Since in the process of sublimation a specific volume of substanse changes and energy is absorbed (the heat of sublimation), sublimation is the first-order phase transition. The reverse process of sublimation is desublimation, in which a substance passes directly from a gas to a solid phase, for example, such atmospheric phenomena as frost on the earth surface and hoarfrost on tree branches and wires.

Theta-Healing is a new technology of healing through meditation, which completely changes reality.

Transpiration is the process of water movement through a plant and its evaporation through the external organs of a plant, such as leaves, stems and flowers. Water is necessary for life of a plant, but only a small part of water supplied through the roots is used directly for plant growth.

Evapotranspiration - or a total evaporation is the amount of moisture that is transferred to the atmosphere in the form of vapor as a result of transpiration (physiological evaporation) and physical evaporation from the soil and the vegetation surface.

Eutrophication - the saturation of water bodies with biogenic elements, accompanied by an increase in the biological productivity of water bodies. Eutrophication can arise due to both natural aging of a water body and anthropogenic impacts. Phosphorus and nitrogen are the main chemical elements that contribute to eutrophication.

Instead of Conclusion

Water-related sciences and professional interests of specialists in our sector have passed a long way of transformation under the influence of those challenges which society faced in the process of using water as a resource and a factor affecting human life, and then they have changed due to coverage of new areas of water use. At the beginning, a man simply studied the water to understand where it comes from, what it depends on and how to measure it. Links between hydrology (water science) and meteorology, geography and astronomy have arisen.

With the increase in water use and its delivery over long distances, engineering sciences have emerged to facilitate creating water infrastructure for managing water and producing energy and various products on the basis of water use, as well as for desalinization and purifying water. Having become the dominant factor for survival of humankind, water management has required multidisciplinary approaches based on economics, ecology, sociology, jurisdiction, and ethics and, in the end, turned into an essential component of geopolitics. Nowadays, water acquires the features of political tool and means of certain pressure of some water users on others, some countries on others, and even sometimes serves as a mechanism for enforcement in human relations, or a source of profit and unfair income. Some forces try to use access to water as a means that gives odds in competition, trump card in dealing with any issues, creating a mechanism of dependence and the possibility of constant or temporary pressure and enforcement. Therefore, water professionals must constantly monitor these trends and try to resist the transformation of water into a commodity or means of pressure, taking into consideration the social and economic importance of water.

The rules for life and professional activity must be sustainable in time and space, avoiding momentary political and human preferences and drafted taking into account the future. An example of such a far-sighted approach is the 1909 Boundary Waters Treaty between United States and Canada signed 100 years ago for establishing of the International Joint Commission, the provisions of which have stood the test of a rapidly changing time and which, according to the current politicians of both countries, no one would sign at present time.

However, guided by this Treaty, both countries in the conditions of greatly increased industrial, natural and anthropogenic loads perfectly cope with all water problems related to water consumption, water quality and climate change.

I am sure this small generalization of the multifaceted profile of our specialty, which I have tried to present to you in this introduction to our noble profession, will force you to think about your choice. I hope it will help you to find the right solutions in all your actions based on the openness of information and strengthening the mechanism of enriching with experience and knowledge, honesty and trust along with other mechanisms of ethics, practice and professional responsibility for the most priceless gift of nature entrusted to us.

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