WCD Briefing Paper

# Development of Dams in the Russian Federation and other NIS Countries

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# The WCD Knowledge Base

This report is one component of the World Commission on Dams knowledge base from which the WCD drew to finalize its report "Dams and Development-A New Framework for Decision Making". The knowledge base consists of seven case studies, two country studies, one briefing paper, seventeen thematic reviews of five sectors, a cross check survey of 125 dams, four regional consultations and nearly 1000 topic-related submissions. All the reports listed below, are available on CD-ROM or can be downloaded from www.dams.org

**Case Studies (Focal Dams)**

- Grand Coulee Dam, Columbia River Basin, USA
- Tarbela Dam, Indus River Basin, Pakistan
- Aslantas Dam, Ceyhan River Basin, Turkey
- Kariba Dam, Zambezi River, Zambia/Zimbabwe
- Tucurui Dam, Tocantins River, Brazil
- Pak Mun Dam, Mun-Mekong River Basin, Thailand
- Glomma and Laagen Basin, Norway
- *Pilot Study of the Gariep and Van der Kloof dams- Orange River South Africa*

**Country Studies**

- India
- China

**Briefing Paper**

- Russia and NIS countries

**Thematic Reviews**

- TR I.1: Social Impact of Large Dams: Equity and Distributional Issues
- TR I.2: Dams, Indigenous People and Vulnerable Ethnic Minorities
- TR I.3: Displacement, Resettlement, Rehabilitation, Reparation and Development
-
- TR II.1: Dams, Ecosystem Functions and Environmental Restoration
- TRII.1: Dams, Ecosystem Functions and Environmental Restoration
- TR II.2: Dams and Global Change

- TR III.1: Economic, Financial and Distributional Analysis
- TR III.2: International Trends in Project Financing

- TR IV.1: Electricity Supply and Demand Management Options
- TR IV.2: Irrigation Options
- TR IV.3: Water Supply Options
- TR IV.4: Flood Control and Management Options
- TR IV.5: Operation, Monitoring and Decommissioning of Dams
-
- TR V.1: Planning Approaches
- TR V.2: Environmental and Social Assessment for Large Dams
- TR V.3: River Basins – Institutional Frameworks and Management Options
- TR V.4: Regulation, Compliance and Implementation
- TR V.5: Participation, Negotiation and Conflict Management: Large Dam Projects

- **Regional Consultations – Hanoi, Colombo, Sao Paulo and Cairo**
- **Cross-check Survey of 125 dams**

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- ABB
- ADB - Asian Development Bank
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- Atlas Copco
- Australia - AusAID
- Berne Declaration
- British Dam Society
- Canada - CIDA
- Carnegie Foundation
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- Denmark - Ministry of Foreign Affairs
- EDF - Electricité de France
- Engevix
- ENRON International
- Finland - Ministry of Foreign Affairs
- Germany - BMZ: Federal Ministry for Economic Co-operation
- Goldman Environmental Foundation
- GTZ - Deutsche Geschellschaft für Technische Zusammenarbeit
- Halcrow Water
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- People's Republic of China
- Skanska
- SNC Lavalin
- South Africa - Ministry of Water Affairs and Forestry
- Statkraft
- Sweden - Sida
- IADB - Inter-American Development Bank
- Ireland - Ministry of Foreign Affairs
- IUCN - The World Conservation Union
- Japan - Ministry of Foreign Affairs
- KfW - Kredietanstalt für Wiederaufbau
- Lahmeyer International
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- Norway - Ministry of Foreign Affairs
- Switzerland - SDC
- The Netherlands - Ministry of Foreign Affairs
- The World Bank
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- United Kingdom - DFID
- UNEP - United Nations Environment Programme
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# Executive Summary

## Introduction

As part of its activities the World Commission on Dams (WCD) sponsored case studies of several dams in different regions of the world and country-review papers on the development experience with large dams in India and China. To complete the world coverage, this briefing paper looks at the Russian Federation and Central Asian States formerly part of the CIS.

Two background papers were used to develop this briefing paper. They were prepared by organisations in Russia and Central Asia and translated into english. The paper was prepared by members of the Russian Academy of Sciences based in the Institute of Geography in Moscow. The work was co-ordinated by the IUCN office in CIS. It provides a the historical view of dams and hydropower, and the current decision-making context more specific to Russia rather than to other states (Belarus, Ukraine, Moldova, Azerbaijan, Armenia and Georgia). Information that covers the developments up to the 1990s and the general context refer to all the former Soviet Union states together. Information on other central Asian States is provided in Annex 3 as a contributing paper entitled, "Summary Paper on Dams and Reservoirs in Central Asia". This contribution was prepared by the experts from five Central Asian states, namely: Kazakhstan, Uzbekistan, Kyrghyzstan, Turkmenistan and Tadjikistan. The work was co-ordinated by the Law and Environment Eurasia Partnership a NGO network in Central Asia. Access to current information was limited for Turkmenistan and Tadjikistan. While both background papers are limited in scope and depth, they nevertheless provide an overview of the circumstances and trends concerning water resources and dams in these states, as well as emerging perceptions. A network of professionals drawn from the government, industry, NGO and Civil society interests within the region as well as regional experts from abroad was asked to provide contributions, inputs and comments on the draft papers.

**Summary Points:**

Most of Russia is not water stressed. The official statistics indicated that most of the major reservoirs and dams in the Russian Federation and other NIS are hydropower, though many are multipurpose. A total of 205 large dams are reported in the World Register of Large Dams (1998) maintained by the International Committee on Large Dams (ICOLD). The following table shows the number registered by state and provides comments based on any additional information contained in the papers.

| States | Number of Dams Reported (Above 15 Meters) ICOLD Registry | Comments based information in the Briefing Paper |
|---|---|---|
| Russian Federation | 91 | Mostly register hydropower dams. Additional 2000 reservoirs/ |
| Armenia | 16 | All in operation |
| Azerbaijan | 17 | All in operation |
| Belarus | 0 | No large dams above 15m |
| Georgia | 14 | 21 large dams |
| Kazakhstan | 12 | 9 in operation |
| Kyrgyzstan | 11 | 13 large dams |
| Moldova | 2 | |
| Tadjikistan | 7 | 17 large dams in operation |

| | | |
|---|---|---|
| Turkmenistan | 0 | 15 reservoirs more than 1 sq. km |
| Ukraine | 21 | 9 in operation |
| Uzbekistan | 14 | 21 including those above 10m |
| **Total** | **205** | |

The official data sources focus on dams with roles in hydropower production and therefore the data very likely underrepresent the total number of dams for all purposes. For example, other statistics suggest there are more than 2 000 different large water storage reservoirs in Russia alone, which points to additional large dams beyond the 91 reported in the ICOLD Registry (1999).

In most periods of the last century, the Russian political and economic system was orientated to the development of large public infrastructure projects. Similar to situations in most western countries, the environmental and social implications were not fully understood or even recognised, and certainly these factors were less important in decision-making than were the broader economic growth aims of the day and the engineering considerations. Moreover, the Russian State has always maintained ownership of all land, water and energy resources and the collective and agriculture and industrial enterprises. In the decades after World War II Russia also had a major influence on dam building programmes in many countries in the world though its technical assistance and development assistance programmes. For example, Russian engineers and technicians assisted China in its own dams development programme in the 1950s and 1960s where approximately half the world dams have been built.

After the political and economic disintegration of the former CIS in the early 1990s, dam construction came largely to a halt in the region. This included the abandonment of a number of large dams under construction. During the 1990s, as a result of the economic crisis, the water consumption for both general and industrial purposes in Russia decreased. It fell by more than 25% in regions such as Far East and by 35-50% in Povolzhsky and the Northern-Caucasian regions. As compared to 1990, the water use levels at the century's turn decreased by 40% on average for agricultural purposes and 10% for domestic needs. In the mid to late 1990s, due to the deteriorating quality of existing water and energy services and shifting patterns of demand and use, more attention was paid to restoring and upgrading existing facilities including the completion of several large dams previously abandoned mid-way through construction. This included the resumption of construction on the world's tallest dam (the 325m Rogun dam) in Tadjikistan. More recently, authorisation to proceed with construction of some new dams has been under consideration. Nevertheless, all the governments in the region are struggling to finance these activities, whether it is for normal maintenance, restoration or expansion of existing assets, or for new projects.

The political, economic transition and institutional landscape for water and energy resources development in the Russian Federation and Central Asian states is being totally reshaped and transformed. Within this ongoing transformation civil society and public participation are emerging. This has resulted in a broader range of constituencies involved in water and energy resources planning. Increased scrutiny, criticism and in some cases opposition to plans for renewed dam building by emerging environmental movements is also apparent. Challenges for the future relate both to the refurbishment, upgrading and management of existing assets and investment in new development initiatives, as the broader circumstances and the criteria for decision-making evolve.

## 2. Water Resources of Russia and the NIS

The total freshwater resources of Russia and the NIS amount to nearly 65 000 km$^3$. The cumulative mean annual river streamflow equals 4400 km$^3$, where Russia's share is about 4 000 km$^3$, equivalent to 10% of the world stream flow, and second only to Brazil.

- The volume of water per unit area is 1.5 times less than the world average. Spatial distribution of water resources is extremely uneven and in most cases does not correspond to the population density, and the location of industry and agriculture. The problem is exacerbated by the high seasonal variability of streamflow and climate.
- The stream flow of many rivers in the NIS has reportedly decreased in the past decades as a result of river basin modification, abstractions and water resources development. The rivers in the southern regions, where water resources are mainly used for irrigation have been affected most. The streamflow depletion is most acute in Central Asia, particularly in the downstream of Syr Darya and Amu Darya rivers. This is often cited as one of the main reasons for the desiccation of the Aral Sea.
- The quality of water resources is deteriorating because of the continuous pollution of rivers and reservoirs with wastewater. Based on the international criteria, by the early 1990s, about 20% of all water resources of Russia were included in the national list of polluted and heavily polluted. The downstream reaches of rivers in Central Asia are characterised by high salinity levels.
- Water use in Russian Federation amounts to about 1/3 of the total water consumption of the NIS countries. Less than 20% of the total water consumption in Russia is used for agricultural and household needs; the rest is used to satisfy industrial requirements.

In the Russian Federation water resources planning and management are now to be based on the river basin planning principle, the requirement for which has been integrated into government legislation – though in practice the institutional capacity has yet to be developed. The Federal body of Water Resources Management is a member of the government. Basin Water Boards and Local Committees on Water Management have been established under the Federal Ministry of Natural Resources and are regulated by government. All entities of the Federation located in the basin of the same river are required to sign a Basin Agreement (Treaty) with each other and with the federal body on joint sound management and protection of trans-boundary rivers. This Basin Agreement is to be based on a programme of water activities developed for the entire basin, as applied to the existing and planned 'water economic complexes'. The basin treaty signed by all the territories and entities located in the basin assigns the rights to dispose property. In the mid-90s, a set of targeted Federal programmes was initiated on a number of river systems including the Volga revival, the Ob and Tom.

The modern period of transition to market economy is also characterised by paid water use, inter alia for water pollution (proceeding from the 'polluter pays' principle) on the basis of licenses for water resources use and regulation. A package of legislative and regulatory acts has been developed in Russia to regulate the imposition of payment for water use, which has yet been implemented - only partially due to institutional constraints.

## 3. Dams and Water Reservoirs: Statistics and History

More than 2 000 different water storage reservoirs and more than 90 large dams have been built and put into operation in Russia alone. From the total number of reservoirs, 105 have volumes over 100 million m$^{3.}$ The cumulative volume of reservoirs, each with the capacity of more than 1 km$^3$, amounts to nearly 90% of the total water volume in Russian reservoirs. In the republics of Central Asia, there are 60 reservoirs with the storage capacity in excess of 10 million m$^3$; the total reservoir capacity accounts for about 50% of the annual stream flow in Central Asian rivers.

- About 55% of reservoirs in Russia and the NIS are multipurpose (hydropower - 78%, irrigation - 58%, water supply - 47%, navigation - 43%, recreation - 15%, flood control - 7%).

- The distribution of functions for single purpose dams is: irrigation - 57%, hydro -35%, water supply/flood control/navigation each - less than 3%. While there are only 205 large dams (including 91 large dams in Russia) registered with ICOLD, it should be noted that the number of dams is under-reported.

Use of rivers for hydropower began in the late 19$^{th}$ century. By 1941, the foundations of energy development in the Soviet era were laid and all regions of the country relied on the hydropower resources to some extent. The post World War II years were the main decades of large hydropower construction, at its height in 1960-80s.

## 4. Hydro Power: Statistics and Prospects for Development

Hydro plants generated 157.5 TWh in 1997 in Russia, about 5% of the estimated gross theoretical hydro potential of 2 900 TWh/year. Dams now contribute 20% of the total electricity production in the Russian Federation with the balance provided mainly from fossil fuel and nuclear sources.

- The proportion that hydropower represents of electricity production in other states varies. Georgia's electricity is 89% hydro-generated, Tajikistan (96%), Kyrgyzstan (45%), Armenia (25-30%) with further development of small hydro stations to decrease dependency on imported fuels. Kazakhstan and Uzbekistan have about 13% of power from hydro with plans for further development; Azerbaijan (11%) Ukraine (5%) with a number of large dams under construction or planned by the year 2010; and Turkmenistan—less than 1%, Belarus (0.1%).

- Russia has one of the largest hydropower stations in the world - Sayano-Shushenskaya with a capacity of 6 400 MW. Tajikistan has some of the highest dams built in the world; Nurek (300 m) and Rogun (325m - under construction); reservoir-induced seismicity applies reportedly applies to both but is not considered to be a safety hazard.

In recent times the short-term and long-term objectives of hydro development in Russia have been identified in official documents such as "The Russian Energy Strategy up to the Year 2010" (1994) and "An Ecological Programme of Power Engineering of Russia" (1996). The latter document identifies the main directions of nature conservation activities associated with the power construction up to the year 2025. At present the main attention is on the Far East and Northern Caucasus regions to address severe energy crisis that exists in these regions. The current emphasis is placed on the upgrade and modernisation of the operational dams and thermal power stations. Development of hydropower potential of the major Siberian Rivers is expected to secure self-reliance of the adjacent territories in energy supply in the future. Large-scale dam construction is foreseen to be limited at present due to financial constraints and unresolved environmental concerns.

One focus in the future development of hydro power potential is likely to be greater emphasis on the construction of small and medium hydro power stations (SHPS), which have a number of advantages over large HPS on major rivers in the current financial and political circumstances. Another major trend is to the greater regional interconnection of power grids to obtain the advantages of complementary operation of the grids, which includes reserve sharing.

## 5. Benefits and Adverse Impacts Derived from Hydro Power Stations and Reservoirs

The government and power industry of the Russian Federation and Central Asian States see a number of advantages in continued dam development as related to hydropower. The reasons cited in policy documents and reflected in the perception presented in this report include:

- reduction in fossil fuel use;
- the possibility to meet peak demands in energy;
- labour savings (Hydropower is characterised by higher productivity as compared to thermal and nuclear power, as well as by the decreased labour resources required due to the elimination in hydro power industry such processes as extraction, transportation and processing of fuel and production of wastes disposal. Reduction of labour demand in such regions as Siberia, Far East and Far North is of particular significance.);
- hydropower is not severely affected by inflation processes in the economy. (This consideration is particularly attractive to the regions and entities of the Russian Federation and other NIS countries which have an under-developed economy and a fuel and energy resources deficit.);
- water supply is regulated at the national economy level, where all the dams and stations are connected and integrated into unified energy system (Integral use of water resources was one of the main conditions of hydro construction in the previous years.);
- transformation of the regime of rivers by means of reservoirs makes it possible to deliver cargo from inland to the nearest seaports (Recently, the situation deteriorated due to the adjustments of flow regulation made by individual local administrations, leading to the risk of transit navigation being terminated in the European parts of Russia.);
- flood protection;
- development of recreation facilities and health care institutions;
- assured water supply for industrial, agricultural and domestic purposes.

Among the adverse impacts that are increasingly cited as issues that the government and industry must address, and on which the emerging civil society and environmental NGOs are now focusing attention include the following:

- inundation of agriculture and other lands: the cumulative area of lands withdrawn from beneficial use as a result of hydro construction was estimated to be 4,4 million ha;
- reduction of fish productivity: the attempts to install fish ladders at dams have not yielded the desired results (Artificial cultivation, establishment of ponds and lakes, commercial fishery farms proved to be more efficient.);
- loss of Livelihood of Indigenous People: adverse effects on fauna and flora, which in turn affected livelihoods of many indigenous peoples whose survival was largely based on hunting;
- riverine Ecosystem Transformation: changes in stream flow and temperature regimes, the loss of fertility and bio-productivity of flood plains and changes in meteorological conditions are concerns. (River runoff reduction and desertification of Amu Darya and Syr Darya deltas contributed to an extreme sanitary-epidemiological situation in the Aral Sea area. The biological reproduction of water and land ecosystems is undermined leading to health risks and environmental hazards.);
- resettlement: according to data provided by the Ministry of Fuel and Energy, during the entire period of hydro construction in Russia 832, 000 people were resettled, including 666 000 resettled in the course of Volga-Kama construction programme. While some compensation was provided to individual families, the compensation measures would in most cases be considered inadequate to the level dislocation caused – certainly judged by the standards of today.

The paper provides estimates of the number of persons displaced by the construction of hydropower dams in Russia. However, displacement and all the aspects of resettlement were conducted within the political and economic system of the day. Retrospective assessment of the practices in Russia is complicated by the problems of determining the numbers displaced due to all dam construction programmes within the massive scale of population displacement that occurred throughout the different periods of Soviet history.

# 6. The Impact of the Economic Crisis of the 1990s

By the late 1990s, as a result of the economic crisis, the water consumption for both general and industrial purposes in Russia decreased by between 25% and 50% in different regions.

- The rate of decrease in the main indicators of water use and consumption was considerably lower than the rate of production decline (gross agricultural output declined often by more than 50% in most countries). The efficiency of the water use deteriorated, while water use per unit of output increased by between 150% and 200%.

- Political and economic instability, especially in the Caucasus (Armenia, Azerbaijan, Georgia, Chechnya) and Tajikistan, led to the disruptions in the construction, operation and maintenance of hydro facilities, and increased the danger of damage as a result of military and terrorist activities.

The circumstances that emerged in the 1990s is regarded within Russia and other NIS countries as a temporary one, caused by transition to a new economic system with a considerable share of market structures and features.

In the early 21st century, the revival of the economy with the implication for increased water and energy services is expected. The extent to which the incremental demand in services is to be met by improvement in the supply and use of existing resources or by new developments is uncertain at this point. It is envisaged that the economic transformation will have implications for an increased demand for hydropower development. The official policies for energy production development in Russia are reflected in the Basic Directions of Energy Policy Development and Structural Adjustment of the Fuel and Energy Complex of the Russian Federation of May 7, 1995 N 472, and in the Russian Energy Strategy adopted by the Government of the Russian Federation on October 12, 1995. Specifically, the Decree states that "further electrification development, inter alia through economically and ecologically justified use of atomic and hydro-power stations, and non-traditional renewable sources of energy" is a priority of Russian energy policy for the period to 2010.

# 7. Public and Institutional Influences on Water Resources Development Projects

Prior to 1980, participation in and influence on water resources development decisions by general public and environmental groups in the Soviet Union was minimal. Since the late 1980s and during the 1990s, the environmental movements has become more organised and have spread throughout all the regions, leading to formation of the environmental lobbies, extensive publications and the wide dissemination of their findings. Most of the NGOs are just beginning to deliver services and be held accountable to communities. They are active to different extents throughout the region, with the recent exception of Turkmenistan, where they face extreme government opposition.

- It is believed that criticism by the environmental NGOs of the hydro projects contributed to the minimisation of dam construction conducted in the 80s and 90s within the NIS territory.

However, construction of many facilities stopped due to the convergence of a number of factors so it is difficult to attribute events to any one reason. Visibly growing problems with some of the existing facilities, growing understanding and acknowledgement of problems and cause and effect relationships, financial constraints and critique both internally and from the emerging environmental movements and public attitudes were all factors.

- As early as the 1960s, reportedly due to adverse environmental implications, the projects of Nizhne-Obskaya (Lower Ob, Siberia) and Nizhne-Volzhskaya (Lower Volga) HPS were turned down by authorities. In the 1980s extensive discussions were held in respect of projects involving large-scale inter-regional transfer of water resources in the European and Asian parts of the USSR. The Government decided to terminate the project and research activities on the transfer of Siberian river flows to the south due to the lack of information on the environmental implications. There were also what were considered to be extreme suggestions for environmental restoration, such draining some reservoirs (Rybinskoye on Volga, Tsimlianskoye on Don etc.).

- The Russian public is generally aware of the controversial environmental, social and health hazards related to mines and nuclear power. After the Chernobyl nuclear incident in 1987, interest and awareness in the media and general public in environmental matters became more widespread. Hydropower is today largely perceived to be a cleaner and renewable alternative to nuclear and thermal power generation. The negative impacts of damming rivers on ecosystem functions, and on the environment more generally, as well as the situation-specific social consequences of displacement are mainly recognised in academic circles and relevant state agencies. Such issues have fairly recently entered into the media and public view.

- Despite local opposition and by environmental movements, the latest Russian government decision, in May 2000, was to raise the level of the dams for some reservoirs and proceed with the construction of a few controversial projects (eg Boguchany on the Angara river, Bureya on the Bureya river, Irganai and Zaramag in the Caucasus etc.).

- There is also some internal criticism of the new institutional arrangements in the water, energy and environment sectors. For example, the State Committee on Ecology and Environment Protection is no longer a separate government body, but operates as part of the Ministry of Natural Resources. This is seen by critics as constituting a conflict of interest and undermining the possibility of balanced debate before decisions are taken.

Other views are that decisions regarding the water and energy sector and the energy portfolio for all the states are still driven by the government and industrial monopolies, allowing very limited public involvement. While NGOs involvement in the political decisions of the nature of dams is increasing, this does not seem to translate into changes in policies or their implementation. Public participation in the political context is developing but is still considered to be fragile. Information and knowledge access is uneven throughout the regions and segments of population, often leading to misinformed choices and the opportunity to manipulate perceptions.

## 8. Key Challenges for the Future

Among the challenges for the future that are cited in the briefing paper are:

- difficulty in integrating the principles of environmental sustainability with political and economic decisions to increase productivity and provide adequate supply of services (including hydropower generation and flow regulation) under the constraints of a country in transition and a recurring financial crisis;

- securing financing and investments for refurbishment and upgrading of the existing dams is constrained and dependent on overall investment climate. The quality of the projects underway depends to a large extent on the government control and regulation and policies of international financial institutions. Enforcement and monitoring are problematic;

- The Russian Federation and other NIS are at different stages of transition with different political priorities attached to environmental and social goals. The transformation process is slow and uncertain. Building further public awareness and improving investment climate are considered to be essential.

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# 1. Introduction

Dams represent one of the most radical and powerful means of affecting water resources and environment. Their construction in the NIS (former USSR excluding Lithuania, Latvia and Estonia) was considered to be justified by highly uneven spatial and temporal distribution of water resources which is different from that of the demand and frequently does not meet the requirements of the population and economy. Thus, in most of the NIS territory, between 60 and 70% of the annual streamflow (which forms the bulk of water resources) falls during a limited period of spring flood and/or flash flood, while the most pressing need for water, especially in irrigated agriculture, arises during summer low-flow period.

Limited flow regulation is possible by means of agro-technical and forest improvement techniques. But the principal approach still consists of hydro-technical regulation with the use of constructed dams and water storage basins. Water storage basins also ensure improved territorial redistribution of water resources. The establishment of water storage reservoirs can help to meet the following challenges: provision of sustainable water supply of human settlements and irrigated lands, production of electricity, flood control, provision of guaranteed depths for water vessels, meeting recreational needs of the population, etc. It is also necessary to emphasise the special value of hydro-energy because the operation regime of hydro-power stations (HPS), in contrast to typical thermal and atomic power stations, is flexible enough to quickly accommodate short-term fluctuation in energy demand. It is worth noting that both thermal and atomic power stations cannot do without using water (mainly for heat exchangers cooling) and setting up water storage basins and cooling ponds, whereas HPS are non-consumptive water users.

The benefits of hydro-technical construction were recognised long ago. Initially, these installations had the form of small mills and plant weirs. Latter, larger multi-purpose hydro-technical weirs were constructed. The USSR has gradually become one of the leading countries in the field of dam and reservoir construction. The experience gained by local hydro-engineers found a great demand abroad. The most well known facility constructed under the guidance of USSR professionals abroad is the Aswan Dam on the Nile River in Egypt, currently known as the 'Nasser dam'.

Numerous large dams and reservoirs as well as small dams and ponds have been built throughout the territory of the former USSR. In Russia alone there are more than 2,000 reservoirs (with the volume of over 1 million $m^3$) with the total full capacity of about 850 $km^3$ and the active capacity of more than 382 km3. Most of the reservoirs are of multi-purpose nature, ie they satisfy the requirements of several water uses simultaneously. In the northern regions, the reservoirs were established mostly for energy production purposes. In the southern regions, the primary reason for reservoir development was agricultural irrigation. In certain regions (the Far East of the Russian Federation, for example) flood control was the major issue. In the most valuable rivers in terms of fisheries (the Volga river, for instance), an important aspect of weir operation is the provision of spring waterways required for fish spawning. However, with the intense water economy balance it is extremely difficult to operate these waterways to the full extent and the general priority of energy requirements remains.

The examples of water regulation facilities established in the USSR territory include such major reservoir systems as Volzhsko-Kamsky (Central Russia), Dneprovsky (Ukraine), Angarsky (Siberia - with Bratsky reservoir being one of the biggest water storage basins in the world with the full volume of 169 $km^3$ and active volume of 48.2 $km^3$), the high Nurekskaya Dam (300 m), etc. Non-typical weirs include the complex of hydro-technical facilities for protecting St Petersburg from floods called a 'dike'. The total length of this dike under the project specification is 25.4 km, including 22.2 km along the Finnish bay with the average depth of 2.9 m. The protection complex includes 2 vessels passages and 6 water passing weirs, 11 stone-earth dams. By 2000 the major part of the dam was built except for its southern most part.

Besides the evident benefits derived from dams and reservoirs, there are also several obvious negative implications related to lands and upstream weir flooding, population resettlements, the destruction of natural habitats, especially of passing and semi-passing fish, micro-climate changes, etc. These problems were acknowledged long ago, but the negative implication were normally viewed as being less important than the benefits derived from reservoirs for power engineering, water economy and water transport.

The situation began to change in the 1960s when the projects of Nizhne-Obskaya (Lower Ob, Siberia) and Nizhne-Volzhskaya (Lower Volga) HPS were turned down due to adverse environmental implications. The change has become more evident since 1980s when widespread discussions were held in respect of projects of large-scale inter-regional re-distribution of water resources in the European and Asian parts of the USSR, and the Government decided to terminate the project and research activities on the transfer of a part of the Siberian rivers' flow to the south due to lack of knowledge of environmental implications. The intention of reducing damage to the environment caused by weirs, is also reflected in their actual operation. In the Volga river basin, annual spring fishery flood-flushes were legitimised. In order to improve spawning conditions in the Volga's eastern delta, a unique hydro-technical facility – a water separator was built at its upper part. Ecological expertise in all projects was strengthened. This contributed to the rejection of a whole set of new projects, including Turukhanskaya and Sredneenisseiskaya HPS (Siberia), Rzhevsky weir (Volga) etc.

Criticism of hydro-technical construction in the country was well justified. Such construction did not take adequate account of environmental implications, mainly because of the giant-mania which was typical of certain stages of the country's political evolution. Thus, if in the world 10 water storage basins (0.02% of the world total) account for 22% of the aggregate capacity of water storage basins, in Russia these 10 water storage basins (0.3% of the country's total), accounted for 40% of the total storage capacity. At the same time, criticism of the reservoir construction by the representatives of the 'Green Movement' was considered by industry observers as not always justified:

The view was that the ecological lobby had become so powerful, that it became practically impossible to secure approval of any new large water project. Together with the political, social and economic crises in the country, it contributed to the minimum level of new hydro-technical construction in the last decade in the NIS territory. Thus, in 1991-1995 only 8 HPS were put into operation, ie less than 3% of the total number built between 1942and 1995. This is also less than what was built during the 1942-1945 war years. The total capacity of facilities put into operation between 1991 and 1995 amounted to just 2.5% of the total volume for the period from 1942 to 1995. Many facilities were frozen, including the St Petersburg dike. Moreover, there were appeals to drain some water storage basins, particularly Rybinskoe (on the Volga River) and Tsymlianskoe (on the Don). The danger of damaging the weirs as a result of military activities and terrorist acts increased dramatically.

In the 1990's, the scale of energy production decreased both in Russia and the NIS, although less drastically than that of industrial production which resulted in the increase in unit cost of energy.

However, the situation that emerged in the 1990s is regarded in Russia and other NIS countries as a temporary one, caused by transition to a new economic environment with a considerable share of market structures and features. In the early 21st century, the revival of the economy and increase in energy production are expected. It is envisaged that this will have implications for an increased demand hydropower development as well. The first signs of this improvement were already visible in 1999-2000. The prospects of energy production development in Russia are reflected in the Basic Directions of

Energy Policy Development and Structural Adjustment of the Fuel and Energy Complex of the Russian Federation of May 7, 1995 N 472 and the Russian Energy Strategy adopted by the Government of the Russian Federation on October 12, 1995. Specifically, the Decree states that "further electrification development, inter alia through economically and ecologically justified use of atomic and hydro-power stations, non-traditional renewable sources of energy" is one of the top priorities of the Russian energy policy for the period up to the year 2010.

The Russian energy strategy provides two options of energy production development. The first is related to the development of energy production in the environment of strict energy saving policy conducted in the country. All available market mechanisms, pricing system and legislative regulation, as well as an intense programme of education and promotion through mass media during the period up to the year 2010 are to be used. This option provides for a minimum construction of new energy facilities, particularly thermal power stations. The second option proceeds from the assumption that the country is unable to implement the energy saving policy to the full extent and that it will be necessary to construct a set of new power stations, including HPS.

Both options provide for the possibility of meeting the permanently increasing energy needs through the construction of medium and small-size HPS, mainly at the rivers of low-populated mountainous regions of Siberia, the Far East, and the Northern Caucasus. Further strengthening of the Unified Energy System of Russia is also to be ensured.

Further development of energy production in Russia is deemed impossible without large-scale international co-operation on a mutually beneficial basis. Russia has gained rich positive experience in energy production development, inter alia in the field of hydropower, reservoir construction as well as in the area of complex water resources use. The latter include complex use of reservoirs, which satisfy multiple industrial water demands, agricultural demands and ecological water requirements. Promising technologies have been developed in the country for constructing large reservoirs on water-abundant plains rivers with non-rocky beds, in extreme climatic conditions ( including the Far North and permafrost regions), and in seismic zones. In its turn, the Russian Federation especially values foreign experience, particularly in the field of energy facilities and reservoir operation in market economy conditions.

This document represents the first attempt to briefly highlight the major issues related to streamflow regulation, reservoir construction and operation, in the technical, social, political and environmental context. Many of such issues are considered below. Specifications of dams and water storage basins are given for the territory of the former USSR and the NIS (especially Russia) with particular focus on the largest of them typically connected to relevant HPS. The document intends to address such issues as the prerequisites for and the history of hydro-technical facilities construction, views in favour of and against the reservoir establishment, together with the evaluation of alternative ways of energy production, as well as specific steps for the optimisation of reservoir operation.

It is inevitable that due to the time and budget limitations, a number of issues have only been skirted. In other cases, the discussion is precluded by the limitation of available information. The material presented/cited above is based on published sources, the list of which can be found at the end of the text.

# 2. Water Resources of Russia and the NIS

## 2.1 General Information

By the term "water resources" of any territory, in a broad sense we understand the aggregate stock of all types of surface and underground waters in different stages. For direct use in everyday life only a small portion of the total stock of water resources is suitable - mainly the fresh waters. This is why the assessment of water resources of a territory usually focuses on its fresh water supplies.

The territory of Russia and the NIS possesses a large natural stock of fresh waters with the total volume amounting to nearly 65 000 $km^3$. About 40% of this volume is concentrated in lakes (where 90% of the total lake volume is in Lake Baikal). Polar and mountainous ice fields contain 20% and the underground ice - 25% of the total freshwater resources. The rivers and artificial water storage basins (reservoirs) contain only 6% and 1% of the total freshwater resources, respectively.

Water is a renewable resource, but some types of waters in the natural hydrological cycle are renewed so slowly that they can be practically regarded as constant under modern climatic conditions. The most economically important water resources are those which are annually renewed. The bulk of such resources is represented by the river stream flow. Consequently, the term 'water resources of large territories and states"' usually applies to the amount of annual stream flow. The common measure of the magnitude of the annual stream flow is the Mean Annual Runoff (MAR) -- the expected average volume of streamflow in any one year.

The total MAR of the territory in question amounts to about 4400 $km^3$, with Russia's share reaching 4000 $km^3$. This figure represents nearly 10% of the world stream flow and is the second in the world after Brazil. However, the rates of water resources per unit area in the NIS territory are 1.5 times less than the world average. If we draw a similar comparison for the most valuable underground stock, which does not require regulation, this difference becomes even more pronounced. This implies that the need to regulate stream flow on the territory in question is acute.

## 2.2 Major water bodies

Rivers of the territory belong primarily to the basins of the Pacific, Atlantic and Arctic oceans (see Table 2.1). 63% of the total MAR belongs to the basin of the Arctic Ocean. This basin encompasses the majority of large rivers - Severnaya Dvina, Pechora, Ob', Enissei, Lena, Yana, Indigirka, Kolyma. The basin of the Pacific Ocean encompasses the river catchments of the eastern part of Russia (21% of the total stream flow), and includes one of the largest rivers - Amur. The basin of the Atlantic Ocean includes rivers of the European part of Russia - Neva, Don and Kuban in Russia, Dnepr, Dnestr and Danube in the Ukraine and Moldova (7% of the total stream flow). A part of the NIS territory belongs to the Aral-Caspian area of internal flow since it has no exit to the ocean (9% of the total stream flow). The basin of the Caspian Sea includes such rivers as Volga, Ural, Terek, Kura, while the basin of Aral Sea includes the Amu Darya and Syr Darya rivers.

**Table 2.1 Large Rivers of Russia and the NIS**

| River | River basin area, $10^3$ $km^2$ | Length, km | Mean annual discharge, $10^3$ $m^3/sec$ | Water resources, (MAR), $km^3$ |
|---|---|---|---|---|
| Enissei | 2580 | 5940[1] | 19,9 | 630 |
| Lena | 2490 | 4270 | 16,8 | 532 |
| Ob' | 2990 | 5570[2] | 12,8 | 404 |
| Amur | 1855 | 4060[3] | 10,9 | 344 |
| Volga | 1380 | 3090 | 8,04 | 254 |
| Danube | 817 | 2850[4] | 6,43 | 132 |
| Pechora | 322 | 1790 | 4,12 | 130 |
| Kolyma | 647 | 2600 | 4,03 | 123 |
| Severnaya Dvina | 357 | 1310[5] | 3,46 | 109 |
| Khatanga | 422 | 1510[6] | 2,79 | 100 |
| Neva | 281 | 74 | 2,48 | 78,5 |
| Dnepr | 504 | 2285 | 1,71 | 54 |
| Indigirka | 360 | 1790 | 1,7 | 53 |
| Yana | 238 | 1170 | 0,97 | 30,7 |
| Don | 422 | 1970 | 0,89 | 28,1 |

The average lake density in the NIS territory (without the Caspian and Aral seas) exceeds 2% and varies from 13% to nearly a zero. The most lake-rich areas are Karelia and the North-Western part of Russia. Small parts of land with increased lake density (more than 10%) can also be found in the deltas of the Volga, Lena and Terek rivers. Lake density is high as well (5-10%) in the northern zones of tundra and forest-tundra (in particular, in the Kolsky peninsular, in the Western Siberia's tundra zone, in the Yano-Indigirskaya lowlands). Comparatively many lakes are also located in the dry areas of the Caspian basin and in the Northern Kazakhstan. In the Far East, as well as in the mountainous regions of the Caucasus, Altai and Sayany lake density is not very high and amounts to about 1-2%. The lowest lake density (0.5% or less) is found at the plains of the Central Asia. The largest lakes of Russia and the NIS countries are listed in Table 2.2.

Swamps and wetlands occupy nearly 10% of the territory. Most of the wetlands are located in the Western Siberia, where they occupy up to 70% of the area. Other wetland-rich regions are Karelia, and

[1] From the headwaters of river Selenga (the length of the Enisei River itself is 3350 km).
[2] From the headwaters of river Irtysh (the length of the Ob' River itself is 3680 km).
[3] From the headwaters of river Shilka (the length of the Amur River itself is 2850 km).
[4] Mouth part in NIS is 40 km.
[5] From the headwaters of river Sukhona (the length of the North Dvina River itself is 730 km).
[6] From the headwaters of river Kotui (the length of the Khatanga River itself is 3680 km).

the Kol'sky peninsular in the north of Russia and the Pripiat' river catchment in Ukraine, where this figure amounts to about 30%. In general the levels of soil moisture are high and contribute to the survival of both wild and cultivated vegetation. But, the main agricultural regions are insufficiently supplied with water and are prone to droughts.

In the territory of Russia there are vast areas of so-called surface frosting which are located in the Arctic region (more than 50 000 $km^2$). These areas include such regions as the Land of Franz Joseph, Novaya Zemlya and Severnaya Zemlya. The regions of mountainous frosting are located mainly in the southern parts of the NIS - the Caucasus and Central Asia.

**Table 2.2 Large Lakes of Russia and the NIS**

| Name | Plain area, $km^2$ | Average depth, m | Max. depth, m | Volume, $km^3$ |
|---|---|---|---|---|
| Caspian sea | ≈390000 | ≈200 | 1025 | 78000 |
| Aral Sea[7] | 35500 | - | - | 310 |
| Baikal | 31500 | 730 | 1637 | 23000 |
| Balkhash | 18300 | 6,1 | 26 | 112 |
| Ladozhskoe | 17700 | 51 | 230 | 908 |
| Onezhskoe | 9720 | 29 | 127 | 285 |
| Issyk-Kul | 6280 | 279 | 702 | 1730 |
| Zaisan | 5510 | 9,6 | - | 53 |
| Taimyr | 4560 | 2,8 | 26 | 13 |
| Khanka | 4190 | 1,3 | 11 | 16,5 |
| Tchudsko-Pskovskoe | 3550 | 7,1 | 15 | 25,2 |
| Alakol' | 2650 | 22,1 | 54 | 58,6 |
| Tchany | 1990 | 2,2 | 9 | 4.3 |
| Tenguiz | 1590 | 7 | 8 | 11 |
| Sevan | 1360 | 43,2 | 86 | 58,5 |

Distribution of water resources throughout the territory is extremely uneven and in most cases does not correspond to the population density, location of industry and agriculture. The average annual stream flow in the territory also varies considerably. In plains, it decreases from north to south, while in the mountains it increases with altitude. In the mountainous regions, the unit stream flow equals 2,500-3,000 mm, at the north-west of the European part – 300-400 mm, in the central zone - 100-200 mm, in the plains and semi-arid regions - 5-15 mm, and in the deserts of the Central Asia it is close to zero.

The bulk of stream flow is concentrated in the northern and eastern parts of the territory. The European part of Russia, which is the most populated and economically developed, accounts for less than 25% of the total water resources. The main contribution to water resources of the southern slope is made by the

7 Data as of 1990 ("Big Sea").

largest river of the European part of Russia, the Volga River. Its basin occupies 8% of the Russia's entire territory and is inhabited by almost 40% of the country's population.

The largest high-water rivers of the Asian part, namely Ob', Enissei, Lena, Amur, flow in the economically less developed and less populated regions. The basins of these large rivers cover more than $1,110^6$ $km^2$ (65% of the total territory of Russia) and together supply 2,160 $km^3$ or 50% of the country's water resources.

## 2.3 Water resources of the individual states and economic regions of Russia

Water supply per $km^2$ of area in the region in question amounts to about 200,000 $m^3$ per annum and 16,000 $m^3$ per capita. Among the NIS countries, the stream flow is distributed very unevenly. Water supply with local water resources (formed within the administrative boundaries of states) is high in Russia, Kyrghyzstan, Tadjikistan and Georgia. The countries with the lowest local supply from local waters are Turkmenistan and Moldova. In dry years, water supply decreases by between 150% and 200%. However, it increases due to the stream flow coming from the neighboring countries (see Table 2.3).

**Table 2.3 Water Resources Distribution between the NIS.**

| Territorial unit | MAR, $km^3$ | | |
|---|---|---|---|
| | Flow formed within the territory | Inflow from the neighbouring countries | Total |
| Azerbaijan | 4,4 | 20,2 | 24,6 |
| Armenia | 6,52 | 2,08 | 8,6 |
| Belarus | 36,2 | 21,7 | 57,9 |
| Georgia | 51 | 10,4 | 61,4 |
| Kazakhstan | 67 | 56 | 123 |
| Kyrgyzstan | 48,7 | 0 | 48,7 |
| Moldova | 1,2 | 11,4 | 12,6 |
| Russia | 4043 | 219 | 4262 |
| Tadjikistan | 50,3 | 47,9 | 98,2 |
| Turkmenistan | 1.1 | 68,9 | 70,0 |
| Uzbekistan | 9,9 | 98,1 | 108 |
| Ukraine | 62 | 157 | 219 |

Distribution of natural waters within each country is also uneven. In Kazakhstan the main portion of water resources is concentrated in the northeastern and southern regions of the republic, while the central regions are practically lacking water. Considerable water deficit is also experienced in the Donbass area (coal mining region), in the Urals, the northern Caspian area and some other heavily populated regions.

Most of Russia is not water-stressed. Its water resources amount to 4262 $km^3$ per year or 237,000 $m^3$/annum/$km^2$ and about 28,000 $m^3$/annum/capita (Table 2.4). The highest water supply is registered in the northern economic region and in the Asian part of Russia. The regions where water supply is the lowest per capita include the Central, Central-Tchernozemny and Northern-Caucasian economic regions.

**Table 2.4 Water Resources Distribution between the Economic Regions.**

| Economic regions | Local Flow (formed within the territory) | | Inflow from the neighbouring countries | Total | Per capita | |
|---|---|---|---|---|---|---|
| | $Km^3$ /annum | $M^3$ $10^3$ per annum/per $km^2$ | | | Local, $m^3$ $10^3$ per annum | Total, $m^3$ $10^3$ per annum |
| Northern | 494 | 337 | 18 | 512 | 85,39 | 88,50 |
| North-Western | 47,7 | 243 | 42,5 | 90,2 | 5,97 | 11,29 |
| Central | 88,6 | 183 | 23,4 | 112 | 2,99 | 3,78 |
| Volgo-Viatsky | 47,8 | 180 | 105 | 153 | 5,71 | 18,27 |
| Central-Thrnozemny | 16,1 | 96 | 4,8 | 20,9 | 2,05 | 2,66 |
| Povolzhsky | 32 | 60 | 244 | 276 | 1,90 | 16,34 |
| Northern-Caucasian | 44 | 124 | 27 | 71 | 2,48 | 4,01 |
| Uralsky | 122,7 | 149 | 9,3 | 132 | 6,01 | 6,47 |
| Western-Siberian | 513 | 211 | 70 | 583 | 33,95 | 38,59 |
| Eastern-Siberian | 1097 | 266 | 27 | 1124 | 120,93 | 123,91 |
| Far East | 1538 | 247 | 312 | 1850 | 209,65 | 252,18 |
| Kaliningradskaya oblast | 2,71 | 179 | 20,4 | 23,1 | 2,87 | 24,50 |
| Russian Federation | 4043 | 237 | 219 | 4262 | 27,48 | 28,97 |

## 2.4 Temporal variability of water resources

The stream flow is characterised by a very uneven seasonal distribution. Russia has a predominance of rivers with typical spring flash floods, while in the summer and winter seasons they carry very little water. Sustainable base flow under natural conditions amounts to about 25% of the total stream flow. For two or three months in spring, from 50 to 80% of the annual stream flow is formed in the bulk of the territory. In the forest plains and plain zones, the share of spring streamflow amounts to more than 75-95% of the annual flow. In the small rivers in arid and semi-arid zones, it amounts to 90-100%. In the mountainous regions of the Caucasus, Central Asia and Southern Kazakhstan, the seasonal distribution of water resources is also uneven, but is still more favourable for water use for irrigation purposes - here from 60 to 80% of the annual stream flow falls on the spring and summer period. On a considerable part of the territory of Siberia and the Far East from 50 to 80% of the annual flow falls on the period of spring and summer flash flood.

The flow during the dry seasons (winter and summer) normally does not exceed 5-10% of the MAR. Many small rivers dry out in summer and freeze in winter completely.

Considerable fluctuations of stream flow not only occur during the year but vary from one year to another as well. However, the cumulative water resources of such large regions as Russia as a whole do not significantly fluctuate from one year to another. This is related to a certain asynchronism of stream flow in different parts of the country, which evens out the fluctuations in the flow volume in different years. For certain territories and river basins, these fluctuations can be very considerable. And they are the more considerable the smaller and the dryer is the region. The biggest fluctuations are typical for the southern part of the territory with limited water resources.

In the 1990s,a unique hydro-climatic situation occurred in Russia. It is related to the fact that a large part of the territory was dominated by a prolonged period of increased moisture: in the European part of Russia, Eastern-Siberian and the Far-East economic regions, the stream flow values were higher than the average perennial figures. In Volgo-Viatsky, Povolzhsky and Uralsky economic regions of Russia they were 25% higher than the normal level. Such distribution of river flow on a vast territory cannot be regarded as an ordinary event.

The prolonged phase of increased moisture on most of the southern part of the Russian plains, which has occurred since the late 1970s, has had important implications. Thus, in 1978-1995 the stream flow of the Volga increased on average by 30% as compared to the previous dry decade (and approximately by 5% as compared to the normal level). This caused an almost three- meter increase in the level of the Caspian Sea.

## 2.5 Use of Water Resources.

The level of water resources utilisation in different regions of the NIS territory differs considerably. Water resources are under-utilised in the northern and northeastern regions of the European part of Russia, in Siberia and the Far East. One the other hand, they are most intensively used in the main regions of irrigated agriculture - the main user - in the south of the European part of Russia, in Kazakhstan and Central Asian republics. On average in the NIS, about 50% of water is used for agricultural purposes, mainly for irrigation, about 40% --for industrial purposes and 10% - for household and personal consumption.

The share of the Russian Federation amounts to about one third of the total water consumption of the NIS countries. Such a small share in the total NIS balance is related to comparatively low extent of irrigated agriculture. On average in Russia less than 20% of the total water consumption is used for agricultural, household and personal needs, while two thirds are used by the industry (see Table 2.5).

**Table 2.5 Use of Water in the Russian Federation as of the Late 1990s**

| Economic regions | Total use of fresh water, km$^3$/annum | Structure of water use, % by sector | | |
|---|---|---|---|---|
| | | Domestic | Industrial | Agricultural |
| Northern | 4,21 | 15 | 84 | 1 |
| North-Western | 7,01 | 12 | 87 | 1 |
| Central | 10,1 | 38 | 58 | 4 |
| Volgo-Viatsky | 2,02 | 29 | 64 | 7 |
| Central-Thernozemny | 2,04 | 27 | 58 | 15 |
| Povolzhsky | 7,15 | 20 | 37 | 43 |
| Northern-Caucasian | 15,54 | 8 | 51 | 41 |
| Uralsky | 8,52 | 22 | 72 | 6 |
| Western-Siberian | 5,46 | 22 | 68 | 10 |
| Eastern-Siberian | 5,75 | 14 | 80 | 6 |
| Far East | 2,2 | 27 | 68 | 5 |
| Kaliningrad District | 0,174 | 48 | 44 | 7 |
| Russian Federation | 70,2 | 19 | 64 | 17 |

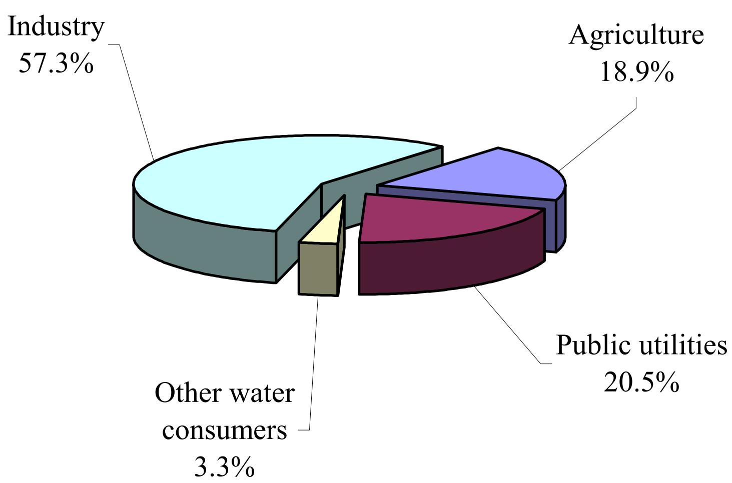


**Figure 2.1 Freshwater Use in Russia by Sectors in 1998.**

Among the economic regions of the Russian Federation, the Northern-Caucasian region stands out in respect of water consumption. It uses almost one fourth of the total water used in Russia and more than a half of all waters for agricultural purposes. Both in water resources and in the economy of the country three regions - Central, Povolzhsky and Uralsky - standout. These regions have more than 45% of the country's population, they occupy 10% of the territory and produce almost half of the GDP. The same regions use about 40% of all fresh water use, discharge 35-40% of waste and polluted waters and concentrate more than 55% of reusable and second hand water supply systems. The regions of the

Siberian part of Russia use and discharge about 20% of water. These regions contain about 20% of the population, produce 30% of the GRP and occupy about 75% of the territory.

Crisis phenomena in the economy experienced by Russia in the 1990s have affected water economy as well. By the end of the 1990s water consumption for both general and industrial purposes decreased by more than 25%. This process was the most intensive in the Far East, Povolzhsky and Northern-Caucasian regions (35-50% decrease). As compared to 1990 water consumption for agricultural purposes decreased by 40%, for household and personal needs - by less than 10%. The volume of recycled and second hand waters in the recent years decreased by 25%. The pace of decrease in the main indicators of water use was considerably lower than the pace of production decline. Consequently, the efficiency of the use of water resources deteriorated, while water use per unit of output increased by between 150% and 200%.

## 2.6 The impact of economic activities on water resources

### 2.6.1 Streamflow reduction

As a result of constant increase in the use of river flow for economic needs, which continued until early 1990's and corresponding growth of permanent water abstractions, the streamflow volume in many rivers of the territory in question has decreased. This relates in the first place to southern rivers where water resources are mainly used for irrigation. The aggregate intake of fresh water from water basins in Russia in general in an average year amounted to 3% of all water resources, but in some river basins (Kuban, Don, Terek, Ural, Iset', Miass, etc.) it amounts to 50-90% of flow. The possibilities of irrevocable intake of water from these rivers are practically exhausted.

The flow of some small rivers of Russia has been modified even to a greater extent, especially in the plains and forest plains zone, in the Urals industrial zone and in the vicinity of major industrial centres. The situation with water resources depletion is most acute in the Central Asia, particularly in the downstream of Syr Darya and Amu Darya (Table 2.6). This is the main reason of the Aral Sea drying out.

### 2.6.2 Water pollution

The water environment situation in Russia and the NIS countries is aggravated by mass pollution of rivers and reservoirs with waste waters and other economic wastes.

Waters are relatively clean only in the north-east of the Russian Federation occupying about one third of its area and possessing approximately the same share of river water resources. In the European part of Russia, low level of pollution is also typical of north-eastern regions. The bulk of water resources of other regions are polluted. By early 1990s about 20% of all water resources of Russia were included in the list of polluted and extremely polluted. To the greatest extent, water was polluted in Moscow District and a number of other administrative units in central Russia, Tcheliabinskaya, Kurganskaya districts, Krasnodarsky region, etc. These are regions with population of about 30 million people.

**Table 2.6 Reduction of River Stream Flow under the Impact of Economic Activities**

| River | MAR, $km^3$ | Reduction of stream flow under the impact of economic activities | |
|---|---|---|---|
| | | $km^3$/annum | % |
| Volga | 254 | 16 | 6 |
| Dnepr | 54 | 14 | 26 |
| Don | 28.1 | 8 | 28 |
| Kuban | 13 | 5 | 38 |
| Terek | 11 | 4 | 36 |
| Amu Darya | 70 | 57 | 81 |

In recent years, no major changes have occurred in the quality of water resources. In some regions the situation has reportedly changed somewhat for the better, mainly due to the termination of industrial production, reduction of the quantity of fertilisers and pesticides use in agriculture, while in others it has worsened due to the decrease in the quality of waste waters purification and loosening of water protection control. Increased wetness in the most part of Russia's territory has contributed to certain alleviation of hydro-ecological situation.

Practically all large cities and adjacent territories still remain in the list of heavily polluted areas. That means that a considerable part of urban population of the country lives in the environment of heavily polluted surface water and ground waters and complete degradation of water ecosystems. In the territory of the Ukraine and Moldova the highest level of pollution is registered in Danube delta and in Dnepr. In Russia, many big and small rivers are polluted to a certain extent. Thus, such rivers as Volga, Don, Kuban, Terek, Ob', Enissei, Lena are regarded as "polluted", particularly in the most inhabited areas. Their major tributaries - Oka, Kama, Tom', Irtysh, Tobol, Miass, Iset', etc. - as "heavily polluted"; this category also includes Ural river upstream.

The conditions of small rivers remain poor, especially in the zones of major industrial centres due to penetration of large quantities of pollutants with surface waters from the territory and waste waters into these rivers' waters. Considerable damage to small rivers is caused in rural areas due to violation of rules set for economic activities in water protection zones and disposal of organic and mineral pollutants into watersheds, as well as soil wash of as a result of water erosion.

The main pollutants found in the majority of water basins studied are oil products, phenols, easily oxidised organic substances, metals compounds, ammonium and nitrite nitrogen, as well as specific pollutants discharged with waste waters by various industries, rural enterprises and public utilities, surface waters. The quantity of pollutants in surface waters is seriously affected by secondary pollution.

The downstream reaches of rivers in the Central Asia (Amu Darya, Syr Darya, Zeravshan) are characterised by very high salinity levels.

### 2.6.3 Large-scale impacts of water storage facilities

The uneven spatial and temporal distribution of stream flow have triggered the implementation of the intensive set of flow regulation measures. The available by now water reservoirs make it possible to reduce flood volumes by 16% and by more than 1.5 times increase the resources of sustainable stream flow in the NIS territory. The greatest changes occurred in the stream flow of Dnepr, Volga and Don where the magnitude of floods have been reduced by more than twice with the simultaneous increase in the dry season flow volumes by 2.3, 2.7 and 4 times, respectively.

At the same time as a result of flooding of large territories, reservoirs considerably increase evaporation through additional losses from the water surface (especially in the southern regions) which leads to the reduction of the aggregate water resources of the region. Thus, an additional evaporation from Kuibyshevskoe, Volgogradskoe and Bukhtarminskoe reservoirs amounted to about 1.1-1.5 $km^3$ a year each. In the NIS in general water loss due to evaporation from surface water storage basins is estimated at 15-20 $km^3$ a year.

The impact of the reservoirs on water quality is fully known. However, the unsatisfactory state of water quality in many of the reservoirs is caused partly by the frequently uncontrolled wastewater discharge into them. Thus, the level of pollution in Volga reservoirs remains rather high for a number of years and the quality of water is regarded from "polluted" to "heavily polluted". The quality of water in Ivan'kovskoe reservoir - the main source of Moscow City water supply - is characterized as "moderately polluted". Water in Tsymlianskoe reservoir on the Don river is qualified as "heavily polluted". Saiano-Shushenskoe and Krasnoyarskoe water storage basins at the Enissei river are characterised as "polluted". Bratsk and Ust-Ilimsk water storage facilities at Angara in Siberia are heavily polluted by wastewaters from forestry complex enterprises and water is qualified from "low polluted" to "moderately polluted".

Thus water storage facilities in the NIS have become an important man-made factor of water resources change. Their impact is particularly high in the transformation of hydrological regime with all its implications for economy and environment. The review of this implications is provided in the following sections

## 2.7 Basin Principle of Water Resources Management

A river basin represents a hydrological entity and a balanced geo-ecological system where all components of water resources (eg rivers, groundwater etc.) are closely related with each other and with human economic activities. For this reason, the basin principle is being increasingly accepted in many countries as the basis for sustainable water resources management. This is becoming increasingly important with the increasing pressure on water resources and growing degree of flow regulation. The main principles of integrated basin management in the context of Russia are reflected in the Water Code of the Russian Federation (1995).

To implement the system of sustainable water resources management a relevant institutional structure needs to be established. In the context of Russia it includes three vertical levels of management:

- federal body;
- basin body;
- territorial body.

The federal management body is a member of the Government of the Russian Federation and represents the interests of the state in water related matters. This role is performed by the Water Service of the Ministry of Natural Resources. The basin management body is subordinate to the federal body, is empowered with some of its rights and functions and represents the interests of the state in the field of use and protection of water resources of the river basin. The territorial body has dual subordination - to the basin body and to the Government of the territory - the entity of the Federation. It therefore secures the territorial water interests linking them with the state interests.

The rights to the disposition of property are separated between the federal bodies and bodies of the entities of the Federation on a treaty basis. All entities of the Federation located in the basin of the same river, sign a Basin Agreement (Treaty) with each other and with the federal body on joint sound management and protection of water resources of a trans-boundary river. This Basin Agreement is based on the program of water activities developed for the entire basin as applied to the existing and planned "water economic complexes". The major role in these complexes is to water storage facilities.

In the former USSR, the automated management systems (AMS) were established for water economic complexes management in river basins of inter-republican importance as part of the automated management system of the Ministry of Water Economy of the USSR (AMS-Minvodhoz), which in its turn interacted with automated systems of the ministries of individual republics and comprised the General State Automated System (GSAS). The AMS-Syrdaria, for example, included 70 largest inflow points and 5 reservoirs. The AMS-Dnepr included 11 inflow points and 6 reservoirs of the Dnepropetrovsky system. The operation regimes of most reservoirs is determined by "Reservoir operation rules" developed by the design bureaux.

The modern period of transition to market economy is characterised by paid water use, inter alia for waters pollution (proceeding from the "polluter pays" principle) on the basis of licenses for water resources use and regulation. A package of legislative and regulatory acts has been developed in Russia to regulate the imposition of payment for water use, which has yet been implemented only partially.

Following the basin principle, a state policy of water economic complex development is pursued in Russia through the realisation of federal programs. In 1995-1997 a set of federal targeted programs were developed, which have the focus on specific river systems ( "Volga's Revival", "Ob'", "Tom'", etc.)

### 2.7.1 Inter-State Interaction in the Use of Water Resources

The cases of two or more states claiming the same water resources are regulated by the international law. It is more common when the river basin is located within the borders of two or more states. In regions of developed irrigated farming disputes mainly arise due to claims to the volume of water resources, in other regions - to the quality of water arriving from neighboring countries. At border rivers disputes may arise over the course of water transport navigation.

Before the dissolution of the USSR conflicts in respect of water resources more often occurred with China (about Amur and Irtysh basins), with Iran (Tedjen and Murgab basins), Romania and Hungary (Danube basin). In order to settle these disputes a set of agreements was concluded between 1921 and 1986, regulating water use in the border rivers. After the dissolution of the USSR Dnepr, Zapadnaya Dvina, Ural and some other rivers, formerly flowing within a single country, became trans-boundary watersheds. Russia and Ukraine, Russia and Kazakhstan concluded agreements on the use of water resources of the inter-state rivers. At the same time the existing treaties between the USSR and other countries as applied to new borders were updated. These agreements include the elements of basin agreements which are in force in the Russian Federation and previous international arrangements based on the Convention on the Protection and Use of Trans-Boundary Watersheds and International Lakes (UN Economic and Social Council, European Economic Commission, 1992). The Water Code of the Russian Federation (1995) declares that generally recognised principles and norms of the international law and international treaties of the Russian Federation in the field of use and protection of water facilities shall be an integral part of the legal system of the Russian Federation".

# 3. The main issues related to dams and reservoirs in Russia and NIS

## 3.1 Historical perspective

### 3.1.1 The early period (1860-1917)

The industrial use of water power in Russia began in the 1860s and was closely related to the developments in metallurgy, which utilised only water wheels as engines. At this time more than 200 dams were constructed in the Urals, Altai, Karelia, Trans-Baikal and in the central regions of Russia. Industrial dams reached 200 meters in length, while their height was about 6-6.5 meters. Hydro-technical installations of the so called "Russian type" consisting of earth dams with wooden spillways and wooden water-raising dams were characterised by well-designed configuration, originality of engineering methods and expediency of construction. Dams were usually built in a single constructive season, but the fact that many of the Ural dams constructed during this period are still used at present demonstrates high competence of hydro-technicians and the quality of construction.

In contrast to the Western Europe, Russia used exclusively near-dam schemes of hydro-power installations under which all the installations were constructed in the form of a single unit (Ekaterinburgsky, Egoshikhinsky, Kolyvanovsky plants, etc.). Deviation from this rule and exploitation of the foreign ideas without taking into account the peculiarities of the Russian rivers and climate led to serious disasters and destruction.

For the first time turbines were used by the industry in the 1830s. The first water turbine in Russia - a water jet engine of radial type with water passing through guide case from the centre to the sides created by the serf dam master IE Safronov - became operational in 1837 at the Neivo-Alapaevsky metallurgic plant in the Urals. Latter on such turbines were installed at the Irbitsky and Neivo-Shaitansky metallurgic plants. These turbines moved 5-6 times faster than water wheels, were much smaller in size while their efficiency was 0.7 and their parameters were superior to those of all the turbines in the world known at that time.

Engineering of power supply systems in Russia started in 1880. By this time, in our countries ways were already identified as to the use of natural forces through electricity and the hydro-power potential of the country's rivers was estimated, possible savings resulting from the replacement of steam engines by water engines were calculated and the methodology of power supply line construction was proposed. The pioneer of the Russian hydro-power engineering is considered to be Zyrianovskaya Hydro-Power Station (HPS) producing 150 kW, launched in the spring of 1892 at the mining Altai (the Berezovka River). The energy from this HPS was used for shaft spillway at the Zyrianovsky mine.

Transition to the technology from the direct current to the three-phase one provided a new impetus to the HPS construction, creating wide opportunities for cost-efficient transfer of large power capacities at a long distance. In 1896 a Russian engineer R.E. Klasson together with a leading power technician and inventor V.N. Tchikolev created one of the first hydro-power installations of the modern type near Petersburg at the Okhta river. The energy from this HPS with 300 kW capacity was transmitted to the Okhtensky gun powder plant which happened to be one of the first industrial enterprises not only in Russia but also abroad where electricity lighting of workshops was conducted and wide electrification of industrial processes on the basis of hydraulic power engineering was done.

Intensive use of water power potential of the Russian rivers began in the last decade of the past century at the low-capacity HPS in different regions of the country. This process developed at a high pace and by 1917 the total capacity of HPS in the Russian territory reached 16 $10^3$ kW. The largest HPS had the capacity of producing 1 350 kW.

### 3.1.2 Hydro-power development before the war (1917-1941)

This period is characterised by the implementation and exceeding the targets of the GOELRO Plan, which laid down the foundations of energy development in the Soviet times and represented a program of energy empowerment of the country and drastic reconstruction of the economy on the basis of electrification. The plan envisaged the establishment of 10 HPS, while actually 19 HPS were constructed, including such major ones as Dneprovskaya, Nizhnesvirskaya, Ivankovskaya, Uglichskaya, Rybinskaya, a number of HPS in the Caucasus and Central Asia with the capacity exceeding the envisaged one by 20%. From the very beginning the development of energy resources was based on the principle of flight location of weirs as the most efficient method for using these resources.

Installations on the mountain rivers with large amount of sediments (Northern Caucasus) consisted of a complex set of facilities ensuring long working life of HPS and protection of their equipment. Northern power stations (Nizhnetulomskaya and Nivskaya) to a certain extent can be regarded as prototypes of the future large HPS in the northern regions of Russia. At these facilities advanced constructions of lift installations were tested under low temperature conditions.

By the end of this stage of hydraulic power engineering development there was practically no region in the country, which did not use in some way the hydropower resources available within its territory. In parallel with this, large hydraulic facilities emerged with much wider purposes. They became the focal points uniting several energy systems and setting up regional energy associations. The schemes for using water power potential of large watersheds of the country, such as Volga, Angara and Dnepr were developed and launched. These schemes pursued the task of complex use of water resources for the benefit of energy, water supply, irrigation, water transport, fishery and recreation.

### 3.1.3 Hydraulic power engineering during the war (1941-1945) and reconstruction period (1945-1950).

During this period the geography of hydro-technical construction changed. In the zone of possible military activities, the construction of HPS with a total capacity of 1 million kW was suspended. Hydro-technical construction was launched in the regions where industrial enterprises from the western parts of the country were relocated. For example, construction of Verkhoturskaya, Shirokovskaya, Argazinskaya and other HPS was expediently launched in the Urals while in the Central Asia the construction of nearly 40 HPS was conducted of which many were put into operation within extremely short term. During the war years new HPS with the total power of 280 thousand kW became operational.

With the liberation of the territory of the country from invaders the reconstruction of the destroyed HPS began.[8] By the end of the war, the HPS with the total power of 250 MW were reconstructed. A more expedient process of HPS reconstruction as compared to heating power stations contributed to the increase of HPS share in the energy balance of the country in comparison to the pre-war level.

### 3.1.4 Two decades of large hydro-technical projects (1950-1970).

[8] Five large HPS with the total power of 780 MW (a half of the total HPS capacity registered in 1940) were destructed - Dneprovskaya, Nizhnesvirskaya, Kegumskaya, Kondopozhskaya and Boxanskaya.

This period in hydro-technical development is characterised by the construction of large HPS in the most diverse natural and climatic conditions. Establishment of HPS dams in Central Russia on large water-abundant rivers within concentration points located far from each other and non-rock foundations was dictated by a number of reasons: the need to expediently restore economic facilities destroyed in the European part of the country which required a powerful energy base; the vicinity of potential sources of hydropower to industrial centres; growing requirements of different sectors of economy in assured water supply. HPS placement was also influenced by technical and economic difficulties experienced in mass transmission of electric energy at long distance (lack of experience in setting up powerful energy transmission lines -ETL). In Siberia and the Far East, the intensive construction of energy facilities was launched later due to low industrial development of theses regions and remote location of potential sources of hydropower from users.

For the first time in the world practice of dam construction the following problems were addressed: sustainability of earth and concrete head installations on soft soils of large capacity; ensuring safety of filtration flow at the bottom part of installations; lowering down of the energy of the flow disposed through water holes during the flash flood period; achieving dynamic sustainability of the bottom part and installations during disposal of large amounts of water, etc. Many technological solutions used at the Kuibyshevskaya and Volgogradskaya HPS were very advanced. In particular, special form of aprons were developed which considerably reduced filtration pressure on the bottom of concrete installations and at the same time served as anchor device increasing the stability of the entire construction. A special form of floor devices and connections with the river bed contributed to the establishment of such a hydraulic regime in the lower race of weirs which excluded scour of the soft soil of the river bed and ensured reliability of the entire installation. The configuration of earth wasteway dams and their drainage devices provided sustainability and safety of the bottoms of installations. Designs of the HPS buildings with water disposal holes were developed (later were called "Russian" throughout the world).

Construction of Tchirkeiskaya HPS (at the Sulak river) with the arch dam 232 meters high and Ingurskaya HPS (at the Inguri river, Georgia) with an arch dam 270 meters high can serve as examples of a very high competence of designers, researchers and constructors. The Ingurskaya dam remains the highest arch dam in the world.

In the second half of the 1950s, the pace of hydraulic facilities construction increased in Siberia. In 1956 Irkutskaya HPS - the top stage of the Angara river system was put into operation. This weir is relatively simple in its composition and type of construction. Aligned building design of this HPS ensured the flow of flash flood waters, which made it possible not to construct a concrete water discharge dam. This happened to be the first domestic experience in constructing large and meaningful hydro-technical installations under severe climatic conditions of the Eastern Siberia. With the lack of practical experience in such a construction exclusion of a concrete installation requiring great deal of work was regarded as a considerable technological advantage.

In 1955 the construction of Bratsky reservoir was launched which was conducted in wide taiga environment and required the establishment of a new powerful complex of construction industry, building of many living premises and communications as well as conducting a large volume of research, including calculations of the durability of installations and the bottom, sustainability of the entire system; analysis of the temperature regime stipulated by the construction period and external impact in the course of operation, etc. Taking into account severe climatic conditions a special technology of conducting the entire set of construction works was developed, particularly with regard to concrete works, special compositions of concrete, technology of their preparation, transportation, laying down and cure. The climatic peculiarities of the region of construction were reflected in the very structure of the dam - a new design of concrete gravitational dam with increased construction welds was found.

The construction technologies tested in Bratsk, were further implemented during the construction of the Krasnoyarskaya HPS at the Enissei river. New engineering and technological solutions which contributed to the simplification of works implementation included the pipeline of the power station removed from the block of the station's dam. At the power station, the largest at that time hydro-devices were installed with the unit power of 500 MW. Within Krasnoyarsky weir a major sloping canal lift was installed for the first time in our country. This ensured transit of vessels through the HPS.

In 1962, the construction of the largest HPS in Russia and one of the largest in the world - Sayano-Shushenskaya HPS on the Enissei River- was launched. The Enissei river valley in the area of the HPS was blocked by an arch-gravitational dam 1.07 km. wide and 244 m. at the maximum construction height. In the central part of the dam, the power conduit water intake holes and deep located water discharge holes are built with the total discharge capacity of 13 600 $m^3$/sec.

In the 1960s, the construction of large HPS was started in the Far East: in 1960 - Viluiskaya HPS at the Vilui river in Yakutia, in 1964 - Zeiskaya HPS at the Zeia river, an affluent of the Amur river. The Viluiskaya HPS was constructed under severe climatic conditions - in the region close to the cold northern pole of the planet. A special technology of summer storage of permafrost earth was developed for laying them in the winter period, a technology for concrete laying down under any outside temperature in heated premises, etc. Water basin of Zeiskaya HPS is formed by a concrete counter-force dam 110 meters high. This is the largest dam of this type in Russia and one of the largest in the world.

One of the main tendencies in water power resources development typical during this period in all the regions of the country was the principle of complex use of water resources for the benefit of different sectors of economy, including energy, irrigated agriculture, water supply of industry and population, water transport, flood control, etc. Hydraulic power engineering played a pioneer role in bringing life into previously undeveloped regions from the economic point of view and establishment of major industrial centres. The high potential of the construction industry which was set up for constructing large HPS, qualified personnel, cheap energy - all these became the economic and social basis for the development of industrial centers of Volzhsky, Toliatti and Balakovo cities on Volga; Bratsk and Ust-Ilimsk cities in Siberia, etc.

During this period, the construction of the HPS system was practically completed in the Volga-Kama basin, hydro-resources of the Kolsky peninsular were developed to a large extent, and the most attractive hydropower resources of the Northern Caucasus were developed. In Siberia, the Far East and Yakutia, major hydropower facilities became operational or were under construction, which in the future formed the basis of the regional power supply.

### 3.1.5 Hydro-technical development after 1970.

At the beginning of this period, intensive hydraulic facilities construction was underway throughout the country. By the end of 1980, 37 HPS were under construction with the total power of 28,000 MW and projected annual production of energy of 74 TW/hour annually, including 11 facilities in the European part of the country, six in the Northern Caucasus, seven in Trans-Caucasus, five in Siberia, three in the Far East and five in Central Asia and Kazakhstan. As a result of this construction, 15 new HPS with a total capacity of 18 $10^6$ kW were launched in 1976-1980.

Construction of large hydro-technical facilities was initiated in Central Asia, the region with high seismic activity. The dam of Nurekskaya HPS at the Vakhsh river was constructed of gravel and pebble materials with the central loamy core and located in a region with 9-point seismic activity. During the construction of the Toktogulsky dam weir on the Naryn river a full mechanisation of internal block processes was used for the first time in the world, while the central block of the dam was filled mainly with low-cement concrete. This technology of dam construction turned out to be similar to the technology of hard pressed concrete mixtures which emerged in the 1980s. This is widely applied at present, inter alia at a number of construction facilities in Russia, for example at Buriatskaya HPS.

Initiated economic transformations and a subsequent investment crisis have led to a drastic construction slow down of many hydro-technical facilities. Reduction of the need for energy in a number of regions as a result of a long economic decline has complicated the solution of the issues related to power stations energy supply. Even now, Boguchanskaya HPS at the Angara river (construction launched in 1980), Bureiskaya and Nizhnebureiskaya HPS at the Bureia river (construction launched in 1978) are not yet operational. As a result of financial difficulties, the construction of Nizhnekureiskaya HPS initiated in 1990 and a system of Zelenchukskaya HPS at the Kuban river, Zaramagskaya HPS at the Ardon river, and Irganaiskaya HPS at the Avarskoye Koisu river, etc have been suspended.

Thus, in Russia by 1995 -1996, 9 hydraulic facilities were under construction with the total power of 8.2 $10^6$ kW and the total projected annual energy production of 34.8 $10^9$ kW per hour.

Table 3.1 illustrates the growth in HPS capacity and energy production in Russia in 1950-1995. The dynamics of the HPS, which were put into operation in consecutive five-year periods within the boundaries of the former USSR, are illustrated by Table 3.2.

**Table 3.1 Growth of Hydropower Facilities in Russia in 1950-1995**

| Year | Established capacity, $10^6$ kW | Energy production, $10^9$ kW per hour |
|---|---|---|
| 1950 | 1,3 | 5,6 |
| 1955 | 2,6 | 10,7 |
| 1960 | 9,3 | 32,4 |
| 1965 | 15,0 | 59,6 |
| 1970 | 22,7 | 93,6 |
| 1975 | 27,2 | 96,0 |
| 1980 | 34,9 | 129,4 |
| 1985 | 41,3 | 159,8 |
| 1990 | 43,2 | 167,0 |
| 1995 | 43,8 | 178,0 |
| 1996 | 44,1 | 155,3 |
| 1997 | 43,9 | 158,4 |
| 1998 | 44,1 | 159,5 |

**Table 3.2 The Dynamics of HPS put into Operation**

| Years | Number of HPS | Number of installations | Total capacity, kW |
|---|---|---|---|
| 1942-1945 | 12 | 21 | 101620 |
| 1946-1950 | 35 | 78 | 735076 |
| 1951-1955 | 38 | 106 | 2525000 |
| 1956-1960 | 33 | 156 | 8100000 |
| 1961-1965 | 27 | 104 | 7442000 |
| 1966-1970 | 32 | 112 | 9005000 |
| 1971-1975 | 25 | 97 | 9197000 |
| 1976-1980 | 19 | 60 | 11405000 |
| 1981-1985 | 16 | 72 | 9398000 |
| 1986-1990 | 13 | 28 | 3042500 |
| 1991-1995 | 8 | 17 | 1562400 |
| Total | 258 | 851 | 62513596 |

## 3.2 HPS Dams and Reservoir Specification

More than 2,000 different water storage basins have been built and put into operation in Russia. The aggregate indicators (including reinforced lakes) include: surface water area – 1076820km$^2$, total storage capacity - 849230.0 $10^6$ m$^3$, active storage - 382142.0 $10^6$ m$^3$. From the total number of water storage basins 105 have volumes over 100 $10^6$ m$^3$. The cumulative volume of water reservoirs with the capacity of more than 1 km$^3$ amounts to nearly 90% of the total reservoir storage in Russia. The general information on the largest reservoirs in Russia and the NIS is presented in Table 3.3.

The majority of reservoirs are located in the European part of Russia in the basins of the Volga and Kama Rivers and in Karelia. In Siberia the main flow regulating structures are located at the Angara-Enissei system of HPS. HPS systems in Siberia positively differ from the European ones both in economic and ecological terms due to greater water pressure and capacities with lower indicators of areas flooded and drastic capacity reduction.

Most of the reservoirs were designed for multi-purpose use, but the structure of water use is different. Volga's reservoirs (Kuibyshevskoe, Saratovskoe, Volgogradskoe) have a pronounced irrigation focus compared to their northern counterparts. At present, Volga's water is used to irrigate more than 200 $10^6$ ha. In Angara-Enissei basin, water from 22 reservoirs is used to irrigate 16 $10^3$ ha. Ivankovskoe reservoir is intended mainly for Moscow water supply, while Gorkovskoe and Rybinskoe reservoirs are also used for timber rafting. Mainskoe reservoir downstream of the Saiano-Shushenskoe reservoir plays a counter-regulating role. Khantaiskoe and Kureiskoe reservoirs are used exclusively for hydropower generation.

## Table 3.3 HPS Water Reservoirs in Russia and NIS with a Capacity of more than 1 km$^3$

NSL - Normal Supply Level; Dam type: A=arch; B=buttress; E=earthfill; G=gravity; R=rockfill

- projected data

| Water reservoir | River | Year of filling | NSL, m, BC | Capacity, km$^3$ | | Length, km | Surface area, $10^6$ ha | Area | | Flooded area, $10^6$ ha | | | Dam parameters | | | | Volume of discharge at the dam's concentration point | Energy production $10^9$ kW per hour | Resettled population, $10^3$ people |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | full | active | | | Total | Avr. | Agric. | forest | other | type | height m | length, m | volume, m$^3$*10$^3$ | | | |
| Bratskoe | Angara | 1961:1965 | 402 | 169.3 | 48.2 | 565 | 547 | 540.9 | 166.3 | 52 | 326.9 | 47.7 | E/G | 125 | 4417 | 10962 | 91.6 | 21.9 | 67.4 |
| Bukhtarminskoe | Irtysh | 1956:1960 | 402 | 49.62 | 30.81 | 350 | 549 | 332.8 | 171.3 | 41.3 | 8.3 | 153.2 | G | 90 | 380 | 1170 | 18.6 | 3.25 | 27 |
| Onezhskoe | Svir' | 1951:1955 | 33.3 | 13.76 | 13.05 | 350 | 99.3 | 11.8 | 1.9 | 0.1 | 6.8 | 3.1 | | 17 | | | 19.3 | 0.53 | 6.2 |
| VerkhneTulomskoe | Tuloma | 1961:1965 | 80 | 11.52 | 3.86 | 120 | 74.5 | 61.4 | 0.2 | 0 | 59.5 | 1.7 | | 63 | | | 5.9 | 0.83 | 0.5 |
| Vilyujskoe1,2 | Vilyui | 1966:1970 | 244 | 35.88 | 17.83 | 470 | 217 | 196.1 | 1.3 | 0.1 | 120.1 | 74.7 | R | 64 | 600 | 3740 | 20 | 2.53 | 0.4 |
| Volgogradskoe | Volga | 1956:1960 | 15 | 31.45 | 8.25 | 540 | 311.7 | 269.3 | 137.4 | 30.4 | 70.2 | 61.7 | E/R/G | 47 | 3974 | 25932 | 251 | 10.92 | 15 |
| Votkinskoe | Kama | 1961:1965 | 89 | 9.36 | 3.7 | 360 | 112 | 92.2 | 31.1 | 23.9 | 42.2 | 18.9 | E/G | 44 | 4982 | 9330 | 53.73 | 2.54 | 61 |
| Vygozerskoe | N.Vyg | 1931:1935 | | 6.44 | 1.14 | 85 | 124.4 | 61.8 | 6.2 | 1.8 | 44.1 | 11.5 | | 6 | | | | | |
| Gor'kovskoe | Volga | 1951:1955 | 84 | 8.82 | 2.78 | 430 | 157 | 129.2 | 66.6 | 21 | 50.6 | 12 | | 17 | | | 52.5 | 1.49 | 48 |
| Dneprovskoe | Dnepr | 1931:1935 | 51.4 | 3.3 | 0.84 | 130 | 41 | 22.4 | 11 | 2.1 | 6.5 | 4.9 | G | 60.5 | 761 | 732 | 52.2 | 3.64 | 13 |
| Dneprodzerzhinskoe | Dnepr | 1961:1965 | 64 | 2.45 | 0.27 | 115 | 56.7 | 48.2 | 28.4 | 9.8 | 19.4 | 0.4 | E/G | 34 | 35642 | 22031 | 52 | 0.98 | 45 |
| Dnestrovskoe | Dnestr | 1981:1985 | 121 | 3 | 2 | | 14.2 | 13.8 | 4.9 | 3.5 | 8.7 | 0.2 | | | | | 8.16 | 0.87 | 18.4 |
| Zeiskoe | Zeia | 1971:1975 | 315 | 68.42 | 38.26 | 225 | 241.9 | 229.5 | 3.9 | 0 | 127 | 98.6 | B | 115 | 758 | 2160 | 24.4 | 4.9 | 4.5 |
| Ivan'kovskoe | Volga | 1936:1940 | 124 | 1.12 | 0.81 | 120 | 32.7 | 30 | 18 | 3 | 12 | 0 | E/G | 28 | 9920 | 15450 | 9.63 | 0.08 | 30 |
| Imandrovskoe | Niva | 1951:1955 | 127.5 | 11.2 | 2.32 | 120 | 87.6 | 5.5 | 0 | 0 | 1.7 | 3.8 | | 13 | | | 4.79 | 0.13 | 0 |
| Ingurskoe | Inguri | 1976:1980 | | 1.1 | 0.08 | | 2.1 | 1.5 | 0.2 | 0 | 1.2 | 0.1 | A | 272 | 680 | 3960 | 4.85 | 4.04 | 0.2 |
| Iovskoe | Iova | 1961:1965 | 72 | 2.06 | 0.55 | 60 | 29.4 | 12.5 | 0.2 | 0 | 10.4 | 1.9 | | 36 | | | 7.2 | 0.55 | 0.1 |
| Iriklinskoe | Ural | 1956:1960 | 245 | 3.26 | 2.2 | 73 | 26 | 25.4 | 20.6 | 3.4 | 2.8 | 2 | | 35 | | | 2.21 | 0.07 | 3 |
| Irkutskoe | Angara | 1956:1960 | 457 | 48.1 | 46.45 | 700 | 146.6 | 138.6 | 38.8 | 38.8 | 87.9 | 11.9 | E/G | 44 | 2500 | 11560 | 60.73 | 4.02 | 18 |
| Karakumskoe | Syr Darya | 1956:1960 | 347.5 | 4.16 | 2.6 | 55 | 51.3 | 49.5 | 4.7 | 4.7 | 30.9 | 13.9 | | 24 | | | 66.75 | 0.52 | |
| Kamskoe | Kama | 1951:1955 | 108.5 | 12.2 | 9.2 | 270 | 191.5 | 175.5 | 68.1 | 10 | 83.4 | 24 | E/G | 37 | 2286 | 27720 | 51.5 | 1.77 | 48 |
| Kanevskoe | Dnepr | 1971:1975 | 91.5 | 2.62 | 0.3 | 130 | 67.5 | 65.6 | 25.9 | 5.1 | 19.1 | 20.6 | | 11 | | | 43.9 | 0.8 | 12 |
| Kapchagaiskoe | Ili | 1966:1970 | 485 | 28.14 | 6.64 | 170 | 184.7 | 182.4 | 135.2 | 7.3 | 17.1 | 30.1 | E | 52 | 840 | 6220 | 14.7 | 1.19 | |

| Water reservoir | River | Year of filling | NSL, m, BC | Capacity, $km^3$ | | Length, km | Surface area, $10^6$ ha | Area | | Flooded area, $10^6$ ha | | | Dam parameters | | | | Volume of discharge at the dam's concentration point | Energy production $10^9$ kW per hour | Resettled population, $10^3$ people |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | full | active | | | Total | Avr. | Agric. | forest | other | type | height m | length, m | volume, $m^3*10^3$ | | | |
| Kataikoski | Paz | 1956:1960 | 118.03 | 4.96 | 2.46 | | 110 | 2.2 | 0.1 | 0 | 1.9 | 0.2 | | | | | 4.79 | 0.07 | |
| Kahovskoe | Dnepr | 1951:1955 | 16 | 18.2 | 6.8 | 230 | 225.5 | 219.9 | 42.5 | 6.1 | 143.6 | 33.8 | E/G | 37 | 3629 | 35640 | 52.2 | 0.9 | 45 |
| Kievskoe | Dnepr | 1961:1965 | 103 | 3.73 | 1.17 | 110 | 92.2 | 80 | 48 | 6.6 | 18.6 | 13.4 | E | 68 | 41185 | 42841 | 33.4 | 0.61 | 40 |
| Knyazhegubskoe | Kovda | 1951:1955 | 37.2 | 3.44 | 1.93 | 60 | 61 | 18.9 | 0.2 | 0 | 13.6 | 5.1 | | | | | 8.67 | 0.74 | 3.8 |
| Kolymskoe | Kolyma | 1986:1990 | 450 | 14.56 | 6.51 | 150 | 44.1 | 39.7 | 1.5 | 0.2 | 33.1 | 5.1 | R | 130 | 780 | 10000 | 14.2 | 3.28 | 0.3 |
| Krasnoyarskoe | Enisei | 1966:1970 | 243 | 73.3 | 30.4 | 390 | 200 | 175.9 | 120 | 44.2 | 58 | 17.9 | G | 124 | 1065 | 5580 | 88 | 19.64 | 56.1 |
| Kremenchugskoe | Dnepr | 1956:1960 | 81 | 13.52 | 9.07 | 185 | 225.2 | 222.1 | 120.9 | 44.9 | 75 | 26.2 | G | 33 | 12144 | 31492 | 47.8 | 1.27 | 132 |
| Kubanskoe | Kuban' | 1971:1975 | | 1 | 0.5 | | 1.9 | 1.7 | 0.4 | 0 | 1 | 0.3 | | | | | | 1.27 | |
| Kuibyshevskoe | Volga | 1956:1960 | 53 | 58 | 34.6 | 650 | 644.8 | 504 | 277.8 | 69.5 | 163.3 | 62.9 | E/G | 45 | 3781 | 33869 | 241 | 9.44 | 150 |
| Kumskoe | Kuma | 1961:1965 | | 13.35 | 8.68 | 150 | 191 | 22 | 0.8 | 0.1 | 21.2 | 0 | | 33 | | | | 0.34 | 1 |
| Kureiskoe | Kureika | 1986:1990 | 100 | 9.9 | 7.3 | 100 | 56 | 55.8 | 0 | 0 | 30.5 | 25.3 | E | | | | | 2.6 | 0 |
| Mingechaurskoe | Kura | 1951:1955 | 83 | 16.07 | 7.4 | 70 | 63.5 | 63.4 | 37.8 | 0 | 18.9 | 6.7 | E | 80 | 1550 | 15600 | 12.6 | 1.05 | 4.6 |
| Nizhnekamskoe* | Kama | 1976:1980 | | 11 | 4.6 | 270 | 155 | 119.4 | 64.4 | 13.5 | 45.5 | 9.6 | E/G | 36 | 6200 | 23000 | 89.3 | 1.4 | 44 |
| Novosibirskoe | Ob' | 1956:1960 | 113.5 | 8.8 | 4.4 | 200 | 107 | 95.1 | 28.4 | 4.8 | 31.2 | 35.5 | | 20 | | | 51.9 | 1.99 | 37 |
| Nurekskoe | Vakhsh | 1971:1975 | 910 | 10.5 | 4.5 | 70 | 9.8 | 9.3 | 1.5 | 0 | 0.1 | 7.7 | E | 300 | 704 | 58000 | 20.46 | 11.17 | 1.8 |
| Pavlovskoe | Ufa | 1956:1960 | 140 | 1.41 | 0.89 | | 12 | 8.4 | 4.8 | 3.4 | 2.6 | 1 | | | | | 10.48 | 0.58 | 2.8 |
| Pirengskoe | Pirenga | 1936:1940 | | 3 | 0.88 | | 22.7 | 6.5 | 3.2 | 0 | 3.3 | 0 | | | | | | | |
| Proletarskoe | Manych | 1936:1940 | | 2.03 | 0.76 | 190 | 79.8 | 40.1 | 4.2 | 0.9 | 1 | 34.9 | | 4 | | | | | |
| Rybinskoe | Volga | 1946:1950 | 102 | 25.42 | 16.67 | 360 | 455 | 434 | 174.5 | 58.2 | 241.2 | 18.3 | G | 30 | 628 | 2545 | 35.2 | 0.92 | 117 |
| Saratovskoe | Volga | 1966:1970 | 28 | 12.37 | 1.75 | 350 | 183.1 | 116 | 53.1 | 7.5 | 47.3 | 15.6 | E | 40 | 15260 | 40400 | 247 | 5.3 | 25 |
| Sayano-Shushenskoe | Enisei | 1976:1980 | 540 | 31.3 | 15.3 | 230 | 62.1 | 54.6 | 18.3 | 2.9 | 30.5 | 5.8 | A/G | 245 | 1066 | 9075 | 46.7 | 23.55 | 9.7 |
| Segozerskoe | Segezha | 1956:1960 | | 4.7 | 4 | 50 | 81.5 | 6 | 1 | 0.4 | 4.5 | 0.5 | | 5 | | | | | 0.5 |
| Serebryanskoe | Voron'ya | 1966:1970 | 154 | 4.17 | 1.68 | 160 | 55.6 | 26.9 | 0.2 | 0 | 9.3 | 17.4 | | 65 | | | 3.15 | 0.58 | 0.2 |
| Toktogul'skoe | Naryn | 1971:1975 | 900 | 19.5 | 14 | 65 | 28.4 | 26.4 | 21.2 | 3.9 | 0 | 5.2 | G | 215 | 293 | 3345 | 11.36 | 4014 | 4 |
| Uglichskoe | Volga | 1936:1940 | 113 | 1.25 | 0.8 | | 24.9 | 13.7 | 11 | 5.6 | 11.5 | 1.2 | | | | | 10.8 | 0.18 | 25 |
| Ust'-Ilimskoe | Angara | 1971:1975 | 296 | 59.4 | 2.77 | 300 | 187.3 | 154.9 | 21.8 | 13.3 | 127.8 | 5.3 | R | 102 | 3725 | 8866 | 100.5 | 20.5 | 14.2 |
| Ust'-Khantaiskoe | Khantayka | 1966:1970 | 60 | 23.52 | 17.3 | 160 | 212 | 187 | 0 | 0 | 86 | 101 | R | 50 | | | 17.6 | 2.06 | 0 |
| Tsimlyanskoe | Don | 1951:1955 | 36 | 23.86 | 11.54 | 360 | 270.2 | 263.3 | 195.3 | 46 | 30.1 | 37.9 | E/G | 41 | 13245 | 33891 | 22.3 | 0.59 | |

| Water reservoir | River | Year of filling | NSL, m, BC | Capacity, $km^3$ | | Length, km | Surface area, $10^6$ ha | Area | | Flooded area, $10^6$ ha | | | Dam parameters | | | | Volume of discharge at the dam's concentration point | Energy production $10^9$ kW per hour | Resettled population, $10^3$ people |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | full | active | | | Total | Avr. | Agric. | forest | other | type | height m | length, m | volume, $m^3 * 10^3$ | | | |
| Shamkhorskoe | Kura | 1981:1985 | 158 | 2.68 | 1.43 | | 12.6 | 11.9 | 6.2 | 0 | 5.7 | 0 | | | | | 9.93 | 0.99 | 0.5 |
| Sheksninskoe | Sheksna | 1961:1965 | 113 | 6.51 | 1.85 | 160 | 167 | 52.7 | 22.1 | 6.5 | 26 | 4.6 | | 15 | | | 35.2 | 0.12 | 16.3 |
| Shul'binskoe | Irtysh | 1986:1989 | 240 | 2.4 | 1.5 | | 25.5 | 22.8 | 18.9 | 4.1 | 1.1 | 2.8 | | | | | 29.7 | 0.34 | 8 |
| Charvakskoe | Chirchik | 1966:1970 | 890 | 2.01 | 1.2 | | 4 | 3.5 | 0 | 0 | 3.5 | 0 | R | 168 | 764 | 21600 | 6.59 | 1.94 | 2 |
| Chardarinskoe | Syr Darya | 1966:1970 | 252 | 5.7 | 4.7 | 70 | 90 | 87.2 | 77.8 | 0.8 | 8.4 | 1 | | | | | 22.39 | 0.22 | 2 |
| Cheboksarskoe* | Volga | 1976:1980 | 68 | 9.5 | 5.7 | 330 | 105.5 | 80 | 22.7 | 3.7 | 47 | 10.3 | G | 42 | 3497 | 8350 | 112.7 | 1.6 | 42 |
| Chirkeiskoe | Sulak | 1971:1975 | 355 | 2.78 | 1.32 | | 4.3 | 4 | 3.3 | 0.6 | 0 | 0.7 | A | 233 | 333 | 1358 | 5.58 | 2.22 | |
| Yushkozerskoe | Kem' | 1976:1980 | 103 | 3.81 | 1.37 | | 4.7 | 6 | 0.5 | 0 | 5.2 | 0.3 | | 10 | | | 3.22 | 0.08 | |
| Boguchanskoe | Angara | under constr. | 208 | 58.6 | 2.3 | 375 | 232.6 | | | | | | R | 79 | 1816 | 27360 | 107.24 | 17.78 | 12.2 |
| Bureiskoe | Bureya | under constr. | 256 | 20.94 | 10.7 | 150 | 74 | | | | | | G | 139 | 810 | 3561 | 27.6 | 7 | 1 |
| Rogunskoe | Vakhsh | under constr. | 1290 | 13.3 | 8.6 | 65 | 17 | | | | | | E/R | 335 | 660 | 75500 | 19.9 | 13.3 | 16 |

## 3.3 Hydro power potential and the prospects for its development

According to the latest data, the *hydro power potential* of Russia amounts to 2,900 $10^9$ kW per hour of annual energy production, of which 83% is the potential of large and medium rivers (see Table 3.4). A technically attainable level of use of this potential is estimated at 70%, while its economic potential which takes into account a number of factors, including the conditions of economic development of the area, economic efficiency, ecological factors, etc., amounts to 35%. The bulk of this potential is located in Siberia and the Far East. In the European part of Russia, the yet unused economic potential is concentrated in the North and in certain regions of the Northern Caucasus (see Table 3.5). In the central part and in the Urals, only the potential of small rivers is under-utilised. The potential of the Far East rivers is the least developed.

In general, as far as the level of development of economically efficient water resources is concerned, Russia lags behind a number of developed countries. This level in Russia is estimated at 21%, in the USA and Canada at 50 to 55%, in the countries of Western Europe and Japan at 60 to 90%.

**Table 3.4 Economic Hydropower Potential of Large Rivers in Russia and Energy Production in 1995**

| N | River | Economic hydropower potential, $10^9$ kW per hour | Energy production, $10^9$ kW per hour |
|---|---|---|---|
| 1 | Volga | 56,0 | 39,7 |
| 2 | Kama | 9,7 | 7,2 |
| 3 | Ural | 5,4 | 0,1 |
| 4 | Terek | 7,0 | 0,5 |
| 5 | Sulak | 8,0 | 2,9 |
| 6 | Don | 2,5 | 0,6 |
| 7 | Kuban | 7,5 | 1,9 |
| 8 | Pechora | 17,0 | - |
| 9 | Severnaya Dvina | 6,0 | - |
| 10 | Ob' | 94,0 | 2,3 |
| 11 | Enissei | 288,0 | 104,6 |
| 12 | Angara | 163,0 | 53,0 |
| 13 | Lena | 235,0 | 2,8 |
| 14 | Vilui | 7,2 | 2,6 |
| 15 | Kolyma | 27,0 | 2,4 |
| 16 | Amur | 58,0 | 5,0 |
| 17 | Zeia | 15,0 | 5,0 |

**Table 3.5 Regional Distribution and the Level of Economic Hydropower Potential Development in Russia**

| Economic regions | Economic hydro power potential, $10^9$ kW per hour | Developed economic hydropower potential at HPSs in operation and under construction, $10^9$ kW per hour | Level of potential development, % |
|---|---|---|---|
| Total in Russia | 852 | 199,9 | 23,4 |
| Including regions: | | | |
| Northern | 37 | 9,3 | 25 |
| North-Western | 6 | 3,6 | 60 |
| Central | 6 | 1,5 | 25 |
| Central-Tchernozemny | - | - | - |
| Volgo-Viatsky | 7 | 4,8 | 68 |
| Povolzhsky | 41 | 30,5 | 74 |
| Northern Caucasian | 25 | 8,5 | 34 |
| Uralsky | 9 | 4,4 | 49 |
| Western-Siberian | 77 | 1,7 | 2 |
| Eastern-Siberian | 350 | 116,6 | 33 |
| Far East | 294 | 19,0 | 6 |

In 1998 the energy production in Russia amounted to 827 $10^9$ kW per hour. The contribution of HPS to this figure amounted to 160 $10^9$ kW per hour or 19% of the total energy produced. Despite the fact that Russia has some of the world biggest HPS (eg Saiano-Shushenskaya with the power of 6.4 $10^6$ kW), the country is behind Canada, USA and Brazil in energy production.

Decline in the industrial production experienced in recent years has resulted in the decrease of the total energy production, both at Thermal Power Stations (TPS) and HPS. However, HPS have continued not only to sustainably produce 165-175 $10^9$ kW per hour of energy, but have even increased their output by 5 to 7%. Prior to the disaggregation of the USSR, the HPS produced energy amounting to about 14%, while in 1995 it reached 21% in Russia, ie the role of HPS in energy production has increased considerably.

Today, the role, objectives and ways of development of hydropower engineering is reflected in a number of official documents, such as "The Concept of the Russian Energy Policy Development in a New Economic Environment" (1992), "The Program on Fuel and Energy" (1993) and "The Russian Energy Strategy up to the Year 2010" (1994). In 1996 "An Ecological Program of Power Engineering of Russia" was developed and adopted by the President of Russian Unified Energy System (RAO EEC) of Russia, which identified the main directions of nature conservation activities of the energy sector up to the year 2005.

On the basis of these documents the main short-term and long-term objectives of hydropower engineering development have been established and the stages of specific activities implementation have been identified. In accordance with the Programme on Hydropower Engineering Development elaborated by the Institute ‘Gidroproject’ (Hydro project) for 1997-2005 and for the future up to the year 2030, the main focus is to be placed on the development of hydraulic power facilities construction in the Far East and Northern Caucasus in order to address a severe energy crisis in these regions. Thereafter a priority direction should be the use of the hydropower potential of the Siberian rivers. However, it is difficult to expect a serious increase in the capacity in the present economic environment. Therefore, the emphasis is placed on the reconstruction and modernisation of the operational HPS, which have been operational for many years and have obsolete equipment. For example, on January 1 1997, 59% of HPS in Russia had equipment, the design life of which was over long ago. By 2000 the number of such stations reached the level of about 70% of the total number of HPS. Analysis of accidents and emergencies at HPS and the results of surveys of many installations have shown that more than 50% of these accidents were caused by obsolete equipment.

In recent years, HPS equipment has been used more intensively due to the lack of organic fuel in certain regions of the country and installations in some cases have to be exploited in an inappropriate manner, which reduces their design life. At present, the capital repairs to a number of hydro technical facilities is underway. Extended capital repairs make it possible to extend the design life of the equipment and to increase the reliability and efficiency of its use.

The primary objective related to the new HPS, as seen by the energy sector, is the completion of those HPS whose construction has been suspended. In the Amurskaya district (the Far East), this concerns Bureiskaya and Nizhnebureiskaya HPS (the latter is a counter-regulator), in Magadanskaya District, it is the Ust'-Srednekanskaya HPS, the construction of which would increase the reliability of power supply and optimise the work of Kolymskaya HPS. In the Mirninsky region of the Sakha Republic , there are the Viluiskaya HPS, and in Kamchatka, a system of Tolmachevsky HPS. In Siberia, the construction of Boguchanskaya HPS on the Angara river is in process. Completion of the Telmamskaya HPS is linked to the completion of the Lensky gold mining complex.

A complicated social, economic and political situation in the Caucasus makes it necessary to intensify the use of hydro power resources in order to increase the reliability of power supply and to ensure the energy safety of the entities of the Russian Federation. To this end, efforts have been taken to complete the construction of Irganaiskaya HPS at the Avarskoe Koisu river. Also at this river, the construction of Gotsatlinskaya HPS ha been launched (first stage of Zirani HPS).

In order to supply the Northern Ossetia Republic (Alania) with energy it is necessary to complete the construction of Zaramagskie HPS, while in Kabardino-Balkaria the construction of a system of Nizhne-Tcherekskie HPS is in progress.

At the North-West of Russia, the Beloporozhskaya HPS is being constructed.

Besides those HPS listed above, the opportunities for new hydro power development in Russia are numerous. The unused economic hydropower potential is currently estimated at 650 $10^9$ kW per hour. The priority regions for hydropower development include those of the Far East where low energy supply is the main deterring factor of economy development and the source of social tension. It is planned to initiate the construction of the new HPS on the Bureia river (after completing the construction of Bureiskaya and Nizhnebureiskaya HPS), and Urgalskaya HPS on the Niman river, Giluiskaya HPS on the Zeia river (the only way to address energy supply problems of Amurskaya District). The possibility of building the Dalnerechenskie HPS at Bolshaia Ussurijka river is being also considered, although this project in the early 1980s was severely criticised by the general public. In the future one cannot exclude the establishment of Khingansky hydro facility at the Amur river as a joint effort of Russia and China. In Magadanskaya District, after the Ust-Srednekanskaya HPS is completed, the creation of the Verhne-Kolymsky reservoir is envisaged. The construction of Amguemskaya HPS and a number of small HPS in Kamchatka (Petropavlovskaya HPS on the Zhupanova river, Kronotskie HPS, and HPS on the Bystraya river is also regarded as a promising endeavour.

There are extensive hydro-facilities construction programmes in the Sakha Republic (formerly Yakutia). The primary objective is to construct Tchirkuokskaya HPS on the Vilui river with the intention of supplying inhabited western regions with energy. In the future, construction of the first HPS on the Olenek river (Sredne-Olenekskaya HPS) and Adychanskaya HPS in the north is possible. It is still problematic, but extremely important to establish a Yuzhno-Yakutsky hydraulic power engineering complex, which would consist of a set of HPS (first stage would be Sredne-Uchurskaya HPS with a counter-regulator, and the second stage, Idzhekskaya and Nizhne-Timptonskaya HPS on the Timpton river).

The concept of hydropower development in Siberia envisages limited development of HPS, justified levels of electricity supply outside Siberia and addressing the task of self-reliance of some territories on energy supply. Thus, the construction of Mokskaya HPS on the Vitim river is regarded as an opportunity to establish a promising and real base for electrification of the Northern Trans-Baikal region that is rich in water resources. In the future this station is to become a connecting and regulating link between the Far East and Siberian joint energy systems.

To supply certain regions with energy, Shilkinskaya HPS in the Amur river basin, Tuvinskaya - on the Enissei river effluents, Nizhnekureiskaya and Khatunskaya HPS, as well as HPS in the downstream reaches of Angara, the middle part of Enissei and in the south of Krasnoyarsky region on the Abakan and Kizir rivers are planned.

In the Caucasus, the demand for energy supply is almost unlimited. Construction of HPS is limited by financial constraints, ecological restrictions and capacity of the construction companies. The most active interest in developing plans of hydro technical construction is demonstrated by Kabardino-Balkaria which intends in the very near future to proceed with the construction of the Baksansky system, small-scale HPS at the Malka river and later with a system of Kurpskie HPS and small HPS for recreational purposes. This will make it possible to meet about 75% of the Republic's electricity requirements. In Northern Ossetia, Digerskie HPS on the Urukh river and Djerakhovskaya HPS on the Terek river are planned. In the long term, there is a plan to construct a mountainous Dariali HPS. As a result of complex social and political situation in Chechnya the prospects of hydro technical development are unclear, but it is envisaged that the hydropower potential of the Argun’ river will be utilised in the future. The problem of power supply in Dagestan Republic is not very acute. Besides HPS under construction mentioned above, it is planned to develop water resources of the Andiiskoe Koisu river. It is also possible to establish HPS on the upper parts of the Avarskoe Koisu and Samur rivers.

In the Northwest of Russia the HPS prioritised for construction are in Karelia on the Tchirka-Kem' river and a small system on the Vodla river, on the Kolsky peninsular, two HPS on the Iokanga river, and in the future, the systems of HPS on the Rynda, Kharlovka and Vostochnaya Lisitsa rivers.

The flat topography of the territory, the high fishing value of rivers and a number of ecological restrictions in Arkhangelskaya District, preclude the plans to engage in a large-scale hydro-technical construction. A possibility of constructing Arnemskaya HPS on the Onega river is, however, being considered.

## 3.4 Assumed Benefits of Hydro Technical Construction

The hydrotechnical engineering in Russia, due to its high level of development and extensive and complex impacts, has effectively transformed itself into a large inter-sectoral part of national economy, which is seen by the industry and governments to benefit the country in a number of ways including:

- power supply and reduction of the country's needs in organic fossil fuel; reduction of labour demand which is particularly important in regions with adverse climatic conditions;
- regulation of stream flow for the benefit of irrigation, industrial, and domestic water supply;
- flood control;
- development of water transportation systems;

- establishment of new infrastructure for economic development;
- establishment of recreational facilities and health care institutions.

More specifically, the aspects of hydro technical engineering development in Russia the are considered by the government and industry to be positive include:

1. reduction in demand for fossil (organic) fuels. (In 1995 Russia's HPS produced 178 $10^9$ kW per hour which is equivalent to the release of 65 $10^6$ tons of fossil fuel. As to the physical volume of fossil fuel replaced, Russia's HPS operation in 1995 was approximately equivalent to annual extraction of energy coal in Kuzbass - the largest coal basin in the country.);

2. Labour savings (HPS operation is characterised by the higher productivity (compared to TPS and NPS), as well as by the higher level of automatisation, reduced labour resources required for extraction, transportation, processing of fuel and production waste disposal. As a result, the personnel required to operate a HPS is about 20 times less than that of a TPS with fuel bases and transport servicing the latter. At present the total number of people employed at all HPSs in Russia equals approximately 25000. The personnel of replaced TPSs, including extraction and transportation of fuel, amounts to about 500 000 people. Reduced labour demand in such regions as Siberia, the Far East, the Far North, where it equals approximately 155,000 people, is of particular significance.);

3. cost efficiency (HPS are based on the renewable source of energy, they do not depend on fuel supply, produce energy without polluting natural environment and allow to reduce the load placed on surface transportation systems. All the stations constructed have already paid off.);

4. economic efficiency (Average unit cost of 1 kW per hour produced at HPSs is much less than at TPSs. This difference drastically increases with the increasing prices of organic fuel.);

5. electric power produced by HPSs is practically unaffected by inflation processes in the economy. (This consideration is particularly attractive to the regions, entities of the Federation and the NIS which have under-developed economy and are experiencing fuel and energy deficits.);

6. Regulated stream flow provided industry, domestic and institutional sectors and agriculture with assured water supply (In the 1980-1990s in Russia HPS water reservoirs supplied 102-110 $km^3$ a year, including 15 $km^3$ for the population, 57 $km^3$ for industry, and 30-35 $km^3$ for agriculture. In the European part of the country these figures amounted to 90-98, 12, 50 and 28-38 $km^3$, respectively. In the absence of large rivers streamflow regulation, acute problems would have emerged in many regions of the country. The efficiency of water resources use and their role in energy production at HPS increases with the connection of reservoirs into reservoir systems, and the latter become into balanced large-scale energy systems. This balance is achieved through asynchronism of spatial and seasonal fluctuations of streamflow and through different regulating capacities of the reservoirs.);

7. integrated use of water resources (Reservoirs have made major contribution into the solution of transportation problem. The systems of water storage facilities on Volga, Kama and Don have established a deep water transportation system through the entire European part of the country, connecting northern and southern seas of the region. The volume of cargo transportation by steamship companies of big rivers basins, where the new waterway were constructed, exceeded manifold the capacity of these watersheds in their natural state.);

8. guaranteed depths at previously navigated sites on theVolga increased by between 150% and 200% times, on Kama by between 200% and 250% (A Volga site between Andropov and Kalinin city became navigated with the total length of 364 km. Provision of sufficient and relatively common depths at the water-transportation route allowed self-propelled vessels with the capacity of 2000-5000 tons to be used on Volga, Kama, Dneper and other rivers instead of previously used barges with the capacity of only 600-1000 tons. The introduction of hydrofoil motor boats increased the speed of the river passenger transport up to 80-100 km /h.);

9. longer navigation periods (Periods of complete freezing of the reservoirs usually do not affect the duration of navigation due to the use of ice-breakers. On Volga and Kama reservoirs the ice-breakers helped to extend the navigation period for 15 days on average.);

10. delivery of cargo (One of the most important economic and geographic implications of the transformation of the regime of the rivers by means of the water storage facilities of the former USSR included the possibility of delivering cargo from inland regions of the country to the nearest sea ports. Vessels of "L" grade (lake-type) with the capacity of 2000 tons and more as well as those of "S" grade (sea-type) established for inland watersheds, are (with certain limitations) suitable for near-coast sea transportation, since for most of the year the sea wave heights around the former USSR do not exceed 3 meters. Consequently, vessels of the "L" grade passing through the internal waterways may operate at sea as well.);

11. the termination of certain navigation links (From as early as in 1965, the cargo from the USSR inland regions was transported by river vessels without coming into ports of the Baltic sea (Riga, Klaipeda, Kalinigrad) to all the ports of the Caspian and White seas, as well to the ports of Poland, Germany and Finland. Individual vessels made pilot cruises to ports Orkhus (Denmark) and Pyrei (Greece). The experience gained has shown the feasibility of expanding such transportation, and direct links with many European countries were established. In recent years, however, the water transportation situation on Volga river has been deteriorating, particularly due to the adjustments introduced to flow regulation structures by local administrations. In 1996, This led to reduced navigation activity downstream of the Nizhegorodskaya HPS to such an extent that the transit through this site has become practically impossible. This may lead to a disintegration of a unique single deep-water way system of the European part of Russia into northern and southern part, if the navigation risks are to be avoided. However in recent years the water transportation situation of the Volga river has been deteriorating, particularly due to the adjustments of the regime of flow regulation by water storage basins, made by local administrations. Navigation downstream of the Nizhegorodskaya HPS was reduced in 1996 to such an extent that transit through this site was practically halted. All this suggests the future disintegration of a unique single deep-water system of water routes of the European parts of Russia in the northern and southern part. Thus transit navigation links will be terminated.);

12. HPS water storage basins seem to be an effective means of flood control (The total area of protected territories with developed agriculture and many millions of people is estimated at 1.2 million ha. The cumulative reservoir volume used for flood control in Russia and the NIS countries equals 221 $km^3$ or 22% of the total reservoir capacity of the former USSR.);

13. recreational facilities (Practically all reservoirs are intensively used by population for recreational purposes. In the former USSR, about 55% of health resorts, 60% of recreational institutions, 60% of tourist institutions and 90% of county-side recreation were located along water basins banks (seas, lakes, big and small rivers and reservoirs. About a half of them were located at reservoir banks. According to the data provided by the Water Problems Institute of the Russian Academy of Sciences, the reservoir banks in Russia and the NIS form the place of

residence for more than 30 million people of urban population, while approximately 50 million people live within a two-hour distance from the reservoirs.);

14. the creation of recreational facilities (In a number of cities of the former USSR, the systems of water facilities were established which considerably modified the landscapes of the cities and created favourable conditions for meeting recreational needs of the population. The obvious examples include the Moscow city (Khimkinskoe reservoir) and Minsk city (Vileiskoe reservoir, reservoir and pond systems on the Svisloch river and its affluents, Zaslavlskoe reservoir).);

In a new economic environment, the recreational importance of all inland water facilities has considerably increased. In Russia the recreational role of reservoirs has decreased after the alienation of recreational zones in the Baltic sea region, Crimea, Caucasus, Carpathians, partially at the Azov sea and at Issyk-Kul' lake.

## 3.5 Major Negative Implications of Hydro Technical construction

Water resources projects face the general problems in the economy – including lack of funding of maintenance and non payments of debts for services provided (eg electricity generation at dam). At the same time, dams construction itself, has a number of negative impacts on the existing social and economic conditions and natural environment which include:

- land flooding;
- damage to fisheries;
- negative effect on climate, flora and fauna in the vicinity of a reservoir;
- modification of hydrological and temperature regime;
- social and economic issues related to the population resettlement, transfer of industrial facilities and transport communications.

***The Flooding of lands*** is perhaps considered the main negative implication of hydro technical development for natural, social and economic environment. Large-scale hydro facilities construction conducted in the 1950-1960s in the European part of Russia were accompanied by the submergence of considerable land resources. The aggregate area of lands withdrawn from use as a result of hydro technical construction amounts to 4 460 000 ha, including agricultural lands - 1560 000 ha; forest, bushes - 2140 000 ha; unused lands - 760 000 ha. Agricultural lands include plowed field - 453 000 ha (0.3 of the total area of the country's plowed field), hay fields, pasture lands - 1107 000 ha.

Each reservoir project envisaged a set of measures to compensate for the loss of agriculture output from the flooding of land. These measures include: expansion of other agricultural lands, different methods of land improvement for productivity increase, agricultural output processing and storage facilities. Unfortunately, this form of compensation and the institutional forms of its implementation turned out to be inefficient and the loss has not always been compensated in full. The existing complementary compensation measures include expansion of the area of irrigated lands using the newly available reservoir water. In the regions with insufficient water, the irrigated areas reached 0.5 million ha.

Reduction of the area of lands flooded as a result of reservoir construction remains the main objective of the Russian hydro technical engineering. Table 3.6 illustrates the reduction in area lost for flooding per unit of energy produced by HPS.

**Table 3.6 Indicators of Areas Flooded by the Reservoirs in Russia**

| Years / Flooded areas: ha per million kW/h | 1926-1950 | 1951-1960 | 1961-1970 | 1971-1980 | 1981-1990 |
|---|---|---|---|---|---|
| Total | 78 | 61 | 28 | 11 | 6 |
| Agricultural | 27 | 29 | 10 | 3 | 1 |
| Forests, bushes | 44 | 20 | 13 | 6 | 4 |

At present, the method of large-scale hydro technical construction on rivers flowing through flat areas is being rejected. HPS construction has been shifted to foothills and mountainous regions, the environmental capacity of the local area is taken into account and the engineering protection of the territories is implemented. In many new hydro technical facilities, the unit flooding area does not exceed and in many cases is considerably lower than the indicators of the latest period indicated in Table 3.6. More details on land alienation for reservoirs may be found in one of the following sections.

Hydro technical construction has caused considerable damage to ***fishery.*** Changes in the habitat of passing and semi-passing fish, reduction of spawning areas, destruction of migration routes, change of hydrological and temperature regimes have resulted in the reduction of the natural reproduction of fish and decreased their stock. The attempts to install fishways at dams have not yielded the desired results. A more efficient means of fish productivity restoration in the regulated rivers has proved to be artificial cultivation, establishment of ponds and lakes, commercial fishery farms, etc. Construction of several fish-processing plants on in the lower reaches of Volga has made it possible to restore the production of sturgeon species in the Volga-Caspian basin and even increase the catches of this most valuable fish species.

The reservoirs are not used adequately for fish production. Most of the reservoirs have not reached the set targets of fish harvesting due to insufficient preparation of their bed for flooding, low volume of fishery activities and adverse effects of reservoir operation on fish. At most of the reservoirs, catches amount to between 5 and 10 kg per ha of water surface. At the same time, at Tsimlianskoe and Kakhovskoe reservoirs, fish productivity has reached the level of 40 kg per ha.

Reduction of fish productivity, inter alia in regulated rivers, is also caused by excessive pollution of rivers with industrial, domestic and agricultural wastes. Adverse conditions of HPS water storage basins construction also include intensive transformation of their banks, especially during the flooding stage. This has led to reduction of the areas of forests, agricultural lands, destruction of industrial facilities, appearance of sloughs, karst and other geological processes and requires valuable strengthening operations.

Construction of dams adversely affects ***fauna*** in the flooded zones and downstream of dams. During the filling stage, many small animals die - shrews, mice rodents, etc. - while larger animals migrate from the flooding zone and their numbers usually decrease. New reservoirs destroy the traditional routes of animal migration.

Flooded areas in many regions (Siberia, the Far East) are rich hunting lands and in many cases -the basis for survival for many indigenous peoples. Damage to fauna is not only related to increased animal death rates, and modification of the animal species structure, but also causes the destruction and loss of fodder fields, increased anxiety factor, etc. Considerable losses are incurred by reindeer breeding farms through productivity decrease resulting from HPS construction and subsequent development of the rain-deer pasture areas. A positive factor of artificial water reservoirs construction is seen in the increase of swimming animals and bird species, and in the use of new water areas for migrating bird stopovers. On the other hand, the reservoirs frequently infringe on the areas of settlement of rare animals and birds listed in the Red Book.

The downstream adverse effects of the reservoir construction are mainly related to the change of the rivers' ***streamflow regime*** and the loss of fertility and biological productivity of the flood plains. With the establishment of the Volga system reservoirs, the decreased flow that has resulted has led to the transformation of the ecosystems in the Volgo-Akhtubinskaya flood plain and the Volga delta. Reduced duration and magnitude of flood has led to the change in the hydrological regime of the flood plain landscapes, reducing productivity of meadows complexes. Changes in the soil moisture conditions has led to decreased yields of the vegetation mass at the downstream Don River reaches (in certain years the yields decreased by 25%). There is a well-known, widely described example of the loss of the fertility of the Irtysh flood plain soils, its navigation, as well as swamping of certain sites as a result of flood-flushes after the creation of Bukhtarminskoe reservoir.

In the regions with cold climate, there is a considerable change in the ***thermal regime*** of rivers downstream of the large reservoirs, which is manifested in delays in water cooling in autumn and its warming in spring, while in winter time a non-freezing air hole in ice is formed. This leads to the deterioration of meteorological conditions: frequent fogs, and in large industrial cities (Krasnoiarsk, Irkutsk, Bratsk, Ust-Ilimsk) – the formation of smog due to the concentration of discharge of hazardous substances in the air. This adversely affects people's living conditions and their economic activities (increased incidence of colds, cardio-vascular diseases, deterioration of land and air transport operation, deterioration of recreation conditions).

***People's resettlement*** from the flooding zones is a very painful social issue associated with large-scale hydropower construction. In the former USSR, the issues of land alienation for reservoirs and the compensation for it were addressed through transfer from one form of use to another. Use of lands for certain purposes was determined on the basis of special regulations issued by the USSR Council of Ministers and Basin Land Legislation with thorough analysis of economic efficiency of the options of this use. Permission for land alienation for reservoir construction was issued by the Councils of Ministers of the individual Republics.

During a reservoir construction, special land improvement and construction works were usually conducted for settling residents removed from the zone of flooding. The reservoir projects provided for economic land organisation of collective farms and other land-users and the restoration of agricultural output production. Activities related to people's resettlement were conducted in a planned way using funds allocated for the dam construction and other appropriations with obligatory provision of resettled population with employment. All housing and household facilities affected were to be constructed at the new improved settlements; for some re-settlers, especially in the cities, apartment houses were built. In doing so housing was provided on the basis of the existing norms.

According to data provided by the Ministry of Fuel and Energy, during the entire period of hydro technical development in Russia, 832,000 people were resettled from the reservoir construction zones, including *666*,000 people re-settled in the course of the construction of the Volgo-Kama system. Improved settlements equipped with required communications and social and cultural institutions were constructed for re-settled people. They were also paid material damages. However, previously applied measures and set volumes of compensation for resettlement were in the most cases inadequate in comparison to the material and moral damages caused by resettlement. (*Additional details on this issue are provided in one of the following sections.)*

The magnitude of resettlement to a large extent depends on the extent of the flooding. Therefore, with the reduction of flooded areas the number of people to be resettled also decreases. On average, in the 1950s, 11 people were re-settled per 1 million kW per hour of additional energy production. In the 70s and 80s this indicator decreased to one person. It has remained at this point up to the present.

However, a comprehensive assessment of social and ethnic implications of hydrotechnical construction and other economic activities in places where indigenous people live has not been conducted. Compensation has been provided, but losses for indigenous peoples have been neither forecasted nor assessed.

At present, the academic community and public organisations of small nations (at meetings, conferences, in numerous publications, etc.) discuss many social and ethnic aspects of the problem of hydropower construction (Kamchatka peninsular, Sakhalin island, etc.. Legislative and executive bodies recognise and emphasise the right of indigenous peoples to preserve their ethnic and cultural identity. This right requires protection on the part of the Government, which to this end works on the elaboration of a package of Federal laws on the rights of indigenous peoples. Besides these efforts certain approved Federal laws, which have already come into force (the Land Code, on the Payment for Land, on Environment Protection, on Subsoils, on Education, on Wildlife, etc. specify the rights of indigenous peoples to natural resources and their cultural heritage.

The new concept of the Energy Programme takes into account the specifics of the territories inhabited by indigenous peoples. In particular, it recommends the development of low-scale power engineering and its non-conventional forms allowing it to establish conditions for sustainable provision of heat and light from environmentally acceptable sources of energy which do not disturb the way of life of indigenous peoples.

The negative implications of the reservoir construction caused the criticism of such projects mainly from the representatives of the environmental movement. The criticism was sometimes very sharp culminating in appeals to drain large reservoirs. Actual problems and issues were sometimes supplemented with alleged ones. This criticism revolved mostly around the following points:

- reservoirs occupy valuable agricultural lands;
- reservoirs slow down the water circulation, form peculiar "blood clot" in the river's waterway and deteriorate the quality of water resources;
- reservoirs cause ecological disasters and deterioration of the people's quality of life.

The counter arguments put forward by the specialists include the following.

The total area of agricultural lands in the former USSR has decreased as a result of the reservoir construction by approximately $3\ 10^6$ ha or only 0.31% of the total country's land area, 0.5% of the area of agricultural lands and about 0.3% of plowed field. Obviously, the size of relative alienation of lands within certain regions, in the Volga basin for example, is much higher. But even in this case they are not usually the main reason of problems in agriculture, which has its roots in the general adverse agro-climatic conditions, as well as in political, social and economic fields. Moreover, without reservoirs it would be impossible to carry out irrigated land improvement required for dry regions or engage in productive agriculture in the areas of infrequent summer floods. Thus, the multipurpose reservoirs have allowed three times more land to be developed than the entire area of agricultural lands, flooded by all reservoirs of the USSR.

The perceptions that the water cycle slows down and that reservoir construction leads to a deterioration in water quality are completely misleading. In this respect, the situation with river streamflow which is naturally regulated by lakes is quite typical. This example includes the Neva River, in which water quality together with water quality of Ladozhskoe and Onezhskoe lakes for many centuries (until the industrial and agricultural development) has remained at a very high level. Even to a greater extent this relates to the Angara River and Lake Baikal. The main reason for the unsatisfactory quality of water in some reservoirs and rivers passing through them – is the increased pollutant load which comes with waste waters from agricultural and urbanised territories. Moreover, the reservoirs make it possible to fully dissolve pollutants, especially during low-flow periods, to transform into bed sediments and vegetation residues the enormous amounts of hazardous ingredients effectively withdrawing them from the water mass. The process of self-regulation is more expedient in the natural than regulated waterway. But without the Volgo-Kamsky reservoir system, which contains large volumes of conserved water, the Volga and Kama in summer and winter low-flow periods would turn into waste channels, while a great number of pollutants currently buried in the sediment beds of the reservoirs would reach the Caspian sea and cause irreversible damage to the unique system of this water basin.

With respect to the impact on natural environment in general and social conditions of people's life it is necessary to emphasise that there are no evident adverse implications of reservoir construction. Some adverse implications are possible, but they can be considerably reduced through nature protection activities. Besides, the reservoir construction yields positive social and economic results as well. Analysis of the proposal to empty the Volgo-Kama reservoir system has shown that the benefit of such extraordinary move would be nebulous. However, the negative implications are clear and include the following:

1. Withdrawal from the Single Energy System of 11 400 MW in HPS installed capacity and of 40 000 GWh in annual production, the bulk of which being the most valuable peak electric power. Compensation for losses of this power at TPS and NPS will lead to enormous investments and environmental costs.
2. The entire cargo turnover of the Single Deep-Water System of the European part of the country will be destroyed since modern vessels cannot pass through Volga in the low-flow period. This will require enormous funds to compensate for losses using rail-road transport.
3. Complete reorganisation of water supply of many cities and rural settlements will be required.
4. Reorganisation of the entire structure of water recreation will be required.
5. The threat of flooding and semi-flooding of territories as a result of high floods and flash floods, from which they are currently protected by dams will increase dramatically.
6. Pollutants currently buried in bed sediments will become dynamic and will pollute both Volga and Kama and the Northern Caspian region.
7. Agricultural development of released lands, many of which are covered with slime and sand with heavy concentration of pollutants, will require enormous additional costs.
8. The existing natural and economic complexes within the reservoir systems will be destroyed.

All this does not mean that any criticism of a particular hydro technical project has no basis. In a number of cases, economic and environmental costs can be so high that it is feasible to turn down a construction proposal, to introduce changes in the available reservoirs or even drain some of them.

In general, the majority of established reservoirs have a very high economic and social value. Consideration of proposals of reservoir destruction is unlikely to be a feasible and logical way to go. On the contrary, the possibilitiesof improving the efficiency of the existing reservoirs should receive further attention.

## 3.6 The impacts of Dams on Fish Resources

This issue was marginally considered in the previous section, but it requires more attention because of itsimportance. In general, dams have had a negative impact on fish resources, especially on the most valuable species of fish. The greatest damage has been caused to the unique stock of sturgeon species in the Volga river-Caspian sea basin, which accounts for about 90% cent of the world sturgeon catch. Water storage basins have flooded the majority of natural spawning places, while dams have obstructed the water ways which used to ensure access to them. Artificial waterways facilitates the access of passing and semi-passing fish species to spawning places, whereas detouring of river dams has turned out to be inefficient. As a result of dams construction on the Volga river, the area of sturgeon spawning has decreased from 3,000-4000 ha to 4,00-430 ha which amounts to about 12% of the former spawning area in the Volga delta and Volzsko-Akhtubinskaya floodplain. Natural spawning areas for sturgeon species have remained mainly in the Ural river.

As a result of the Volgo-Kama reservoir system construction, the water regime of the Volga river has changed considerably. The volume of spring flash flood has decreased and the remaining spawning places are now less frequently filled with water while the timing of filling has changed as well. At the same time, discharge has increased in the low-flow period, especially in winter when energy requirements are particularly high. This negatively affected the conditions of fish stock hibernation in the lower parts of the Volga river. Annual loss of sturgeon species caused by flow regime change in the Volga river alone is estimated at more than 10,000 tons. This amounts to about 60% of the catch of fish in the Volga-Caspian basin in the 1940s - before the initiation of construction of large HPS in the central and downstream reaches of the Volga river. Immediately after the establishment of large dams - Kuibyshevskaya (1957) and Volgogradskaya (1960), the catch of sturgeon species has decreased by almost 30% - from 17,500-18,000 tons to 12,500-13,000 tons a year. However, later the catch has increased and reached its peak in the late 1970s amounting to 25,000-30,000 tons. This has been mainly caused by the success of efforts which have made it possible to maintain the numbers of sturgeon species at a high level and even to increase the catch through the establishment of fish breeding farms and certain measures that regulate the harvesting. However, the negative factors (including rivers and ponds pollution and illegal catch of sturgeon, which has particularly gained momentum after the disaggregation of the USSR) persist.

In 1976, attempts were made to improve the fish habitat in the lower parts of the Volga river through the establishment of the Astrakhan' watershed station. This represented a set of hydro facilities set in place in order to create a temporary water dam 4.5 meters high at the upper part of the Volga river delta and to flood the spawning areas in the eastern part of the delta and lower part of Volga-Akhtuba flood plain for 40-50 days, ie for the period of spring passage of fish for spawning, as well as in autumn for 30-50 days for the passage of the main stock of passing and semi-passing sturgeon species for hibernation.

It is difficult to assess the ecological efficiency of the watershed station in full detail since it has only been used for a limited number of times due to the non-converging interests of fishery and agriculture in the volume and timing of spring flooding required, due to certain differences in respect of this volume on the part of sturgeon and tchastic fish species, as well as due to the phase of increased humidity experienced in the Volga river basin since 1978, which made the problem of water sharing among different sectors of the economy (and required fishery flood-flush) less acute.*

The Volga river serves as an example of a river basin where, due to its especially high economic value, a set of compensatory, although insufficient, measures has been taken. It has to be admitted, though, that as far as other rivers affected by hydro technical development are concerned, the situation with the implementation of such measures is much less favourable. For example, the issue of fishery flood-flushes required at the lower parts of the Don river and Tsymliansky reservoir has not been addressed for many years.

## 3.7 Compensation for Lands Submerged or Lost in Dams Construction

The Land Fund of Russia and the republics of the former USSR as of 1987 amounted to 2 231 Mha, including 6049 Mha of agricultural lands (228 Mha of plowed field, 39.4 Mha of hay fields, 333.2 Mha of pasture lands and 5.1 Mha of other agricultural lands).

Land resource protection was regulated by the Basic Provisions of the USSR Land Legislation adopted in the late 1960s. In the follow-up to these Basic Provisions, the Council of Ministers of the USSR adopted the Regulation of August 9, 1974 N 636 "On the Compensation for Losses to Land Users and Losses of Agricultural Production in the Course of Alienating Lands for the State and Public Purposes". In the course of power engineering facilities construction land resources protection was provided in different areas. In particular, these measures included the selection of the composition of generating capacity of power stations and the places of their location so there would be minimum damage to land resources, especially agricultural lands. Other provisions included the introduction into project design documentation of compensation activities related to alienation and deterioration of lands and forest-covered areas; protection of lands allocated for construction from natural disasters, such as floods, mud flows, erosion processes in the course of HPS construction and their reservoir establishment; and protection from flooding, semi-flooding and banks destruction; re-cultivation of lands temporarily allocated for the construction of power engineering facilities and obsolete installations. Compensation for lands allocated for power engineering facilities construction represents one of the main components of the agricultural fund rehabilitation.

In accordance with article 19 of the Basic Provisions of the USSR Land Legislation, alienation of agricultural lands for industrial enterprises construction (including power engineering facilities) should be compensated through the development of an equal area of new lands accompanied with relevant works for amelioration and fertility improvement thereof. In allocating lands for power engineering facilities such compensation was traditionally envisaged in relevant projects.

The main part of lands used by dams (more than 95%) is allocated for the construction of HPS and their reservoirs. However in hydro power engineering facilities construction, the activities related to compensation for the alienation of agricultural lands are conducted earlier and on a wider scale (in volume - even to a large extent) than in the course of construction of other power engineering facilities.

Compensation activities usually include: development of new lands - virgin areas, difficult terrain, lands covered by forests and bushes, low-productive pasture lands and hay fields, irrigation and drainage of the lands used, etc. Compensation activities in different regions of the country were implemented in different ways depending on local natural and economic conditions. In the forest and especially taiga zones these activities typically included the development of lands covered with forest. In the forest-plains and plains zones the main type of activity consisted in the improvement of lands used for agricultural purposes since in these zones free land funds fit to be used as agricultural lands are scarce. In the regions of irrigated agriculture alienated lands were compensated mainly through irrigation of new sites or increased provision with water of available irrigated areas.

The level of compensation for alienated lands at different stages of hydropower engineering facilities construction was far from being the same.

In the 1920-30's development of new lands instead of alienated ones by HPS was of limited nature (Volkhovskaya, Dneprovskaya HPS, the Moscow Channel) due to an erroneous perception of the inexhaustible nature of land resources, while the scale of alienation was relatively small.

In the 1950-60s the issue of agricultural land protection attracted more attention. However, the projects included only the most simple, low-cost and under-valued means of compensation for lands. This is particularly true in respect of HPS constructed at that time at the Volga river. In the course of certain HPS construction either no compensation was envisaged in the projects at all (Rybinskaya and Uglichskaya HPS) or was provided at a limited scale (Gor'kovskaya, Volzhskie HPS). In the 1950s in general, the level of compensation for the loss of agricultural lands amounted to 25-35%, which negatively affected the state of the land fund, particularly that of hay fields in the areas of HPS reservoir construction.

In the 1960s, the compensation for land losses amounted to 50%. In the 1970-80s the HPS construction projects provided for a 100% compensation (in area) of alienated lands. Here it should be borne in mind that absolute and unit alienation of agricultural lands in these years decreased considerably. However, in practice it is very difficult to assess the actual level of compensation of land losses since the funds for land development and land improvement transferred to special accounts of the agricultural bodies of the Union republics were used for conducting these activities not only in the areas of HPS construction, but in other regions with increased efficiency of agricultural investments as well, which means that the central agricultural bodies utilised allocated funds for needs not related to new lands development.

The largest alienation of land were made in the 1950-60s with the start of construction of large reservoirs at the plain rivers of the European part of the USSR, and in the following decade in the Eastern Siberia, Kazakhstan and the Far East. After 1985 in Ukraine, Moldavia, Baltic and Trans-Caucasian republics the areas of lands used by hydro facilities has practically remained the same.

In 1986-1990 the main part of lands alienation was connected with the establishment of the reservoirs of the Kureiskaya and Bureiskaya HPS in the eastern regions of the USSR, Shulbinskaya HPS in Kazakhstan and Rogunskaya HPS under construction in Tajikistan (the construction of the latter, however, has been stopped). However, the former two of the listed reservoirs hardly use agricultural lands at all.

As Table 3.7 illustrates, in addition to agricultural lands large forest-covered areas were flooded - 2.6 Mha. The share of flooded forest areas has increased particularly with the relocation of hydraulic power engineering facilities construction into the Asian part of the country - to the Eastern Siberia and the Far East. There is also negative experience in water storage basins construction in the forest areas when forest area, before water storage basins filling, for different reasons has not been logged (Rybinskoe water storage basin) or logged only partially (Bratskoe water storage basin, etc). Flooding of territories covered with forest has become the main environmental problem related to the construction of large HPS in Siberia, particularly in the Angaro-Enisseisky basin.

**Table 3.7 Alienation of Land for Reservoir Construction (as of 1990).**

| State | Total land area, Mha | Agricultural land, Mha | Forested land, Mha |
|---|---|---|---|
| Russia | 4853 | 1741 | 2286 |
| Ukraine | 761 | 304 | 297 |
| Moldavia | 5 | 3 | 1 |
| Lithuania | 10 | 7 | 1 |
| Latvia | 8 | 4 | 2 |

| | | | |
|---|---|---|---|
| Estonia | 4 | 1 | 2 |
| Belarus | 11 | 7 | 3 |
| Georgia | 10 | 7 | - |
| Azerbaijan | 76 | 45 | 25 |
| Armenia | 3 | 3 | - |
| Uzbekistan | 71 | 43 | 11 |
| Kirgyzia | 32 | 23 | - |
| Tajikistan | 62 | 7 | 32 |
| Turkmenia | 1 | 1 | - |
| Kazakhstan | 702 | 464 | 44 |
| Total | 6609 | 2660 | 2704 |

In the 1970s, relocation of HPS construction within the European part of the USSR to mountainous and foot-hills areas in the Asian part to the under-developed in economic respect territories, as well as a recent shift to a more strict approach to the selection of reservoir control lines and strengthening marks in general, have led to the improvement of technical and economic indicators of land alienation per unit production of energy by HPS (Table 36).

During the period from 1926 to 1990, unit indicators of lands flooding, particularly that of agricultural lands, in the USSR systematically improved (Table 3.6). These indicators have shown a particularly drastic improvement since 1970 with the relocation of HPS construction to mountainous and foothills areas of the country.

Comparison of unit indicators of lands alienation for certain operational HPS of the former USSR and foreign countries shows that the indicators for the later have a wider range of variation and differ considerably both for the better and for the worse as compared to the average unit indicator amounting to 29 ha/million kWt per hour. The best unit indicators, in ha/million kWt per hour, in the USSR are typical of HPSs located in the North-West of the country: Kegumskaya - 4.9, Pliavinskaya - 1.6 and Rizhskaya - 6.4; HPS located in the mountainous areas of the Northern Caucasus and Trans-Caucasus: Tchirkeiskaya - 1.9, Shamkhorskaya - 1.2 and Zhinvalskaya - 2.5; in the mountainous areas of Central Asia: Kurpsaiskaya - 0.5, Toktogulskaya - 6.8, Nurekskaya - 3.6 and Tcharvakskaya - 2.3 as well as the largest HPS built in Siberia: Krasnoiarskaya - 10.2, Ust-Ilimskaya - 8.7 and Saiano-Shushenskaya - 2.7.

The worst indicators of HPS built in the 1940-50s at the plains rivers of the European part of the USSR, namely at the Volga, Dnepr, Don and particularly Rybinskaya HPS (505.5 ha/million kWt per hour) were constructed in the post-war period when with the large surface water area of the reservoir, production of electricity was relatively low. However, it should be borne in mind that this reservoir regulates the flow at the upper part of the Volga river serving the interests of water transport and HPSs located in the lower parts. The same picture is seen in the case of Tsymlianskaya and Kakhovskaya HPS (465.8 and 299.3 ha/million kWt per hour, respectively) whose reservoirs are also multi-purpose in nature and are intended in the first place for meeting the requirements of water transport, water supply and irrigation.

Comparison of unit indicators of lands alienation (ha/million kWt per hour) for the largest HPS of Russia located at the Enissei and Angara rivers (Saiano-Shushenskaya, Krasnoiarskaya and Ust-Ilimskaya) and the largest HPS of the USA also located in the mountainous and foot-hills areas: Grand-Kuly (1.3), Rampart Canyon (8.5) and Gouver (10.9) shows that the Siberian HPSs in these indicators do not lag behind the North American and Canadian ones: Churchill Falls (3.4), Portige-Mountain (13.1), Nechako-Kemano (7.8). The same can be said when comparing for this indicator the Siberian HPSs with the largest Brazilian: Itaipu (2.0), Ilia Solteira (5.1), as well Argentinean ones: Isla Del-Patti (4.5) and Santa Rosa (4.5). The largest HPSs of China: Uchansi (8.8), Lutsziasia (2.3) and Canmynsia (3.5) have unit indicators similar to the above mentioned Siberian HPSs.

The same indicators of medium-scale HPSs of the former USSR located in the mountainous and foot-hills areas: Zhinvalskaya, Shamkhorskaya, Ust-Kamenogorskaya and Tcharvakskaya HPS and North American ones: Big Band (22.0), Fort Randoll (28.5) and Oakhe (38.5) are close although they lag behind the indicators of some HPSs in Switzerland: Batiez (0.24), Limmernboden (0.5), Barberin (0.2) and France: Jenisia (0.") and Siteron (0.2). At the same time, there are such power stations in France as, for example, Sarran (4.5) and Grandvall (14.8) and in Turkey: Karababa (7.2) which are similar in lands alienation indicators to the above mentioned Russian HPSs.

Thus, it is possible to say that the majority of Russian and NIS HPSs in respect of unit indicators of lands alienation do not lag behind foreign stations with the exception, as has already been mentioned, of certain HPSs constructed in the 1940-50s at the rivers of the plains of the European part of the country.

## 3.8 Safety and Monitoring of Hydro-Technical Facilities

Dams and reservoirs built on rivers of different countries of the world, Russia and the NIS have proved to be safe and reliable. Many of them have been operated for dozens or even hundreds of years. There have been dam failures similar to other countries. However, an increased interest in the safety of hydro-technical facilities all over the world shown in recent years has a serious basis. Data collected from world statistics and recent events demonstrate that it is impossible to exclude fully the possibility of damage and destruction of dams and installations adjacent to them.

The probability of accidents at dams in Russia and the NIS during the period of their economic transition to market economy has increased which can be explained by a number of factors which place assets at higher risk. These include the elimination of certain water management bodies, no 'owner' in respect of some reservoirs, reduction of hydro-meteorology services network forecasting floods and flash floods, ageing of facilities and erosion of equipment as well as military activities, ethnic and social conflicts and possible terrorist acts.

In Russia and adjacent countries there has been no major destruction of large dams, which is related, in the first place, to clearly defined norms of construction design. However, accidents at small dams of water storage facilities, including Kiselevskaya and Tirlianskaya (Urals and Bashkortostan) having serious economic implications and human casualties, damage of turbine of Dubossarskaya HPS at the Dnestr river during the period of military conflict, the threat posed to the preservation of Nurekskaya HPS in Tadjikistan, as well as excess of the established terms of operation of a number of other water power facilities, failures in the work of particular installations of hydro power facilities and delays with or complete lack of maintenance works as a result of financial difficulties have forced the state authorities and relevant agencies to pay serious attention to the state and safety of dams and reservoir operation.

The Ministry of Fuel and Energy of the Russian Federation has taken specific steps to reduce the risk of hydropower facilities damage. At present, capital repairs are underway at a whole set of hydro-technical installations, dams are being strengthened, the carrying capacity of weirs is being increased and additional installations are being set up to dissipate energy at downstreams. Dams are verified in respect of their compliance with modern Construction Norms and Rules as to the class of seismic activity etc., hydro power characteristics are being specified including discharge values, works are underway to modernise the HPS management systems and to increase the level of automation.

Several measures have been taken to reduce danger and damage in the course of HPS operation related to various geodynamic processes, primarily with earthquakes. To this end, seismological and geophysical services of different ministries were tied into a single Federal System of Seismological Observations (FSSO). The main objectives of the FSSO include provision of timely forecasts of earthquakes, early warning of the central and regional authorities on the forecast geodynamic dangers, set up of a seismological and geodynamic data bank, elaboration of regulatory documents on the protection of the population, economic facilities and the territory from the impact of earthquakes and other natural disasters. In 1993 within the framework of the Hydroproject Institute, a service for geodynamic observations in the electro-energy branch was set up to expedient control of geodynamic (including seismic) situation in the vicinity of the most important energy facilities. Taking into account an extreme danger of seismic manifestations, the Centre of the Geodynamic Observations Service in 1996 developed an integrated programme to increase the seismic resistance of hydropower engineering facilities in Russia.

On July 29, 1997 a Federal Law "On the Safety of Hydro-Technical Facilities" was adopted by the both chambers of the Russian Parliament and signed by the President of the Russian Federation which identified the specific responsibility for the provision of safe operation of dams and other hydro-technical facilities at the rivers and liability for possible accidents and emergencies. The Law envisages not only measures taken and monitored by the state, but also the procedure of provision of safe operation of installations by their owners and operating organisations. In particular, it is mandatory to conduct diagnostic monitoring of the state of facilities and their bottoms using modern test equipment and computer monitoring systems.

Practice shows that damage from accidents usually exceeds the actual value of facilities. At the same time, control of the state of the environment in the amount of 1-2% of the facility's value decreases the probability of accidents manifold. Due to this reason in the numerous measures related to hydro-technical facilities safety provision, including the above-mentioned Law, an increased focus is placed on monitoring. Under the term "monitoring" we understand a system of measures related to observation, evaluation, control and management of the state of hydro-technical facilities taken in order to prevent or reduce the probability of accidents and their disastrous implications.

At present, a number of steps have been taken to exercise production control over the safety of energy plants, to improve the means of monitoring, to computerise on-site observations of the state of energy facilities, to publish the results of energy plants observations, etc. The existing means of monitoring have a capability of ensuring high level modern detection of the facilities' defects, to increase the speed of decision-making, and to reduce difficulties in data collection, processing, storage and analysis. In addition, preventive measures are developed and taken to protect and preserve hydro-technical facilities, besides monitoring their actual protection. This has required serious efforts not only on the part of scientists, designers and operators, but of law-enforcement, governmental and legislative bodies as well. These preventive measures also include such objectives as expansion of fundamental scientific research to address applied tasks, increase of the professional level and training of new staff in the field of natural disasters and catastrophes response, forecasting risk factors and mapping of possible implications of accidents, to name a few.

Increased emphasis is placed on the hydro-meteorological support of monitoring, improvement of regulatory documents, the methods of expert evaluation of reliability and safety of dams, the methods of automated control of the safe operation of energy plants, seismic control, etc.

Many state-of-the-art instruments and methods of monitoring have been tested or are already introduced at selected operated energy facilities. Thus, a transformer of installations linear deformations and a transformer of soil tensions have been introduced at Nurekskaya HPS. The methodology of on-site observations analysis to identify and localise pre-accident sites has been introduced at the channel and right bank dams of Ust-Khantaiskaya HPS, and device measuring excessive pressure of filtration flow in hydro-technical installations and their bottoms have been introduced at Pliavinskaya HPS. Several devices are already in use at Tcharvakskaya HPS, Zagorskaya HAPS, etc.

Currently, a set of measures is taken to implement the law and to conduct monitoring. To coordinate these activities, in particular, an Inter-Agency Coordination Council on the Safety of Hydro-Technical Facilities has been set up which includes representatives of the Ministry of Fuel and Energy, the Ministry of Nature and the Ministry of Emergencies. Within the system of RAO EEC of Russia the main energy oversight of the state of energy plants has been established, etc. All these and many other activities represent important stages of the implementation of state programmes including the state system of forecasting emergencies and alleviating their implications intended to preserve people's health and life, to reduce the level of damage caused to natural environment and material losses.

## 3.9 Achievements and Prospects of Russian Power Engineering Development

The discussion above has naturally focused on hydro technical development, which is the main purpose of this document. However, the issues related to hydropower development should be viewed in broader context of the overall energy industry. Power engineering represents the most important life-supporting branch of the country's economy. It consists of more than 700 power stations with the total capacity of 215.6 million kW.

The Unified Energy System of Russia (UES) is one of the largest highly automated energy complexes in the world that produce, transmit and distribute energy and ensure centralised operation management of these processes. The UES of Russia includes about 450 large power stations belonging to different agencies with the total capacity of more than 200 000 MW. Per capita energy production in 1998 amounted to over 5 630 billion kW per hour.

The structure of energy production is shown in Table 3.8.

**Table 3.8 The Structure of Energy Production in Russia, GWh/ %**

| Energy production: | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|
| Total | 860<br>100 | 847,2<br>100 | 834<br>100 | 826<br>100 |
| TPS | 583,7<br>67,8 | 582,9<br>68,8 | 567,1<br>68,0 | 564<br>68,3 |
| HPS | 177,3<br>20,6 | 155,3<br>18,3 | 158,4<br>19,0 | 158,5<br>19,2 |
| NPS | 99,5<br>11,6 | 109<br>12,9 | 108,5<br>13,0 | 103,5<br>12.5 |

The Table shows that the structure of energy production by the types of power stations in recent years has been practically stabilised and that the changes in the total demand in energy affects mainly the production of thermal power stations, which is in turn affected by the rivers water capacity and, consequently, energy production at HPS in certain years. Reduction of energy production at NPS in 1998 is mainly caused by the activities conducted with the aim of increasing their safety.

Despite the disintegration of the USSR and the decline in industrial production, HPS have continued to produce energy at a stable level and their share has increased from 14% in the former USSR to 21% in 1995 and then, after a certain decrease in 1996, has remained stable (19% and more). HPS share in the total capacity and energy production in different energy systems is shown in Fig. 3.8.

Hydropower in the Russian context is considered to have certain advantages as compared to other sources of energy for electricity generation, which were described in detail in the one of the previous sections. Today, the important role of HPS in the national economy is determined first and foremost by the fossil fuel saving and low-cost energy production. Fuel saving ensured by the existing HPS in 1998 amounted to about 55 million tons of coal. Low unit cost of energy produced at HPS results in low tariffs on their energy as compared to tariffs established for energy produced at TPS and NPS. In the case of HPS absence or their replacement, by TPS for example, the tariff on energy would increase by 25%.

As has already been mentioned previously, many HPS have been established under adverse natural conditions, in the permafrost zone with extremely low winter air temperatures, limited and contrast thermal resources, long period of ice freezing, etc. In this environment, unique hydraulic power engineering facilities of different types have been constructed and new technologies have been developed. Construction of HPS in Russia in the northern regions is characterised in the world hydro power engineering as a novel approach which has almost no analogue in the world practice.

In the course of HPS construction in the North and Siberia due to the lack of access roads and long distances from the industrial centres a new infrastructure of the entire regions has been developed which has served as a future foundation for developing natural resources and establishing energy and industrial complexes. This has ensured 10-12% of the total saving of investments and a decrease in production costs through its co-operation, complex usage of labour resources and infrastructure facilities such as housing, transport etc. This experience may without any doubt be used in other northern countries.

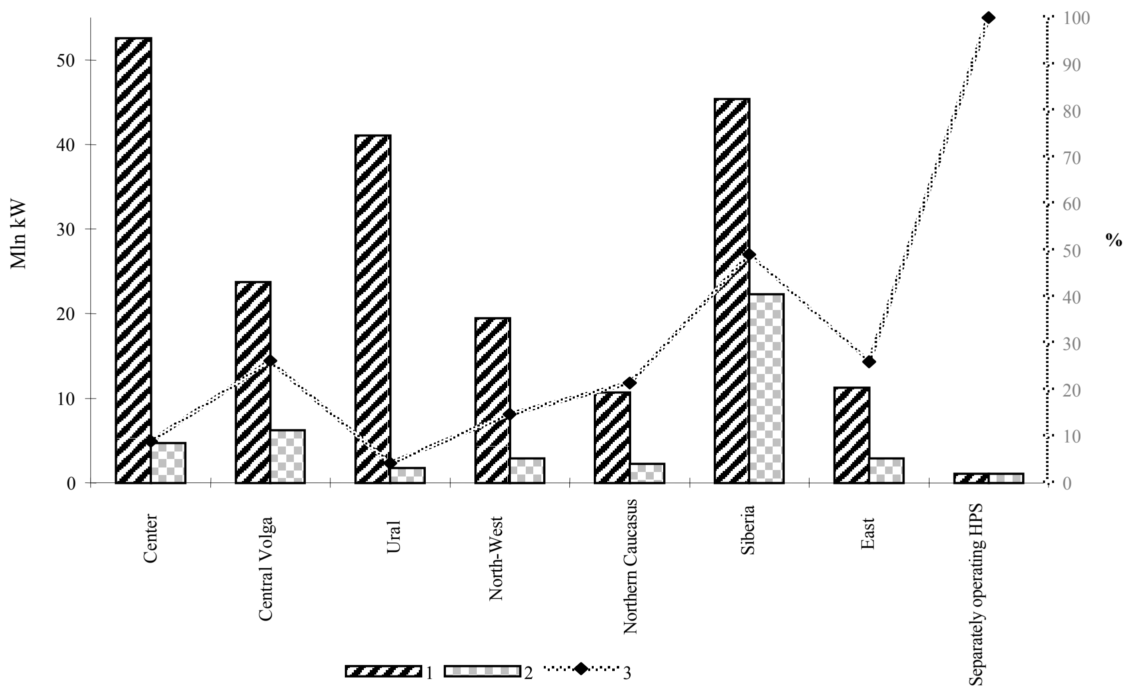


**Figure 3.1 Established Capacity of Power Stations by Unified Energy Systems (1), million kW, including HPS (2), and the Share of Hydro Power (3) as of January 1, 1999.**

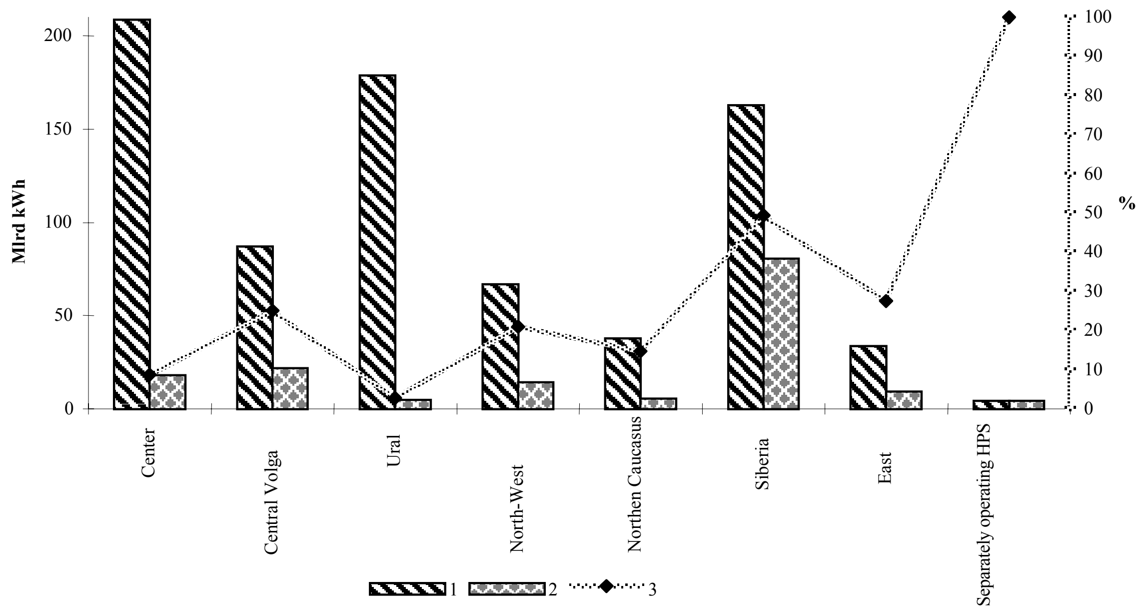


**Figure 3.2 Energy Production (1), billion kW per hour, including HPS (2), and the unit share of hydropower (3) in the unified energy systems.**

In Russia, HPS systems have been established with their construction initiated at the upstream parts of the rivers. This is viewed as producing multiple benefits, since regulation of discharge by dams constructed earlier and situated in the upstream reaches makes it possible to use the most simple and the least costly construction solutions and facilitates the closure of river valleys for those HPS which are under construction downstream.

The hydropower construction in Russia has been conducted without using services of foreign experts. At the same time, the Russian experience has been extensively applied in other countries (Vietnam, Brazil, Iran, Egypt, etc.). Russia also supplies energy to other countries. In 1998 these supplies to foreign countries amounted to 5 785.14 million kW per hour from the UES of Russia (to Mongolia, Finland, Norway, China, Turkey). The UES also supplies energy to the former republics of the USSR (Belarus, Kazakhstan, Ukraine, Georgia, Latvia, Lithuania).

Development of power engineering in Russia is documented in the Main Directions of the Energy Policy of the Russian Federation up to the Year 2010 adopted by Decree of the RF President of May 7, 1995 N 472. In accordance with this Decree, the main direction of power engineering strategy in the environment of continued crisis situation in the national economy is seen in the increase of efficiency of energy consumption and energy saving. Energy saving is considered both in our country and abroad as the determining factor for solving the problem of energy supply and environment protection.

A federal programme "Russia's Energy Saving" aims to ensure the transition of the economy to the energy saving way of development with the reduction of energy capacity of gross domestic product by the year 2005 by 13.4%. RAO UES of Russia has implemented a set of energy saving projects and developed a programme entitled "The Concept of RAO UES of Russia in the Field of Energy Saving" which addresses the problems related to efficient use of energy taking into account modern requirements of power engineering, economy and ecology.

Energy saving is ensured in several directions. First, this relates to technological break-through on the basis of achievements of technical and technological progress and creation of energy saving equipment and instrumentation. Second, this is caused by the transformation of the structure of the fuel and energy balance of the country in order to reduce the share of organic fuel (oil, gas condensate, gas, coal and other types of solid fuel) through increasing the share of hydro power engineering and a more intensive use of renewable non-traditional sources of energy. And finally, this includes a set of activities aimed at the reduction of energy losses and improved use of secondary energy resources, elaboration of measures of economic nature for encouraging efficient use of fuel and energy, etc.

Activities in the field of technology include, in the first instance, technical re-organisation, replacement of obsolete equipment at power stations and power networks by highly efficient and ecologically acceptable ones. Energy saving is also facilitated by a more professional operation of power engineering facilities, improvement of the quality of their construction and design, etc.

In the future, TPS will remain the main source of energy production in Russia. However, according to expert assessments, by the year 2010 it will be necessary to terminate operation of TPS with the total capacity of about 75 $10^6$ kW and to update the equipment which would make it possible to save about 10-30% of organic fuel. The priority direction in establishing new TPS is the introduction of gas-turbine and steam-gas installations and after the reconstruction - the use of the steam-gas cycle. The use of advanced steam-gas technology at certain power engineering facilities (TPS) has demonstrated the possibility of lowering fuel utilisation for producing 1 kW per hour by 3-5%.

The second direction in energy saving is the shift in priorities in the use of different types of fuel - HPS, wind, solar energy, etc. This direction requires substantial time and financing.

Most of adverse implications and protests of the environmentalists are caused by the large HPS whose projects have not been sufficiently substantiated in terms of their energy, economic efficiency and ecological safety. Therefore, the main tendency in hydropower engineering construction should be the establishment of medium and small-size HPS, predominantly in the mountainous and foothill regions. There is also another consideration, which has led to freezing and termination of construction of certain HPS. For example, in Siberia HPS provide about 50% of the total energy production, but a series of dry seasons have demonstrated that power supply can not rely exclusively upon hydro power engineering which constitutes in Siberia a considerable share of base-line and the entire peak load. The main part of this load should be carried by more reliable sources of energy, ie the TPS.

Adverse ecological implications of large HPS construction, depletion of hydro power resources of large rivers in certain regions, high cost and complexity of organic fuel delivery to remote, hard to access regions - all these factors have increased the interest in small-scale power engineering. The most promising direction is seen in the construction of small-size HPS (SHPS) in mountainous regions where waterfall levels are high, where water discharge has little seasonal variation, where rivers do not freeze in winters while flooded and semi-flooded areas are relatively small.

SHPS can be constructed not only at small rivers but at medium and large ones as well using a part of their water discharge and functioning channels, in ship passages, at water storage basins of non-power engineering orientation, in the industry, ie everywhere where there is a marked change in hydraulic head, etc. Supplementing small and medium-size HPS with small-scale power engineering facilities increases the reliability of energy supply and allows more efficient use of the hydro potential of rivers. The possibility of SHPS operation as independent sources of energy supply in remote regions, replacement of costly and dangerous, in ecological terms, organic fuel, relatively small damages to nature and population as compared to larger HPS, make it possible to regard small-scale power engineering in the future as an independent and highly efficient branch of the fuel and energy complex, particularly in the under-developed and remote regions. It has to be noted, however, that a number of reservoirs on small and medium rivers (about 400 in total) do not include HPP and are constructed for different purposes.

A certain contribution to energy balance and energy saving improvement can be made by the development of alternative, non-conventional sources of energy - geo-thermal waters, tide currents, wind and solar energy, etc. The scale and rate of development of such sources in Russia and NIS lags behind many other countries and do not meet the needs of national economy. The potential of these sources of energy is high, although at present they contribute to a saving of one million tons of reference fuel. The level and the prospects of development of the sources mentioned above are different, and the greatest emphasis seems to be placed on wind energy development. However, there are a number of similarities typical of the development of all these branches of power engineering which make it possible to express a common point of view on them. It is as follows. Adjustment of the structure of the country's fuel and energy balance towards alternative sources of energy is possible subject to considerable investments in scientific research and design, new technologies, as well as in the production of equipment for these branches of power engineering. Taking into account technical and economic indicators of energy facilities which use non-conventional sources of energy, lack of knowledge of many implications of their construction for nature and people, it is possible to say that they can not yet fully replace the traditional sources of energy, but can considerably facilitate the solution of the energy related problems related in many regions of the country.

The policies on the use of the nuclear power stations (NPS) in Russia and the prospects of new construction are contained in the directions of: i) provision of operational safety on existing NPS; ii) finalisation and putting into operation of the NPS energy blocks, which in many cases are characterised by a high level of preparedness (Rostovskaya, Kalininskaya, Voronezhskaya, Balakovskaya NPS); and, iii) finalisation of design and construction of the new blocks (NPS of "a new generation").

In the view of different experts, the experience of Bilibinskaya NPS operating at Tchukotka shows as way for construction of similar stations taking into account their relatively small capacity allowing energy supply of comparatively large consumers (mining and manufacturing enterprises, adjacent human settlements, etc.), subject, of course, to the establishment of energy blocks of a new generation (with improved safety indicators) as well as to finding a solution to radioactive wastes disposal. These NPS could be included in the list of environmentally acceptable facilities whose establishment is not possible until the year 2000 while their actual putting into operation is possible much later. The prospects of nuclear power development are confirmed by the world statistics: in the countries, where a per capita share of NPS amounts to 20% of the total energy production and hydrocarbon emission into the air is at the minimum level. These countries include Spain, Korea, Hungary, France, Sweden, Belgium. Thus it is considered necessary to search for options which do not have adverse implications for the economy and environment.

In the transition to market economy, the issues of design and construction of energy facilities are extremely complicated. In the first place this requires to work out the scenarios of the country's energy complex development in general which to the best extent take into account natural, climatic, economic, ecological and social problems of the entire territory (and specific regions), to find sources of financing

Power engineering experts generally agree that economic, ecological, social and regional problems in design and operation of power engineering facilities have not been taken into account in past, or have been considered inadequately. They also note that powerful public movements have emerged which strongly oppose the construction of power engineering facilities, particularly HPS. By the early 1990s more that 60 power stations of different types with the total capacity of 160 million kW were either put into conservation or were not constructed in the territory of the former USSR – due to varying reasons. The view of the leading experts of the Russian Ministry of Fuel and Energy, is that new capacity is needed to ensure the necessary development of the power engineering industry for the next 10-15 years. It is obvious that not all of these 60 power stations fully meet the requirements of ecological safety. However, construction of some of them, including HPS in the east of the country with adequate ecological justification and expertise of projects would have prevented the critical state of power engineering in Khabarovsky and Primorsky regions in the Far East and several other regions of Russia and would have prevented social tensions (coal mining workers strikes, marches of protest, etc.).

## 3.10 Advantages and Disadvantages of Small HPS

As indicated in the previous section, the development of hydropower potential of small rivers has become one of the leading directions of power development in a number of regions of the Russian Federation. The estimated potential of small-scale hydropower engineering amounts to 1520 $10^9$ kW per hour or 30% of the total potential of the country. The estimates of economically feasible potential range from 493 000 GWh including more than 100 000 GWh in the European part of the country to 80 000 GWh including 20 000 GWh in European part. It was planned to raise the installed capacity of small HPS (SHPS) to 3000 MW by 2000, producing more than 12 000 GWh a year. This plan could have yielded savings of more than 4 million tons of organic fuel (in reference fuel). However, factors such as the disaggregation of the USSR, economic transformation as a result of transition to market economy, drastic reduction of industrial production and energy demand have led to curtailing of hydro power engineering facilities construction and to the conservation of many facilities at the stage of construction, including SHPS. This plan to raise the installed capacity of SHPS has not been implemented even at the 5% level.

As was mentioned in section 3.1, the development of hydropower engineering in Russia began with small hydropower stations. Many dams at small rivers were built as early as in 1930s. By 1940 15,000 new small water basins were constructed and 22 were repaired. The most intensively SHPS construction (with the capacity less than 5 MW) began in the post-war period (1946-1952). A Bureau of small HPS of Hydroelectroproject established before the war intensified its activities. Besides, special design organisations and enterprises producing equipment were established. In a short term (six years) about 7000 small HPS were constructed with the total capacity of 1500 MW.

Development of SHPS gave impetus to the research in streamflow regime and conditions of small river runoff generation, which at that time were at the inception state. The physical aspect of many phenomena related to small rivers flow was unknown as well. Therefore, in the first years of intensive development of small rivers, the design of hydraulic power engineering facilities was conducted without necessary hydrological data support which led to their destruction, or high costs of construction. There are well documented cases of hydraulic power engineering facilities destruction at small rivers in Altai, Turksib and Fergana.

As early as by mid-1950s, the interest in small power engineering died away as a result of large-scale power engineering construction, which made SHPS non-competitive in the economic respect. Design activities, construction and production of equipment and spare parts for small-scale hydraulic power engineering have stopped, and the closure of small HPS began. In 1962 the number of small HPS decreased to 2665.

By now nearly 30% of SHPS have ceased to produce current although many buildings and installations remain intact and can be restored. It should be noted that this process of curbing construction as well as the operation of the existing HPS was typical not only of Russia but for all developed countries, including USA, France and Japan.

In recent years the interest in SHPS has increased again. Construction of SHPS with capacity of up to 30 MW has a number of advantages as compared to large-scale hydropower engineering facilities. However, they address different tasks and complement rather than exclude each other. The role of small HPS has increased recently with the deficit of and increase in the cost of organic fuel, the need to electrify isolated rural and industrial consumers, high costs of transportation of diesel fuel into remote areas with scattered energy consumers, which have no access to power supplied by electric power lines.

Construction of small-scale power engineering facilities at small rivers and streams has a number of economic, environmental and social advantages. In the transition to market economy, the construction of SHPS is *economically* feasible for the following reasons:

- SHPS construction does not require big investments, which facilitates the search for investors and is less labour consuming, which is particularly important in the Far North environment;
- SHPS are constructed and paid-off more speedily, although the cost of 1 kW of installed capacity at them is higher than that at medium-size and large hydro-power stations;
- due to the development of model designs and unified parts for SHPS construction their cost can be considerably reduced, which, together with short terms of construction and pay-off make these stations attractive for investments;
- a positive factor in SHPS construction lies in the possibility of step-by-step introduction of weirs with constant, if necessary, build up of regulated capacity determined by water consumption at this stage of the region's economic development and relevant stage-by-stage distribution of investments;

- SHPS operation saves organic fuel and does not depend on the situation at the fuel market where the prices on fuel in Russia continue to rise;
- construction of a large number of SHPS reservoirs besides production of electricity helps to supply different industries in various parts of river basins with water resources.

Power engineering facilities make substantive contribution to the aggravation of *environmental situation*. According to experts' evaluations, the share of fuel and energy complex of Russia in air basin pollution amounts to 50%, with 27% falling on power engineering and 11 - on boilers and small heating installations. Establishment of SHPS instead of small power stations using organic fuel leads to considerable amelioration of the air basin.

However, the main positive environmental effect of SHPS is that small weirs better meet the main criteria of optimisation - to meet people's needs with minimum impact on natural environment. "Environmental cleanness" of SHPS first and foremost manifests itself in much smaller area of flooded and semi-flooded territories as compared to medium-size and large hydropower stations. Preparation of their beds for flooding is less complicated. SHPS dams and water storage basins destroy normal habitat of human being and wild life to a smaller extent than other weirs. As far as fisheries are concerned, small SHPS dams are also less dangerous than medium-size and large hydropower stations that cross migration routes of passing and semi-passing fish and flood spawning places.

SHPS environmental effect is the most pronounced if HPS reservoirs are located within the waterway. In this case SHPS dams impact on water and other regimes of small rivers will be the least. There are also projects of SHPS automatic operation, their attachment to the existing hydro power stations.

There is yet another set of positive factors seen in the establishment of small artificial reservoirs establishment. They contribute to the transformation of the surface flow into the subsurface and to the increase in soils moisture, which was noted long before V.V. Dokuchaev and is supported by observations conducted recently in the European part of Russia. Due to their small size, SHPS water storage basins are unable to provoke earthquakes (focused seismicity) and are more safe even if located in the epicentre of seismic disaster.

A positive *social* factor of SHPS creation was considered to be equally important. They do not require large resettlement or infringe upon hunting fields and do not modify the way of life of the indigenous communities to the extent that large projects do. SHPS reservoirs can be used for recreational purposes, fish breeding, etc. It is also important to assess the advantages of SHPS construction in terms of their safety. It is evident that direct harm from damages or complete destruction of SHPS dams as compared to large stations will be considerably less. However, if a small hydropower station is the only source of power supplying a settlement or industrial enterprise with light and heat SHPS damage can have far-reaching implications, especially for regions located far from other sources of power supply.

A set of conditions is to be met in respect of SHPS ensuring their *safe operation*. Thus, at small-size water reservoirs, particular attention should be paid to water saving which necessitates the provision of maximum waterproofness of the facilities, their filtration imperviousness, especially in the area of the dam's crest and at the bottom level of flow discharged, with total exclusion of a danger of erosion at dam's contact point with bottom. Parts of earth dams where spillways are located should be under constant surveillance by service personnel, but even regardless of personnel these parts should be always ready to emergency discharge passage. Besides the listed and many other positive aspects of SHPS construction and their water storage basins it is worth noting the following negative aspects: little knowledge of the small rivers regime and SHPS impact on natural environment, under-developed methodology and consequently complicated forecasting of many aspects of their impact. It is known that per thousand small rivers there is only one gauging station.

Lack of information on the small rivers regime complicates the development of specific projects and assessment of the level of provision of individual regions with water resources. This situation is aggravated by the lack of accurate techniques for small rivers streamflow assessment, since the use of hydrological calculation methods incorporated in the existing Construction Norms and Rules and other recommendations often results in considerable errors. SHPS water storage basins, particularly in mountainous and foothills regions, face an acute problem of silting as well as a related problem of water level rise, flooding and semi-flooding and reduction of hydro power engineering potential of rivers and energy production.

There is yet another aspect of that problem - destruction as a result of sediments formation delays formation in reservoirs of their balance in the dams' downstreams which can adversely affect waterway forming principles. And if the river flows into the sea or lake, the SHPS in mountainous regions cross by their dams the sources of beach forming sediments of their shores (such phenomena are seen in the Caucasus).

Forecasting of the implications of small-size HPS dams construction are sometimes more complicated than of large HPS, since they are usually less studied, have less developed methods of forecasting the changes in different environmental components. For example, the methodology used for large water basins banks processing calculations is not always applicable to small plains water storage basins, etc.

SHPS also have shortcomings from the power engineer point of view. First of all, many of them do not always ensure guaranteed energy production being seasonal power stations. In winter their energy production drastically decreases, snow cover and ice phenomena (ice and slush ice), the same as summer low-flow level and rivers drying, can completely interrupt their operation. The seasonal nature of SHPS required duplication of energy sources and their large amount can lead to the reduced assurance of power supply. Therefore, in many regions SHPS capacity is regarded as a duplicating rather than as a displacing one. As a result it is noted that SHPS are predominantly of local significance.

The identification of environmentally and economically justified scale of small hydropower engineering development requires:

- the improved knowledge of small river flow regimes. In remote areas it is vital to set up an automated network of levels measurements as well as intensive use of remote sensing methods for studying the hydrological regime;
- the evaluation of the demand for energy
- the continual survey of existing and closed SHPS, including those which are agency-owned, addressing the issue on the feasibility of restoration and modernisation thereof, increase in their capacity and better use;
- the understanding that SHPS restoration represents not only restoration of power stations but also reconstruction of their reservoirs with due regard to the specifics of the individual reservoirs, improvement of its banks, forests and bushes cultivation, establishment of water protection zones (if SHPS reservoir is located on a small river), improvement of natural conditions, particularly in the regions of large human settlements, protected areas, recreational facilities, etc.;
- setting up a monitoring system and development of reliable methods for forecasting implications of their establishment, since environmental aspects of SHPS mass construction are still unclear;
- zoning of Russia's territory according to the degree of possible ecological damage resulting from SHPS construction, and development of the best schemes of small-size hydro-power station positioning with due regard to environmental, geographic, economic and social factors.

It is also necessary to note that SHPS large-scale construction is possible, perhaps, only in the case of abandoning individual design and with serial production of simple and reliable equipment and the stations' management automation.

In order to solve the problems faced by small-scale power engineering, totally new equipment and the unified parts for SHPS buildings construction should be designed. It is evident that some enterprises of the military and industrial complex can be converted to meet these purposes.

HPS establishment at small rivers requires knowledge not only of morphological specifics of the river and its hydrology, but the landscape features of the surrounding territory as well, since the wide SHPS construction can result in ground water level rise and different implications typical of certain types of landscapes.

One should not forget that small rivers in themselves are one of the elements of the landscape and the change in their regime can influence the ecosystems' stability. Therefore, SHPS reservoirs being established should facilitate the conservation of the small rivers'aquatic life.

Table 3.9 presents the information on the number of SHPS which are planned for construction in different parts of the country.

**Table 3.9 SHPS Planned for Construction**

| Region | SHPS totals | Including those using unified hydro-devices |
|---|---|---|
| Stavropolsky region | 26 | 26 |
| Northern Ossetia | 14 | 9 |
| Kabardino-Balkaria | 14 | 5 |
| Dagestan | 31 | 13 |
| Altai Republic | 28 | 20 |
| Primorsky region | 30 | 29 |
| Khabarovskaya District | 6 | 2 |
| Magadanskaya District | 5 | 5 |
| Tchukotka | 4 | 4 |
| Kamchatskaya District | 12 | 11 |

## 3.11 The Prospects of Power Engineering Construction in Kamchatka and Small HPS in the Far East

The Kamchatskaya oblast has the lowest rate of per capita energy production in Russia (less than 4,000 kW an hour per person). Power for this oblast is produced in Petropavlovsk-Kamchatskaya TPS and hundreds of diesel power stations. High costs and difficulties of mineral fuel delivery contribute to constant deficit in electricity and heating.

Kamchatka is rich in its own fuel and energy resources which are practically unused (gas, geothermal waters, wind and water resources): the entire power engineering is based on the imported costly organic fuel. Attempts to use Kamchatka's water resources were made in the early 1950s. In the early 1980s the Lenhydro project developed a Scheme of HPS Construction in Kamchatka and Sakhalin which considered possible specific weirs on all the big rivers of the Kamchatskaya oblast. Theoretical (gross) hydraulic power potential of rivers was estimated at 50.6 billion kW per hour, economically feasible at 5 billion kW per hour, including 1.5 to 2 billion kW per hour proposed to be used in the very near future, particularly for the Central power station energy supply (including Petropavlovsk-Kamchatsky) fully dependent upon deliveries of liquid organic fuel.

In the 1970s a project on water potential of the Kronotskaya river development to the north-east of the main Kamchatka's city, where there is no migration of spawning salmon fish because of the waterfalls, although many geo-ecological problems of HPS construction require further studies. As an alternative to Kronotskie HPS for the Central power station, the Petropavlovsky weir at Zhupanova river is considered as being more accessible in terms of transport.

In the central part of Kamchatskaya oblast it seems advisable to construct Kamchatskaya HPS at the Bystraya river producing 260 million kW per hour a year.

Taking into account Kamchatka's human settlements scattering, complexity and high costs of organic fuel delivery, the possibility is being considered of developing small-scale power engineering capable of considerably increasing the reliability of the power supply of individual regions. In doing so it is possible to construct SHPS without dams. Thus, during practically just one year (1995) Bystrinskaya SHPS was constructed at the Bystraya river where water intake into HPS installations was done without dams and even without waterway constriction. Thanks to this technological solution the river's water regime is not disturbed, there are no obstacles to fish passing for spawning, and winter flow in the river allows the station to produce power during the entire year.

A flight of three SHPS is planned at the Tolmacheva river. In doing so, Tolmacheva lake with the area of 12 sq. km, from which the river stems, is used as water storage basin for flow regulation. However, water level in the lake is raised by the dam of the 1st HPS by 12 meters ( which is within the limit of historically observed levels) and will flood more than 2,000 ha of coastal territories.

The power engineering development project at Tolmacheva river should not, in view of the project organisation Lenhydroproject, cause damage to the basin's landscapes and the river's waterfalls. It provides for a full removal of forest and bushes in the flooding zones, construction of an ichthyological station at Tolmacheva lake and implementation of nature protection activities and complex monitoring begun in 1993.

Five HPS at small rivers in Koriaksky autonomous district, including three HPS with automated option following Bystrinskaya hydro power station type, are planned SHPS construction is planned at two stages - with the attainment of set water power targets at the second stage. After putting these stations into operation the total annual savings of diesel fuel can amount to 17-18 thousand tons (nearly 30 per cent of the annual total imported in the district).

In the Far East where about 3000 diesel power stations with the power up to 500 kW operate power supply of the most part of the territory depends on fuel deliveries. Lenhydroproject has proposed more than 200 sites for promising SHPS construction with the aggregate production of power of up to 1,500 million kW per hour a year.

Joint operation of a single complex of SHPS, wind and solar stations as the optimal regime to compensate for daily and seasonal irregularity of power production has also been considered.

## 3.12 Non-Traditional Renewable Sources of Energy

In the majority of the countries of world and in Russia the concept of energy policy includes wider use of non-traditional renewable sources of energy (energy of the solar and wind, geothermal energy, energy of tides and biomass, etc). Development of renewable energy resources (RER) in Russia has a whole set of advantages:

1. RER contribute to the reduction of industrial pollution and degradation of environment, prevents forests from destruction and improves people's well-being. It is very important to reduce discharge of the products of combustion of organic fuel into the atmosphere which lead to concentration of $CO_2$ and global climate changes;.
2. Growth of the non-traditional power engineering appears to be an integral part of energy-saving activities aimed at saving deficit organic fuel. Redistribution of the items of the energy balances of many regions, decrease in the share of organic fuel (oil, gas condensate, coal and other types of solid fuel) through the increased use of RER is the most important direction of the energy-saving policy. In addition, development of the non-traditional power engineering makes it possible to reduce the levels of transportation of organic fuel and the costs of its transportation;.
3. The shift of the structure of power engineering in Russia to RER is also facilitated, besides many other factors, by the increase in the depth of oil processing up to 75to 80%, which decreases manifold the opportunity to use diesel fuel, inter alia for power stations.
4. The use of RER resolves the problem of energy provision of a vast segment of small territorially disintegrated consumers. Simultaneous use of renewable energy resources makes it possible to take into account inter-agency regional interests, including ecology and specific plans of economic and social development of individual territories. The social role of RER also consists of balancing energy provision of territories with different population density, including highly inhabited and low accessible low populated territories, which leads to drastic transformation of the style of energy consumption in day-to-day life
5. Wider use of RER also contributes to the production of a separate resource by the main equipment of many power stations built in 1940-1960s. A question inevitably arises as to which fuel they will use and hoe they can be replaced. A rise in the cost of energy produced as a result of combustion of organic fuel is also possible.
6. Today the issue of wider use of RER has become so acute in Russia due to the fact that more than 70% of its territory with population of 20 million people are located in the zone of decentralized energy supply. This zone covers the regions of the Far North, Far East, Siberia, Buriatia, Yakutia, Altai, Kuril Islands, many of which are populated by the small indigenous peoples. The majority of these regions are located in the zone with severe climatic conditions and permafrost areas, where special requirements as to reliability of power facilities operation and energy supply are to be met, since power engineering in these areas is based mainly on imported organic fuel and breaks in power supply accompanied by the lack of regular transport communication in these regions lead to very serious implications and can result in human casualties.

   It is planned to replace a considerable part of organic fuel imported to the North (with 6.5 million tons imported currently), two-thirds through the use of RER and one third through local types of fuel.

   These as well as some other measures should result in considerable restructuring of the energy balance in Russia and in the country in general to increase the RER share to 20% while in certain regions - to 50 or more per cent.
7. It also seems necessary to call to mind that in Russia before restructuring large power engineering facilities were set up which used organic fuel, uranium, the energy of large rivers,

powerful ESL. All these facilities required enormous investment from the state budget. At the present time with considerable autonomy of the entities of the Russian Federation, its krais and oblasts RER appear to be the most accessible and acceptable sources of energy which could also create additional jobs, employ conversion enterprises, etc.

8. In the modern economic environment characterised by the lack of investments RER can be put into operation in the form of small modules which do not require large investments and then can be built-up as necessary.

These advantages facilitating the introduction of RER have a dual impact: the interest to non-traditional renewable sources of energy strengthens relevant research and developments, contributes to the improvement of equipment and reduction of its cost, creates opportunities to achieve economic competitiveness with traditional power engineering.

However, certain researchers characterise RER as environmentally absolutely clean, with no adverse effect on natural environment and human beings.

Meanwhile, as early as in 1991 experts from the UN and many specialists noted that the existing perceptions of RER as environmentally absolutely clean sources of energy are, particularly considering environmental costs related to construction of equipment, inter alia to extract raw materials for their production.

The main installations of renewable power engineering operating in Russia include Pauzhetskaya GeoTPS (11 MW) on Kamchatka, Kurilskaya GeoTPS (500 kW), Kislogubskaya tide station (400 kW) at the Kolsky peninsular, Vorkutinskaya WPS (1.5 MW), Kalmytskaya WPS (1 MW), up to 1 500 wind installations of different capacity (from 0.08 to 30 kW), solar photo-electric installations (with the total power of 100 kW), as well as about 300 small HPS producing annually 2.2 billion kW per hour.

The state of RER resources is shown in Figure 3.3.

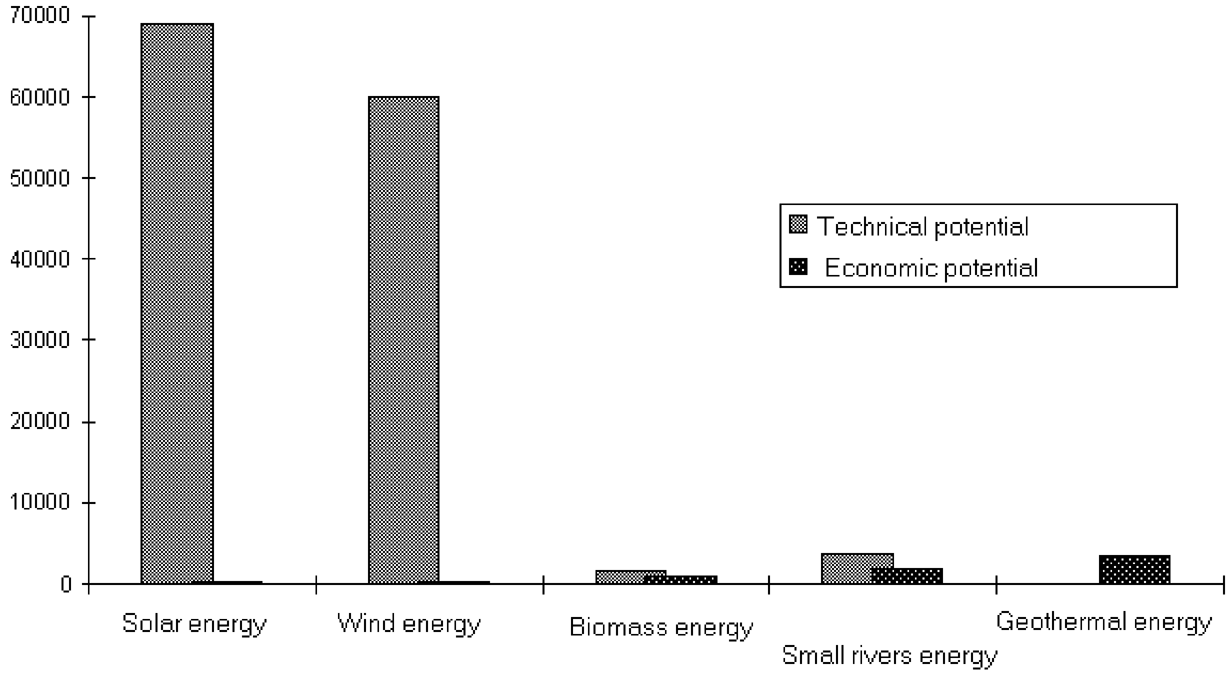

**Figure 3.3 Resources of the Non-traditional Renewable Sources of Energy in Russia ($10^{15}$ J per year)**

The use of non-traditional renewable sources of energy presents a real alternative to traditional power engineering technologies. However, lack of sufficient knowledge of possible unfavourable environmental and other implications of their use presents a serious obstacle restricting their development. Thus, operation of SHS can change the coefficient of reflection of the earth in such a way that it can lead to unpredictable changes of climate on vast territories.

There is also a set factors of an economic and legal nature preventing from intensive introduction of WHS. The most important of them include high land requirement and massiveness of power installations that can lead to the change of land use structure and create totally new environmental and social problems. Study of different sides of RER use is possible with additional funding and encouraging research and developments in this field of power engineering.

In general, current prices of traditional types of fuel justify economic non-competitiveness of RER. In this respect the most important steps are to improve RER producing equipment, to improve their characteristics, to reduce costs and thus increase their economic competitiveness with the traditional power engineering.

Non-traditional power facilities require a lot of research, materials and capital. High costs of their installation and a long investment cycle make them unattractive for investment. The legislation in force in the field of economy and power engineering promote development of traditional systems which are currently in operation and in fact do not encourage the introduction of RER. Lobbying of the interests of monopolies, which develop and use mineral resources and nuclear sources of energy, at the highest levels of power also presents a serious obstacle to RER introduction. The situation is also complicated by the inertness of certain agencies and commitment to the established ways of production and use of energy in which considerable funds have already been invested.

Russia's participation in the World Solar Programme as well as in the programmes of the European Council "Thermo" and "Alteier" can become an important step towards RER wide development. On the initiative of UNESCO, the Ministry of Science and the Ministry of Fuel and Energy in coordination with other interested organisations an "InterSolarCentre" has been set up in Russia whose activities are guided by the slogan: "Renewable energy for sustainable development and environment protection".

# 4. Observations and Conclusions

The material listed above provides only a fragmentary picture of a very extensive problem of interaction of dams and reservoirs with human economic activities and environment.

The prevailing perspective in the government and industry circles is that the role of HPS in water economy of Russia and other NIS is often underestimated. The reservoirs allow water resources to be used in an integral way for power engineering, water transport, water supply of different sectors of the economy, irrigation, recreation and other purposes. HPS reservoirs make it possible to prevent spring, summer and winter floods without excessive costs. At the same time, HPS and their reservoirs represent environmentally clean sources of energy and water subject to sound design, to accounting for the diversified water demands, to the preparation of water storage basins beds for flooding, prevention of unpurified waste waters into water basins, compliance with relevant measures on flora and fauna protection and other nature conservation activities.

There are a set of factors characterising the high economic efficiency of HPS. First and foremost, they are based on renewable sources of energy - water resources, which allows other types of fuel to be saved.

- HPS are known for their high economic efficiency and pay off very quickly. The unit cost of HPS-produced energy is between five and seven times less than at TPS and NPS, which is particularly important for the regions of the Far East of Russia, where the economic complex is characterised by high energy consumption. HPS start to produce energy and pay off even before their construction is complete.

- HPS are characterised by high productivity due to lack of expenditures on fuel as well as through high level of automation of production, high efficiency of the capital equipment, etc. Water facilities save labour resources: only 2% of Russia's power engineering staff work in this sector.

- HPS play a significant role in power engineering systems due to the balancing of load schedules. Hydropower stations form the basis of establishing joint power engineering systems and operational and strategic reserve of power for covering unforeseen changes in the power load.

- HPS construction plays a vital role in natural resources development in new regions and creation of powerful industrial zones.

There are also very evident negative implications that arrise from the establishment of reservoirs, particularly land flooding. The most important negative implications for nature and economy are related to large reservoirs constructed in areas with a flat topography. The establishment of small and medium-size reservoirs in flat low-populated regions, as well in mountainous areas and foothills reduces this negative factor considerably.

As far as water quality is concerned, the construction of reservoirs is not the main reason for water quality deterioration. Low quality of water is frequently caused by concentrated waste discharges, industrial effluents and run off pollution from agricultural fields.

Inefficient use of water resources can be considerably reduced through the implementation of relevant water conservation, protection and water demand measures. It also seems relevant to emphasise the importance of the implementation of such measures in the catchment area. Proper water basin zoning, planning and monitoring may increase economic significance of HPS and their reservoirs and improve the state of water resources.

The environmental and economic value of reservoirs increases when they are designed and established with due regard to the schemes for optimal use of water resources of a river basins and the interests of different regions and neighbouring states. These schemes should include the most sound ways of flow regulation which take into account the specifics of the environment and the pattern of water demands.

In the context of economic transformation in Russia and the NIS countries it is highly important to elaborate a long-term programme of hydro power development, as an integral part of environmentally sustainable economic development of these countries, because the way out of the social-economic crisis lies, amongst others, through the efficiency of the energy complex operation.

In summary, the prospects of dams construction and further hydro technical development are related to compliance with the following conditions:

- improvement of the quality of forecasts of HPS impacts on natural environment;
- consideration of social and economic interests of the local population; improvement of the projects' quality, their optimisation, reduction of forecasted adverse impacts of HPS construction on natural environment to the levels acceptable by general, public and major stakeholders
- selection, after finding appropriate sources of financing, of a contractor on a competitive basis in accordance with international practice;
- compliance with project parameters during the construction phase;
- provision of normal safe operation and compliance with necessary terms of acceptable environmental safety of reservoirs;
- promotion of the social and economic benefits of hydro technical development in the mass media, particularly in the regions of suggested HPS construction, because the local population has the right to be informed on all aspects of a project, especially on its environmental implications, on compensation issues and on measures to be implemented to preserve the quality of life;
- for existing large reservoirs, it is necessary to develop a set of measures on the improvement of their safety and reduction of their negative impact on natural environment.
- Critical also is the inclusion of the views of the emerging civil society and NGO voices in planning and policy development activities as well as wider public information and debate.

# References

Avakyan A. B. 1999. O vode s trevogoj i nadezhdoj. Ekaterinburg: Izdatel'stvo RosNIIVX,

Avakyan A. B., Saltankin V. P., Sharapov V. A. Vodoxraniliwa. M.: Mysl', 1987, 325 pp.

Dobroxotov V. I., Shpil'rajn E'. E'. Vozobnovlyaemy istochniki e'nergii. Problemy i perspektivy // Vozobnovlyaemaya e'nergiya, Intersolarcentr, 1997, № 1, p. 10-14.

E'del'shtejn K. K. Vodoxraniliwa Rossii: e'kologicheskie problemy, puti ix resheniya. M.: GEOS, 1998, 277 pp.

Elektroenergetika I priroda (Ekologicheskie problemy razvitia elektroenergetiki)/ Pod red. G.N. Lialika, S.Sh. Reznikovskogo -M., Energoatomizdat, 1995. - 352 pp.

E'lektroe'nergetika Rossii (istoriya i perspektivy razvitiya). Pod obwej red. A. F. D'yakova. AO «Informe'nergo», 1997, 567 pp.

General concept (program) of CIS collaboration in hydropower development. Association of hydraulic construction. M., 1992.

Gosudarstvennyj doklad: O sostoyanii okruzhayuwej prirodnoj sredy Rossijskoj Federacii v 1998 g. M.: Centr mezhdunarodnyx proektov, 1999.

Hydropower stations of Soviet Union (reference book). Hydroproject Institute, M., 1979

Koronkevich N. I. Vodnyj balans Russkoj ravniny i ego antropogennye izmeneniya. M., Nauka, 1990, 205 pp.

Koronkevich N. I., Malik L. K. Osnovnye podxody k geografo-e'kologicheskomu prognozirovaniyu vliyaniya gidrotexnicheskogo stroitel'stva na prirodnuyu sredu // E'nergeticheskoe stroitel'stvo, 1992, № 6, p. 39-48.

Koronkevich N.I., Malik L.K., Barabanova E.A. Prognoz posledstvij razrusheniya gidrouzlov//Izvestiya RAN, seriya geogr., 1995b, № 2, p. 58-66.

Koronkevich N.I., Zajceva I.S. Izmenenie udel'nogo vodopotrebleniya v Rossii v poslednie desyatiletiya //Vodnye resursy. T.26. №1. 1999. p. 90-95.

Koronkevich N.I., Zajceva I.S., Dolgov S.V., Yasinskij S.V. Sovremennye antropogennye vozdejstviya na vodnye resursy.// Izv. Ran. Ser. geograf. 1998. №5. p. 55-68.

Kuznetsov, Zotov at all. Hydropower engineering of Russia: issues and solutions. “Hydraulic construction”, 2000, № 1.

L'vovich M. I. Mirovye vodnye resursy i ix buduwee. M.: Mysl', 1974, 448pp.

Malik L. K. E'kologicheskie aspekty koncepcii razvyitiya gidroe'nergeticheskogo stroitel'stva // E'nergeticheskoe stroitel'stvo, 1992, № 1, p. 32-40.

Malik L. K. Geograficheskie prognozy posledstvij gidroe'nergeticheskogo stroitel'stva v Sibiri i na Dal'nem Vostoke. M.: IGAN SSSR, 1990, 317 pp.

Malik L. K. Monitoring soxrannosti gidrouzlov vodoxraniliw // Izvestiya RAN, seriya geograficheskaya, 1999, № 2, p.77-79.

Malik L. K. Perspektivy razvitiya gidroe'nergetiki v Rossii i bezopasnost' gidrotexnicheskix sooruzhenij // Geografiya i prirodnye resursy, 2000, № 2.

Malik L. K. Problemy malyx GE'S na malyx rekax // Gidrotexnicheskoe stroitel'stvo, 1998, № 6, p. 45-49.

Malik L. K., Barabanova E. A. Gidroe'nergetika Rossii v e'kologicheskom izmerenii // E'nergiya: e'konomika-texnika-e'kologiya, 1995, № 9.

Malik L. K., Barabanova E. A. Sravnitel'naya ocenka vodoxraniliw GE'S po geoe'kologicheskim pokazatelyam // Geografiya i prirodnye resursy, 1993, № 2, p. 25-30.

Melioraciya i vodnoe xozyajstvo, № 3, 1998.

Melioraciya i vodnoe xozyajstvo. T.5. Vodnoe xozyajstvo: Spravochnik. M.: Agropromizdat, 1988. – 399 pp.

Nezhixovskij R. A. Gidrologo-e'kologicheskie osnovy vodnogo xozyajstva. L., Gidrometeoizdat, 1990, 229 pp.

Shiklomanov I.A. Issledovanie vodnyx resursov sushi: itogi, problemy, perspektivy. L.: Gidrometeoizdat, 1988. 153 pp.
Smirnov I. M., Lyashenko V. S., Chemodanov V. I., Bobyleva N. V., Sokolova N. Yu., Kucherov Yu. K., Okin A. A. Perspektivy razvitiya Edinoj e'nergeticheskoj sistemy Rossii na period do 2010 goda // E'lektricheskie stancii, 1999, № 9, p. 1-16.
Texnicheskij uroven' e'lektroe'nergetiki 1996 g. Nauchno-informacionnyj i kommercheskij centr e'nergetiki i e'lektrifikacii AO «Informe'nergo». RAO «EE'S Rossii»». M. 1997, 239 pp.
Tekhnicheskii uroven' elektroenergetiki. 1998. AO "Informenergo", M., 1999. - 203 pp.
Vasil'ev Yu. S., Xrisanov N. I. E'kologiya ispol'zovaniya vozobnovlyayuwixsya e'nergoistochnikov. L.: Izd-vo Leningr. un-ta. 1991, 343 pp.
Vladimirov A.M. i dr. Oxrana okruzhayuwej sredy. L.: Gidrometeoizdat, 1991. 424 pp.
Vliyanie vodoxraniliw GE'S na xozyajstvennye ob~ekty i prirodnuyu sredu. L., «E'nergiya», 1980.
Vodnyj kodeks Rossijskoj Federacii // Melioraciya i vodnoe xozyajstvo, № 1, 1996.
Vodoxraniliwa i ix vozdejstvie na okruzhayuwuyu sredu. M.: Nauka, 1986, 368 pp.
Vody Rossii (sostoyanie, ispol'zovanie, oxrana) 1997 god. Ekaterinburg, 1998. 135 pp.
Vuglinskij V. S. Vodnye resursy i vodnyj balans krupnyx vodoxraniliw SSSR. L., Gidrometeoizdat, 1991, 223 pp.
World hydro potential and development “Hydropower and Dams 1998 World atlas” and industry guide.
Zajceva I.S. Malovodnye gody v bassejne Volgi: prirodnye i antropogennye faktory. M.: IG AN SSSR, 1990, 184 pp.
Znakom'tes', voda Rossii. Meet waters of Russia. Ekaterinburg: Izd-vo «Viktor», RosNIIVX, 1993, 65 pp.
Zonn, I.S. Kaspii: illuzii I real'nost'. M, TOO "Korkis", 1999, 467 pp.

# Annex 1: Use of water reservoirs with volume larger than 1 million.$m^3$

1 - public utilities;
2 - industry;
3 - agriculture;
4 - irrigation;
5 - thermal energy production;
6 - water transport;
7 - fishery;
8 - hydro energy production;
9 - others (recreation, flood control, water protection, etc.)

| River, lake, canal | Water Reservoir | The year of flooding | Reservoir use |
|---|---|---|---|
| | Vologodskaya District | | |
| r.Vytegra | Belousovskoe | 1961 | 8 |
| lake Kovzhskoe | Vytegorskoe | n.s. | 9 |
| r.Sukhona | Kovzhskoe | 1828 | 6,7,9 |
| r.Vytegra | Kubenskoe | 1961 | 6 |
| r.Sheksna | Novinkinskoe | 1963 | 1,2,4,6,7,8,9 |
| r.Paz | Cherepovetskoe | 1963 | 1,8 |
| | Murmanskaya District | | |
| Lake Notozero | ' | 1964 | 1,7,8,9 |
| Lake Imandra | Borisoglebskoe | 1936 | 1,7,8,9 |
| Sistemaozer | Verkhnetulomskoe | 1960 | 8,9 |
| Lake Inari,r.Paz | Imandrovskoe | 1942 | 8 |
| Lake Kovdozero | Iovskoe | 1956 | 7,8,9 |
| r.Tuloma | Kataikoski | 1936 | 1,7,8 |
| Lake Pinozero | Kniazhegubskoe | 1934 | 8 |
| Lake Pirengskoe | Nizhnetulomskoe | 1936 | 7,9 |
| lake Inari,r.Paz | Pinozerskoe | 1955 | 1,8 |
| Lake Lovozero | Pirengskoe | 1971 | 1,7,8 |
| r.Voron'ia | Raiakoski | 1965 | 1,8 |
| lake Inari,r.Paz | Serebrianskoe-1 | 1970 | 8 |
| r.Paz | Serebrianskoe-2 | 1950 | 1,8 |
| r.Povenchanka | Khevoskoski | 1933 | 6,8 |
| lake Vedlozero | Ianiskoski | 1932 | 7,8 |
| | Republic Karelia | | |
| lake Vygozero | Borovetskii ples | 1932 | 1,2,6,7,9 |
| r.N.Vyg | Vedlozerskoe | 1955 | 1,6,8 |
| r.Suna | Vodlozerskoe | 1938 | 1,8 |
| r.Koloda | Vygozerskoe | 1933 | 9 |
| r.Tunguda | Vygostrovskoe | 1956 | 9 |
| lake Topozero,lake Piaozero | Girvasskoe | 1961 | 8 |
| lake Loimolan-Iarvi | Glubokskoe | 1937 | 9 |
| lake Lososenskoe | Korbozerskoe | 1799 | 9 |
| r.Voloma | Kumskoe | 1960 | 9 |
| r.N.Vyg | Loimolan-Iarvi | 1933 | 7 |

| River, lake, canal | Water Reservoir | The year of flooding | Reservoir use |
|---|---|---|---|
| lake Mashozero | Lososenskoe | 1799 | 7,9 |
| lake Ondozero | Maslozerskoe | 1957 | 9 |
| lake Ondskoe,r.Ond | Matkozhnenskoe | 1955 | 9 |
| r.N.Vyg | Mashozerskoe | 1933 | 6,8 |
| Sistemaozer | Ondozerskoe | 1928 | 1,2,7,8,9 |
| r.Kem' | Ondskoe | 1971 | 1,6,7,8 |
| r.Kem' | Palokorgskoe | 1956 | 1,8,9 |
| lake Ragnozero | Pal'eozerskoe | 1931 | 1,6,7,8,9 |
| lake Salon'iarvi | Poduzhemskoe | 1939 | 7,8 |
| lake Segozero | Putkinskoe | 1957 | 7,9 |
| r.Voloma | Ragnozerskoe | 1934 | 9 |
| lake Sumozero | Salon'iarvskoe | 1964 | 9 |
| lake Sundozero | Segozerskoe | 1948 | 7,9 |
| lake Topozero,r.Topoz | Sonozerskoe | 1946 | 9 |
| lake Tulmozero | Sumozerskoe | 1928 | 0 |
| lake Tungudskoe | Sundozerskoe | 1956 | 0 |
| r.Ukhta | Topozerskoe | 1928 | 8 |
| r.Salmozerka | Tulmozerskoe | 1967 | 9 |
| r.Cherga | Tungudskoe | 1959 | 9 |
| lake Shalozero | Ukhtinskoe | 1932 | 0 |
| lake Ianis-Iarvi | Khizhozerskoe | 1940 | 7,8 |
| r.Pchevzha | Cherginskoe | 1959 | 9 |
| r.Svir' | Shalozerskoe | 1952 | 1,2,6,7,8,9 |
| r.Volkhov | Ianis-Iarvi | 1926 | 1,2,4,6,8,9 |
| r.Oredezh | Leningradskaia District | 1953 | 9 |
| r.Izhora | Budogoshskoe | 1722 | 1,2,9 |
| r.Vuoksa | Verkhne-Svirskoe | 1937 | 8,9 |
| lake Vrevo | Volkhovskoe | 1952 | 4,7,9 |
| r.Narva | Vyritskoe | 1955 | 1,2,8,9 |
| r.Svir' | Izhorskoe | 1933 | 2,6,7,8,9 |
| r.Oredezh | Lesogorskoe | 1954 | 9 |
| r.Vuoksa | Luzhskoe | 1945 | 1,8,9 |
| r.Sestra | Narvskoe | 1723 | 1,2,9 |
| r.Suma | Nizhne-Svirskoe | 1979 | 4 |
| r.Schegrinka | Rozhdestvenskoe | 1928 | 8,9 |
| lake Valdaiskoe | Svetogorskoe | 1958 | 6,7,9 |
| lake Vel'e | Sestroretskoe | 1944 | 7,9 |
| lake Borovno | Sumskoe | 1933 | 9 |
| r.Peretna | Novgorodskaia District | 1928 | 1,2,9 |
| ruch.Veretenka | Borovnovskoi GES | 1978 | 7 |
| r.Snezhet' | Valdaiskoe | 1932 | 5 |
| r.Solova | Vel'evskoe | 1978 | 7 |
| r.Vablia | Gorneshinskoe | 1978 | 7 |
| ruch.Ivotok | Obrechenskoe | 1961 | 1 |
| r.Vymkla | Brianskaia District | 1978 | 7 |
| r.Pes | Andreikovichskoe | 1972 | 7 |
| r.Lutenka | Beloberezhskoe | 1968 | 7 |
| r.Sudost' | Brusnianskoe | 1977 | 7 |
| r.Vaga | Desiatukhinskoe | 1978 | 4,7 |

| River, lake, canal | Water Reservoir | The year of flooding | Reservoir use |
|---|---|---|---|
| r.Maritsa | Ivotskoe | 1978 | 7 |
| r.Loknia | Kryzhinskoe | 1975 | 7 |
| r.Peksha | Kul'nevskoe | 1976 | 2,9 |
| r.Podyksa | Lutnianskoe | 1977 | 4,9 |
| r.Markusha | Novoselkovskoe | 1935 | 2,9 |
| r.Ukhtokhma | Novoscherbinichskoe | 1928 | 5 |
| r.Uvod' | Sevskoe | 1937 | 1,2 |
| lake Piros | Strashevichskoe | 1954 | 3,9 |
| lake Volgo | Vladimirskaia District | 1944 | 6,7 |
| r.Tsna | Vdkhr.na r.Peksha | 1719 | 2,6,7,8,9 |
| r.Kemka | Suzdal'skii kompleks | 18 century | 6,7,9 |
| r.Msta | Ivanovskaia District | 1794 | 4,6,7,9 |
| r.Negoch' | Markushinskoe | 1965 | 2,9 |
| lake Shlina,r.Shlina | Milovskii prud-okhladitel' | 1812 | 9 |
| r.Bryn' | Uvod'skoe | 1968 | 7 |
| r.Nepolod' | Tverskaia District | 1950 | 1,8,9 |
| r.Vorona | Berezaiskoe | 1978 | 9 |
| r.Vypreika | Verkhnevolzhskoe | 1965 | 7 |
| r.Lompad' | Vyshnevolotskoe | 18 century | 2,9 |
| r.Iachenka | Kemetskoe | 1981 | 9 |
| r.Ucha | Mstinskoe | 1936 | 1,8,9 |
| r.Moskva | Nizhne-Negochanskoe | 1877 | 4,6,9 |
| r.Oka | Shlinskoe | 1932 | 4,6 |
| r.Ruza | Kaluzhskaia District | 1980 | 1,8,9 |
| r.Moskva | Bryn'skoe | 1877 | 2,4,6,9 |
| r.Moskva | Liudinovskoe | 1877 | 2,4,6,9 |
| r.Moskva | Miliatinskiiprud | 1878 | 4,6,9 |
| r.Doninka | Prud Maloiaroslavetskii | 1964 | 4 |
| r.D'iakusha | Sukreml'skoe | 1965 | 7 |
| r.Volga | Iachenskoe | 1937 | 1,2,5,6,7,8,9 |
| r.Iksha | Moskovskaia District | 1937 | 1,6,9 |
| r.Istra | Akulovskoe | 1934 | 1,6,8,9 |
| r.Moskva | Andreevskoe | 1936 | 2,6,8,9 |
| r.Kliaz'ma | Beloomutskoe | 1936 | 2,6,8,9 |
| r.Shalovka | Verkhne-Ruzskoe | 18 century | 2,9 |
| r.M.Istra | Gidrouzla Severka | 1964 | 7 |
| r.Moskva | Gidrouzla Sof'ino | 1960 | 1,6,8,9 |
| r.Pakhra | Gidrouzla Faustovo | 1968 | 2,4 |
| r.Ramenka | Doninskoe | 1964 | 7 |
| r.Ozerna | D'iakushinskoe | 1966 | 1,6,8,9 |
| r.Moskva | Ivan'kovskoe | 1936 | 2,6,8,9 |
| r.Viaz' | Ikshinskoe | 1937 | 1,6,9 |
| r.Pakhra | Istrinskoe | 1949 | 1,2,4 |
| r.Ucha | Karamyshevskoe | 1937 | 1,6,9 |
| r.Moskva | Kliaz'minskoe | 1934 | 1,8,9 |
| r.Ruza | Kupavinskoe | 1965 | 8,9 |
| r.Sestra | Maloistrinskoe | n.s. | 2,4,7,9 |

| River, lake, canal | Water Reservoir | The year of flooding | Reservoir use |
|---|---|---|---|
| r.Griada | Mozhaiskoe | 1964 | 2 |
| r.Moskva | Novlenskoe | 1877 | 2,4,6,9 |
| r.Khimki | Novoselkovskoe | 1936 | 2,6,8,9 |
| r.Tsna | Ozerninskoe | 1966 | 7 |
| r.Polia | Perervenskoe | 1925 | 5,7 |
| r.Iauza | Pestovskoe | 1977 | 7 |
| r.Iauza | Podol'skoe | 1977 | 7 |
| r.Iauza | Pialovskoe | 1977 | 7 |
| r.Iakhroma | Rublevskoe | 1937 | 9 |
| r.Zusha | Ruzskoe | 1957 | 9 |
| r.Oka | Senezhskoe | 1954 | 2,5,9 |
| r.Belaia | Sychevskoe | 1933 | 7 |
| r.Tsna | Trudkommunovskoe | 1960 | 6 |
| r.Shitiag | Khimkinskoe | 1967 | 7 |
| r.Vialsa | Shalakhovskoe | 1880 | 2 |
| r.Vysha | Shaturskoe | 1957 | 0 |
| r.Oka | IauzskoeN1 | 1913 | 4,6,9 |
| r.Tsna,r.Moksha | IauzskoeN2 | 1955 | 4,6,9 |
| r.Prona | IauzskoeN3 | 1974 | 2,4,5 |
| r.Syntulka | Iakhromskoe | 1780 | 2,9 |
| r.Tsna | Orlovskaia District | 1958 | 6 |
| r.Vazuza | Lykovskoe | 1978 | 1,7,9 |
| lz.Penisnar' | Orlovskoe | 1963 | 0 |
| r.Desna | Riazanskaia District | 1979 | 2,5 |
| lake Soshno,r.Shesnitsa | Bel'skii prud | 1977 | 2,5 |
| r.Dresna | Borkovskoe | 1972 | 2,5 |
| r.Iauza | Butyrskii prud | 1977 | 1 |
| r.Plava | Vialsinskoe | 1982 | 4 |
| r.Liubovka | Zatonskoe | 1932 | 2,4,5,7,9 |
| r.Pronia | Kuz'minskoe | 1971 | 2,4,5,9 |
| r.Cherepet' | Rassypukhinskoe | 1953 | 2,5,7,9 |
| r.Shat | Riazanskaia GRES | 1933 | 2,4,9 |
| r.Upa | Syntul'skoe | 1950 | 2,5,7,9 |
| r.Volga | Ten'siupinskoe | 1963 | 8,9 |
| r.Volga | Smolenskaia District | 1943 | 6,7,8,9 |
| r.Velet'ma | Vazuzskoe | 1934 | 7 |
| r.Volga | Penisnarskoe | 1955 | 1,2,4,6,7,8,9 |
| r.Lakshitsa | Smolenskoi AES | 1975 | 4 |
| r.Volga | Smolenskoi GRES | 1981 | 1,2,4,6,7,8,9 |
| r.Gostenka | Smolenskoi TETs-2 | 1955 | 7 |
| r.Lozovaia | Iauzskoe | 1967 | 7 |
| r.Vorsklitsa | Tul'skaia District | 1955 | 7 |
| ruch.Lisenok | Krapivenskoe | 1950 | 7 |
| r.Graivoronka | Liubovskoe | 1950 | 7 |
| r.Vorsklitsa | Pronskoe | 1938 | 2,9 |
| r.Oskol | Cherepetskoe | 1977 | 1,4,7,9 |
| r.Uraeva | Shatskoe | 1955 | 7 |
| r.Voronezh | Schekinskoe | 1972 | 1,2,4,5,7,9 |
| r.Seim | Iaroslavskaia District | 1976 | 1,5,7 |
| r.Svapa | Rybinskoe | 1975 | 2,4,7,9 |
| r.Chervlenaia | Uglichskoe | 1952 | 4,6,7 |

| River, lake, canal | Water Reservoir | The year of flooding | Reservoir use |
|---|---|---|---|
| r.Chervlenaia | Nizhegorodskaia District | 1952 | 4,6,7 |
| r.Volga | Velet'minskoe | 1958 | 1,2,3,4,6,7,8,9 |
| r.Karpovka | Gor'kovskoe | 1952 | 4,6,7 |
| r.Vetlianka | Lakshinskoe | 1958 | 3,4,9 |
| r.S'ezzhaia | Chuvashskaia Republik | 1978 | 3,4,9 |
| r.Kondurcha | Cheboksarskoe | 1981 | 1,4 |
| r.Volga | Belgorodskaia District | 1955 | 1,2,4,6,7,8,9 |
| r.Kutuluk | Borisovskoe | 1941 | 4,7,9 |
| r.Gusikha | Golovchinskoe | 1966 | 7 |
| r.B.Glushitsa | Kosilovskoe | 1968 | 1,3,4 |
| r.Talovka | Lisenkovskoe | 1953 | 4 |
| r.Teplovka | Novostroevskoe | 1954 | 3,4 |
| r.Chernaia | Soldatskoe | 1953 | 4,9 |
| r.Sura | Starooskol'skoe | 1979 | 1,2,4,5,7,9 |
| r.M.Uzen' | Uraevskoe | 1976 | 3,4 |
| r.M.Uzen' | Voronezhskaia District | 1950 | 1,3,4 |
| r.Kamyshevka | Voronezhskoe | 1984 | 1,4 |
| r.M.Uzen' | Kurskaia District | 1985 | 1,3,4 |
| r.Viazovka | Kurskaia AES | 1973 | 3,4 |
| r.M.Uzen' | Mikhailovskoe | 1965 | 3,4 |
| r.Tolstovka | Volgogradskaia District | 1979 | 4,9 |
| r.Eruslan | Bereslavskoe | 1962 | 1,4,7 |
| r.Kochetova | Varvarovskoe | n.s. | 3,4 |
| r.Kamelik | Volgogradskoe | 1968 | 1,4 |
| r.B.Uzen' | Karpovskoe | 1965 | 1,3 |
| r.Al'shanka | Samarskaia District | 1940 | 3,4 |
| r.Volga | Vetlianskoe | 1967 | 2,3,4,6,7,8,9 |
| r.ZhidkaiaSolianka | Gavrilovskoe | 1956 | 3 |
| r.Bych'ia | Kondurchinskoe | 1927 | 3 |
| r.B.Irgiz | Kuibyshevskoe | 1972 | 1,4,9 |
| r.Talovka | Kutulukskoe | 1912 | 3,4 |
| r.Tolstovka | Pikelianskoe | 1979 | 3,4,9 |
| r.M.Kholmanka | Poliakovskoe | 1961 | 2,3 |
| r.M.Uzen' | Talovskoe | 1981 | 1,4 |
| r.Chertanla | Teplovskoe | 1979 | 3,4 |
| r.Chirka | Chernovskoe | 1981 | 4 |
| r.Karichka | Penzenskaia District | 1984 | 4,7 |
| r.Burets | Penzenskoe | 1976 | 4 |
| r.StepnoiZai | Saratovskaia District | 1962 | 1,5,7,9 |
| r.M.Sul'cha | Aleksandriiskoe | 1977 | 4 |
| r.Bugul'm-Zai | Varfolomeevskoe | 1957 | 2,4,9 |
| r.B.Sul'cha | Verkhnekamyshevskoe | 1974 | 4 |
| r.Amgamka | Verkhneperekopnovskoe | 1979 | 4 |
| r.V.Kamenka | Viazovskoe | 1977 | 4 |

| River, lake, canal | Water Reservoir | The year of flooding | Reservoir use |
|---|---|---|---|
| r.Pit'ialka | Gannovskoe | 1976 | 4 |
| r.Terpelia | Korneevskoe | 1976 | 4,7 |
| r.Iinka | Lebedevskoe | 1976 | 4 |
| r.Sukhoiash | Markelovskoe | 1982 | 4 |
| r.Maliasha | Mar'evskoe | 1980 | 4,7 |
| r.B.Sul'cha | Matveevskoe | 1978 | 4 |
| r.Elga | Mikhailovskoe | 1978 | 4 |
| r.SaklavSu | Saratovskoe | 1978 | 4,7 |
| r.Sikiia | Sel'skoe | 1981 | 4 |
| r.Dyrdygyz | Sinen'koe | 1983 | 4,7 |
| r.Igania | Sulakskoe | 1981 | 4 |
| r.Abim | Talovskoe | 1972 | 4 |
| r.Belaia | Tolstovskoe | 1950 | 2,4 |
| r.Psif | Tsimlianskoe | 1974 | 4 |
| r.Kuban' | Chernopadinskoe | 1973 | 1,4,7 |
| r.Bugundyr' | Shkol'noe | n.s. | 4,7 |
| r.Neberdzhai | Republik Tatarstan | 1960 | 1,2 |
| r.Sups | B.Frolovskoe | 1930 | 4,7 |
| r.Psif | Bekhterevskoe | 1971 | 4,9 |
| r.Afipe | Burbashskoe | n.s. | 4,7 |
| r.Chibii | Zainskoe | 1964 | 4,7 |
| r.B.Egorlyk | Ivashkinskoe | 1964 | 8 |
| r.Tomuzlovka | Karabashskoe | 1956 | 4,7,9 |
| r.Kuban' | Lashmankinskoe | 1962 | 1,4 |
| r.B.Egorlyk | Malo-Saltykovskoe | 1961 | 2,4,8,9 |
| r.Alikonovka | Verkhne-Kamenkinskoe | 1983 | 9 |
| k-l B.Stavropol'skii | Memdel'skoe | 1968 | 4,8 |
| r.Kura | Minniarovskoe | 1930 | 4 |
| r.Kura | Nadezhdinskoe | 1948 | 3,4 |
| r.Egorlyk | Nizhne-Sukhoiashskoe | 1952 | 3,4,5,9 |
| r.Kuma | Novokamkinskoe | 1966 | 2,4,7 |
| r.Podkumok | Novo-Il'movskoe | 1961 | 9 |
| r.Kura | Novo-Il'movskoe | 1940 | 4,9 |
| r.Kuban' | Saklav-Bashskoe | 1957 | 2,9 |
| r.Kura | Sikiiskoe | 1939 | 4,7 |
| r.Vostochnyi Manych | Summarokovskoe | 1969 | 1,2,3,4,7,9 |
| r.Z.Manych | Iazykovskoe | 1939 | 3,4,6,7,9 |
| r.SeverskiiDonets | Krasnodarskii region | 1914 | 4,6,9 |
| r.SeverskiiDonets | Varnavinskoe | 1914 | 2,3,4,6,9 |
| r.SeverskiiDonets | Ganzhinskoe | 1914 | 2,3,4,6,9 |
| r.SeverskiiDonets | Keslerovskoe | 1914 | 2,3,4,6,9 |
| r.SeverskiiDonets | Krasnodarskoe | 1914 | 2,4,6,9 |
| r.Don | Kriukovskoe | 1920 | 1,4,6,7,9 |
| r.SeverskiiDonets | Neberdzhaevskoe | 1914 | 3,4,6,9 |
| b.Temernik | Oktiabr'skoe | 1977 | 9 |
| r.Don | Semenovskoe | 1975 | 4,6,9 |
| r.Z.Manych | Shapsugskoe | 1939 | 4,6,7,9 |
| r.Kundriuch'ia | Shendzhiiskoe | 1952 | 2,4 |
| r.Don | Stavropol'skii region | 1952 | 2,3,4,6,7,8,9 |

| River, lake, canal | Water Reservoir | The year of flooding | Reservoir use |
|---|---|---|---|
| r.Aksai | Bufernoe | 1968 | 4,7,9 |
| r.Karakoisu | Volch'i Vorota | 1938 | 1,8 |
| r.Sulak | Golovnoe | 1974 | 3,4,7,8 |
| r.Sulak | Egorlykskoe | 1959 | 2,4,7,8 |
| r.Terek | Kislovodskoe | 1976 | 4 |
| r.Sunzha | Kubanskoe | 1932 | 2 |
| r.Terek | Kurganenskoe | 1969 | 9 |
| r.Goita | Kurskoe | 1961 | 2,5 |
| r.Tobol | Novo-Troitskoe | 1962 | 1,2,4,5,9 |
| r.Kurtamysh | Otkaznenskoe | 1976 | 1,2 |
| r.Borovka | Piatigorskoe | 1957 | 3,4,9 |
| r.B.Kumak | Rostovanovskoe | 1962 | 1,2,4,9 |
| r.Domashka | Sengileevskoe | 1937 | 3,4,7,9 |
| r.Elshanka | Sovetskoe | 1937 | 3,4,9 |
| r.Ural | Chograiskoe | 1958 | 1,2,4,5,7,8,9 |
| r.Mondybai | Rostovskaia District' | 1978 | 3,4,9 |
| r.Krutinka | Veselovskoe | 1956 | 4 |
| r.Sukho-Pusto-Karagalka | Gidrouzel N2 | 1978 | 1,3,7,9 |
| r.Ushkota | Gidrouzel N4 | 1973 | 1,3,4,9 |
| r.Zyrianka | Gidrouzel N5 | 1969 | 2,7,9 |
| r.Sepych | Kalitvenskoe (GU-6) | 1981 | 4,9 |
| r.Kama | Kamenskoe (GU-7) | 1961 | 2,4,6,7,8,9 |
| r.Siuz'va | Kochetovskoe | n.s. | 9 |
| r.Ocher | Nizhne-Zhuravskoe (GU-3) | 1862 | 9 |
| r.Kama | Nizovoe | 1954 | 2,4,6,7,8,9 |
| r.Lys'va | Nikolaevskii GU | 1785 | 2,7,9 |
| r.Zyrianka | Proletarskoe | 1953 | 2,5,9 |
| r.Nytva | Sokolovskoe | 1979 | 1,2,9 |
| r.Ocher | Tsimlianskoe | 1770 | 2,4,7,9 |
| r.Ocher | Republic Dagestan | 1961 | 2,4 |
| r.Suksunchik | Aksaiskoe | 1729 | 2,9 |
| r.Kos'va | Gergebil'skoe | 1946 | 1,2,8,9 |
| r.Iug | Chirkeiskoe | 1746 | 1,2,9 |
| r.Neiva | Chiriutskoe | 1704 | 1,2 |
| r.Aiat' | Chechenskaia Republik and Republik Ingushetiia | 1941 | 2,4,5,7,9 |
| r.Vyia | Nadterechnoe | 1952 | 1,2,9 |
| r.Tura | Sunzhenskoe | 1949 | 1,8 |
| r.Iset' | Chervlenskoe | 1938 | 2 |
| r.Glubokaia | Chernorechenskoe | 1885 | 9 |
| r.Bobrovka | Kurganskaia District | 1924 | 1,2,5 |
| r.El'chevka | Kurganskoe | 1954 | 2 |
| r.Tagil | Kurtamyshskoe | 1978 | 2,9 |
| r.Neiva | Orenburg District | 1877 | 2 |
| r.Iset' | Borovskoe | 1813 | 2 |
| r.Sarana | Verkhne-Kumakskoe | n.s. | 9 |
| r.Tura | Domashkinskoe | 1956 | 1,2,4,5,7,9 |
| r.Revda | Elshanskoe | 1969 | 1,2 |
| r.Neiva | Iriklinskoe | 1975 | 9 |

| River, lake, canal | Water Reservoir | The year of flooding | Reservoir use |
|---|---|---|---|
| r.Revda | Krasno-Chabanskoe | 1962 | 1,2,9 |
| r.Reft | Krutinkovskoe | 1968 | 1,2,5,7,8,9 |
| r.Sysert' | Sukho-Pusto-Karagal'skoe | 1977 | 1,2,9 |
| r.Istok | Ushkotinskoe | 1729 | 1,2 |
| r.Miass | Permskaia District | 1929 | 1,2 |
| r.Sintashta | Verkhne-Zyrianskoe | 1978 | 1 |
| r.Ural | Volkovskoe | 1968 | 1 |
| r.V.Iremel' | Votkinskoe | 1969 | 1 |
| r.Ural | Grigor'evskoe | 1938 | 1 |
| r.Miass | Dubrovskoe | 1952 | 1 |
| r.Ufa | Kamskoe | 1976 | 1,2 |
| r.Miass | Lys'venskoe | 1964 | 1 |
| r.Ui | Nizhne-Zyrianskoe | 1962 | 2,5 |
| r.Miass | Nytvenskoe | 1969 | 1,2,7 |
| r.Uvel'ka | Ocherskoe | 1955 | 2,5 |
| r.Ural | Pavlovskoe | 1974 | 2,9 |
| r.Bui | Suksunskoe | 1968 | 2,5,9 |
| r.Nugush | Shirokovskoe | 1965 | 1,2,7,8,9 |
| r.Ufa | Iugo-Kamskoe | 1959 | 1,2,3,7,8,9 |
| r.Votka | Sverdlovskaia District | 1759 | 1,2,4 |
| r.Izh | Alapaevskoe | 1760 | 1,2,5 |
| r.Kambarka | Aiatskoe | 1977 | 1,2,9 |
| r.Pudem | Verkhne-Vyiskoe | 1759 | 2,9 |
| r.Alei | Verkhoturskoe | 1979 | 1,4 |
| r.Proslaukha | Volkovskoe | 1978 | 4,7,9 |
| r.Chesnokovka | Glubochinskoe | 1977 | 4 |
| r.Alei | Egorshinskoe | 1976 | 1 |
| r.SukhaiaSolonovka | El'chevskoe | 1975 | 7 |
| r.Alchedat | Lenevskoe | 1965 | 9 |
| r.Inia | Neivo-Shaitanskoe | 1975 | 2,4,5,7,9 |
| r.M.Bachaty | Nizhne-Isetskoe | 1965 | 2 |
| r.Istok | Nizhne-Saraninskoe | 1979 | 4,7 |
| r.Kinia | Nizhne-Turinskoe | 1936 | 9 |
| r.Kara-Chumysh | Novo-Mariinskoe | 1967 | 1,9 |
| r.Kandalep | Petrokamenskoe | 1964 | 9 |
| r.Matiushinskaia | Revdinskoe | 1975 | 2,4,9 |
| r.PravyiUrop | Reftinskoe | 1981 | 4 |
| r.Shumikha | Sysertskoe | 1979 | 4,7 |
| r.Kuro-Iskitim | Chernoistochinskoe | 1979 | 4 |
| r.Ob' | Cheliabinskaia District | 1956 | 1,4,6,7,8,9 |
| r.Chernaia | Argazinskoe | 1972 | 5,7 |
| r.Iurga | Bredinskoe | 1980 | 1,2,4 |
| Canal Abakanskii | Verkhne-Ural'skoe | 1954 | 3,4 |
| r.Uibat | Iremel'skoe | 1971 | 1,4 |
| Canal Koibal'skii | Magnitogorskoe | 1968 | 7,9 |
| r.Barga | Miasskoe | 1952 | 2,5 |
| r.Kamysh | Niazepetrovskoe | 1958 | 7 |
| r.Dolgaia | Polikarpovskoe | 1942 | 2,5,9 |

| River, lake, canal | Water Reservoir | The year of flooding | Reservoir use |
|---|---|---|---|
| r.Erba | Troitskoe | 1982 | 4,9 |
| Canal Koibal'skii | Shershnevskoe | 1968 | 7,9 |
| r.B.Irba | Iuzhno-Ural'skoe | 1981 | 1,2 |
| Canal Abakanskii | Republic Bashkortostan | 1953 | 3,4,7,9 |
| Canal Koibal'skii | Il'tibanovskoe | 1966 | 3,4,7,9 |
| r.Kanzyba | Karmanovskoe | 1979 | 1,2 |
| r.Enisei | Nugushskoe | 1967 | 1,2,4,6,7,8,9 |
| r.Kureika | Pavlovskoe | n.s. | 8 |
| r.Enisei | Udmurtskaia Republic | 1984 | 8 |
| r.Dzhep | Votkinskoe | n.s. | 7,9 |
| Canal Koibal'skii | Izhevskoe | 1968 | 3,7 |
| r.Bidzha | Kambarskoe | 1969 | 4 |
| Canal Koibal'skii | Pudemskoe | 1965 | 3,4,7 |
| ruch.Podkamennyi | Republic Altai | 1962 | 1,9 |
| r.Enisei | Gilevskoe | 1978 | 8 |
| Canal Koibal'skii | Kornilovskoe | 1961 | 3 |
| r.Fyrkalka | Logovskoe | 1970 | 4 |
| r.Khantaika | Skliuikhinskoe | 1975 | 6,8 |
| r.Kharaelakh | Solonovskoe | 1968 | 5 |
| r.Angara | Kemerovskaia District | 1961 | 1,2,4,6,7,8,9 |
| r.Angara | Anzhero-Sudzhenskoe | 1956 | 1,2,6,7,8,9 |
| r.Mamakan | Belovskoe | 1961 | 8 |
| r.Angara | Gur'evskoe | 1974 | 1,4,6,8,9 |
| r.Artemovka | Zhuravlevskoe | 1978 | 2,5 |
| r.Berestovets | Zenkovskoe | 1981 | 4 |
| r.Bogataia | Kara-Chumyshskoe | 1962 | 2 |
| r.Vishnevka | Listvianskoe | 1976 | 1,2 |
| r.Gorbusha | Matiushinskoe | 1966 | 1,2 |
| r.Ivnianka | Mokhovskoe | 1982 | 4 |
| r.Kugukovka | Shumikhinskoe | 1981 | 4 |
| r.Kulikovka | Iagunovskoe | 1980 | 4 |
| r.KuchelinovKliuch | Novosibirskaia District | 1960 | 5 |
| r.Nezhdanka | Novosibirskoe | 1960 | 2 |
| r.Pereval'naia | Tiumenskaia District | 1970 | 1,2 |
| r.B.Pionerskaia | Surgutskoe | 1936 | 2 |
| r.Kontrovod | Iurginskoe | 1973 | 5 |
| r.Rakovka | Krasnoiarskii krai | n.s. | 1,2 |
| r.Slavianka | Abakanskoe | 1979 | 4 |
| r.Sorochevka | Abakanskoe | n.s. | 4,9 |
| r.Zeia | Adaikol' | 1975 | 8,9 |
| r.Kivda | Bol'shoeBarginskoe | n.s. | 5 |
| lake Priadchinskoe | Golovnoe | 1981 | 7 |
| r.Chalgana | Dolgoe | 1974 | 2 |
| | Erbinskoe | | |
| r.Kolyma | Zalivnoe | 1982 | 8 |
| r.Kamenushka | Irbinskoe | 1959 | 1,2 |

| River, lake, canal | Water Reservoir | The year of flooding | Reservoir use |
|---|---|---|---|
| r.Kamenushka | Krasnoe | n.s. | 1,2 |
| r.Magadanka | Krasnoe | 1975 | 5 |
| lake Goreloe | Krasnokamenskoe | 1970 | 1,2 |
| r.Talaia,r.Uzkaia | Krasnoiarskoe | n.s. | 1,2 |
| r.Viliui | Kureiskoe | 1967 | 8 |
| r.Ilin-Iuriakh | Mainskoe | 1966 | 3,4 |
| r.Ireliakh | Makovkino | 1964 | 1,2 |
| r.Olongoro | Maloe | 1983 | 5 |
| r.Sytykan | Moskovskoe | 1975 | 1,2 |
| ProtokaTulaginskaia | Podgornoe | 1980 | 1,4 |
| r.Tuima | Podkamennoe | 1986 | 4 |
| r.Kuokhara | Saiano-Shushenskoe | 1952 | 1 |
| r.Groevka | Sosnovoe | n.s. | 1 |
| r.Groevka | Fyrkal | n.s. | 1 |
| r.Groevka | Khantaiskoe | n.s. | 4 |
| r.Lava | Kharaelakhskoe | 1926 | 7 |
| r.Lava | Irkutskaia District | 1924 | 7 |
| | Bratskoe | | |
| | Irkutskoe | | |
| | Mamakanskoe | | |
| | Ust'-Ilimskoe | | |
| | Primorskii krai | | |
| | Artemovskoe | | |
| | Berestovetskoe | | |
| | Bogatinskoe | | |
| | Vishnevskoe | | |
| | Gorbushinskoe | | |
| | Krolevetskoe | | |
| | Kugukovskoe | | |
| | Kulikovskoe | | |
| | Kuchelinovskoe | | |
| | Nezhdankinskoe | | |
| | Pereval'nenskoe | | |
| | Pionerskoe | | |
| | Primorskoe | | |
| | Rakovskoe | | |
| | Slavianskoe | | |
| | Sorochevskoe | | |
| | Amurskaia District | | |
| | Zeiskoe | | |
| | Kivdinskoe | | |
| | Priadchinskoe | | |
| | Chalganovskoe | | |
| | Magadanskaia District | | |
| | Kolymskoe | | |
| | Magadanskoe-1 | | |
| | Magadanskoe-2 | | |
| | Magadanskoi TETs | | |
| | Sakhalinskaia District | | |

| River, lake, canal | Water Reservoir | The year of flooding | Reservoir use |
|---|---|---|---|
| | Goreloe | | |
| | Korsakovskoe | | |
| | Republic Sakha (Iakutiia) | | |
| | Viliuiskoe | | |
| | Ilin-Iuriaskhskoe | | |
| | Ireliakhskoe | | |
| | Neriungrinskoe | | |
| | Sytykanskoe | | |
| | Tulaginskoe | | |
| | Tumul'skoe | | |
| | Churapchinskoe | | |
| | Kaliningradskaia District | | |
| | Velikoe | | |
| | Verkhnee | | |
| | Liublinskoe | | |
| | Pravdinskoe HPS3 | | |
| | Pravdinskoe HPSs4 | | |

# Annex 2: Characteristics of Dams and Reservoirs in CAS

| N | Reservoir name | River | Dam | | | Year of Constr. | Reservoir | |
|---|---|---|---|---|---|---|---|---|
| | | | Height (m) | Length (m) | Type | | Capacity ($10^6$ $m^3$) | Area ($km^2$) |
| | | | | **Kazakhstan** | | | | |
| 1. | Bukhtarminskoye | Irtysh | 90 | 430 | Gravity, concrete, facilitated | 1964 | 49620 | 5490 |
| 2. | Malo-Ulbinskoye | Malaja Ulba | 10 | 110 | Rock-fill | 1937 | 90 | 7 |
| 3. | Kapchagaiskoye | Ili | 35 | 1900 | Hydraulic-fill and earth-fill | 1970 | 28140 | 1847 |
| 4. | Chardarjinskoye | Syrdarya | 26,5 | 4760 | Hydraulic-fill | 1968 | 5700 | 900 |
| 5. | Ust-Kamenogorskoye | Itrysh | 65 | 390 | Concrete Gravity | 1952 | 630 | 37 |
| | | | | **Uzbekistan** | | | | |
| 1. | Tujamujunskoye | Amudarya | 25 | 710 | Earth-fill | 1979 | 7300 | 790 |
| 2. | Yuzhnosurkhanskoye | Surkhandarya | 30 | 4930 | Earth-fill | 1964 | 641 | 64,6 |
| 3. | Uchkizilskoye | Surkhandarya | 11,5 | 3410 | Earth-fill | 1960 | 160 | 10,0 |
| 4. | Chimkurganskoye | Kashkadarya | 33 | 7500 | Earth-fill | 1964 | 440 | 45,1 |
| 5. | Kamashinskoye | Karabag Canal | 13 | 900 | Earth-fill | 1946 | 25 | 3,4 |
| 6. | Pachkamarskoye | Guzardarya | 70 | 593 | Rock-fill | 1967 | 243 | 12,4 |
| 7. | Gissarakskoye | Aksu | 138 | 5280 | Rock-fill | 1985 | 170 | 4,1 |
| 8. | Talimardzhanskoye | KMK canal | 35 | 9745 | Earth-fill | 1977 | 1530 | 77,4 |
| 9. | Kajumazarskoye | Zaravshan, ABK | 32,5 | 6000 | Earth-fill | 1966 | 306 | 16,3 |
| 10 | Tudakulskoye | Zaravshan, ABK | 15,0 | 20000 | Earth-fill | 1983 | 875 | 25 |
| 11 | Shorkulskoye | Kanimekh canal | | | Earth-fill | 1983 | 170 | 17,0 |
| 12 | Uchkurganskoye | Naryn | 35 | 2800 | Rock-fill | 1961 | 54 | 3,7 |
| 13 | Andizhanskoye | Karadarya | 115,5 | 965 | Round-head buttress | 1970 | 1750 | 60,0 |
| 14 | Karkidonskoye | Kuvasai | 70 | 420 | Rock-fill | 1964 | 218 | 9,5 |
| 15 | Akhangaranskoye | Akhangaran | 100 | | Rock-fill | 1974 | 399 | 8,1 |
| 16 | Tujabugusskoye | Akhangaran | 43 | 2900 | Rock-fill | 1966 | 204 | 20,7 |
| 17 | Chrvakskoye | Chirchik | 167 | 768 | Rock-fill | 1978 | 1990 | 40,3 |
| 18 | Khodzhikentskoye | Chirchik | 40 | | Gravity-concrete | 1977 | 80 | 2,5 |
| 19 | Gazalkentskoye | Chirchik | 36 | 544 | Rock-fill | 1980 | 20 | 1,7 |
| 20 | Dzhizakskoye | Sandzar | | | Earth-fill | 1962 | 73,5 | 12,5 |
| 21 | Kattakurganskoye | Podvodiashi canal | 28,6 | 3900 | Earth-fill | 1968 | 845 | 84,5 |

| N | Reservoir name | River | Dam | | | Year of Constr. | Reservoir | |
|---|---|---|---|---|---|---|---|---|
| | | | Height (m) | Length (m) | Type | | Capacity ($10^6$ $m^3$) | Area ($km^2$) |
| **Tajikistan** | | | | | | | | |
| 1. | Golovnoye | Vakhsh | 46 | 1300 | Hydraulic -fill | 1962 | 95 | 6,5 |
| 2. | Kairakkumskoye | Syrdarya | 32 | 1100 | Hydraulic -fill | 1956 | 4100 | 430 |
| 3. | Nurekskoye | Vakhsh | 300 | 700 | Rock-fill | 1967 | 10500 | 185 |
| 4. | Baipazinskoye | Vakhsh | 68 | 600 | Rock-fill | 1086 | 225 | 5 |
| **Kyrgyzstan** | | | | | | | | |
| 1. | Kirovskoye | Talas | 83,7 | 258,5 | Concrete | 1975 | 550 | 28,6 |
| 2. | Orto-Tokoiskoye | Chu | 52 | 365 | Concrete | 1961 | 470 | 24 |
| 3. | Toktogulskoye | Naryn | 215 | 292 | Concrete | 1974 | 19500 | 284,3 |
| 4. | Kurpsaiskoye | Naryn | 113 | 360 | Concrete | 1981 | 370 | 12 |
| 5. | Tashkumyrskoye | Naryn | | | Concrete | 1998 | | |
| 6. | Bazarkorgonskoye | Kara-Unkjur | 25 | 500 | Gravity-concrete | 1962 | 22,5 | 2,67 |
| 7. | Atbashinskoyee | Atbashi | 79 | 55 | Concrete | 1974 | 9,6 | 0,457 |
| 8. | Papanskoye | Ak-Buura | 100 | 107 | Concrete | 1983 | 260 | 7,1 |
| 9. | Tortkulskoye | Isfara | 34 | 1094 | Gravity | 1972 | 90 | 6,6 |
| 10 | Naimanskoye | Kyrgyz-Ata | 40,5 | 2700 | Gravity | 1966 | 39,5 | 4,2 |
| 11 | Uch-Korgonskoye | Naryn | 31 | | Gravity-concrete | 1964 | 52,5 | 4,0 |
| 12 | Ala-Archinskoye | Ala-Archa | 22 | | Gravity | 1966 | 39 | 5,2 |
| 13 | Sokulukskoye | Sokuluk | 28 | | Gravity | 1968 | 11,5 | 1,77 |
| **Turkmenistan** | | | | | | | | |
| 1. | Tashkeprinskoye | Murgab | | | | 1940 | 8,5 | 39,9 |
| 2. | Sary-Jazskoye | Murgab | | | | 1960 | 660 | 78,5 |
| 3. | Kolkhzbentskoye | Murgab | | | | 1910 | 30 | 20,4 |
| 4. | Iolotanskoye | Murgab | | | | 1910 | 24 | 10,6 |
| 5. | Gindukushskoye | Murgab | | | | 1896 | 15 | 5,5 |
| 6. | Gindukushskoye | Murgab | | | | 1896 | 16 | 6,1 |
| 7. | Khor-Khor | Tedzhen | | | | 1959 | 18 | 3,4 |
| 8. | Tedzhenskoye 1 | Tedzhen | | | | 1952 | 30,5 | 20,7 |
| 9. | Tedzhenskoye 2 | Tedzhen | | | | 1960 | 132 | 42,0 |
| 10 | Khayz-Khanskoye | Karakumski | | | | 1962 | 875 | 207 |
| 11 | Zapadnoye | Karakumski | | | | 1964 | 48,5 | 10,6 |
| 12 | Vostochnoye | Karakumski | | | | 1980 | 6,2 | 3,3 |
| 13 | Kopetdakskoye | Karakumski | | | | 1973 | 218 | 33,0 |
| 14 | Mamedkul | Artek | | | | 1980 | 16,4 | 6,3 |
| 15 | Dekhili | Artek | | | | 1980 | 11,0 | 7,0 |

# Annex 3: Summary Paper on Dams and Reservoirs in Central Asia

## 1.1 Water Resources

Central Asia is located in a zone of arid soil and limited water resources. It is currently experiencing a number of social-economic and geopolitical problems, including rapid population growth, lack of outlet to the sea, regional environmental crisis, and the proximity to Afghanistan, which has become a zone of military conflicts and a major world drug producer.

After the break down of the USSR, the problem of interstate distribution of water resources has become urgent. Water resources originate mostly in Afghanistan, Tajikistan and Kyrgyzstan, and water shortages are experienced in Kazakhstan, Turkmenistan and Uzbekistan. The latter 3 Republics are more concerned with irrigation and environmental issues, whereas Kyrgyzstan and Tajikistan see their future in the development of hydropower. The potential for achieving fair and sustainable water allocation depends on successful resolution of existing tension among Central Asian republics and prevention of regional conflicts.


Central Asia is largely an arid region, where, evaporation exceeds rainfall and annual precipitation is below 200 mm. This means, amongst the others, that agricultural production is impossible without irrigation. The main water resources of the region include the streamflow the Amudarya and Syrdarya rivers and the series of basins of internal runoff: the Zaravshan and Kashkadarya, the Tedzhen and Murgab, the Chu and Talas rivers, Issyk-Kul, Kara-Kul and Rang-Kul lakes.

The Amudarya basin covers an area of approximately 1327000 km$^2$ , of which 1018600 km$^2$ are in Central Asian Region (CAR: Turkmenistan – 488100, Uzbekistan – 388200, Tadjikistan – 131000, Kyrgyzstan – 11300). The mountainous part of the catchment occupies an area of about 230000 km$^2$.

The Mean Annual Runoff (MAR) of this catchment is about 79 $km^3$ , or half of the cumulative MAR produced within the mountainous regions of Central Asia..

The catchment area of the Syrdarya River is 444 000 $km^2$ and is split between four independent states: Kyrgyzstan, Tadjikistan, Kazakhstan and Uzbekistan. The upstream area of 150 000 $km^2$ produces an MAR of 36 $km^3$. The Amudarya and Syrdarya rivers make up about 75% of the streamflow generated in the mountainous parts of Central Asia.

The internal rivers of Turkmenistan – the Murgab, Tedzhen and small rivers of the Kopetdag mountain range have a total catchment area of about 193 $km^2$ and an MAR of 6 $km^3$. The streamflow generation areas are located outside of the republic, but about 4.9$km^3$ of the flow ends up in the republic. The total catchment area of the Chu and Talas river basins and the Issyk-Kul Lake are 50 000 $km^2$, the streamflow from these basins is 9.2 $km.^3$

The streamflow is characterized by extreme intra-annual variability. Most of the rivers in the region are fed by glaciers and/or snow in the mountains. Depending on the dominant source of water, annual summer floods are observed in July-August or May-July. Water resources are also unevenly spatially distributed (Table 1) and normally the Central Asian Republic share the major river basins.

**Table 1: Water Resources of the Central Asian States**

| State | Area, $10^3$. $Km^2$ | Total water resources, $km^3$ | Inflow from the neighboring states, $km^3$ | Local MAR, $km^3$ | Mean local unit flow, $10^3$ $m^3/km^2$ |
|---|---|---|---|---|---|
| Kazakhstan | 2,717.3 | 123 | 56 | 67 | 20.0 |
| Turkmenistan | 488.1 | 70 | 68.87 | 1.13 | 2.32 |
| Uzbekistan | 447.4 | 107 | 97.5 | 9.5 | 21.2 |
| Kyrgyzstan | 198.5 | 49 | 0 | 49 | 246 |
| Tajikistan | 143.1 | 65.1 | 12.9 | 52.2 | 365 |

At present all water resources of the Aral Sea are used to support economic activity. Streamflow is generated mostly in the mountains of Tadjikistan and Uzbekistan, while most of water is used to irrigate the lands of all five Central Asian republics. Therefore, there is a need for constructive dialogue and mutually agreed management of water resources of the Aral Sea basin in the interests of all states of the region, taking into account all ecological requirements including the provision of streamflow for river deltas. Another important need for the region is to implement water conservation activities to minimize losses.

One of the most important problems is the quality of water resources. Since the 1960s, due to the wide development of new lands, intensive development of industry, stock-raising complexes, urbanization and increasing diversion of river flow for irrigation, the water quality in river basins has deteriorated dramatically. The main cause of increasing water mineralization is the specifics of water consumption in the region, where 90-95% of water resources withdrawn from rivers is used for irrigation. The applied water is then returned to the rivers as "return flows" from agricultural fields. These flows are highly mineralized.

In the downstream of the Amudarya River, the mineralization increases two or more times compared to its values in the streamflow generation area. In the flow generation area of the Surdarya river catchment, the mineralization is 0.25 g/l in the middle, and down stream reaches it increases to 0.5 - 0.6 g/l. During a year, the mineralization of the Syrdarya river waters may change from 0.5 to 0.95 g/l during a flood, and from 0.96 to- 2.0 g/l during a low-flow period. The water mineralization in the

Chu river upstream is constant and equals to 0.25 g/l. In the middle and down stream reaches of the river it increase and reaches 2-10 g/l in the delta.

Increased content of salts in river waters aggravates the soil salinisation in the delta areas of the Amudarya, Syrdarya, Zaravshan and other river. that in its turn causes a need for additional ameliorative works, such as washout and drainage systems construction.

## 1.2 History of Hydro Technical Development

The development of agricultural irrigation and hydro-technical construction in Central Asia at all stages were characterized by an increasing use and regulation of water resources. The start of reservoir construction in Central Asia goes back to the 5th century B.C. According to Arabian geographers of the Middle Ages, the first reservoirs in Central Asia existed as early as the 10-11th centuries. Of these, dams on the Osmansai River have been preserved until today, and the dam on the Sultanbent River was destroyed many times in the past as a result of catastrophic floods and wars but was restored anew after each destruction. The construction of modern reservoirs started late in the 19th century and reached its peak in the second half of the 20th century. The first reservoirs with a total capacity of 13 $10^6$ $m^3$ were built in the valley of the Murgab River in 1896. In 1909-1910 the Sultanbentskoye and Iolatanskoye reservoirs were constructed, with a total capacity of 65 $10^6$ $m^3$.

The post-revolutionary construction period was marked by the construction of new irrigation systems and reconstruction of old ones. In 1934 the Chumyshskaya dam was built on the Chu River, and in 1937 the construction of the reservoir with the same name was finished on the Malaya Ulba River. By 1940 the Tashkeprinskoye reservoir was built and the reservoirs exploited in the Murgab-Tedzhenskiy oasis were reconstructed. In early 1940s, construction of dams of the Urtatokaisky reservoir began, as well as construction on the Kasansai River and of the Kattakurgansky reservoir in the valley of the Zaravshan River which were done stage-by-stage and finished in early 1950s. In late 1950s and early 1960s, reservoirs were constructed with the purpose of irrigation of thousands of hectares of old arable and virgin lands the Muminobadskoye, Selburskoye, Kattasaiskoye and Karakumskoye.

The peak of hydro-technical construction was in 1960-80s. The regulation of river streamflow was used not only for power engineering and irrigation development but also for urban and industrial water supply and water transportation.. During this period, a number of big reservoirs such as Bukhtarminskoye, Shulbinskoye on the Irtysh River, Kapchagaiskoye on the Ili River, Chardarinskoye on the Syrdarya River, Charvakskoye on the Chirchik River, Toktogulskoye on the Naryn River, Nurekskoye on the Vakhsha River, Tyuyamuyunskoye on the Amudarya River and a whole number of smaller reservoirs were created.

At first, reservoirs were constructed primarily on plains for irrigation purposes. Reservoirs of the Toktogulskoye-Andizhanskoye-Kairakkumskoye-Chardarinskoye system changed the natural streamflow regime significantly . In the 1960s the reservoir constructions were transferred to mountainous areas because mountain river valleys have favourable lake-type widening for the construction of reservoirs and also narrow areas, favourable for the construction of dams. Deep storage reservoirs of the mountainous regions have the advantage of reduced evaporation and large capacity at the same time.

In Central Asian basins of the Amudarya, Syrdarya, Chu, Talas and Atrek rivers, and areas of internal drainage of Turkmenistan, there are 60 reservoirs with the capacity of more than 10 $10^6$ $m^3$.

- The total storage capacity of artificial reservoirs in Central Asia is 61.6 $km^3$ which is approximately 50% of the total river streamflow in the region. The total area of reservoir water surface is estimated as 3,949 $km^2$. In Kazakhstan, without the basins of the Chu and Talas rivers, there are 158 reservoirs with the total capacity of 90 $km^3$

## 1.3 Use of the Reservoirs

In CAR, water demand exceeds the exploitable water resources. Central Asia and Southern Kazakhstan are the regions where irrigated agriculture is a priority in the economy.

Hydropower and water supply to the population and industry develop simultaneously; normally they do not intersect and do not have competing interests. However in Central Asia, in the basin of the Syrdarya and Amudarya rivers, the favourable conditions for hydroelectric power station construction are concentrated in the upstream parts of the basin: in the mountainous areas where it is possible to create reservoir capacities. Such are the rivers of Pyandzh and Vakhsh up to their junction with Amudarya, and Naryn in the basin of the Syrdarya. The problem of reconciliation of irrigation and hydropower demands in the reservoir operation is specific to Central Asia. The contradictions between these water use sectors are as follows:

- hydro power requires high water levels in a reservoir to be maintained to ensure the maximum hydraulic head at HPS and is characterized by increased demands during autumn/winter period;
- irrigation requires the maintenance of the reservoir water levels, which could provide a continuous water abstraction during the plant growth period into subordinate irrigation systems. In cases when irrigated lands are located downstream of a reservoir, the necessary water levels in the river should be ensured by appropriate water releases.

Fisheries require the maximum possible reduction of available winter capacity of reservoirs to prevent the asphyxiation of fish. In spring, fisheries require that the reservoirs be filled up to the normal backwater level mark by the start of the fish spring spawning (April-May) and that this mark is maintained until spawning is over.

For flood control, it is necessary to have a spare reservoir capacity to accept floodwaters. Winter floods are not desirable from the irrigation point of view.

There is also a need for special sanitary and environmental releases (e.g. for water quality maintenance). These releases are of different magnitude, frequency and duration.

The required water levels in reservoirs are also determined by allocations to industry and transport utilities located in the reservoir coastal area. Besides inter-sectoral industry competing water demands, there are also intra-sectoral contradictions in water requirements. In the multipurpose use of reservoirs, it is almost impossible to fully satisfy the requirements of all users. Therefore, the operation regimes of reservoirs often represent a compromise, where cutting the requirements of all or most of the users to this or that extent for the sake of achieving an optimal allocation effect in the system as a whole is inevitable. In most cases, the complex use of reservoirs is economically more beneficial, than establishing a number of smaller single-purpose reservoirs.

To enhance the use of the reservoirs, the following activities are carried out:

- Development of the basic principles of reservoir exploitation and their approval;

- Development of detailed rules of exploitation, instructions, release schedules, etc. taking into consideration all possible situations of normal and extreme exploitation of reservoirs;
- Development and implementation of specific annual, seasonal and other regimes of reservoir capacity maintenance, operation of water intakes, hydroelectric power stations, etc. on the basis of water inflow to a reservoir and consideration of a economic situation.

## 1.4 Hydro Power and Land Resources

It is estimated that the full potential energy of the rivers of Central Asian states is 554.5 $10^9$ kWh and with the rivers of Kazakhstan is 753.1 $10^9$ kWh.

Tajikistan in CAR has the largest total hydropower potential of 299.6 $10^9$ kWh/hour, and the unit potential of 2,100 MWh per 1 $km^2$ . Only Georgia and Kyrgyzstan have potentials close to these figures. Other states - Russia, Ukraine, Uzbekistan, Kazakhstan - have unit potential values which are of smaller magnitude. The exploitable potential is about 85 $10^9$ kWh.

The total hydro potential in Kyrgyzstan is 142.5 $10^9$ kWh/hour, of which 48 $10^9$ kWh is exploitable. The unit potential equals 717 MWh per 1 $km^2$.

The rivers of Kazakhstan have a total hydro power potential of 198.6 $10^9$ kWt/hour which is more than in Kyrgyzstan but due to its large territory, the unit values are only 73 MWt/hour per 1 $km^2$ Only 27 $10^9$ kWt/hour is considered to be economically exploitable.

The full potential hydro power resources of the Republic of Uzbekistan are more than twice as low as in Kazakhstan and amount to 88.5 $10^9$ kWt/hour, with the unit value of 197 MWt/hour per 1 $km^2$ , which is 2.5 times larger than in Kazakhstan. Economic hydropower resources of the Republic amount to 11 $10^9$ kWt/hour.

The Republic of Turkmenistan with its total potential of 23.9 $10^9$ kWt/hour, and economic potential of 1.7 $10^9$ kWt/hour is the poorest. The unit potential is 49 MWt/hour. Dams producing electric energy were built here since 1950s, but had limited development, which was stopped in 1960s completely.

The major hydro power stations in Central Asia include: Toktogulskaya HPS on the Naryn river with the installed capacity of 1,200 MWt, Nurekskaya HPS on the Vakhsha river with the capacity of 2000 MWt, Charvakskaya HPS on the Chirchik river with the capacity of 600 MWt, Tyuyamuyunskaya HPS with the installed capacity of 160 MWt, Kurpsay (800 MWt) and Tashkumir (450 KWt) on the Naryn River, Kapchagay (434 MWt) on the Ili and Bukhtarma (675 KWt) on the Irtysh. The portion of the HPS in the total output of electric energy is approximately 30-35%. The basis of the energy system of Central Asia is formed by big thermal power plants (Tashkentskaya HPS, Syrdarinskaya HPS, Navoiskaya HPS, Oshskaya central heating and power plant).

In 1999 Uzbekistan was far ahead of other Central Asian states in energy output, Kazakhstan and Tajikistan with almost equal energy outputs shared the second place, Kyrgyzstan - the third and Turkmenistan - the fourth. Energy production by all the states exceeded their total energy consumption. The programmes of small HPS construction have been developed for Uzbekistan and Tajikistan. The Uzbek energy system fully covers the needs of the Republic and makes it possible to export power to neighbouring states. Four new HPS are in the design stage in Kyggyzstan.

In Kazakhstan the construction of HPS can be considered only in the Irtysh river basin. It is economically feasible to use the potential of small rivers. There are more then 350 resources that have been identified in several districts that have the potential for the construction of small HPS. Environmental specialists however, claim that the construction of even mini HPS on mountainous streams, which eventually feed into the larger basins with outlets located in the arid zone (the Balkhash-Alakolskiy basin, the Aral basin), may result in a noticeable damage to the ecosystems of the downstream parts of such larger basins.

**Table 2: Potential Hydro Power Resources of CAS**

| State | Area, $10^3$ $km^2$ | Total potential $10^9$. KWt/h | Potential of large and medium rivers $10^9$. KWt/h | Potential of small rivers $10^9$. KWt/h | Unit potential MWt Hour/ $km^2$ |
|---|---|---|---|---|---|
| Uzbekistan | 447,4 | 88,5 | 84,1 | 4,4 | 197 |
| Kazakhstan | 2717,3 | 198,6 | 162,9 | 35,7 | 73 |
| Kyrgyzstan | 98,5 | 142,5 | 135,5 | 7,0 | 717 |
| Tajikistan | 143,1 | 299,6 | 285,6 | 14,0 | 2100 |
| Turkmenistan | 488,1 | 23,9 | 22,1 | 1,8 | 49 |

Deserts and semi-deserts comprise a considerable part of Uzbekistan, Turkmenistan and Kazakhstan. (Karakumy, Kizilkumy, Muyunkumy, Ustyurt, Betpakdala deserts, etc). The territory of Kyrgyzstan and Tajikistan is located mostly in mountainous parts of Central Asia, which are of little use for development. The total area suitable for irrigation in Central Asia is about 15 $10^6$ hectares, of which 9 $10^6$ hectares are in the basin of the Amudarya river and 6 $10^6$ - in the basin of the Syrdarya river. The growth of irrigated lands in CAS is illustrated in Table 3.

**Table 3 Irrigated areas in CAS ($10^3$ ha)**

| Country | 1970 | 1980 | 1986 | 1999 |
|---|---|---|---|---|
| Uzbekistan | 2696 | 3476 | 4020 | 4280 |
| Kazakhstan | 1451 | 1961 | 2230 | 2284 |
| Kyrgyzstan | 883 | 955 | 1020 | - |
| Tajikistan | 518 | 617 | 662 | - |
| Turkmenistan | 643 | 927 | 1185 | - |

## 1.5 Social, Economic and Environmental Impacts of the Reservoirs

Reservoirs play a significant role in the improvement of drinking water supply. There role is extremely important in flood control, health resorts establishment, recreation, fishing. Reservoirs together with their hydro-systems also play an important role in improving the infrastructure of regions, and the general conditions of life. Industrial development without reservoirs in the conditions of extreme flow variability would be limited. Agricultural production in arid conditions without flow regulation is impossible.

The significant increase of irrigated areas for cotton, rice and other cereal and technical crops is possible only where there is an assured water supply, which may only be a result of flow regulation. The creation of reservoirs will allow irrigated areas to significantly increase by means of more rational use of the runoff. This will supply water to fields in necessary amounts in accordance with optimal irrigation schedules, and to increase areas of self-flowing irrigation thus decreasing expenditureon the pumping of water in mechanical irrigation.

The development of power industry is impossible without reservoir construction. HPSs with their regulating reservoirs in power systems increase the reliability of these systems.

Reservoirs represent an effective flood protection measure and promote the development of fishing industry in internal basins. The creation of reservoirs may disturb the conditions of reproduction and life of fish, but it may also enhance the number of indigenous fish.

Reservoirs play a special role in recreation. Facilities for various types of sport (swimming, yacht sport, water skiing, etc), and their aesthetic influence on coastal landscapes, etc. make it possible to consider reservoirs as natural resorts. Most of the recreational facilities and all the short term rest areas are located directly on the reservoir banks or nearby.

Reservoir construction and flow regulations certainly affect the natural hydrological river regime. The environmental changes upstream of a reservoir depend, first of all, on the size, configuration and morphology of a reservoir, and also on rock composition, exploitation regime and climate conditions of the region. Changes downstream of an HPS are mainly related to a degree of modification of the flow regime – total flow reduction and changes in seasonal distribution of flow caused by regulation. Reservoirs influence all components of lithosphere, hydrosphere, atmosphere and biosphere that form the environment of adjacent territories, i.e. on geodynamic conditions and relief, groundwater regime, climate, soil, flora, fauna and a landscape in general.

The reduction of river flow downstream creates condition of stress in rivers, which affect the normal functioning of biological communities, reduces the buffering capacity of ecological systems (without additional pollution), decreases water quality, promotes the development of alien biotic communities and the disappearance of indigenous ones. The unstabilised banks andthe disorder which frequently accompanies construction, such as construction rubble and uprooted trees,have negative effects on human health and damage riverside ecosystems.

The influence of reservoirs on agriculture of the regions adjacent to a river in the area of backwater and downstream of the dams include the alienation of lands, deterioration of quality or conditions of the use of agricultural holdings, changes in water supply, etc. Economic, transport, cultural and other links are changed as a result of breaking communication networks and population resettlement.

Most of the reservoirs in Central Asia and Kazakhstan are experiencing severe sedimentation problems. For example, the volume of sediments accumulated in Nurek reservoir after 28 years of operation is about 2.4 $km^3$, and the active capacity of this reservoir has reduced to 0.9 km3 . Many structures and equipment of CAS reservoirs are in poor condition.