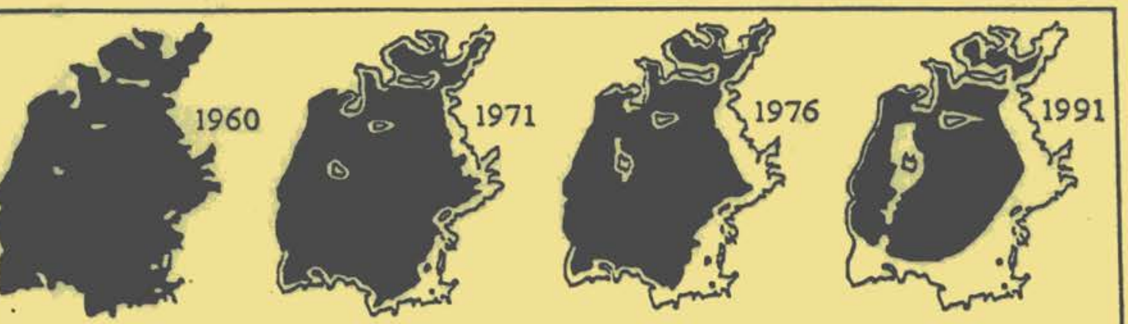
United Nations Environment Programme

The Aral Sea



YEAR	AVERAGE LEVEL (meters)	AVERAGE AREA (sq.-km)	AVERAGE VOLUME (cu.-km)	AVERAGE SALINITY (grams/liter)
1960	53.41	66,900	1090	10
1971	51.05	60,200	925	11
1976	48.28	55,700	763	14
1991		33,800	290	
large sea	37.31	31,000	270	~30
small sea	38.41	2,800	20	~30
2000		21,421	140	
large sea	31.90	19,701	131	65-70
small sea[1]	38.00	1,720	9	~36

[1]Eastern part, which receives flow from the Syr Dar'ya, only.

Chronology of Aral Sea Changes

Diagnostic Study
for the Development of an Action Plan
for the Conservation of the Aral Sea

DIAGNOSTIC STUDY

FOR THE DEVELOPMENT OF AN ACTION PLAN

FOR THE CONSERVATION OF THE ARAL SEA

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NOTE

This Diagnostic Report reflects the combined efforts of many dedicated individuals working on the numerous problems associated with the current changes in the Aral Sea and its drainage basin. It represents a consensus document, prepared on the basis of many, often diverse, deliberations of the Working Group of Experts for the Preparation of an Action Plan for the Rehabilitation of the Aral Sea Basin. Thus it should be viewed as a working document, comprising the best efforts of all those involved in its preparation.

It also is noted that this report is the integration of individual components from many contributing authors. Accordingly, efforts were made to provide appropriate linkages between relevant topics and sub-chapters. Nevertheless, many of the contributing authors used differing styles and forms in preparing their materials. One such element is the use of references. Some contributors incorporated tables, figures and similar materials directly into the body of the text, without reference to their specific source. Others explicitly identified the sources of the materials used in their contributions. It also is noted that many of the references are available only in Russian.

Because of these factors, it was not possible to readily compile a summary listing of the specific references used in this report. A complete listing of references is available upon request.

CHAPTER I

INTRODUCTION

In the last decades of the twentieth century, humanity has been confronted by several environmental disasters. Among these, the demise of the Aral Sea and its drainage basin stand out as a paramount example. The diversion of the waters of its major inflow tributaries, for the purpose of irrigating cotton and other crops in this region, have had devastating effects on the Aral Sea, a huge lake in Central Asia. During a single human generation, the Aral Sea has shrunk significantly in size and volume. The salinity of the water in the Aral Sea has increased significantly, resulting in decreased water use possibilities for the basin population, and a fundamental change in the flora and fauna of the lake. The surrounding regions and basin of the Aral Sea also have undergone dramatic environmental degradation. Further, profound social, economic and medical problems have accompanied this environmental degradation.

The decision to produce a "Diagnostic Study for the Development of an Action Plan for the Conservation of the Aral Sea" is a direct response to this dramatic situation. The decision recognized that no resolution to the problems involved is possible in the absence of a rigorous and comprehensive identification and consideration of the problems. The significance of the present study, therefore, lies in its provision of information necessary to begin resolution of the significant problems of the Aral Sea and its drainage basin. The study was launched by UNEP, in collaboration with the Center for International Projects (Moscow). It was supported by advice from an international working group of experts drawn from several countries outside those of the former Soviet Union (United States of America, France, Australia, Germany, Poland, Czechoslovakia).

The explicit aim of the project was to provide UNEP with a Diagnostic Report, incorporating environmental, demographic and economic issues which identify the basic causes of problems in the Aral Sea basin. Therefore, in the first instance, the report has been prepared for UNEP. Its preparation, however, also presages wider use: it is hoped that the report will be of value not only to UNEP, but to all those bodies, international and national, governmental and nongovernmental, who have an interest in, and concern for, the natural environment and inhabitants of the Aral Sea basin.

The report is based on information from numerous sources. It draws upon multiple publications listed in its reference section. It draws also on the experience of the expert working group. Nevertheless, it also is acknowledged that less information is available than is desirable. In this context, the project identified a number of specific deficiencies.

Preparation of the report began as a collaborative effort of scientific consultants of the USSR Academy of Sciences, the Academy of Sciences of the union and subsequently autonomous states of Central Asia and Kazakhstan, the Council on Productive Forces of the USSR, the Operational Association "Sovintervod", and other administrative bodies and organizations working on the ecological problems of the Aral Sea region. During the process of preparation, however, changes to the political nature of the former USSR occurred, with accompanying changes in the status of the republics of the Aral Sea drainage basin. Nevertheless, these changes, including economic and social issues, did not detracted significantly from the work of preparing the report.

The working group met on four occasions. The first meeting was held in Nukus (Uzbekistan) in September 1990. The second meeting took place in Moscow in February 1991. The third meeting took place in Alma-Ata in June 1991. The fourth and final meeting took place in Geneva in September 1992.

The preparation of the document was supported by the Committee on Ecology and Rational Utility of Natural Resources of the (former) USSR Supreme Soviet. The investigation also received assistance from leading administrative figures of Karakalpakstan, of the Khoresm Region of Uzbekistan, of the Tashauzskaya Region of Turkmenistan, and of the Kzylordinskaya Region in Kazakhstan. Considerable encouragement was provided for the meetings of the UNEP working group by the governments of Kazakhstan, Karakalpakstan, Uzbekistan and Turkmenistan.

The report deals first with the natural and physical history of the Aral Sea basin, and its human, natural and economic potential. It then deals with the natural environment of the basin, and the major changes to its terrestrial ecology. Physio-chemical and biological changes to the Aral Sea itself are considered next, followed by consideration of human health and issues involving environmental pollution. Basic causes of the problems in the basin are comprehensively addressed in a penultimate chapter. Conclusions are discussed in the final chapter. The report includes a set of references and appendices supporting the report.

CHAPTER II

THE NATURE AND HISTORY OF THE ARAL SEA DRAINAGE BASIN

The Natural Environment of the Aral Sea Drainage Basin

The Aral region is usually designated as the basin of the Aral Sea, including the basins of the Syr Darya, Amu Darya, Tedjen, and Murgab rivers. It also includes a number of smaller rivers draining the western part of Tien Shan and Kopet Dag, the area of the Karakum Canal, and the closed drainage basin between these rivers and around the Aral Sea (Figure 1). Apart from the general Aral Sea basin, there is a less definite geographical notion of "Priaralye" (the Aral Sea Basin), which consists of the coastal area around the Aral Sea and the deltas of the Amu Darya and Syr Darya rivers.

With regard to administrative divisions, the Aral region includes the entire areas of Uzbekistan, Tadjikistan, part of the territory of Kazakhstan (Kzylordinskaya and Chimentskaya regions, the southern part of the Aktyubinskaya region), Kirghiztan, Turkmenistan (except the Krasnovodskaya region), and parts of northern Afghanistan and northeastern Iran. The Soviet area of the region in these boundaries is about 1.5 x 10^6 km^2, and the whole region is about 1.8 x 10^6 km^2.

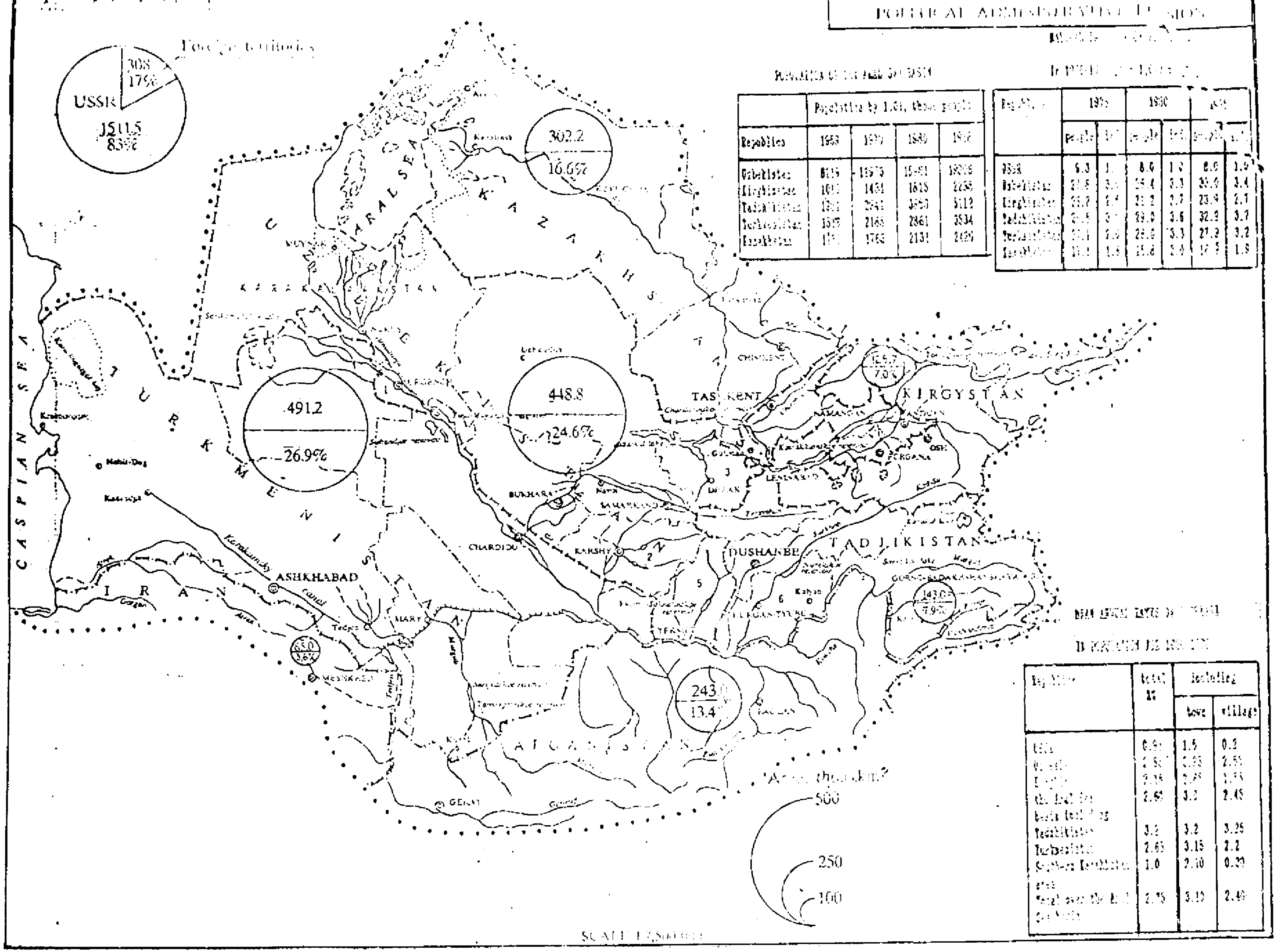
The Aral Sea basin is an immense natural and historic area of Eurasia, whose geographical position and orography have created a spectacular and highly diverse region with sharply-contrasting features. The region has a complicated geomorphology, ranging from the vast Turanian Plain to tremendous mountain ranges joining it in the south and southeast, with peaks reaching 6000 to 7000 meters and higher. The plains take up about 80% of the total area of the basin, while the mountains occupy only 20%.

In the Aral basin, the mountain ridges of Kopet Dag, Paropamisus and Hindu Kush form an orographic barrier between the typically sub-tropical climate of Iran and Afghanistan and the temperate belt. The high mountain systems of Tien Shan, Cissaro-Alay and Pamir, whose protracted offspurs deeply penetrate into the Turanian lowland area in the north and southwest, deeply affect the formation of natural conditions.

The climate in the northern parts of the Aral Sea basin is continental. In the southern parts, it is subtropical. The position of the basin in the center of the continent, and far from the oceans, produces the continental climate. The territory receives considerably more solar energy than any other part of the former USSR. The amount of total radiation at the latitude of the Aral Sea is 140 $kcal/cm^2$. Farther south, it is 160 $kcal/cm^2$, and the radiation balance is 45 to 60 $kcal/cm^2$. Temperatures during the remarkably long summer are high (the average temperature in July is 25 to 33 °C). In the winter

Diagnostic material

POLITICAL ADMINISTRATIVE DIVISION



POPULATION OF THE ARAL SEA BASIN

	Population by 1,000 thous people			
Republics	1959	1970	1980	1989
Uzbekistan	8119	11975	15491	19026
Kirghizstan	1010	1434	1615	2236
Tadzhikistan	1981	2941	3953	5112
Turkmenistan	1519	2165	2861	3534
Kazakhstan	[illegible]	1763	2131	2620

Republics	1970		1980		1989	
	people	[illegible]	people	[illegible]	people	[illegible]
USSR	6.3	[illegible]	8.0	[illegible]	8.9	1.9
Uzbekistan	[illegible]	[illegible]	25.4	3.3	33.0	3.4
Kirghizstan	[illegible]	[illegible]	21.2	[illegible]	23.9	2.7
Tadzhikistan	[illegible]	[illegible]	30.0	3.6	32.9	3.7
Turkmenistan	[illegible]	[illegible]	25.0	3.3	27.2	3.2
Kazakhstan	[illegible]	[illegible]	15.8	[illegible]	17.5	1.9

Republics	total %	including	
		town	village
USSR	0.9	1.5	0.2
Uzbekistan	2.5	[illegible]	2.55
Kirghizstan	2.35	[illegible]	[illegible]
the Aral Sea basin (excluding	2.65	3.2	2.45
Tadzhikistan	3.2	3.2	3.25
Turkmenistan	2.65	3.15	2.2
Southern Kazakhstan area	1.0	2.10	0.39
Total over the Aral Sea basin	2.75	3.19	2.46

... the Aral Sea drainage basin

months, however, cold air masses reach this area, causing the general temperatures to fall significantly. The winter is rather severe. In the northern deserts, for example, the average temperature in January is -10 to -15 °C. Only in the south is the average temperature above 0 °C. The continental character of climate is manifested by considerable, and often sudden, changes of meteorological conditions, which result in large daily changes in the weather.

Most of the year, the major movement of air masses in the upper half of the troposphere and higher generally is from west to east. Moreover, a system of jet streams with velocities of air flow reaching 35 to 44 m/sec passes over the arid zone of the former USSR. The northern stream flows at altitudes of about 13 km, at approximately 41 °N. Because of the mountains, the southern stream splits into two branches, moving approximately along 43 °N and 38 °N at great heights. In the lower troposphere, the winds blow in different directions, although west winds slightly predominate.

The resulting transport of moisture through the atmosphere is mainly from the west. However, calculations of moisture transport, and studies of glaciers, also indicate a considerable input of moisture from the south to form precipitation, and to glacier formation on the southern slopes of Gissaro-Alay, Pamir, and Tien Shan.

On the plains of the Aral region, the annual amount of precipitation is 90 to 120 millimeters. In the piedmont areas, it is 400 to 500 millimeters, while on the western slopes of Tien Shan it is more than 2000 millimeters. The total quantity of precipitation in the region reaches 500 km^3/yr. Atmospheric precipitation (100 mm/yr) is mostly limited to that brought to the area by the humid air masses of the Atlantic Ocean, resulting in the extremely arid climate. In the northern deserts, the humidity coefficient is 0.1 to 0.2; in the southern deserts, it is less than 0.1.

The effects of continentality and aridity are most striking on the plains, and in the piedmont areas; they also influence mountain climate. Intensive radiation in the lowland plains covering the major part of the territory creates the arid climate, and promotes the appearance of desert landscapes. However, in the mountains, altitude, orientation of slopes, depth, width and respective positions of mountain valleys, etc., produce a number of climatic peculiarities. These peculiarities include higher solar radiation, and regular fall of atmospheric pressure and air temperature.

The plains of the Aral basin are mostly covered with automorphic soils, specifically gray-fallow, sand and takyrlike. Among hydromorphic soils are the meadow and boggy soils and solonchaks. As a result of many centuries of soil husbandry, the "cultivated-irrigated" (lysis) soils were formed. These soils were developed in certain soil-climate zones and belts where, to varying extent, they still retain the features of the corresponding natural soils.

The character of vegetation depends on the features of orography and macrorelief, the peculiarities of climate, and the sub-surface, underground and surface distribution of water. In this respect, the Turanian botanical province is unique, because of a typically xerophytic flora. The landscape of the desert zone has its own *vegetation groups, such as the dominant xerophytic undershrubs (mostly sagebrush and halophytes), the sparsely- grouped dendritic bushes, mostly haloxyon (saxaul), and some of the dendritic or psammophytic leguminous shrubs. Against the desert background, the unique natural-economic oases stand out as a product of economic activity.

The plains region of the Aral Sea basin is comprised of two landscape systems--sub-boreal (temperate) landscapes of dry territories, and subtropical landscapes of dry territories. Between these two landscape systems, and the northern and southern desert landscapes, situated in different climatic belts, the boundary runs along the southern rim of Usturt, and across the lower reaches of the Amu Darya to the northern spurs of the Karatau Ridge.

The geology of the Aral Sea basin is determined by its location on the continental platform and in folded areas. Structurally, the platform area is the Turanian plate, composed of a folded basement layer and a sedimentary platform-cover layer. The folded basement is made of rocks of pre-Paleozoic and Paleozoic age. The platform cover is of Meso-Cenozoic deposits. The folded areas frame the Turanian plate with epi-geosynclinal mountain chains in the south, and epi-platform mountain chains in the southeast. These areas have complicated tectonic structures; their rocks date back to pre-Paleozoic, Paleozoic and Meso-Cenozoic time.

Most of the atmospheric precipitation evaporates. Less than one-third actually supplies rivers and recharges ground waters. The Syr Darya and Amu Darya rivers are the principal water sources of the Aral Sea. The surface water resources of the basin also include the runoff of the blind drainage rivers Kashka Darya, Zarafshan, Murgab, Tedjen, Chu, Talas, and other smaller rivers flowing in the territory of the former USSR, and of the rivers Hulm, Balkh, Sary Pul, Shirintagar, and others in the territory of Afghanistan. The average perennial river runoff totals about 116 to 120 km^3 per year.

Hydrogeology

The spatial distribution of aquiferous, low-permeability and impermeable rocks is determined by the geological structure of the area. There are northeastern and southwestern basins within the Turanian plate. The northeastern group is in a hydrodynamically-active zone of water exchange, with a common area of formation and drainage baseline of ground waters. The most important ground water deposits are formed by the confined waters of the Mesozoic complexes. In the southwestern area of the artesian basins, the hydrodynamic pattern shows not only the presence of the upper level with active water exchange, but also the lower level with slower water exchange. The largest ground water deposits are located in river valleys in the zone of active water exchange, and are connected with riverside and sub-sand fresh ground waters of river valleys.

The intermontane, intramountain and piedmont artesian basins and hydrogeological massifs are located in folded areas. The artesian basins of those areas have a two-story hydrodynamic structure, with an active and a slower water exchange. The upper story, usually a thick layer of Quaternary sediments, contains the largest deposits of fresh ground waters (detrital fans, river valleys, etc.) The confined pressure waters are in the lower story.

The Aral region has considerable ground water resources. The latest data (from I.S. Zektser) indicate the potential resources of fresh and brackish waters on the territory of the republics in Central Asia and in Kazakhstan total about 98.9 km^3/yr, including 45.5 km^3/yr not directly connected hydrologically with the surface runoff. At present, the ground water discharge is 14 km^3/yr. Moreover, there are significant resources of brackish and salt waters.

Physical Features of The Aral Sea

Before the decline of its water level in the mid-20th century, the area of the Aral Sea was 68,320 km^2, including 66,090 km^2 of water and 2,230 km^2 of islands. Its water volume was about 1,066 km^3. The maximal depth was 69 meters, although most of the Aral Sea was less than 30 meters deep. Mineralization of the Aral waters was 10 to 12 percent; this index persisted throughout the period of instrumental measurements.

The Aral Sea has the "Aral type" of embayed coast (Berg, 1908), with numerous lagoons, shallow and narrow passages between the islands, lakes and closed basins periodically communicating with the Aral Sea and forming natural evaporator basins which strongly affect the salt balance of the sea. River runoff and evaporation have the greatest influence on the water balance of the Aral Sea (Table 1).

Fluctuations in the Water Level of the Aral Sea

The water level of the Aral Sea is determined by a combination of the effects of climate, geomorphology, and tectonics; in the last few thousands years, it also has been affected by human economic activity. The basic data on the level

Table 1.--Average perennial water balance of the Aral Sea

Gain	(km^3/yr)	Loss	(km^3/yr)
River runoff	52 to 56	Evaporation and evacuation with wind	58 to 65
Ground water discharge	0.07 to 0.3		
Atmospheric precipitation	5 to 8	Infiltration and separation in lagoons	1 to 2

of the Aral Sea were derived from studies of ancient coast lines and bottom sediments. The Aral Sea probably first appeared in the Pliocene Era, or even as early as the late Pleistocene Era. In the upper Pliocene and Quaternary layers, there were several advances and recessions of the Aral Sea, which have been fairly well studied.

In historic times, the water level of the Aral Sea was affected not only by natural factors, but anthropogenic factors as well. During the Mongolian invasion of the region in the twelfth century, and at the time of Timur's campaigns in the fourteenth century, many irrigation systems were destroyed. This essentially changed the direction of the Amu Darya runoff and, consequently, the level of the Aral Sea.

The precise level of the Aral Sea in the past several centuries is uncertain. Nevertheless, since salt lakes respond sensitively to changes in their catchments and to climatic events, it is certain the water levels have fluctuated considerably during this period. Some scientists suggest that present water levels of the Aral Sea are comparable to those found some 400 years ago. Other scientists are less confident that such low levels occurred so recently. In any event, the present of tree roots (Saxaul) in certain parts of the present seabed (exposed and submerged) certainly indicates lower water levels in former times. Paleolimnological studies presently underway will add considerably to our knowledge of past water level fluctuations, as well as the relationships between water levels and salinity in the Aral Sea. In any case, it appears that the water level of the Aral Sea has fluctuated far below levels in recent years. The reasons for these fluctuations need to be explored in more detail, even while actions may be undertaken in the short-term to address more immediate problems.

During the last 200 years, the water level of the Aral Sea has fluctuated. However, the amplitude apparently did not exceed four meters. In the first half of this century, the water level variations have not been more than one meter. An analysis of the Aral Sea basin indicates that, in the 1950's, the ecology in the region was essentially stable. Nevertheless, compared to freshwater lakes, the greater sensitivity of salt lakes to catchment events and climatic fluctuations has resulted in considerable fluctuations in the lake size in previous years. Some of these fluctuations may have been so great as to desiccate significant parts of the lake.

History of the Economics of the Aral Region and Its Effects on the Natural Environment

A major feature of the history of the population in the Aral region is a long-term interaction of the settled agricultural population, whose economic were based on irrigated husbandry, with the semi-nomadic, cattle-raising people of the deserts and steppes. In the region of central Asia and Kazakhstan, the ethnographers distinguish three major economic-cultural types, including, (1) the settled oases inhabitants and irrigation farming, (2) the semi-settled population combining cattle raising and farming, and (3) the cattle-raising nomads.

In the territory of the former USSR, archeologists have identified three ancient centers or seats of culture, including southern Turmenistan (the Caspian center), the Caucasus (the Trans-Caucasian center), and the northern, coastal Black Sea area. All three centers are related to a still more ancient southwestern Asiatic center (discovered by N.I. Vavilow). In this ancient center, cultured wheat and barley species were found in layers dating as far back as the 8th and 7th millenium B.C.

Archeological research has revealed a pattern of gradual movement of the early agricultural crops, in the period from the 6th millenium B.C. to the 3rd millenium B.C., from southern Turkmenia to the east and northeast, into the zone of Neolithic hunters, fishermen and gatherers on the steppes and in the mountains of central Asia. At the end of the 5th millenium B.C. and the beginning of the 4th millenium B.C., the farming/cattle-raising tribes populated the delta of the Tedjen, and settled on the Murgab River. Archeological finds (of V.M. Masson) in Turkmenia on the Altyn Depe site (3,000 to 2,000 years B.C.) demonstrate the agricultural population had been tilling barley species, using regular irrigation practices.

At the turn of the 2nd millenium B.C., bronze metallurgy technology was widely spread throughout the Aral Sea basin and the adjacent areas, encouraged by cultural connections with even older agricultural civilizations in Central Asia, and with ancient cattle-breeding tribes of the Volga-Urals region.

Further development and distribution of irrigation husbandry was induced by local geographic conditions and water resources of the different natural zones (plains, piedmont areas, and mountains). In the piedmont and mountain zones, irrigation was necessary, primarily because of lagoon and wadi-creek irrigation which occurred only once per year and with limited effect. On the plains, and in the valleys and deltas of large rivers in

Central Asia, progress in irrigation farming was not rapid. It developed from once-a-year lagoon irrigation to regulated floods, by initially damming smaller delta streams and subsequently larger ones. Creation of extensive irrigation systems, with various structural components, required new forms of social systems.

Relatively large hydrotechnical structures were first built in the southern part of the Surkhan Darya valley, on the Murgab and Tedhen rivers. They were apparently mentioned by Herodotus as the river Ak (Akes), with its dams and canals. At the beginning of the 1st millenium B.C., the degenerating lowland delta streams of the Murgab were being turned into the main canals. The establishment of the local Margian State in the ninth to seventh centuries B.C. was coincident with the organization of large-scale irrigation systems.

In ancient times, on the plains of the Aral Sea basin, in Rhoresm on the Amu Darya, and Sogda on the Zarafshan, even larger irrigation systems than existed in Margian were built. Archeologic topographic research was carried out in the region of ancient irrigation systems in the Aral district, located 4.5 million hectares from the Sarykamyshskoe Lake and Usturt to the middle reaches of the Syr Darya. T. Markvart (and later S.P. Tolstov) stated that a large State system was set up in this area in the seventh and sixth centuries B.C. It encompassed the Sako-Massaget tribes, lead by the Siyavushids family. At that time, the main canals in Khoresm were 100 to 150 kilometers long, 10 to 30 meters wide, and two to three meters deep. The pattern of the irrigation system was as follows: the river with the major water intake construction, the main canal (arna), waterways of the first and second order, irrigators, and fields. The construction of these vast irrigation systems involved the labour of an enormous number of people, and exacting State supervision. In the middle of the 1st millenium B.C., an acute social and economic crisis disrupted the progress of irrigation agriculture in the ancient Khoresm oasis.

In ancient Sogda, the rivers Zarafshan and Kashka Darya were the major sources of irrigation water, along with contributions from numerous small mountain streams and creeks of the piedmont. Marakanda, the largest town of Sogda, was supplied with stream and spring water through three main canals.

In the Ferghana valley, irrigation agriculture began at the turn of the 1st millenium B.C. The farming was based on water from small rivers and brooks in the piedmont zone, and cattle grazing on distant mountain pastures. In the Tashkent oasis, in the valleys of the Chirchik and Akhangaran, irrigation of land for husbandry, as a supplement to cattle-raising activities, was commonly pursued in the 1st millenium B.C. In the lower reaches of the Syr Darya, irrigation farming appeared about the middle of the 1st millenium B.C., later than in the Amu Darya region.

On the territory of the Syr Darya and Amu Darya interfluve, the principles of primitive irrigation and semi-settled cattle-breeding, and agriculture-fishing economics have been persistently maintained since the Bronze Age.

The peak of ancient irrigation was reached in the Kushan Age in the first centuries A.D., with the growth of cities, handicraft industries, and hydrotechnical knowledge. At that time, trade flourished, and the Silk Way reached from eastern Asia to Europe. However, the great Kushan State subsequently collapsed through deterioration of economic conditions, severe social confrontations and devastating wars.

Violent historic events changed not only the political map of the Aral region, but also the territorial relations between the major agricultural and nomadic economic-cultural groups. Dynamic interactions between the nomad and settled husbandman set into motion century-to-century changes in economic adjustments, labour quotas, trade exchange, and cultural relationships.

The essential transformation of the entire irrigation system in the Khoresm oasis was achieved during the rule of Khoresm Shahs in the 11th and 12th centuries. The irrigation system of the Middle Ages (11th to 12th centuries) in Khoresm was characterized by major links used in recent times. These included protection dams on the main stream of the Amu Darya, the major water intake constructions (saka), the main canals (arna), the large distributors (yab), the secondary aryks, the water wheel (chigir) pits, and water-regulating devices. The chigirs provided higher-altitude fields with water and increased the irrigation area, an achievement impossible in ancient times, when the farmland was not more than 10 to 20 percent of the whole irrigated area.

The development of irrigation in the area of Samarkand reduced the water supply to the lower part of the Bkhara oasis, where irrigation decreased. All the land surrounding Samarkand, up to the Piandjikent settlement of the early Middle Ages, was amply irrigated and formed a flourishing oasis. Timur, who became Emir in 1370, made Samarkand the metropolis of his vast land properties. Ustrushana is an ancient historic-cultural locality in the piedmont and mountain zone of the Aral Sea basin. In the Middle Ages, the Chack and Ilak oases in the Chirchik and Angoen valleys in the middle reaches of the Syr Darya, were the most thriving oases with developed irrigation. In the 7th to 9th centuries, a vast fan-like irrigation network was built near Otrara, a large trade center. In later years, the fan-like systems changed to intricately-branching systems of the classical scheme, similar to that in Khoresm; namely, river-water intake construction, distributors of the first and second order, irrigators, and fields.

Large areas of the lower reaches of the Syr Darya preserved many ancient features of economic development. Livestock was an important part of economics, and often was combined with partial and irregular farming on mired delta streams and meandering lakes.

At the turn of the 20th century, the population of the agrarian oases of the Aral Sea basin consisted of Uzbeks, Tadjiks, Karakalpaks, Turmanians, and Kazakhs. These populations inherited the rich experiences of irrigation husbandry, and of construction and exploitation of large irrigation systems which turned desert landscapes into cultivated oases, from their forefathers. The anthropogenic impact was greatest on the plain in the river valleys, where the intensity of large-oasis irrigation farming was the greatest (in combination with stall-fed and desert-grazing livestock activities).

In the piedmont zone, the occasional oasis irrigation was combined with cattle grazing on distant desert pastures. In the valleys of Alay, Pamir, Tien Shan, small watered oases and bogar, crop raising were widespread. This type of farming was combined with cattle grazing on distant mountain pastures.

Over many centuries, nomadic and semi-nomadic cattle raising, developed on the vast desert, steppe, and mountain meadow areas, had a significantly different ecological impact on nature than did agricultural activities.

In the oases, from ancient times to the first half of the 19th century, economic activities developed with sufficient land reserves for reclamation, and enough water to irrigate lands. Crop irrigation was combined with cattle herding to pastures, handicrafts, and trade-exchange on oases boundaries with the nomads of the steppes. The natural environment was most significantly affected by expansion of irrigated lands at the expense of desert lands.

The intensive development of irrigation agriculture in the second half of the 20th century was carried out on a large scale by reclamation of large areas of salted, and otherwise unsuitable, lands with a shortage of irrigation water, followed by population growth and intensive application of chemicals in agriculture (mostly for cotton production). Ecologically-harmful agriculture and crop-care methods were used. All these factors inflicted serious damage on the environment and the population. They have reduced the water level of the Aral Sea, and caused a series of other negative phenomena, now jointly described under the general label of the "Aral Crisis". Many of the deleterious practices are subject to partial or complete action at the local level, without waiting for further large-scale surveys.

CHAPTER III

HUMAN RESOURCES, NATURAL RESOURCES AND ECONOMIC POTENTIAL OF THE ARAL REGION

Introduction

Uzbekistan (with Karakalpakstan), Kirghiztan (the Oshskaya region and Narynskaya zone of the Issyk Kul region), Tadjikistan, Turkmenistan, and southern Kazakhstan (the Chimkent and Kzylordinskaya regions) constitute the area of the Aral Sea basin. This area is strikingly different from the other areas of the former Soviet Union in natural resources, and in socioeconomic, ecologic and other characteristics (Figure 1). The region has a considerable economic and scientific-technical potential, various natural resources, and significant areas of arable land. However, it also has an insufficiently-developed industrial and social structure. The major characteristics of the region are a high population growth rate and labour resources (which exceeds the average rate for the country by a factor of three), an increasing deficit in water resources, and the resulting ecological crisis.

Central Asia and southern Kazakhstan are major manufacturers of natural fiber. They produce 90% of the cotton, 75% of the raw silk, and 67% of the wool manufactured in the former Soviet Union. A prominent fuel and power base is located in the area. It also is an important producer of nonferrous and ferrous metals and chemicals, as well as other kinds of industrial production. Moreover, it also is the source of subtropical fruit, vegetables, grapes, melons and other agricultural products.

Historically, the Independent States in the Aral Sea basin are characterized by numerous similar economic, social and demographic features, and ecological development. These features include a specific way of life, social psychology, and social and cultural relationships. However, all these factors presently are being drastically affected by the environmental crisis in the Aral Sea basin.

Population and Labour Resources

Between 1976 and 1990, the population of the region increased from 23.5 million to 34.0 million people (Figure 1, Table 2). More than 32 million (93%) of these people dwell in the territory of the republics of Central Asia, and 2.5 million people (7%) inhabit southern Kazakhstan in the Aral basin, in the Kzylordinskaya and Chimkentskaya regions.

Table 2.--Area and Population of the Aral Sea Basin, referenced to January 1, 1987[a]

States	Area ($x1000\ km^2$)	Percent of basin	Population (in thousands) 1959	1970	1980	1989
Uzbekistan	448.8	24.6	8119	11973	15961	19906
Kirghiztan	126.7	7.0	1010	1434	1815	2238
Tadjikistan	143.0	7.9	1981	2941	3953	5112
Turkmenistan	491.2	26.9	1516	2188	2861	3534
Kazakhstan	302.2	16.6	1180	1766	2131	2420
Subtotal:	1511.5	83.0	13806	20302	26721	33210
Northern Afghanistan	243.0	13.4				
Northeastern Iran	65.0	3.6				
Total for Aral Sea Basin	1815.5	100.0				

[a]The population numbers (yearly average) are taken from data supplied by the State Committee. The past estimates and future projections are referenced to the population as of January 1, 1987. The population data for the Kirghiztan regions in the Aral Sea basin were provided by the Kirghiztan Institute of Economics; the population data for southern Kazakhstan were provided by the Kazakhstan Institute of Economics.

The major difference in the demographic development of the Central Asian republics and the southern regions of Kazakhstan, and other republics of the Union is the natural reproduction rate of the population. It is very high, exceeding the corresponding average all-Union indices by two or three times (Table 3).

In the Kzylordinskaya and Chimkentskaya regions of southern Kazakhstan, the indices of natural population increase are close to the indices characteristic of republics in Central Asia. The high rates of natural population increase, compared to a background of low migration, is the determining factor for population numbers and labour resources of the region.

The dynamics of population growth for the indicated five-year periods can be determined from the mean annual increases. For the USSR in general, it was 0.86% for 1976-80, 0.9% for 1981-85, and 0.9% for 1986-90. For the republics of Central Asia, it was 2.65%, 2.7%, and 2.8%, respectively. The data for the last five-year period (1986-90) are summarized in Table 4.

Table 3.--Natural population increases in the USSR, the republics of Central Asia and Kazakhstan, 1976-1985

Location	1975 People	1975 Index	1980 People	1980 Index	1985 People	1985 Index
	(Per Thousand People)					
USSR	9.3	1.0	8.0	1.0	8.0	1.0
Uzbekistan	27.8	3.0	26.4	3.3	30.0	3.4
Kirghiztan	23.2	2.5	21.2	2.7	23.9	2.7
Tadjikistan	29.5	3.2	29.0	3.6	32.9	3.7
Turkmenistan	27.1	2.9	26.0	3.3	27.9	3.2
Kazakhstan	17.1	1.8	15.8	2.0	16.9	1.9

Table 4.--Average annual rate of population increase, 1986-1990

	Total	Average annual rate in towns	Average annual rate in villages
USSR	0.95	1.5	0.2
Uzbekistan	2.88	3.25	2.55
Kirghiztan	2.15	2.65	1.85
Including the Aral basin	2.60	3.0	2.45
Tadjikistan	3.2	3.2	3.25
Turkmenistan	2.65	3.15	2.2
Southern Kazakhstan	1.06	2.10	0.30
Total for Aral Sea basin	2.75	3.10	2.40

An analysis of data in Table 4 shows the high rates of population increase in Central Asia. A somewhat different demographic situation is observed in southern Kazakhstan, particularly in agricultural areas. For example, in the Kzylordinskaya region, the population has decreased by 6,000 people in the last five years, as a result of the deterioration of ecological, social and living conditions in agricultural areas.

During the last five-year period, the total population increase in the region is expected to reach 4.4 million people (more than one third of the All-Union increase). Sixty-two percent of the increase will occur in Uzbekistan.

The high level of natural increase in population determines its peculiar age structure (i.e., the relatively small group of economically- active population). More than half the population is outside the working age interval. As a result, the demographic labour load on the working portion (working-age interval) of the population is heavier. In Central Asia, the proportion of children and teenagers aged 15 years or younger is 42.5% of the total population, compared to 26.8% in the former USSR. The proportion of able-bodied people in the population is 49.2%, compared to 56.7% throughout the country. The age structure is southern Kazakhstan is close to that of the republics of Central Asia.

The region has a considerable labour potential. Of the total labour resources of 16.8 million people, more than 92% (15.6 million people) are in the republics of Central Asia, and 8% in southern Kazakhstan. The high growth rate of the able-bodied group in the republics of Central Asia and in southern Kazakhstan, coupled with considerable labour reserves in the accessory and household sectors of society, provide the region with sufficient labour. In the readjustment period of the region's economic system, the region's labour capacity will be a hindrance to intensification. Therefore, the effects of extensive factors should be taken into account. Demographic features, and the branches of economic activity in the Aral region, essentially indicate the ways of applying the region's labour resources.

A specific feature of the republics of Central Asia is a relatively low employment in the social production sector. Education and training outside the production sphere and private household activities, traditionally occupy a relatively large proportion of the population. This tendency is particularly obvious in southern Kazakhstan. For example, 80.3% of the labour in the republic is employed in productive activities, both social and private accessory, whereas this index is only 71.7% in southern regions. This is because of the 18.4% of labour occupied in household private activity, compared to 10.8% for the whole republic.

In 1990, 2.5 million people in the republics of Central Asia and southern Kazakhstan were employed in household activities. Seventy to ninety percent were women with large families, traditionally not considered to be part of real labour resources.

However, a large number of young, educated people have problems finding employment, mainly because labour resources grow disproportionately larger than does job availability. A low mobility of the native population also concentrates labour in agricultural regions. The number of people occupied in accessory and household activities is increasing, causing a labour shortage in towns with factories that acutely need qualified labour. It is difficult to determine the exact number of people looking for work because there is no unified method for their registration.

The adoption of Employment Law should introduce the necessary regulation in labour resources, providing for registration of the unemployed, and indications of reasons for their unemployment.

The differentiation of indices of labour for the whole region is considerable. For example, 75.2% of labour in Central Asia is occupied in production. The index is 73.8% for Uzbekistan, 78.1% for Kirghiztan, and 79.7% for Turkmenia. Likewise, essential deviations are observed in the level of employment in different economic spheres and branches of these republics. For example, 54.3% of labour (9.1 million people) is employed in different branches of production for the Aral Sea basin. In Uzbekistan and Turkmenistan, this index is 53%. In Kazakhstan, it is 50.8%, mainly because there is a high employment level in private household production. The index of employment in unproductive economics is 20.3% for the entire region, which is three percent below the All-Union average.

About one third of the region's population was employed in agriculture (4.7 million in 1990). If this index is compared with the agricultural index of the whole country (for example, the share of Kazakhstan is not above 7%), it becomes clear the region's agricultural area concentrates a considerable surplus of labour. Even if labour-intensive cotton production is taken into account in farming activities in the republics of Central Asia, the labour expenditure of a single person employed in agriculture is relatively low, implying extensive forms of economics.

If current social conditions continue, the pressures causing increasing deterioration may prevail. The rate of population growth in the last 15 to 20 years in Central Asia and southern Kazakhstan is not expected to change significantly before the year 2010. Basically, the region will have sufficient (actually excessive) labour resources, with an insignificant migration of the native population to other republics. The latest trend in the region's population growth indicates the rate of increase may lessen somewhat in the future, but still will remain considerably higher than the average All-Union index.

One of the most acute problems of rational employment of the region's labour force is the need for training of qualified workers in practically all branches of economics. A greater emigration rate of highly-qualified labour in the last two to three years (i.e., Russians from the republics of Central Asia, and Germans from Kazakhstan) may have a negative effect in the very near future. Urgent measures will have to be taken to increase the professional qualification of the native labour force, and to organize the training of local personnel for adequate employment under market conditions, and in a fundamentally-changing economic structure. Because one third of the young people in industry alone get professional qualifications from technical training schools, the cost of training qualified workers in 1991 through 1995 will approximate not less than 36 million rubles.

To summarize, the demographic features of the region require urgent solutions to social problems. The employment of the native population clearly is a paramount concern. It would be a fundamental mistake to assume that long-term issues of water and land degradation can be effectively addressed without also considering the associated problems of population growth and an unhealthy economy.

Natural Resources

The territory of the former Soviet Union designated as the Aral Sea basin covers 1,507,500 km^2, or 6.9% of the total area of the former Soviet Union. Figure 1 shows the distribution of the territory of the basin among the republics of Central Asia and Kazakhstan.

Water Resources

The water resources of the Aral Sea drainage basin are composed of surface and ground waters, distributed in an extremely irregular pattern throughout the basin. The upper reaches of the Amu Darya and Syr Darya are the zones of formation of surface runoff, and have an abundant supply of good-quality water. In contrast, the middle and lower reaches of these rivers are deficient in potable water resources.

Surface Waters

The Aral Sea basin is a closed drainage region, entirely cut off from the oceans. Hydrogeographically, it contains several separate and independent basins of the rivers Amu Darya, Syr Darya, Zarafshan, Kasha Darya, Murgab, Tedjen and the blind rivers of Turkmenia and northern Afghanistan (Figure 2).

The Aral Sea itself represents a water resource of considerable significance to the region. Although it is now smaller and more saline than it was in 1960, the Aral Sea has considerable potential for commercial, recreational, tourist and other uses. It also is noted that its current salinity is lower than that of the oceans.

The specific features of the formation and regime of surface waters are revealed primarily in the extremely irregular distribution of water streams over the region. These features are a function of its location (remote from the oceans) and the resulting continental and arid climate, as well as by the elements of surface relief, etc. The mountainous part has an extended network of streams with the average runoff module of about 6.5 $l/sec.km^2$. The vast plains covering about 70% of the

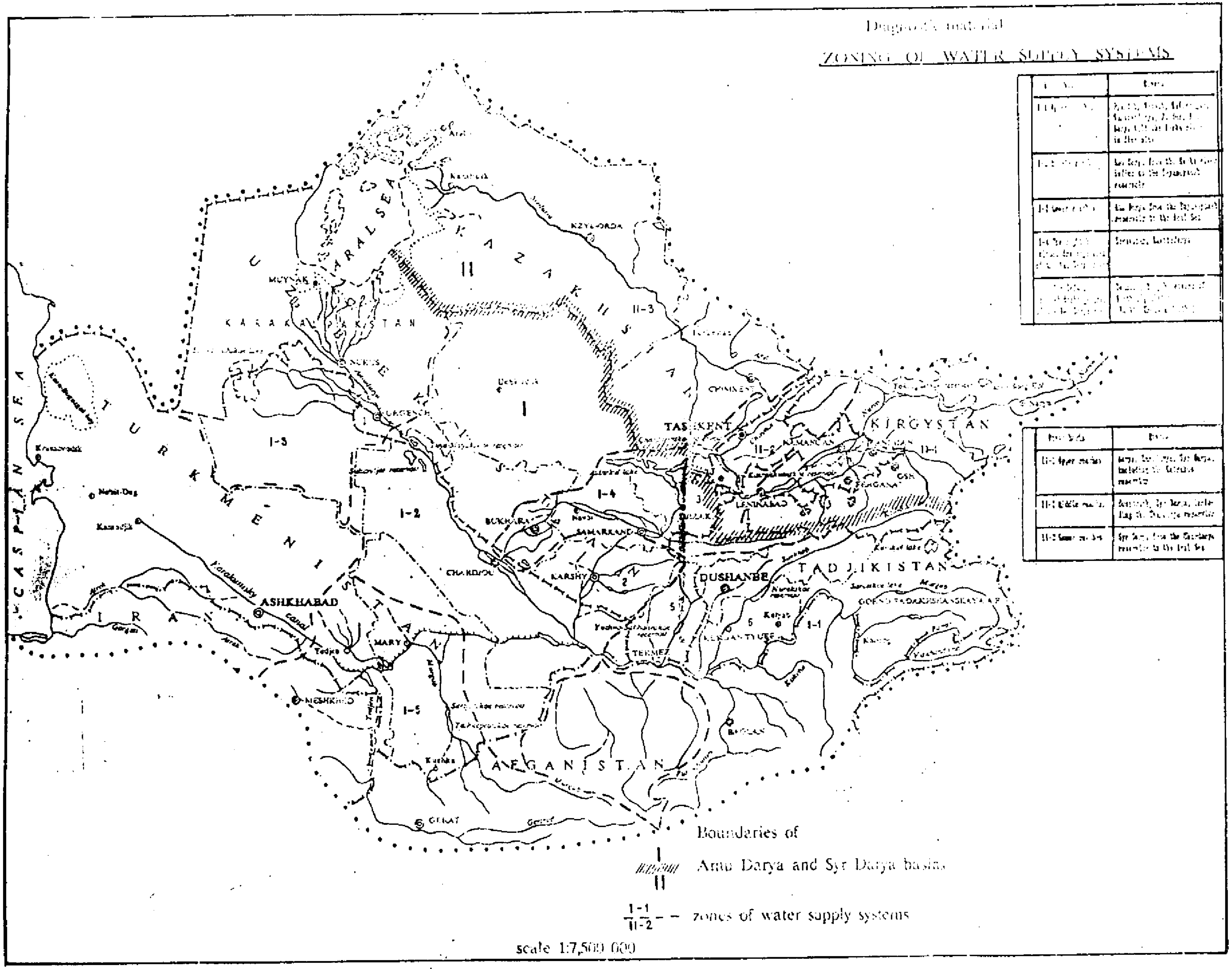


Figure 2. --Surface water resources of Aral Sea drainage basin.

territory have very few streams; moreover, most of them do not reach the Aral Sea. The only exception is two of the major rivers in the basin, the Amu Darya and Syr Darya. After traversing many hundreds of kilometers, they flow into the Aral Sea.

The Amu Darya and Syr Darya are the principal water arteries in the region. The basins of the blind rivers Zarafshan and Kashka Darya, Murgab and Tedjen, the rivers of northern Afghanistan, and the smaller rivers flowing from the northern slope of Kopet Dag, supply considerable quantities of water to different parts of the region. The primary source of all rivers in the Aral Sea drainage basin are mostly snow/glacier runoff.

The Amu Darya Basin.--The Amu Darya basin covers the largest area, and has the highest water-bearing capacity of the region. It includes streams that form the runoff of Amu Darya and smaller rivers whose waters are completely consumed. The latter include Zarafshan, Kashka Darya, Tedjen, Murgab, and the rivers of northern Afghanistan and the northern slope of Kopet Dag. The basin is divided into two physico-geographic parts. These include the eastern mountain area with the highest peaks in the former USSR, which is the primary source of river waters, and the western part of lowland deserts and semideserts where the runoff is dispersed.

The Amu Darya, a product of the confluence of the Piandj and Vakhsh rivers, is 1,445 kilometers long. Its average perennial discharge is 2,000 m^3/s. The waters of the Vakhsh and Piandj compose most of the Amu Darya runoff. The maximal water discharge is in July-August. The minimal discharge is in December-March, when the Amu Darya draws its water almost entirely from underground aquifers. The maximal water discharge of the Amu Darya (9,180 m^3/s) is at the town of Kurki. The minimal discharge is 480 m^3/s. The average perennial runoff during the observation period (1925 to 1989) was 69.1 km^3.

Hydrologic observations were started in the Amu Darya basin in the zone of ancient irrigation as far back as 1889 on the Zarafshan River (at Dupuli bridge), in 1891 on the Murgab River, and in 1914 on the Tedjen River. On the Amu Darya itself, runoff observations have been conducted since 1910 (at Kerki and Danisher). Since 1918, measurements of levels, and later of discharges, of the Surkjan Darya River (at Manguzar) have been carried out. The runoff of the Kafirnigan River (at Tartki village) has been measured since 1929. The runoff of the Vakhsh (at Tutkaul) and Pindj (at Nizhniy Piandj village), the largest tributaries of the Amu Darya, have been measured since 1932 and 1960, respectively. Measurements of water discharge at the water intake, and in the discharge canals of irrigation systems on the Amu Darya, Kafirnigan, Surkhan Darya and Sherabad were started in the 1930's. Measurements in the Vakhsh and Piandj basins began in the early 1950's.

Within any one-year period, the runoff distribution of the Amu Darya does not provide a steady water supply for irrigation with existing technology. Low-water periods of the Amu Darya occur every four to five years and high-water periods occur every six to ten years. Further, protracted low-water periods of five to six years and longer may occur, causing interruptions in water consumption, even with regulated runoff (Figure 3).

<u>The Syr Darya Basin</u>.--The Syr Darya is the longest river in Central Asia (2,140 km). The area of the basin before it reaches the Ferghana valley is 142,000 km^2. It includes the runoff from the rivers Naryn and Kara Darya, rivers of the Ferghana valley, the Chirchik, Keleye and others. This amounts to 38.4 km^3 in a year with 50% of supply, and 28.22 km^3 in a year with 90% of supply. The annual water discharge variations of the Syr Darya are greater than those of the Amu Darya. The lowest water discharge was observed at the Chardarinskiy hydropower station in 1982 to 1983, which amounted to 620 m^3/s (runoff was 20 km^3). The highest water discharge was 1,810 m^3/s (runoff was 57.1 km^3; discharge into the Arnoosai was 13 km^3) in 1969 to 1970.

The Syr Darya regime immediately after confluence of the Naryn and Kashka Darya resembles that of rivers supplied with water from snow/glacier runoff. The low-water period is October-March, while the highest water discharge is in June-July. Further downstream, the hydrograph becomes more level.

The chronological chart of the annual discharge variations of the Syr Darya clearly demonstrates a cycle in the succession of low-water and high-water years. The low-water periods occur every three to four years and last five to six years. The high-water periods often are shorter. The runoff distribution within one year is unfavorable for irrigation farming.

The period of hydrologic observation of the rivers of the Syr Darya basin is one of the longest in the former Soviet Union. Observations of runoff of the Naryn, the largest river in the Syr Darya basin, were started in 1896 at Uchkurgan. Since the very first years of this century, runoff observations have been conducted on other tributaries of the Syr Darya, including the Chirchik (at Chinaz village) since 1902, the Arys (at Shaulder, now Timur) since 1904, the Arkhangaran (at Turk village) since 1916, and the Kara Darya (at Kampyrravat settlement) since 1910. The total catchment area of those rivers makes up about 50% of the area of the Syr Darya basin (213,000 km^2 at Tumen Aryk). The runoff of the Syr Darya itself has been measured since 1910 at Bekabad (142,000 km^2) and at Kzyl-Orda (219,000 km^2), as well as at Kazalinskaya since 1911, and Tumen Aryk since 1913.

Despite long periods of hydrologic observations, estimation of the parameters of natural runoff (water resources) of the Amu Darya and Syr Darya basins is complicated by the impacts of economic activity. The intake and discharge of water for irrigation and, in recent years, regulation of reservoir

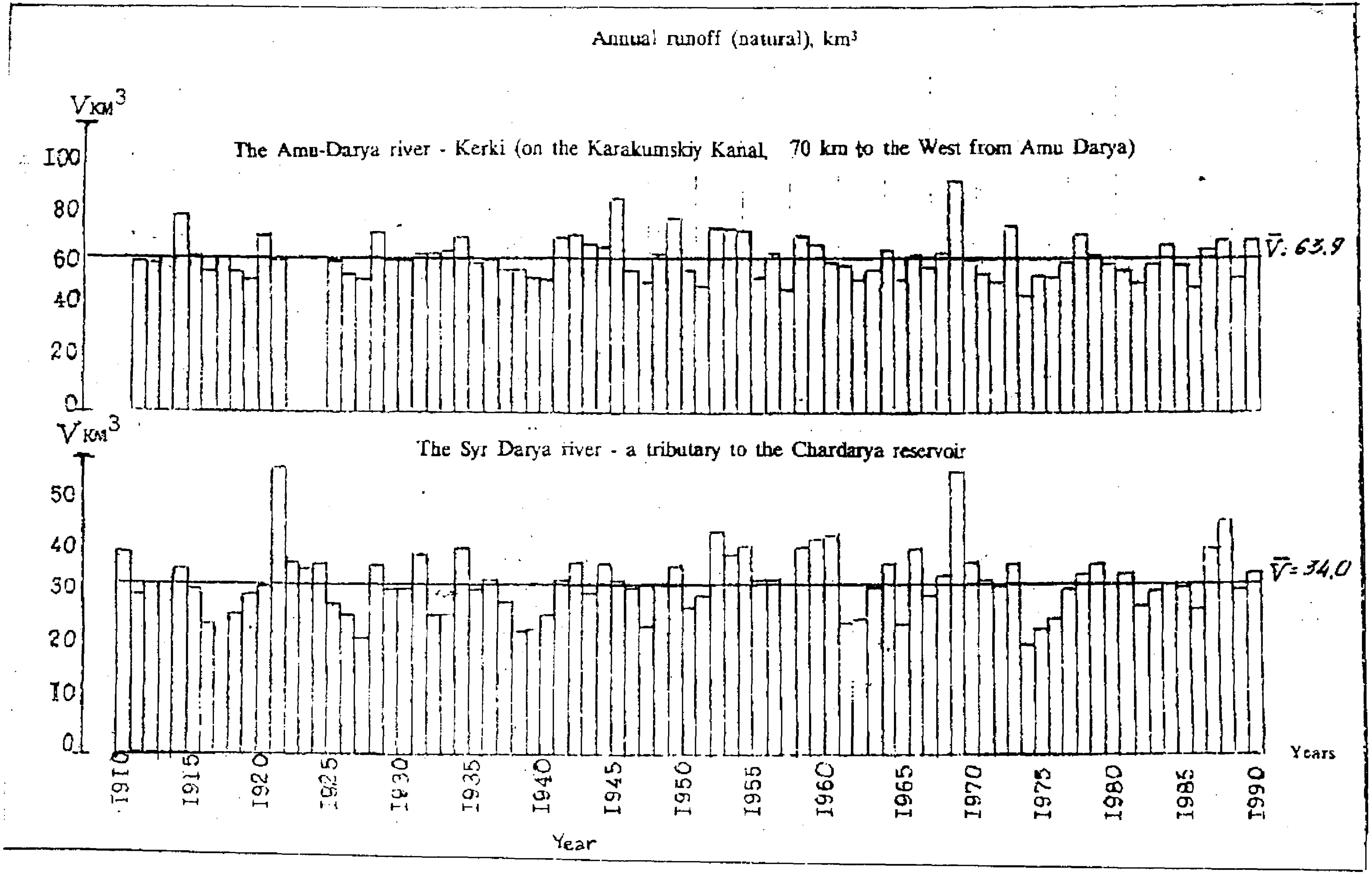


Figure 3. --Runoff distribution of Amu Darya and Syr Darya rivers, 1910-1990

discharge, distort estimation of the natural runoff. Hydrologic data on water consumption no longer reflect the real amount of natural water resources. To obtain the natural expenditure of water, the runoff recorded by the hydrometeorological service should be recalculated, with due consideration given to the quantity of water intake and discharge, and of filling and discharge of regulating reservoirs.

Because the data on water intake from rivers and reservoirs, and of inflow of return and discharge waters into reservoirs, are unreliable, estimations of natural water resources of the Amu Darya and Syr Darya basin given by different administrative bodies and researchers (the State Meteorological Committee, the USSR Academy of Sciences, the Ministry of Energy, and Ministry of Water Management) are ambiguous. These data result from inadequate and inaccurate information about irrigation water intake and drainage-water collector discharges (cdw) into rivers. Calculations from indirect data obtained using different methods obviously cannot produce the same results.

The length of the period of runoff record is important for the accuracy of estimates of the volume of average perennial water resources, and for adequately estimating anthropogenic factors. These factors are responsible for differences in the estimates of natural runoff of water from the area of its formation, as recorded at hydrometric stations located where the rivers flow out of the mountain areas.

Table 5 illustrates the range of estimates for different periods, as calculated by different institutions of the USSR Academy of Sciences, the State Meteorological Committee, and the Ministries of Energy and of Water Management. These estimates were based on runoff records covering different-length time periods, and different observation periods for anthropogenic factors which distort the natural runoff data.

The present estimates of natural average perennial water resources of the Amu Darya and Syr Darya basins are apparently the most reliable, and correspond to the uniform observation series obtained for the period between 1932 to 1985.

The annual and seasonal runoff of the Amu Darya and Syr Darya basins have perennial variations. For example, the annual runoff in the Amu Darya basin in the 1969 high-water year was about 110 km^3. In the 1974 low-water year, it was about 65 km^3. In the Syr Darya basin, in the same high-water year of 1969, the annual runoff was about 70 km^3, and in the low-water year of 1983, it was about 20 km^3.

The range of variations of the annual runoff for the Amu Darya basin is 45 km^3, and that for the Syr Darya is 50 km^3. The deviation from the average perennial runoff is from +34 to -12 km^3, and from +32 to -18 km^3, respectively.

Table 5.--Natural average perennial surface runoff of the Amu Darya and Syr Darya basins (zone of runoff formation)

River	Range of estimations (km^3/yr)
<u>Amu Darya basin</u>:	
Amu Darya	65.6 to 71.8
Closed drainage right-bank rivers	6.5 to 7.7
Murgab, Tedjen and rivers of northern Afghanistan	4.5 to 5.2
Subtotal:	76.6 to 84.7
<u>Syr Darya basin</u>:	
Syr Darya	
Upper reaches to Karakum reservoir	25.9 to 26.8
Middle reaches to Chardary	8.9 to 10.4
Lower reaches	2.1 to 2.6
Subtotal:	36.9 to 39.8
Total:	113.5 to 124.5

If water consumers base their expectations on the average perennial runoff, it seems obvious they will experience a shortage of water resources during low-water years. Therefore, water consumption by economic enterprises, and by natural-ecological complexes should not be calculated from the average perennial runoff, but rather from its guaranteed portion. Guaranteed water consumption can be provided by regulated runoff both within the year (seasonal) and for a period of many years.

Regulation of river runoff does not amplify water resources, but allows a redistribution of river runoff within the year and perennially in such a way as to guarantee the necessary amount to consumers in any year and in any season. However, if more than 90% to 92% of the average perennial runoff is distributed, regulation becomes unstable.

At present, the guaranteed annual volume of surface runoff in the Amu Darya basin is 62.5 km^3; in the Syr Darya basin, it is 35.3 km^3. The total guaranteed annual runoff volume for the Aral Sea basin is 97.8 km^3. This volume of runoff is guaranteed 90% of the time. In this case, this figure is a relative value expressed in percent, illustrating the number of years in the studied series which guarantees the runoff volume necessary for the consumer. The water consumers of the Amu Darya and Syr Darya basin are currently guaranteed a supply of annual runoff of 62.5 km^3 and 35.3 km^3 (90 and 100 years, respectively) (Table 6). For the remaining years, the guaranteed runoff can be reduced, but by no more than 20% of the annual guaranteed volume.

Table 6.--Surface runoff in the Aral Sea drainage basin

Basin	Natural runoff of different degrees of guarantee: Average perennial	90%	Guaranteed runoff: At present	Forecast for 2000-2005*
		(km^3)		
Amu Darya	77.4	61.3	62.5	68.6
Syr Darya	38.4	28.2	35.3	35.3
Total for Basin	115.8	89.5	97.8	104.1

*The guaranteed runoff will increase by the years 2000-2005, due to introduction of the Rangoon and other reservoirs.

All the existing reservoirs, and those under construction, in the Amu Darya and Syr Darya basins are adapted to this provision regime. Such a high, reliable provision (90%) is based on the fact that farming in this zone is possible only on irrigated land and cannot depend on sparse precipitation. This is in contrast to the zone of insufficient humidity, where water provision is usually rated at 75%.

Natural Variations in River Runoff.--Many problems of the Aral Sea basin are related to water balance variations and depletion of surface runoff water. Runoff variations occur both for natural reasons (especially climatic) and because of anthropogenic impacts.

The water balance of rivers depends, to a considerable extent, on the amount of atmospheric precipitation and evaporation. The Aral Sea has experienced periodic fluctuations between warm and cold periods lasting for several years. In relatively warm epochs, the basin evaporation increases, precipitation varies, and river runoff decreases. In relatively cold epochs, evaporation is lower, while precipitation and river runoff increase. An analysis of reliable data on river runoff, formed in the mountainous parts of the Aral Sea basin, indicates an essential change in runoff over the last 60 years.

The mean runoff over many years has been on the order of 116 km^3/yr. In 1970, a wet period began, during which the runoff was three percent above the mean value for several years. The dry period since then has continued to the present time. The value is only eight percent of the annual average water supply. Macrocycles, each of which consisted of less-extensive wet and dry phases, also were observed. The dry phases differ in duration. The wet phases include the following periods: 1933 to 1937 ($p = 5$ $K_m = 01.04$); 1941 to 1945 ($p = 5$ $K_m = 1.09$); 1952 to

1960 (p = 9 K_m = 1.1); and 1966 to 1970 (p = 5 K_m = 1.12). Dry phases included 1938 to 1940 (p = 3 K_m = 0.88); 1950 to 1951 (p = 2 K_m = 0-92); 1961 to 1965 (p = 5 K_m = 0-92); 1971 to 1977 (p = 7 K_m = 0.86); and 1980 to 1986 (p = 7 K_m = 0.86).

Runoff water expenditures are deduced from both natural losses and anthropogenic uses. Natural losses are defined by evaporation losses and transpiration in river beds and flood plains, including the parts of river valleys and deltas inundated under natural conditions. Natural losses in the basin until the first stage of new development during the Soviet period (the early 1930's) totaled approximately 22 km^3/yr. As a result of runoff regulation, subsequently there was a decrease in floods and inundation of flood plains and deltas, which reduced natural losses. At present, they total approximately 4 km^3/yr (Table 7). Anthropogenic water losses, which presently exceed 90 km^3/yr, are discussed further in Chapter III.

Ground Waters

Ground waters are an important water source in the Aral region which can be directly tapped for the water supply. It is the best source of sanitary drinking water. The distribution of ground waters over the study region is irregular, because of the difference in the geologic structure of the crust, different climatic conditions, relief elements, and composition of water-bearing rocks (Figure 4).

The study of hydrologic conditions in the Aral Sea basin, most comprehensively described in the monograph, "Hydrology of the USSR", was based on the material of small-scale and middle-scale hydrologic surveys and the data on ground water resources. The hydrologic survey scale (1:200,000) covered the entire basin, except for the exposed Aral Sea bottom and high-mountain areas.

An atlas of hydrogeographic and engineering-geologic maps (scale of 1:1,000,000) was prepared in the beginning of the 1980's by the territorial hydrogeological organizations of Central Asia and southern Kazakhastan. On the basis of these materials, the "Gidroingeo" institution has predicted the potential ground water resources of river basins and of individual republics (Table 8).

Of the predicted ground water resources, only waters with mineralization of 5 g/l or less are acceptable for consumption in economic activities (e.g., water supply, irrigation, watering of pastures). The total volume of this quality of ground water totals 33.87 km^3/yr, including 13.67 km^3/yr in the Amu Darya basin and 20.2 km^3/yr in the Syr Darya basin.

Table 7. -- Average river runoff losses in the Aral Sea drainage basin

Period	Annual runoff losses (km3/yr): Syr Darya basin Natural	Syr Darya basin Anthropogenic	Syr Darya basin Sum	Amu Darya basin Natural	Amu Darya basin Anthropogenic	Amu Darya basin Sum	Total for Aral Sea Natural	Total for Aral Sea Anthropogenic	Total for Aral Sea Sum	Discharge to lower parts of deltas to Aral Sea
1932-40	6.7	14.7	21.4	15.1	6.3	21.4	21.8	21.0	42.8	--
1941-50	6.0	18.8	24.8	10.3	15.5	25.8	16.3	34.3	50.6	--
1951-60	3.7	24.7	28.4	9.7	18.9	28.6	13.4	43.6	57.0	56.0
1961-70	2.9	30.0	32.9	8.2	29.5	37.7	11.1	59.5	70.6	43.3
1971-80	1.7	31.8	33.5	3.3	50.2	53.5	5.0	82.0	87.0	16.7
1981-85	1.6	31.9	33.5	2.5	62.7	65.2	4.1	94.6	98.7	2.0
1986-88	--	--	--	--	--	--	--	--	--	10.8
1989	--	--	--	--	--	--	--	--	--	5.3

Table 8.--Predicated ground water resources of the Aral Sea drainage basin

Basin or Republic	Total resource	Mineral content (g/l): up to 1	1 to 3	3 to 5	more than 5
	(km^3/yr)				
Amu Darya basin, including	40.56	7.42	2.92	3.33	26.89
1. Uzbekistan	8.0	3.13	1.65	1.85	1.37
2. Tadjikistan	4.28	3.83	--	0.45	--
3. Turkmenistan	28.28	0.46	1.27	1.03	25.52
Syr Darya basin, including	21.03	15.31	4.65	0.24	0.83
1. Uzbekistan	11.04	10.4	0.64	--	--
2. Kazakhstan	6.76	2.05	3.64	0.24	0.82
3. Kirghiztan	1.66	1.66	--	--	--
4. Tadjikistan	1.57	1.20	0.37	--	--
Total Aral Sea basin, including	61.59	22.73	7.57	3.57	27.72
1. Uzbekistan	19.04	11.53	2.29	1.85	1.37
2. Kazakhastan	6.76	2.05	3.64	0.24	0.83
3. Kirghiztan	1.66	1.66	--	--	--
4. Tadjikistan	5.85	5.03	0.37	0.45	--
5. Turkmenistan	28.28	0.46	1.27	1.03	25.52

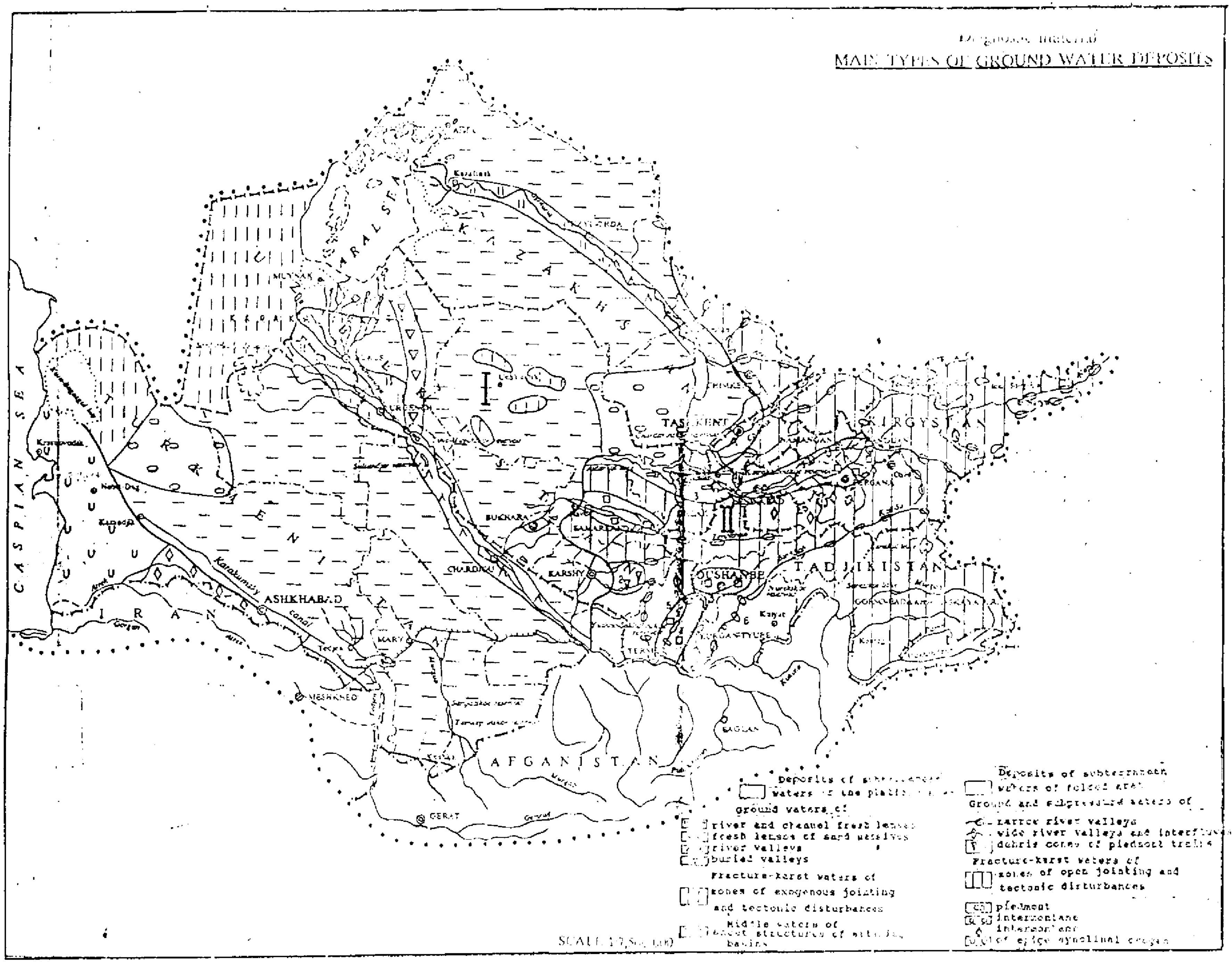


Figure 4. --Major ground water deposits in Aral Sea drainage basin.

On the plains of the region, a large part of the underground waters is collected in fresh water lenses along rivers and in large irrigation canals. The Quaternary underground waters are closely connected hydrologically with surface waterways. As a result, the intake of any underground water reduces surface runoff by the same volume.

Calculations carried out by the "Gidroingeo" have established that the quantity of fresh and moderately-salty waters (up to 3 g/l) hydrologically unconnected with surface runoff reaches 5.5 km^3/yr. Of this amount, 2.0 km^3/yr are in the Amu Darya basin, and 3.5 km^3/yr in the Syr Darya basin. Therefore, the potential underground resources whose consumption will not deplete the surface water resources of the basin are 5.5 km^3/yr.

At present, more than 250 underground water reservoirs of economic significance have been identified in the basin. Most of them are identified on the "Updated Map of Underground Water Consumption in the Economics of Central Asia and southern Kazakhstan", at a scale of 1:1,000,000.

Table 9 illustrates systematized data on explored underground water deposits, State underground water records, and data on exploring and supervising water intake installation. These calculations were carried out by the institutions of the USSR Ministry of Geology.

The intake of ground waters, established by the territorial hydrologic surveying parties in the Aral Sea basin, totals 12.3 km^3/yr, including 3.98 km^3/yr in the Amu Darya basin and 9.32 km^3/yr in the Syr Darya basin. Of the total quantity of the available underground waters, the share of the established underground water resources is only 2.86 km^3/yr, including 0.94 km^3/yr in the Amu Darya basin and 1.92 km^3/yr in the Syr Darya basin. As the estimates of the "Gidroingeo" indicate, at an intake rate of ground waters now reaching 12.3 km^3/yr, the surface runoff is reduced by 9.8 km^3/yr. Therefore, the intake of underground waters for recharging water resources for economic purposes may not exceed 4.0 km^3/yr (Table 10).

Total Water Resources

The total average perennial surface runoff on the former USSR territory totals 115.8 km^3, including 77.4 km^3 in the Amu Darya basin and 38.4 km^3 in the Syr Darya basin. Moreover, between 2.5 to 5.5 km^3/yr of water can be obtained from underground waters without depleting surface runoff. This total ranges from 0.5 to 2 km^3/yr in the Amu Darya basin, and from 2 to 3.5 km^3/yr in the Syr Darya basin. Therefore, the total volume of perennial water resources in the Aral Sea basin averages 118.3 km^3 (Table 11).

Table 9.--The established ground water consumption for economic purposes.

Republic	Underground Water Resources Basins: Amu Darya	Syr Darya	Aral Sea
		(m^3/s) / (km^3/yr)	
Uzbekistan	45.5 / 1.45	155.2 / 4.9	200.7 / 6.35
Kazakhstan	--	43.0 / 1.3	43.0 / 1.3
Kirghiztan	--	14.8 / 0.47	14.8 / 0.47
Tadjikistan	34.5 / 1.1	33.2 / 1.04	67.7 / 2.1
Turkmenistan	34.2 / 1.07	--	34.2 / 1.07
TOTAL	114.2 / 3.6	246.2 / 7.8	361.0 / 11.4

Table 10.-- Annual volume of underground water intake which does not impair surface water runoff

Basin	1985	1990	1995
		(km^3/yr)	
Amu Darya basin	0.5	1.0	1.5
Syr Darya basin	2.0	3.0	3.0
TOTAL	2.5	4.0	4.5

Table 11.-- Average perennial water resources of the Aral Sea basin

	Amu Darya	Syr Darya	Aral Sea
		(km^3)	
Surface runoff	77.4	38.4	115.8
Underground runoff	0.5	2.0	2.5
TOTAL	77.9	40.4	118.3

An increase in guaranteed water resources in the future can be expected only in the Amu Darya basin, primarily as a result of many years of regulated runoff of the Amu Darya itself. The guaranteed water resources in the Amu Darya basin can be obtained if the Rogunskoe Reservoir, with a capacity of 8.6 km^3, is built in 1995. Consequently, water consumers in the Amu Darya basin are guaranteed 89% of the average perennial runoff. At present, 35.3 km^3 (92%) of the average perennial volume of water is guaranteed in the Syr Darya basin. Both figures reflect the limit of water availability. In addition, further regulation is unlikely to permit more intensive water use.

Land Resources

The agricultural management of land in the Aral Sea basin is extremely diversified. Selection of land for potential reclamation stock, and elaboration of necessary measures, are based on estimation of the natural-reclamation state of the basin territory.

Land resources of the Aral Sea basin total 151,200,000 hectares. Of this area, 99,100,000 hectares are agricultural (Figure 5). Of the agricultural land, 8,300,000 hectares are actively farmed; 300,000 hectares are fallow; 600,000 hectares are hayfields; 89,400,000 hectares are pastures; and 600,000 hectares are perennial plantations.

The largest area of farmed land is in Uzbekistan (4,300,000 hectares), and the smallest is in Kirghiztan (600,000 hectares). Desert pastures are predominant in Turkmenistan. In Uzbekistan, the dominant land form is mountain pastures. The land area used as hayfields is insignificant in all republics; it is smallest in Tadjikistan and Turkmenistan. Because of the arid climate, approximately 90% of all farmland (7,400,000 hectares) is irrigated (Table 12).

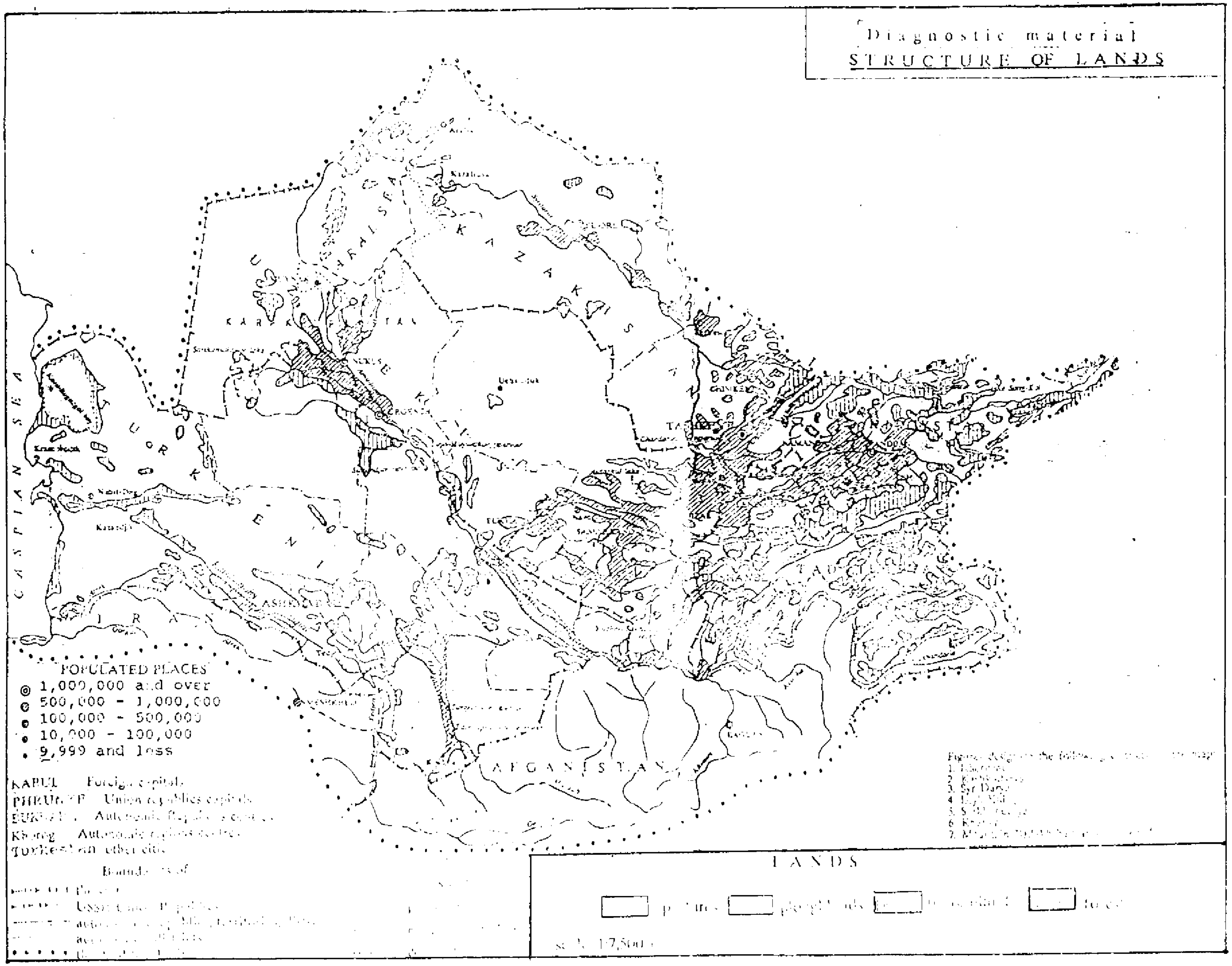


Figure 5. --Land resources of Aral Sea drainage basin.

Table 12.--Land stock in administrative boundaries, 1 November, 1985*

Republic	Total area	Total agricultural areas	I. Agricultural Lands — including: Farmland	Fallow	Perennial plants	Hayfields	Pastures
	(x10³ hectares)						
Uzbekistan	44884.5	28010.6	4321.1	47.4	379.0	119.3	23143.8
Kirghiztan	12873.2	6523.3	589.8	10.8	28.9	182.5	5711.5
Tadjikistan	14254.5	4426.2	838.1	24.5	100.2	31.5	3431.9
Turkmenistan	49120.9	38958.7	1078.1	105.2	76.1	36.8	37662.5
Kazakhstan	30220.3	21217.5	1443.6	67.3	40.4	249.4	19416.8
BASIN TOTAL	151153.4	99136.3	8270.7	255.0	624.6	619.5	89366.5

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Table 12.--Land stock in administrative boundaries, 1 November, 1985* (Continued)

Republic	Total area	II. Non-agricultural Lands: Forest	Trees and bushes plant.	Marshes	Under water	Under roads	Other lands
	(x10³ hectares)						
Uzbekistan	44884.5	1126.2	221.3	80.9	4086.0	228.5	11131.0
Kirghiztan	12873.2	738.0	24.6	6.1	602.	79.9	4698.6
Tadjikistan	14254.5	348.4	167.0	2.6	253.1	66.0	8991.2
Turkmenistan	49120.9	394.6	83.3	-	2922.2	95.8	6666.3
Kazakhstan	30220.3	1298.6	94.0	77.3	3255.9	72.9	4204.1
TOTAL BASIN	151153.4	3905.8	590.2	166.9	11119.9	543.1	35691.2

*Includes land allotments around houses, and cooperative fruit and garden vegetables.

This distribution of farmland is caused by variety of natural conditions. The basin is divided into three agro-climatic zones. The first is the desert zone of aggradation plains, with flat relief comprised of alluvial and talus-proluvial deposits of different compositions. The major part of this zone is covered by the Karakum and Kyzylum deserts, with their characteristic rolling, hummock, barkhan topography. In contrast is the denuded plain of the Usturt plateau, composed of limestones, marls, and clays. The majority of ground water aquifers in the plains region lies at depths below three to five meters (except on irrigated land and in river deltas). Their mineralization content varies from 1 to 15 g/l, seldom exceeding this amount. The soil is gray-brown, desert takylike, desert sandy, meadow desert and meadow.

The second agro-climatic zone is the piedmont-desert area, which has a very complicated agriculture. This zone covers the territory of the piedmont, flat and rolling hummock plains. The plains are composed of alluvial-proluvial and talus-proluvial deposits of mostly loamy composition, often with an admixture of skeletal elements. Ground waters generally lie at considerable depth, except in gardening and irrigation areas. Their mineral content is varied. The soils are mostly automorphic grey, with subordinate semi-hydromorphic and hydromorphic soils.

The third agro-climatic zone in the basin is the mountainous shrub-steppe and dry forest zone, which has much dissected relief. The soils are brown and gray-brown, usually eroded, and covered with rubble and stones. Of the three agro-climatic zones, the land in this zone is the least suitable for agriculture (Table 13).

The depth and regime of ground waters in the Aral Sea basin vary greatly, depending on their sources and drainage patterns. The automorphic soils overlying deep ground waters cover about 65% (21,100,000 hectares) of the land suitable for irrigation. The remaining 35% is composed of semi-hydromorphic and hydromorphic soils.

The land stock of the Aral Sea basin is estimated by the productive capacity of the soils, which is determined by classes and groups of soil fertility. The soil-fertility classes are established by constant factors of the natural environment, while the fertility groups are determined by dynamic features. Fertile lands, designated as the first class, make up 46% of the total area. Lands in the second class, with lower fertility, make up 42% of the total area. Low-fertility lands (third class) and lands with very low potential fertility (fourth class) comprise 10% of the basin area (Table 14). However, because of dynamic factors (mostly salting of ground soils), the soils with low and very low fertility (22%) dominate in the Aral Sea basin.

Table 13.--Gross distribution of land stock, based on latitude and altitude

Basin	Desert	Zones desert	Mountainous brush, steppe, dry steppe	Total
		($x10^3$ hectares)		
Amu Darya	17392	4713	624	22729
(irrigated)	4392	1412	89	5672
Syr Darya	4392	4826	687	9904
(irrigated)	1524	2326	218	4069
Aral Sea	21784	9539	1311	32633
(irrigated)	5687	3738	315	9740

(Notes: (1) Includes land irrigated continuously and periodically.
(2) The total irrigated area of 9720 hectares includes roads, settlements, channels, etc. Using a land-use coefficient of 0.75, the recalculated total irrigated area is about 7402 hectares).

Table 14.-- Estimation of land stock (gross) on the basis of soil fertility

	Reclamation stock	Including irrigated land	Estimation of reclamation stock on the basis of soil fertility as of 01/01/1988			
			I	II	III	IV
			(million hectares) (%)			
Aral Sea Basin	32.63	9.74	15.70 48.0	13.30 42.0	3.40 9.4	0.230 0.6

The land stock can be divided into the following categories, on the basis of different irrigation-economic conditions:

(1). Lands with systematic irrigation;
(2). Land with conditional and sporadic irrigation;
(3). Lands whose irrigation was stopped at different historical periods and which, for various reasons, are no longer in agricultural use; and
(4). Bogar (non-irrigated) and virgin lands used in agriculture.

Bogar farming is limited to one percent of the arable land. The arid conditions of the basin make bogar farming possible only on piedmont plains and in intermontane valleys. The rest of the farmland, making up about 35% of all irrigated lands in the former USSR, is irrigated.

The crops on irrigated land are grown in the following proportions: cotton - 51%; fodder -27%, grain - 16%; potatoes, vegetables and melons - 5%. In addition to the arable land, gardens, vineyards, pastures, etc., also are irrigated. However, these latter land uses represent only a small portion (approximately 10%) of the total irrigated agriculture.

Reclamation of irrigated lands depends on many natural factors, and on the reclamation activity itself. A number of regions in the upper reaches of the Syr Darya and Amu Darya have considerable irrigated areas in the first and second categories (more than 80%). However, even in these reaches (in Ferghana and Vakhsh), there are locally-distributed salty soils.

The lands in the middle reaches of rivers are mostly (more than 57%) in the second category. However, there are large land areas in the third and fourth categories, with middle and high soil salinity, and ground water depths of less than three meters. In the past 15 to 20 years, reclamation efforts have become increasingly unsuccessful.

Large areas of irrigated lands in the lower reaches of the Syr Darya and Amu Darya are in an unsatisfactory reclamation state. Land in the third and fourth categories now total 40% to 55% of the area; this land is completely salted. Areas with middle and high salinity comprise 35% to 70% of the total. The ground water depth generally is one to three meters.

The magnitude and complexity of the deterioration of irrigated lands is suggested by reports from Uzbekistan, showing the extent of salinization. For the republic as a whole, the change in the situation between 1982 and 1985 is illustrated in Table 15.

Table 15.--Salinization in the Republic of Uzbekistan, as a percent of the used irrigated area

Year	Total	Degree of salinization		
		Weak	Average	Strong
		($x10^3$ hectares)		
1982	1200	774	336	89
	*(38.3)	(64.5)	(28.0)	(7.5)
1985	1643	892	545	206
	(42.8)	(54.3)	(33.2)	(12.5)

*number in parentheses indicates percent of total area of salinized land.

Intensive development of irrigated farming without sufficient consideration of natural conditions in the region, low quality reclamation constructions, violations of proper agricultural techniques, a disregard of the recommendations of agricultural science, etc., have resulted in severe deterioration of the soils in the Aral Sea basin. The means of rehabilitation in places it is practicable are known, and need not await extensive study.

Mineral Resources and Raw Materials

Fuel and Energy Reserves

The fuel and energy resources of the region are composed of large reserves of coal, oil and natural gas. The potential coal resources (30.5 million tons) are concentrated mostly in Kirghiztan and Uzbekistan. Potential oil resources (1.4 billion tons) and potential natural gas resources (17.3 trillion m^3) are located in Turkmenistan and Uzbekistan. The degree of exploration of the region's potential coal resources is not high, being only 17.5% (25% in Uzbekistan, 7.5% in Kirghiztan, and 6.3% in Tadjikistan), implying possible industrial reserves for the future. Explored reserves represent 40% of the initial potential oil resources, and 34.6% of the natural gas resources. The developing and ready-for-extraction deposits total about 53% of the explored coal reserves, 82% of the oil reserves, and 93% of the natural gas reserves.

By 1988, the Aral basin had been providing coal for economic uses for 116 years. Uzbekistan had provided coal for 154 years, Kirghiztan for 117 years, and Tadjikistan for 99 years. In Kazakhstan, coal mining ceased with the Lengerskiy deposit becoming economically unprofitable.

Provision of oil at the 1989 level from explored and extracted outputs in the whole region is estimated to last about 41 years. It also is estimated the oil reserves in Turkmenistan will last 41 years, those in Uzbekistan for 37 years, those in Tadjikistan for 22 years, and those in Kirghiztan for 78 years. In Kazakhstan, the new deposit in Kumkon is now being exploited in the Kzylordisnskaya region.

The natural gas output from explored sources for the whole region is 28 years, including 28 years in Turkmenistan, 25 years in Uzbekistan, 41 years in Tadjikistan, and 77 years in Kirghiztan.

Mineral Resources

A significant potential for the development of various useful polycomponent minerals enhances the long-term prospects for developing and strengthening the mineral and raw material base for the region's mining industry. It also enhances the economic importance of the complex extraction of deposits of combustible minerals, nonferrous, rare and precious metals, rare-earth elements, and agrochemical raw materials for the former Soviet Union and regional republics.

Hydropower Resources

The hydropower resources are concentrated in Tadjikistan and Kirghiztan (third largest in the former USSR). The potential hydropower resources of the Amu Darya and Syr Darya total 306 and 162 billion kilowatt hours, respectively. The economic potential of the hydropower resources for the whole region is 127 billion kilowatt hours, including 80 billion kilowatt hours in Tadjikistan, 37 billion kilowatt hours in Kirghiztan, and 10 billion kilowatt hours in Uzbekistan.

The region has considerable energy reserves in the form of smaller rivers, streams, etc., for development of "minor" energy resources. The expenditure of hydropower resources is not high.

Resource Base for Ferrous Metallurgy

The resource base for ferrous metallurgy in the region is composed of several small ferrous deposits in Tadjikistan and Kazakhstan (not intended for mining), and of numerous ore deposits, most of which are located at inaccessible mountain sites. Potential ferrous ore resources total about 5.53 billion tons, the balance of the reserves totaling 117.6 million tons.

Resource Base for Nonferrous Metallurgy

The Aral Sea region contains more than a half of the All-Union potential resources of antimony, a third of quicksilver, and a considerable share of copper, lead, zinc, tin, tungsten, molybdenum, fluorite, strontium, lithium, and many other nonferrous, rare and precious metals.

The antimony resources are concentrated in Tadjikistan and Kazakhstan. Explored reserves make up more than 60% of the All-Union resources. The output of antimony reaches 30% of the All-Union resources. The mercury resources are concentrated in Kirghiztan, Tadjikistan and Uzbekistan. The explored reserves make up more than 40% of the All-Union reserves, with the output being more than 50% of the reserves. There is insufficient provision of reserves for the Khaydarkanskiy mercury plant. The Aral region has large potential mercury resources, and the future mercury output can be increased with the development of explored sites.

Copper resources are primarily concentrated in Uzbekistan, with smaller deposits in Kirghiztan, Tadjikistan, and the Chimkentskaya region of Kazakhstan. The output of copper is small, and the rate of development of deposits is not high. The geological exploration for copper in the region during the studied period was mostly limited to Uzbekistan, for the purpose of finding higher-quality ores.

The lead and zinc resources of the region are concentrated in Uzbekistan, Tadjikistan, Kzylordinskaya and Chimkentskaya regions of Kazakhstan. The explored sources of lead in the Aral Sea basin amount to more than one-fifth of the All-Union sources, while those of zinc are approximately one-seventh of All-Union sources. Lead output is one-fourth and zinc output is less than one-tenth of the All-Union output.

Tungsten resources are concentrated in Uzbekistan and Tadjikistan, while the major output is from Uzbekistan. The region's tungsten reserves comprise a small portion of the All-Union explored reserves; the predicted resources total about five percent of the All-Union reserves. An increase in tungsten reserves can be expected from extraction in Kyzyklum, provided the new extractive plant has a sufficient supply of fresh water.

The molybdenum resources of the region are not large, but its output is 10% of the All-Union output. The explored reserves are concentrated in several complex deposits in Uzbekistan. Geologic exploration is planned in western Uzbekistan, where veins and zones of lead-silver minerals were found. The same applies to the Aksuyskiy region of Tadjikistan.

Fluorite resources are considerable, and the output is about 10% of the All-Union output. Explored reserves are located in Uzbekistan, Kirghiztan, Tadjikistan and the Chimkentskaya region of Kazakhstan. The developing deposits of fluorite ores in Uzbekistan, as well as the complex ores in the Oshskaya region of Kirghiztan, are the most important of these resources. The fluorite content in the Uzbekistan mines is below the normal level.

The precious and rare metals resources in the region are of All-Union importance. The ores contain gold, silver, strontium and other metals. In Uzbekistan, the output of gold is one of the highest in the former USSR. The balance of the strontium reserves are concentrated in Turkmenistan, Uzbekistan and Tadjikistan. In eastern Turkmenia, the Arikskoe deposit is the only one developed in the republic. Four explored deposits are in reserve in this area.

Celestine output at the Arikskoe deposit is deliberately restricted, because of outdated notions about the country's economic demand for celestine concentrate and strontium salts. A number of essential items in the consumer market are being disregarded. For example, there are large-scale consumers of low-quality celestine ores, both within the region and outside its borders. The ores are used as a highly-effective increaser of fluid weight during deep drilling activities in carbonate oil and gas reservoirs. There also are potential large-scale consumers in ferrous metallurgy (for the production of frost-resistant steels), and in glass, ceramic and other industries.

The region has large reserves of mining-chemical raw materials. The major reserves of iodine, bromine, sulfate of sodium, natural sulfur, sodium chlorite, etc., for the whole country are concentrated in this region. The bay of Kara Bogaz Gol is a unique natural storehouse, containing a combination of useful minerals. Recently, a large raw materials industry was organized in the region for the production of mineral fertilizers. These include phosphorites in central Kyzyl Kum in Uzbekistan, and potash salts at the Karliukskoe deposits in Turkmenistan and at the Tiubegatskoe deposit in Uzbekistan.

The republics of Central Asia and southern Kazakhstan are rich in various useful non-metalliferous minerals. These minerals are indispensable in the building industry (sand, bentonite clays, facing stone, granite, marble, gypsum, basalt, dolomites, etc.).

The accumulation of secondary resources and waste materials (scrap metal, associated useful minerals, textile and agricultural vegetable wastes, etc.) continues to increase in the region. Their rational use and industrial processing will be of great importance to the economy of the area. For example, the secondary kaolines, accumulated in the dumps of Angrynskiy coal, are a reliable source of raw elements for industrial production of building materials, and for other branches of industry. Figure 6 illustrates the locations of useful mineral deposits in the Aral Sea basin.

Recreational Resources

The Aral Sea basin has extensive possibilities for development of a recreational industry, especially for tourism. The beautiful monuments of worldwide fame located in Khiva, Kun Urgench, Bukhara, Samarkand and Turkestan, and the numerous estates, fortresses, cult buildings, and relics of ancient cities on the "Great Silk Way" are of great historic and scientific interest. If properly organized, tourism in the Aral Sea region can become part of a system of international tourism.

There are a large variety of mineral waters and medicinal muds in Sultan Sandisar, Nukusskoe, Andreevskoe, and Goek Ata lakes. Climatic conditions in the Aral Sea region also are favorable for recreation. There typically are 200 warm days during the year, steady periods of sunshine, hot and dry weather, and low relative humidity. All these climatic factors are beneficial for successful medication of many functional maladies of the nervous system, respiratory system and kidneys.

The prospects for recreation in the Aral region depend on the stabilization of the Aral Sea's water level and improvement of its water quality. A permanent reservoir with a steady regime can be created in the Usturt part. Wonderful beaches, and the peculiar "moon" landscape of the chinki (border scarps) of Usturt, will help promote the establishment of a large recreational center.

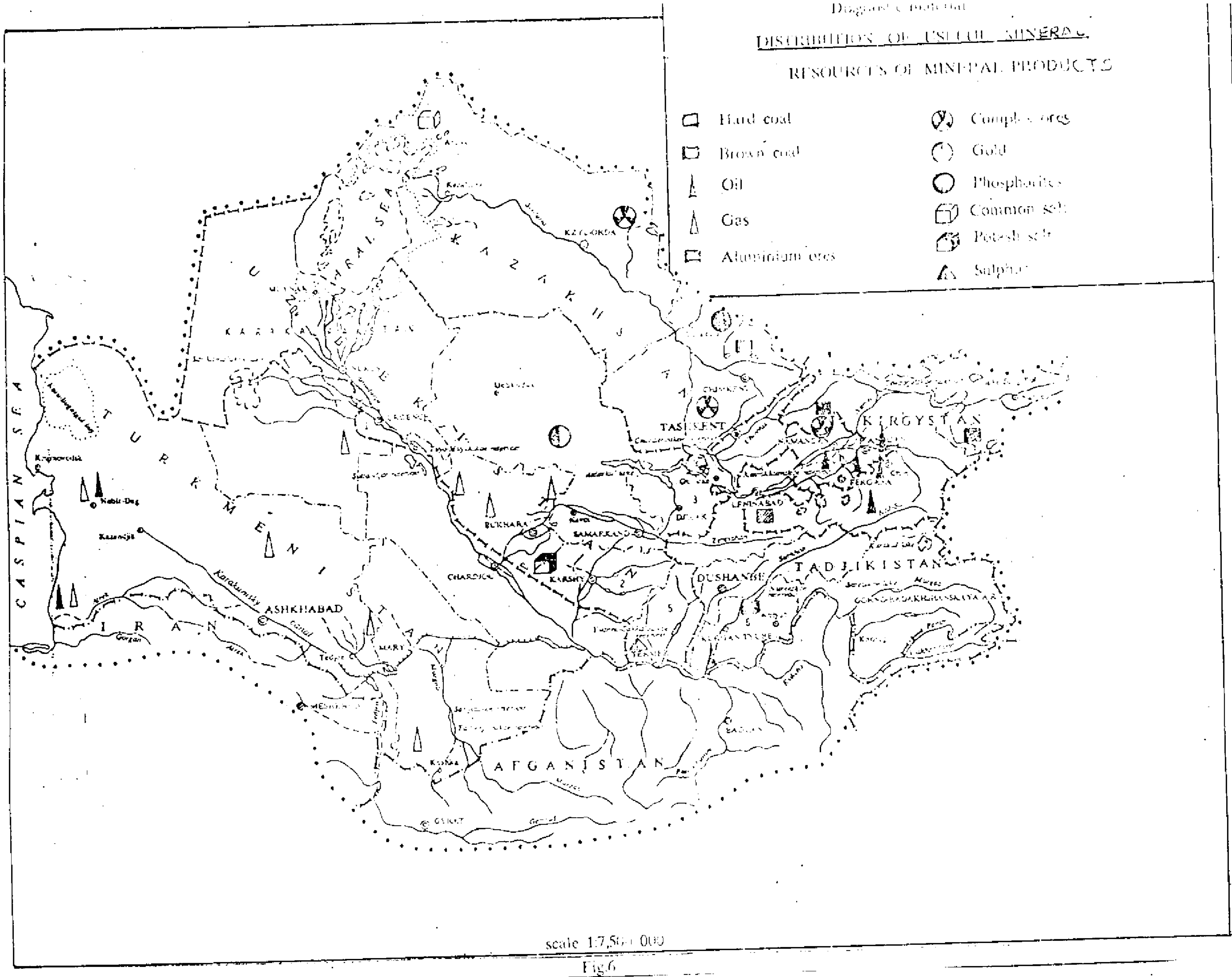


Figure 6. --Distribution of useful mineral resources in Aral Sea drainage basin.

CHAPTER IV

THE NATURAL ENVIRONMENT OF THE ARAL SEA DRAINAGE BASIN, AND PRINCIPAL CHANGES IN ITS TERRESTRIAL ECOLOGY

Human-Induced Climatic Changes

Human-induced, large-scale environmental changes of the Aral Sea basin and adjacent territories have taken place over the last 20 years. Because of increased water diversions, the hydrogeographic network of Central Asia and Kazakhstan was subjected to fundamentally negative changes. River runoff has decreased, resulting in the decline of the water level of the Aral Sea, and causing a drying of branches and arms in the Amu Darya and Syr Darya river deltas. Natural lakes on the plains in the Aral basin have disappeared, or are reduced, while irrigation wastewater lakes have formed along the periphery of irrigated zones.

In increasing areas of the irrigated lands, there has been a decrease in the propagation of steppe and desert vegetation, a formation of new landscapes on the exposed and desiccated bottoms of lakes and the Aral Sea, and a disturbance of the natural dynamics of the water medium. These events have changed the regime of soil moistening, the depths of ground water levels, and the natural heat-water balance correlation.

A growing phytomass increment on irrigated massives and near the canals resulted in higher transpiration. The microclimate in the zone of influence of the Karakum canal also was affected; the transpiration reached 0.6 km^3/yr, and the evaporation from the canal bed and filtration lakes also has increased. Summer temperatures on sites with new vegetative communities several meters wide decreased by 3.6% at a height of two meters. The relative humidity increased by 10% to 20%. These differences diminish above the height of two meters, and are characteristic of microclimate effects.

Desiccation of the Aral Sea has resulted in variations of some climatic and meteorological indices over larger areas. The climate in the Aral area has changed to a certain extent. The climate became more continental. The amplitude of the summer and winter air temperatures at coastal stations increased by 1.5 to 2.5 °C. The amplitude of diurnal temperatures increased by 0.5 to 3.3 °C. The highest temperature variations took place during the last decade, accompanied by the reduction of the Aral Sea water surface level. However, this regularity is typical for both coastal stations and for stations far inland from the Aral Sea. Significant winter cooling during the last decade, and certain summer warmings occurring both in the Aral Sea region and at some distance from it, cannot be explained solely on the basis of a disturbance of the Aral Sea regime. Atmospheric processes have affected temperature variations to a great extent.

Mean annual relative air humidity at coastal stations has decreased by two to three percent. The decline reached nine percent in spring and summer. A continuous decrease of humidity, coinciding with intensive Aral Sea desiccation characterizes the coastal stations after 1960. At a distance of 200 kilometers, at an atmosphere layer up to the level of 700 g/Pa, the effect of the water's mirror-like surface on the humidity regime is not observed. Recurrence of rainless days has increased considerably. Between 1950 to 1959, there were 30 to 35 especially dry days annually in Muynak. However, between 1970 to 1979, the number increased to 120 to 150 days. An anthropogenic effect on the humidity regime exceeded that of natural circulation factors. As a result of reduced air humidity, formation of condensational moisture, conditions of ground water recharge, and soil moisture needed for desert vegetation decreased in the seaside regions of the Aral Sea.

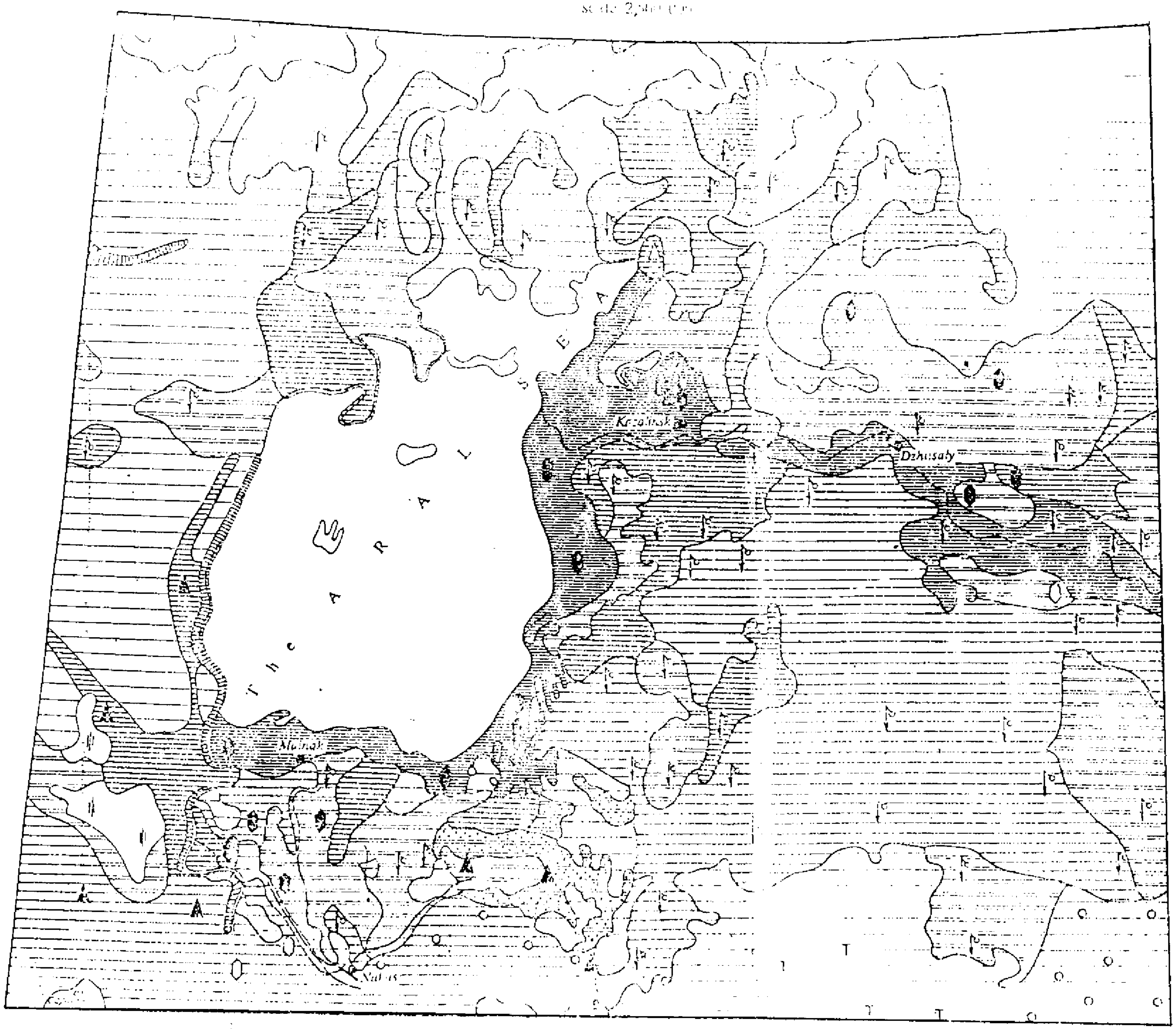
Data obtained at individual meteorological stations indicate a change in regional seasonality has occurred; spring came seven days later, and autumn 12 to 13 days later (i.e., date of transition of mean diurnal temperatures over zero degrees). The last frosts of spring also were observed at some later dates, while the first autumn frosts were observed 10 to 12 days earlier at Muynak. Thus, in spring and autumn, Muynak lost the temperature-dampening effect of the Aral Sea.

The annual cycle of precipitation volume also changed. In 1950 to 1959, the maximum precipitation occurred in February to March, and the minimum in September. However, in 1970 to 1979, the maximum was observed in April, and the minimum in July.

An intensified effect of continentality on the climate was observed. The albedo of areas formerly occupied by the Aral Sea increased sevenfold, producing a more than threefold increase in the reflected solar radiation value in the Aral area. Decreased sea water surface area appeared to have an insignificant role in producing the variations in cloud formation over such a small region.

A dry coastal band on the northeastern and eastern seashore, over 40 to 50 kilometers wide, contributes to the development of dust debris cones reaching over 500 kilometers in length. Winds blow in northern, northeastern, eastern and southeastern directions. This phenomenon is clearly seen on the satellite photograph (Figure 7). From 1966 to 1980, the number of days with dust storms, and storms with drifting dust in coastal regions, increased by more than 50%. At some locations, the number increased 3.6 times.

SCALE 2,500 000



CONVENTIONAL SIGNS
TYPE OF DESERTIFICATION

- Degradation of vegetation cover
- Desertification around wells
- Deflation
- Salinization of irrigated soils
- Salinization of soils caused by decline of the sea level and regulated flows
- Technogenous desertification
- boundary of a contour
- No desertification
- Slight
- Moderate
- Severe
- Very severe

CATEGORIES OF LANDS EXCLUDED FROM ASSESSMENT OF DESERTIFICATION

- solonchaks
- stony slopes
- bedrock outcrops
- a shore of the sixties

Fig. 6

Figure 7. --Anthropogenic desertification in Aral Sea

Both increases and decreases in the number of dust storms have been observed in oases. At some locations on the Ustyurt, such as the Karakalpakia station, the number of dust storms increased by 60-fold between the 1950's to 1970's. It is believed this increase in the number of dust storms is associated not only with the desiccation of the Aral Sea, but also with the anthropogenic degradation of vegetation and soil cover in Ustyurt itself.

The length of dust flows in dust storms at the southern periphery of stationary high anticyclones is usually 170 kilometers, while in frontal dust storms, it is 270 kilometers. The most powerful sources of debris cones are between the Syr Darya mouth and the former Uyaly Island (Grigoryev, Lipatov, 1982). The mass of dust in a dust storm may reach 1,680,000 tonnes (Grigoryev, Lipatov, 1979). Dust debris cones decrease the absolute values of the diurnal radiational atmospheric balance 200% (Kondratyev, 1986).

Surface Runoff Water Losses Related to Human-Induced Climatic Changes

Anthropogenic losses are caused by human economic activity. They represent irreversible water consumption by various industrial and agricultural activities, and human populations, as well as additional evaporation from reservoir surfaces. Only the irreversible water consumption through irrigated agriculture will be further explained.

Agricultural irrigation includes the diversion of water from rivers, as well as operational wastes from irrigated massives back to the rivers. Irreversible water consumption includes evaporation and transpiration in irrigation systems, as well as operational waste from irrigated massives to closed drainage depressions, to lakes without outflow and to the desert.

On the whole, anthropogenic runoff uses in the basin over the last 60 years have increased more than three times. They now exceed 90 km^3/yr (see Table 7). It should be emphasized that 85% to 98% of anthropogenic use of runoff is for irrigated agriculture (Table 16).

Only 8% to 15% of the decrease in runoff volumes is caused by climatic factors. The majority of the decline in the runoff to the Aral Sea and to the lower parts of the deltas is associated with anthropogenic effects, especially with irreversible losses in consumptive use by irrigated agriculture.

Table 16. -- The use of water resources in the Aral Sea basin

Branch of economy	Water intake	Water diversion	Consumptive water use
		(km^3/yr)	
Municipal economy	3.1	1.6	1.5
Industry and power generation	8.3	6.4	1.9
Rural drinking water supply	0.86	no data	no data
Fishery	2.0	1.0	1.0
Irrigated agriculture	113.9	38.7	75.2
TOTAL:	128.16	47.7	79.6

(Note: The water intake volume is larger than the average perennial runoff (see Table 7), due to the waste of drainage and runoff water to rivers and their secondary use).

Important consequences of water balance variations in the Aral Sea basin include the following:

(1). A rise of the ground water table on and near irrigated massives with insufficient drainage, as well as near canals and the main drains. This results in salinization and waterlogging of soils, and subsidence of surface structures;

(2). A sharp increase in the discharge of high-mineral content drainage water to rivers. The pesticide and mineral fertilizer content of these waters leads to deterioration of river water quality;

(3). The formation of new discharge lakes in closed depressions, where drainage water from irrigated massives are discharged;

(4). Decreased river water inflow to the lower parts of the Amu Darya and Syr Darya deltas. This leads to desiccation of deltas and the disappearance of many delta lakes;

(5). A decrease in the river water inflow to the Aral Sea, which caused a decline in its water level, decrease in area and volume, increase in salinity, disruptions of the sea ecosystems, and formation of new land areas. In turn, these changes resulted in a number of climatic and meteorological variations;

All the above have caused a change in, and in most cases a deterioration of, living conditions for the area's population. Economic activity also has been made more difficult.

Changes in the Terrestrial Biota of the Aral Sea Basin

The Aral region is located in a desert zone. Its northern part is characterized by the deserts of Kazakhstan, and its southern part by deserts of the Central Asian type. Overall, the region is a complex combination of sand deserts (northwestern and western part of Kyzylkum, Aral Karakum, Major and Minor Barsuki), clay deserts of Ustyurt, northern Aral area and relic uplands, and the vast alluvial delta plains of the Syr Darya and Amu Darya rivers.

Vegetation

Zonal clay deserts are represented by sagebrush (Artemisia terrae albae, A.herba alba) in complexes, and in combinations with communities of Anabasis salsa, A. Aphylla, A.eriopoda, Salsola oriebtali, S.arbuscula, S. arbusculiformis, Nanophyton erinaceum, Ceratoides pappos, and others. Communities of Artemisia pauciflora and A.lercheana often occur in the north.

Cereal cenoses are frequent, examples being Agropyron fragile, Stipa sartptana, Poa bulbosa, and others. Considerable areas also are sometimes occupied by Haloxylon aphyllum.

Sand deserts, mainly with ridge-hillocky sands, are occupied by saxauls (Haloxylon persicum and Haloxylon aphyllum in different combinations) and dzhuzgun brush (Calligonum spp.). Also seen are Ammodendron conollyi, Astragalus, Eremosparton aphyllum, Salsola arbuscula species, and others. Additional typical vegetation includes Ephedra spp., Artemisia terra algae, A.arenaria, Ceratoides papposa, Mausolea fragile, Carex phyzodes, and others. Smoothed and fine-hillocky sands are covered with saxauls, sagebrush (A.terrae albae, A.lercheaba, A.turanica, A.arenaria), cereal groups (Agropyron fragile, S.Sareptana, Stipagrostis pennata, Leymus racemosus), and similar vegetation.

Solonchaks, with Halocnemum strobilaceum, Kalidium caspium, Halostachys caspica, as well as Salsoa, Suaeda, Climacoptera, Halimocnemis, and Bienarta genera and others, are distributed in all the regions. However, they do not occupy large areas of land.

Considerable pattern structure and complexity are typical of the vegetative cover. Such territories traditionally are used as pastures.

Productivity of saxaul-ephemers pastures approximated three to six centners/ha (one centner = 100 kilogram), ephemeroids-sagebrush two to five centners/ha, biyurgun - one to seven centners/ha, zhitnyak - four to seven centners/ha, and solyankoviye with tamarisk - two to eighteen centners/ha. Impacts of declines in the water level of the Aral Sea were not immediately observed in these areas. In the 1980's, some shifts toward halophytization were observed. However, the vegetative cover of the region started to degrade much earlier, as a result of the irrational use of the land resources. For example, pasture areas were reduced because of plowed lands and nonregulated land use, especially on sites with good ponds. Unsystematic grazing also led to significant desertification, causing the replacement of natural vegetative communities with less-productive and less-valuable vegetation. In areas distant from human settlements and ponds (including the coastal band), reduced pasture use is observed, accompanied by lower crop yields. Such lands account for 20% of the Aral region territory.

.Vegetation in the flood plains and deltas of the Amu Darya and Syr Darya rivers is of special significance. To begin with, this is the so-called "tugai", where Populus, Tamarix, Eleagnus, Halimodendron species predominate, with rich grass cover. Alhagi and Phragmites australis communities are widely distributed. The latter occupy the largest areas of island archipelagos, especially in the eastern part of the Aral Sea. Reedbed productivity approximated 18 to 45 centners/ha (up to a maximum of 255 centners/ha). In combination with meadow communities (Aeluropus litoralis), this vegetation was the richest agricultural and hunting land. In fact, this was the region in which began the catastrophic changes associated with the decline in the water level of the Aral Sea. Hydrophyllic vegetation appeared under conditions of insufficient water supply.

An area of tugai woods along the Syr Darya decreased by a factor of three, and dead wood approximated 60% in the preserved forests. Further, 800,000 hectares of land were deprived completely of reedbeds. These changes in vegetation structure are striking, and exceed natural processes by a factor of ten to twenty. At regions of destroyed phytocenoses, climax or solonchak communities began to be formed (under conditions of high salinization). Parallel with these changes, hydromorphic soils were transformed to solonchak and automorphic takyr-like soils. Solonchak vegetation is preserved for many years, and the productivity of such communities does not exceed three to four centners/ha.

Thus, out of 420,000 hectares of hay meadows in the Amu Darya delta in 1960, only about 70,000 hectares still existed at the end of the 1980's. Productivity of the meadows decreased to 15 to 40 centners/ha; on the inundated lands, it decreased to only 0.7 to 0.8 centners/ha. The grazing area decreased by a factor of three, and its productivity decreased by more than half. Unusual processes occurred on the newly-exposed Aral Sea bottom area (about 45,000 km^2) because of its declining water level. Development of vegetative cover is controlled by processes such as variations in the ground water regime and quality, and migration of salts. At the first stage of vegetative cover development, small species such as stenoptopic aggregations of annual halophytes (Suaeda, Salsola and Salicornia) are formed. They are subsequently replaced by

Atriplex aggregations which, upon migration, can exist in dry areas for decades. Under these conditions, plant-deprived heathlands, with saline soils and dense crusts, are formed. Coastal vegetative species then proceed to colonize the lake bottom.

Under conditions of continuing severe salinization, tamarisk aggregations are formed, and subsequently replaced by karabarak and sarsazan. On sandy soils with lower salinization, seline aggregations are formed, to be replaced with eremosparton, stragal, and dzhuzguns. However, large land areas remain in the first stage of succession, and appear to be either completed void of vegetation, or else covered with undeveloped, often annual, aggregations. Thus, the economic potential of the land is completely negated, and the necessary phytoreclamation is made much more difficult. This situation also contributes to erosion processes and removal of salts.

Also noteworthy are the changes that occur around water-regulating and storage reservoirs, because of conducting drain runoff. This influence can reach a distance of one to one-and-a-half kilometers. The main effect is underflooding, and accompanying soil salinization. Desert semibrush, sagebrush, and solyankoviye communities are rapidly (about four to six years) replaced by solonchak and swamp-meadow communities. Common vegetation is Aeluropus litoralis, Suaeda, Salicormia, and sometimes Tamarix, Climacoptera and Halostahys.

These various processes have been accompanied by an impoverishment of the flora as a whole, especially that of formerly-existing and newly-formed communities. Prior to the desiccation of the Aral Sea, the flora of its basin approximated 1,200 species of angiosperms. The richest tugai forests of the Amu Darya had 576 species, including 29 species endemic to Central Asia. Today, 54 species of these plants are on the verge of extinction. Species of water lilies, aldrowands and ferns have disappeared, and licorices and other species have been significantly reduced.

Animal Populations

Essential changes also characterize the fauna of the Aral Sea basin. Animal populations of argillaceous deserts were most significantly affected by direct human activity. They were significantly affected by activities relating to cultivation of new territories, including transport, construction, plowing, laying-in of firing, and fires. Non-regulated hunting for large animals (saiga, Dzeiran) and game birds also fundamentally affected these species. In regions where the land was completely irrigated, the indigenous mammal and bird populations were totally disrupted. Zoocomplexes in solonchak-type ecosystems with weed-halophilic vegetation were significantly impacted. Moles and earwigs are prevalent, while solonchak, short-toed larks and sea-plovers are relatively scarce.

Bird fauna in reed complexes used to be extremely rich. They included 21 species of waterfowl, including 11 species of nesters. The Khiva pheasant, the ibis (Platalea leucorodia), several species of predatory birds, and over a dozen species of sparrows existed there.

In the Syr Darya floodplain and on the shores of the Aral Sea, marbled ducks, stiff-tailed ducks, ibis (Platalea leucorodia and Plegadis), long-tailed sea eagles, serpent sea eagles, booted eagles, pond herons and little white herons were common.

Hogs and jungle cats were usual inhabitants of the brushwoods. The Central Asian tiger was observed until the 1930's.

At present, in addition to degradation of delta reed swamps, it is clear that the loss of very large numbers of islands in the southeast portion of the Aral Sea basin has led to an enormous decrease in the conservation value of the lake to wildlife.

Desertification of deltas and flood plains resulted in the regrouping of species in zoocomplexes. Waterfowl also migrated to new regions. In the 1960's, the Syr Darya delta contained 100,00 hectares of lake area, while the Amu Darya contained 300,000 hectares. By the late 1980's, the areas had been reduced six-and-a-half times. Vegetative cover had changed completely. The disappearance of fish populations in the Aral Sea, and scarce food in delta reservoirs, led to the displacement of the whole complex of fish- and insect-eating birds over a wide area. Populations of many thousands of red-billed and red-headed diving ducks, river ducks swans (Cygnus), ibis (Platalea leucorodia), great comorants, and white and Dalmatian pelicans migrated beyond the region boundaries to the Turgei lakes (300 to 400 kilometers northward). Within the region, migration of white and Dalmatian pelicans and great cormorants took place. New master colonies of these birds appeared on the Sarykamysh lake. Birds in the river deltas are limited to small discharge and fish-breeding lakes.

Conditions in the river deltas became unfavorable for such game as hog and muskrat. During the 1950's, from 70,000 to 230,000 muskrat skins were obtained in the lower reaches of the Syr Darya. Hunting ceased in 1978. During the 1970's, up to 50,000 muskrat skins were taken in the Amu Darya delta. Hunting ceased in the beginning of the 1980's. In 1987, hunting ceased on the Sudotchye lake as well.

Changes in the tugai fauna are significant. A typical khangul species (the Bukhara deer) has practically vanished. At present, there are only 10 individuals in the Badai-tugai reserve. The number of birds, especially predatory birds, has been sharply reduced.

At the same time, however, new animal populations have formed in areas affected by irrigation. Such birds as mute-swan, ibis and other water birds have found nesting sites in depressions and areas flooded by drain-header waters. Desiccation of aquatic ecosystems have made new land available for as many as 25 mammal species, 15 bird species and approximately 10 reptile species, as well as a relatively small number of invertebrates (mostly halophilic species).

Rats (Nesokia indica) and house mice, and birds such as Glareolidae, Oenanthe oenanthe, and short-toed larks, appear first on the dried land in the Amu Darya delta. Earwigs and moles are abundant. This is followed by Meriones meridianu, which then inhabit the sites. Lesser short-toed larks (Calandrella rufescens, C. cuberea) start to nest, while migratory hamsters (Cricetulus migratorius) and small five-toed jerboa (Allactaga elater) appear. As the vegetative cover is

destroyed and heath lands form, vertebrates gradually disappear. A few arthropods, mainly spiders, remain.

Development of irrigated agriculture in the Aral region caused the replacement of natural desert ecosystems with agrocenoses over an area of 7,200,000 hectares. Reservoirs flooded 277,000 hectares of flood plain and desert ecosystems. Canals disturbed 40,000 hectares of ecosystems. Drain waters flooded 300,000 hectares of desert. As a result, new solonchak-type ecosystems were formed over an area of 4,060,000 hectares. New, unstable ecosystems have formed on 4,500,000 hectares of newly-formed lands. The scale of ecosystem transformation in the Baikal area is enormous.

Biota in the region is being affected by three important factors:

(1). Indirect effects of the desiccation of the Aral Sea and its delta regions;
(2). Physical destruction of ecosystems at construction sites; and
(3). Reclamation, plowing, and unsystematic use of rangeland.

These factors contribute to the gradual expansion of human-derived desertification over large territories, including the southeast portion of the lake area (see Figure 7).

CHAPTER V

CHANGES IN THE WATER AND SALT BALANCE OF THE ARAL SEA

Water Balance

The main gains and losses determining the water balance of the Aral Sea are its river inflows and precipitation, and evaporation from the lake surface, respectively. Other gains and losses (e.g., underground drainage and filtration) do not significantly influence its water balance. The dynamics of the Aral Sea water balance in the period between 1960 and 1990 are given in Table 17. Its water level during the last two centuries (up to 1963) was more or less stable, within the limits of 52 to 53 otm. This level corresponded to an average annual inflow of 56 km^3.

In the period between 1956 to 1960, the total inflow into the Aral Sea was 280 km^3. From 1966 to 1970, it was 235 km^3. In contrast, between 1981 to 1985, the total inflow into the lake was only 10 km^3. The evaporation from the lake surface in the 1980's was more than 200 km^3. As a result, the Aral Sea volume decreased during the period between 1960 to 1985 by 690 km^3. Beginning in 1960, the lake level began to fall drastically.

During these thirty years, the water level by 15.6 meters. At the present time, the Aral Sea actually is divided into two independent reservoirs -- the Big and Small Seas. These two waterbodies have independent inflow water supplies. Currently, the water level of the Big Sea is 37.8 meters. The level of the Small Sea (based on visual examination and aerospace photographs) is 1.0 to 1.5 meters higher than the Big Sea. On January 1, 1991, the total surface area of the Aral Sea was 34,800 km^2, and its volume was approximately 304 km^3 (Figure 8).

Salt Balance

In considering the possibility and necessity of preserving the Aral Sea within some acceptable limits, estimation of its salt balance is of major importance. Determination of the salt balance is necessary for diagnosing the salinity and composition of the lake water, and to determine its possibilities for different hydrobionites. Thus, it is necessary to examine separately the average salt balance of the Aral Sea over many years, as well as the changes that have taken place over the last 30 years (i.e., the period of the drastic fall of the Aral Sea water level). There presently are several estimates of the salt balance of the Aral Sea (Table 18).

Table 17.--Annual water balance and main parameters of the Aral Sea, 1911-1992.

Years (1)	Sea level (m) (2)	Sea volume (km^3) (3)	Sea surface (x103 km^2) (4)	Average salinity (o/oo) (5)	River inflow into sea (km^3) (6)	Preci-pitation (km^3) (7)	Evapo-ration (km^3) (8)
1911-1960	53.0	1064	66.10	10.2	-- / 56.0	-- / 9.1	-- / 66.1
1961-1965	53.38	1089	67.34	9.94	197.2 / 39.4	43.9 / 8.9	344.9 / 68.9
1966-1970	52.06	1004	62.96	10.91	235.7 / 47.0	36.8 / 7.36	313.0 / 68.6
1971-1975	51.27	955	60.41	11.23	106.9 / 21.2	29.8 / 6.0	292.3 / 58.5
1976-1980	48.52	795	56.03	13.95	58.0 / 11.6	31.9 / 6.4	251.6 / 50.3
1981-1985	45.52	632	51.03	17.70	10.0 / 2.0	30.7 / 6.1	229.3 / 45.9
1986	41.4	440	43.00	22.0	--	--	--
1987	40.54	404	41.06	26.8	8.8	6.9	48.4
1988	39.84	365	39.40	28.3	8.0	6.8	44.0
1989	38.6	330	36.90	30.1	5.37	3.48	38.0
1990	37.3	304	34.80	33.3	9.4	4.3	35.0
1991	34.4	-	--	--	13.88	5.2	30.0
1992	37.2	-	--	--	7.16	2.5	--

(Notes: (1) For periods 1911-1960 and 1986-1990, average annual data is used; for the period 1961-1985, the average data for five year periods are used.

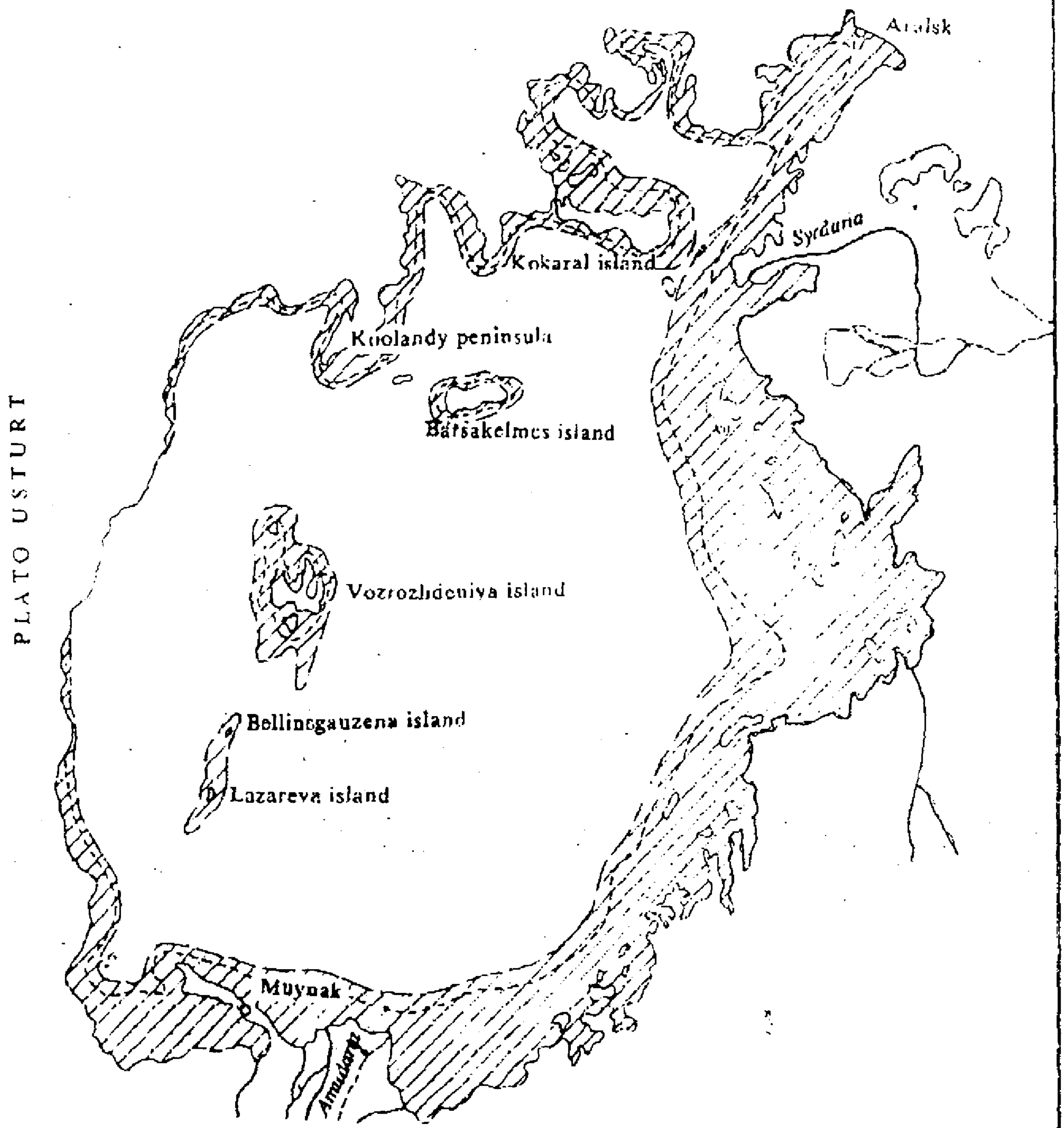
(2) For the period 1987-1990, sea volume and surface area are based on GOIN curves.

(3) River inflow and precipitation are based on observations.

(4) In columns (6), (7) and (8), the denominator is the average annual quantity for the indicated five-year period.

A SCHEMATIC MAP

OF THE ARAL SEA LEVELS FOR 1991



CONVENTIONAL SIGNS

——— a shoreline of 1960

------- a shoreline of 1960

— — — a shoreline of 1960

/////// exposed sea floor

Years	Mark m	Area km²	Volume m³
1960	53.38	67.34	1089
1980	46.12	52.10	605
1990	37.80	34.80	301

Figure 8. --Schematic map of Aral Sea water levels. 1991.

Table 18.-- Average annual salt balance of the Aral Sea before the fall of its water level, according to different investigators

Elements of the Salt Balance	Blinov (1956)	GOIN (Contemporary; 1972)	Bortnikov (1979)	Chernenko (1983)	Glazovsky (1987;1983)
	GAINS ($x10^6$ t/yr)				
River inflow	23.79	32.21	23.79[1]	23.79[1]	29.19
ground water inflow	0		1.4	23.70	0.7-3.3
Precipitation	0.0648		0.4	0.065[1]	3.9
TOTAL	23.85		25.6	47.55	33.79-36.39
	LOSSES ($x10^6$ t/yr)				
Evaporation	1.107	0.23-0.28	0.107[1]	0.107[1]	0.38-0.5
Evacuation under filtration of water into banks	12.85		1.5	1.95	0.21
Evacuation and sediments in the bays			12.9	34.6	14-16
Sediments on the sea bottom	10.94		10.94[1]	10.94[1]	13-15

[1]According to Blinov (1956).

Sources of Potential Error in Calculating Water and Salt Balances

Methodological difficulties in estimating the qualitative characteristics of regional processes are large. In addition, the existing system of monitoring the separate indices is inadequate. As a result, calculations of separate elements of water and salt balance may be inaccurate.

River drainage and salt accumulation in bays and bottom deposits are of major importance in the lake's salt balance. Mistakes in the estimation of these major items of the salt balance do not exceed 20 to 25%. At present, other items of the salt balance can only be approximated. Potential errors can reach 200 to 300%.

However, the imprecise calculations of some elements of the salt balance do not influence the principal conclusions concerning the ratio of the elements, the general salt balance, and salt accumulation in the water of the Aral Sea. The effects of river inflows and salt accumulation at the lake bottom and in bays are the elements which determine the general salt balance of the Aral Sea.

The salinity of the Aral Sea did not increase significantly because of two factors. First, the majority of the carbonates entering the lake accumulated as sediments at the bottom. The salt also accumulated in bays, removing a considerable quantity of salt from the main part of the lake. The annual accumulation of salts in the lake water did not exceed four million tonnes (Table 19). This constituted only 0.04% of the total quantity of salt in the Aral Sea (10.8×10^9 tonnes). A mistake of two- to threefold in the estimate of the annual accumulation would not change the general conclusion that there was only an insignificant accumulation of salt in the water of the Aral Sea.

As a result of several factors, including the development of irrigation, changes in the water balance, the fall of the water level and changes in lake morphometry, the salt balance of the Aral Sea has changed, and will continue to change. The development of irrigation has resulted in a stronger migration of soluble combinations into the lake basin (Table 20).

The main volume of salts is carried in drainage water. The mineral content of water in the drainage flow from irrigated lands reaches 20 g/l, in contrast to a normal value of 2 to 8 g/l. The volume of salt withdrawn from irrigated lands with drainage flow is up to 60 to 70 t/ha.yr. The greater part of the drainage waters goes into rivers, leading to higher mineralization of the river water. For example, the mineral content of water in the lower reaches of the Syr Darya increased from 0.8 g/l in 1960 to 2.8 g/l in 1985. The same process was evident in the Amu Darya, where the mineral content reached 1.7 g/l.

Changes in the Salt Balance During the Last 30 Years

Chlorides, sulfates, sodium and magnesium come mostly from irrigated lands. The quantity of sodium and chloride ions in the Amu Darya and Syr Darya basins increased 2.5 to 5.3 times. Magnesium and sulfate increased 1.8 to 3.5 times, calcium by 20 to 40%, and hydrocarbonates by 10 to 15%. Correspondingly, the composition of the ion content of the major rivers of Central Asia and Kazakhstan changed from hydrocarbonate and calcium types to sulfate natrium and chloride natrium types. There are some differences between the salt composition of drainage waters from irrigated lands brought by different rivers. Thus, sulfates predominate in the water basin of the Syr Darya and chlorides in the water basin of the Amu Darya. This difference may be associated with the location of the majority of irrigated lands on the higher and middle part of the Syr Darya, where the land has a relatively high sulfate content. Chlorides flow more extensively into the lower parts of the Syr Darya. Salts in the Amu Darya basin drain off irrigated lands in the middle, and especially, the lower part of the river. The land in these regions has accumulated sodium chlorides that migrate easily.

Table 19.--Total salt balance of the Aral Sea before the decline in its water level

Elements of the balance	HCO_3^-	SO_4^{2-}	Cl^-	Ca^{2+}	Mg^{2+}	Na^++K^+	TOTAL
			GAINS ($\times 10^6$ t/yr)				
River inflow	10.75	6.1	3.88	4.6	0.85	3.0	29.18
Underground inflow	0.04	0.19	0.9	0.06	0.09	0.6	1.88
Precipitation	1.68	1.95	1.04	0.72	0.53	1.36	7.28
TOTAL	12.47	8.24	5.82	5.38	1.47	4.96	38.34
			LOSSES ($\times 10^6$ t/yr)				
Evaporation	0.01	0.11	0.13	0.02	0.02	0.09	0.38
Filtration into banks	0.003	0.063	0.074	0.09	0.012	0.49	0.73
Accumulation in the bays	0.29	4.77	5.62	0.70	0.91	3.38	15.67
Bottom deposits	12.17	1.56	--	4.65	--	--	18.38
TOTAL	12.47	6.5	5.82	5.38	0.94	3.52	34.69
Accumulation in the sea water	0	1.74	0	0	0.53	1.44	3.7

As a result of the development of irrigation, the ion ratio in the water in different parts of the river has changed. The flow of salts in the water from irrigated lands was higher than from the land which served as the source of the river flow (Table 20).

New areas have emerged as endpoints to the ion surface flow, specifically lakes which receive drainage water. The biggest drainage water lakes are Arnasai in the Syr Darya basin and Sarykamysh in the Amu Darya basin.

The supply of salts to the land increased considerably as a result of water filtration in canals, withdrawal of ground water from irrigated lands, and outflow of drainage water to the limits of oases. Thus, development of irrigation led to the movement of salts that were stored in the ground, and their redistribution over vast territories of arid land.

Table 20.--Surface (river and drainage) runoff in the Aral Sea drainage basin

Processes	HCO_3^-	SO_4^{2-}	Cl^-	Ca^{2+}	Mg^{2+}	Na^++K^+	Total
			($\times 10^6$ t/yr)				
Inflow from abroad	3.95	3.3	1.9	1.8	0.35	1.7	13.0
Evacuation from lands where USSR flow is formed and from old irrigated lands	1.4	11.0	4.9	6.3	1.2	4.4	41.2
Total runoff	17.35	14.3	6.8	8.1	1.55	6.1	54.2
Supply to landscape	-6.6	-8.2	-3.0	-3.5	-0.7	-3.1	-25.1
Runoff to Aral Sea	10.75	6.1	3.8	4.6	0.85	3.0	29.1
Inflow from abroad and evacuation from lands where USSR flow is formed and old irrigated lands	15.9	13.4	6.8	7.5	1.4	6.0	51.0
Supply from newly-irrigated lands	5.0	22.1	18.6	4.4	3.1	13.8	67.0
Total runoff	20.9	35.5	25.4	11.9	4.5	19.8	118.0
Supply to manmade lakes receiving drainage water (Sarykamysh & Aransai)	-3.3	-10.7	-8.0	-2.4	-1.6	-6.2	-32.2
Subtotal	17.6	24.8	17.4	9.5	2.9	13.6	85.8
Supply to landscapes	-15.5	-18.8	-12.6	-7.7	-2.2	-9.6	-66.4
Runoff to the Aral Sea	2.1	6.0	4.8	1.8	0.7	4.0	19.4

(Note: Data on the present ion flow are not exact because the ion flow is constantly changing).

The dissolved constituent load carried by rivers decreased, although not in proportion to the reduction in the volume of river runoff. During the period before the drop in river volume, the river inflow into the Aral Sea decreased from 56 km^3/yr to one to ten km^3/yr. Between 1980 to 1990, the ion concentration in river runoff decreased from 28-33x10^6 t/yr to 5-10x10^6 t/yr. At the same time, Bortnik (1979) noted that, because of changes in the composition of the river water, most of the dissolved salt stayed in the lake water and did not precipitate.

The underground runoff of dissolved matter to the Aral Sea, as a result of the lower water level, is projected to double. Thus, the current runoff of 0.67-3.63x10^6 t/yr will increase to 1.34-6.7x10^6 t/yr. Because the supply of salts from the river inflows has decreased, it is possible the underground runoff may play an increasingly important role in the future salt balance of the Aral Sea.

Salt exchange between the Aral Sea and the atmosphere changes under the influence of two factors. On one hand, as the surface area of the lake decreases, the removal of salt also decreases. On the other hand, part of the salt taken by the wind from salt marshes on the dried lake bottom fall into the lake, increasing the supply of salts to the remaining lake volume. Changes in the salt exchange between the Aral Sea and the atmosphere generally is predicted to increase the quantity of salt in the lake.

The removal of salts during filtration into banks is influenced by two factors--the length of banks decreases (e.g., the filtration front decreases), and the salinity of lake water increases. It is difficult to estimate how this element of the Aral Sea salt balance is changing.

Because its banks are becoming less jagged, evaporation of Aral Sea water, and the accumulation of salts in its bays, evidently is decreasing. This will lead to a preservation and accumulation of salts in the Aral Sea itself. Precipitation of both carbonates and gypsum salts will continue at the lake bottom. In general, if the water flow into the Aral Sea does not increase significantly, one can expect a progressive growth in the salinity of its water.

Changes in the Salt Reserves of the Aral Sea

Calculations based on annual data on the water volume in the Aral Sea and its mineral content indicate the salt reserves between 1961 to 1984 varied from $10.5\text{-}11.17 \times 10^9$ tonnes. The salt reserves began to decrease after 1984, reaching 9.07 billion tonnes in 1986 (Table 21). However, calculation of the salt reserves are imprecise. A mistake of 0.1 to 0.2% in the calculation of the average annual salinity for the Aral Sea may result in an error of $50\text{-}200 \times 10^6$ tonnes in the calculated salt reserves. Every one percent error in the determination of the Aral Sea water volume potentially results in a 100-million tonne error in the calculation of salt reserves. It is possible the reported variations in salt reserves are within the limits of error of the calculations.

The decrease in the salt reserve held within the volume of lake water recorded during the most recent years is more reliable. This decrease may be a result of the increase of salt removal from the Aral Sea, because of the gross precipitation of carbonates and gypsum at the lake bottom, as well as a decrease in the salt supply to the lake.

Table 21.--Salt accumulation in the water of the Aral Sea

Year	Salt accumulation	Year	Salt accumulation (x10^9 t)	Year	Salt accumulation
1961	10.74	1970	11.09	1979	10.86
1962	10.81	1971	10.57	1980	10.89
1963	10.76	1972	10.75	1981	10.96
1964	10.94	1973	10.68	1982	11.06
1965	10.89	1974	10.68	1983	11.03
1966	10.81	1975	11.17	1984	10.86
1967	10.54	1976	10.85	1985	10.08
1968	10.90	1977	10.66	1986	9.07
1969	10.57	1978	10.69		

Wind-Induced Movement of Salt from the Exposed Aral Sea Bottom

Salts and dust are being carried from the drained sea bottom into the atmosphere. Current estimates of the quantity of salt and dust being moved varies from 16-264x10^6 tonnes. More likely figures vary from 30-150x10^6 tonnes annually. The increase in the quantity of salts entering the atmosphere influenced the mineral content of atmospheric precipitation, which increased six to seven times in the Aral area.

It should be noted that during the past two decades, the mineral content of precipitation also increased at locations some distance from the Aral Sea. In many cases, this increase apparently resulted from the greater removal of salts from local sources, particularly from man-made marches in the outlying areas, and from irrigated lands. Delineation of the ratio between Aral Sea sources and local sources of salt entering the atmosphere needs special attention.

CHAPTER VI

THE NATURAL ENVIRONMENT OF THE ARAL SEA AND CHANGES IN ITS AQUATIC ECOLOGY

Aquatic Ecology Prior to 1960

Before 1960, the Aral Sea was characterized by a low biological diversity. There were 20 species of fish, 195 species of invertebrates, 71 species of parasites, 12 species of higher plants, and 82 species of other plants. There is no scientific consensus on the exact number of species found in different communities, but it is estimated that between 24 and 36 zooplankton species existed, with 50 to 95 zoobenthos species and 26 to 32 phytobenthos species. However, the low numbers of species probably reflects the fact that many scientists did not include species in the communities at the mouths of the Amu Darya and Syr Darya. The biota of these communities is traditionally considered as being alien to the Aral Sea, even though it occupied considerable areas in the southern coastal zone.

The dominant phytoplankton species were diatoms, dinoflagellates and blue-green algae. Only diatoms formed large populations in the open part of the Aral Sea. The leading species of diatoms was Actibicilus ehrenbergii var. crassa. In some cases, its density was more than 10^6 kl/l. Phytoplankton biomass varied from 0.5 to 2.6 gr/m^3.

Phytobenthos included mostly seaweed, Zostera nana in particular. Vaucheria dichotoma, Cladoforgracilis species, Polysiphonia violacea, and Tolipella aralica also were present. The highest biomass recorded for Zostera nana was 90 g/m^2. The highest biomass for T. aralica was 95 g/m^2, while V. dichotoma reached 53 g/m^2. In general, Zostera nana dominated the biomass (75%).

Because of the high transparency of the water and shallow average depth, 90% of the total plant biomass was phytobenthos. In this respect, the Aral Sea is different from other aquatic ecosystems.

Zooplankton consisted of Rotifera, Cladocera, Copepoda, and insect larvae. Its density was low, possible due to food scarcity. The average zooplankton count in the open water was approximately 10,000/m^3. The biomass was 150 mg/m^2. During summer, 70 to 98% of the total biomass was Arctodiaptomus salinus.

Zoobenthos included Bivalvia, Gastropoda, Oligochaeta, Crustacea and larvae of insects. The average biomass was 23 g/m², evenly distributed. In fact, only one community existed in the bottom sediments. It changed only in response to changes in the composition of the bottom sediments. Dreissena comprised more than 80% of the benthic biomass in areas of grey silt (all Mollusca - 63% and larvae of insecta - 33%).

Carp predominated among fishes (bream, sazan, caspian roach and others), but there also were three species of perch (pike-perch, perch and ruff). There also was one species each of sturgeon, salmon, sheat-fish and pike. The annual catch before 1960 was 44,000 tonnes.

Changes in Aquatic Ecology Since 1960

Physical Factors Causing Changes in Aquatic Communities

The negative human influence on the ecosystem of the Aral Sea became evident at the beginning of the 1960's. Four factors were important, specifically a higher salinity, a drop in the water level, the introduction of new species, and changes in the input of biogenic substances to the lake. This last factor affected phytoplankton and phytobenthos (unfortunately, higher plants were not examined during the period in which the Aral Sea was drying). Apparently, phytoplankton and phytobenthos were quickly replaced by marine and euryhaline species. In the mid-1970's, when the average salinity surpassed 14 g/l, the biomass and the density of phytoplankton decreased three- to five-fold, and diatoms began to become dominant. Data on phytoplankton in the mid-1980's are very limited. However, in 1989, near Barsakelmes Island, the density of phytoplankton was 5×10^6 kl/l. Diatoms predominated (25 species). However, blue-green algae, mostly Gleocapsa vacuolata) had a higher biomass. The increase in transparency of the water that accompanied the desiccation of the Aral Sea was associated with changes in phytoplankton, probably decreased plankton density. Some research conducted in 1989 showed a large quantity of bacteria and heterotrophic organisms in the water. At that time, oxygen saturation was 55 to 76%. Primary production and respiration were equal (0.5 mg O_2/1.24 h), at least at the beginning. Hallophilic heterotrophic bacteria were widely represented. Of 52 phytoplankton taxons, half were diatoms. However, the biomass was dominated by blue-green algae.

Changes in the phytoplankton community reflected not only changes in salinity, but also changes in the concentration of biogenes. Therefore, when the inflow decreased considerably, the influence of biogenes on the phytoplankton also decreased. An acute change of this sort occurred in 1987.

The lower water level also had a negative effect on the phytobenthos. Rapid drying of shallow areas and the disappearance of the Amu Darya and Syr Darya deltas caused a mass destruction of angiosperms and other macrophyte species. Cane plants vanished completely in a rather short period of time. The

area covered by T. aralica decreased greatly. At present, only one macrophyte remains, Zostera nana.

Changes in the ratio of bottom plants in the euphotic zone following the decrease in the water level also affected the nature of the phytobenthos. Originally, the sand bottom changed to silt at a depth of ten meters, stretching along the eastern, southern, and northern coasts. Presently, after more than a 13-meter drop in the water level, the silty bottom reaches almost up to the water's edge.

The silty, silty-sand and sand-silty bottom now comprises 100% of the area covered by water. Before the water level of the Aral Sea began to recede, this type of bottom comprised 66% of the water-covered area. Only Vaucheria dichotoma and bottom diatoms flourish now.

The decrease in the size of the Aral Sea caused by the drop in its water level has leveled and smoothed the coastline and resulted in the disappearance of several bays. Many shallow bays exist now as isolated, separate waterbodies. As their salinity was, and is, higher than that of the Aral Sea, it would be very useful to study them with regard to the effects caused by the increasing salinity of the Aral Sea itself. Monitoring of these bays indicates similar conditions may emerge in the Aral Sea itself in 5 to 15 years. Their current production and microbiological processes are much different from those in the open waters of the Aral Sea. For example, in slightly-mesotrophic Butakov Bay, now separated from the Aral Sea, primary phytoplankton primary productivity has increased to 0.3 to 0.6 $g/m^2.22$ h. Its value is 20 to 25% higher than that observed in the open waters of the Aral Sea. Its biomass varies from 1.15 to 1.45 10^6 kl/ml. The quantity of heterotrophic bacteria has reached 650 kl/ml. It has been proved that halophilic microorganisms are better adapted to the higher salinity in this bay.

Introduction of Non-Native Species

Initial changes were brought about by the introduction of new species of organisms (acclimatization). Before 1954, only fish had been introduced, which resulted in considerably higher predatory pressure by fish on the phytoplankton and zoobenthos. Some types of invertebrates were actually exterminated by the fish. After 1954, invertebrates were introduced. This event drastically altered the zooplankton composition. Calanipeda aquaedulcia was introduced from 1966 to 1970. By 1972, it had spread throughout the lake, becoming the dominant zooplankton.

The previously dominant zooplankton, A. salinus, has not been found in the Aral Sea since 1973. Additionally, as a result of the introduction of the benthic organisms, new types of planktonic larvae appeared in the zooplankton. The introduction of planktivorous fish may be the reason for a decrease in the average biomass of zooplankton. Between 1959 and 1966, plankton biomass did not exceed 15 mg/m. The large species of zooplankton, A. salinus, Moina mongolica and C. reticulata, were quickly eaten. Subsequently, the zooplankton population of the Aral Sea consisted only of taxa with small-sized individuals.

Introduced species also changed the composition of the benthofauna. Two types of shrimp were introduced between 1954 and 1956. In 1957, only one type, Palaemon elegans, was detected. In 1958 to 1960, four mysids were introduced. Three became successfully established (Paramysis lacustris, P. intermedia, and P. ullish) in the lake. Between 1960 to 1963, Nereis diversicolor and Abra ovata were introduced. Nereis became established in 1963, and Abra in 1967. In 1976, a small crab (Rhitropanopeus harrisii tridentata, was identified in the lake. Its larval forms may have been brought in with other introduced species. Between 1987 and 1988, an attempt was made to introduce the Mediterranean mollusc, Mytilus galloprovincialis. This attempt failed because the bottom sediments were unsuitable for this mollusc.

Introduced benthic-feeding fish and benthic invertebrates interacted with the original benthic fauna, reducing the benthic biomass to one-third of its original value. In 1966 and 1967, the zoobenthos biomass did not exceed 9 g/m^2. Not until 1970, after a considerable reduction of the benthic-feeding fish population, did the biomass reach values corresponding to waterbodies of this type.

As previously noted, beginning in 1964, the biomass of Dikerogammarus decreased at a rapid rate. The species has not been detected in the lake since 1973. D. aralensis disappeared from the lake because of biotic, rather than abiotic factors. The species was preyed upon by fish, and its place subsequently taken by introduced species.

Since 1927, 18 fish species have been introduced. Fifteen of the species have survived. Between 1927 to 1934, and 1948 to 1963, sturgeon was introduced. It has been found in fish catches since 1957. Between 1954 to 1965, two types of grey mullet were introduced. However, they did not become established in the lake. Together with the grey mullet, six types of bullhead were introduced. Atherina and Belone belone were introduced by accident, and subsequently flourished. Atherina and three types of bullheads were detected in great numbers in 1958 and 1959.

Because of artificial introduction, plaice and black amur have appeared in the Aral Sea. Black amur snakehead have been found both in river deltas and the rivers themselves.

Two types of parasites, Polypodium hydriforme and Nitzchia aturionis, were introduced coincident with the sturgeon. The Polypodium parasitized the sturgeon's ovaries, while the Nitzchia parasitized its gills. The parasites then switched from the sturgeon to Acipenser nudiventris. Despite a considerable increase in diversity, the composition of fish suitable for sale did not change greatly, nor did the annual volume of catch increase.

Effects of Increasing Salinity

Considerable changes in the fauna followed the decrease in the size of the Aral Sea and the increase in its salinity. The first signs of the impacts of salinity on the zooplankton appeared in 1971, when the average salinity exceeded 14%. Almost all of the freshwater and moderately halophilic plankton died. However, euryhaline zooplankton species survived and reached high densities. The average zooplankton biomass gradually increased from 22 mg/m^3 in 1969, to 123 mg/m^3 in 1981. This growth of zooplankton biomass resulted from two factors. First, favorable conditions developed for the introduced C. aquaedulcis, which comprised 30 to 70% of the total zooplankton mass. Second, the food requirements of planktivorous fish decreased. When the salinity exceeded 23%, the abundance and diversity of the zooplankton was drastically reduced. In 1989, the average biomass of the zooplankton varied from 19 to 535 mg/m^3 in the Big Sea. C. aquaedulcis produced 85 to 95% of the population and 96 to 97% of the zooplankton biomass.

The first signs of the salinity impacts on the zoobenthos became noticeable immediately after the initial salinity increase. In 1963, irregularities in the distribution of the zoobenthos were noticed, and communities began to be dominated by euryhaline species which had initially flourished only in coastal bays. This population shift was most noticeable in the shallow waters of the eastern coast, where there was an immediate reaction to the change in the salinity.

Beginning in 1971, when the salinity reached 12%, other changes in the composition of zoobenthos species were detected. Oligochaetes and insect larvae became the first victims of the increased salinity. Only euryhaline species of Mediterranean and Atlantic origin, and species originating from the inland salt lakes, survived when the salinity reached 12 to 14%.

Between 1969 to 1988, the average zoobenthos biomass gradually increased from 117 g/m^2 to 184 g/m^2. The apparent reason for this increase was the corresponding increase in zooplankton biomass (i.e., the existence of favorable conditions for the development and reproduction of Abra ovata and other benthic forms, along with the decreased food requirements of the benthic-eating fish). In the late 1980's, when the average salinity exceeded 23%, the quantity and diversity of ostracods (and probably other small invertebrates) decreased significantly. In 1987 and 1988, only Cyprideis torosa remained in the Aral Sea. At present, the measured zoobenthos biomass is 274 g/m^2 in the Small Sea, and 108 g/m^2 in the Big Sea. The molluscs A. ovata and Cerastoderma istmicum are prevalent.

Despite the worsening conditions, the 1950's and 1960's saw a gradual increase in diversity, as indicated by the Shannon diversity index. However, as there were no sufficient or exact data on the abundance of certain forms of zoobenthos, the index

value was determined on the basis of biomass data. The index reached its maximum in 1968, and then began to decline.

The mid-1960's saw the first negative effects of higher salinity on fish, when the salinity exceeded 14 o/oo in the spawning areas of local fish. The impact was compounded by a drop in the water level, such that the area suitable for spawning decreased by three to five times in the late 1960's. Fish also were affected in the 1960's by the construction of weirs and dams in the flood plains of the Syr Darya and Amu Darya. One dam near Kzil-Orda alone reduced the spawning territory of Acipenser nudiventris by 90%, and that of barbel by 80%. The total impact of introduced species, dam construction, increased salinity and lower water level reduced the overall annual fish catch to 175,00 centners (17,500,000 kilograms). Between 1960 to 1970, the annual catch was reduced to one-third of its previous level.

The adverse effects of salinity on mature fish first became evident in 1971. Growth norms for many fishes declined, the mortality rate increased quickly, the population numbers decreased rapidly, and many morphological aberrations appeared. From the mid-1970's, the natural reproduction of most fish ceased. Juvenile specimens of fish practically vanished in the second half of the 1970's. In the 1980's, fishing was no longer practiced. All types of fish, not just local forms, nearly disappeared from the Aral Sea. Isolated adult fish could be found only near the mouths of the Amu Darya and Syr Darya. At present, only a small number of fish remain (atherina, five surviving types of plaice, bullhead, three-spined stickleback, and sprat).

Summary of Impacts on Ecological Structure of Aral Sea

In summary, the ecological structure of the Aral Sea has recently gone through at least two main cataclysms. The first was the result of the introduced species, and the second was the result of increased salinity. The biological changes brought about by increased salinity were of a non-linear character, in that some specific critical periods of mass mortality are distinguishable. In the period between the crises, there was relative stability. The first crisis took place between 1971 to 1975, when the salinity was 12 to 14 o/oo. During this period, most species of freshwater and saltwater origin disappeared. In 1987 to 1988, when salinity reached 22 to 28 o/oo, the second crisis occurred. Biota died out on a mass scale.

Thus, four probable stages of change can be distinguished for the Aral Sea, as follows:

(1). When its salinity was 7 to 11 o/oo, and the biota was mainly of freshwater origin;
(2). When the salinity was between the 7 to 11 and 22 to 28 o/oo range, and the biota was euryhaline;
(3). When the salinity was between the 22 to 28 and the 36 to 42 o/oo range, and the biota was of marine origin; and
(4). When the salinity was greater than 36 to 42 o/oo, and the biota originated from continental salt lakes.

The duration of these four stages is determined by the salinity corresponding values, which makes the search for possible surviving species easier. However, it is necessary to emphasize that any future introduction of species into the Aral Sea should be implemented only after intensive ecological and physiological research.

Finally, attention again is drawn to a point made previously in regard to conservation values; namely, the great decrease in the conservation value of the Aral Sea following the decline in its water level, and the increase in its salinity. To a considerable degree, the factors involved here are the destruction of the islands in the southeast portion of the lake, the degradation of deltas and, of course, the effect of salinity on food organisms and the ecosystem as a whole.

CHAPTER VII

POLLUTION OF THE ENVIRONMENT OF THE ARAL BASIN

Industrial Pollution

Industry is the cause of significant atmospheric pollution in the Aral Sea drainage basin. The highest air pollution emissions in the region have been observed in the Tashkent region (50,000 t/yr), which produces approximately 56 tonnes of pollution per square kilometer. This is twice the level of air pollution measured in the overcrowded Moscow region. Air pollution values in the Fergana area also are close to those in Tashkent. The noxious gas level in the Tashkent region, the Fergana valley, and the Zarafshin oasis exceed the maximum permissible concentration (MPC) by a factor of 1.5 to 6. A similar situation exists in other industrial regions in the Aral Sea basin.

This situation is caused by the national distribution of productive forces. During former five-year periods, investment in funds for environmental protection was implemented on the basis of a "residual" principle. During the XIIth five-year period, the Uzbek SSR spent less than one-third of all its environmental protection funds on measures to protect its basin's air quality. This capital investment represented only 0.25% of all capital expenditures, compared to an overall expenditure of 1.62% in the former USSR, and 3% to 3.5% in developed countries (Belgium, Denmark, Japan, USA). Further, the rate of emission reduction in the Uzbek SSR is four times lower than in the former USSR (1.5% compared to 6%).

Pollution of surface water resources with industrial wastes occurs in all the Aral regions (Table 22). Oil wastes discharged into the Kargilansai in the Fergana region exceed the MPC for oil by dozen of times. The concentration of oil products in wastes from the Kuvasai cement enterprise exceeds the MPC by 34 times. Wastes discharged into the Amu Darya, Syr Darya, Ak Darya, Zarafshan, Isfarimsai, Karasu and Sylar contain a variety of harmful substances at concentrations much larger than the MPC for these substances.

None of the 33 waste-purification plants controlled in 1989 operated efficiently. They were overloaded, poorly maintained, and poorly operated. Further, they were put into operation, even though containing significant defects.

Industrial wastes discharged into surface receiving waters severely affect water ecosystems. Wastes from oil processing, chemical, heavy industry, and non-ferrous metallurgy production, and from enterprises producing mineral fertilizers, are especially dangerous to the environment.

Table 22.--Discharge of polluted wastes to surface reservoirs from USSR republics

Republic	1985 TOTAL SEWAGE	1985 POLLUTED SEWAGE:	1985 With no treatment	1985 With insufficient treatment	1989 TOTAL SEWAGE	1989 POLLUTED SEWAGE:	1989 With no treatment	1989 With insufficient treatment
	($x10^6$ m^3)							
USSR	155853	15929	6850	9079	153453	32649	10305	22344
Uzbek SSR	25801	411	76	335	21234	264	207	57
Kazakh SSR	6768	280	49	231	7470	339	55	284
Kirghiz SSR	673	12	6	6	1042	40	10	30
Tadzhik SSR	6153	60	11	49	4194	110	10	100
Turkmen SSR	4299	0.9	0.9	0	3256	-	-	-

Agricultural Pollution

Agricultural activities, as well as industrial enterprises, create pollution. Most agricultural pollution occurs as a result of improper use of pesticides and fertilizers, and because of technically-deficient cattle-breeding farms.

A significant quantity of fertilizers and herbicides are applied to irrigated lands being used for monoculture. For example, fertilizers applied to irrigated lands of Central Asia exceed the all-Union level by a factor of 10 to 15. Even in the 1970's, 44,000 tonnes of organochlorides, 6,000 tonnes of organophosphates, and 15.4 tonnes of other chemicals were used in the Uzbek SSR alone. Before 1982, the organochloride DDT was widely used, and frequently applied to the land.

In the Central Asian republics, the insecticide preparations used most often include Phasalon, Sevin, Chlorophos, Antio, Keltan, Thiosan, Nitrophen, Carbophos and others. Popular herbicides include Katoran, Prometrian, Propanid, Propasin, Simasin, and others. Currently, up to 54 kg/ha of various herbicides and defoliants are used in the Aral region, compared to a mean value of approximately 3 kg/ha in the former USSR.

Application of pesticides by airplanes causes air pollution. It also leads to direct contact with humans and animals from pesticides in the air. Further, persistent pesticides can easily get into food products or fodder. A significant part of the pesticides is found in main drainage waters. In addition, current hydrometeorological data indicates high DDT concentrations in water in the republic of Uzbek.

Chemical pollution in the Aral region also is a problem. It is estimated 1,112 tonnes of banned pesticides are being kept in storehouses in Uzbek. Unfortunately, no responsible official or authority knows what to do with these stored pesticides.

Serious problems also are being caused by the improper use of mineral fertilizers. The quantity of fertilizers used on irrigated lands in Central Asia is 10 to 15 times larger than the mean values for the former USSR. Numerous scientific studies have indicated that plants absorb nutrients in the ratio of 50 to 70 for nitrogen, 7 to 15 for phosphorus, and 30 to 50 for potassium. The remaining nutrients in the applied fertilizers are not assimilated, and may be both highly soluble and mobile. They frequently are washed into open surface waters and ground waters.

Many fertilizers and pesticides also contain microelements in large quantities. Therefore, the content of these elements has increased by two- to twelve-fold in agricultural drainage waters.

The possible use of industrial and municipal sewage sediments as fertilizers in the republic is limited by the danger of possible soil contamination with heavy metals. The heavy metal content in soils and sediments must be strictly controlled. With a higher level of sewage treatment, the amount of heavy metals in sewage and sediments can be reduced.

Unfortunately, the situation is aggravated by a lack of sufficient numbers of storehouses for fertilizers and pesticides. For example, the Uzbek republic has only 37.8% of the needed storage facilities.

A high level of contamination also is caused by liquid waste from cattle-breeding farms. Only 30% of the region's agricultural facilities have manure depositories. In Uzbekistan, only 28% of the 20,000,000 m^3 of waste formed annually at cattle-breeding farms is directed to treatment plants. Further, these plants may not provide adequate treatment of these wastes, because of technical imperfections and an inability to handle large volumes of waste.

Discharge of drainage and sewage waters to rivers causes a serious negative impact on the quality of the environment and on human health. There presently are 10 canals along the Amu Darya, which withdraw the river water at a rate of 180 to 300 m^3/sec. There currently are 39 large, operating intake points on the left bank, and 50 on the right bank, of the Amu Darya. At the same time, however, the Amu Darya has become a sewer. Originating as pure water from the Karshin Steppe, the river subsequently receives discharges of polluted, mineralized waters from the Chardzhou, Burkhara and Tashauz areas, as well as from lower reaches of the river. These discharges to the river are made without regard to the welfare of the more than 700,000 rural people who live in the lower reaches of the river, and who drink water directly from the river and its canals. The total runoff of strongly-mineralized drainage waters discharged into the Amu Darya from these territories totaled 3.77 km^3 in 1988, equivalent to 11,900,000 tonnes of salts in the drainage water. In 1989, the runoff of drainage water decreased to 1.7 km^3, because of drought conditions. However, its salt content was higher. Therefore, the quality of the Amu Darya has continuously deteriorated. More than 12 km^3 of drainage waters, with a salt content of up to 10 g/l, were discharged into the upper and middle reaches of the Syr Darya river bed alone.

Atmospheric Pollution

Single, maximum concentrations of pollutants in industrial emissions have exceeded the permissible levels by the following factors:

(1). Carbon monoxide in Fergana and Samarkand by 7 to 8 times;
(2). Fluorhydric in Almalyk by 9 times; and
(3). Ammonia in Chirchik by 24 to 30 times.

The cities of the Aral region on the list of former USSR cities with the most polluted air are identified in Table 23. Natural conditions and agricultural production produce the high dust content in the atmosphere, approximating 110 to 120 mmg/m^3, and with strong winds, up to 2000 mmg/m^3.

Soil Contamination

Use of pesticides and fertilizers leads to soil contamination. Thus far, only limited testing has been done to determine the extent of contamination in the Aral basin. The research that has been conducted showed the DDT content of the soil exceeded the standard in many regions. For example, in Kirghizin, DDT soil concentrations exceeded the MPC by a

Table 23.--Cities of the Aral Sea drainage basin with the greatest atmospheric pollution in 1988.

City	Substances defining high pollution level	MPC Excesses: Mean-annual	Maximum
Chimkent	dust	3	14
Osh	dust	6 - 7	
	benzopyrene	14 - 16	
Dushanbe	dust	4 - 5	17
	formaldehyde	2 - 4	
	benzopyrene	9	
	carbon monoxide		6
	nitrogen dioxide		10
Ordzhonikidzeabad	dust	4 - 5	
	carbon monoxide	2 - 4	
Nulyab	dust	4 - 5	10
Kurgan-Tiube	dust	4 - 5	15
	ammonia	2 - 4	
Ashkabad	dust	3	10 - 11
Chardzhou	dust	3	10 - 11
	hydrogen fluoride	2 - 3	
	benzopyrene	5	
Mary	dust	3	14
	nitrogen dioxide	2 - 3	
	benzopyrene	5	
Tashauz	dust	3	
	benzopyrene	5	
Bezmein	dust	9	15
Fergana	phenol	2 - 3	6
	ammonia	2 - 3	
	formaldehyde	8	
	carbon monoxide		7
	nitrogen dioxide		8 - 10
Almalyk	dust	2 - 3	
	ammonia	2 - 3	9
	hydrogen fluoride	3 - 4	

/...Continued

Table 23.--Cities of the Aral Sea drainage basin with the greatest atmospheric pollution in 1988 (Continued)

City	Substances defining high pollution level	MPC Excesses: Mean-annual	Maximum
Namangan	dust	2 - 3	
Andizhan	ammonia		18
Navoi	dust	2 - 3	
Samarkand	dust	2 - 3	10 - 16
	carbon monoxide		7
Marzhlan	sulfur dioxide	2 - 3	
	nitrogen dioxide	2 - 3	
	benzopyrene	14	
Urgench	sulfur dioxide	2 - 3	
Narimanov	ammonia	2 - 3	
Andizhan	dust		10 - 16
	ammonia	2 - 3	
	formaldehyde	8	
Chirchik	ammonia	2 - 3	
Kokand	hydrogen fluoride	3 - 4	
Termez	dust		10 - 16
Nukus	dust		10 - 16
Tashkent	carbon monoxide		8 - 10
	nitrogen dioxide		6
Bukhara	phenol		6

factor of two to nine in vegetable-growing areas, and by a factor of 33 to 46 in cereal-growing areas. In Uzbekistan, soils in cotton-growing areas exceeded the MPC by a factor of 31 to 86.

It also should be pointed out that 10 to 15% of the DDT content in the soil will appear later in the agricultural products themselves. In soils with DDT concentrations at levels of 20 to 90 MPC, the DDT concentrations in alfalfa, fodder root-crops, onions and corn amount to 3 to 12 of the MPC.

In a study limited to Uzbekistan, a magnesium chlorate defoliant was observed on 4.9% of the surveyed territory in the spring time. By the autumn, 58% of the territory contained the defoliant. The defoliant concentrations exceeded the MPC by a factor of 19 in gardens, and by a factor of 53 in soils with cotton crops.

A selective survey of soils around cities showed the lead content exceeded the MPC near Chimkent. Further, the fluoride content near Samarkand (where phosphate fertilizers are produced) exceeded the MPC by a factor of two to four.

Water Pollution

Excess concentrations of pesticides in river waters, especially synthetic pesticides used by humans that are banned in the former USSR (e.g., DDT and hexochlorobenzene) are especially alarming. Organochloride pesticides are found in practically all the region's rivers. At the Char Darya sampling station on the Syr Darya, these indices have reached values of ten times the MPC, and show indications of increasing over time. Furthermore, the study of basic regularities of water resource pollution is entirely deficient. Nevertheless, it is noted that excessive doses of fertilizers, and their adverse methods of application to the land, have lead to water pollution with biogenic elements.

An additional pollutant is salt itself. In almost all irrigated areas of the world, irrigation leads to salinization of land and waters, unless careful management is undertaken. Without such careful management, both land and water resources may be irreparably damaged. Evidence of this process is already at hand in the Aral Sea basin. As a result of the discharge of drainage runoff, the mean annual mineralization of the Amu Darya within the Karakalpakian Republic has increased over time. Its total salt content was 456 mg/l in 1912 (Tsinzerling, 1927), 471 mg/l in 1957, 741 mg/l in 1968, 1,411 mg/l in 1983, 913 mg/l in 1985, 1,360 mg/l in 1986, and 1,518 mg/l in 1989. A similar increase was observed on the Syr Darya. In its lower reaches, at the Karalinsk sampling station, the mineral content of Syr Darya water was 543 mg/l from 1911 to 1960; 1,055 mg/l during 1961 to 1970; 1,312 from 1971 to 1980; and 1,844 mg/l in 1981 to 1985.

The increase in river water salt concentrations was accompanied by a change in its ionic composition. For example, the relative content of carbonates in the Syr Darya has decreased four times, which was balanced by an increase in its chloride and sulfate content.

The quality of drinking water has become worse, because a considerable portion of the water supply of rural populations comes from surface waters in the region. For example, the mineral content of running waters in practically all the large settlements of Karakalpakia exceeded the MPC by a factor of 1.2 to 1.7.

CHAPTER VIII

STATE OF HUMAN HEALTH IN ARAL SEA DRAINAGE BASIN

Human Health in the Aral Sea Drainage Basin

This section is devoted to available data characterizing people's health and possible environmental causative factors. It provides a preliminary analysis of possible connections between observed human pathology and peculiarities of the ecologic and socioeconomic situation in the Aral region. The materials below are based on official documents of local health services, scientific publications, reports from scientific institutions, and other data from the literature.

The ecologic, socioeconomic, and sanitary-epidemiological situation in the Aral region has become extremely dangerous for humans in recent times. The Aral Sea basin may even be considered "a region of ecological calamity". This statement is based on a complex analysis of current health service data regarding the living conditions and state of health of the population.

A comprehensive analysis of the state of the health of the Aral Basin population indicates it is characterized by a high level of intestinal infectious diseases, and an increasing number of difficult pathologies (intestinal disorders, oncologic, cardiovascular, blood-formation organs, and respiratory system). Pathology associated with pregnancy also is observed. Infant morbidity and mortality is high, and congenital deformation and other genetic diseases have been observed in increasing numbers.

Over the past 15 years, the rate of illness from typhoid (T) in the Kzyl Orda area increased by as much as 29-fold during certain years. Viral hepatitis (VH) increased by as much as sevenfold, and paratyphoid (PT) increased fourfold. During these same years, more than 60,000 people in the region had viral hepatitis, and over 70,000 had acute intestinal diseases. Almost every year, waterborne outbreaks of typhus, paratyphoid and viral hepatitis have been registered in the thirty settlements in the area. Tens of thousands of people were affected by water-related outbreaks of viral hepatitis between 1976 to 1986. The Kzyl Orda region had 40% of the total incidences of viral hepatitis, and 45% of the typhoid cases registered in Turkmenia.

Further, between 1976 to 1980, the mean annual typhoid morbidity index increased by 20%. It should be noted that approximately 75% of those suffering from acute intestinal infections were children. Thirty percent of infantile mortality could be attributed to intestinal infections.

Neither tuberculosis nor natural-source infections (Crimean hemorrhoic fever, Ku-fever, or visceral leishmaniose) decreased in number. Indices of somatic (non-infectious) diseases also increased; the number of people with gastrointestinal tract pathology, as well as diseases of the liver and kidneys, increased threefold. Pathology of the cardiovascular system doubled. The gullet cancer index in the Tashauz region was the highest in Turkmenia.

About 70% of expectant mothers suffered from expressed anemia. Over half of the pregnant women had some extragenital pathology, especially diseases of the kidney and cardiovascular systems. In turn, this pathology affected childbirth, and produced a high morbidity and mortality of new-born infants. In addition, such diseases as rachitis, hypotrophy, and anemia were prevalent among the children. These conditions were caused by a deficient diet, containing insufficient vitamins and irreplaceable amino acids.

The situation in other regions of the Aral Sea basin differed only in intensity. In all the regions, both the incidence and rate of increase of disease cases exceeded those of the Republic or the Union. In Karakalpakia, mortality resulting from acute infections of respiratory organs increased almost threefold between 1981 to 1987. Liver cancer doubled, while gullet cancer increased by 25%. During some years, esophageal cancer increased by up to a factor of two. Forty-three percent of individuals afflicted with esophageal cancer were of working age; of these individuals, 70% died within a year of the diagnosis of the disease. Although cancer is considered to be a disease of old age, the morbidity level among younger people increased by more than twofold over the past five years.

From 1981 to 1987, the number of people afflicted with hypertonia, heart disease, and gastric and duodenal ulcers increased twofold. Similarly, the incidence of gallstones increased by a factor of five, and chronic nephritis increased threefold.

The mortality of infants and mothers was high. Compared to the preceding five years, the past five years were characterized by a tripling of the mortality of mothers. Infant mortality increased from 34.6 per 1000 newborn in 1965 to 52 per 1000 in 1989. In some regions it exceeded 100 deaths per 1000 newborn. The overall rate of infant mortality in Karakalpakia increased by almost 20% between 1980 to 1989.

The incidence of premature birth, congenital hypotrophy, "uterine unripeness" and other deviations attributable to changes in the environmental conditions in the region increased by almost 31%. An analysis of the age structure of infant mortality in the towns of Nukus and Takhiatash exhibited the following increase in neonatal mortality: 22.2%

in 1977, 25.8% in 1980, and 30.0% in 1982. The percent of children in cities who died during the first week of life increased from 15.6% of the total neonatal mortality in 1977 to 43.7% of the total in 1982.

Based on official statistics, 60.1% of the children who died before the age of one year in the cities of Karakalpakia succumbed to respiratory disease. Of this total, 97% died of acute pneumonia. Other causes of infant mortality in the statistics included infections and parasitic diseases (14.5%), inborn anomalies (4.4%), and other reasons (20.1%). However, expert analysis of clinical records indicate pneumonia was over-diagnosed as a cause of infant death, while infections and parasitic diseases were under-diagnosed. There was insufficient registration of certain causes of perinatal death and congenital anomalies. After expert analysis of each death, figures for infant mortality included 26.1% due to diseases of respiratory organs, 30.17% due to infectious-parasitic diseases, 31.0% due to some reasons of perinatal death, 7.6% due to congenital anomalies, and 5.1% due to other causes.

Over the last three years, a decrease in infant mortality was observed (48.7% in 1990). Analysis of the 1989 to 1990 index of infant mortality comparing towns to villages showed rural newborn mortality to have decreased by eight percent, while urban mortality increased by one percent. This situation hardly seems possible, considering the much greater level of medical services available in urban areas.

Results of a dispensary system used in 1988 showed that more than 80% of women of childbearing age in the autonomous republic suffered from anemia, compared to the mean Union level of 25 to 30%. The situation was aggravated by the fact that over 50% of the pregnant women suffered from other (extragenital) diseases. One out of every three women had a miscarriage, and the number of children born with congenital developmental anomalies increased. This situation, together with a high mortality of mothers and infants, is indicative of a worsening state of human health of the region's population.

Statistics for intestinal infections also were significant. Typhoid (T) and viral hepatitis (VH) morbidity indices exceeded the mean Union levels by a factor of 2.5 during some years. The mean typhoid morbidity index for 1977 to 1986 in Karakalpakia exceeded the republic's morbidity level for the same period by a factor of 1.5, and that of the Union by fivefold. In 1981, the corresponding figure was 50 times greater. Typhoid morbidity was high in Karakalpakia every year, and exhibited no definite trends in its dynamics.

Dysentery morbidity levels were much lower in Karkalpakia than in the Uzbek Republic or the former USSR. However, beginning in 1982, a steady increase in the number of disease cases was observed. By 1987, the relative index reached the mean level of the republic.

Morbidity attributable to viral hepatitis in Karakalpakia always exceeded the mean Union level. On some occasions (e.g., 1982), the morbidity level was twice that of the Union level.

The tuberculosis morbidity level almost doubled over the past ten years, and remained more than three times higher than in the Uzbek Republic or the Union. People living in regions of ecological calamity are subjected to this disease more often than the general population. Active forms of tuberculosis were observed an average of two- to threefold more often in the Muynak and Chimbai regions than in Karakalpakia.

An analysis of the total dispensary system used for the Karakalpakian population in 1988 to 1989 indicated that more than 66% of the adults and 61% of the children suffered from various pathologies. These indices were noted to increase very steadily. Morbidity data of G. S. Khadzhibayeva indicated that respiratory organs rank first (32.9%), followed by blood and blood-forming organs (27.7%), nervous system and sense organs (8.3%), infectious and parasitic diseases (4.9%), and diseases of digestive organs, as a cause of death.

Infantile morbidity attributable to viral hepatitis in Karakalpakia doubled (from 5.7 to 12.1%) for seven to ten years. Medical service reports from the Uzbek Republic indicated 8.9% of the total population of children was at risk of infection. The group of sick children represented 1.2% of the total population of children. Thus, only 10.1% of the children in Karakalpakia were unhealthy. At the same time, dispensary materials indicated 45.6% of the total population had been ill.

The same acute situation was observed in the Tashauz region of Turkmenia. For the past decade (1980 to 1989), the population morbidity from acute intestinal infections remained at a high level (355 to 528.2 percent/1000 people). In 1988, the viral hepatitis morbidity in the Tashauz region exceeded the republic level by a factor of two (547.8, compared to 264.3 percent/thousand people), and was one-third greater than the all-Union index (305.4 percent/1000 people). Similarly, throughout the past decade, the absolute figure and the morbidity index exhibited a constant increasing trend. These rates increased from 378.5 in 1980 to 706.6 percent/1000 people in 1989, compared to the former USSR figure of 316.6 percent/1000 people. Peaks of morbidity were manifested during certain years in the decade.

For the last several years, human morbidity not associated with intestinal infections also steadily increased. The indices of human morbidity due to tuberculosis in the Tashauz region (264.0 to 367.0 percent/thousand people) is greater than that of the republic (mean value for Turkmenia is 240.0 percent/thousand people) and of the Union (210.0 percent/thousand people).

Morbidity associated with the formation of new malignancies, both in the region (295.0 to 334.0 percent/1000 people) and the republic (91.2 to 176.0 percent/1000 people), remained steady at a very high level.

Table 24 illustrates the especially-acute nature of social problems in the Aral Sea drainage basin, particularly health service problems.

The level of infant mortality varies over the former USSR. The mortality rate is 49 deaths/1,000 newborn infants in Tadzhikistan, 43 deaths/1000 in Uzbekistan, and 19 deaths/1,000 in the Russian Federation. The infant mortality index is 59.9 in Karakalpakia, 56.4 in all Turkmenia, and 75.2 in the Tashauz region. Further, based on data of the Turkmenian Ministry of Public Health, the Tashauz region had an acute deficiency of physicians (22 per 10,000 people) in 1988, compared to the typically high all-Union ratio of 43.8 per 10,000 people. The Tashauz region also had a deficiency in hospital beds of 93.9 per 10,000 people, compared to the all-Union index of 116.9 per 10,000 people. Summary data of the public health of the Aral basin population also is discouraging. Compared to the 1985 data, the general morbidity in the region in 1989 increased 4.1 times, gastritis by 3.3 times, gallstone disease by tenfold, and bladder stone disease by a factor of six. Anemia occurred in approximately 39.9% of women capable of infant delivery in 1985, compared to 56.3% in 1988. Based on dispensary data ("Aral-89"), 73.6% of the region population suffers from various kinds of disease.

Possible Environmental Factors Affecting Human Health

The situation described in the previous section suggests the population living in the Aral Sea basin is suffering from the pathologies of poverty, aggravated by the effects of environmental degradation. As the available statistics are aggregated over relatively large areas, an analysis of cause-and-effect relationships must, by necessity, be limited to what is known as the "ecological" approach. The following section contains a review of the full range of causative factors known to medical science as being of potential importance in regard to human health in the Aral region. Their relative significance in the Aral Sea basin can only be determined by more appropriate epidemiological studies, linking specific exposures to specific morbidities.

Table 24.-- Comparative public health data for 1988

Indices	USSR	Turkmenia	Tashauz region	Uzbekistan	Kara-kalpakia
Life expectancy at birth (yr)	70	67.7	61.4	68.6	64.8
Mothers' mortality (deaths per 100,000 live births/yr)	47.7	77.1	93.0	--	150.0
Infant mortality (deaths before age one per 1,000 newborn/yr)	24.7	56.4	75.0	46.1	59.9
Virus hepatitis (incidence per 100,000 people/yr)	305.4	264.3	547.8	--	253.2
New malignant formations	--	--	--	295 (1985)	--
(incidence per 100,000 people/yr)	--	--	--	334 (1988)	--
Inborn deformities	--	--	--	301 (1985)	--
(incidence per 100,000 infants/yr	--	--	--	437 (1988)	--

With this approach, one can attempt to ascertain the reasons for the degraded public-health situation in the Aral Sea basin. The population morbidity situation suggests microbial and chemical factors are involved. Microbes define high intestinal infectious morbidity. Their transfer typically is by water, food and usual human contacts. In the case of chemicals, which can cause non-infectious somatic diseases, oncopathology, genetic diseases, and negatively affect the human immune system, their transfer by water, air and food also is possible. Indeed, the observed pathology suggests serious disturbances of the human environment, characterized by high levels of microbial pollution of drinking water, as well as minerals and pesticides in the water, pesticide and salt admixtures in the air, and pesticides in food products. Under unfavorable social and living conditions, reduced food rations also possibly negatively aggravate the situation.

There currently is no doubt that adverse environmental factors in the Aral Sea basin are directly related in some degree to the processes that created the Aral Sea ecological crisis and destabilized the natural environment in the Aral region. A significant factor is the lack of a sustained water supply, water treatment, sewers, sewage treatment, and community health-care facilities. These needs can be corrected independent of actions affecting basin water management.

The considerable increase in water withdrawals in the upper and middle reaches of the Amu Darya and Syr Darya, in conjunction with the increase of irrigated lands, led to a reduction of the river runoff volume. In the 1980's, river water inflow into the Aral Sea was essentially absent for a number of years. Additionally, there was a significant lengthening of the hydrographic (drain) network, an increase in the volume of reverse agricultural sewage waters, an increase in the salt content of water in the main water arteries of the Aral Sea basin, and desiccation of the Aral Sea itself. The Aral Sea water fell from 53 meters in 1960 to 40.3 meters in 1987, and its volume decreased from 1,064 km^3 to 404 km^3. The ground water level was variable, rising by several meters on irrigated lands in a number of regions. This was coupled with an intensive secondary soil salinization. Climate variations included a decrease in the mean annual relative humidity, displacement of the annual pattern of precipitation volumes, an increase in the number of days with dust storms, and increased salt removal from the desiccated sea bottom (from 40,000,000 to 150,000,000 t/yr, according to different sources) accompanied by an increase in the salt content of atmospheric precipitation.

All these phenomena affected the life and health of people in the Aral region. Microbial pollution of surface waters (and possibly food) appear to be associated with poorly-developed sewage systems in the settlements. At the same time, polluted water from the Amu Darya and Syr Darya are a main source of water for the rural population. However, rural communities sometimes must use water from canals, or even aryks, for household and drinking purposes. Therefore, sanitary conditions in the Aral Sea basin are acutely deficient in the ability to provide the necessary quality and quantity of water for household and drinking purposes.

The first deficiency (poor water quality) is associated with the necessarily widespread use of the main water arteries (Syr Darya and Amu Darya) and irrigation canals, as well as brackish and freshened ground waters. The second deficiency (insufficient water supply) arises from the poorly-developed system of centralized water supply and a periodic lack of water from the water sources.

The discharge of highly-mineralized, pesticide-containing, reverse drainage waters from agricultural lands, along with a significant reduction in runoff volume because of surplus water withdrawal for irrigation, are the main reasons for the essential deterioration of water quality. Data from water agencies delineate the process that has occurred over the past 10 to 15 years. The mineral content of the water, reaching two to three g/l or more in the lower reaches of the Syr Darya and Amu Darya, has sharply increased. The total hardness reached 15 to 25 mg-equ/l, the chloride content 450 to 700 mg/l, and the sulfates 700 to 1000 mg/l.

In addition, residual amounts of pesticides, synthetic surface-active substances, phenols, oil products and other anthropogenic substances were present in the water. Pesticides and phenols are the primary contaminants in the Amu Darya. In the middle reaches of the river, concentrations of both are an order of magnitude greater than the MPC. In the lower reaches, concentrations are 1.5 to 2 times greater than the MPC.

Indications of bacterial water pollution are significant, especially in the spring-to-summer period. The intestinal bacillus content of water used for household, drinking and everyday purposes exceeds water standards by tens to hundred of times. Pathogenic microorganisms have been isolated from the river water.

The ecological situation in the lower reaches of the Amu Darya, which is regulated by a reservoir and thereby probably less affected by sewage and reverse waters, is less severe than that in the lower reaches of the Syr Darya. However, water quality is constantly declining with the ever-decreasing runoff volume of the Amu Darya River.

Poor water quality at the water sources inevitably affects the water quality of centralized water lines. The existing water treatment facilities, which utilize settling, coagulation, filtration and chlorination, are unable to insure a sufficient degree of treatment and bacterial purity of the water.

Furthermore, high water turbulence is a cause of frequent failures in the structural integrity of the water delivery network. This leads to secondary infection of the water lines. As a consequence, the quality of the water in the water line network in the Kzyl Orda region does not meet State standards for bacterial indices in 25 to 30% of collected samples. In rural areas, this index increases to 30 to 46%. In Karakalpakia, in the lower reaches of the Amu Darya, this index value sometimes reached 43% for the period between 1981 to 1987. In the Tashauz region, it was 46.8%.

At the same time, centralized water lines supplied by the Syr Darya provide water to people living in the largest settlements in Kzyl Orda (65% of the population). However, water consumption in these settlements is three to four times below the standard 20 to 80 liters per person per day. In the territories on the lower reaches of the river, the drinking water deficit reaches 10 liters per person per day.

Thus, the rural population is obliged to use imported water, as well as desalinized water from brackish ground water sources, both of which sharply restrict water consumption. The impacts of these water sources are not clear. Water wells remain a source of drinking water for four to ten percent of the rural population in various regions.

In the territory of the lower reaches of the Amu Darya (Karakalpakia), a centralized water supply is guaranteed for about 33% of the population, including 59.8% of the urban and eight percent of the rural population. In the spring and summer, over 90% of the rural population in Karakalpakia uses water from the irrigation network. During the winter, the population uses water from wells dug into the dry river bed. Geologic soil conditions, a high water table, and high soil permeability contribute to contamination of the water wells. The wells have a high coliform index, and have been observed to contain pathogenic enterobacteria.

Inter-republic canals and sub-canal lenses of fresh water are used mainly as drinking water sources in the Tashauz region. The salt content of these waters exceeds standards two to three times, while the phenol content exceeds standards by six to 14 times. Nitrates and pesticides also occur in excess amounts. Ninety-eight percent of the region has water with a mineral content greater than 1 g/l, which is above drinking water standards. However, the region has no other water sources.

In addition to serious water-supply deficiencies, there typically is a low level of sanitary services and amenities for settlements in the Aral Sea basin. In Karakalpakia, only three towns are even partially canalized. Nukus is 30% canalized, Takhlatash is 20% canalized, and Kurgrad is 10% canalized. There also are serious problems associated with cleaning the settlements.

Contamination of agricultural products with chemical substances (fertilizers, and more importantly, pesticides) in quantities that greatly exceed the MPC, are especially significant to the environment of the Aral Sea basin. Perennial and extensive development of monoculture agriculture was accompanied by the use of organophosphate and organochloride pesticides. These include such persistent pesticides as DDT, Butyphos, Hexachloran, Lindane and others. Their annual use totals thousands of tons. At present, up to 54 kg/ha of various herbicides, defoliants, etc., are used in Uzbekistan. While DDT use was officially banned in 1983, the ban on Butyphos is more recent. The use of fertilizers exceeds the All-Union levels 10 to 15 times.

Thus, inhabitants in the Aral Sea drainage basin are subjected to pesticide exposure. Pesticides are found in large quantities in water sources, in drinking water, in the air, in food products, and even mother's milk. From 1.3 to 13.5% of water samples taken from open reservoirs in Karakalpakia between 1981 to 1983 contained pesticide residues. Of these samples, over 90% exceeded the MPC values. Data on food samples from Karakalpakia indicate the amount of food products containing pesticides increased from 1.3 to 37.3% (from 2.8 to 32% in milk) between 1979 to 1985. Some samples of cereal, fruits and vegetables also contained pesticides.

Every other sample taken in the Kzyl Orda region contained pesticides. Every seventh sample contained pesticides exceeding the MPC. Pesticides levels exceeding the MPC also were found in each 50th sample of fruit, and each 30th to 50th sample of fodder. Atmospheric pesticides in the rural areas are associated with the treatment of agricultural land and with soil erosion. In cities, atmospheric pesticides are related to activities of cotton-cleaning plants, which pollute the air with pesticide-contaminated dust.

Thus, one can trace a connection between an increase in the level of chemical (pesticides, salts) contamination of the human environment and a change in the region's economy, particularly of land and water use. Social neglect is primarily responsible for the microbial contamination of drinking water.

The pathogenic (harmful) effects of the biological and chemical substances found in the environment require consideration of the connection between population morbidity and the state of the environment. Research in Karakalpakia, undertaken by the Scientific-Research Institute of Epidemiology, USSR Ministry of Public Health (within the framework of integrated studies headed by the Institute of Water Problems, USSR Academy of Science), confirmed the role of water as a factor in the propagation of viral hepatitis, typhoid and dysentery among the population.

Less obvious is the role of water and other factors of the Aral region in noninfectious morbidity. Epidemiological proof of the connection between these factors and the human health of the region is insufficient. Nevertheless, the present level of scientific knowledge about environmental factors and their role in public health indicates a connection between environmental pollution and human health in the Aral region. A high mineral content in drinking waters affects the morbidity of digestive, cardiovascular and urine-secretion system organs, as well as the development of gynecological and pregnancy-related pathology. There is sufficient information on the effects of pesticides on the level of oncological, pulmonary, and hematological morbidity, as well as on inborn deformities and other genetic factors. Exposure to pesticides also has been linked to immune system deficiencies, which contributes to an increase in the level of infectious disease.

Parasitic infections also affect the immune system. The incidence of parasitic diseases, such as ascaridos and himeneleptidos (recorded in scientific literature) in the Central Asian republics, may be one more reason for a reduced level of immunological protection in an organism.

The ability of environmental factors to produce pathological conditions can sharply increase in a population also suffering from protein and vitamin deficiency. If one also considers an inadequate level of medical services, a deficit of hospitals and related qualified personnel, this combination of reasons for the serious health concerns in the Aral Sea basin becomes more evident (Figure 7).

However, the problems of morbidity and health in the Aral Sea population should be considered within a wider spectrum. A chain of developing events is evident here. Related sociopolitical, socioeconomic, personal economies, and ecological phenomena resulted in the worsening of the population's health conditions.

The material in this section defines the nature and direction of additional studies necessary for the formation of concrete proposals to overcome the critical state of health of the Aral region's population. First, a comprehensive analysis of the current state of human health is necessary to specify the dynamics and cause-and-effect relationship of observed trends to increasing morbidity. A more precise formulation of infantile and adult pathology should define the development dynamics and interrelations of various nosological forms, and their relations to different environmental factors. Hygienic and sociohygienic research is needed to consider environmental factors such as water, air and soil, as well as social factors such as living conditions, food, medical services, etc. This research is needed to substantiate the requirements for planning both the short-term and long-term measures directed toward reducing pathological environmental factors, and toward improving the social conditions of the lives of the people of the Aral region. This research perspective was presented to UNEP as a separate sub-project in 1991.

CHAPTER IX

BASIC CAUSES OF THE ARAL SEA CRISIS

Introduction

Considering the environmental and economic history of the Aral Sea region, one can see that its geosystems were in a state of dynamic balance until the 1960's. The main factor causing destabilization of ecological conditions in the Aral Sea basin was the growing anthropogenic impact. Most importantly, new technologies and extensive development of irrigation, and intensive use of chemicals associated with agriculture, significantly affected the region. In contrast, the influence of changing natural factors on the destabilization of the environment was much smaller.

Regional Economic Development Strategy and Distribution of Production Forces

The economic development strategy for the Aral Sea region is fundamental to the resulting environmental and social impacts. It is further suggested that it may be more the manner in which the strategy was pursued, than the strategy itself, that is responsible for the resulting crisis, including its long-term repercussions on the environment, economy and social relations in the region. The strategy for distribution of production inappropriately focused on water-consuming production, with very negative effects, and created a critical ecological situation in the Aral Sea basin.

The strategy itself, designed to develop crop production in Central Asia, required accurate analysis of the effectiveness of this production, especially for irrigation-based agriculture. For years, however, the economic effectiveness of land reclamation in the former USSR was often overestimated. Thus, in calculating economic effectiveness, the fact that the land already was yielding crops and other agricultural products, even before land reclamation efforts, was not considered. This means the economic effectiveness was not calculated in relation to the additionally-yielded crops, but rather in relation to the gross yield of crops on reclaimed lands. Priority supplies of resources, better equipment and fertilizers also were not considered in the calculations. Further, estimation of effectiveness also was distorted somewhat because it was based on cost, rather than additionally-yielded crops.

The widely-held opinion that agriculture in Central Asia is exceptionally effective does not appear to be based on substantive data. For instance, the cost of grain in the RSFSR, WSSR and BSSR is two to three times lower than in Central Asia (Table 25). The cost of vegetables in the RSFSR is the same as in Central Asia, is lower in the Ukraine, and is considerably lower in Belorussia. Further, the production of one centner (one center = 100 kg) of grain in the RSFSR requires 1.1 man-hours of direct-labour expenditure. In Kirghiztan, it requires 1.7 man-hours, in Turkmenia 4.8 man-hours, in Uzbekistan 5.3 man-hours, and in Tadzhikistan 7.4 man-hours.

When discussing the causes of the Aral Sea crisis, it is necessary to analyze the results of the development of cotton growing in detail. One of the main arguments for new, broad land reclamation in Central Asia was the necessity of increasing cotton production. It was thought this increase would provide clothing material for the entire country, and drastically increase the export of cotton and cotton products. Cotton production in the republics of Central Asia and Kazakhstan in the period between 1960 and 1975-80 almost doubled. After these years, however, production declined. How effectively the cotton produced during this period was used is questionable.

Part of the cotton is used for military purposes. With an improving international climate and availability of cotton substitutes, the use of cotton for military purposes can be decreased considerably. This is true of other technical uses as well. According to existing estimates, chemical fibers can be substituted for 30 to 70-80% of the cotton used in this country for technical purposes, and for household goods. In the United States, four to five times less cotton is used for these purposes than in the former USSR.

A considerable quantity of cotton is used for the production of fabrics and clothing, both for consumption and export. At the same time, a comparison of cotton fabric production shows that, in most developed capitalist countries, the annual production of cotton fabrics per person is two times lower than in the former USSR (Table 26). The considerable growth in cotton fabrics production could have been justified only by a considerable growth in cotton export. Unfortunately, between 1965 to 1985, the export of cotton fabrics actually decreased from 272 million tonnes to 163 million tonnes, while the imports grew from 95 million tonnes to 419 million tonnes (Table 27).

The former USSR trade balance in cotton, cotton fabrics, yarn and cotton products is generally very unsatisfactory. The export-import balance in these products was 83.7 million rubles in 1960, but only 79.2 million rubles in 1985, illustrating the worsening of the trade balance (Table 28).

Table 25.--Cost of producing one tonne of agricultural products in 1986.

Republic	Grain C	Grain S	Cotton C	Cotton S	Potatoes C	Potatoes S	Vegetables C	Vegetables S
	(rubles)							
USSR	91	109	580	660	122	162	141	129
RSFSR	95	111	-	-	148	168	161	120
UKSSR	73	80	-	-	113	156	122	116
BSSR	118	128	-	-	82	97	93	81
UzSSR	140	314	550	669	247	303	130	158
TadzhSSR	233	194	624	644	187	184	127	155
TSSR	157	228	650	869	324	963	180	244

(Note: C=collective farms; S=state farms).

Table 26.--Production of cotton fabrics in different countries of the world in 1986.

Countries	Total production (x billion m^2) All fabrics	Total production (x billion m^2) Cotton fabrics incl.	Per person production (m^2) All fabrics	Per person production (m^2) Cotton fabrics incl.
USSR	10.4	7.8	37.4	28
Bulgaria	0.508	0.4	51	39
Hungary	0.389	0.3	38.4	30
GDR	0.776	0.5	45.5	29
CSSR	0.802	0.6	53	40
China	18.152	16.3	16.7	15
Great Britain	0.64	0.3	11	5
France	1.33	0.7	25.4	14
FRG	1.285	0.8	22.2	14
USA	12.43	3.3	51.5	14
Japan	5.63	1.9	46.7	16

Table 27.--Export and import of cotton, cotton fabrics and staple fibers.

Type of product	Exports 1960	Exports 1965	Exports 1985	Imports 1960	Imports 1965	Imports 1985
Cotton fibers ($x10^3$ tonnes)	391	458	659	193	183	187
Cotton fabrics ($x10^6$ meters)	195	272	163	143	95	419
Staple fibers ($x10^3$ tonnes)	-	-	-	56	61	-

Table 28.--USSR trade balance in textile, fabrics and textile products.

Type of product	Exports 1960	Exports 1985	Imports 1960	Imports 1985	Balance 1960	Balance 1985
			($x10^6$ rubles)			
Cotton, cotton fabrics, yarn and products	304	907.2	220.3	828	+83.7	+79.2
Silk fabrics and natural silk wastes	3.5[a]	15.6[b]	37.0	224.3	-33.1	-208.7
Flax fabrics, fibers and flax tow	13.9	18.8	5.4	16.2	+ 8.5	+ 2.6
Wool, woolen fabrics and yarn, carpets	26.8	53.2	198.6	642	-171.8	-588.8
Jute, jute fabrics and jute bags	--	--	12.2	154.5	-12.3	-154.5
Synthetic fabrics and threads	--	--	36.9	216.9	-36.9	-216.9
Clothing, underwear, knitted wear, table and bed linen, headgear, blankets, thread	8.5	18.7	499.8	3896.5	-491.3	-3877.8
TOTAL					-553.2	-4964.9

[a]Including synthetic fabrics
[b]Excluding furs

The balance for other textile products, part of which is made of cotton (clothing, underwear, knitted wear, etc.), became even worse. In 1960, the import of these products into the former USSR exceeded the export by 491 million rubles. In 1985, this figure grew to 3.88 billion rubles. The amount of cotton and cotton fabrics exported from the USSR decreased from 6.1% of the export volume in 1960 to 1.2% in 1985. Clothing and other cotton products dropped from 0.17% of the export volume to 0.026% (Table 29).

This is the principal difference between the USSR and most of the other former socialist countries with approximately-equal production of cotton fabrics per person (Table 26). Exports constituted only 3.9% of cotton fabric production, whereas in other countries it constituted between 10.8 to 32.1% (Table 30). The difference in the export of clothing, knitted wear and underwear is even larger. For example, Hungary produces 28 times less fabric than the USSR, but exports 40 times more clothing. Therefore, special attention should be paid to the structure of the exports from the USSR. In fact, it is necessary to increase the export of the finished products, by improving their quality. At the same time, it is important that export of raw materials, such as cotton fabrics, and especially cotton, be reduced.

The apparent effect of choosing a predominately cotton-based strategy for the economic development of Central Asia, in order to receive hard currency, was partly based on an incorrect forecast of the world cotton market and the price of cotton. Hope for a highly effective export of cotton was not realized, as the world market price for cotton fell from $2.27/kg in 1960 to $1.38/kg in 1985. This represents a 40% decline in price. At the same time, the price of rice also fell, from $435 to $226 per ton. It seems that, instead of extensively increasing the amount of land used for cotton production, more attention should have been paid to its subsequent processing. This would provide a greater economic benefit, and diminish the negative environmental effect. Changes in crop yields of cotton and several other crops between 1961-1987 are illustrated in Table 31.

Introduction of Cotton as the Major Regional Crop

The state of the environment also deteriorated because, in many areas of the Aral Sea basin, cotton was grown in a single-crop system (monoculture). Single-crop agriculture demands the extensive use of mineral fertilizers and herbicides, thereby increasing the possibility of negative environmental impacts. Improper storage and usage of these substances also had negative effects on the environment and human health.

Table 29.--Export of cotton and cotton fabrics, clothing and linen in the total export volume.

Type of product	1960	1985
	($x10^6$ rubles)	
TOTAL VOLUME OF EXPORT	5007.3	72,663.7
COTTON, COTTON FABRICS YARDS AND PRODUCTS	304 *(6.07%)	907.2 (1.2%)
CLOTHING, UNDERWEAR, KNOTTED WEAR, BLANKETS, THREADS	8.5 (6.07%)	18.7 (0.026%)

*indicates type of product as percent of total export volume.

Table 30.--Production of fabrics, export of fabrics and clothing in some socialist countries, 1987.

Country	Production of fabrics ($x10^6$ m^2) Total	Cotton	Export of fabrics Total	Cotton	Percent[1]	10^6 rubles[2]
USSR	11,643	7945	329.3	312	3.9	20.3
Bulgaria	503	358	43.8	38.5	10.8	297.4
Hungary	416	311	129.6	99.9	32.1	806
GDR	763	464	186.5	132	28.4	700
Czechoslovakia	1,041	618	198.8	155	25.1	625

[1]Export of cotton fabrics in percent of their production.
[2]Export of clothing, knitted wear and underwear in million rubles.

Table 31. -- Average annual yield changes (in percent change from previous years)

Crop	Republic	1961-1965[a]	1966-1970	1971-1975	1976-1980	1981-1985	1986	1987
Cotton	Tadjik SSR	4.3	12.0	13.3	0	-3.0	-1.4	-8.5
	Uzbek SSR	7.9	14.6	13.5	3.2	-9.2	-9.0	-5.3
	Turkmen SSR	9.2	34.3	-3.3	-3.0	-4.4	-18.2	14.9
Grains	Tadjik SSR		13.7[b]		51.8	16.7	8.8	-3.1
	Uzbek SSR			13.1[b]	104.2	7.2	-14.4	1.7
	Turkmen SSR			154.5[b]	44.3	8.9	-11.8	-36
Vegetables	Tadjik SSR			102.4[b]	18.7	3.6	6.9	-4.6
	Uzbek SSR			66.7[b]	26.7	4.3	-10.1	2.6
	Turkmen SSR			85.5[b]	13.5	-3.1	-9.7	-12.9

[a]With respect to 1960.
[b]With respect to the average annual yield between 1958 to 1960.

Development of Water-Consuming Rice Cultivation

A vast quantity of water (25,000 to 55,000 m^3/ha) is used for rice growing in Central Asia and Kazakhstan. The productivity of rice grown at the northern border of this area is low. Reducing the land area under rice cultivation by at least 100,000 hectares would free at least 3 km^3 of water annually.

Irrigation systems were designed, built and maintained at a very poor level. This is the leading factor of land reclamation producing negative environmental after-effects. One can determine the following concrete drawbacks to land reclamation.

In some cases, irrigation systems were not ready for actual use in irrigation. In some years, up to 43% of the areas where irrigation canals were built, were not used for irrigation. Further, not all prepared land was irrigated. The low quality of construction, and bad maintenance of irrigation systems, made lands unusable for irrigation. In Uzbekistan and Kazakhstan between 1964 to 1967, the introduction of newly-irrigated land was lower than the withdrawal of land from irrigation. The situation improved somewhat between 1970 to 1975. Even during that period, however, the withdrawal of lands from irrigation equaled 40% of newly-introduced lands in Uzbekistan, 30% in Tadjikistan, and 75% in Kazakhstan.

Irrigation of Unprepared Agricultural Lands

Analysis shows that the real growth of irrigated land in Turkmenistan, and in some periods, in Tadjikistan, was many thousands of hectares higher than the official statistics. This means a large part of the land was irrigated without the necessary preparation. As a result, the lands deteriorated drastically, and productivity on the irrigated lands was very low.

Usage of Low-Productivity Lands and Related Difficulties in Land Reclamation

Extensive growth of land reclamation led to the introduction not only of land relatively good for reclamation, but also of lands where reclamation was difficult. These lands had high soil salinity or degraded soil composition, with unfavorable hydrologic, geomorphologic or other conditions. The irrigation of these soils produced many negative ecological effects, including secondary salinity, and the formation of a large quantity of salt drainage. Adyrs in the Fergana valley is an example of such soil.

It is necessary to withdraw low-production, salinized lands from irrigation. These lands produce the lowest harvest, while at the same time requiring the highest expenditure of water. If even five percent of the land not good for irrigation (about 15,000 m^3/yr) is removed from irrigation, seven km^3 of water will be saved annually. From an ecological and economic point of view, it is quite possible that it will be worthwhile to withdraw an even larger area from irrigation. Approximately 15% of irrigated lands in the Aral Sea basin are in a very unsatisfactory condition. Their withdrawal from irrigation would save approximately 15 to 20 km^3 of water annually, or even more.

It must be stressed that withdrawal of lands from irrigation must follow the solution of the social problems of the population dependent directly or indirectly on the irrigated lands. New working places must be created, people must be retrained or relocated from the most unfavorable places, and people and enterprises should receive compensation for losses connected with the withdrawal of land from irrigation, and changes in the economy. Without these measures, the withdrawal of lands from irrigation will result in many difficulties. Recultivation of lands withdrawn from irrigation should also be considered.

Lack of facilities for combatting infiltration in the canals leads to intensive filtration and loss of water. Over a 16-year period, filtration from the Karakum Canal reached 20.58 km^3 (on average, 1.29 km^3/yr). At its inception, and before the canal filled with silt, filtration reached 1.9 to 2.3 km^3/yr. Water consumption in the main part of the Canal reached 3.3 to 4.1 km^3/yr. The same was true of many other irrigating canals.

At many irrigation systems, the levelling of the land is not satisfactory. As a result, the distribution of irrigation water over the surface of the field is not uniform, requiring additional water supply, increasing irrigational erosion, causing water logging, and making soil conditions very diverse within the same field.

In order to divert ground waters, stabilize their water tables, and desalinate the lands in the Aral Sea region, efficient drainage of the irrigation waters is necessary. According to the Sredahydrovodhoz, depending on the composition of the soil and ground, it is necessary to have the following specific lengths of drains: (A) 120 m/ha for heavy loam and clay; (B) 50 m/ha for medium loam; and (C) 20 m/ha for light loam.

However, in most of the Aral Sea region, the length of the irrigation drainage water collector network is considerably shorter, or is nonexistent. For example, in Turkmenia, secondary salting of the lands is occurring on 400,000 hectares, because of the lack of collector-drainage networks. It is imperative that a irrigation water collector-drainage system be created. It must be done without delay on 280,000 hectares, as these lands will soon be useless. This would involve a collector-drainage network 13,000 kilometers long.

In Uzbekistan, the water table of the ground water is critically high on 1.6 million hectares. It is necessary to set up modern drainage systems on 2 million hectares (i.e., about half of the total irrigated territory). The situation is similar in other republics of the Aral Sea region.

As a result of technologically-inadequate irrigation systems, the poor quality of the irrigation waters, and the use of water at no cost to the user, the accepted norms of irrigation and current water application are far too high. As seen in a comparison of the irrigation norms and actual water use (Table 32), all the republics of the Aral Sea use too much water for irrigation.

Table 32.--Actual specific consumption of water for irrigation purposes and comparison with average-based irrigation norms.

Republic	Average-based irrigation norm (m^3/ha.yr)	Actual specific water application in 1980 (m^3/ha.yr)	(percent of irrigation norm)
Kazach SSR	7721	13704	201
Kirghiz SSR	6061	7402	122
Uzbek SSR	9380	15404	164
Tadjik SSR	9586	15190	158
Turkmen SSR	10536	17635	167

Thus, the major task now is to reconstruct the irrigation systems. For example, the reconstruction of the Yushno-Golodnostepnoi Canal, and the adjacent irrigation systems, made it possible to economize 4,170 m^3 of water per hectare on lands requiring irrigation, compared to the average figures for Uzbekistan. Lower filtration in the canals will make available at least 10 to 20 km^3 of additional water. These are not the only effects of the reconstruction. It will be possible to reduce the soil-flushing norms because of the improved quality of the land, thereby receiving some additional cubic kilometers of water per year. As a result of the reconstruction of irrigation, the productivity of the lands also will improve.

Theoretically, it is possible to increase the efficiency of the irrigation systems. One way is to improve irrigation techniques. The present irrigation techniques are very primitive. For example, in 1977 in the Uzbek Republic, furrow irrigation was used on 89.5% of the irrigated lands, while overhead (spray) irrigation was used only on 1.5% of the lands. There are no systems of permanent control over the humidity of the soil or air, or the conditions of the crops. Automation of irrigation could theoretically increase the coefficient of performance of the irrigation systems up to 25 to 28 km^3/yr.

The reconstruction of the irrigation systems not only will provide additional quantities of fresh water, but also improve the conditions of the land. Consequently, it will enhance their productivity.

The problems is complicated by the fact that currently-accepted irrigation norms are not based on scientifically-sound rationale. The accepted norms do not consider many peculiarities of the soil and agricultural crops. They often are determined with the maximum (in contrast to the most efficient) yields in mind. On the whole, based on the experience on advanced farms, the irrigation norms are excessive. The basis of the calculations of the norms is water-balance and water-heat-balance methodology. This approach only considers the water and physical properties of the soil, but not all the soil properties (Enlarged Norms, 1984). The norms were elaborated without consideration of the possibility of short-term droughts, mineralization, or the composition of irrigating waters.

The main guidebook ("Enlarged Norms") for the irrigation experts in the USSR erroneously distinguishes zones of different natural humidity content. The isolines of the coefficient for natural humidity content, calculated by different authors for different areas, do not agree with each other at the administrative borders.

The most common bioclimatic method for determining the consumption of water is to multiply the evaporation and the mean bioclimatical coefficient for a number of years. However, this method does not consider the variability of these indices over time, or their changes with regard to the sizes and specific locations of the irrigated lands.

All these factors result in the irrigation norms being much higher than necessary. Because consumption exceeds even these badly-elaborated norms, the irrigation results in the useless loss of considerable quantities of water.

Inappropriate Use of Agricultural Drainage Waters

According to various authors, the total water drainage in the Aral Sea region (i.e., the amount of drainage and dump water) ranged from 29 to 46 km^3/yr in the first half of the 1980's. Because of expansion of irrigated areas, the water drainage recently has increased even further, reaching 32 to 47 km^3/yr. Of this total water volume, 22 to 26 km^3 are discharged into rivers, 7 to 12 km^3 into lakes, and 3 to 15 km^3 into deserts. It is noted that all these figures must be qualified, since the existing monitoring system does not permit determination of the exact volume of drainage waters.

The problem of utilizing the drainage water flows must be addressed. On one hand, the drainage flow is a water resource which should be used, because of the scarcity of water in the desert regions. On the other hand, discharging drainage water in the deserts increases soil salinity in some cases. Discharging into the rivers increases the mineralization of river water, as well as the content of toxic substances in the water. Discharging large volumes of irrigation drainage water into rivers has very negative consequences, including deterioration of the quality of the river for drinking water supply, and as an irrigation water source. Higher mineral contents in the irrigation water also requires more water to be supplied to the agricultural fields.

Various ways of utilizing drainage water are being considered, including its discharge into the Aral Sea, establishing a cascade system of irrigation, diluting the water, and discharging it into closed cavities. In many cases, a combined usage of drainage water should be considered. The choice of a specific utilization of the water depends on the volume of the drainage flow in a particular region, the mineral content of the water, its content of toxic substances, the general outflow of salts, the position of the irrigated area in the river basin, the availability of land suitable for irrigation by drainage water, and its energy potential.

Lack of Economic Incentives for Production, Imperfect Economic Mechanisms, and Management Shortcomings

These above-noted factors underlie numerous problems in the former USSR, the republics, and the Aral region. For example, excessive use of water in different spheres of the Aral region economy, particularly in irrigated agriculture, is believed by some analysts to be due largely to the fact water is available at no cost to the user. In addition, the production of healthy (ecologically pure) food has not been encouraged to the present time.

Departmental planning of the economy also played a very unfavorable role in the socioeconomic situation. For an extended period of time, billions of rubles were allocated to the Ministry of Water Economy of the USSR for land improvement. First and foremost, however, the Ministry was concerned with expanding its construction projects, which resulted in an increased scope of irrigation, often without any justifiable need.

Another negative impact resulted from the system of economic planning. The assessment of results in this area was based on the fulfillment of certain intermediate operations, rather than on the final product. For instance, various technological and irrigation operations were planned for cotton production, and money was allocated for their implementation. However, this type of planning system did not encourage the introduction of water-saving technologies, or the selection of agricultural crops requiring little water or fewer technological operations during their growth. Naturally, the same general causes for economic inefficiency in the Aral region are common to the whole of the former Soviet Union.

Finally, many problems of the region are caused by management shortcomings. Within the Aral region, there are Basin Departments managing water economy and trying to regulate water usage in each river basin. However, these departments do not have any effective mechanisms for exerting pressure on those who violate water use plans and agreements.

Inadequate Monitoring of the Environment, Population and Economy

Another problem in the Aral Sea basin is that the water-monitoring system is not well-developed. For example, the existing water monitoring system does not allow precise determination of how much water, and of what quality, is used for irrigation. The present system of land-improvement monitoring made it impossible to obtain reliable data on the conditions of all irrigated soils.

The absence of a system of space monitoring permitted irrigation of so-called "hidden" areas of irrigated land, which were not contained in the statistical accounts. The crop harvests from these territories were supplied to the black market, or used to prove the existence of allegedly high harvests on the irrigated lands included in the official statistics.

Monitoring of the health of the population did not produce reliable, comprehensive data, either because of lack of necessary medical personnel, inadequate health indices, and (or) incomplete coverage of the population. A major task now is to initiate a comprehensive monitoring of the environment and population of the region.

Inadequate Ecological Education

Much of the general population, as well as many managers and politicians in the Aral region (as in many other regions of the former USSR and the world at large), are ecologically illiterate. There are many examples of this ecological illiteracy. For example, many people are unaware of the possible hazardous consequences of using pesticides, and do not have adequate health education. Therefore, another major task is to develop (in a broad sense) ecological education.

Inadequate Research Efforts

The main research shortcoming in the spheres of production forces and use of nature is apparent. Instead of setting an economic target to be achieved after elaboration of alternative methods of increasing food production, providing consumer goods for the population, etc., only one project was chosen for study. The system of research financing enabled scientists to get considerable sums of money from representatives of certain ministries (being monopolists), rather than from independent research foundations. This system gave the ministries and departments the ability to finance research projects which were not contrary to their own interests.

Furthermore, the relatively insufficient funds allocated for science at large did not allow adequate technology or some necessary research. Therefore, it is extremely important to increase financing of independent research, and investigation of alternatives for reaching the final goals, aimed at enhancing the welfare of the population.

CHAPTER X

SUMMARY AND CONCLUSIONS

Degradation of the Natural and Social Environment of the Aral Sea Drainage Basin

The Aral Sea crisis has been associated, directly or indirectly, with a number of negative impacts on the natural environment, human health, and the social structure of the basin population. Specific impacts include:

(1). Significant degradation of the environmental quality, ecosystem structure, and individual components in the Aral Sea drainage basin;
(2). Deterioration of the health of the basin population;
(3). Reduction in the economic efficiency of the basin population, and growth of social tensions; and
(4). Significant desiccation of the Aral Sea itself, including increased salinity of its waters and degradation of the previously-existing ecosystems.

There are many reasons postulated for these problems, including:

(1) Inappropriate choices in the development strategy for the region, including the productive forces; and
(2) Inappropriate choices in the development of agriculture, especially in the design, construction and operation of irrigation systems, and excessive use of chemicals in agricultural activities.

The degree of deterioration of the state of the environment, population and economy is different in various parts of the Aral Sea drainage basin. At present, we can only identify the very general features of this differentiation of impacts. Comparison of the state of nature and the economy in different parts of the Aral Sea basin show the ecological situation to be better in the upper reaches of the river basins of Central Asia than in the lower reaches. Decreased water runoff, and increased environmental pollution and degradation of natural ecosystems, are most pronounced in the Syr Darya and Amu Darya deltas. Social and economic indices have the same general characteristics as the environmental impacts. For example, infant mortality in Kirghiztan and Tadjikistan, located in the upper reaches of river basins in Central Asia, has shown a decreasing trend. In contrast, Uzbekistan and Turkmenistan, located in the middle and lower reaches of the river basins, exhibit an increasing trend in infant mortality. Further, cotton, vegetable and grain crop yields were reduced to a lesser degree, and at a later period, in Kirghiztan and Tadjikistan than in Uzbekistan and

Turkmenistan. Further, specific expenditures using irrigated lands on an irrigation system (CHAKIR) in the middle reaches of the Syr Darya river increased by 47% during 1966-1978. In contrast, they increased by 79-102% in the lower reaches during the same period. As a result, the cost of cotton on CHAKIR increased by a factor of 1.3-1.7 in the middle reach, compared to a factor of 2-3 in the lower reaches.

It is evident that environmental changes in the upper parts of the river basins affects the state of the environment and social sphere in the lower parts of the basins. Thus, one can speak of the existence of cascade natural-social geosystems, whereby changes in the upper links of the systems can fundamentally affect those in the lower links of the systems.

A detailed characterization should be made of the Aral Sea region in the future, differentiating the extent of the critical natural-social systems. The integrity, depth and extent of the irreversibility of changes in the natural environment, social and economic indices, and necessary expenditures on compensational measures should be used as criteria in such a characterization. This characterization would be of great practical value, since it would identify those regions where necessary remedial measures should first be undertaken. It also would enable the fairest distribution of financial, technical, scientific and humanitarian assistance.

Public awareness of the Aral Sea problems also has fundamentally changed. The public did not appear to appreciate the seriousness of the situation several years ago. However, at present, many residents of the region, as well as the scientific community and governing bodies, now understand the situation to varying degrees.

An analysis of the problems of the Aral Sea drainage basin reveals two aspects of the Aral crisis that must be considered:

(1) The necessity to solve social, ecological and economic problems of the Aral region that originated as a result of inappropriate decisions in choosing the strategy of development of productive forces, especially agriculture, as well as unsatisfactory design, construction, and use of irrigation systems; and
(2) Preservation of the Aral Sea itself.

These two aspects clearly are interrelated. Thus, a set of measures of differing urgency and scope should be initiated to find solutions to this environmental and social crisis.

Short-Term Actions

Over the short-term (the immediate future), the priority measures should be aimed at improving the living conditions and health of the basin population. Such measures should include (1) provision of drinking and household water supplies, (2) provision of sewerage systems and treatment facilities, (3) elimination of the direct discharge of pesticides and untreated or saline waters to the rivers, and (4) raising the level of medical services and increasing supplies of quality food products to the basin population.

A wide public campaign also is needed to raise the level of social culture and sanitary-hygienic behavior of the basin population.

Republic, union and international foundations for the rehabilitation of the Aral Sea region should be created. Further, international scientific committees and centers are needed to provide necessary funds, to insure medicine and qualitative food products for the population, to introduce modern technologies, and to improve the level of scientific research.

Mid-Term Actions

Over the mid term (2-10 years), necessary rehabilitative measures include (1) the reconstruction of irrigation and water supply systems, (2) the use of operational wastes, (3) the introduction of new agricultural types, methods and technologies, (4) changes in the structure of agricultural production, and (5) introduction of new forms of economy; if necessary, these new economic forms should include specific and free economic zones.

Long-Term Actions

Over the long term (10-15 years), necessary rehabilitative measures should include (1) changing the strategy of development of economic and productive forces in the Aral Sea region, (2) expanding the number of branches of the basin population's economy, (3) solving demographic problems, and (4) improving the administrative division of the Aral Sea region. It is emphasized that "long term" does not mean the implementation of these measures should wait for a number of years; on the contrary, these measures should be started as soon as possible, and immediately after the necessary scientific substantiation has been realized. The description of these measures as long term is related only to the larger scope of the proposed changes contained therein, the necessary significant capital investments, and the necessity of considerable scientific knowledge and substantiation.

The solution to the problems of the preservation of the Aral Sea itself is vitally and fundamentally related to the solutions to the other problems in the Aral Sea drainage basin.

It is clear that many of the projects currently aimed at rehabilitation of the Aral Sea have no scientific and technical substantiation, are much too large in scope, and have unpredictable ecological and social consequences.

Therefore, after the ecological, social and economic requirements for the rehabilitation of the Aral Sea and its drainage basin have been defined, more realistic measures (which may be less effective in some regards) must be devised. An example would be an increasing river inflow to the Aral Sea resulting from implementation of water-saving measures in the basin. However, this reality does not exclude detailed analysis of other potential rehabilitative measures and their subsequent implementation if deemed scientifically and socially necessary.

It has been noted that strict measured directed to water economy in the basin would allow the liberation of 35-50 km^3 of water per year. Such measures include (1) reconstruction of inadequate irrigation systems, (2) reduction of irrigation standards, (3) removal of low-productivity lands from irrigation, (4) introduction of modern irrigation methods and systems of water management, and (5) decrease of the areas containing the most water-consuming crops. It is suggested this is the minimum quantity of water sufficient to preserve the Aral Sea as an integral productive ecosystem in its present condition.

Identification of the most-acceptable variant of the solution to preservation of the Aral Sea clearly is impossible without (1) a detailed determination of the ecological demands of the Aral Sea, (2) a more precise salt balance equation, (3) prediction of regional climatic variations, and (4) detailed assessment of each proposed project for the rehabilitation of the Aral Sea.

Determination of the social and economic requirements of the Aral Sea should include a wide discussion of the inherent problems, and a comparison of the wishes of the basin population with the necessary funds to develop and implement them.

Nevertheless, at least at the first stage, it is clear that a solution to the problems of the Aral Sea region will require considerable funds and the introduction of modern technology and methodology.

It is noted that the problems of the Aral Sea region are typical for many other regions of the world. Thus, a study of the reasons for the Aral Sea crisis, and subsequent experience with the development and implementation of a satisfactory plan of action may be useful in many parts of the world with similar problems.

Economic Losses Associated with the Demise of the Aral Sea

Assessments of economic losses in the Aral Sea drainage basin resulting from the development of irrigation agriculture, and lowering of the Aral Sea water level, were made by a number of authors. At the same time, it is noted that no comprehensive analysis has yet been done.

The first predictive assessment (Problem..., 1973) of the effects of the activities leading to decreasing Aral Sea water level indicated the gross income of the region may decrease by 15 to 30 million rubles. Even if these figures were doubled in 15 to 20 years, "the gross income would not exceed 30 to 60 million rubles a year." The authors of these forecasts believed that "comparison of these data with the effects of irrigation" show that the economic effects produced by using Syr Darya and Amu Darya waters for irrigation does not compare to the benefits produced by allowing their continued input to the Aral Sea and thereby preserving its modern economic usage. However, such comparisons likely are not correct, mainly because they do not consider the negative secondary effects of irrigation, the costs of agricultural production compared to other regions, and the social and economic aspects of the problem. At the 1980 level, the annual economic losses in the lower part of the Amu Darya alone constituted at least 92.6 million rubles.

The minimum general damages inflicted on the natural environment and economy of the Aral Sea region should be assessed on the basis of the full benefits and costs of the measures taken to eliminate the negative consequences of the Aral crisis. These measures will cost at least 37 billion rubles. It is this latter figure, rather than 30 to 100 million rubles, that should be accepted as the minimum financial assessment of the damage to the Aral region.

Further, it is quite probable that the real loss of the economy of the region, including direct losses from reduced agricultural production, and losses related to the worsened health of the human population and related compensation expenditures, will be even greater over the long term.

APPENDIX 1

Listing of Central Asia and Kazakhstan Activities Focusing on Aral Sea and its Drainage Basin

(1). Aerosols in dry saline lake beds; a US/CIS joint research project (Dale Gilette, G. Golytsyn). Past Activities: "A Joint Soviet-American Experiment for the Study of Asian Desert Dust and its Impact on Local Meteorological conditions and Climate", 20 September 1989. Planned Activities: "US/CIS Cooperative Project on the Geochemical Cycle of Atmospheric Toxics: The sources, transport and deposition of arsenic in the Owens Lake dust plume." Investigator: Dale Gilette, National Oceanic and Atmospheric Administration (NOAA), Environmental Research Laboratories, 325 Broadway, Boulder, Colorado 80303-3328, U.S.A.

(2). US/USSR Conference, "The Aral Sea Crisis: Environmental Issues in Central Asia", 9-13 July 1990. Organized by the Research Institute for Inner Asian Studies, Indiana University, and the School of Environmental Affairs, Bloomington, Indiana 47405. Sponsored by the Soros Foundation and the Rockefeller Family Foundation. Conference Proceedings forthcoming.

(3). Russian meeting, "The Aral Crisis: Causes, Consequences & Ways of Solution.", held in Nukus, 2-5 October 1990 (in "Environment" magazine, symposium identified as "The Aral Crisis: Origins & Solutions").

(4). IGU Critical Zone Study Group, October 1990, Nukus. Organized by Soviet Institute of Geography, under leadership of Nikita Glazovsky and Galina Skasyuk.

(5). Zhu, Zhouping & Raskin, Paul (Stockholm Environment Institute, Boston Center) and Stavisky, Dimitry (Institute of Geography, Soviet Academy of Sciences, "Water Development Strategies for the Aral Sea Region", paper prepared for Seventh World Congress on Water Resources, 12-18 May 1991, Rabat, Morocco.

(6). Aral Sea Environment Exchange, 26-05 25th Road, Astoria, New York 11102, U.S.A., "The Aral Sea Crisis", 17-18 May 1991. Goal was increased media coverage, convened conference on political advocacy, safe drinking water, medical assistance; now focusing on bring safe drinking water to Central Asia. Muecke, Jack Victor, Columbia University Station, Box 250250, New York, New York 10025, U.S.A. Focus: Aral Sea basin, concern with clean drinking water through grass roots initiatives to locate or generate clean drinking water for local inhabitants.

(7). National Academy of Sciences Study exploratory mission to Central Asia (Aral Basin), 14-17 September 1991, Ashkhabad. National Academy of Sciences (NAS) and Academy of Sciences of the Turkmen, SSR. Cooperative program with NAS of the U.S.A. and organizations in Turkmenistan, Uzbekistan, Kazakhstan, Kirghiztan, Tadjikistan, Azerbaidzhan, and Russian Federation.

(8). Colorado Amudarya Rivers Project (CARP), U.S. Fish & Wildlife Service, 5-17 October 1991. Project coordinators: Zonn, Igor (Russian Federation) and Glantz, Michael (National Center for Atmospheric Research, Boulder, Colorado, U.S.A. This activity is covered under USA-USSR bilateral agreement, Area V, Protection of Nature and the Organization of Reserves; project is a joint comparative assessment of the problems and prospects of water resources use and development in the basins of the Colorado River and the Amudarya River/Aral Sea.

(9). "GIF's Aral Sea Project: Organizing for Success", Feller, Gordon (president), 14 October 1991, Atlanta, Georgia, U.S.A., First International Congress of Global Infrastructure Foundation (GIF).

(10). "The Problem of the Aral Sea in the Light of New Geopolitical Policy", Zonn, Igor S., GIF meeting, Ankara, Turkey. Prepared for Second International Planning Meeting, Global Insfrastructure Foundation (GIF), 21-14 May 1992, Istanbul, Turkey.

(11). "Central Asia in Transition" or "Understanding Central Asia of the Future", Center on East-West Trade Workshop, Investment and Communications, Duke University. Sponsored by Title VIII Program of Soviet-East European Research & Training Act of 1983, U.S. Department of State, U.S.A., held in Arizona, U.S.A., Summer 1992. Jerry Hough, Box 90401, Durham, North Carolina 27708-0401, U.S.A. Focus: Politics of water in Central Asia.

(12). "Aral Sea Action Plan" (ASAP), Global Environment Fund (GEF), World Bank, Washington, D.C. Manager: Rathman, Michael S.V., 600 19th Street, N.W., Environment Division, World Bank, Washington, D.C. Meeting held on 12 August 1992; reconnaissance mission.

(13). Academy of Sciences, Republic of Uzbekistan State Committee of Protection of Nature of the Republic of Uzbekistan, Ministry of Melioration & Water Economy, Republic of Uzbekistan, Fund of Ecology & Health of Uzbekistan "Ecosan". "International Scientific-Practical Conference on Problems of the Aral Sea & its Adjoining Area," Nukus, 27-28 August 1992; sponsored by various Uzbekistan organizations, including Uzbekistan Academy of Sciences.

(14). "Diagnostic Study for the Development of an Action Plan for Conservation of the Aral Sea," International Conference, Expert Committee, Geneva, Switzerland, September 1992. Also called "The Development of an Action Plan for the Aral Sea, UNEP/CIS, and "USSR/UNEP Project on Assistance in the Development of an Action Plan for the Rehabilitation of the Aral Sea."

(15). "Central Asia: Its strategic importance & future prospects, seminar, Connelly Center, Villanova University, U.S.A., 30-31 October 1992.

(16). A.M. Sysin Research Institute of Human Ecology and Environmental Health, Russian Academy of Medical Sciences, 10 Pogodinskyaya Street, Moscow 119121. Sidorenko, Gennady I. (Director); Area: Studies on water and health in the Aral region.

(17). Potts, W., Royal Society of the United Kingdom, Institute of Biology and Environmental Studies, Lancaster University,

(18). Zhu, Zhongping, Tellus Institute, Broad Street, Boston, Massachusetts. Subject: developing simulation model of water resources/water use in Aral Sea basin.

(19). Richards, Lynn A., Institute for Soviet-American Relations (NGO), 1601 Connecticut Avenue, N.W., Suite 301, Washington, D.C. 20009, U.S.A.

(20). Entingh, Mel (President), Entingh Water Conditions, Inc., 3211 Dryden Road, P.O. Box 546, Dayton, Ohio 45449-0546, U.S.A. Interest in helping provide clean drinking water to Aral Sea region.

(21). Conway, Stuart (Director), New Forests Project, 731 Eighth Street, S.E., Washington, D.C. 20003, U.S.A. Interest in establishing agroforestry training center in Central Asia.

(22). Davoren, William (Executive Director), Aral Sea Information Committee, 1055 Fort Cronkhite, Sausalito, California 94965, U.S.A.

(23). "Training program for young investigators in water resource management", proposal with Turkmenistan Academy of Sciences and Uzbekistan Academy of Sciences, Summer 1994 and 1995.

(24). Eurasia Foundation, 2021 K Street, N.W., Washington, D.C. 20006, U.S.A. Incorporated April 1993, with start-up funds provided from a grant of the Agency for International Development, and from future enlistment of private funds. Goal: Develop program ideas and structures, with exclusive task of assisting in the reform of NIS. To establish five field offices, in Russia, Ukraine and Central Asia. Foundation is a response to need for a new, rapid response, flexible, privately-managed foundation for making grants in support of economic reform and democratic institution-building activities in the NIS.

(25). Environmental Protection in the Islamic World, International Conference organized by Islamic Academy of Sciences (Amman, Jordan), 10-14 August 1992, Kuala Lumpur, Malaysia.

APPENDIX 2

Terms of Reference for the Working Group Preparing
The Action Plan for the Aral Sea and its Drainage Basin

In cooperation with UNEP, and under the direct supervision of ____________________, the Working Group is requested to do the following:

Taking into account the Diagnostic Study for the Development of an Action Plan for the Conservation of the Aral Sea, other relevant documents and materials, and the conclusions of supplementary studies, the objective of the Working Group is to produce an Action Plan for the environmentally-sound and sustainable development of human, land and water resources. This task is to be achieved through effective management practices which lead to a quantitative and qualitative ecological balance of the Aral Sea and its basin.

The Action Plan, to the extent possible, should be sufficiently details that it can form a solid basis for consideration by multilateral, bilateral and other financial institutions. It should address both preventive and curative actions necessary in Aral Sea basin countries. Further, the Action Plan should address these needs through coordinated actions by each concerned Government to carry out policy and regulatory reforms, capacity building, and capital investments to improve human health, reduce the wasteful use of land and water resources, reduce water and air pollution, and conserve ecologically-sensitive and economically-valuable areas. The success of the Action Plan will depend, among other things, on a series of national and international interventions that must be implemented within the framework of political, social, economic and institutional restructuring already underway in all Aral Sea basin countries.

Accordingly, the Action Plan should include the following six components:

(1) <u>Polices, Laws and Regulations</u>

This component of the Action Plan should focus on developing the policies and regulatory measures necessary to establish a long-term framework, and system of incentives and legal requirements. This new policy and regulatory framework shall lead to incremental improvements in environmental, social and economic conditions over a period of 20-30 years. Initiatives should include revision and harmonization of environmental standards and guidelines, adoption of realistic water-user charges, and development of an effective system for collection of local revenues to finance water management and environmental improvements, etc.

(2) Restoration of Human Health

The Action Plan shall be especially concerned with the restoration of human health in the Aral Sea basin by reducing adverse environmental impacts. Immediate measures should be taken to reduce or eliminate chemical and microbial pollution of surface and sub-surface waters, to improve drinking water supply and sanitation facilities, including the sewerage systems. Special attention should be given to the promotion of public awareness of safe drinking water supplies and sanitation.

(3) Institutional Strengthening and Development of Human Resources

The Action Plan shall focus on strengthening the institutions and human resources needed to enforce regulations, and on effectively managing water and related land resources. Effective management of water and related land resources should be viewed as a prerequisite for stable agricultural and other relevant economic productivity in the Aral Sea basin.

(4) Investment Activities

The Action Plan should identify a multi-year programme of specific measures needed for effective management of water and related land resources in the Aral Sea drainage basin. Investment priorities must be identified primarily by the character and magnitude of the impact, particularly of public health and the environment, and the economic feasibility and effectiveness of proposed interventions. All major constraints affecting the establishment of priorities, and the choice and sequencing of investments, should be explicitly addressed. Recognizing limited capacity to mobilize financial resources to meet capital and recurrent costs, the Action Plan should promote a phased approach for the implementation of the investment programme. In this approach, each investment should be seen as an incremental and integral part of the overall, basin-wide water resource management system to be established over the longer term. The investment programme should focus on the areas of special concern, where specific action may produce the largest positive and cost-effective impact on the Aral Sea drainage basin.

(5) Environmental Activities

The Action Plan should focus on the amelioration of the environmental degradation, the improvement of overall environmental conditions, and the development of the sound scientific basis needed to enhance understanding of the complex and critical problems in the region, and to derive resolutions to them. Especially important in this context are matters related to water-resource management. Applied research should be oriented towards improving monitoring activities, and the provision of a data base to help better understand past, p resent and likely future changes and impacts.

(6) Public Awareness

The Action Plan should identify the actions needed to develop a broad and sustainable base of support for its implementation. The participation of nongovernmental organizations (NGOs), and the development of effective environmental education programmes, will be important in supporting both public awareness and political commitment. These activities are vital to the development of a public will to accept the necessary measures for improvement of water and related land resource management, such as increased water user fees and taxes.