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Translation

TRANSLATIONS ON MAJOR USSR RIVER DIVERSION PROJECTS

Volume I

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VOLUME I

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PREFACE

This is the first of a four volume special report. Most of the translations are reports or discussions on proposals for or ramifications of projects to divert part of the flow of certain major northward flowing river systems into areas of the southern USSR, especially Kazakhstan and Central Asia.

This collection of translations was prompted by a notable increase in the volume of material published regarding the feasibility of river diversion during the last third of 1980 and the first months of 1981, as the 26th CPSU Congress approached. The material scanned included a quite broad selection of Soviet newspapers and journals, provincial as well as central, and in the local languages of the Central Asian Republics as well as in Russia.

STATEMENTS BY POLITICAL LEADERS

UDC 011.1+63

COTTON-GROWING, WATER RESOURCES, RESEARCH HIGHLIGHTED IN AGRICULTURAL REPORT

Moscow VESTNIK SEL'SKOKHOZYAYSTVENNOY NAUKI in Russian No 12, Dec 80 pp 1-11

[Article by Sh. R. Rashidov, CPSU Central Committee Politburo candidate, first secretary, Uzbek SSR Communist Party Central Committee: "Introduce the Achievements of Science Into the National Economy"]

[Excerpts] The infrastructure of the agro-industrial complex--industry, agriculture, and water management--has its own major scientific problems, in the solution of which the appropriate sector scientific research institutes, VUZ's planning organizations, and design bureaus are taking part. Eleven integrated programs dealing with the republic's agriculture and water management were approved in the 10th Five-Year Plan. They include creation and introduction of a general-purpose cotton harvester adapted for the harvesting of medium-fibered and fine-fibered varieties of cotton, creation and introduction of low-toxicity defoliants and pesticides, improvement of irrigation procedures and equipment, and so on.

There are many unsolved problems in irrigation and land reclamation. We are already experiencing tremendous difficulties associated with water shortages every year. The meagerness of the water resources and the water shortage, which is quickly growing, will continue to be problems in the future as well. It has become urgently necessary to develop and implement an integrated program aimed at sharply raising the efficiency of irrigation systems, new productive irrigation methods, and ways to economically stimulate effective use of water resources. It should be emphasized that in the immediate future, and even after part of the flow of Siberian rivers is diverted to Central Asia, the problems associated with economical water consumption will remain acute.

In terms of land reclamation, we need to concentrate the efforts of scientists on developing and introducing more effective forms of drainage, and improving leaching methods, finding soil desalinization methods and so on.

The republic has developed scientifically grounded measures for introducing technical progress into cotton growing and into other sectors. Targets for introducing wide-row plantations, precision sowing methods, double-level plowing, herbicides, mechanized chopping, mechanical cotton harvesting, crop rotation, and other measures were set for each oblast in the republic for each year of the 10th Five-Year Plan. The economic impact from their introduction is climbing to 300 million rubles. Constant concern is being displayed for creating new harvesting and other equipment for cotton growing, new, less toxic defoliants, concentrated fertilizers, biological agricultural pest control methods, improvements in irrigation equipment and procedures, working out the problems of diverting part of the flow of Siberian rivers into Central Asia, development of animal husbandry, and reinforcement of the feed base.

In their efforts to advance the achievements of science into production, the Central Asian branch of the All-Union Academy of Agricultural Sciences imeni V.I. Lenin and other institutes are being given daily assistance by the Uzbek SSR Communist Party Central Committee in coordinating the work of scientific, planning, and design organizations, as well as industrial enterprises manufacturing new equipment, attachments, fertilizers, and chemical means of protecting plants.

The achievements of agricultural science and the growth of its role as an immediate material force elevating all farming and animal husbandry sectors have become possible owing to the presence of highly skilled scientists. Today, 170 doctors and more than 2,500 candidates of sciences are working on the pressing scientific problems of the republic's agriculture. The serious theoretical and practical problems we must solve require a dramatic improvement in the training of scientists with the top qualifications, mainly doctors of sciences. The number of scientists with top qualifications employed in major research programs still fails to satisfy the growing demand. This is why energetic steps are being taken to afford promising workers with the necessary conditions for their creative growth, since the future of our science depends on how well we do this today. Our scientists are making a tremendous contribution to developing cotton growing and other sectors, raising the effectiveness of production and improving product quality, developing agro-industrial integration, eliminating the disproportions between different sectors of the agro-industrial complex, and solving the social problems of rural areas. The Uzbek SSR Communist Party Central Committee is providing all-out assistance and support to the great detachment of workers in agricultural science by defining the fundamental directions of scientific inquiry, improving control over scientific research, and strengthening the ties between science and production, and it will continue to do so in the future.

The fatherly concern of the Leninist party and the outstanding successes of the Soviet people in economic and cultural development inspire the republic's scientists to new creative efforts and discoveries. Persistently raising the effectiveness of research, and concentrating their strengths and resources in the decisive directions of agricultural development, they are fully resolved to make a substantial contribution to accelerating scientific-technical progress and honorably welcoming the 26th CPSU Congress.

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ECONOMIC ASSESSMENTS

POTENTIAL BENEFITS OF RIVER REVERSAL OUTLINED

Tashkent ZVEZDA VOSTOKA in Russian No 8, 1980 pp 5-16

[Article by Anatoliy Yershov: "People, Water and Economics"]

[Text] A bearded peasant holding a rifle was talking with a stylishly dressed gentleman.

"Let me tell you, my fine gentleman, that we will definitely take the land in our own hands. Definitely! And we will rebuild everything."

"Will you dig up mountains?"

"Why sure. If they are in the way we will dig them up."

"And will rivers flow backwards?"

"The rivers will flow where we tell them to flow."

This is a conversation that was recorded by A. M. Gor'kiy in Petrograd in 1917. I recalled it at the all-Union conference of economic scientists from higher educational institutions in the country which was held for several days in Tashkent. The scientists at the meeting were focusing their attention on a problem whose essential point is precisely expressed by the words: "Turning part of the flow of the Siberian rivers to run to Central Asia." Thus, the people who became rulers of the land in October 1917 are carrying out their dreams.

Throughout the conference I kept thinking, "We live in amazing times." How can one not be amazed? The subject, after all, was the greatest such project in world experience. No other country of the world yet has had the courage to undertake the transformation of nature on such a magnificent scale.

It was an economic conference, so of course the debate at it centered chiefly on issues related to economic development and social consequences of transferring part of the northern waters to the south.

The technical side of things also struck the imagination, of course. To build a canal roughly 2,300 kilometers long is a very difficult job. It is as hard as the challenge of building the BAM [Baikal-Amur Mainline]. Incidentally, it is just as expensive too. Building the canal will require a whole fleet of powerful earth moving machines and various other unique equipment. To provide all this machinery it will be necessary to rebuild some enterprises or build special plants, to say nothing of the construction industry enterprises which will certainly have to be organized.

Nonetheless, for me the most interesting thing was the social aspect of carrying out this vast project.

Central Asia is a land of incalculable wealth. We who live here have become accustomed to this statement. But let us try evaluating the potential of our region not from an emotional standpoint using ringing words, but from an economic standpoint, relying on dry figures. This is what the participants at the conference did.

So, if we look at a physical map of Central Asia and southern Kazakhstan, we see the predominant colors are brown and yellow: mountains, deserts, semi-deserts, and arid steppes. Green, the color of oases, occurs only along the river valleys and canals. The area of irrigated land in those places is only about 7 million hectares. But scientists have calculated that more than 50 million hectares is suitable for raising crops.

Another aspect of our wealth is the warm climate. The length of the frost-free period here ranges from 6 to 9 months and summer air temperatures permit the ripening of heat-loving crops such as cotton, tobacco, rice, soybeans, grapes, melons, and many types of subtropical fruits.

I cannot refrain from citing some figures here: one hectare of irrigated land produces 1,340 rubles of output compared to 140 rubles received from a hectare of unimproved land.

"Well, then, what is the problem?" the reader will ask and say, "Let's get to work and develop and irrigate new lands if it's so profitable in our region!"

Of course, that is what we are doing. At the dawn of Soviet power V.I. Lenin wrote the following: "There is still unused land. Excellent land, which must be plowed!" Communists have made Lenin's dream their program of action. Since the first years of the socialist Fatherland plans have been written to develop the virgin lands and they are being brought into cultivation. In the 1950's a project unprecedented in human history began to develop the virgin land. At this time the Soviet peoples joined their efforts to transform the virgin land region of Kazakhstan. At almost the same time in Uzbekistan we began to bring back into production lands which had not been used for centuries.

"At about the same time," is how it seems to us today when that heroic beginning is somewhat removed in time. But to be accurate, the development of new land on a broad scale in our republic began under the direct impact of the virgin land transformation in Kazakhstan.

Older and middle-aged people remember this well. It was 1956. The newspapers ran the decree of the CPSU Central Committee and USSR Council of Ministers on development of 300,000 hectares of land in the Goldnaya Steppe. The enthusiasm of young people was unprecedented. The republic Komsomol sent the best and most worthy of them for the assault on the previously uninhabited steppe region.

The years passed. The Golodnaya Steppe, which is often called the little sister of the great Virgin lands, became an oasis of economic importance comparable to the natural oasis, the lush, Fergana valley! The sovkhozes built on the new irrigated land, after 1956 that is, grew and in their existence have sold the state more than 4 million tons of raw cotton. In this way they have long since repaid the cost of their development.

But people are not satisfied with past achievements. A new all-Union shock Komsomol construction project called the enthusiasts. This was the Karshinskaya Steppe. Its young sovkhozes have already harvested their first million tons of cotton. In the future they will harvest this much every year, and it will be the most valuable kind of cotton, fine fibered.

But the virgin lands of Uzbekistan do not end with the Golodnaya or the Karshinskaya steppes. Today this project cannot be imagined without developing land in the Central Fergana region, Surkhan-Sherabad valley, the Dzhizakskaya Steppe, and the lower regions of the Amu-Dar'ya in Karakalpakistan. It is a vast and heroic idea!

During the Ninth Five-Year Plan more than 510,000 hectares of virgin lands were brought into agricultural use in Uzbekistan. During the 10th Five-Year Plan another half million hectares are to be irrigated. This means 1 million hectares in a decade! Where else, in what other country, is work going forward on such a scale?

And these are the reasons for the pride that every Soviet citizen felt when reading Leonid Il'ich Brezhnev's book "Tselina" [The Virgin Land].

How portentous that this book was published in 1978. That was the year in which our country celebrated the 60th anniversary of Lenin's decree on irrigation of lands in Turkestan and it was just before the 25th anniversary of the beginning of development of the virgin lands in Kazakhstan.

It is difficult to grow cotton anywhere. But it is especially hard on virgin lands. This land takes a great deal of care. It has to be watered and made fertile. But there is nothing that the virgin lands developers will not do. They conquered the deserts of our region and once barren lands became flourishing oases. One-third of the cotton of Uzbekistan today comes from the virgin lands!

As you see, the developers of our steppes and deserts have done brilliantly. And they are ready to continue that in the future. But, and this will be the subject of discussion, everything ultimately relies on water. The resources of the Syr-Dar'ya will be fully exhausted by 1985. By the 1990's the reserves of the region's largest river, the Amu-Dar'ya, will be depleted.

Underground sources may help somewhat, of course, but they are also exhaustible. Then what will happen?

Water is an amazing substance. You cannot substitute for it with supplementary doses of mineral fertilizer, chemicals to control field pests and weeds, or any other chemical products! I cannot help remembering here the remarkable words of Saint Exupery, who came to know the true value of this marvelous liquid when his airplane crashed in the Sahara. "Water! You have no taste, no color, and no odor. It is impossible to describe you. People enjoy you without realizing that you are necessary for life. You are life itself. You fill us with a joy that we cannot explain. You return to us the strength that we have lost. The dried-up springs of our heart begin flowing again by your grace."

The inhabitants of the arid regions of the world know the value of water very well. Central Asia is one of those regions. The peoples of our region wisely say: "Where water ends, life ends," and "It is not land that gives life, but water."

Indeed, the inhabitants of the arid zone know the true value of a drink of water. Where there is no water we have sun-scorched desert. The watered land is bountiful; oases flourish, cities grow, and the economy develops. It would, perhaps, be no exaggeration to say that the level of development of the Central Asian republics can be evaluated by the level of development of their water management systems.

The area of irrigated land in Uzbekistan has doubled during the years of Soviet power. In this same time 20 large reservoirs, real manmade seas, have been built. Among them are Charbakskoye, Andizhanskoye, Kattakurganskoye, Yuzhno-Surkhanskoye, Talimarzhanskoye, and Pachkamarskoye. Their total volume exceeds 4.5 billion cubic meters. And this is still not all; in addition, reservoirs in the mountains of neighboring republics also "work" to irrigate the fields of Uzbekistan. Among them are such large reservoirs as Toktogul'skoye and Nurekskoye. The blue ribbons of canals have formed a dense network covering the oases of the republic. These manmade rivers are more than 150,000 kilometers long. Those who like "astronomical comparisons" could circle the globe four times with these canals. No capitalist country can boast of such up-to-date and sophisticated irrigation and land improvement structures as Soviet Uzbekistan. That is why, incidentally, people from around the world come to study irrigation here.

But no matter how we improve and refine our water management system, we are approaching the time when it will be necessary to say: "Moisture reserves have been exhausted."

There is one thing to do: transfer water to our region from far away, for example from Siberia where vast regions suffer from a surplus of moisture. It is not accidental that the people there say, "Water is disaster," and "Always expect trouble from water."

But serious background studies must be done before undertaking such a project. This work is being done by associates at the Institute of Water Problems of the Academy of Sciences USSR, the Institute of Geography of the Academy of Sciences USSR, the Council for the Study of Productive Forces of the Academy of Sciences of the Uzbek SSR, the Tashkent Institute of the National Economy, the Central Asian Scientific Research Institute of Irrigation, the Soyuzvodproyekt [All-Union Association for Water Management Planning] Association, the Soyuzgiprovodkhoz [All-Union State Order of the Labor Red Banner Planning-Surveying and Scientific Research Institute of Water Management Construction] Institute, and many others. a total of 120 scientific and planning institutions in all. The purpose of the conference in Tashkent was to hear reports on the results of their work.

The actual idea of transferring Siberian water to Central Asia arose in the last century. In 1968 Ya.G. Demchenko, an agronomist from Kiev, submitted a report memorandum to the Russian Geographic Society entitled: "Flooding the Aral-Caspian Lowland To Improve the Climate." The problem raised in the memorandum was not a pressing one and few people understood it at the time. After all, Demchenko was proposing to improve the climate of a remote frontier of the country. His idea was not evaluated; it could be said it was simply not noticed. Interest in the idea arose only after Great October. In the 1920's and 1930's several projects were proposed to build dams on Siberian rivers and deliver the water to Kazakhstan and Central Asia. The first plans contemplated redistributing the water by gravity-flow. A fundamentally new concept advanced in 1936 proposed using pumps to get over the water divide. In this scheme the flooding of floodplains is greatly diminished. This idea formed the basis for current planning development. It could have begun earlier, of course. But like many other projects, the starting time for implementation of this vast conception was postponed by the Great Patriotic War. But in 1946 the Gidroenergoproyekt [possibly Hydroelectric Power Planning] Institute began preliminary development of the technical side of the problem of reversing the flow of the Siberian rivers to run to Kazakhstan and Central Asia. Small surveys and tests were made. This work was directed by engineer Mitrofan Mikhaylovich Davydov, who had worked here in Central Asia at an earlier time, in 1921-1932, and even then had been infatuated with this bold idea. In recent years the periodical press has written a great deal about the planning work, and it has been called the "Davydov Plan." In reality, of course, a large group of engineers, some 40 people, took part in the work. By 1954 the zealots had collected sufficient material to give an idea of the character and scale of work necessary to carry out this incredible conception. The four-volume work "Irrigatsiya Uzbekistana" [Irrigation of Uzbekistan] by the Academy of Sciences Uzbek SSR defines the result of the explanatory stage as follows: "The results obtained confirmed the possibility of transferring the water by building large hydroengineering complexes."

In the early 1960's at the Central Asian division of the Gidroproyekt [All-Union Planning, Surveying, and Scientific Research Institute imena S. Ya. Zhuk] Institute I became familiar with a large book whose title page read: "Reversing the Flow from the Ob' River Basin to Kazakhstan and Central Asia." This was one more step toward implementation of the idea. It was then that I began my first report on reversing the flow of the water from north to south.

I wrote an account of an imaginary future trip along the canal. Yes, it was imaginary because actually doing it seemed to be far in the future. And now, it appears, we have arrived at this future and will witness the implementation of the plan which not long ago was considered to be fantastic. Such are the "giant steps" taken by the Soviet five-year plans, which move our economy ahead at an incredible pace and have converted the most audacious plans into actual oases, cities, scientific laboratories orbiting the earth, or canals of enormous length.

"Carry on scientific research and, on this basis, do developmental work related to the problem of diverting part of the flow of northern and Siberia rivers to Central Asia, Kazakhstan, and the Volga river basin." That was what the 25th CPSU Congress resolved, almost 5 years ago. Today thousands of people, the most highly qualified specialists in the country in the fields of irrigation, soil science, economics, climate, and others, are putting this party resolution into effect.

A broad panorama of socioeconomic transformations which will occur in our region with the arrival of Siberian water is now open before us. The reports by G. V. Voropayev, director of the Institute of Water Problems of the Academy of Sciences USSR, I. A. Gerardi, deputy chief engineer of the Soyuzgiprovodkhoz Institute, Professor M. Sh. Sharifkhodzhayev, rector of the Tashkent Institute of the National Economy, and representatives of other scientific and planning centers helped participants at the conference see these prospects.

Kuz'ma Ivanovich Lapkin, academician of the Academy of Sciences Uzbek SSR, deputy chairman of the Republic Council for the Study of Productive Forces, and one of our leading economists, presented an interesting calculation. Studies made by a collective of specialists under his direction made it possible to determine the economic potential of one cubic kilometer of water used in the fields of the republic. Such a quantity of water makes it possible to get 112,000 tons of cotton, 116,000 tons of vegetables and melons, 41,000 tons of fruit and grapes, 7,000 tons of meat in slaughter weight, 114,000 tons of milk, and 400 tons of silkworm cocoons. In monetary terms, all this output is estimated at 153 million rubles.

But even this is not the complete result; it is only the part that will come directly from agriculture which, as we know very well, supplies raw material to industry. Therefore, the scientists made similar calculations for the industry that processes agricultural raw material. It turned out that each cubic kilometer of water makes it possible to receive 500 million rubles of output from the agroindustrial complex. The researchers calculate that the net income from this amount will be 193 million rubles!

Just the first phase of diverting part of the flow of the Siberian rivers to Central Asia envisions delivering 25 cubic kilometers (or 25 billion cubic meters) of water to our region each year. It is true that part of the water is to be used en route, in Kazakhstan and the RSFSR. Nonetheless, the bulk of it is for our fields and will result in snow-white bales of cotton, rows of sweet-smelling fruit trees, and tasty vegetables.

Further into the future, at the turn of the century, engineers contemplate diverting 60 and even more cubic kilometers of water a year from the north to the south, the equivalent of the entire Amu-Dar'ya. This water will undoubtedly produce truly abundant harvests in our fields. They will run into thousands and millions of tons.

But does the value of this output justify the capital that must be invested in construction of the canal and spent for transporting the water? Economists answer: Yes! At the conference they stated that this capital would be repaid in 5-6 years. Even by cautious calculations the repayment period is no more than 10 years.

When speaking of the advantages that 1 cubic kilometer of water produces, we did not mention another figure. But it is one that should be not just mentioned, but thought about. The number I have in mind is 50,000. This is how many jobs each cubic kilometer of water can provide in our republic. We can properly evaluate the significance of this figure if we remember the high birth rate in our region. As a result of it, it is realistic to expect that the population of Central Asia will double by the turn of the century, while at the same time the growth of population on the average for the country as a whole will be just 22 percent.

We must recognize that this means that without additional sources of water, or to be more specific without diverting part of the flow of the Siberian rivers to our regions, it will be difficult for us to employ in public production all the children being born in our day. The analysis of the economists showed that industrial development alone cannot meet this challenge. In addition, we must take account of the local population's traditional inclinations for agricultural labor. This labor can be provided only if new land is brought into use, and this requires irrigation.

It would be unrealistic to suppose that many local inhabitants want to go and work developing the riches of Siberia and the Far East. A few, of course, will want to tie their destiny to the remote regions, but most of the population of Central Asia is not inclined to migrate. They prefer to remain in customary climatic conditions.

Therefore, from the standpoint of better use of the country's labor resources it is also advantageous to transfer part of the flow of the Siberian rivers to Central Asia.

But possibly the Siberians themselves would be hurt by this operation?

The facts cited at the all-Union conference of economists indicate the opposite. The water that the Siberian rivers will give to the fields of Central Asia is just a small part of their total flow and, therefore, will have little impact on them. After all, the Ob' and Yenisey alone, two of the world's largest rivers, carry roughly 950 cubic kilometers of water a year to the Arctic Ocean! By contrast, the inhabitants of Siberia, by sharing their excess water, will receive a direct benefit from the development of orchard farming and grape growing in the southern regions of the country. According to calculations by

Siberian economists, this region must import at least 500,000 tons of vegetables and melons and roughly 1.5 tons of fruit, berries, and grapes from the southern regions, the Ukraine, Moldavia, and Central Asia. Some of the vegetables can be raised in local areas using hothouses. It is true that this requires major capital investment and the quality of the output from covered ground is not, of course, comparable to that which we receive from land that is directly heated by the hot southern sun. The calculations of the economists indicate that it would be wise to establish large-scale production or nourishing garden and orchard crops in Central Asia, near Siberia. This would make it possible to save about 500 million rubles a year in transportation costs alone.

Sociologists called attention to an equally important factor: the improvement in supply of fruit and vegetables will help keep workers at development sites in the North. This means that, by giving water to southern fields, we will be more successful in work to use the natural riches of Siberia.

The arrival of large amounts of water from Siberia in Central Asia and Kazakhstan will lead to the irrigation of millions of hectares of virgin lands, provide jobs to millions of people, and give birth to new cities and dozens of industrial enterprises. Large new oases to produce cotton, fruit, and vegetables will appear. A proper evaluation of the coming changes enables us to say with confidence that a nationally important large new region for the production of food products will be created in our region.

But what can the arrival of Siberian water give to the Uzbek SSR, for example? The report at the conference by deputy chief engineer of the Uzgiprozem [possibly Uzbek SSR Land Planning Institute] Institute V. N. Grechikhin and M. I. Kochubey, chief specialist of the same institute, answered this question. According to their outline, we can expect to add more than 10 million hectares of irrigated land, including 3.5 million hectares in established farming zones and 7 million in new irrigation regions. Implementation of this program will mean that the agroindustrial complex of Uzbekistan will practically triple! Think about that word "triple." It means that we will have three times as much of everything we have today in the fields of agriculture and the industry that processes its raw materials, all that we take pride in! Then the sphere of agricultural production will attract 7 million people, including 4.6 million in zones of new irrigation. But the last figure is not a final one, because the sectors of the agroindustrial complex will also develop in the new irrigation regions and they will need just as much labor.

This calculation was made on the basis of the maximum potential of our land resources, that is, the existence of land area that can be put to agricultural use by existing methods. Needless to say, this figure does not include so-called "especially difficult" lands for whose development rational and acceptably inexpensive techniques have not yet been found. Putting them to human use is a matter of the remote future.

We understand, of course, that the first stages in diverting Siberian water will not be able to supply water to all the undeveloped land. Only the best and most acceptable lands will be used.

Another calculation, made by A. V. Bostandzhoglo, scientific associate at the Council for the Study of Productive Forces of the Academy of Sciences Uzbek SSR, puts the figure for new irrigated land in Uzbekistan at 3 million hectares. This is on the condition that 60 cubic kilometers of Siberian water enters the Aral Sea basin.

This is the figure that economists are using today in their planning projections. This volume of water is to be distributed among the neighboring southern republics. Part of the water will be used en route in Kazakhstan. In the southern regions of that republic it will irrigate heat-loving crops, while in the more northerly regions, Alma-Ata specialists believe that the water can be used to irrigate grain crops. This will make it possible to raise their yield from 15 to 50 quintals per hectare.

The Turkmen SSR will be able to put large areas of virgin land to agricultural use with Siberian water. They have more than 12 million hectares suitable for irrigation, and only 1 million is in use.

The arrival of large supplies of water will be an important stage in the development of the unique mineral deposits of Kazakhstan and Central Asia also. After all, neither industry nor agriculture can develop without water. For example, it takes 15-26 cubic meters of water to smelt a ton of steel and up to 6,000 cubic meters to get a ton of synthetic fiber! Siberian water will make it possible to develop a number of unique mineral deposits whose exploitation could not even be planned without it.

And of course, water is also needed for continued urban development. It has been calculated that it takes 270 tons of water to support one person for 1 year.

The manmade river will promote stronger economic ties between economic regions of the country. Construction of the supercanal will also mark the beginning of the creation of the unified water management system of the Asian USSR, one of the key links in the unified nationwide water management system now being shaped.

Long ago, in prehistoric times, during the Ice Age, the waters of the ancient Siberian rivers, the Ob' and Yenisey, did not flow north. They flowed south, through the Turgay Gates which connect the West Siberian and Aral Caspian lowlands. Over time the powerful glaciers that created the pressure head melted and retreated and the Turgay Gates were raised above water level by movement of the earth's crust. The gates were closed and the rivers found a new route to the north, depriving vast southern regions of life-giving moisture. Today Soviet people are preparing to correct nature's "mistake." The waters of the Siberian rivers will again flow south, becoming a unique source which will make it possible to open the door to incalculable riches in the vast arid regions of the country. In the future the Ob' and Irtysh, and possibly other Siberian rivers, will come to the rescue of the Syr-Dar'ya and Amu-Dar'ya.

According to the projections of the All-Union Soyuzvodproyekt Association the route of the future trunk canal will run to the lower regions of the Syr-Dar'ya and Amu-Dar'ya, which is the region that experiences the greatest shortage of moisture today. The Siberian water will connect up with the Amu-Dar'ya in the region between the cities of Nukus and Urgench. At this point a special branch will run off the main canal and electric pumps will deliver northern water along it to the Tyuyamuyunskoye manmade sea now under construction on the Amu-Dar'ya. This reservoir is expected to support irrigation of the lands in the lower reaches of our region's principal river. Thus, the entire zone of the lower reaches of the Amu-Dar'ya will be completely nourished by Siberian water and the river's flow liberated thereby will go to irrigate land in the Kashkadar'ya basin (including the fields of the Karshinskaya Steppe), the Bukhara oasis, and along the Karakumy canal which will stretch to Bakharaden.

This predicament allows us to say that at the turn of the century the lower reaches of the Amu-Dar'ya and Syr-Dar'ya will become the country's largest region of hydro land improvement construction. Plans call for irrigating 4 million hectares of new land there with Siberian water; in addition to this, roughly 2 million hectares of existing land will be reorganized.

So-called "ancient irrigation" lands (irrigation arose in these regions roughly 4,000 years ago) will also be used in development of the lower reaches of the region's two largest rivers. In the Middle Ages many irrigation systems were destroyed because of feudal wars and large sectors of fertile land were covered up by sand. It is much easier to prepare them for farming, however, than virgin desert lands. As science has demonstrated, irrigation in oases causes the formation of fertile manmade soils that are unlike any natural soils. For this reason archeologists are making detailed maps of the regions of ancient irrigation and carefully studying the organization of the irrigation network in past centuries. Today all these findings are beginning to be useful to land developers. Ancient irrigated soils, scientists allege, have good texture, are usually less weed infested, and contain more substances useful to plants than lands that were not irrigated. The experience of the ancient irrigators must also be taken into account in choosing the routes of contemporary main canals and planning the detailed irrigation network.

The problems of continued development of the lower reaches of Amu-Dar'ya and Syr-Dar'ya are closely tied to the fate of the Aral Sea, the second largest internal-drainage body of water in the USSR (after the Caspian Sea) and fourth largest in the world. The Aral only exists because of the waters of the Amu-Dar'ya and Syr-Dar'ya. Just 2 decades ago these rivers and atmospheric precipitation carried almost 60 cubic kilometers of moisture a year to the sea. The same amount evaporated. The Aral had a volume of 1,060 cubic kilometers and a surface area of 66,000 square kilometers. Its water level fluctuated around 53 meters above sea level. Today all these figures are hopelessly out of date. Because large volumes of water are being taken from the rivers for irrigation, evaporation from the sea now exceeds the inflow of moisture significantly. The level of the Aral Sea has dropped 7 meters and will continue to drop in coming years. The water is swiftly retreating from the docks, beaches, and fish spawning grounds. This has caused great alarm not only among inhabitants of the Aral region, but in national public opinion. A great deal has been written about the fate of the Aral. I will not repeat these things here, but will only observe that most of the statements have been highly emotional, while the loss has been discussed in generalities.

The Tashkent conference of economists offered me my first chance to hear a concrete discussion with thoroughly substantiated figures. Associates from the Council for the Study of Productive Forces of the Academy of Sciences Uzbek SSR presented their calculations to the audience. They were asked to give a socioeconomic evaluation of the negative consequences of the lowering of the level of the Aral Sea. The scientists from this research center had to work out a special methodology for this which enabled them to determine expected economic losses with adequate precision. In addition, they worked out the scientific foundations of steps to mitigate the consequences of the sea's drying up.

Well, what is going to happen in the Aral region because of this process? There is no question that the climate will become more continental. As the volume of water decreases the heat reserve stored by its water will also diminish. It is expected, therefore, that the average air temperature will drop by 1-3 degrees, spring frosts will be later, and fall frosts earlier. Therefore, the growing season for the development of agricultural crops will be shortened. It is contemplated that the sum of effective temperatures will be reduced. This means that cotton will not be able to receive sufficient heat to mature during the summer.

The processes of desertification will develop. The first signs of them can already be observed around Kyzyl-Orda and Tashuz. Ground findings have been confirmed by observations from space which detect clouds of saline dust driven by storm winds from the Aral Sea in the direction of the Tienshan and Kopetdag.

There is more. The greatest disaster that awaits the Aral region in the future is degradation of the land in the delta of the Amu-Dar'ya and Syr-Dar'ya, an area of 1 million hectares. The process of desertification has not touched the agricultural zone yet, and associates of the Council believe that it can still be prevented from entering this zone. These lands will be saved, of course, by the timely arrival of Siberian water. But it would be a mistake to place all hopes on the transfer of this water and not take local steps to stop the process of desertification today. After all, surveying and work on the project are still underway, and at the present time there are no concrete deadlines for construction of the canal. The beginning of its construction could be delayed for various reasons, and then time will be lost and processes in the delta soils will become irreversible. Large capital investment, running into billions of rubles, will have to be spent to restore these lands. This can be avoided if implementation of a program is begun immediately, as recommended by the Council for the Study of Productive Forces of the Academy of Sciences Uzbek SSR. Then changes in the natural world will not catch us by surprise.

One of the immediate steps is to reorganize the whole structure of agriculture in the Aral region. It appears that the northern boundary of cotton-growing will be shifted to the south. This is understood in Karakalpakistan, where intense work has begun in recent years to develop virgin lands for cotton fields in the southern part of the autonomous republic. In its northern regions a zone to raise seed alfalfa should be established. A quintal of seeds of this feed crop is worth thousands of rubles. Therefore, a yield of just 3 quintals of alfalfa seed per hectare will earn just as much money as 60 quintals of cotton.

The favorable natural conditions of the Aral region make it possible to get up to 8 quintals of alfalfa seeds. These figures are their own propaganda.

Animal husbandry is another sector that should be developed intensively here in the coming years. Any comment on the significance of developing this sector would be superfluous.

I do not think there is any need to go into all the details of the upcoming reorganization of human economic activities in the Aral region. We need only point out that a high degree of coordination among the neighboring republics of Kazakhstan, Uzbekistan, and Turkmenistan is needed for this. It will help avoid unnecessary losses.

But there will, of course, be losses. It is already clear today that the Aral is ceasing to be a major supplier of valuable commercial fish species. These losses can be compensated for in a quantitative sense (but not qualitative!) by the development of pond aquaculture and planting young fish in reservoirs. The Aral fur industry has also gone into decline; the drying up of the delta has had its impact on purchases of muskrat fur. Mineralization of the water is growing in these regions, which leads to a drop in the yield of agricultural crops. These losses can be evaluated in rubles. However, with the drying up of the Aral we also encounter a loss that cannot be quantified by economists. You understand, of course, that I am referring to esthetic losses, for the Aral Sea is one of the most marvelous regions of our country.

When Siberian water reaches Central Asia in the future the level of this declining sea will stabilize. But it is now obvious that it will not be possible to return it to its original condition.

That is how we must pay for water. Incidentally, how much does it cost?

Each month city-dwellers pay a very modest amount to the cashier's office for water service. Yet the kolkhozes and sovkhozes, who pour whole rivers onto their fields, do not pay anything at all. They pay for electricity, but not for water, even though the state uses that same electricity to pump the water. Suffice it to say that roughly one-third of the planted area in Uzbekistan is irrigated with water delivered by pumps! We have built large machine irrigation canals such as the Amu-Bukhara and Karshi canals. The latter is designed to raise water 130 meters to the steppe. The electric pumps installed along this manmade river use as much electricity in a year as was produced by all the power plants in Tsarist Russia. That is how the scale of things in our region has changed.

But now we see that the water, whose delivery to the fields costs so much human labor, does not cost the waterer anything. No matter how much water is used. this is not reflected at all in the economic indicators of the brigade or the kolkhoz. In practice, therefore, an unspoken rule is often followed: it is better to use too much water than too little.

This statement cannot help causing alarm. It is no accident that many specialists at the all-Union economic conference in Tashkent raised the question of paying for water.

Speakers at the conference recalled that a payment for water was once instituted in the Uzbek SSR, during the 1950's but it was later abolished. At that time the decision was correct, for science then was unable to recommend adequately substantiated norms of water use. It turned out in practice that the additional expenditures were carried by farms who were developing difficult land that required large volumes of water for flushing. As a result, instead of being rewarded for bringing virgin land into production the farms paid a penalty for overuse of water. In practical effect they were punished for developing new lands. Price policy is a subtle economic tool. Sometimes it comes out in a completely unexpected way. Nonetheless, life demands that a payment for water be instituted again in the interests of water conservation. Other regions of the country, for example Kirghizia, are already undertaking such efforts. But as participants at the conference observed, this experience has not been entirely successful. What has happened in practice has been a "shifting of money from one pocket to the other." Therefore, the conference proposed that a more refined system of charges for water be worked out. It recommended that such a system be introduced gradually, after testing in particular regions. It is essential to solve the problems of keeping strict accounts of water. At the present time the kolkhozes and sovkhozes do not have measuring devices and the volume of water delivered to divisions and brigades is in fact determined "by eye." Only the test fields of the scientific research institutes have water measuring instruments today.

It is particularly important to charge for water today, when we are preparing to receive it from the Siberian rivers. Every cubic meter of this distant water will cost 80 kopecks. But economists figure that this will still be barely half the cost of water from local reserves which it is planned to take before the end of the century by rebuilding the existing irrigation network. After all, it is very expensive to "dress" the canals in "concrete clothing." Machine builders know very well that it is very expensive to improve the machining of parts. Costs rise sharply with a higher grade of metalworking. In the same way, "fine tuning" will be quite expensive in irrigation. But the efficiency of the irrigation system cannot be raised without such expenditures. And, of course, it is the job of the economists to determine the wise limits of such "fine tuning."

The conference showed that economic science faces many challenges. One of the most important is to find economic mechanisms that will permit us to organize efficient use of water, a precious natural resource. The 25th CPSU Congress called this a major economic problem. A. N. Kosygin, chairman of the USSR Council of Ministers, said in his talk at the congress, "We must focus attention on steps toward economical use of water. Agriculture has major reserves for water conservation, especially in the large amount of water used for the needs of irrigation. These reserves must be utilized."

In concluding my remarks on the scientific conference, I would like to give the main conclusion of the meeting of scientists: it is absolutely essential to build a manmade river from Siberia to Central Asia. This project should be carried out quickly as possible to prevent the occurrence of a gap in time between depletion of local moisture resources and the arrival of Siberian water. If we delay we are threatened by a decline in the yield of our fields and major economic losses.

We are still hoping that this vast construction project will begin in the near future. It will be one more manifestation of the friendship among Soviet peoples, who have joined their efforts to carry out the most grandiose plans.

There is a saying in the East: "When you go to work with a friend, the snow is melted away." Speaking of snow, it is solid water, after all, and, as everyone today knows, will be "fuel" for the thermonuclear power plants that are expected to supply people with adequate, inexpensive electricity in the future. For now, the fraternal Soviet peoples have already begun reversing the flow of rivers and moving mountains.

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PLANS FOR SUPPLYING WATER TO CENTRAL ASIA, KAZAKHSTAN

Tashkent PRAVDA VOSTOKA in Russian 30 Dec 80 p 3

[Article by A. Bostandzhoglo, candidate of technical sciences: "Life Hurries On"]

> [Text] "...To continue scientific and design studies on the transfer of water from Siberian rivers to Central Asia and Kazakhstan." (From the CPSU Central Committee draft for the 25th Party Congress)

This problem became apparent long ago and has been under discussion in connection with the development of a depopulated region resulting from the dwindling supply of fresh water to the Aral Sea and the Amudar'ya and Syrdar'ya deltas. Various areas of the deltas along with reservoirs and part of the estuarine coastal waters have lost agricultural, fishing and fur trade value. The water supply of population centers is suffering. Under these conditions it is not to be expected that the considerable land resources available here can be used efficiently.

In essence, the region's problems can be solved only by transferring a portion of the flow of the Siberian rivers Yenisey, Ob' and Irtysh to Central Asia and Kazakhstan. Only then will favorable conditions exist for developing irrigated farming and for full provision of the area's fast-growing population with essential foodstuffs, grain, vegetables and fruits and only then will the potential exist for intensive cotton and rice cultivation as well as other types of agriculture and industry.

It is likely that at least three five-year plans will be needed to put a specific program into practice for development of the region's farming and water management. That is to say, this amount of time will be required for developing the technical and economic bases, completing research and development and getting the projects operational.

The project's technical and economic bases (TEO) include plans to construct a feeder canal taking water from the Ob' River near the city of Belogor'ya at the northern mouth of the Irtysh and routing the head section of the canal along the left-bank bench of the Irtysh River valley.

After 316 kilometers, the canal's head section will join up with the head waters of the Tobol'skiy water distribution system which is planned for the Irtysh and from there the water will be conducted southward to the Turgayskaya ravine via a series of five pumping stations.

After crossing the Turgayskaya watershed, the canal route will continue to follow a southerly direction and, 1,39C kilometers from the Irtysh, will join with the planned Tegizskoye reservoir. Then it will change course to the south-east, intersect the Syrdar'ya River near the city of Dzhusal and come out into the Amudar'ya River near Dzhumurtau.

Thus, the overall length of the feeder canal from the Tobol'skiy water distribution system to the Amudar'ya will be 2,230 kilometers.

Three different primary water supply systems are considered for the canal in the technical and economic bases. The main water supply will be taken from the Ob' River in the first and second phases of the transfer. The Ob' and Yenisey with their huge drainages will be the main rivers used in the flow diverted to the Central Asian republics and Kazakhstan. A system of distribution laterals will be built to the west and east of the main canal to supply water to adjacent regional industrial complexes.

Development work on the sequence and scale of the operations is being done by the Institute of Water Problems of the USSR Academy of Sciences, as the chief scientific research organization, together with 120 other scientific research institutes. The environmental impact of the transfer on the zones from which water is diverted, its transportation and allocation are under investigation. These studies arrive at the same basic conclusions.

Land resources suitable for irrigation in the Aral Sea watershed amount to 50 million hectares.

Water resources in the Aral Sea basin will be exhausted in the near future, but approximately 8.5-9 million hectares of land could be irrigated using the natural flows of the Amudar'ya and Syrdar'ya. Development of the national economy in this area until practically the end of the century will probably be oriented toward utilizing local water resources, which will require developing new control reservoirs, further improving and very carefully conserving surface and underground water resources and also reexamining the optimum siting of reservoir facilities.

Diverting part of the flow of Western Siberian rivers to Central Asia and Kazakhstan will create new opportunities for developing irrigated farming in the vast lands of the Aralo-Kaspiyskaya watershed, carrying out particularly widespread reclamation and developing industry and civil water services for the enormous territories of Western Siberia, the Urals, Kazakhstan and Central Asia. The task is made even more urgent by the fact that the size of the population is growing rapidly in Central Asia and Kazakhstan.

A reduction in the flow of river water to the Aral Sea will cause a further lowering of its level and an increase in salinity. We note that the projected diversions of water to the sea basin may not stop these processes in practice. Right now, along with investigation of the unfavorable consequences of drying up the Aral Sea, an unremitting search is being made for compensatory measures which, as far as possible, would prevent these effects from occurring.

Of course, certain changes will take place in the environment after a portion of the Siberian river drainage is diverted but they will have a local character on the whole. Previous studies have shown that limited redistribution of the flow on the scale outlined for the first phase will not produce climate change on a global scale.

Particular attention must also be given to further development and extension of research on hydrogeological conditions and, as the first priority, on more accurate determination of the amount of seepage from various sections of the canal.

Since the first phase of the transfer of the Siberian rivers' flow could be accomplished no earlier than the end of the century at best while the natural water resources of the Amudar'ya River will be exhausted by 1990-1995, it will probably be necessary to draw up a general plan for redesigning and rebuilding the existing irrigation systems of Central Asia and to discover a way to intensify the utilization of water resources of the Amudar'ya and Syrdar'ya, primarily by increasing regulation of the river flow and raising the efficiency factors of irrigation systems and the effective utilization of reservoirs, underground water and certain other sources.

An interrepublic Amudar'inskiy and Syrdar'inskiy watershed department will probably have to be formed to allocate water resources among irrigation districts on the basis of developed and coordinated regulations for joint operation of all of the watersheds' reservoirs. At the same time, it would be advisable to set up a bureau to control the joint operation of reservoir stages in the Amudar'ya and Syrdar'ya watersheds.

An applied science conference took place recently in Nukus concerning problems of the Aral Sea and the Amudar'ya Delta. Scientists assembling in Nukus from all over the country agreed unanimously on the need for a very rapid start of operations. So, it was proposed that the phrase "...to continue scientific and design studies on the transfer of water from Siberian rivers to Central Asia and Kazakhstan," which appears in a section of the CPSU Central Committee's plan "Development of the Agricultural Production Complex," be replaced by "To complete scientific and design studies on the transfer of water from Siberian rivers to Central Asia and Kazakhstan and to begin performing the basic operations."

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INSTITUTE'S PROJECTS

Tashkent PRAVDA VOSTOKA in Russian 8 Jan 81 p 3

[Article by director of the Sredazgiprovodkhlopok Institute V. Antonov in the column "Discussion of the Plans of the 25th Congress of the CPSU Central Committee": "Plans and Life"]

[Text] The final year of the 10th Five-Year Plan has come to an end and each worker and crew is evaluating the results of plans made by the 25th Congress of the Communist Party of the Soviet Union, what resources remain unused and what can be done to welcome the 26th Party Congress appropriately. All of this, naturally, also involves the staff of the Sredaziatskiy Order of the Red Banner of Labor State Planning, Surveying and Scientific Research Institute on Irrigation and Reclamation Construction--Sredazgiprovodkhlopok--imeni A. A. Sarkisov which for more than 50 years has been devoting its efforts and knowledge to implementing Lenin's magnificent plan to develop irrigation in the Central Asian republics.

The Sredazgiprovodkhlopok staff has also done excellent work during the 10th Five-Year Plan. Every year it has fulfilled the assigned quotas and socialist commitments. Over the 5-year period, 53.5 million rubles worth of work has been accomplished, meaning that 205 projects were turned over to clients, 27 standard operations were completed and studies were conducted on 49 scientific themes during this period. Among the studies done by the institute were large-scale projects such as "A Design for the Comprehensive Utilization and Protection of Land and Water Resources of the Syrdar'ya River Basin," "Technical and Economic Basis for Procedures To Divert the Flow of Siberian Rivers to the Aral Sea Basin," "A Comprehensive Engineering Design for the Second Phase of Irrigation and Development of the Karshinskaya Steppe," "A Design for a Water Supply Dam on the Kokcha in Afghanistan," the sovkhoz projects "Uzbekistan" and "Druzhba" for Ivanovskaya Oblast in the RSFSR and others. In addition, planning and estimate documentation at the detail plan and engineering design stage has been produced for current construction projects involving more than a billion rubles worth of construction and installation work. The institute is doing most of the work to order for Glavsredazirsovkhozstroy [Main Administration for Central Asian Sovkhoz Irrigation System Construction] in whose system it is directly included.

Following the resolutions of the 25th Party Congress, the highest priority projects of the Sredazgiprovodkhlopok Institute are development and irrigation of the virgin lands of the Golodnaya, Karshinskaya and Dzhizakskaya steppes and construction of the Andizhanskiy reservoir. According to the institute's plans, 200,000 hectares of new irrigated land have been readied for cultivation and the first and second starting systems of the Andizhanskiy reservoir have been made operational and approved by the State Commission with an excellent rating. This success becomes even more noteworthy when it is considered that large savings above the estimated cost were achieved, almost 20 million rubles, because the plan adopted during development incorporated efficient engineering solutions into the Andizhanskiy reservoir construction.

An institute-designed starting system with a 600 million cubic meter capacity for the Talimardzhanskiy reservoir on the Karshinskaya steppe, a starting system for the Dzhizakskaya main pumping station and other projects were also put into active operation.

Last year the institute staff completed development of technical and economic bases for the third phase of irrigation for the Karshinskaya steppe and the Nizhniy Karshinskiy lateral canal and pumping station stages and irrigation of the Mubarekskiy tract. In the near future an engineering design will be produced to develop the second phase for the Dzhizakskaya steppe.

The institute has achieved certain successes but still has significant unutilized reserves. The attention of the administration and party, trade union and komsomol organizations has been directed toward putting them to use. Included in the socialist competition for an appropriate reception of the 26th CPSU Congress is a plan proposed by the CPSU Central Committee "Basic Directions for Economic and Social Development of the USSR in 1981-1985 and for the Period Until 1990." The institute staff has adopted increased socialist commitments and is devoting all of its energy to their successful accomplishment.

At a recent meeting of executive party members of the Sredazgiprovodkhlopok Institute where the CPSU Central Committee's plan for the 26th Party Congress was discussed, a resolution to complete the initiated plans with top performance and to make a meritorious contribution to further development of irrigated farming in Uzbekistan, other Central Asian republics and the Ivanovskaya Oblast of the RSFSR was approved.

It should be noted that successful further development of the virgin lands in Uzbekistan and other Central Asian republics as well as in Kazakhstan and the planned increase in volume of agricultural production will be possible only by providing radical solutions for the water supply problems. Since the water resources of the Central Asian rivers will be completely exhausted by 1985-1990, it will be necessary to complete the first phase of the operation to divert part of the flow of Siberian rivers to this region by no later than the end of the 12th Five-Year Plan.

During the years since the 25th CPSU Congress, considerable work has been done by scientific research institutes and planning organizations of our country on investigating and substantiating the problem of diverting the Siberian water. It has resulted in the "Technical and Economic Bases (TEO) of the First Phase of the Transfer of a Portion of the Flow of Siberian Rivers to Central Asia and Kazakhstan" developed by the Soyuzgiprovodkhoz Institute of the USSR Ministry of Land Reclamation and Water Management. The Sredazgiprovodkhlopok Institute participated directly in composing this document.

The materials of this TEO are presently being examined by the State Expert Commission of USSR Gosplan. The work in the Technical and Economic Bases is detailed enough to allow engineering design and preparatory work on the transfer projects to begin as early as 1981. Everything involved in the scale and complexity of the impending construction will take considerable time. Therefore, it is very important that this project be implemented promptly without losing a single year.

It should be mentioned that the water management and construction organizations of the Central Asian republics and Kazakhstan are fully capable of beginning work on the diversion. The Sredazgiprovodkhlopok Institute is also prepared to undertake the development of engineering designs for this job.

In view of this, the assembled members of the Sredazgiprovodkhlopok Institute have proposed that a paragraph be inserted in the next edition of Basic Directions concerning the diversion of the flow of northern and Siberian rivers: "To continue scientific studies and develop engineering designs for projects to transfer a portion of the flow of northern and Siberian rivers to the Volga River basin, Central Asia and Kazakhstan. To begin preparatory work on the first phase of the transfer projects."

Considering that large pumping stations will have to be built to divert part of the rivers' flow, the Sredazgiprovodkhlopok Institute has also offered to add the following paragraph to Basic Directions:

"To develop, fabricate and procure heavy-duty electromechanical pumping and underground conveyance equipment as well as shut-off and control hardware for the pumping stations."

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IRRIGATION INSTITUTE'S DIRECTOR URGES CONSTRUCTION TO BEGIN

Tashkent PRAVDA VOSTOKA in Russian 18 Jan 81 p 3

[Article by V. Dukhovnyy, director of the Central Asian Scientific Research Institute of Irrigation imeni V. D. Zhurin: "Share Your Water, Siberia..."]

> [Text] "Insure the rational and economical use of natural resources, materials and labor as the crucial and most effective means of multiplying the natural wealth of the country...." (From the CPSU Central Committee's draft for the 26th Party Congress)

The need for water, which gives life to the desert, is increasing. The need to increase irrigation is always on our agenda. Just how far can we develop irrigation in the region with water from The Syr-dar'ya and Amu-dar'ya, however?

In recent years we have seen increasing evidence that these rivers do not have an endless supply of water. Apparently, we have reached that point beyond which nature says "no," beyond which it will no longer be able to cope with the tasks assigned to it.

Today, water from the Syr-dar'ya is used one and a half to two times. After watering hundreds of thousands of hectares it is returned to the river channel through a system of drains and collectors. The amount of water returned is almost the same as the amount removed, but the quality differs greatly.

The mineralization of Syr-dar'ya water has risen 4- to 5-fold, and scientists predict that it will become even greater as the water shortage and the frequency of its use increase.

The effectiveness of agricultural production will steadily decline as a direct result.

How far will the mineral level rise if additional water is not delivered to the region within the next few years? Some tracts of land along the lower reaches of the river are even now becoming white salt marshes in places. Will this "white death" spread to the fertile fields of the Golodnaya Steppe, Fergana and Dal'varzin?

The condition of the Aral Sea is alarming. Its water level is dropping 40 to 60 centimeters a year, and the shore has receded several kilometers within the past 15 years. Continued lowering of the water level will bring climatic changes, and the boundary of the cotton cultivation area will recede to the south, as a result.

In 1950, 40 to 55 cubic kilometers of water was entering the Aral Sea annually. It was receiving only half this amount in the 1960's, and only 10 to 12 cubic kilometers of water was entering the sea in the 1970's. In some dry years the Syr-dar'ya has brought practically none of its water to the Aral. Losses resulting from the shortage of water along the lower reaches have increased, reaching 120 million rubles annually.

Could we stop irrigating?

What would we do about agriculture if we did? How would we meet the growing food needs of the population? How would we keep the population employed in production?

Calculations show that if we were to halt the development of irrigation because water supplies have been exhausted, socioeconomic losses in the form of reduced national income would exceed 1 billion rubles, and the figure would become even greater in the future.

What must we do to prevent this from happening?

Within the next few years we must complete all of the projects aimed at reducing nonproductive water losses. Unquestionably, we are going to have to do a great deal to achieve more efficient water use, and this program has become the prime concern of water management and agricultural agencies in all of the Central Asian republics for the decade ahead. Overall improvement of the old irrigated land is underway universally, a determined battle is being waged against nonproductive water losses, irrigation systems are being automated, improved irrigation technology is being adopted, and scientific forecasting is being used for determining times and norms for irrigating. This is the arsenal of means being placed into action to reduce the water shortage for some time. All of this also reduces the volume of water returned to the system, however. Because of this the net amount of additional water obtained by implementing all the measures aimed at preventing water losses is appraised at 10 to 12 cubic kilometers per year, which will meet the region's needs for no more than 10 years.

The diversion of Siberian water is the only way to resolve the many urgent problems.

The joining of Siberia's water resources with the enormous natural and labor resources of Central Asia is the way to achieve efficient utilization of reserves indicated for us by the CPSU Central Committee's draft plan for the 26th Party Congress.

This combining of resources would make it possible not only to thoroughly solve the problem of providing employment for Central Asia's growing population and providing it with food, but also to make a significant contribution to the accomplishment of the country's food production program, which was discussed by Comrade L. I. Brezhnev at the October 1980 Plenum of the CPSU Central Committee.

Increasing the area of irrigated land by only 4 million hectares, using our own resources and Siberian water, will make it possible to raise an additional 5-6 million tons of rice and 7-8 million tons of feed grain, to increase animal husbandry output 6- to 7-fold, increase cotton production to 12 million tons per year, and provide the country an enormous quantity of fruits, vegetables and grapes.

The problem of reversing Siberian rivers is a grand one, of course, and we have to give some serious thought to the question of whether it is feasible.

Our country has everything it needs to accomplish the task. More than 100 scientific and planning and surveying organizations are working on it.

The gigantic experiment in water resources development in the republics of Central Asia proves that the plan is realistic. A 500-kilometer canal reaches 200 kilometers from the Syr-dar'ya, irrigating the Golodnaya Steppe, a man-made river, the Karakum Canal, crosses almost 1,000 kilometers of desert, and the unique Karshinskiy series of large pumping stations lifts Amu-dar'ya water 180 meters.

Our hydraulic engineers and land reclamation specialists have learned how to move many thousands of kilometers of earth within a matter of hours. Extremely intricate pumping stations will be placed into operation in a year and a half, using prefabricated elements and large-unit hydraulic installation techniques [ukrupnennyy gidromontazh].

The question on the minds of all the specialists today is how to speed up construction of the canal and how to reduce the cost.

The canal builders have proposed digging a primary trench for the canal by means of directed blasting and then using hydraulic excavation equipment, walking excavators and other machinery to enlarge the trench. This would considerably reduce the amount of time required and cut the peak need for machinery by almost a quarter.

The SANIIRI [Central Asian Scientific Research Institute of Irrigation] has been working on this grand project for a number of years. It has demonstrated the socioeconomic justification for the project and produced a forecast of the development of agriculture at various water supply levels and with various amount of work performed toward total renovation of the land. It has proved that the normal development of Central Asia's agriculture can only be achieved by diverting part of the discharge from Siberian rivers to Central Asia no later than 1990. Changes in the mineralization of the flow of the Syr-dar'ya and Amu-dar'ya have been forecast to the end of the century, both with and without Siberian water. Work is being performed at special model installations to establish the parameters for the transfer canal. It has been determined that it would be possible to increase speed of the flow by 5 to 10 percent over that previously proposed. Model studies have been made of various plans for taking water from the Ob', and the best one has been recommended.

Siberian water could reach Central Asia and Kazakhstan by 1990, if we unite the efforts of irrigators in the Russian Federation, Uzbekistan and Kazakhstan and build the canal from both ends toward the center, and if we use the basis of operations already created within such large organizations as Glavsredazirsovkhozstroy [Main Administration for Irrigation Sovkhoz Development in Central Asia?], Glavrissovkhozstroy [Main Administration for Rice Sovkhoz Development?] and the Uzbek SSR Ministry of Land Reclamation and Water Resources.

It is apparent that local water resources will be exhausted between 1990 and 1992. It will take 10 years to complete the water-diversion project. If we are to provide Central Asia with a supply of water by the time we are able to begin using its natural resources and developing it, we must not only continue the planning of surveying work under the 11th Five-Year Plan, as stated in the draft plan, but we must also begin the actual construction. We therefore consider it essential to state the matter in the following manner: "Begin the preparatory work for diverting the flow of Siberian rivers to Central Asia."

This will speed up the arrival of Siberian water in Central Asia and Kazakhstan. It will breathe new life into the extremely fertile land and give rebirth to the Aral with the water which will be returned to its basin. New land will blossom into thousands of hectares of fields and orchards. And a reverse "river" of cotton, rice, vegetables, fruits, watermelons and cantaloupes will flow into Siberia.

11499
CSO: 1829/148

ECONOMIC COSTS OF WATER SHORTAGE NOTED

Tashkent PRAVDA VOSTOKA in Russian 30 Jan 81 p 3

[Article by Senior Scientific Associate of NIEI [Scientific Research Institute of Economics] of Uzbek SSR Gosplan Z. Salokhiddinov: "The Limiting Factor"]

[Text] A broad program for further development of the economy and productive capacities of the Central Asian republics was outlined in the CPSU Central Committee draft for the 26th Party Congress. This economic region of the country has great potential resources for implementing this plan: favorable natural and climatic conditions, availability of land suitable for putting into crop rotation and mineral, raw material, hydropower and labor resources.

From 1981-1985, 1 million 55,000 hectares of new irrigated land will be brought into cultivation and about 25 million hectares of pasture supplied with water in the republics of Central Asia and Kazakhstan. In conjunction with this, not only cotton growing but also other sectors of the cotton and agro-industrial complex will be developed further.

In the future as many as 25 million hectares of new land can be developed, with 14 million of them most suitable for top-priority development.

But the shortage of water is a serious limiting factor in the region's development.

Both in Central Asia and in Kazakhstan measures are being undertaken to relieve the pressure of the water distribution. Specialists are attempting to increase the capacity of existing reservoirs and build new ones, to raise the efficiency of irrigation systems, to draw on underground water, to reduce mineralization and contamination of water and to purify and use recovered water. But calculations show that none of this can normalize the situation.

The demands of living and time are dictating the necessity of beginning preparatory work in 1981-1985 and in 1986-1990 beginning the diversion of part of the flow of northern rivers to the Volga basin and of Siberian rivers to Central Asia and Kazakhstan. Delay in accomplishing this very important task may involve undesirable consequences of an economic, social and ecological nature not only for Central Asia and Kazakhstan but for the rest of the country as well.

According to expert estimates, the total direct production loss in the lower reaches of the Amu-dar'ya considering the prospects for development of the region amounts to about 600 million rubles per year. The water shortage is having a negative impact on employment of the population and its welfare, consumption funds, the rate of accumulation, and the rates of development of productive forces.

When there are relatively high rates of natural population growth and negligible rates of migration, each additional cubic kilometer of water makes it possible to engage 43,000 people in productive labor in various sectors of the agro-industrial complex.

8945
CSO: 1829/150

ECONOMIST ADVOCATES ADOPTION OF MEASURES TO SAVE ARAL SEA

Tashkent PRAVDA VOSTOKA in Russian 31 Jan 81 p 3

[Article by Candidate of Economic Sciences E. Rakhimov and Candidate of Geographical Sciences E. Zoltarev, sector heads of the Council for the Study of Productive Forces of the Uzbek SSR Academy of Sciences: "The Tomorrow of the Priaral'ye"]

[Text] In the CPSU Central Committee draft for the 26th Party Congress considerable attention was focused on the subject of protecting nature and the rational use of natural resources, with the goal of further improving the working and living conditions of the Soviet people.

As applied to the Central Asian region, one of the most important problems associated with this is the problem of the Aral Sea and the Priaral'ye as a whole. As is known, the southern part of this zone, Khorezmskaya Oblast and Karakalpakskaya ASSR, has substantial land, mineral and raw material, and human resources which create the prerequisite for sharply increasing the level of development of productive forces. However, the task is complicated by a number of serious factors, first and foremost the lowering of the level of the Aral Sea, along with impending processes of anthropogenic desiccation of the Priaral'ye.

At the end of last year, a joint out-of-town session of the Presidium of the Uzbek SSR Academy of Sciences and the republic's applied science conference on "Problems of the Aral Sea and the Amu-dar'ya Delta" took place in Nukus. Scientists and specialists from Moscow and the republics of Central Asia and Kazakhstan discussed the problem of accelerated development of the productive forces of this zone in light of the changing natural and socioeconomic conditions.

It was emphasized that it would be possible to increase the production of cotton, rice and alfalfa, and also livestock production significantly by providing water to Karakalpakskaya ASSR, Uzbekistan's Khorezmskaya Oblast and Turkmenia's Tashauzskaya Oblast.

This problem can be fully solved only by bringing in Siberian water.

But much could be done even now. The problem lies in accelerating work directed toward mitigating the adverse effects of the drying of the Aral Sea.

Therefore, in the CPSU Central Committee the phrase "and Aral Sea" should be added to section nine where there it says: "To accelerate the construction of reservoirs in the Black, Azov, Baltic and Caspian Sea basins," and the sentence "To carry out planning studies and, during the 11th Five-Year Plan, to begin on their basis to implement practical measures in Priaral'ye to mitigate the adverse effects of the lowering of the level of the Aral Sea." should be added to Chapter 10 following the words "to improve reclamation and the provision of water for irrigated land."

8945
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IMAMALIYEV URGES RIVER REVERSAL AS MEANS OF INCREASING COTTON PRODUCTION

LD030851 Moscow PRAVDA in Russian 18 Feb 81 p 2

[Article by A. Imamaliyev, academician of the V.I. Lenin All-Union Academy of Agricultural Sciences and director of the All-Union Scientific Research Institute for Cotton Farming: "The Irrigated Field: Problems and Opinions"]

[Text] Tashkent--From time immemorial the peoples of Central Asia have had a saying: "Put a staff in irrigated ground and a tree will grow." This was the figurative way the ancient peasants spoke of the mighty power of irrigated land. Indeed, in the conditions of Central Asia, where almost all year round the fields are warmed by the generous rays of the sun, the ground is capable of giving birth more than once. In other words in a year several harvests of various crops can be grown from it.

The chief place belongs to cotton. Given sufficient water and observance of agrotechnics, this crop produces stable high yields here. That is why its cultivation on irrigated land in Central Asia is highly profitable. The country needs an increase in harvests of "white gold." How then can we increase production of cotton?

The farmers of Uzbekistan are doing a great deal to provide the country with more of the valuable raw material. From year to year and from one 5-year plan to the next they increase harvests. Last year they passed the 6 million mark--the country received 6,237,000 tons of raw cotton from the republic's farms.

On what basis did they manage to rise to such heights? The successful implementation of the long-term program for reclaiming land had the prime effect. In the last decade alone in the republic about 0.5 million ha of new land annually was brought into use. Irrigation systems are being installed. But by itself this land would not produce the required output without the golden hands of the masters of high yields, modern equipment, the use of fertilizers and other chemical agents and the introduction of advanced scientific methods, in short, without production intensification and the improvement of farming standards. If Uzbekistan obtained over 33 quintals of cotton from every hectare last season this was the direct result of measures to intensify agricultural production. As the draft "Basic Guidelines" for the economic and social development of the country envisage, cotton growing will continue to develop by this method in the future too.

However, first, we should not rule out other possibilities for increasing cotton production and, second, it is necessary to solve more actively a number of problems inhibiting the development of the sector. I am referring primarily to the imbalance between the accelerated opening up of new areas and reserves of irrigation water. According to specialists' calculations, after 1985 the very limited water resources of Central Asia will not be capable of providing the necessary moisture for the areas which will be brought into agricultural use. Yet there are huge land reserves in this region. In the Aral Sea Basin alone there are tens of millions of hectares of land. With sufficient water, they will produce high and stable yields in the skillful hands of the farmers here. This means the country will receive more cotton, grain, vegetables, fruit and other crops.

The solution of this important national economic problem could be helped by speeding up the preparatory work for diverting part of the flow of Siberian rivers to Central Asia and Kazakhstan. And this is not the only worthwhile objective of carrying out such a necessary and important plan. Even today the shortage of irrigation water on land which has been opened up is the cause of a considerable shortfall in the harvests of various agricultural crops. For example, because of this in Syrdarinskaya and Dzhizakskaya Oblasts farmers have been forced to stop irrigation prematurely and instances of crops drying up and yields declining have become more frequent.

It is quite clear that Siberian water will not come to the fields of Central Asia immediately. In these conditions it is important to find a way out of the situation on the basis of local moisture resources and to utilize this moisture with maximum thrift. Every drop must be cherished like a nugget of gold. What is necessary for this? Primarily proprietorial attitude to matters: It would be possible to avoid or at least considerably reduce water losses if canals were concreted on a broader scale, water seepage reduced, and the irrigation network repaired expeditiously and always kept in good condition. Such measures would greatly increase the water utilization ratio. Correct capital planning of fields and consideration of the relief and special features of the soil are also of great significance here.

In Uzbekistan over half the land is now highly or moderately saline. The absence of a good operational distribution and drainage system in such areas means that cotton harvests are considerably lower and the quality of the raw cotton is poorer.

Without radical capital amelioration of saline land it is difficult to hope for high output. In this respect the example of Khorezmskaya Oblast is highly indicative--a fair proportion of the fields have been exhausted because of excess harmful substances. But now in recent years model distribution and drainage systems have been created here and with their help the level of subsoil waters has dropped and the soil has been saved from the pernicious action of salts. The fruits of this "doctoring" are very evident today: Every hectare produces 50-60 quintals of raw cotton. Throughout the oblast as a whole over 42 quintals of cotton are obtained from every hectare.

At the same time 1.5 million ha of land in Central Asia are still awaiting improvement. This will provide an extra annual harvest of over 500,000 tons of raw cotton and will promote higher fiber quality. It goes without saying that capital irrigation work requires considerable funds and the allocation of appropriate equipment. But practice convinces that the expenditure is recouped with interest.

When applying fertilizers the optimum correlation of the various types is far from always maintained. Science and advanced practice has proved that for normal plant growth and high cotton yields phosphorus must be applied in a proportion of 1:1 or at least 1:0.8 with nitrogen. But these proportions are not observed by any cotton growing republic. In Uzbekistan, for instance, the proportion is 1:0.6. The reason for this is the undersupply by industry of nitrogenous fertilizers. Few trace fertilizers are being produced--copper, zinc and molybdenum--although their use has long since been confirmed as advisable.

Nor is it possible to increase soil fertility without considering organic content. At the all-union agronomic conference held at the end of last year, it was noted that in many regions of the country a considerable drop in the organic content of the soil is being observed. According to scientists, in cotton-growing areas in the last five decades the humus content has fallen by one-third and the yield is maintained primarily on the basis of the application of high doses of mineral fertilizers. This may affect the fiber quality since mineral fertilizers only contain certain elements: nitrogen, phosphorus, potassium and sometimes zinc and copper. For normal plant growth and development a considerably greater range of nutrients is necessary. This can only be supplied by the application of organic fertilizers.

The farmers have one more powerful ally--correct crop rotation; with the help of this, the topsoil is also improving. One of the main crops in the crop rotation system is alfalfa. In 3 years it builds up about 600 kilograms of biological nitrogen per hectare, which is more valuable than the nitrogen from mineral fertilizers. Repeated experiments have shown that well-planned crop rotation promotes 7-10 quintal increase in cotton yields.

Leading farms in Uzbekistan and other republics attach paramount importance to the system of alternating different agricultural crops--the trusty method of wise farming. However this requirement is often violated, for example, the Fergana Valley cotton is sown on almost 80 percent of the sowing area. The farms here are faced with the task of finding as rapidly as possible land reserves for the full introduction of cotton-alfalfa crop rotation. Otherwise there is a threat of an outbreak of wilt--one of the most dangerous cotton diseases. It seems agricultural organs must think about redistribution of crops so that in all areas of the cotton-growing republics it is possible to master scientifically based cotton-alfalfa crop rotation in the next few years.

The achievements in the sphere of irrigated farming in our country are indisputable, but they must be consolidated and increased. For this it is important to continue to carry out broad scientific research in developing new and more progressive methods of cultivating crops, mechanization and chemical treatment, selection and seed-growing.

Life demands the utmost striving to introduce scientific achievements into practice as rapidly as possible and to strengthen the alliance between scientists and producers. In this respect it is important to aim more boldly to create science-and-production and scientific academic associations. Thus it would be expedient to organize a science-and-production association for cotton-growing on the basis of existing research establishments, VUZes, design bureaus and experimental farms in the sector. This would help not only to solve more rapidly topical problems of science and production but also to accelerate the introduction of innovations and to improve the training of highly skilled specialists for modern farming.

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SCIENTIFIC AND TECHNICAL ANALYSES

ENVIRONMENTAL PROTECTION ISSUES AND THE SOUTHWARD DIVERSION OF SIBERIAN RIVERS

Washington, D.C. SOVIET GEOGRAPHY: REVIEW AND TRANSLATION in English Jan 79 pp 15-21

[Translation of article in Russian by N. I. Mikhaylov, V. A. Nikolayev and I. Ye. Timashev, in VESTNIK MOSKOVSKOGO UNIVERSITETA: GEOGRAFIYA, Moscow, No 5, 1977 pp 50-56]

[Text] Abstract: Under contract to Soyuzvodproyekt, the water-management agency, the authors investigated environmental protection problems associated with the proposed diversion of the streamflow of Siberian rivers to the arid regions of Kazakhstan and Central Asia. On the basis of physical-geographic investigations; a wide range of measures are recommended, ranging from the points of water withdrawal on the Ob' River, to the zones along the main diversion canals and the new areas of irrigation and pasture watering developed as a result of the project. It is stressed that some of these measures must be taken as early as the drawing up of engineering designs for the water-diversion project as well as during the construction stage and after completion of the project.

The basic guidelines for the 10th Five-Year Plan (1976-80) called for "research and engineering design work relating to the problem of the diversion of part of the streamflow of North Russian and Siberian rivers to Central Asia, Kazakhstan and the Volga basin" ("Materialy XXV s"yezda KPSS" [Proceedings of the 25th Party Congress], Moscow, 1976, p. 203). An important part of the research now under way involves the design of water transfer in the so-called Midlands Region of the USSR, a vast territory situated between the Urals and the Yenisey River; and between the Kara Sea and the southern frontier of the Soviet Union, with a total area of 7 million sq. km, a population of 50 million. This territory contains millions of hectares of cropland and pasture and most of the irrigable land of the USSR.

The water-diversion design worked out by the Soyuzvodproyekt agency calls for the first-stage withdrawal of 25 cu. km. of water a year from the Ob' and Irtysh basins and its transfer through the proposed Ob'-Caspian canal as far as the Aral Sea. The length of the canal, which would run along the Tobol

River valley and through the Turgay trough to the lower reaches of the Amudarya, would be 1,700 km; its depth would be up to 15 m, and its width 500 m. In subsequent stages of the project, water might be withdrawn also from the upper reaches of the Ob' River and partly from the Yenisey, with an increase in the total transfer volume to 100 cu. km. and the extension of the canal to the Caspian Sea.

The implementation of the project is expected to yield benefits by making possible the utilization of millions of hectares of land in Kazakhstan and Central Asia that at the present time either is not being used at all or only extensively. On the other hand, the diversion of such a large volume of water is expected to have an environmental impact on the area of withdrawal, the transit area and the area of destination. Therefore, consideration should be given as early as the engineering design stage to the three following aspects: First, the character of likely ecological impacts and the areas affected; second, the nature of both positive and negative impacts; third, a system of measures designed to enhance positive impacts and weaken negative impacts. It would also be useful to define and implement measures that would insure environmental protection, enrichment and amelioration throughout the Midlands Region.

The present paper is devoted to some of the ecological problems to the north of the Syrdarya that were investigated under contract with the Soyuzvodproyekt agency.

Any environmental protection measures would have to consider: 1) the peculiarities of the environment in various parts of the study region as well as their landscape structure; 2) the changes likely to result from the diversion project; 3) the existing Soviet legislation dealing with protection of the environment, land, water, forests, mineral resources, etc. In view of the uniqueness of the diversion project, it may be necessary to work out entirely new approaches to environmental protection in the Midlands Region and possibly back it up with additional legislation. There is also a need for predicting the likely environmental impact of the proposed water-management structures and of the use of the diverted water for irrigation and pasture watering as well as the measures that may be required for special-purpose protection of the environment, for example, the creation of protected water-conservation zones.

In the area of water withdrawal, in West Siberia, the impact of the proposed reservoir on the environment of the upper and lower reaches would have to be assessed. The present plan calls for headworks on the Ob' River just below the mouth of the Irtysh River. The flow of water would then be reversed by pumping stations along the Irtysh to Tobol'sk through three barrages or via a special canal envisaged by the project. From a small reservoir at Tobol'sk, whose water level would be roughly the present level of the Irtysh River, the water would then be diverted into the Main Diversion Canal.

This plan is now being advanced instead of an earlier proposal calling for the withdrawal of water directly from a large reservoir at Tobol'sk. Physical-geographic analysis showed that the creation of such a reservoir, 1,000 sq. km in area, would flood the meadow and forest landscapes of the floodplain and some of the forests and swamps on the first river terrace. Some cropland and useful forest land would also be under water. The creation of a large reservoir in the southern taiga, where landscapes already suffer from excess moisture, might raise the watertable and thus further enhance the formation of swamp and waterlogged forest, some of the present meadow land would be gradually converted to meadow swampland, and existing swamps would become even more waterlogged.

The new version calling for a smaller reservoir at Tobol'sk will be more costly in view of the additional electric power required to pump water from the Ob' River upstream along the Irtysh. However, it will be more cost-effective from the standpoint of avoiding environmental deterioration and preserving valuable farmland and the conditions of industrial development in the Irtysh valley around Tobol'sk.

Other measures that may become necessary would include compensatory development of farmland and amelioration of forest quality; protection and renewal of fishery reserves, including fish ladders and other protective devices; and prevention of hydraulic pressure from the proposed canal that might further raise the watertable in wet portions of this swampy forest zone.

The actual diversion canals--the Main Canal, Kulunda Canal and Irtysh-Tobol Canal (depending on the design)--pass through steppe and semidesert. These are regions of crop and livestock agriculture that require strict land conservation in the design and operation of water-management projects. Alone the construction of the canals would remove tens of thousands of hectares of land from agricultural uses. The width of land allocated to these canals should therefore be kept to a minimum.

Special attention should be given to the conservation of steppe forest groves in the zone of the Main Diversion Canal (the Aman-Karagay and Naurzum-Karagay forests). With a view to preserving these unique forests, canals and approach roads should be located at least 5 to 7 km away.

The desert landscapes in the zone of influence of the Main Canal (sand ridges and mounds, solonchaks, claypans) are more susceptible to anthropogenic impacts than some of the more northerly landscapes. Steps would therefore have to be taken to prevent or at least reduce negative environmental reactions to the water project by lining the canal in these areas, inhibiting the destruction of hydromorphic landscapes and of sandy areas as much as possible, and limiting the local use of the canal.

Measures intended to protect the environment of the region and to insure optimal use of water resources will have to be worked out together with the project designs. These measures would include:

(A) careful planning of the amounts and the priorities of use of the diverted water for irrigation and pasture watering in the southern half of the Midlands Region as well as the maximum volume of withdrawal from the Ob' River.

(B) the elaboration of new techniques and improvement of existing methods for irrigating land in the desert, semidesert and steppe zones to insure more efficient water use and prevent secondary salinization of irrigated land; proposed methods should be the subject of experimentation in special testing grounds;

(C) cheap and reliable methods of lining canals to reduce infiltration, especially in sandy desert;

(D) recultivation of canal dikes and amelioration of the canal zone, requiring the selection of suitable tree, shrub and grass species and experimental cultivation in testing grounds;

(E) working out methods for the development of compensatory agricultural land in waterlogged areas of the swampy forest zone, and testing of the proposed methods in experimental plots;

(F) protection of fishery resources in the Ob' and Irtysh basins;

(G) drafting of special environmental protection legislation for the water-diversion area.

Experience has shown that construction agencies often ignore environmental protection measures, causing harm to natural landscapes. It would therefore be desirable to set up a special control commission, made up of representatives of interested ministries, environmental protection agencies and local authorities, to insure that construction agencies observe environmental regulations. The charter for such a control body, listing its rights and obligations, should be drawn up and approved at a high level before the start of construction.

The alienation of land for construction purposes must be kept to a minimum in the area of future reservoirs and dams and in new irrigation districts. In the swampy forest zone, the future reservoir bed must be cleared, trees must be felled and peat layers removed in areas slated for flooding.

Every effort should be made in the course of construction work to preserve existing forests, especially near reservoir shores and canals.

Reservoir shores and canal banks must be protected against abrasion and slumping. At the same time, work should be pressed in the swampy forest and wooded steppe zones to develop compensatory areas of agricultural land and useful forest as well as recreational zones along reservoir shores, subject to strict controls.

Since local building materials (gravel, sand, brick clays, etc.) will be used in construction, contractors will have to make every effort to develop quarries with the least damage to the environment; and then recultivate the mined land in accordance with existing legislation.

Canal construction in chernozem and chestnut soils must start with the careful removal by bulldozers and scrapers of the humus soil horizon (to a depth of 30 to 40 cm), which should then be stacked for later use in recultivation.

In steppe and semidesert, there are many lithochemical varieties of earth materials (saline clays, loesslike loams, sands and gravels) that may be excavated and either discarded in spoil banks or used in the construction of canal dikes. When freshly dumped, these materials tend to be unstable and subject to water and wind erosion, slumping, compacting, etc. This may produce the deformation and silting in the canal bed as well as the degradation of nearby farmland.

Spoil banks and canal dikes should therefore be strengthened and protected against any anthropogenic loads, such as road construction or the grazing and watering of livestock. For the watering of nearby grazing lands, water should be diverted from canals through channels or pipes into the interior of the steppe.

Since the waterlevel in canals will usually be higher than the watertable, there will be some loss of water into the canal bed and sides and a rise of the watertable. A canal zone 6 to 9 km wide is likely to be affected by the changing moisture conditions along most of the Main Canal, including exudation of the infiltration water and a rise in the watertable to within 2 meters from the surface, with some capillary water actually reaching the surface. A canal zone of such width would generally be affected in the swampy forest, wooded steppe, steppe and semidesert, but the affected zone is likely to expand to several tens of kilometers in some areas, especially in desert depressions, where waterlogging and solonchak fo nation may be expected. These phenomena might be avoided by soil drainage systems and lining of the canal.

An effort should be made to recultivate land in the canal zone after construction; this might include grass seeding and afforestation on exposed subsoils to convert disturbed land into pasture and forest. The most favorable soils for biological reclamation are loesslike loams; loose sand and especially saline clays are less suitable. Unsuitable subsoils should be covered by loam to as great a depth as possible. Biological reclamation can be further promoted by covering exposed subsoil with a humus layer of 20 to 30 cm, using previously stacked humus material.

Our experience with the biological reclamation of disturbed land in the steppe of the Midlands Region suggests a need for selecting plant species that are both drought- and salt-resistant. The best plants for that purpose are perennial grass mixtures. The most important components should be legumes (sweet clover, alfalfa, sainfoin) which enrich the soil with assimilable nitrogen, as well as cereal grasses.

Other suitable plant species for the reclamation of disturbed land are trees like the weeping birch, box elder, scotch pine (in the steppe) and shrubs like acacia, sweetbrier, Russian olive, tamarisk, salt tree, dzhuzgun (Calligonum) and pea shrub (in steppe and semidesert).

In the process of construction, steps must also be taken to guard against water pollution during the operation of the canals. This may require the setting aside on both sides of the canal of a protected zone in which access to livestock and the discharge of wastewater would be prohibited.

Together with the completed project, any operating rules and environmental protection measures required by law would enter into effect. Water users whose activities might affect the condition of reservoirs and canals would be expected to take steps to prevent pollution and to insure optimal water use, especially for irrigation.

On the Ob' River, care must be taken not to exceed the approved volume of withdrawal for diversion to the south (especially in dry years) in accordance with seasonal needs both in the areas of irrigation and pasture watering and in the lower reaches of the diversion reservoir. In an effort to neutralize the impact (especially on fisheries) of a reduction of the height and duration of the flood stage in rivers of the swampy forest zone, management of the reservoir must provide for regular drawdowns intended to flood the floodplain (or parts of it) in the lower reaches. The flooding of the middle level of the floodplain, where the most valuable hay meadow occurs, is particularly important. Drawdowns for flooding the upper level of the floodplain will probably not be desirable since prolonged flooding of the upper level is likely to cause damage to the local economy.

Care must also be taken to maintain a minimum waterlevel in the lower reaches for flushing purposes since a reduction of streamflow associated with the project would raise the concentration of pollutants entering the river with industrial and household wastes. Reservoir drawdowns for flushing purposes are particularly important in winter on the Ob' River in view of common fishkill phenomena. These affect not only fisheries, but also the quality of water used in industry and households. Measures are also needed to preserve water quality in the diversion reservoir and canals, using the criteria for the maintenance of water-supply sources. A reduction of reservoir drawdowns for flushing purposes would be fraught with particularly undesirable consequences in the swampy forest zone since a decline in the natural minimum streamflow would occur at the expense of runoff from areas not affected by fishkill.

The construction of diversion canals, irrigation of large areas of cultivated land and the watering of rangeland may facilitate a resolution of many problems of environmental protection in the steppe and semidesert landscapes of Kazakhstan, including control of soil blowing and overgrazing of natural range.

The usual method of controlling wind erosion, namely the planting of windbreaks, has been hampered by the aridity of climate and the high lime and salt content of soil and subsoil. The planting of windbreaks may be greatly facilitated by periodic watering of seedlings.

The overgrazing of natural steppe and semidesert range arises mainly because of the uneven livestock load on range provided with watering sources and range not supplied with water. The range would be watered more uniformly as a result of the construction of feeder pipe from the main diversion canals to stock-watering places. It would also be useful to introduce pasture rotation and to improve pastures periodically by reseeding and irrigation, which would convert steppe and semidesert range of low productivity into productive pasture.

The availability of water in the steppe and wooded steppe of the Midlands Region should also be used to revive the dense network of lakes that have gradually been drying up in recent decades. We can envisage a diversified lake economy in the future, including fisheries, the raising of waterfowl and fur animals such as muskrat, the harvesting of natural fertilizer (the organic sapropel ooze of lake bottoms), aquatic forage plants (duckweed) and crustaceans (the mormysh, a gammarid amphipod). The revived system of lakes would also constitute an important element in the overall watering system.

Once the diversion canals start functioning, it will be quite natural for the local population to try to settle along the new watercourses. The formation of new settlements will be inevitable. However, areas should be strictly allocated for that purpose and, insofar as possible, the existing settlements of canal builders should be transferred to the local population. Inevitably, there will also be the construction of industrial establishments along the canal, but they must not be permitted to pollute the water and the soil. Similar restrictions should be imposed on recreational zones.

Environmental protection considerations should also guide the irrigation of new cropland and the development of stockraising (the creation of new watering places, limitations of the livestock load on rangeland, control of bacterial infestation of water, etc.).

The use of the Siberian water on the right bank of the Syrdarya will be quite limited, and the needs of the northern Aral region will have to be met from the Syrdarya's own streamflow, groundwater and artesian water. The Main Diversion Canal in this region will have to be dug through highly dynamic landscapes of loose sand and saline depressions so that the maintenance of canal lining, prevention of soil salinization and the afforestation of sandy areas in the canal zone will assume particular importance.

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PREDICTIVE EVALUATIONS OF THE CLIMATIC CONSEQUENCES OF THE REDISTRIBUTION OF WATER RESOURCES IN THE CENTRAL REGION OF THE USSR

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[Article by L. A. Chubukov, Yu. L. Rauner, K. V. Kuvshinova, L. S. Potapova and Yu. N. Shvareva, Geography Institute USSR Academy of Sciences]

[Excerpts]

Abstract: On the basis of field observations and office processing of extensive data the authors evaluate the influence which the redistribution of waters in the Central region will exert on changes in the principal components of the meteorological regime and on the structure of weather, as well as on the moisture cycle over the Central Asia region. The conclusion is drawn that the macroclimate will not change; directed changes are expected only at the micro- and mesolevels; they will also be partially reflected in types of weather.

1. Some general points. A geosystemic analysis and predictive evaluations of possible changes in the environment in connection with proposals being developed for the shifting of some of the river flow into the arid regions of the USSR is a timely problem in Soviet developmental geography. In this article we discuss some possible changes in the climatic link, representing an important component of the entire natural complex. The authors proceed on the assumption that in the next 15-20 years, that is, for all practical purposes to the end of the present century, no clearly expressed climatic trends are expected in this territory, in particular, its thermal regime and atmospheric humidity. In any case, short-period climatic anomalies with a cycle from one to several years, caused by the stochastic variability of the macrocirculation regime, will create dispersions of the climatic fields, in absolute value exceeding the trend dispersions considerably. The work recently carried out for Western Siberia (Glukh, Kononova, 1978) also revealed some differences in the atmospheric moisture in this region, especially its northern regions, being manifested during the more prolonged period between the last two circulatory-climatic epochs of the 20th century. A general tendency to a decrease of precipitation and a lowering of temperature is proposed as a preliminary background forecast for the next epoch. In the future further corrections can be introduced with refinement of our concepts concerning the possible character of the impending circulatory-climatic epoch both for the entire northern hemisphere and for a particular sector.

An analysis of available climatological studies for the Central region (Orlova, 1962; Shvareva, 1963, 1976; Zhukov and Potapova, 1972; Chubukov and Shvareva, 1959; Shvareva, 1969; Uteshev, 1972; Kuvshinova and Chubukov, 1958; Kuvshinova, 1968; Kuvshinova, Orlovskiy, 1978; Kuznetsova, 1978, et al.), and also materials from expeditionary and office investigations of the long-term regime of individual meteorological elements and local weather in different parts of the region, will make it possible to make some preliminary predictions. The most important of these is that the diversion of the waters of West Siberian rivers (Ob' and Irtysh) to Kazakhstan and Central Asia in a volume of 25 km^3 will not lead to a change of the present-day macroclimatic characteristics of the entire Central region, governed by the characteristics of the radiation regime and atmospheric circulation in the extratropical latitudes of the northern hemisphere, and also the conservative character of the major properties of the geographic medium in this region.

The principal directed changes in the meteorological regime are expected only at the micro- and mesoclimatic levels, and to a certain degree may also be reflected in a change of weather classes. The most important changes should be manifested in the arid parts of the considered territory, especially due to a sharp change in the thermodynamic properties of the underlying surface and transformation of the structure of the thermal and radiation balances in the atmospheric surface layer. The vertical scales of such "disturbances" are characterized by several tens of meters and the horizontal scales by several kilometers.

Although such a conclusion to some degree has the characteristics of an expert evaluation, it is quite convincing since it has been supported by most climatologists participating in the discussion of this problem at an interdepartmental conference at Valday early in 1978 (see Malik, et al., 1978).

Below we give a detailed exposition of the most important results of investigations of different climatological aspects of this problem carried out in the Climatology Section Geography Institute USSR Academy of Sciences.

Studies recently made (Budyko, et al., 1978) indicate, in particular, that applicable to the Central region of the USSR in the 21st century there can be a substantial increase in atmospheric moistening and an increase in the level of the resources of the flow, primarily in regions of extraction of water with a relatively small change in the hydroclimatic regime in arid regions. In the future it will probably be necessary to make a more detailed examination and comparison of special climatic and ecological predictions for the more remote future for the particular variant applicable to the problems involved in the geographical redistribution of water resources.

We emphasize in conclusion that the evaluation of background changes in climate in the coming decade unquestionably is one of the key problems in a geographical prediction of the state of the environment as a result of interbasin diversion of streamflow. However, the climatic aspect of this problem follows directly from solution of the timely problem of superlong-range prediction of the dynamics and evolution of global and regional climate, a fundamental approach to whose solution has only very recently been made by climatologists. Its scientific content is complex to the highest degree and in the future success will be dependent to a considerable extent on the concentration of efforts of different scientific directions in the modern science of the earth's climate.

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5303
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TWO RIVERS REVERSAL MODELS DEVELOPED BY INSTITUTE

Tashkent ZVEZDA VOSTOKA in Russian No 12, 1980 pp 13-19

[Article by Viktor Dukhovnyy, director of SANIIRI [Central Asia Scientific Research Institute of Irrigation]: "Advances in Irrigation"]

[Excerpt] The extensive application of the advances of scientific and engineering progress as a whole with respect to water management in the republic involves large capital investments and long time periods. In spite of all the measures associated with rational utilization of the existing water resources their shortage steadily will become more acute. An effective means of fundamental solution of many of the problems generated by the water shortage is the redirection of water into Central Asia from those regions of the country where there is a water surplus. Siberia has just such a surplus. The resolutions of the 25th CPSU Congress transferred the river reversal problem from the sphere of hypotheses to the rails of practical realization. In the resolutions of the Congress it was stated: "To carry out scientific investigations and then perform on this basis planning studies associated with redirection of part of the flow of the Northern and Siberian rivers into Central Asia and Kazakhstan and into the Volga River Basin."

The river reversal plan has no analog in worldwide practice. The resolution of so grandiose a task can be carried out only by the powerful planned economy of a socialist society. More than a hundred of the country's scientific and planning and surveying organizations are already occupied with the realization of this epochal task.

Studies have been made at SANIIRI for a scientific basis of specific aspects of the river reversal plan, primarily the hydraulic calculations of the parameters of the project. Two unique large-scale models have been constructed at the Institute. Studies related to selecting the most rational scheme of water diversion from the Ob' River into the reversal canal without the use of dams are being carried out on one of the models. Studies are being made of the schemes of the hydro system to be constructed near the city of Belogor'ye, where the Siberian water will begin its two-thousand-kilometer run to the cotton plantations and orchards of Central Asia. The parameters of the future river reversal canal are being studied on the other model. The scientists must provide the planners with precise recommendations on the dimensions of the canal and the water flow velocities in order to ensure stability of the stream bed and minimal volume of earthwork. The researchers are developing a prognosis for the change of the quality of the water in the Aral Sea basin as a result of the reversal and are participating in the social and economic justification of the need for this gigantic project, which is extremely important for successful development of the Central Asia region.

Sh. R. Rashidov, first secretary of the Uzbek CP Central Committee and candidate member of the Politburo of the CPSU Central Committee, wrote in an article entitled "On the Road to Unity and Fraternity" the following: "It is becoming clearer than ever that the united efforts of the peoples, their unified will, their collective thought are capable of resolving any problem of our social life. This is showing up with new vigor in the broad and creative search for ways and means for the realization in the future of a tremendous project--the redirection of part of the flow of the Siberian rivers into Central Asia, which will make it possible to irrigate millions of hectares of presently arid lands and will make it possible to initiate a sharp increase in the rate of development of the agrarian sector of the economy of the entire country."

In formulating the basic objectives which the party set before the country's agriculture in the 10th Five-Year Plan, L.I. Brezhnev, general secretary of the CPSU Central Committee, said in his Accountability Report at the 25th Party Congress: "....to secure for the country a reliable supply of food and raw materials, always to have adequate reserves for this purpose." The scientists of Uzbekistan's water management organizations are contributing their part to the resolution of this national task.

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THE PROBLEM OF THE CASPIAN SEA

Moscow VODNYYE RESURSY in Russian No 5, 1980 pp 5-20

[Article by D. Ya. Ratkovich, USSR Academy of Sciences Institute of Water Problems, published as a starting point for discussion]

[Text] The Caspian Sea is the earth's largest water basin without an outflow--it collects water from a territory of about 3 million km^2, and evaporates it from a water surface area presently totaling about 360,000 km^2. The northern Caspian, which has an average depth of about 5 meters, is sharply delimited by its bottom relief.

The natural inflow into the sea is estimated at 315 km^3/year, with more than three-fourths of this total being provided by the Volga.* The sea's mean salinity is stable (close to 13 $^0/_{00}$), but according to (21) within the limits of the northern Caspian, freshened by Volga discharge, salinity fluctuates significantly (from 5 to 12 $^0/_{00}$).

More than 100 million hectares of agricultural land are contained in the basins of rivers flowing into the Caspian. More than a third of the country's industrial and a fifth of its agricultural products are produced and a third of its hydroelectric power is generated in these basins. They are responsible for a fourth of the total fish production of the country's inland water basins, and the sturgeon catches make up 90 percent of the world total. Marine and river transportation is broadly developed in the basin: Just the Volga and its tributaries alone handle 70 percent of the freight turnover of the European USSR's inland water routes.

The demands placed upon the regimen of the Caspian Sea and of the rivers flowing into it by different sectors of the economy are inconsistent, which creates a number of conflicts (16).

Thus development of irrigation has significantly reduced the flow of the basin's Caucasian rivers, and the plans for irrigating new land will noticeably

* Different publications offer different estimates of the inflow into the sea. However, because apparent evaporation from the sea's surface is defined as the remainder of the equation for the water balance, change in normal inflow would also change normal evaporation; therefore these minor differences have practically no influence on forecasts of the sea's level (*Author*).

reduce the flow of the Volga, the Kura, and the Ural. Because the flow of the Volga is subjected to multiple use, there is not enough water to support development of irrigation within the Volga basin (due to the limited capacity of the reservoirs); considering further growth of the annual withdrawals of more than 10-15 km^3 for these purposes, in low-water years we will have to settle for reduced energy production by hydroelectric power plants and narrower navigable channels.

Moreover maintenance of navigable depth along the lower Volga requires a water flow rate of up to 4,000 m^3/sec below the Volgogradskiy Hydraulic engineering complex in the summer-fall low-water period, which is about twice the domestic consumption. The guaranteed output of hydroelectric power plants in the Volzhsko-Kamskiy cascade and the Mingechaurskaya (on the Kura) and other GES's can be achieved in the presence of a significant increase of winter domestic water consumption only by decreasing the height and duration of the high-water period. This has an unfavorable effect on spawning conditions in the lower reaches of the Volga, as well as on the moisture supply afforded to land of the Volgo-Akhtubinskaya floodplain and the delta. On the other hand the dumping of water unused out of Volgogradskaya Reservoir to provide water to land lower down and to maintain the minimum necessary spawning conditions on the Volga would be accompanied by significant energy losses.

Finally, a decrease in the flow of water into the Caspian owing to irreversible withdrawal of water from the basin would promote increased salinization of the sea's northern part and create the conditions for a decline in its level. If it turns out to be long-lasting, a further drop in the level of the Caspian Sea in comparison with the present level would do tangible harm to fisheries, and it may elicit undesirable, irreversible processes.

For these reasons the water management balance of rivers in the Caspian basin, and mainly the Volga, is already being looked at with concern, even though the flow withdrawals are relatively low: about 10 percent in the basin as a whole, to include about 5 percent of the Volga's flow.

Low water in the 1930's dropped the level of the Caspian Sea by about 2 meters, and the increasing withdrawal of the flow of the basin's rivers and the expenditure of water to fill reservoirs caused further reduction of its level (14); the present position of the sea at about the -29 meter mark is approximately in keeping with the gravitation level, given the present irreversible losses of flows estimated at 35-40 km^3/year.

Change in the level of the sea affects fisheries primarily. The most valuable migratory fishes--the sturgeons, salmonids, and fish of secondary commercial importance--enter the rivers only for spawning as a rule, living in the seas for the most part; the seas are where the fish put on weight: The lowest links of the trophic chains involved in the transformation of biogenic flow into the feed base of fish form here.

The high biological productivity of the Caspian is associated with active solar radiation, the influx of large quantities of biogenic salts, intense photosynthesis in the vast shallow-water zones, and the unique composition of fauna in the producing ecosystems (6). The total catches per km^2 of the north Caspian have been more than 50 centners per year. Note that the species composition of the flora and fauna may be preserved in the face of significant violations of the optimum conditions (this has occurred many times in the past). The problem here is to restore the high biological productivity of the Caspian Sea (16).

The biological productivity of the Caspian Sea, as was noted earlier, depends mainly on the biogenic flow of the Volga and on freshening of the shallow zone of the north Caspian (this supports effective photosynthesis) by waters of the Volga and the Ural. This is the location of the principal fish fattening ground. The salinity and saturation of biogenic salts in the northern Caspian depend not only on the flow volume but also on its distribution in space, which is typified by relatively abundant inflow of water into the western part of the northern Caspian, and limited inflow into the eastern part. Reduction of the Volga's discharge (particularly during high-water periods as a result of flood control) and a drop in the level of the sea have resulted in greater flow in western and lower flow in eastern channels of the delta.

As a result of a drop in sea level, the area of the northern Caspian decreased by about 35,000 km^2 between the 1930's and 1975; this includes a decrease in productive area of 15,000-18,000 km^2 (Kaydak Bay and contiguous shallow-water zones have never been productive).

Bottom relief has a great influence on the salt regimen of the western and eastern zones of the northern Caspian. Between 1933 and 1975 the cross section along a line extending from the island of Dzhambay to the island of Morskoy decreased by more than two times. Water exchange between the western part of the northern Caspian, which is freshened by the Volga, and its eastern part, which is freshened by the Ural, is decreasing. When the sea level drops to the -29.5 meter mark, the area of the limiting cross section along the line extending from Dzhambay to Morskoy would decrease to 0.2 km^2, which would be only 27 percent of the 1933 cross-sectional area. The water area of the northern Caspian exhibiting a salinity above 12 $^0/00$ (that is, water not suited to the life of brackish-water fauna), would climb to 40,000 km^2. Naturally the Ural would not be able to freshen the eastern part of the northern Caspian (40,000-45,000 km^2), and the entire water area east of the Dzhambay-Morskoy line may transform into a salt lake with any further decline in sea level. As the level of the sea decreases, an increasingly larger proportion of Volga waters will flow through channels in the western delta directly into the central Caspian, carrying biogenic elements away.

A water divider has now been prepared for operation at the top of the Volga delta. With its help, the bulk of the high-water flow will be channeled into the eastern delta (especially in low-water years). The idea behind the water divider is that it would be better to supply a lot of water to a little of the delta than to supply a little water to all of the delta. Moreover it would become possible to keep the water in the central part of the northern Caspian fresh, and to maintain the inflow of nutrients in the face of a certain decline in Volga flow and sea level. However, the water divider will not completely compensate for unfavorable changes in the regimen of the northern Caspian in response to a decline in its level.

We must reassess the demands imposed upon the Caspian Sea by different sectors of the national economy in connection with the planned measures for optimizing the sea's regimen (6). In this case we should not fail to note that the natural regimen of the sea is not optimum from the standpoint of national economic and natural complexes relying on it; if the optimum is to be achieved, compensatory measures will have to be implemented. Recovery of the natural regimen of a water basin can sometimes require great outlays by water users adapted to an altered regimen.

From the standpoint of fishing interests the present low position of the sea's level is critical. The requirements imposed upon the sea's level by other economic sectors can be briefly summarized as follows.

On one hand a decrease in sea level would somewhat worsen the conditions for water intake, but any significant rise in the level of the sea would mean the flooding of many inhabited regions, enterprises, and structures (bridges, gas and electricity lines, quays, and so on); on the other hand a decrease in its level has created better conditions for the growth of reeds--the raw material of cellulose industry.

A decrease in depth associated with a drop in sea level would cause change in the ice regimen of the northern Caspian unfavorable to petroleum industry: The drifting of ice into the vicinity of oilfield facilities on Apsheron Peninsula and to Dagestan could lower the stability of platforms, reduce the depth of approaches to oilfields, piers, and ship repair enterprises, and make it necessary to perform additional dredging operations. A further drop in sea level would make it more difficult to supply industrial water to the oilfields.

Marine transportation is experiencing difficulties due to the decreasing depth of approaches to old ports (new ports, built after the drop in sea level in the 1930's, were designed to allow for the present situation).

Within the limits of the Caspian's western coast, which is freshened by Volga discharge, weakly mineralized water is of interest as an irrigation resource, and in part as a source of water for agriculture. If the sea level drops, we will have to expect a certain degree of freshening of coastal waters in this zone.

Even considering the present low level, certain sections of railroad passing through low-lying places can experience damage; a rise in sea level of any significance whatsoever would be undesirable from this point of view.

In general the national economy is probably interested in an insignificant rise in sea level--approximately to the marks about which it fluctuated in the early 1970's. In essence the issue of attaining an optimum level for the Caspian Sea has lost its importance. In the situation now at hand, we need to halt the decrease in sea level as quickly as possible and, despite growth in water consumption, insure that it does not drop below the -28.5 meter mark on the average, with permissible temporary decline in climatically unfavorable periods to not below the present mark (-29 meters).

The swift growth in water consumption in southern sea basins, and particularly the land-locked Caspian Sea, is to be expected. On one hand the principal water user--irrigation--is developing most intensively in the arid zone, where evaporation exceeds precipitation; on the other hand it is only within the limits of this zone that water basins without an outflow may arise (topographic depressions having sufficient surface area to permit evaporation of inflowing water and precipitation falling on this surface). Therefore at a particular level of the economy's development it will become necessary to implement compensatory measures aimed at minimizing the unfavorable consequences of reduced inflow into the sea.

Compensatory measures may take several directions: a) direct compensation of flow withdrawals by transfers of water from water-abundant regions to the basins of the southern seas; b) reduction of evaporation from the sea surface by separating off parts of the water basin that are of secondary importance to biological productivity; c) redistribution of river flows into the seas throughout their water area; d) regulation of flow rate in the water basins.

These compensatory measures are intended to be long-term measures, and as a rule they require a long time for planning and exploration, for construction of the appropriate facilities, and for the start-up of their normal operation. Hence it follows that they must be based on predictions of the sea's regimen reaching at least several decades into the future.

The present forecast of the sea's regimen is in keeping with the accepted hypothesis that water consumption will grow within its basin, and with the calendar schedule for implementing water management measures influencing inflow. Such raw data, extending several decades over the future, are always conditional to one extent or another, since the plans for the national economy's development are not written so far into the future, since water use technology may experience significant changes, since the time required to make water management facilities ready for normal operation cannot be accurately predicted, and so on. Therefore beyond at least the immediate decade, the hypothesis that water consumption will grow cannot be accepted without reservation; water consumption must be represented by a "branching" of values diverging with time, and the calendar schedule of water management measures must be given in several variants. In this case the principal water user--irrigation--must be described not by estimated requirements for water based on a dry year, but rather by mean perennial values, which may be about 15 percent lower than the estimated values of, for example, the Caspian Sea basin.

The stochastic nature of geophysical processes and absence of dependable weather predictions make it necessary to describe streamflow and other elements of the water balance in terms of probabilities, given a stable norm, and the stability of other parameters of the probability distributions (20).

In principle the elements of the water balance, which reflect changes in climate, are unstable. However, in this case we are dealing with relatively short intervals of time: On one hand the time of observations does not usually exceed 60-80 years, while on the other hand the characteristics of the regimen are extrapolated just a few decades into the future because, as was mentioned earlier, it is impossible to predict development of the economy and of water use technology with a greater lead time. In this situation a description of the elements of the water balance may be based only on the hypothesis that they do remain stable; as far as the sea is concerned, considering the changing character of water use and implementation of compensatory measures, its regimen will always be unstable.

Prediction of the water level is the starting point for predictions of different elements of the regimen of a water basin without outflows--that is, of hydrochemical, hydrobiological, and other processes occurring within the water basin. The procedure for predicting water level can be thought of as sufficiently developed today (4, 8, 12-14, 17, 18, 22, etc.).

Water entering lakes and seas without outflows is evaporated from their surface; natural fluctuations in river discharge, in the amount of precipitation falling on the surface of the water basin, and in the amount evaporated from the surface cause fluctuations in the level of relative equilibrium (the gravitation level).

When we use a linear approximation of the relationship between the level of the sea z and the area of its water surface $F=a+bz$, the gravitation level would take the form

$$\bar{z} \approx \frac{1}{b}\left(\frac{V}{\bar{e}} - a\right), \quad (1)$$

where V--mean inflow into the sea, with a consideration for streamflow withdrawals in the basin, and for replenishment of streamflow by diversions of water from without; $\bar{e}$--normal apparent evaporation (evaporation minus precipitation) from the sea surface.

When the shores are other than vertical, the fluctuations undergo damping, and the more gently the shores slope, the greater is the damping effect (for example a 1 percent decrease in level lowers the gravitation level by a third of a meter in the Caspian Sea).

Predicting the level of a water basin without an outflow for a particular period of time in the future boils down to solving two problems--determining the water level in average hydrometeorological conditions, and evaluating its probable deviation. For the Caspian Sea, we can limit ourselves to analyzing the trend of the water level over yearly time intervals, inasmuch as changes occurring within a particular year are found to be approximately one order of magnitude smaller.

In average hydrometeorological conditions, if the the sea's level differs from the gravitation level, it will change in time in accordance with a law close to exponential.

When streamflow withdrawals in the basin increase and the influence of compensatory measures upon inflow into the sea varies, it would be best to perform the computations successively in relation to yearly intervals using the formula

$$z_{i+1} \approx z_i - \bar{e} + \frac{V_i}{F_i} = z_i - \bar{e} + \frac{\bar{v} - u_i^- + u_i^+}{a + bz_i}, \quad (2)$$

where z_i--water level in the i-th year; $\bar{v}$--normal inflow; u_i^- and u_i^+--volumes of water withdrawn from the basin and added to it respectively, in the i-th year.

The probable deviation of the sea's level Δz_i from that in keeping with the average meteorological conditions of the period of the forecast can be expressed as a conditional standard deviation of the level, σ_i, depending on natural variability of the elements of the water balance, on their autocorrelation and mutual correlation*, the morphometry of the water basin, and the forecasting period i. The confidence limits for a forecast with lead time i can be written in the form

$$z_i^{*} = z_i \pm \Delta z_i = z_i \pm \mu\sigma_i, \qquad (3)$$

where the quantile of the normal distribution μ is selected depending on the given probability of the level's deviation from its mean: The deviation computed by formula (3) would not be exceeded with a probability of 80 percent at $\mu = 1.28$, with a probability of 90 percent at $\mu = 1.64$, and with the probability of 95 percent at $\mu = 1.96$ (Table 1).

Table 1. Probable Deviations in the Level of the Caspian Sea From Values Corresponding to Average Climatic Conditions

Forecast Lead Time i, Years	σ_i	Δz_i at Following Confidence Probability, %		
		80	90	95
5	0,38	0 5	0,6	0,7
10	0,52	0,7	0,8	1,0
20	0,67	0,9	1,1	1,3
30	0,72	0,9	1,2	1,4
∞	0,80	1,0	1,3	1,6

In a number of cases the procedure used to evaluate probable deviations of sea level from the average is more complex, and Table 1 becomes useless. This happens when natural fluctuations in elements of the water balance are superimposed by fluctuations in water consumption, by losses of water due to flooding, by changes in the volume of redistributed flow, and by other effects functionally associated not with time but rather with the water content of rivers feeding the basin or with the level of the sea (we encounter the last of these cases, in particular, when the volume of flow to be diverted each year is determined with regard to the level of the sea).

In all of these cases the regimen of the water basin must be studied in relation to the set of possible realizations of hydrometeorological conditions in the period of the forecast (3, 18). This means that the computations should be made in relation to ensembles of series of elements of the water balance. With this purpose

* The zone in which the inflow into the sea forms is far removed from the water basin; the water source and the water basin exist in different physical and geographical conditions. Therefore there is practically no correlation between fluctuations in inflow and evaporation, which has an effect on the range of fluctuations in level: When the correlation between inflow and evaporation is positive, the range is greater, and when this correlation is negative, the range is smaller (20).

we model several dozen (and sometimes several hundred*) realizations of inflow and apparent evaporation, covering a time equal to the lead time of the forecast; chronological graphs of water consumption, flow losses, and change in river water content caused by implementation of water management measures are superimposed over each pair of realizations of inflow and apparent evaporation. A given growth rate of water consumption and a given chronological sequence of implementation of water management measures are common to all of these graphs; at the same time they are unique in terms of the influence annual flow has on the size of flooding losses, the sea's revealed demand for water subsidies, the amount of water the source of diverted water can provide in a given year, and so on.

Performing the water balance computations, we obtain a corresponding number of realizations of trends in water level; joint treatment of these trends would provide a picture of the behavior of the sea level in both average and experimental conditions (when high water discharge coincides with low evaporation, and vice versa).

When modeling temporal series of the elements of the water balance, we can use a simple Markoff process with linear correlation between the frequencies of adjacent terms as the stochastic model (20). It is recommended that the numerical parameter of the model--autocorrelation coefficient r--be given for river flow depending on the river's unit rate of flow (the flow module). In application to the conditions of the Caspian Sea, the autocorrelation of inflow and apparent evaporation can be adopted equal to 0.3 (14, 20).

Let us now go on directly to an examination of a prediction of the Caspian Sea's level depending on the rate of conditional growth of water consumption within its basin. In this case we should consider the possibility for bringing water in from the Volga to compensate for the yearly irreversible withdrawals in the Azov basin (conditionally, 5 km^3 per year beginning in 1985, and 20 km^3 per year beginning in 1995).

The calculations were performed in application to growth in water consumption changing in time according to a linear law, $u = \alpha t$, where α takes values in the interval from 0 to 2 km^3/year (0, 0.5, 1.0, 1.5, and 2.0 km^3/year are the values for the first through fifth variants of growth in water consumption respectively). Thus by the end of the century, growth in water consumption will change from 0 to 40 km^3/year. It should be noted that the calculations were made with regard to cessation of water outflow in Kara-Bogaz-Gol beginning in 1980; this was adopted as the beginning of the forecasting period. At the beginning of this period the sea level was set at the -28.6 meter mark, which corresponds approximately to the gravitation level that would apply to water consumption in the basin totaling 40 km^3/year. The results of the calculations are shown in Table 2. As we can see from this table, assuming average climatic conditions for the period under examination, by the end of the century the level of the sea will drop down to -29 meters and even more, with all variants of water consumption (with the exception of the first two). In unfavorable climatic conditions, which are characterized in Table 2

* The volume of statistical trials is determined theoretically (when possible) on the basis of the desired accuracy of the results, or from the data of the computations themselves. Stable results in repeated series of computations can serve as the sufficiency criterion.

by frequency levels of 90 percent (in 10 percent of the cases the levels would be even lower), the sea would drop to a point within the interval from -29.4 to -30.4 meters, depending on the rate of growth of water consumption; in the next decade we can expect a further decline in the level by 0.2 (for the second variant) to 1.0 meters (for the fifth variant).

Table 2. Prediction of the Level of the Caspian Sea in the Absence of Compensatory Measures

(1) Год	(2) Отметка уровня (минус м абс.) при значениях α				
	0	0,5	1,0	1,5	2,0
	(3). В средних климатических условиях				
1985	28,6	28,6	28,6	28,6	28,7
1990	28,6	28,6	28,7	28,8	28,9
2000	28,5	28,8	29,0	29,3	29,5
2010	28,5	29,0	29,5	30,0	30,5
	(4) В неблагоприятных климатических условиях				
1985	29,1	29,1	29,1	29,1	29,2
1990	29,3	29,3	29,4	29,5	29,6
2000	29,4	29,7	29,9	30,2	30,4
2010	29,4	29,9	30,4	30,9	31,4
	(5) В благоприятных климатических условиях				
1985	28,1	28,1	28,1	28,1	28,2
1990	27,9	27,9	28,0	28,1	28,2
2000	27,6	27,9	28,1	28,4	28,6
2010	27,6	28,1	28,6	29,1	29,6

Key:

1. Year
2. Sea level (minus *m* abs.) for different values of α
3. In average climatic conditions
4. In unfavorable climatic conditions
5. In favorable climatic conditions

Correspondingly, in favorable climatic conditions there is a 10 percent probability that the level of the sea will not go below present levels in the current century, while with relatively low rate of growth of water consumption (up to 1 km^3/year) it would exceed the present level by about 0.5 meters.

Nevertheless the probability of the desirable parameters of the level of the sea (not below the -28.5 meter mark in average climatic conditions and not lower than -29.0 meters in unfavorable conditions) turns out to be impermissibly low (see Table 3). Levels below the -28.5 meter mark have a probability significantly greater than 50 percent, while levels below the -29.0 meter mark have a probability significantly greater than 10 percent. By the end of the century this minimum level will be characterized by a probability greater than 50 percent in relation to all variants of growth of water consumption, with the exception of the second, corresponding to an increment in water outlays within the Caspian basin totaling just 10 km^3/year by by the end of the century. A drop in the level of the sea to points lower than -29.5 meters will be sufficiently probable by this time.

Table 3. Probabilities of Typical Levels of the Sea in the Absence of Compensatory Measures

(1) Год	(2) Вероятность, % при значениях α				
	0	0,5	1,0	1,5	2,0
(3) На отметках ниже —28,5 м					
1985	60	60	60	65	65
1990	55	60	65	70	75
2000	50	65	80	90	94
2010	50	75	90	98	98,8
На отметках ниже —29,0 м					
1985	15	15	15	15	20
1990	20	25	30	35	40
2000	25	35	50	65	80
2010	25	50	75	92	98
На отметках ниже —29,5 м					
1985	1	1	1	1	1
1990	3	4	6	8	10
2000	6	15	25	35	50
2010	8	25	50	75	92

Key:
1. Year
2. Probability, %, for different values of α
3. For levels below

It should be noted that the levels of the Caspian Sea cited here were arrived at without regard to possible diversions of part of the Volga's flow into the Azov basin by way of the Don. Consideration of the volumes of these diversions would mean an additional decrease (over the amounts shown in Table 2) in the level of the Caspian Sea of 0.5-0.6 meters by the end of the century, and 0.8-0.9 meters by the year 2010.

Were we to orient ourselves on average climatic conditions, we would have to keep the present water balance of the Caspian about the way it is now--that is, growth in the expense account of the ledger would have to be compensated by growth in its revenue account. Maintenance of the sea's balance would require diversions of water into the Volga basin from without. An estimate of the scale of these measures would have to account for, in addition to development of water consumption in the Caspian Sea basin, the need for supplying water from northern rivers to the Azov basin via the Volga. Development of the principal water consumer--irrigated agriculture--should be planned and carried out in conjunction with compensatory measures.

One of the additional ways for maintaining the level of the sea would be to reduce the evaporation area by isolating the eastern shallows of the northern Caspian, which have no value to fisheries. In terms of plankton and benthos, the feed base of the shallows is correspondingly 3-5 and 1.5 times lower than in the eastern half, and 10-15 and 10 times lower than in the western half of the northern Caspian. Because of intense heating, the rate of evaporation of water in the shallows is sufficiently high, with evaporation proceeding both from constantly flooded areas and areas intermittently covered during floods. By diking off the shallows, we could save up to 10-12 km^3 of water per year in the Caspian's water balance. However, erection of an isolating dike would be suitable only in integration with other water management measures aimed at maintaining the level of the sea.

B. A. Apollov suggested maintaining the northern Caspian at its present level by diking it off from the rest of the sea (2). As a result fresh streamflow, which enters mainly the northern part of the sea, would be retained in a volume necessary to maintain the sea at a level not below the target (for example the -28.0 meter mark). Surplus water could be dumped into the central Caspian (if its level is lower).

However, it is entirely obvious that erection of a separating dike would not only fail to solve the problem, but it would also be unsuitable (19). Thus in a few years the salinity of the northern Caspian would decrease to 0.5-1 $^0/00$, owing to which its biological productivity would decrease dramatically. Maintenance of the needed salinity north of the dike by pumping saline water into this part of the sea from the central Caspian would necessitate a pumping volume commensurate with the flow of the Volga. South of the dike the level of the sea will begin to drop quickly, in which case fluctuations in the level of the sea will increase over present values by several times in response to variations in inflow and evaporation. As a result sluices would have to be created at the mouths of rivers entering the sea south of the dike, and marine ports would have to be rebuilt. The possibility that fish could migrate through a gate in the dike is highly doubtful, such that the feed resources of the central and southern Caspian would be cut off from the bulk of the basin's fish school.

Some of these unfavorable consequences may be avoided by supplying only part of the Volga's flow into the northern Caspian, enough to compensate for evaporation from the surface of the sea north of the dike. In this case the surplus discharge should be directed right into the central Caspian by a specially erected canal, and the level of the sea south of the dike could be maintained by diverting water from the Black Sea.

However, this system of measures would necessitate delivery of two-thirds of the Volga's biogenic flow south of the dike, and we know right now that this would be very expensive. Diversion of Black Sea waters into the Caspian Sea, we would have to build a canal bypassing the Caucasian range and crossing several watersheds. As a consequence the unit outlays on achieving such a transfer would be high, but they would not help to preserve the biological productivity of the sea.

The supply of Black Sea water into the Caspian Sea in amounts that would compensate for withdrawal of fresh streamflow will doubtlessly permit us to keep the average level of the Caspian favorable, and control of the volume of entering water depending on the flow rate for the year will afford a possibility for reducing the amplitude of fluctuations in the sea's level, which is also desirable. At least within the next century, diversion of 50 km^3 and more of salty (18 $^0/00$) Black Sea water into the Caspian Sea each year would not noticeably increase the mean salinity of the Caspian Sea; however, this would create the preconditions for a number of unfavorable consequences (5, 6).

Thus due to significant reduction of fresh inflow the area of freshened zones in the northern Caspian would grow smaller, and "spots" of high salinity may possibly appear out in the open sea; as a result the zone of brackish water, which is the site of the feed base of all commercially valuable fishes, including sturgeon fry and juveniles, would grow smaller. The volume of the biogenic flow into the northern Caspian would decrease noticeably (by several dozen percent), which would have an unfavorable effect on the sea's productivity.

Density stratification will become more intense in the zone of inflow of Black Sea waters into the Caspian (owing to their greater density in comparison with the waters of the northern and even the central Caspian), which may result in oxygen depletion in the benthic horizons and formation of asphyxiation phenomena; a salt barrier and an oxygen-deficient zone with a sharply depleted benthos would arise on the west shore of the sea, across the migration routes of sturgeons from the central to the northern Caspian.

Hydrobionts (for example jellyfish and (rapan)) may penetrate into the Caspian with Black Sea waters, which would dramatically reduce production of plankton and benthos; the consequences to Caspian fauna may be disastrous.

Finally, it is not presently possible to evaluate, even qualitatively, the possible biochemical and ecological consequences of these measures to both the Caspian Sea itself and the entire route of water diversion (a large canal would carry sea water over Krasnodarskiy Kray and Rostovskaya Oblast). It would take a long time to study and evaluate these consequences; this alone would preclude diversion of Black Sea waters as a priority measure. We should also consider that diversion of Black Sea water into the Caspian does not solve the problems that have arisen due to the limited water resources of the Volga and the impossibility of supporting the long-range water management balance of the river with the help of Volga flow. However, considering the possibility that this would reduce the amount of streamflow withdrawn from water bodies in the north and northwest and the limits of what they can offer, in the opinion of some specialists we need to study the problem of diverting Black Sea waters as one of the measures to be implemented in the remote future.

Management of the sea with the purpose of raising its biological productivity should entail supplying water into it in those quantities and that flow rate which would produce the greatest impact. In application to the Caspian Sea, this means:

insuring the conditions for intensive spawning in the Volga delta in the face of a lower (in comparison with natural conditions) high-water flow (for example with the help of a water divider);

increasing the water content of the Ural River and the eastern channels of the Volga delta to promote better freshening of the northern Caspian and its saturation with biogenic streamflow (supplying of biogenic streamflow into zones in which photosynthesis proceeds most intensively, and where the conditions for the feed base's existence are the most favorable);

maintaining the sea at sufficiently high levels insuring persistence of relatively favorable conditions for entry of Volga flow into the shallows of the central and eastern parts of the northern Caspian.

Just diversion of water into the Volga alone would solve an entire complex of problems: eliminating the deficit in the water management balance of the river basin in the future (with consideration for diversions of water into the Asov basin), maintaining the level of the Caspian Sea, and preserving the biogenic streamflow and low salinity of the northern Caspian.

The suggested ways for replenishing the water resources of the Volga (10, 11) can be divided into two groups: tapping the waters of the north and northwest slopes of the European USSR; diverting water from the Ob', over the Urals or around them on the north.

According to present ideas the variants in the second group are unfeasible. They require water to be lifted to a greater total height, larger volumes of construction, a much longer construction time, and significantly greater capital investments. Finally, notions of the supposed possibility for withdrawing large amounts of water from the Ob' as a means for increasing the water supply both in the southern part of the European USSR and in Central Asia have turned out to be unfounded as well (9). It should be noted that even if the Ob' were able to provide enough water to both of these regions, variants suggesting separate diversions of water into these zones are more feasible.

Thus in the foreseeable future the water resources of the southern part of the European USSR should be replenished by tapping rivers in the north and northwest of this same zone.

It would be technically possible to withdraw up to 120-140 km^3 of water from local sources on the northern slope of the European USSR per year. However, in this case the flow at the mouths of the northern rivers would be about halved, while at the places of withdrawal it would decrease even more. Withdrawal of flow on such a scale would require creation of huge reservoirs that would flood large amounts of land; this would be accompanied by major disturbances (and sometimes destruction) of evolved ecosystems, and it could have a serious influence on the natural conditions of the Arctic and contiguous territories (1, 7). According to tentative estimates, about half of this withdrawal volume (60-70 km^3/year) may be viewed as the limit for the foreseeable future. The donor water sources would be the Pechora, Sukhona, Northern Dvina, the rivers of the Karelian SSR, and lakes Lacha, Vozha, and Onega. The amount of water that could realistically be diverted into the Volga by the year 2000 would be 20 km^3/year. Moreover the expense part of the sea's water ledger could be reduced somewhat by isolating the eastern shallows of the northern Caspian, from which 10 km^3 of water evaporate each year.

It follows from the above discussion that between 1990 and 2000, we could raise the impact of compensatory measures to 20-30 km^3/year, with an average annual increment of $\beta = 2\text{-}3$ km^3/year. Predictions of the level of the sea have been made in application to this range of values for β, with a prediction period extending up to the year 2010. The calculation results are shown in Table 4.

Table 4. Probability of Typical Levels of the Sea in the Presence of Compensatory Measures

(1) Год	(2) Вероятность, %							
	β = 2				β = 3			
	α = 0,5	α = 1,0	α = 1,5	α = 2,0	α = 0,5	α = 1,0	α = 1,5	α = 2,0
(3) На отметках ниже −28,5 м								
2000	50	65	80	90	45	60	75	85
2010	30	55	75	94	15	35	60	80
На отметках ниже −29,0 м								
2000	25	35	50	65	20	30	45	60
2010	10	25	55	80	4	10	30	60
На отметках ниже −29,5 м								
2000	7	15	25	35	5	10	20	30
2010	2	9	30	55	0,8	3	10	35

Key:
1. Year
2. Probability
3. For levels below

Considering the requirements of keeping the average sea level at the -28.5 meter mark, the rate of growth of water consumption could be increased by the end of the century to $\alpha = 0.5$ km^3/year, assuming that the impact of compensatory measures would be $\beta = 2.0$ km^3/year. Assuming $\beta = 3.0$ km^3/year, α could be raised to 0.6-0.7 km^3/year. If we agree to temporary worsening of the sea's hydrologic cycle at the turn of the century (on the condition that the desirable sea level would be regained by the year 2010), the rate of growth of water consumption may be increased to $\alpha = 1.0$ and 1.3-1.4 km^3/year correspondingly at $\beta = 2.0$ and 3.0 km^3/year.

The question as to whether or not it would be possible to divert water from the Volga to the Don must be answered on the basis of the results cited here, on the condition that α accounts for the dimension of these diversions. Thus given a permissible value of $\alpha = 1.0$ km^3/year, the increment in annual water consumption would be 30 km^3 in the year 2010, while if the Don were to subsidize the water balance with 20 km^3/year, total water consumption in the Caspian basin could be increased by 10 km^3/year.

The cost of the compensatory measures is estimated in the billions of rubles, in view of which the impact of their implementation should be guaranteed with a significant probability. This means that the compensatory measures must be oriented not at the average climatic conditions of the preceding period, but at unfavorable conditions. A frequency of 90 percent (a probability of 10 percent for lower levels) may be adopted as the criterion of an unfavorable situation.

On the other hand we would probably be excessively cautious in demanding a 90 percent probability for the optimum level, which is adopted at the -28.5 meter mark. Therefore we would have to relate this probability to a lower level--in unfavorable one, but one that is acceptable for limited time intervals. In this case we could adopt the -29.0 meter mark.

We can see from Table 4 that given average levels at about the -28.5 meter mark, levels below -29.0 meters would have a significantly greater probability than 10 percent (25 percent on the average); a 10 percent probability is equivalent to about the -29.5 meter mark, which, from what we can envision, would be impermissible. The reason for this is that given added feeding into the sea through systematically full utilization of the capacity of the diversion channel, such diversion could only influence the average sea level (18).

The level of the sea could be stabilized only with compensatory supply of water into the sea, in which case the volume of water fed into it every year taken individually would be specified on the basis of the actual sea level. This means, in particular, that the schedule of compensatory feeding of water into the sea basin from outside sources would have to differ from the schedule of water withdrawal from the basin.

Planning the diversions of water into the Caspian Sea basin, we would have to foresee the possibility for optimum control of flow rate, with an eye on reducing fluctuations in sea level caused by natural variability in the elements of the water balance. The probability that the level of the sea would remain within a certain range--that is, the average time during which the sea level would remain at the required point--could be adopted as an indicator of the sea level's stability. From a technical standpoint, stabilization of the level of the sea can be achieved by increasing the inflow of water at times of low sea level, and decreasing inflow at times of high sea level.

This task was completed in the first approximation in application to the Caspian Sea on the basis of the maximum stability criterion; the rules for determining volume of diversions depending on sea level were determined (15). It turned out that in addition to reducing a range of fluctuations in sea level over a period of several years, we achieve a certain savings in the volumes of diverted streamflow (a decrease in the amount of water transferred in periods of high sea level, when the evaporative surface of the sea is large).*

However, because it would take some time to implement the measures associated with diverting water into the Caspian basin, the transition to variable annual feeding into the sea would become important not right away, but only after the level of the sea reaches an acceptable point; prior to this time, the carrying capacity of the diverted route would have to be utilized fully, as the sources of the diverted water allow. Optimum control of such water diversions would become of practical interest in the very first stages of extending the problem to two water basins--the Caspian and Azov seas.

Inasmuch as water can be diverted into the Azov basin only from the Volga, we encounter the problem of taking water from the rivers and lakes of the northern European USSR to concurrently increase the flow into the basins of both of these seas--Caspian and Azov. Considering the optimum strategy of joint diversion, we would have to take two circumstances into account: First, the inflow into the Caspian and Azov seas is not synchronous, meaning that if the demand for water

*The latter is especially important to lakes used as water sources for the sea.

alternates between the seas we could probably consider a lower carrying capacity for the diversion channel into the Volga than the total maximum demand for water of each of these seas; second, the inertia of the Sea of Azov is relatively low, meaning that it would have priority over short-term intervals; the greater inertia of the Caspian makes it easier to solve the problems of providing water to the Volga connected with fluctuations in the flow rate from the water sources, which do not correlate significantly with the Volga's regimen.

Also of important significance is the flow rate of the Ural River, which decreases in low-water years to a few km^3/year due to greater natural variability of streamflow. By increasing the guaranteed minimum streamflow of the Ural (this figure would have to be substantiated), on one hand we could radically improve the natural spawning grounds, and on the other hand we could reduce the salinity and raise the availability of food in areas of the northern Caspian contiguous with the mouth of the Ural (6). The role of this river in reproducing the sea's fish school is great, and simple land reclamation measures implemented within the limits of its lower reaches promise a significant impact. The water resources of the Ural would have to be replenished in the very first stages of erection of the Volga-Ural Canal, intended primarily to provide water to land situated between the Volga and the Ural. It would be desirable to supply at least a small quantity of water to the Emba in order to freshen the waters at its mouth.

Conclusions

If we are to maintain the unique productivity of the Caspian Sea, avert the unfavorable influence of the northern Caspian's dessication upon the climate, and reduce the harm done by a decline in sea level to a number of sectors of the national economy, these plans for diverting water into the Volga from rivers and lakes of the northern European USSR would have to be tied in with the pace of development of irrigation.

Maintaining the level of the Caspian Sea by diverting Black Sea waters into it would not create favorable conditions for the fish school, and it would elicit a number of ecological apprehensions. This variant of the compensatory measures would not be of interest in the foreseeable future.

We need to accelerate research on the idea of isolating the unproductive eastern shallows of the northern Caspian. It would be unsuitable to stabilize the level of the entire northern Caspian by separating it from the rest of the water basin. Increasing the water content of the Ural River by diverting relatively small volumes of water to it from the Volga would have a noticeable positive influence in freshening the northern Caspian and providing biogenic substances to it.

The water divider that has been built at the apex of the delta, which permits us to control the distribution of streamflow between channels of the Volga delta, and consequently to positively influence the spawning grounds in the delta itself and to freshen the northern Caspian, should be placed into operation immediately, and special field observations over the regimen of the delta and the coastal waters should be organized. This research would produce raw data in behalf of, first, improvements in the rules of using the water divider, and second, the system of land reclamation measures to be applied to the delta in the case where its regimen is controlled.

Apparently it is impossible to predict all of the negative consequences of disturbing--destroying in this case--such large ecosystems as the Caspian: We can assert *a priori* that it would be more expensive to restore these systems than to implement preventive measures as a means to maintain the required conditions. On the other hand withdrawal of water from diversion sources would disturb the water regimen of the latter, which may in turn change the natural conditions with consequences that cannot always be predicted. Therefore when developing measures for territorial redistribution of streamflow, we should devote the most serious attention to this aspect of the problem. We must obviously console ourselves to some unfavorable consequences that may arise in the zones of streamflow withdrawal, if as a result we achieve a much more significant national economic and ecological impact.

The following can be treated as the basic directions of scientific research on the problem of the Caspian Sea:

1) making predictions of the water-salt regimen of the sea and of channel deformations that would occur at the mouths of rivers in response to a decline in sea level;

2) making predictions of possible transformations in the Caspian's ecosystems in response to the expected changes in the water-salt regimen and dessication of the shallow areas of the water basin as a result of the decline in water level;

3) evaluating possible changes in the region's climatic conditions due to dessication of the northern Caspian in response to a decline in sea level;

4) determining the grounds for the composition and scale of compensatory measures to correct for growth in water consumption in the sea basin, on the basis of predictions of change in the sea's regimen, the operation of water ecosystems, and the socioeconomic aspects of the problem; 5) developing the strategy for optimum control of the sea's regimen, with regard to possible diversion of water into the Azov basin, and fluctuations in the water content of sources that are to provide additional water to the Caspian.

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A SYSTEMS APPROACH TO ANALYZING INTERBASIN DIVERSION OF WATER FLOW (BASED ON THE EXAMPLE OF DIVERTING PART OF THE DISCHARGE OF THE USSR'S NORTHERN RIVERS INTO THE VOLGA)

Moscow VODNYYE RESURSY in Russian No 1, 1981 pp 5-22

[Article by A. S. Berezner, N. N. Moiseyev, F. I. Yereshko, and A. V. Lotov]

[Text] Satisfying industry's and agriculture's growing demand for water is a typical problem of many of the world's countries. A lack of available water resources is evident in both individual countries and some large regions in general. An acceptable solution to the problem of sensibly using limited resources can be found only on the basis of a systems approach (4), through systematic inspection of a significant number of alternatives.

Let us examine the machinery of systems analysis with the example of developing a major water management plan for supplying water to the southeastern part of the European USSR by diverting part of the discharge of the country's northern rivers into the Volga basin.

Diversion of part of the discharge of northern rivers in the European USSR into the Volga is a typical example of a complex problem: Its analysis requires consideration of a large number of closely interrelated technical, social, economic, ecological, and other issues. To solve this problem, we would essentially have to concurrently examine the associated problems of developing productive forces, protecting the environment, and raising the population's standard of living, such that we would be dealing to a certain extent with a general program for development of the regions affected by diversion.

In this article, taking a systems approach to planning will mean comprehensively analyzing the complex problem under study, with the assistance of both informal and formalized methods of analysis, combining the merits of a strict computer-assisted study based on mathematical models, and the knowledge of experts.

Systems analysis of any problem entails three basic parts (4): a) analysis of the end goals that must be achieved through solution of the problem under examination; b) development of a system of indicators and, on their basis, criteria for evaluating the possible alternatives; c) selection of the most appropriate variant of achieving the posed goals (operations analysis). The key issue in all of these stages is cooperation between the researchers performing the formal analysis and the experts and practical planners who pose the concrete tasks and make the final decision to adopt one variant or another. One extremely important fact should be noted: Inasmuch as no system of models can embrace the entire problem as a whole, the need arises for isolating a particular problem out of the general situation. The researcher can make it easier to break the general situation down, but it is the expert planner who defines the content of this task. He directs the writing of the scenarios--that is, the possible alternatives for development of national economic sectors and natural systems, he performs the initial ranking of these alternatives, and he provides the necessary information for the models being developed. Next he analyzes the results of the calculations and, relying on his own experience, he evaluates their significance to planning. The experience of the expert is formed through his education--that is, on the basis of planning models he had assimilated a certain number of years ago, on the basis of the concrete tasks which he had formerly completed successfully or unsuccessfully, and on the basis of public opinion. These characteristics, which do not yield to formal definition, determine the style of his thinking and the procedures he uses to eliminate certain variants.

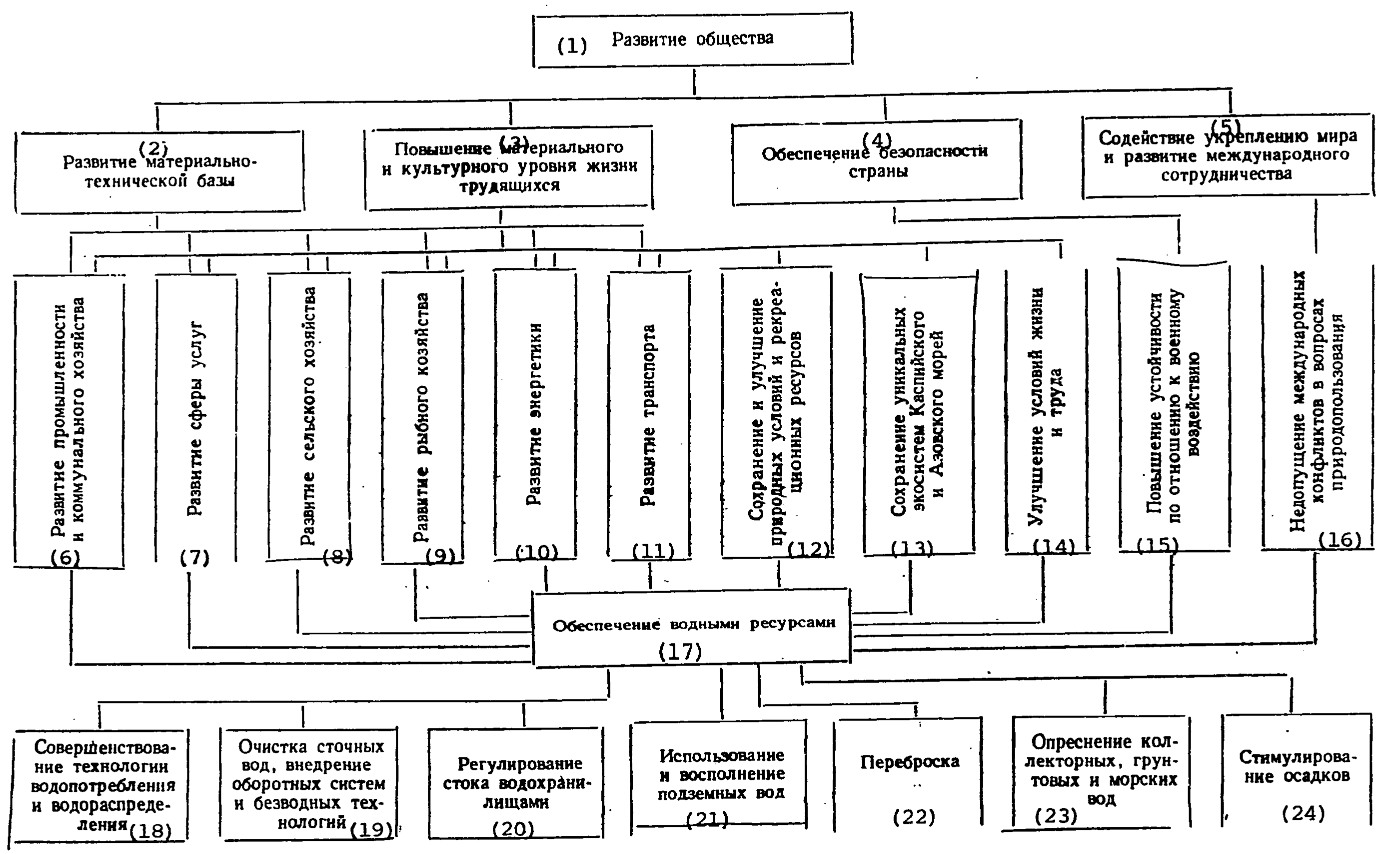
Note that every complex project has its own history of development, and by the moment a single system of mathematical models is created, it is complicated by a number of particular models, the relationships between which are occasionally informal.

Such a complex situation will become evident in the subsequent presentation. Relying upon the methods of system analysis, the researchers and the experts go on next to spell out a single system of viewpoints and approaches leading to a formally clear procedure for analyzing the planning variants on the basis of a simulation system, which is now being developed in the form of a computerized automatic planning system. At the same time this plan makes use of evaluations and particular models reflecting viewpoints which are presently in existence in planning practice and which came into being previous to the simulation system. Before we arrive at formal assessments of the consistency of all models, their joint interpretation would be an informal act of creativity of the experts.

A water supply system is not the end goal of society's development, and therefore were we to follow the methodology of systems analysis, in the first stage of our research we would need to evaluate the place of water management within the overall system of goals and tasks facing the society.

The analysis of goals related to the task of interest to us--sensible water use--begins with drawing up the corresponding graph of goals and tasks (Diagram 1), in which the system of goals is represented in the form of a hierarchical structure--that is, it is broken down into a finite number of levels, where achievement of one of the goals (tasks) of any one level must be preceded by achievement of an associated goal (task) at a lower level (5). Thus a goal (task) at any one level, except at the highest and lowest, must on one hand be achieved before goals of a higher level can be, and on the other hand it itself can be achieved only on the condition that tasks associated with it at a lower level are completed. Goals at the highest (zero) level are the end goals, and the tasks at the lowest level can be completed with the available resources.

Diagram 1. Graph of Goals and Tasks at the Countrywide Level, in Application to the Water Supply Problem



[Key on following page]

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Key:

1. Development of society
2. Development of the material-technical base
3. Advancement of the material and cultural standard of living of the laborers
4. Maintenance of the country's security
5. Promotion of peace and development of international cooperation
6. Development of industry and municipal management
7. Development of public services
8. Development of agriculture
9. Development of fisheries
10. Development of power engineering
11. Development of transportation
12. Preservation and improvement of natural conditions and recreation resources
13. Preservation of unique ecosystems in the Caspian and Azov seas
14. Improvement of living and working conditions
15. Enhancement of stability in relation to military pressure
16. Prevention of international conflicts in nature exploitation
17. Supply of water resources
18. Improvement of water consumption and water distribution technology
19. Waste treatment, introduction of recycling systems and waterless production processes
20. Regulation of discharge by reservoirs
21. Use and replenishment of underground water
22. Diversion
23. Desalinization of runoff, ground water, and sea water
24. Stimulation of precipitation

The first level in this system consists of tasks that must be completed if society is to develop successfully as a whole. The second level singles out not all goals (tasks) that must be achieved in order to support the goals of the first level, but only those which are associated with the task of sensible water use.

The third and fourth levels contain only those tasks which are directly associated with supporting water consumption. Thus we arrived at a graph of goals and tasks, ending with the level of tasks associated with providing water resources; in this case diversion of river discharge is isolated in the lowest level as one of the means of completing this task. Owing to this we can qualitatively describe the requirements imposed on the water supply system, both today and in the future.

Next we would need to examine the problem of choosing a sufficiently detailed variant of the socioeconomic development of the country as a whole, one accounting for the need for natural resources, water in particular, and the possibilities of obtaining them. Then the issue of sensible diversion of a part of the river discharge would be resolved in the course of choosing the most appropriate variant for the country's development. Unfortunately, this task cannot be completed in its full volume because this would require concurrent examination of too many principal and secondary factors having a bearing on the decision made. Therefore in present practice, to solve the particular problems the experts resort to informal decomposition of the overall graph, and on their own recognizance they isolate a rather narrow class of issues that are most closely associated among one another. In this case of analyzing diversion of part of the discharge of northern rivers into the Volga basin, the decomposition procedure affected mainly the geographical boundaries of the zone that would be influenced by such diversion. The following boundaries may be adopted for the region on the basis of the research of previous years (3):

on the west--the western border of the USSR from Norway to the Gulf of Finland; then the watershed between the basins of the Neva and the Northern Dvina and further along the watershed between the basins of the Volga and Don and the Dnepr basin, down to the Sea of Azov;

on the south--the Main Caucasian Range (the eastern Caucasus is treated as part of the water balance of the Caspian Sea, but in the foreseeable future, water from northern rivers will not be fed directly into this region via the Volga);

on the east--the boundary between Europe and Asia, extending along the Ural Range and, south of the range, along the Ural River to the Caspian Sea.

Thus from here on in we will be discussing the provision of water not to the entire country but only to the region isolated above. When we isolate this region, and thus reduce the geographical dimensions of the territory under consideration, we raise fundamental questions associated with the relationship between this region and the country as a whole. To answer these questions, we note that the goals indicated in Diagram 1 are achieved in the course of activity of individual sectors (industry, public services, agriculture, power engineering, fisheries, water management, and so on). Therefore by breaking the territory down we concurrently isolate certain parts of these sectors, territorially located within the boundaries of this region; the relationship between the regional economy and the entire national economy must be spelled out in terms and concepts used to describe the function of sectors. Examining sectors as elements of the economy, we can base their description on a set of factors characterizing production in such a way that part of the factors would predetermine the input of products into the sector, and part would determine the output of products from the sector. The associations existing between the different characteristics of these factors make up economic models at the descriptive level, and mathematical models of the function of sectors at the formal level.

In our case the initial factors are: different types of land, water, and labor resources, the production equipment of the sectors, construction materials, construction equipment, fuel, energy, chemical fertilizers, agricultural machinery, capital investments, operational expenses, and so on. The output factors are represented by the products of the corresponding sectors: in agriculture, for example, grain, vegetables, meat, milk, etc.; in fisheries--the volume of marine, migratory, and semimigratory fish caught, the volume of roe produced; in power engineering--energy production and power supply; in transportation--shipment volumes, and so on. The characteristics of these factors may take the form of both resource limitations and indicators for which improvement would be desirable.

Note that all of the input characteristics of the sectors are exogenous in relation to the regional complex under examination here. Therefore, first, the associations existing between individual sectors in this region manifest themselves only at the level of resource limitations affecting input parameters and, second, the magnitudes of the resource limitations and indicators generated by the input parameters define the load imposed upon the economy by the region. At the same time the limitations and indicators generated on the basis of the output parameters define the load imposed upon the region (the demand on the region) on the part of the economy.

By analyzing the input factors and goals (Diagram 1), we can trace formation of limiting factors and indicators at the expert level.

Land is mainly a limiting factor associated with redistribution of tilled land between different types of farming (dry or irrigated). The indicators may reflect the desire to reduce land flooding accompanying the erection of dams.

Labor resources appear as a limiting factor in all sectors under examination.

Water resources may be utilized in three ways: a) irrecoverable water consumption, where as a result of the production cycle water is evaporated, or it is included in the end product exported from the region; b) recoverable water consumption, where water is returned back to the river, though in contaminated form and, as a rule, in a reduced quantity; c) water use not associated with consumption of water, where presence of a certain amount of water is necessary to the activity of the water user. Research conducted previously on development of the country's water economy (3) showed that in the foreseeable future all forms of water supply (industrial, municipal, agricultural) will not exceed 20 percent of the total increment of irrecoverable use of water resources. The water loss is even smaller (1 percent) in pond fish culture. About 80 percent of the future growth of irrecoverable withdrawals will be concerned with development of irrigated agriculture. Thermal powerengineering holds first place in discharge of recoverable water; however, this sector subjects the dumped water mainly to "thermal pollution", which is relatively less dangerous to the environment, given the scale of development of this sector predicted by experts. Second in volume and first in degree of contamination are the recoverable water discharges of industry and municipal management, and third place is occupied by agriculture (drainage from feedlots, surface runoff and percolating water from irrigated land). Finally, the principal sectors not consuming water irreversibly and not requiring large quantities for dilution purposes include fisheries, hydroelectric power, water transportation and, to a lesser degree, agriculture (flooding of land on the Volgo-Akhtubinskaya floodplain). Judging from the size of irrecoverable water consumption by industry and municipal management, the influence of these sectors upon future water supply would be generally insignificant. As far as the large volume of recoverable water from industry is concerned, this factor will not have decisive significance in the future, inasmuch as no plans for new enterprises are being or will be approved unless they foresee a high degree of waste water treatment; all existing enterprises, cities, and towns, meanwhile, will have to finish construction of treatment plants not later than 1985 (as required by decrees published in 1976-1977 by the CPSU Central Committee and the USSR Council of Ministers on measures to protect the waters of the Black, Azov, Caspian, and Baltic sea basins). In this connection we can examine the variants for development of industry, municipal management, and services separately from the variants of the system for water use within the Volga basin and the basins of adjacent rivers, in which case the demand of these sectors for water resources will be treated as a limiting factor. The volume of water resources and the water supply schedule participate in the formation of limiting factors in other sectors as well, and they are rarely used as indicators, mainly in regard to auxiliary tasks.

Use of construction equipment, construction materials, equipment, fuel, energy, chemical fertilizers, and agricultural machinery is typified as a rule by outlays expressed in monetary terms, which is what predetermines the set of indicators employed. Some of these factors may participate in the formation of limiting factors. We should emphasize that outlays in both cost terms and natural terms must be subdivided into outlays occurring in the course of construction and current outlays.

The goal "Preservation and improvement of natural conditions and recreation resources" imposes a limitation of the following sort on the water supply schedule: The selected variants of water use and diversion must not significantly worsen the natural conditions in the regions where discharge is withdrawn, and concurrently the ecological conditions of the Azov and Caspian seas must show improvement. Concurrently this goal serves as the source of one of the indicators of the quality of the selected variants, from the standpoint of their influence upon both the zone of discharge withdrawal and transportation, and the zone in which the diverted water is distributed. An analysis of this influence is represented in Diagram 2.

The goal "Improvement of living and working conditions" requires irrecoverable use of water, and maintenance of minimum residual discharge in rivers (releases of water for sanitary purposes).

The goals "Development of industry" and "Development of public services" require irrecoverable use of water, and releases of water to clean out water channels.

The goals "Development of fisheries" and "Development of transportation" set limits on releases of water to support normal reproduction and development of the fish school, and navigation.

The goals "Enhancement of stability in relation to possible military pressure" and "Prevention of international conflicts in nature exploitation" impose limitations on the possible variants for development of water supply.

All of the limitations mentioned above are determined by expert assessment.

The goal "Development of agriculture" predetermines the outlays on the creation of certain products and their assortment, and limitations on how much can be produced and on outlays associated with input factors.

The goal "Development of power engineering" predetermines the figures for total and peak energy production.

When we assign particular values to the limitations and choose the system of indicators, we do not as a rule set concrete values for the indicators, inasmuch as a regional complex offers a freedom of choice in selecting the distribution of input factors among sectors and among individual methods of production within the sectors (this pertains mainly to agriculture and power engineering). Therefore we need to define our procedure for selecting the parameters to be controlled more specifically. Together with the informal procedure for creating the system of indicators and limiting factors, this procedure forms the scenario for development of the regional complex, and in the final analysis it predetermines the concrete approach to utilizing the region's water resources. The main objective of automating planning is to generate numerous alternatives for achieving the set goals and evaluating these alternatives within a time period acceptable to the experts. This could be done only by creating a mathematical description of the function of sectors and of the principal physical processes (2), running the system of models in a computer, and organizing the procedures for evaluating the system of indicators within the framework of this set of scenarios.

Diagram 2. Effect of Diversion of the Discharge of Northern Rivers Upon Natural-Economic Complexes

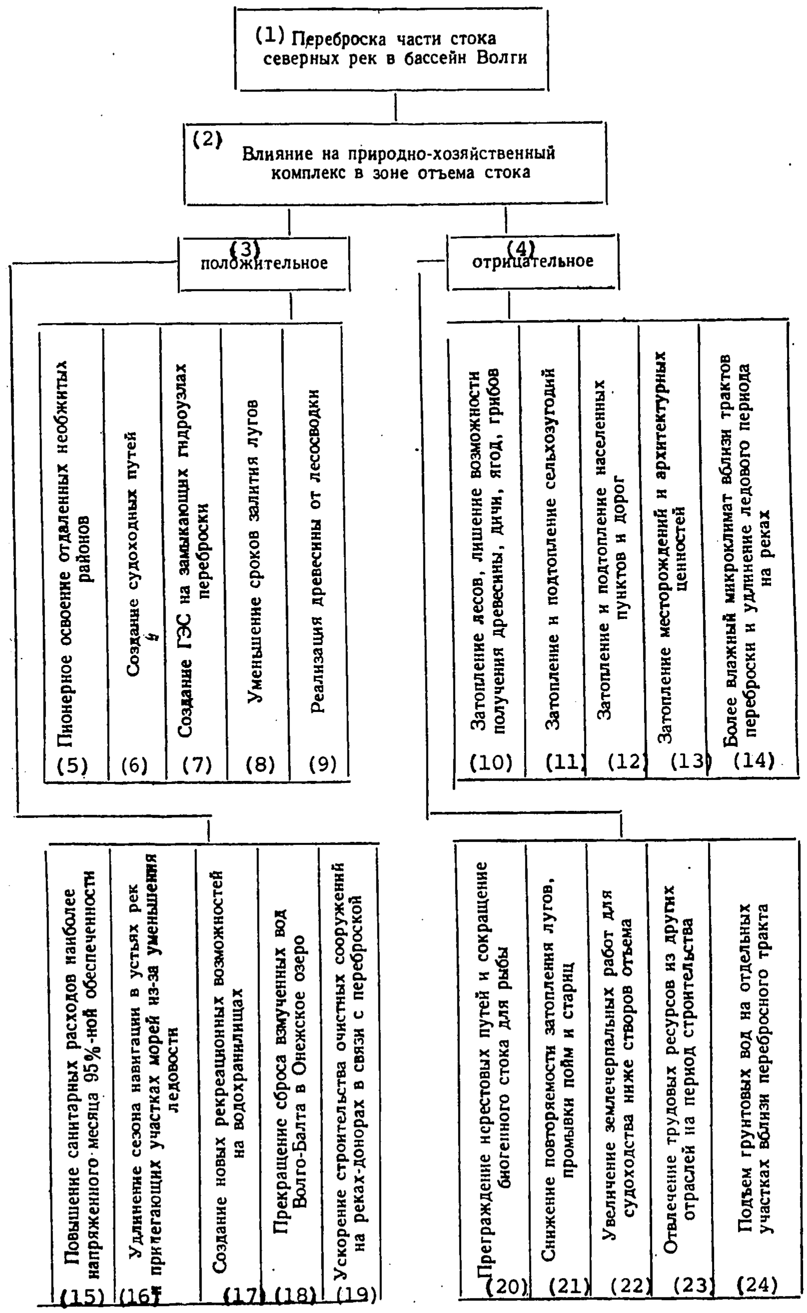


Diagram 2 (continued)

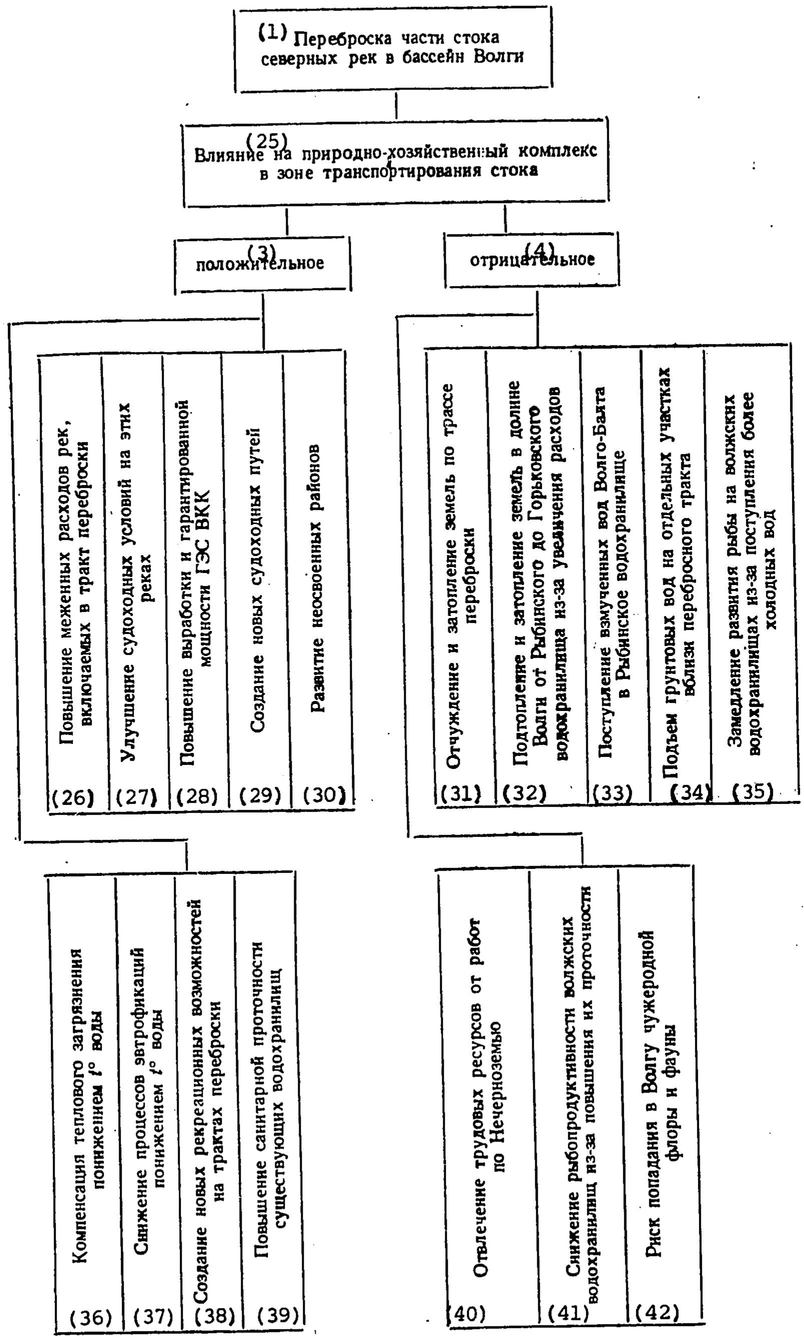
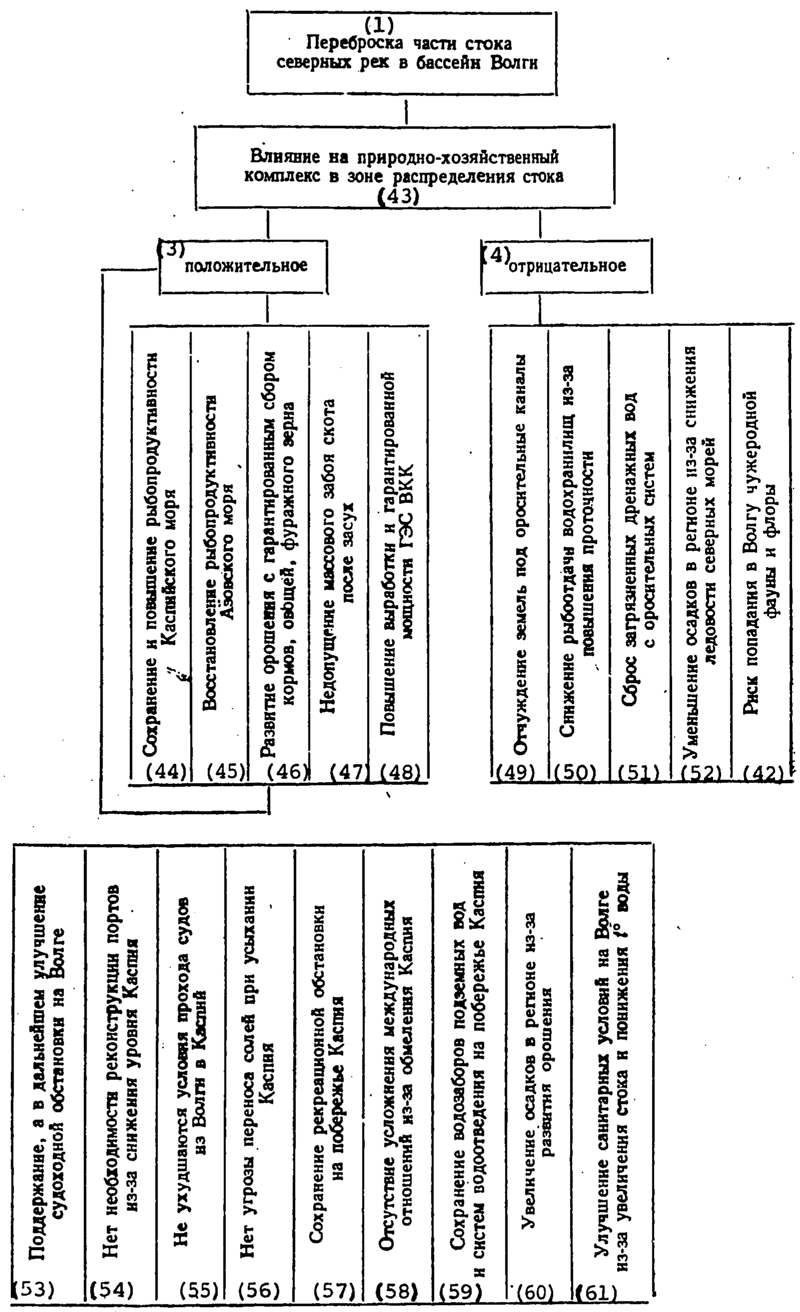


Diagram 2 (continued)



Key:

1. Diversion of part of the discharge of northern rivers into the Volga basin
2. Effect upon the natural-economic complex in the zone of discharge withdrawal
3. Positive
4. Negative
5. Initial development of remote uninhabited regions
6. Creation of shipping routes
7. Creation of hydroelectric power plants at hydraulic engineering facilities along the diversion route
8. Shorter periods of grassland flooding
9. Sale of wood from logging
10. Flooding of forests, lost possibilities for obtaining wood, wild animals, berries, mushrooms
11. Flooding and partial submersion of agricultural land
12. Flooding and partial submersion of population centers and roads
13. Flooding of mineral deposits and architectural landmarks
14. Creation of moister microclimate near diversion routes, and lengthening of the period of ice cover on rivers
15. Increase of consumption of water for sanitation purposes to 95 percent of requirement in the month of most-intense water use
16. Lengthening ofthe navigation season at river mouths and in adjacent sea areas due to less ice
17. Creation of new recreational possibilities at reservoirs
18. Cessation of the discharge of turbid waters from the Volga-Baltic Canal into Lake Onega
19. Faster construction of treatment plants on donor rivers in connection with diversion
20. Creation of obstacles across spawning routes, and reduction of biogenic discharge for fish
21. Lower frequency of grassland flooding, and of the flushing of floodplains and oxbow lakes
22. Increased dredging operations to support shipping below diversion gates
23. Distraction of manpower from other sectors during the time of construction
24. A rise in the water table in certain areas near the diversion route
25. Effect on the natural-economic complex in the discharge transportation zone
26. Higher low-water flow of rivers included in the diversion route
27. Improved shipping conditions on these rivers
28. Higher output and guaranteed capacity of hydroelectric power plants on the VKK [Volga-Kama Cascade]
29. Creation of new shipping routes
30. Development of uninhabited regions
31. Condemnation and flooding of land along diversion routes
32. Partial submerging and flooding of land in the Volga valley from Rybinskoye to Gor'kovskoye reservoir due to higher flow rate
33. Discharge of turbid waters from the Volga-Baltic Canal into Rybinskoye reservoir
34. Higher water table in certain areas near the diversion route
35. Slower fish development in Volga reservoirs due to admission of colder waters
36. Compensation of thermal pollution by decrease in water temperature
37. Slowdown of eutrophication due to decrease in water temperature
38. Creation of new recreation possibilities along diversion route

Key (continued)

39. Higher flushing action in existing reservoirs
40. Distraction of manpower from employment in Nonchernozem zones
41. Lower fish productivity of Volga reservoirs due to higher flow rate
42. The risk of foreign flora and fauna entering the Volga
43. Effect on natural-economic complex in the discharge distribution zone
44. Maintenance of the Caspian Sea's fish productivity, and its increase
45. Recovery of Azov fish productivity
46. Development of irrigation insuring guaranteed harvests of feed, vegetables, forage grain
47. Elimination of mass slaughters of farm animals following droughts
48. Higher output and guaranteed capacity of hydroelectric power plants on the VKK
49. Alienation of land to be used for irrigation canals
50. Reduced fish catches in reservoirs due to higher flow rate
51. Discharge of contaminated drain water from irrigation systems
52. Lower precipitation in the region due to a decline in the ice volume of northern seas
53. Maintenance and subsequent improvement of the shipping situation of the Volga
54. No need for rebuilding ports due to a decrease in the Caspian's level
55. Conditions for passage of vessels from the Volga to the Caspian are not worsened
56. No threat of the dispersal of salts due to desiccation of the Caspian
57. Preservation of recreational opportunities on the Caspian coast
58. No complications in international relations resulting from increasing shallowness of the Caspian
59. Preservation of underground water intakes and water diversion systems along the Caspian coast
60. Higher precipitation in the region due to development of irrigation
61. Improved sanitary conditions of the Volga due to greater discharge and lower water temperature

There are now four basic methods for analyzing mathematical models containing controllable variables: 1) the analytical approach, which permits us to analyze certain properties of models, for example balanced growth, major properties, and so on; 2) the optimization approach, which involves stating a single indicator and finding a control approach in response to which this indicator would assume its maximum value; 3) the multiple-criterion approach, where we create a set of all nondominant or possible values for the system of indicators; 4) the simulation approach in which we describe different variants of (write scenarios for) external influences upon the system under analysis, and evaluate the results of its operation.

Without a doubt all four methods can and must be used when a system under investigation is analyzed with the help of computer modeling. However, only simulation analysis, which involves performing controlled experiments with mathematical models describing the system under investigation, affords a possibility for studying adequate mathematical models of complex systems, models that come close to the real situation. Thus a man-machine system must be based on adequate models that yield to simulation analysis. Thus the entire system is called a simulation system.

To create a simulation system, we would need to spend rather large sums and invest a large amount of time; this is why one cannot be created to solve just a single important problem, no matter how important it is--the assets invested into the system would pay for themselves only if the simulation system becomes an implement of constant and diversified analysis of the object under investigation.

Construction of a simulation system pursues a number of goals:

associating and comparing processes differing in nature--economic, biological, hydrodynamic, and so on, and approaching their analysis from a single point of view;

unifying the information, formulating scientifically grounded requirements on it, and cross-checking its accuracy;

unifying formal and informal methods of analysis, planning, and decision making.

A simulation system is a multilevel system of models, described to different degrees of detail and supplied with software allowing its use by a planning specialist with a minimum background in mathematics. It is the principal tool of planning, and it predetermines the necessary information. In particular, a simulation system can be used to evaluate the quality of certain information, or the influence of uncertainty upon the values of the criteria employed, and so on. Here are the basic components of a simulation system:

a bank of modules, each of which represents part of the object under investigation in the form of a calculation program written in a certain algorithmic language;

a data bank supplied with a developed data retrieval system;

a system allowing for communication between man and computer;

a set of auxiliary simplified models that could support analysis based on optimization methods;

a set of programs for solving multiple-criterion problems;

a set of integrating and disintegrating programs.

A system of mathematical models adequately describing the object under investigation contains hundreds of control instructions and thousands of parameters. Inasmuch as a simulation experiment requires maintenance of control at each moment in time, the researcher may find himself unable to perform a sufficiently sensible experiment without first analyzing the system on the basis of simplified models, using the methods of optimization and multiple-criterion analysis.

Let us now go on to a description of alternative elements in scenarios written on the basis of the functional criterion. Combinations of alternatives from different groups form part of the scenario for defining the parameters to be controlled, the input factors, and geographic boundaries.

The first group of alternatives is associated with possible change in the boundaries of the region due to addition of certain contiguous river basins to the zone under examination. Such basins may include:

donor basins--Northern Dvina, Ob';

recipient basins--Dnepr, Kura, Ural, Tobol.

A basin-wide plan has been written for utilizing and conserving the water resources of the Northern Dvina. It states that only a very small quantity of water could be diverted from this river into the Volga basin, and even so, only in the distant future. Therefore it would be unsuitable to include this basin in the region under examination; small possible transfers of water may be accounted for in the revenue part of the region's water balance.

Only the western (right-bank) part of the Ural basin is included in the region under examination, inasmuch as the waters of the Volga (and, through it, the waters of northern rivers) may be diverted into this part of the basin and into the land area between the Volga and the Ural via the Kuybyshevskiy canal and the "Volga-Ural" system. The high cost indicators of diverting water just to the western part of the Ural basin alone apparently preclude the possibility for supplying Volga water to the basin's left bank. Therefore it would apparently be unsuitable to include the zone east of the Ural channel in the region of use of waters from the northern rivers.

In the Tobol basin, the upper reaches of the left-bank tributaries--Iset', Miass, and others, where the Sverdlovsk and Chelyabinsk industrial centers are located, suffer a water deficit. Diversion of water into this zone from the Volga basin would be possible only in negligible quantities, which thus excludes the Tobol basin from the zone under examination, considering in this case the withdrawals from the Ufa and Chusova rivers in the expense part of the water balance.

Thus the following remain in the first group of alternatives:

I-A--the region delimited by the basins of the Caspian (less the Transcaucasus), Azov, and rivers of the northern European USSR;

I-B--as above, plus the Dnepr basin;

I-C--region I-A plus the Kura basin;

I-D--region I-A plus the Ob' basin.

Variants containing other combinations of two or three additional basins may be added if we find that I-B, C, or D turns out to be better than I-A. In order to keep the analysis simple, these combinations will not be examined at this moment.

The second group of alternatives embraces different variants of agricultural development in the region accounting for a final production target set for the country as a whole. It should be considered in this case that:

All of the variants account fully for the possibility of intensifying agriculture on unirrigated land through mechanization and chemicalization of production, as suggested in existing plans;

the agricultural production volume of the region can vary in response to changes in the growth rate of irrigated farming, which is viewed as the principal approach to intensifying production. In this case the lacking production (seen in variants calling for limited development of irrigation) must be compensated by the supplanted variants (for example, by intensification of the draining of land in West Siberia, faster development of irrigated land in the Ukraine and along the Danube-Dnepr canal, irrigation of land with water diverted from Siberian rivers into Central Asia and Kazakhstan--in other words, through development proceeding outside the bounds of the region under examination).

Four alternatives can be offered f-- examination in the second group:

II-A--cessation of growth of irrigated land area in the region after 1980;

II-B--continued development of irrigation in the region, with the area of irrigated land increasing at the rate achieved in 1976-1980;

II-C--as above, with a higher growth rate;

II-D--development of irrigation at a lower rate, almost twice less than the present one.

The third group of alternatives includes variants of different types of irrigation in which water consumption and, consequently, the need for water diversion would vary:

III-A--in the foreseeable future, sprinkling will be the principal form of irrigation (this is in keeping with the present and foreseeable level of development of irrigation technology); old irrigation systems (there are not many of them in the region) would be brought up to modern standards;

III-B--transition, in the course of 15-20 years, to irrigation technology that is more economical (in relation to water consumption)--drip, subsoil, and finely dispersed, which would reduce water consumption by two or three times while maintaining the same production volume, but which would also require significantly greater foreseeable outlays.

The fourth and fifth groups of variants deal with different possibilities for solving the problem of the inland seas (Caspian and Azov), mainly in relation to development of fisheries. The Caspian Sea now provides the bulk of the most valuable species of fish caught in the country. In recent years, the annual sturgeon catches have been about 1.5 times above the maximum catches of previous years. This was achieved despite the fact that a cascade of hydroelectric power plants was built on the Volga, cutting the fish off from their spawning grounds in the central and upper reaches of the river. Sturgeon production was increased through broad introduction of artificial reproduction. In this same period, there was a decrease in the catches of semimigratory fishes and herring (although the sea's total catches did not change due to an increase in the sprat catch). In the period from 1960 to

1974 the level of the Caspian Sea remained rather stably near the -28.5 meter mark (6). Scientific research institutes have established (1) that a drop of 1 meter in the level of the Caspian Sea would reduce its potential fish productivity by four-five times in relation to sturgeons and by three times in relation to semimigratory fish. Were the sea level to drop by 2-3 meters, the Caspian could lose its entire significance to fisheries in relation to valuable species of fish.

In comparison with all of the seas of the world, the Sea of Azov is typified by the greatest payoff per unit area, with more than half of the catches in the 1930's being represented by valuable freshwater fish genera. The composition of the catches has transformed in recent years as a result of the sea's pollution on the background of its increasing salinity (owing to diversion of water into the Don and Kuban' basins)--valuable genera make up about 5 percent of the gross catches. The present mean annual inflow of river water into the Sea of Azov has decreased from 41 km^3 (the natural situation) to 28 km^3; in this case the salinity of the sea increased from 10.5 to 13 $^0/_{00}$. Were the present trend of increasing water diversion to persist in the basin, in the future the salinity of the Sea of Azov may reach the level of the Black Sea (17-18 0/00), as a result of which the Azov's fauna may be supplanted by the poorer fauna of the Black Sea.

The following variants are suggested for examination in the fourth group (Caspian Sea):

IV-A--acceptance of a declining sea level in connection with growth in water consumption within the Caspian basin; this variant is equivalent to abandoning fisheries in the Caspian Sea, which would concurrently harm a number of other national economic sectors;

IV-B--halting the decrease in the sea's level by placing the first generation of the water diversion system, created for average hydrometeorological conditions, into operation; raising the sea to the level necessary to support productive fishing 10-20 years after introduction of the second generation of the diversion system;

IV-C--as above, except that the level of the sea would be raised 10-20 years after introduction of the first generation of the diversion system;

IV-D, E--as in IV-B and C, but with a consideration for a low-water period in which demand would be satisfied by 75 percent;

IV-F, G--as above, with 90 percent satisfaction;

IV-H, I--as above, with 95 percent satisfaction.

The variants of the fifth group (Sea of Azov) may include the following:

V- -abandonment of fisheries in the Sea of Azov; in this case development of water consumption within the basin following variant II-B would be possible for another 15-20 years (until the inflow into the sea reaches about 22 km^3, which is close to evaporation from the sea's surface), after which water would have to be diverted from the Volga into the Don;

V-B--transfer of water from the Volga to the Don in the immediate future, coupled with gradual increase of the inflow into the Sea of Azov to 32 km^3/year; in this case the sea's salinity would stabilize at about 12.8-13 $^0/_{00}$, which corresponds to the salinity of the Caspian; the Kerch Strait would remain open, and the Dolgaya and Belosarayskaya sand bars at the outlet of the Bay of Taganrog would surface; the bay would transform into a nursery for valuable fish genera;

V-C--closure of the Kerch Strait with a dam and locks; the mean perennial demand for diverted water would decrease in the future to 4 km^3; the sea's salinity would stabilize at 10.5 $^0/_{00}$; in certain years anchovies would be unable to pass through the strait; removal of pollutants from the Azov by flushing action would worsen somewhat;

V-D--gradual recovery of natural inflow into the sea, in response to diversion, to 41 km^3 (salinity would stabilize at 10.5 $^0/_{00}$); the demand for diverted water would be 9 km^3 greater than in variant V-B.

Before making an economic comparison, all variants of groups IV and V must be equalized in terms of fish production. This means that the variant with the greatest production is taken as the basis, and in all others the lacking production is made up by substituting production operations: All fish except the sturgeons are compensated by cultivation of pond carp, sturgeons are compensated by pond bester (a hybrid of beluga and sterlet), and roe, which provides the bulk of the income of fisheries and which cannot be obtained in substituted production operations, is compensated in monetary terms, in a currency equivalent.

Variants in the sixth group consider different uses of water in the Volga basin from the standpoint of producing hydroelectric power (hydroelectric power plants on other rivers of the region are small, and as a rule they operate on demand, capitalizing on releases of water for fishing, navigational, and flushing purposes). Given different volumes of discharge in the Volga (following adoption of certain variants of the previous groups), two variants for regulating Volga discharge are possible from the standpoint of hydroelectric power engineering:

VI-A--a power production variant, in which all of the requirements insuring guaranteed values for the parameters of a hydroelectric power plant in the fall-winter period are satisfied, and production is maximized to the extent possible in this period; unutilized releases of water are minimized in the high-water period;

VI-B--other forms of regulation in which guaranteed values are not maintained for the parameters of a hydroelectric power plant because of the priority placed on the needs of fisheries, water transportation, and irrigated agriculture.

The seventh group concerns itself with the possibilities of river transportation. The object of variation here is the situation on the Volga and the Kama, where the shipment volume is 40 percent of the total for the country's river fleet as a whole. The Don's shipping parameters do not depend in principle on the decisions made as to diverting and distributing the discharge of rivers (due to completion of efforts to create a lock system along the Lower Don in the near future); on the Kuban', Terek, and Ural, shipping is either absent or consists of a negligible volume of local traffic.

The following variants for development of transportation on the Volga are possible:

VII-A--use of vessels with normal draft (a guaranteed depth of 4 meters); in this case a flow rate of 4,000 m^3/sec would be needed below Volgogradskoye reservoir, with 95 percent assurance, for the duration of the continuous part of the navigation season;

VII-B--conversion to vessels with a draft decreased by 0.5 meters, and a flow rate of 3,400 m^3/sec;

VII-C--conversion to vessels with a draft increased by 0.5 meters, with a flow rate of 5,000 m^3/sec.

Other possible variants may consider using water diversion channels for shipping, both in the zone of discharge withdrawal and conveyence, and in the zone of its distribution. To simplify the analysis, these questions are examined as local ones in each concrete variant of diversion canal and route, and the decision to include or not include shipping facilities as part of the diversion route is made according to the conventional procedure used in planning hydraulic engineering systems depending on costs and effectiveness.

Finally, the eighth group of variants includes alternative solutions for diverting water from the north to the south of the European USSR, and their different engineering concepts. Because an infinitely large number of alternatives, with different locations for the gates of hydraulic engineering structures and different parameters and combinations of stages, would be possible for each donor river, it would be best to name just the variant subgroups in this group:

VIII-A--diversion of water from rivers in the northern European USSR, southward along the main trunk of the river system and countercurrent to it, coupled with construction of reservoirs along the diversion route to adjust for the river's irregular flow rates; solutions of this type have been examined for the basins of the Neva River, Lake Vyg, Kemi River, Kovda, Lake Onega, the Northern Dvina (together with the Sukhona and Vychegda), the Mezen' River, and the Pechora;

VIII-B--diversion of water from rivers of the northern European USSR southward, transferring the water through the channel of one of the tributaries that is shorter in length and which has a narrower floodplain (to reduce the flooding area), coupled with construction of reservoirs along the diversion route in order to raise the uniformity of water flow; such variants have been examined for the basins of the Northern Dvina (requiring transfer along the Vaga and Yemets) and the Pechora (requiring transfer along the Pizhma and Izhma);

VIII-C--the diverted discharge is regulated (with the purpose of making the southward flow of water more uniform) not in reservoirs along the diversion route, but in the estuary regions of the donor rivers ("marine reservoirs"); a fundamental possibility for creating such reservoirs was revealed in the Onega inlet on the White Sea and the Pechora inlet on the Pechora Sea, of which the former enjoys the doubtless advantages;

VIII-D--diversion of part of the discharge of the Ob' River basin to the southern European USSR across the Ural range and through the basins of the Pechora and (or) Kama;

VIII-E--measures to reduce evaporation from the surface of the Caspian Sea, which may be equated to diversion in terms of their influence upon the sea's level; two measures of this type would be realistic: reducing (or halting) entry of water into the Bay of Kara-Bogaz-Gol; diking off the northeastern shallows of the Caspian Sea;

VIII-F--transfer of waters from the Black Sea to the Caspian via the Kuma-Manychskoye basin. This measure would be equivalent to transferring the waters of the northern rivers in terms of its influence upon sea level (but not upon salinity and biogenic potential).

The eight groups described above, each of which contain from 2-3 (III, VI, VII) to 35 (VIII) alternative solutions, can be used to create a system of variant combinations. Theoretically, we can create about 160,000 combinations of eight components each out of this set of alternatives. If we consider that some variants of a group are not totally independent of variants of another group (for example VIII-D can be considered only in conjunction with one of the variants of group I, namely I-D), then the total number of real combinations would be lower, though it still would be in the thousands. In view of the impossibility and unfeasibility of studying each of these combinations, it would be more constructive to examine the variants within each group after setting identical external conditions for the other groups of alternatives (that is, for the other groups we would select the variants that may have been chosen previously, or the most probable variants). This makes it possible to reduce the set under consideration to several dozen basic variants. The concrete plan was written and several scenarios were evaluated with the help of particular mathematical models developed to support the most laborious steps in the planning of river diversion, steps in which multiple repetition of identical computations in which only certain parameters are varied offers the best conditions for applying calculation algorithms. These steps include:

a) treatment of the results of hydrological analyses;

b) treatment of the field data obtained in engineering, geological, and hydrogeological studies;

c) optimization of the distribution of the country's agricultural production;

d) optimization of the distribution of capital investments into land improvement, with respect to different oblasts of the region;

e) estimation of water use by irrigated agriculture in the region, with respect to individual oblasts, basin zones, and climatic zones, using perennial meteorological data;

f) water management computations for the Don and Volga basins;

g) estimation of the dynamics of the Caspian Sea's level, in terms of probability;

h) prediction of changes in flow rates in a major lake system in response to diversion (for example in Lake Onega);

i) design and estimation of the construction costs.

We will conclude with a brief survey of the results of expert analysis of variants in the eight groups of alternative solutions to the problem of diverting part of the discharge of northern rivers into the Volga, listed above.

Examination of variants in the first group (the region's boundaries) revealed that diversion of part of the discharge of northern rivers into the Dnepr basin would be about 1.5 times more expensive than diversion of water into this region from the Danube, and because of this and the limited possibilities for withdrawing water from the northern rivers, the latter may be considered only after the possibilities for diverting Danube discharge are exhausted. Diversion of water from the Volga into the Kura basin is deemed unsuitable due to high cost and the complexity of the diversion route.

Variant I-D was not included among the recommended solutions because diversion from the Ob' basin turned out to be three to four times more expensive (in terms of both capital investments and annual expenses) than transfer of water from northern rivers of the European USSR. All of this permitted us to choose variant I-A as the main one upon which to base formation of combinations with variants in other groups.

Analysis of the alternatives in the second group--halting development of irrigation or permitting its growth in three variants--demonstrated that halting the development of irrigation after 1980 would not solve the problem of the Caspian Sea: A water deficit of about 4 km^3 would already exist by this time, and growth in industry, cities, and municipal services would quickly increase this deficit by several orders of magnitude. A study of the effectiveness of land improvement measures, mainly irrigated agriculture, revealed that maintaining, in the future, the rate of growth of irrigated land attained in the 10th Five-Year Plan (1976-1980) would be suitable. However, considering that the rate of diversion of discharge from northern rivers would not keep up with such development, fisheries would be better off with a variant calling for a lower rate of growth, where the future increment of irrigated land area would be 55-60 percent of the rate planned for the 10th Five-Year Plan.

Analysis of the variants of types of irrigation (irrigation technology), which make up the third group of alternatives, led to the conclusion that transition to more-economical forms of irrigation (drip, subsoil, finely dispersed) would be highly limited in scale until the end of the current century (2-3 percent according to some estimates, and not more than 6-8 percent according to others), due to the high cost of construction per hectare. The cost would be 6,000-8,000 rubles per hectare for drip irrigation, which is two to three times more expensive than irrigation with sprinkling systems. Even if we consider that drip irrigation can raise the yield by an average of 25-30 percent and the unit capital investments on water diversion would be somewhat lower, for most crops (except orchards, vineyards, and vegetables) drip irrigation is still about 1.5-2 times less effective than sprinkling. As far as finely dispersed irrigation is concerned, the technology has not been fully worked out yet, and therefore we cannot count on its extensive introducion in the near future.

A study of the variants of the Caspian Sea's level in relation to different combinations of the flow rates of the basin's rivers, water withdrawals, and water transfers showed that a significant decline in the sea's level could not be justified from either an economic or, all the more so, an ecological and social point of view. The most acceptable variant is that of raising the level of the Caspian Sea after the commissioning of the first generation of a discharge diversion system in average hydrometeorological conditions, followed in the future by a transition to control of the sea's level in low-water periods as well.

The recommended variant for the Sea of Azov entailed rehabilitation of Azov fisheries coupled with construction of the Kerch hydraulic engineering complex, which would make it possible to maintain previous salinity (10.5 $^0/00$) in the presence of an inflow of river water totaling 28 km^3 per year on the average of several years. In the event that a positive decision is not made for the Kerch hydraulic engineering complex in view of the elements of ecological risk contained in such a project, a substitute variant would be recommended--stabilizing the salinity of the Sea of Azov at 12.8-13 $^0/00$, maintaining an inflow rate of 32 km^3, and leaving the Strait of Kerch open. In this case Taganrog Bay would play the role of a nursery for sturgeons and semimigratory fish, following restoration of Dolgaya and Belosarayskaya sand bars.

Examination of the variants in the sixth and seventh groups, which are oriented at revealing the optimum schedule of water releases on the Volga, led to the conclusion that priority should be given to the energy and transportation variants that assure the guaranteed planned parameters of the Volga-Kama GES cascade and create conditions permitting shipping with a guaranteed depth of 4.0 meters in the period of the first generation of the diversion system, followed in the future by a transition to a depth of 4.5 meters.

Study of the variants in the eighth group (discharge diversion alternatives) led to selection of the effective variant, entailing diversion, in the first generation of the system, about 35-40 km^3 of water per year from Lake Onega and the upper reaches of the Onega, Sukhona, and Pechora, in which case the volume withdrawn from each of these sources would be set at no more than 10-15 percent of the main channel's discharge at its mouth. Of the possible solutions for the second generation, diversion of water from the "Gulf of Onega" reservoir, created in part of the White Sea basin, offers the best indicators, particularly in terms of lowest influence upon the natural and economic environment. This system would more than double the diversion volume, and solve the problem of supplying water to the southeastern European USSR for the entire foreseeable future.

Successive implementation of the basic premises of systems analysis to develop the technical-economic grounds for diverting part of the discharge of northern rivers permitted planners to conceptualize the problem as a whole and concentrate their efforts on the key factors of such a large, multifaceted water management project.

In the form we used here, systems analysis is a flexible tool for planning the creative work of the planner, and what is extremely significant, it allows us to combine previous developments, many of which entailed manual methods or heuristic techniques, with modern studies presently being conducted with the extensive help of computers and simulation modeling.

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STUDY OF RIVER DIVERSION IMPACT ON USSR DEVELOPMENT, ENVIRONMENT CONTINUES

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[Article: "An Important Step in Development of the Country's Water Supply Problem"]

[Text] The gross volume of industrial production has increased 180-fold during the years of Soviet power. The areas of irrigated lands increased from 4 to 17 million hectares and energy generation at hydroelectric power plants has reached approximately 170 billion kW·hr. The housing problem is being solved successfully and the rates of growth of the people's welfare are increasing. Behind these well-known facts stands the increase in the volumes of water drawn out of sources, from approximately 50 to 500 km^3/year, and as a result in a number of instances the growth of demand for guaranteeing the water content of rivers is commensurate with their flow in low-water years. Water is becoming one of the leading resources which affect the distribution of productive forces, while water supply becomes an ever more significant component of the cost of manufactured products.

The main source of the water resources in the USSR both now and in the foreseeable future is surface waters, in volume of which the Soviet Union occupies second place in the world (4,700 km^3/year). Resources of underground waters, despite the considerably smaller volumes, play an important role in potable and household water supply.

Total water consumption in the USSR comprises approximately 10 percent of the volume of river flow and approximately half of the water used is returned to the sources. However, despite the seeming benefit, the water management balance (correlation of water needs to its presence at the source) is now under stress in some main river basins. This situation ensues from the following factors.

The distribution of water users does not correspond to the distribution of water resources (a total of approximately 20 percent of the country's water resources goes to inhabited and economically developed territories where up to 80 percent of the water needs are concentrated). The frequently high concentration of population and water-consuming industrial plants was historically located in watershed territories rich in minerals, but with shallow rivers characterized by an unstable rate of flow.

The intraannual distribution of streamflow does not correspond to the intraannual variation of water needs (an exception are the Central Asian rivers, the summer flooding of which coincides approximately with the period of greatest irrigation, due to which more than half the flow on the Amu Dar'ya and Syr Dar'ya rivers is used in the national economy with relatively small capacity of regulating reservoirs).

The possibilities of a radical change of the intraannual distribution of flow are limited, which is explained by the absence of favorable topographic conditions for creation of capacious reservoirs or unacceptable flooding of agricultural lands, important national economic or cultural-historical objects, mineral deposits and so on.

The scope of the interannual fluctuations of flow increases as one penetrates the arid zone where the main mass of water consumers is concentrated.

Water supply problems have now been complicated considerably. Implementation of measures related to collection and delivery of water to the user is now inadequate. Making up the water needs has become possible in practically all large and medium river basins (within the main economically developed territory of the country) only with implementation of measures directed toward increasing the available water resources. One of the measures in this plan may be territorial redistribution of river flow.

The main factors which advance the problem of supplementing the river flow of the country's southern slope should be noted.

Thus, creation of cascades of hydroelectric power plants, maintaining the increasing guaranteed depths for water transport, provision of favorable spawning conditions, flooding river lands and so on require conservation of guaranteed water content on the rivers by special water permits. In some cases a "generalized" permit places significantly higher requirements on the volume of guaranteed water resources than the total application to remove water from the source. For example, this is the situation on the Volga, Dnepr and other large rivers.

Moreover, more than half of the country's population lives on the territories of river basins falling into the inland seas: the Caspian, Azov, Aral , Balkhash, Issyk-Kul' and others. Any significant removals of water from the rivers of these basins lead to an unfavorable change of the regime of the seas, which in turn inflicts losses on the national economy and has a negative effect on the environment. One must proceed toward implementation of expensive compensation measures to prevent or soften these consequences.

The development of water consumption is accompanied by an increase in the volumes of spent waters which are returned to one or another extent to the water sources. Enormous work is being carried out in the country, directed toward reducing the amount of polluted substances entering the water sources. It is sufficient to say that the state has spent six billion rubles during the past 5 years on construction of purification plants. Considerable funds are being spent on development of circulating water supply systems which prevent discharge of waste waters into reservoirs, on development of non-waste production processes and so on. However, whereas a dip has already begun in the dynamics of pollution of water resources with industrial wastes in some regions, fundamental solution of the problem requires even greater efforts and additional large capital investments. The fact is that reservoir pollution by fertilizers and toxic chemicals running off cultivated fields in an organized manner (in the form of drain water) and also with thaw and rain water, begins to play an ever more discernible role; the rain runoff of cities carries a significant amount of polluting substances. Purification or accumulation of polluted waters of these types encounters considerable technological difficulties and solution of this problem will apparently not be as rapid as in control of polluting substances of industrial and household origin. Probably it will be necessary for many years to cope with the possible anthropogenic effect on water quality on various rivers and to different degrees. This means specifically that specific volumes of water must be reserved to dilute the incoming polluting substances (of course, provided that a combination of preventive measures is implemented).

Further, a problem inherent to pollution--an increase of the mineralization of river water, which increases downstream due to significant reduction of river flow in general or due to an increase of water intake with retention or an increase of the number of incoming salts (due to flushing of irrigated lands)--occurs on rivers whose flow is taken intensively for irrigation. We note that flushing irrigated tracts is in many cases a compulsory condition of protecting soils against salinization. However, an increase of mineralization of river waters sometimes occurs to limits that begin to make water use difficult. Salinization of lower reaches acquires a specific nature during an increase of water use on rivers which form estuaries, and even more so since the salinity of water in estuaries increases sharply during reduction of flow due to the lesser dilution of the incoming sea waters due to winds (the volume of wind-driven sea water even increases somewhat).

Finally, it should be noted that the problem of transport and distribution of the surplus solid flow occurs for rivers which carry a large amount of detritus under conditions of intensive water intake. The fact is that the transporting capability of the flow decreases due to a decrease of water content and flow velocities, while the detritus load decreases insignificantly.

Finally, it is impossible not to touch on problems of water quality. Restoration and maintenance of the required quality of natural waters should be solved with regard to the effect of the redistributed runoff on it. However, rehandling of flow alone cannot solve this problem if the discharges of polluting substances into water sources are not stopped.

Optimum management of water resources, which includes management of the conditions of artifical and natural water facilities (including the water quality mode) in the interests of various sectors of the national economy and the sphere of social development, distribution of water resources among sectors of the economy and individual water users and distribution of water resources among the country's regions on a different scale, river basins, large lakes and inland and coastal seas, acquires ever greater significance as water needs increase.

Three aspects of this problem should be especially considered in this case.

1. Optimum management of large water management systems, which will encompass ever larger territories when the proposed interbasin transfers of water are implemented. Accordingly, the effect of management will increase as a result of reducing the synchronization between fluctuations of flow of the joined sources and fluctuations of water use in different regions of the water-management system.

2. Optimum management of the conditions of the Sea of Azov and the Caspian Sea under conditions of supplementing the inflow to these seas, which, along with some reduction of the required volumes of water supplied perennially, opens up the opportunity for a significant decrease of unfavorable deviations of the conditions of the seas from these average perennial characteristics.

3. Intensification of the use of underground levels by periodic supplementation of these reserves with surface waters (during periods of a surplus of the latter).

As is known, the main water user is irrigated agriculture, development of which is inherent to the insufficient wetting zone. Therefore, the increase of water needs in the southern part of the country, where resources are limited and the capabilities of using local water resources initially with the natural conditions of water facilities and then with regulated conditions are rather quickly exhausted, is essentially predetermined. This circumstance makes it necessary for interbasin redistribution of water resources.

We note that interbasin redistribution of river flow is in no way an essentially new method of water supply. Examples may be delivery of part of the flow of the Msta River to the Tvertsa River basin (18th century), the flow of Kuban' water to the Manych and Kuma rivers, the flow of Irtysh water to the Nura River, creation of the Karakum canal and so on.

It is also known that one must encounter removal of lands and other natural resources for canals, reservoirs and various hydroengineering installations at the earliest stages of water-management construction. Changes of natural conditions were observed along the routes of diversions: the ground water regime was disrupted, the soil and vegetation cover of adjacent territories was transformed and the regime of the liquid, biogenic and solid flow of rivers was changed. As the scale of water-management measures increases, their effect on the environment naturally increases.

Systems of intra- and interbasin redistribution of flow which not only successfully fulfill multisector economic and social functions but have a favorable effect on the state of the environment of the adjacent territories, exist in the USSR. An example may be the Moscow-Volga (now called the Canal imeni Moscow), constructed during the 1930s, which became a reliable source of drinking, communal-household and industrial water supply for Moscow and the Moscow area and created a deepwater route which connected Moscow to the Baltic, White and subsequently to the Sea of Azov and the Black Sea.

The given example with the Canal imeni Moscow shows the principle capability of territorial redistribution of river flow with relatively low losses to the environment, but with the provision of moderate (compared to the water content of the donor river) volumes of water intake and reclamation of diversion of territories adjacent to the routes.

Subsidies of water resources to three regions of the country--the Caspian Sea and Sea of Azov basins, the basin of the Aral'skoye More and Moldavia and the Southern Ukraine--are now required.

The need to bring in waters from outside these zones is dictated by the following circumstances.

The area of irrigated lands approaches 7 million hectares while the uncirculated water use comprises approximately 70 km^3/years or approximately 2/3 of the average perennial flow of these rivers in the Amudar'ya and Syrdar'ya basins. The efficiency of agriculture is determined by favorable climatic conditions for production of agricultural products (primarily cotton) and also by the high rates of growth of the population and of labor resources. The available water resources of this zone are close to exhausted. True, approximately 15-18 km^3 of water can be additionally acquired annually by regulation of flow. Reconstruction of irrigation systems may also release some quantity of water, but the effect of this measure is limited. Hence, the conclusion suggests itself that intensive development of irrigation in the indicated basins can continue beyond the present century only if one can count on water resources being brought in from outside.

Taking the grandiose nature and complexity of this work into account, one must carefully approach the basis of the rates of development of irrigated agriculture in these regions.

River flow has been reduced by approximately one-fourth as a result of water removal in the Dnepr river basin, where irrigation of grain crops has proved its high effectiveness. Ever increasing distribution of saline Black Sea waters upstream along the Dnepr and Bug rivers is beginning to be felt as a consequence. As water consumption increases, salinization of the Dnepr-Bug estuary may entail unfavorable ecological consequences. True, construction of the Lower Dnepr Hydroengineering Complex will make it possible to release approximately 10 km^3/year, but this cannot fully solve the problem of water supply to the region. Further development of the water-consuming sectors of the economy in the Dnepr River basin requires that water be brought in from the outside.

The need to supplement the water resources of the Caspian Sea and Sea of Azov basins is also caused by development of irrigated agriculture. Although the needs of agriculture and industry in the foreseeable future in this region could essentially by made up by using local water resources, this would result in an impermissible reduction of the influx to the Caspian Sea and Sea of Azov. Moreover, the basins of these seas was long distinguished by high biological productivity which is determined by the large biogenic runoff formed in the valleys of Central Russia, by the shallow water of the Sea of Azov and the Northern Caspian Sea, where photosynthesis occurs intensively under conditions of increased solar radiation, and also by the large area of the distributed zones within the shallow waters with favorable conditions for young age groups of fish shoals.

A reduction of river influx is accompanied by a decrease of the level of the Caspian Sea and by an increase of the salinity of the Sea of Azov. Prerequisites are created for a significant reduction of their biological productivity and deterioration of the sanitary conditions, for the occurrence of unfavorable national economic consequences and also deterioration of natural-climatic conditions on adjacent territories. Achievement of optimum natural conditions in the basins of these seas already requires supplementation of their water resources at the rate of approximately 10-15 km^3/year and compensation of the increased water consumption by bringing water in from the outside.

Thus, supplementation of the water resources of Central Asia and Kazakhstan, Moldavia and the Southern Ukraine mainly follows the goal of increasing the efficiency of utilizing the land resources, whereas subsidies of water to the Azov-Caspian region are intended mainly to increase the functional efficiency of the water ecosystems under the conditions of the developing national economy of this zone.

One of the main problems of supplementing the water resources of the southern part of the country is the establishment of water facilities--donors. It is natural to seek these sources among the water facilities of the surplus moistening zone related to the basins of the country's northern slope. One should take into account in this case both the remote prospects of development and water support of the national economy of these facilities in the basins and the direct effect of planned removal of water resources on their regime and the environment of the basins as a whole. One should apparently proceed from the position that disruption of the regime of water resources should not be accompanied by any significant unfavorable consequences of an economic, natural-climatic, ecological or social nature. At the same time, evaluating the permissibility of one or another inroads into the environment while making large water-management transformations, one should take into account that development of the economy inevitably leads to disruptions of natural conditions. The problem includes minimization of these unfavorable effects for large regions of the country and complete elimination of them for foreign territories and water basins. Therefore, development of measures to prevent or to reduce to the maximum possible the negative consequences of these transformations becomes an important inseparable part of the complex plan for territorial redistribution of streamflowand its scientific basis. This aspect of the problem should also serve as one of the resolving factors of evaluating the scales and variants of the engineering solutions for redistribution of river flow.

The acuteness of the problem of water supply to the southern territories of the country and the condition of the southern seas determined the decision of the directive bodies to compile a technical and economic basis for the first unit of river flow diversion during the current five-year plan.

A large number of planning-research and scientific research institutes have universally studied the problem of territorial redistribution of water resources during the past five years. The investigations specifically made it possible to establish the following:

1. The feasibility of diverting part of the flow of the northern and Siberian rivers to the southern European USSR, Kazakhstan and Central Asia. However, the scales and deadlines for implementing these measures need to be refined.

A complex of measures on the maximum possible efficient use of local water resources must be carried out to implement streamflow diversion. These measures should include regulation of the river flow of these regions, introduction of circulating water supply and waterless and wasteless technology, an increase in the efficiency of irrigation systems by reconstruction of them, converting them to more economical methods of irrigation in water consumption and so on, ferropurification of waste water and miscellaneous measures to protect water quality, achieving the required level of drainage of irrigated lands, repeated use of collector-drain waters and so on.

2. The need to carry out careful investigations and scientific justification of the prospects for development of the national economy of the southern regions of the European USSR and the Central region from positions of their water supply (especially development of the water-consuming sectors of industry and distribution of the irrigated areas and the irrigation conditions of chernozem soils and also additional investigations to establish the optimum conditions and regimes and of the Sea of Azov and the Aral Sea. Possible changes in the environment (especially irreversible negative changes) and the losses that occur as a result of hindering the development of the national economy due to a shortage of water resources (i.e., in the absence of additional supply from the north or delay of it after exhaustion of the water resources of the given regions) should be determined and compared for these territories.

3. The feasibility of separate implementation of the first water delivery units to the Azov-Caspian region and to the basin of the Aral Sea (the water resources of the southern European USSR should be supplemented from the water facilities of its northern slope, the subsidy of waters to Central Asia and Kazakhstan should be supplemented from the closest water facility of Siberia--the Ob' River basin.

The prospects for supplying water to Moldavia and the Southern Ukraine primarily due to the Danube-Dnepr Canal, and in the remote future due to the water facilities of the northwestern European USSR, with regard to which it is undesirable to bring in the latter as first-line donors for the Azov-Caspian region.

4. Step by step territorial redistribution of water resources with a gradual increase of the volumes of delivered water. In this case each following step should be taken with regard to the positive and negative consequences of previous steps.

5. The consequences to the environment in zones of removal and accumulation of streamflow, as in zones of transportation (with respect to the first unit of the planned redistribution of flow of the northern and Siberian rivers) will not be global in nature. Changes may occur in the environment on a relatively small area in the case of implementation of the investigated versions of the first unit of territorial redistribution of flow. These changes will be manifested with different intensity and direction. However, there is no doubt that the possible undesirable changes in the environment will be mainly local in nature and can be prevented, eliminated or compensated for.

6. The obligatory combination of removal of even a comparatively small part of river flow from the northern regions of the European USSR and Western Siberia with water-management development and optimization of the environment of these territories.

The following should be noted in conclusion.

Diversion of part of the flow of northern rivers to the country's southern slope should be regarded as a measure developed by the powerful anthropogenic effect on the water resources of the southern slope and is undoubtedly only one of the methods of supplying water to the country's national economy. Solution of the problem of water supply to the national economy should be based on an optimum combination of various water-management and water-conservation measures such as making the utilization of water resources more efficient in all sectors of the national economy, including a fundamental change of production technology and regeneration of the use of water resources;

increasing the level of utilization of available water resources by regulation of streamflow and conservation of water due to quantitative and qualitative depletion.

An optimum combination of these measures in the socioeconomic and environmental-conservation sense should in the final analysis determine the optimum scales of development of each of them, including the scales and frequency of redistribution of water resources.

Scientific research and planning work related to the country's water supply should be continued during the next five-year plan. The decisions of the 26th CPSU Congress on development of the national economy and an increase of the welfare of the workers of the USSR will be the basis of this work.

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COMMENT ON RIVER REVERSAL EFFECT ON ARCTIC

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[Article by E. Tolstikov, deputy chairman of the State Committee for Hydrometeorology and Environmental Control]

[Excerpt] In recent years, work has been developing successfully in meteorology for estimating the effect of the polar areas on the global balance of heat, moisture, and energy. It has not only important practical significance, but it is necessary as well for studying the general circulation of the atmosphere and the role of the polar regions in it. Investigations have shown that because of the increase in precipitation relative to evaporation over the Arctic Ocean, more than 2,000 cubic km of water is being taken out of the world's water economy annually. After adding the runoff of rivers into the Arctic Ocean, this figure increases to 8,000 cubic km. The computations for estimating the changes in the hydrological regime of the river Ob' as a result of the supposed redistribution of flow, show that the loss of 25 cubic km annually will not have an appreciable influence on the processes of the hydrological cycle.

END

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