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Strategy and Ecological and Societal Results  
of Extensive Resources Development in the South of the USSR

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## TABLE OF CONTENTS

Introduction . . . . .	1
Availability and Utilization of Freshwater Resources . . . . .	2
Rivers . . . . .	2
Reservoirs . . . . .	3
Lakes . . . . .	3
Ground Water . . . . .	4
Agriculture and Irrigation . . . . .	5
Impoundment of Rivers and Ecological Desertification of Estuaries-Sea Systems . . . . .	6
References . . . . .	14

## TABLE OF FIGURES

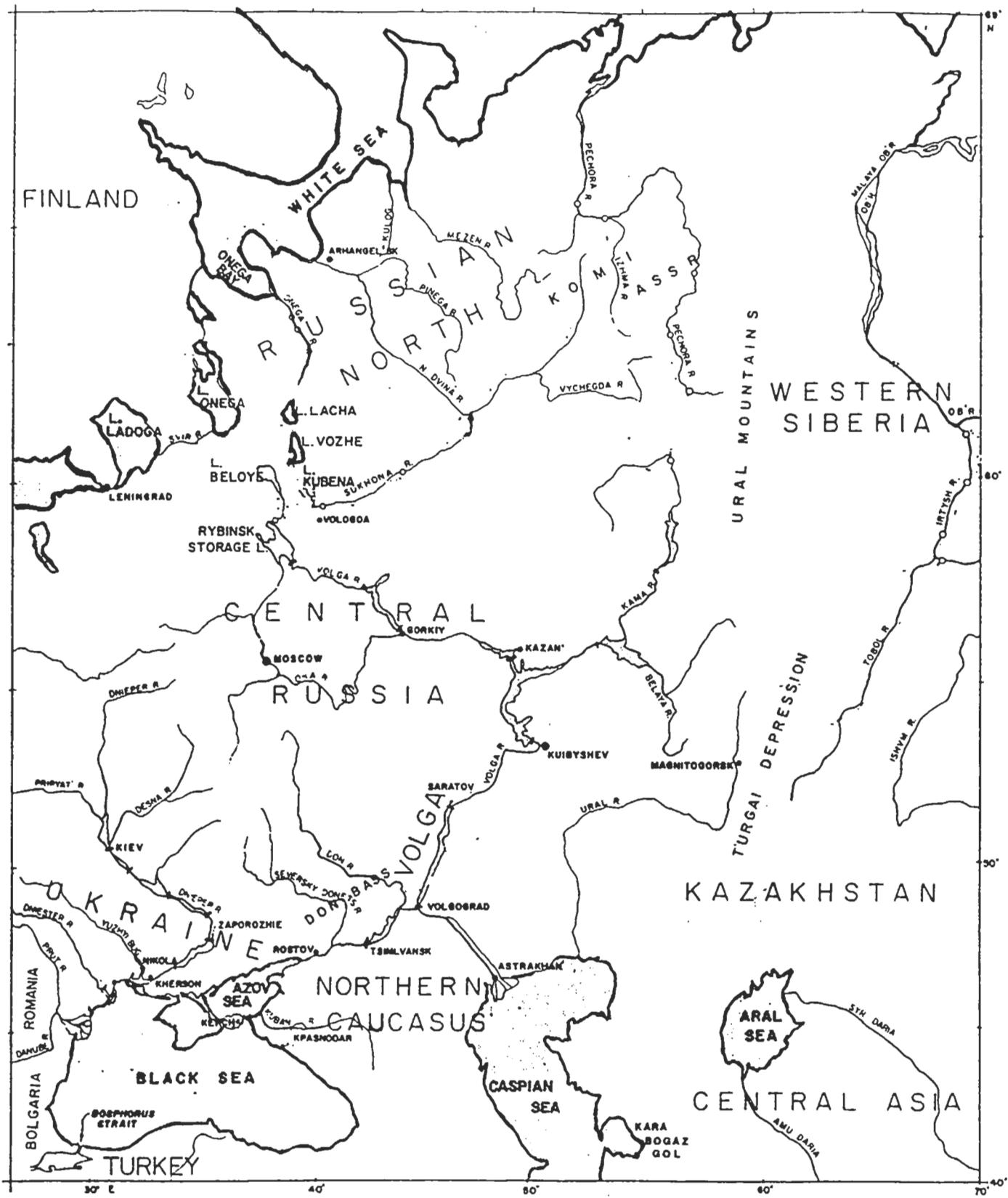
- Figure 1. The USSR large-scale river diversion projects.
- Figure 2. Generalized trends in the decrease of oxygen concentration and the increase in detention time of pollutants in the riverine-estuarine ecosystems affected by water impoundment.
- Figure 4. Conceptual model of the role of the river flow reduction on riverine-estuarine ecosystems.
- Figure 5. Generalized scheme of the impact of excessive water diversion on the environment of the areas adjacent to the Aral Sea.
- Figure 6. The capitalized losses sustained by the fisheries of the Southern Seas because of river impoundments for the period 1977 to 1987.
- Figure 7. The range of percentage increase in birth defects as a result of unsuitable water quality in the Low Volga, Central Asia and South Kazakhstan.
- Figure 8. Conceptual chain reaction between spring river runoff and some major chemical, physical and economic parameters in the delta-estuary-sea economy.

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Michael A. Rozengurt, Ph. D.

Environmental degradation has progressed to such a state across the southern portion of the USSR from Romania to the Chinese border that destruction of the habitat has become the Achilles' heel of the Soviet society, which, through economic, political and social consequences, may bring it down.

In the late 1940s-1950s, water management policies accelerated impoundment of thousands of small and large rivers flowing into the southern seas of the USSR (Figure 1), to cope with energy and food problems. During this period most, if not all, positions of managerial responsibility were staffed by political appointees rather than professionals. This dictatorial administrative "mafia" coupled with unscrupulous conformists from the water management establishment failed to integrate balanced economic planning and alternative projects into the long term ecological and economic benefits of riverine-estuarine-coastal zones ecosystems. Four decades later this failure has triggered the precipitous decline in water and land quantity and quality, and has resulted in irreparable losses in commercial and recreational fishery and reduction in the standard of living for over 120 million people of the South agro-industrial belt of the Black, Azov, Caspian and Aral seas' basins. Conditions are particularly intolerable in the South Kazakhstan and Soviet Central Asia Republics (especially in the Southern part of the Aral Sea Basin) where ecological concerns were suppressed by inflated economic requirements of the local cabal who ruled this area during the last decade, dubbed by Soviet officials as a period of economic, social and political stagnation. At present, this results in unrest among the people living in these despoiled lands and drinking of polluted surface and ground waters. These and other impacts of unlimited water development and land resources utilization on the environment and economy, and, related to them, societal problems of the Southern USSR, are partially summarized below from several studies prepared for the National Council for Soviet and East European Research, Washington, DC. Among those, "Water Policy Mismanagement in Southern USSR: the Ecologic and Economic Impact on Natural Resources of the Southern Seas," (May, 1989) served as a basis for the current presentation. The author gratefully acknowledges the indispensable role of the Council's interest and financial support in having this work completed. The author also thanks Dr. Joyce R. Starr, Co-Chairman of United States Global Strategy Council, Washington, DC, for unflinching encouragement in the course of preparation of this work. The author would like to express his special appreciation for the help of the Administration of the CSDOC (County Sanitation Districts of Orange County, CA) for having this presentation available for the distinguished audience of the 2010 symposium.



The USSR large-scale river diversion projects.

## Availability and Utilization of Freshwater Resources

1. **Rivers.** The USSR has nearly three million streams ranging from less than 10 km long through 54 large rivers over 1000 km long. Approximately 70% of all Soviet rivers are located in the mountainous regions of the Asian part of the USSR. Small rivers constitute 92% of all streams in the USSR, and one third of these small rivers are located in Russia. In European and Asian Russia the flow of these small rivers accounts for 1,239 km<sup>3</sup> (40%) and 1,145 km<sup>3</sup> (37%) of the total of all rivers, respectively. In the semi-arid and arid regions of the agricultural south, over 80% of the small rivers are impounded, and it is these rivers that are considered to be the most polluted streams in the USSR.

The surface normal runoff (SNR, computed as an average over 55 to 60 years) from the Soviet landmass amounts to 4,721 km<sup>3</sup> per year and constitutes 10% of the world's renewable surface runoff. Out of the total SNR, only 330 km<sup>3</sup> originate in neighboring countries. Compared to other countries, this SNR is greater than that for the USA's (2,850 km<sup>3</sup>) and Continental China's (2,600 km<sup>3</sup>) runoff but only about half that for Brazil (9,200 km<sup>3</sup>). However, the SNR per km<sup>2</sup> in the USSR is 1/2, 1/3 and 1/6 that in the USA, France and Norway, respectively.

The European part of the USSR receives only 1,059 km<sup>3</sup>, or 22.4%, of the SNR. In the South, a still smaller portion of SNR totaling about 614 km<sup>3</sup>, or 13% of the total, discharges into the four southern seas--Black, Azov, Aral and Caspian, and of this amount the Caspian Sea receives almost half (about 290 km<sup>3</sup>).

Thus, water supply in the USSR is skewed. Vast areas in the northwest, north and east flood plains, and mountainous regions, which account for 48 to 50% of the landmass of the USSR, have the most water--slightly less than 80% of the total surface runoff, but lower population and less agricultural and industrial potential. Over 64% of the SNR is discharged to the Arctic basin and 22% to the Pacific. The Amur river runoff to the North Pacific alone equals 500 km<sup>3</sup> per year in average.

By contrast, the most industrialized areas of the west, southwest and south--which account for 25 to 27% of the landmass, 70% of the total population of 287 million (1988), and almost 46% of the arable land, totaling 598.4 million hectares--have a disproportionately small fraction of the annual normal runoff (Fig. 2). Suffice it to say that about 400 million hectares of arable land experiences water deficit almost every year. The semi-official name of this land is "the area of high risk agricultural development." In other words, the Southern European Russia, Soviet Central Asia, and Kazakhstan (except the mountainous areas), a land-mass constituting 27% of the USSR, has only 2% of the total surface runoff excluding transit runoff from neighboring republics or countries.

For example, Soviet Central Asia, and the Ukraine and Moldavia possess only 50 to 80 and 40 to 45 km<sup>3</sup> of sustainable water, respectively, while their populations exceed 40% of the Soviet Union total. Consequently, the lowest surface water supply per capita and per one square km is typical for those

geographic areas. However, these republics account for 40 to 49% of industrial output (oil, petrochemicals, coal, heavy metallurgy, agricultural equipment, hydropower, organic and inorganic chemistry, metallic construction, weaponry, etc.), and serve as bread, rice and vegetable baskets for the rest of the country. The highest use of irrigation water is located in these areas.

2. **Reservoirs.** The USSR has over 160 large reservoirs each containing not less than 400 million m<sup>3</sup>, plus 1000 small storage facilities used for seasonal regulation, each containing not less than 1 million m<sup>3</sup>. The vast majority (94%) of the reservoirs were constructed after 1950. Almost 9% of all reservoirs the world over are in the USSR. Their capacity comprises 22% of the total volume of all world water storage facilities.

The quantity of water held in these reservoirs in 1987 was 3.4 times the normal runoff of the Volga River (251 km<sup>3</sup>/year), or 3.4 times of all the country's rivers' runoffs during the dry weather period. The usable volume of 541 km<sup>3</sup> was slightly over 10% of the total normal surface runoff, or 47% of the stable dry weather period runoff of all the country's rivers (nearly 13 times of water accumulated in over 100 small and large reservoirs of California). Compared with the USA, the USSR's proportion of total volume to usable storage differs significantly. Namely, the USA's usable volume equals 443 km<sup>3</sup> out of a total storage of 500 km<sup>3</sup>. These data imply that the effectiveness of water utilization in the USA is over 40% higher than in the USSR although the total storage of the USA is about half that in the USSR. In the European part of the country the usable volume of water amounts to approximately 200 km<sup>3</sup>.

The total area covered by reservoirs equals 122,000 km<sup>2</sup> of which 53,550 km<sup>2</sup> are related to lakes that have an average volume over 50 million m<sup>3</sup>. The total area of the most fertile soil along rivers and valleys associated with lakes equals 136 million acres.

In general, the total consumption of water derived from reservoirs and rivers in the USSR has reached 600 to 650 km<sup>3</sup> of which 250 to 300 km<sup>3</sup> are retrievable. Agricultural use is the largest, especially in the South, and water delivered to irrigated fields, including irretrievable losses account for 70% of this.

3. **Lakes.** Another source of freshwater supply in the USSR are 2,854,166 lakes, although 98% of them are small ponds with a surface area equal to less than 1 km<sup>2</sup>. Over 50% of the total number of lakes are located in the northwestern part of the country, Western Siberia and North Kazakhstan. The surface area of these lakes amounts to 0.5 million km<sup>2</sup>, or 2% of the USSR's territory.

The storage capacity of the sixteen largest freshwater lakes equals 24,500 km<sup>3</sup>. The remaining small lakes total 3,000 km<sup>3</sup>. In comparison, the total volume of the five Great Lakes in North America equals almost 23,000 km<sup>3</sup>.

In sum, the Soviet static freshwater storage equals 27,500 km<sup>3</sup>, of which 82% is found in Lake Baikal. The latter is the largest lake in the world by volume and represents 10% of world surface natural

water storage. It should be emphasized that despite the impressive capacity of large freshwater lakes, their ability to replenish or renew the water storage is insignificant compared to their total volume of water. Naturally, only 0.3 to 1.5% of a total volume can be replenished by seasonal runoffs from watershed. Moreover, the major lakes are located beyond the reach of the South irrigation network.

In addition, the majority of small lakes in the lower reaches of the rivers Dniester, Dnieper, Don, Kuban, Volga, Amu-Darya and Syr-Darya, and numerous others, are dying or drying up. The deposition and accumulation of organic and inorganic nitrogen and phosphorous from agricultural drainage network results in increased occurrence of eutrophication and deoxygenation of deep and bottom layers. This and the desertification of many lakes, even those located in the deltas, have threatened habitats essential to the survival and reproduction of hundreds of species of fish and waterfowl. Such development has become one of the most troubling issues for Soviet ecologists and resource management authorities of southern regions.

4. **Ground water.** The total volume of static ground water storage down to a depth of 2000 meters in the European area (5.5 million km<sup>2</sup>) is 800,000 km<sup>3</sup>, and in the Asian area (16.95 million km<sup>2</sup>) is 2.83 million km<sup>3</sup>. However, the total renewable (dynamic) ground water resources in the USSR are relatively small, 900 km<sup>3</sup>, and are distributed unevenly over different climatic and agricultural zones. Accordingly, their variable chemical properties, constituents and total salt concentration differ from place to place. The current ground water withdrawals have reached 95 to 105 km<sup>3</sup> per year, or 10 to 12% of the renewable ground water supply. The major water consumers are municipalities and industries, especially mining enterprises.

The largest ground water debit and highest salt concentrations are typical in the South in the following regions: Ukraine, Moldavia, North Caspian depression, Central Asia and Kazakhstan (Aral sea watershed) and Western Siberia. Ironically, in Moldavia, where agriculture is the major economic infrastructure, the volume of brackish ground water down to a depth of 100 m exceeds 3.5 times the volume of freshwater.

In Kazakhstan and Uzbekistan the ground water quality is even worse, and in Turkmenistan there is no fresh ground water at all. Moreover, in Soviet Central Asia and South Kazakhstan, which are the major producers of cotton, the brackish ground water table is located very close to the surface layer of arable land. This geomorphologic feature coupled with excessive irrigation (30000 m<sup>3</sup>/ha) as opposed to recommended 6000 to 10000 m<sup>3</sup>/ha) and essential evaporation (10 to 15 km<sup>3</sup> per year) are the dominant factors responsible for the rise of salty water to the surface that aggravates quality of agricultural land and eradicates 30 to 40% of cotton harvest, and poisons the insignificant drinking ground water supply. The excess of fertilizers (100 to 450 kg/ha as opposed to 2 to 30 kg/ha) exacerbates the sanitary problems in this and other southern agricultural regions.

## Agriculture and Irrigation

5. About 47 million people out of 130 to 147 million of the working forces (nearly 17% of the population of the USSR of 287 million) are engaged in agriculture. Capital investments for irrigation amounted to 5 to 8 billion rubles annually in the late 1950s and climaxed to 28 billion per year from 1981 to 1988 on further expansion of irrigation networks whose current length exceeds 700,000 km. The South semi-arid and arid lands consume 200 to 250 km<sup>3</sup> of freshwater, or nearly one-third of the total sustainable water usage in the country. However, nearly 60% of this volume can be defined as irretrievably lost because of evapotranspiration, leakage and drainage releases in ravines and wadies.

Agriculture accounts for 30% of GNP. However, harvests have remained unsatisfactory. The work of 5 million is "lost" because 20% of the annual harvest never gets to market on account of the inefficiency of storage facilities. About 30% to 40% of total harvest of cereals, fruits and vegetables rot before they reach the consumer. In addition, 8 to 10% of harvest is lost due to salinization of the 5 million hectares of fertile arable land. Moreover, wind and water erosion plague 150 million hectares (two-thirds of total) of agricultural and 175 million hectares of pasture and hay-making land (nearly half of total). The expansion of ravines amounts to several million kilometers. Excessive subsidies and lack of incentives, extensive use of water and fertilizers exacerbated the despoliation of land. In sum, over 5 and 9 million hectares of formerly fertile arable land are, respectively, unusable or require reclamation at an estimated cost of \$5 billion per one million hectares.

Several hundred thousand hectares in South Moldavia and Ukraine, North Crimea, and North Caucasus have experienced severe salinization. The black soil (chernozem) of the Russian Plains lost one-third (10 to 15 cm) of its humus, a highly fertile layer, over the last three decades. In the lower Volga watershed and North Caucasus, the desertification engulfed 700,000 hectares. There an annual increment of sand soil equals 50,000 to 60,000 hectares. As a result of erosion, nearly 100 million tonnes of humus washed away and was irrevocably lost for agriculture.

In general, for the last 17 years the average harvest of grain has equaled only 1.5 to 1.8 tonnes per hectare (in the US and Sweden - 5.5 to 6.0 tonnes; milk 5.5 to 6.0 tonnes per cow while in the USSR - 2.7 tonnes).

Soviet economists acknowledge that if the current trend of land abuse and harvest prevails the USSR will require 100 years to catch up with the level of agricultural output of developed countries. They assumed that at least 10% of the GNP must be spent (as opposed to current 1.2 - 2.0%) for the next two decades to modernize an agricultural industry to attain a significant output in food supply for population and livestock. However, at present, the Soviet government has been forced to purchase up to 30 to 50 million tonnes or roughly one-fifth of the world's grain exports during this same period of investment in agriculture.

## Impoundment of Rivers and Ecological Desertification of Estuaries-Sea Systems

6. Water development projects on the major rivers--Dniester and Dnieper (Black Sea), Don and Kuban (Sea of Azov), Volga, Ural, Terek, Kura and others (Caspian Sea), Amu-Darya and Syr-Darya (Aral Sea), and numerous small rivers were based on two erroneous assumptions: (a) river runoff is an inexhaustible source of water supply, and (b) freshwater discharges to adjacent estuaries and seas are wasteful. This linear and single-minded thinking neglected the ecologic appraisal of limited natural tolerance of riverine-estuarine systems and living resources to water diversions.

7. The design and construction of over 30 major storage facilities, built on floodplains of Dnieper, Don and Volga rivers, or in mountainous regions of Ukraine (Dniester), North Caucasus (Kuban), and Soviet Central Asia (Amu-Darya and Syr-Darya) were based on a narrowed assumption that there would be no economic and technological changes in utilization of water and arable land for at least 50 years (the technological, economic and ecological obsolescence of dams was not anticipated). At the same time, over 80 million people are living and working in vicinity of 50 to 200 km of man-made reservoirs. This has brought about a dense concentration of growing population, water-consuming industries (chemical, electronic, food, etc.) and crops, such as cotton and rice, in areas known to be semi-arid and arid zones.

8. To satisfy their conflicting demands for water, the above-mentioned rivers have been subjected to the highest spring (up to 85% of normal) and total annual water withdrawals of all rivers of the USSR. This has triggered water depletion and uncontrolled salinization, and rising of ground water table in the irrigation network of Ukraine, Moldavia, North Caucasus, Central Black Soil provinces and Soviet Central Asia.

It is imperative to underscore the fact that under natural conditions the predominant deviations of average annual or spring freshwater of above mentioned rivers supply for successive 5 running years did not exceed  $\pm 25$  to 30% of normal (as averaged for 55-60 years). And as a rule of thumb, the unimpaired spring runoff exceed several times the summer or fall runoffs (the same was true for any European or American rivers). Today, due to impoundment of rivers, these natural features have ceased to exist.

The current average total spring water withdrawals account for 300 to 350 km<sup>3</sup>, or 56 to 65% of the unimpaired runoff to the southern seas of the USSR. Of this amount, 120 to 150 km<sup>3</sup> are irretrievable losses. Note that over 85% of diverted water is used by agriculture in Soviet Central Asia and Kazakhstan, and non-productive losses (evapotranspiration and leakage) account for 40 to 60% of overall water withdrawals for irrigation, especially in the cotton belt. There only 2 to 8% of irrigation canals are lined.

9. As a result, the annual natural runoff of the South European rivers has been reduced to 68% (Volga), 40 to 50% (Dniester, Dnieper and Don), 15 to 20% (Kuban) and 0.5 to 3% (Amu-Darya and Syr-Darya) of normal. However, in years of subnormal or critical, but natural wetness, the regulated annual runoff could be much less. In other words, water withdrawals superimposed on natural climatic

abnormalities could have runoff depletion aggravated to such an extent that a frequency of occurrence of normally atypical, extremely low flow could exceed 3 to 5 times their natural probability (the same is true for spring regulated runoffs). Inarguably, since the mid-1970s the riverine-estuarine ecosystems have experienced just that gradual water starvation.

10. In practice, since that time, the entire Black, Azov, Caspian and Aral seas' ecosystems were deprived of nearly 650, 400, 1000, and 1250 km<sup>3</sup> of spring runoff, respectively, as well as hundred million tonnes of sediment load, a dozen million tonnes of oxygen, and inorganic and organic matter, and many other chemicals so vital to maintaining the unique diversities of organisms of these ancient ecosystems. This abnormal redistribution coupled with impoundment of river beds has profound, deleterious effects on entire riverine-estuarine and shelf environment.

11. The cumulative losses of runoff coupled with the dissection of rivers by dams have created an eight to ten-fold increase in the detention time of pollutants accumulated in artificial water bodies (Figure 2). This, in turn, has led to eutrophication, oxygen deficiency and fish kills in reservoirs of the middle and lower rivers and deltas in South European and Soviet Central Asia.

Furthermore, thousands of small dams coupled with channelization of rivers and deltas has severely exhausted or destroyed the underground water table down to 10 to 30 m below a river bottom, which is the basis for any river's survival, particularly in summer. Moreover, they impeded the interaction between surface and ground runoffs over a vast area of South river watersheds. Consequently, their aquifers have experienced the significant increases in salt water intrusion. As known, Nature can not stand with an empty niche.

12. This and unprecedented runoff depletion have made the residual runoffs incapable of providing dilution of natural and man-induced waste, repelling salt intrusion into the deltas, or controlling the salt regimes and mixing processes which maintain the flora and fauna in the estuarine - coastal ecosystems of the Black, Azov and Caspian Seas. As a result, substantial accumulation of salt and anthropogenic pollutants occurred. This, in turn, triggered development of vast zones of oxygen depletion (hypoxia) in adjacent marine coastal zones. Note that the dumping of 22 km<sup>3</sup> per year of untreated municipal, industrial and returning waters from irrigation networks into the Ukrainian rivers accelerated the deterioration of riverine - marine systems of the northwestern Black Sea. In addition, the accumulation of nearly 10 billion tonnes of sludge in open landfills that occupy over 440,000 acres of watersheds further facilitated the contamination of surface and ground waters. Similar development is typified the entire sea of Azov and North and Middle Caspian Sea.

In Soviet Central Asia, the Amu-Darya and Syr-Darya rivers accommodate about 8 km<sup>3</sup> and 12 km<sup>3</sup> per year drainage waters from several million hectares of cotton and rice fields, respectively. These discharges, saturated with fertilizers and pesticides, spelled out the demise of rivers and sufferings of a million human beings.

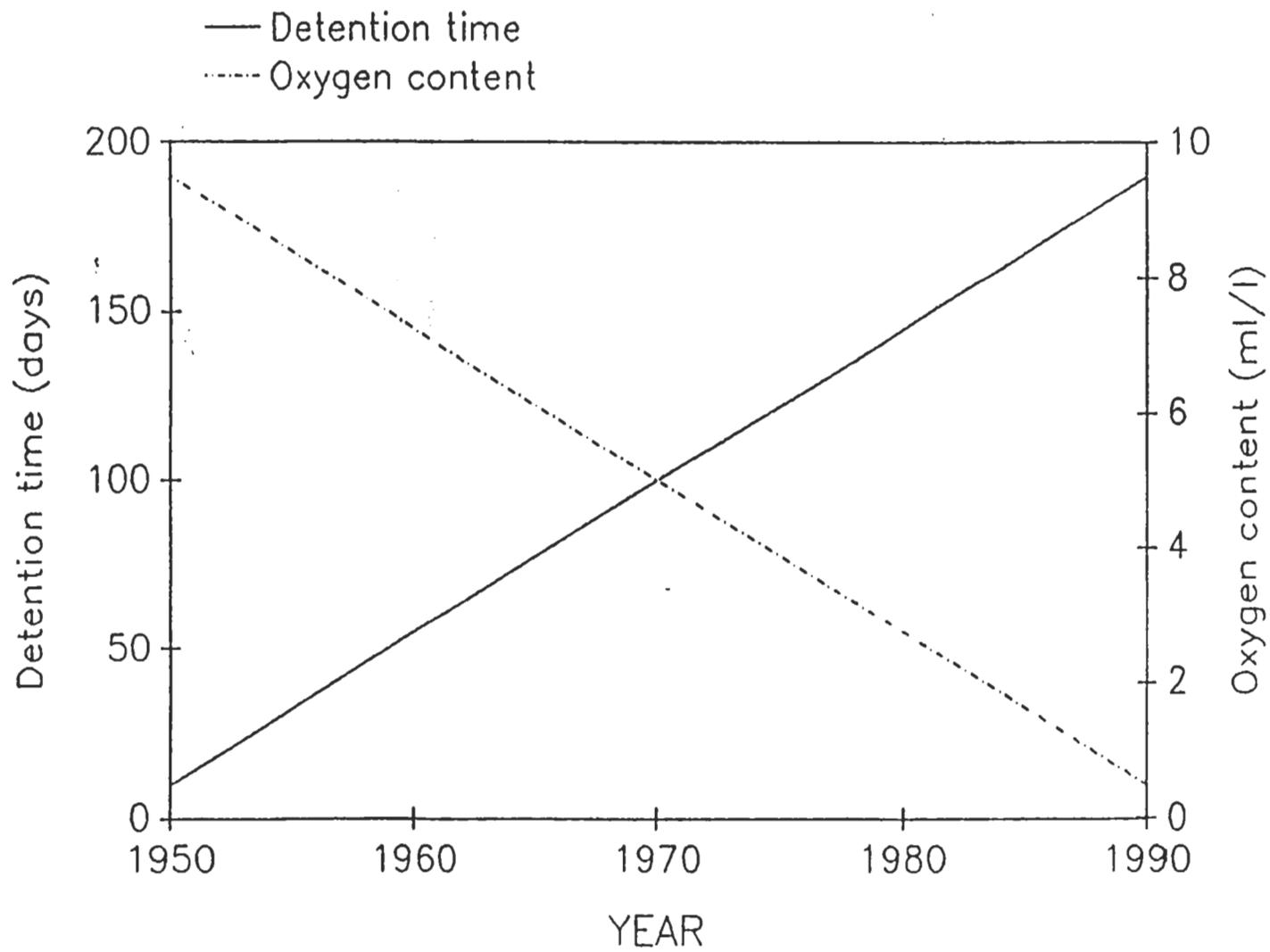


Figure 2. Generalized trends in the decrease of oxygen concentration and the increase in detention time of pollutants in riverine-estuarine ecosystems affected by water impoundment.

On average, over 60% of water withdrawn for industrial and municipal needs is returned into water basins after insufficient treatment and 15 to 25% is discharged untreated. In many populated areas of the agro-industrial complexes of the European (Moldavia and Ukraine) and Asian South (Karakalpakia Autonomous Republic and Fergana Valley) severe shortages of drinking water exist. In practice, the environment of these regions has reached the edge of ecological tolerance and human endurance. For example, Odessa, the largest city on the Black Sea, (population over 1.3 million) and the most important industrial, cultural and resort center of the Ukraine, is considered a zone of ecological disaster.

13. Several decades of expensive attempts to halt progressive salinization and desertification of deltaic arable lands, improve water quality and migration routes for fish, have failed. A vivid example of human miscalculation is the Water Divider built in the head of the Volga Delta and the Peripheral Canal erected in the eastern part of the Volga delta. The performance of these enormous water transfer complexes (646 kilometers of distribution canals, at a cost of 500 to 600 million rubles in 1974) has given strong support to the statement that the lack of water and inequities in the distribution of runoff cannot be compensated for even by a number of sophisticated water conveyance facilities. The Volga Delta and its wetland (roughly the combined size of the states of Delaware and Vermont) seas are dying.

14. In general, salt from the sea and drainage networks place in jeopardy water quality of agricultural, municipal and industrial freshwater intakes in the deltas of the Black, Azov and Caspian seas. At the same time, the salinity in estuaries has increased 1.5 to 4.0 fold their historical values, while in the deltas the salinity exceeded 5 to 10 times their historical limits of 0.20 to 0.35 g/l. For many freshwater fish, birds and fur-bearing animals these increments and their seasonal extremes signified the beginning of their extinction.

15. As to the Aral Sea, the lack of runoff due to enormous water withdrawals of 1970s-1980s has not only nullified the Amu-Darya and Syr-Darya Deltas but also reduced the sea to two small hypersaline lakes (Figure 3). This brought about the near lethal conditions affecting living resources of the Sea ecosystem (Figure 4). For example, about 270 out of 300 formerly highly productive lakes of the vast Amu-Darya and Syr-Darya Deltas dried out. The current surface of lakes is reduced to one-thirteenth of that of 1950s. At the same time, highly contaminated agricultural discharges transformed wadies into 150 saline lakes. About 30 man-made wasted lakes are located in the vicinity of the two most important canals--Amu-Bukharsky and Karakumsky (over 1500 km long). This jeopardizes subsurface water quality and facilitates water-logging of surrounding agricultural fields.

Ground water is saturated with defoliants, DDT, and residual salt (up to 3 to 8 grams/liter) which make numerous wells unsuitable for any purpose (0.25-0.50 grams/liter are sanitary standards). In practice, all available water and soil resources of Soviet Central Asia and South Kazakhstan are exhausted. That is why the harvest of valuable raw cotton constitutes only 15 to 25% of that two decades back (2 to 3 million tonnes).

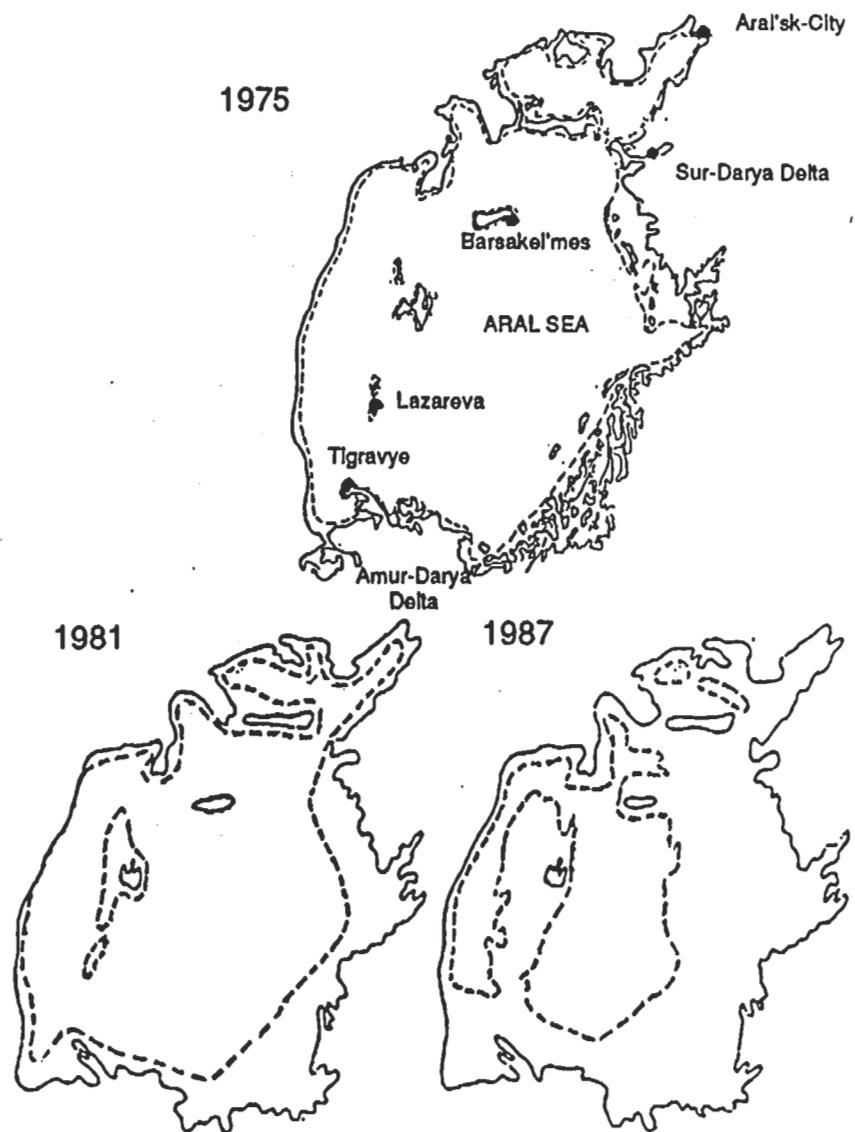


Figure 3. The area covered by the Aral Sea under conditions of positive (full line) and negative (dashed line) water supply in 1975, 1981 and 1987.

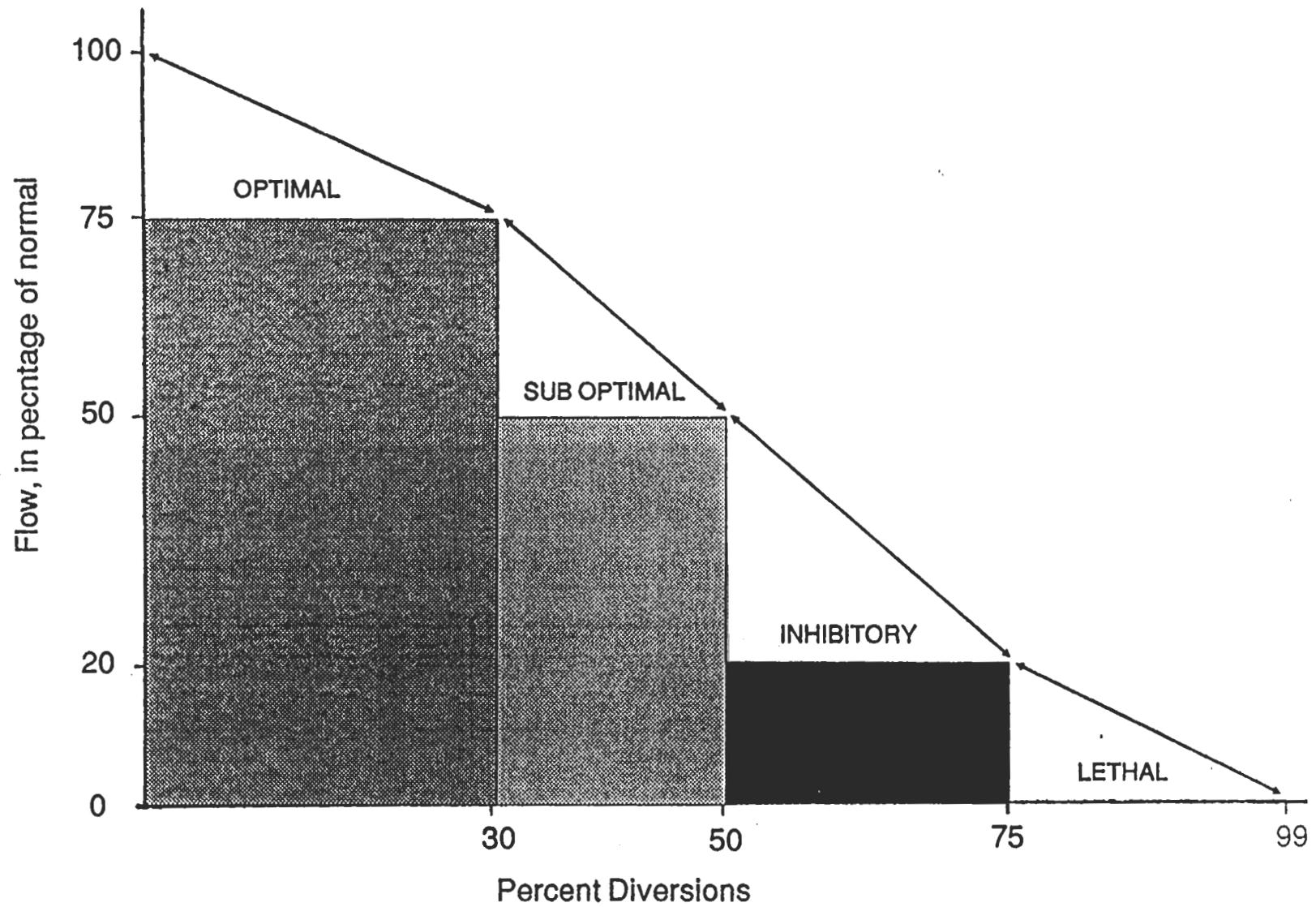


Figure 4. Conceptual model of the role of the river flow reduction on riverine-estuarine ecosystems.

16. The depletion of freshwater in the South Ukraine and Moldavia, North Crimea, and South Russia rivers has reached inhibitory levels if health of population or fishery is of concern (Figure 4).

17. The integrated effect of excessive irrigation and application of fertilizers and pesticides, up to 2 to 5 and 8 to 10 times higher than recommended, respectively, upward evaporation of saline ground waters, improper lining of canals and out of date monoculture practices have resulted in desertification and salinization of over 2 to 3 and 6 to 7 million hectares of arable land in the Ukraine and South Russia as well as in South Kazakhstan and Central Asia, respectively. (The latter is defined as the area of the most advanced development of irrigation networks for the production of 95% raw cotton, 45% rice, 25% and 32% vegetables and fruit, respectively, of the total in the USSR which is harvested there.) For the last decade, economic losses from salt and water erosion have reached approximately \$40 billion.

18. Cascades of dams and water conveyance facilities in the deltas destroyed migration routes, spawning and nurturing grounds and wiped out 90 to 98% of the valuable species of commercial fisheries in all major rivers and estuaries of South USSR. For all practical purposes, the demise of the delta-estuarine ecosystems in this part of the Soviet Union is an unarguable fact.

Nearly 30 years of heroic efforts and hundreds of millions of dollars spent on restoration of estuarine-dependent valuable fishes, especially Russian sturgeon, at more than 150 hatcheries placed in the Black, Azov and Caspian basins have failed. The recreational and commercial catch of Russian sturgeon ceased to exist in the northwestern Black Sea and Sea of Azov, while in the Caspian Sea it constitutes only 1 to 2% of historical catch (14,000 to 38,000 tonnes per year). Note that the latter was one of the most productive seas in the world only two decades back. Over 1,000 commercial fishery ships and boats have been idle in sea ports in the South and there are no fish-related enterprises in the Aral Sea. In practice, only the geographic name of this sea remains; all its infrastructure has been destroyed.

19. To make things worse, the 75-100 million tonnes per year of salt mixed with fine material from desiccated Aral Sea bottom are carried out by winds and deposited over 20,000 km<sup>2</sup> of adjacent land and irrigation network (Figure 5) in quantities up to 520 kg per hectare. This eventually exacerbates the poisoning of the freshwater supply and surrounding arable lands, which are themselves saturated by fertilizers and defoliants excessively used over millions of hectares of cotton growing fields (450 kg/ha rather than of 30 kg/ha recommended). Consequently, the horrendous mixture of different chemicals that includes in some areas almost lethal concentration of selenium, is accumulated in crops and vegetables and washed into the rivers and wells, which, in turn, are the only source of water and food supply for several millions of people and other living creatures. Hence, the Aral Sea is lost for humanity, while the North Black Sea, the Sea of Azov and Caspian Sea march to inexorable destruction.

20. Since the 1970s, many plants that processed valuable fish and shellfish have been closed. Consequently, several hundred thousand fishermen and workers related to the fishery industries in the southern seas had to change their occupations.

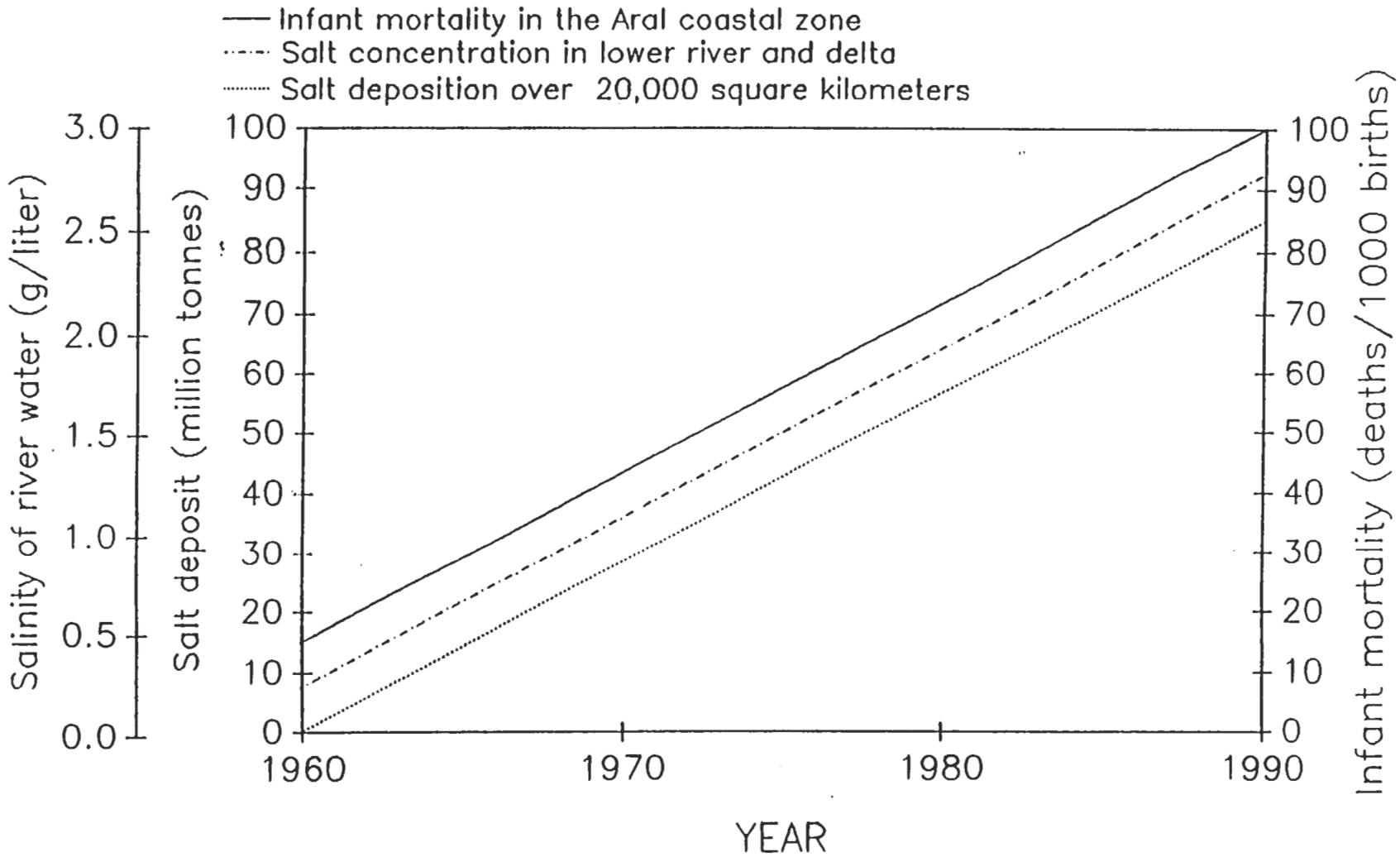


Figure 5. Generalized scheme of the impact of excessive water diversion on the environment of the areas adjacent to the Aral Sea.

21. The approximate estimates of economic losses for fisheries alone in the Black-Azov sea basin amount to \$0.8 to \$1.5 billion per year (capitalized losses, Figure 6). In the Caspian sea basin almost \$2.0 billion, and in the Aral sea basin about \$100 million have been lost. However, the total economic losses in the Aral sea basin linked to million hectares desolated land, despoiled freshwater supply, vanished fisheries, unemployment of hundreds of thousand, the mass spread of diseases and many other societal disturbances amount roughly to \$3 billion.

22. The contaminated water of the southern rivers (especially the Amu-Darya and Syr-Darya, known for years for their abominable sewage network) spreads diverse diseases unreported of in the recent past. As a result, infant mortality in the Karakalpakskaya Autonomous Republic (lower Amu-Darya, population 1.2 million) exceeded the average in the USSR almost 4.7 times, or 100 to 118 per 1000. At the same time, the infant mortality in the Great Fergana Valley (population over 1.3 million, UzSSR) equaled 35 to 55 per 1000, or 2 to 3 times that in the country.

23. Suffice it to say that the Ministries of Health Preservation of the Asian republics and the National Academy of Sciences have related the wide spread of intestinal illnesses among the population as a whole and throat cancer, among adults in particular, to contamination of drinking water because of sharp increases in the concentration of salt leaching into lower layers of soil and wells in an amount of a million tonnes per year. Some toxic chemicals (for example, selenium) are said to be responsible for changes in genetic structure and subsequent generation among infants, animals and waterfowl.

Scientists have discovered an alarming link between contaminated water and grotesque deformities among animals, birds and infants, as well as mental retardation of children (Figure 7). Kidney and liver diseases and miscarriages among the adult population, who absorb the poisonous elements from water and food have plagued the middle and lower Syr-Darya and Amu-Darya watersheds. Poisonous salt entrained by the winds from dry bottom of the sea and scorched fields was found in the milk of nurturing mothers at a distance of 500-1000 kilometers off the Aral Sea.

Based on official sources, there has been a vigorous furor in some areas of Soviet Central Asia and South Kazakhstan over better water among the population in 1987-1990. (These regions account for 27 to 28 million Moslems out of 50 to 51 million of total population.) This embarrassing situation forced the Central Committee of the Communist Party and local governments to issue the executive order excluding from irrigation of 15 to 25% of arable land by 1990 and 2000, respectively. Besides, in 1988 a special commission was established to overhaul water distribution systems and irrigation networks in this region.

24. Several hundred kilometers of shelf zones and recreational "golden" sand beaches of the North Black and Azov seas are contaminated by millions of dead jellyfish. Untreated municipal and industrial waste discharges and, especially, agricultural runoff polluted coastal waters to such a degree that, since the late 1970s, every summer millions of people have been deprived of swimming and sunbathing. Note that sea outfalls in the USSR operate in the surface layer, e.g., within depths of 2 to 20 meters. Consequently, the

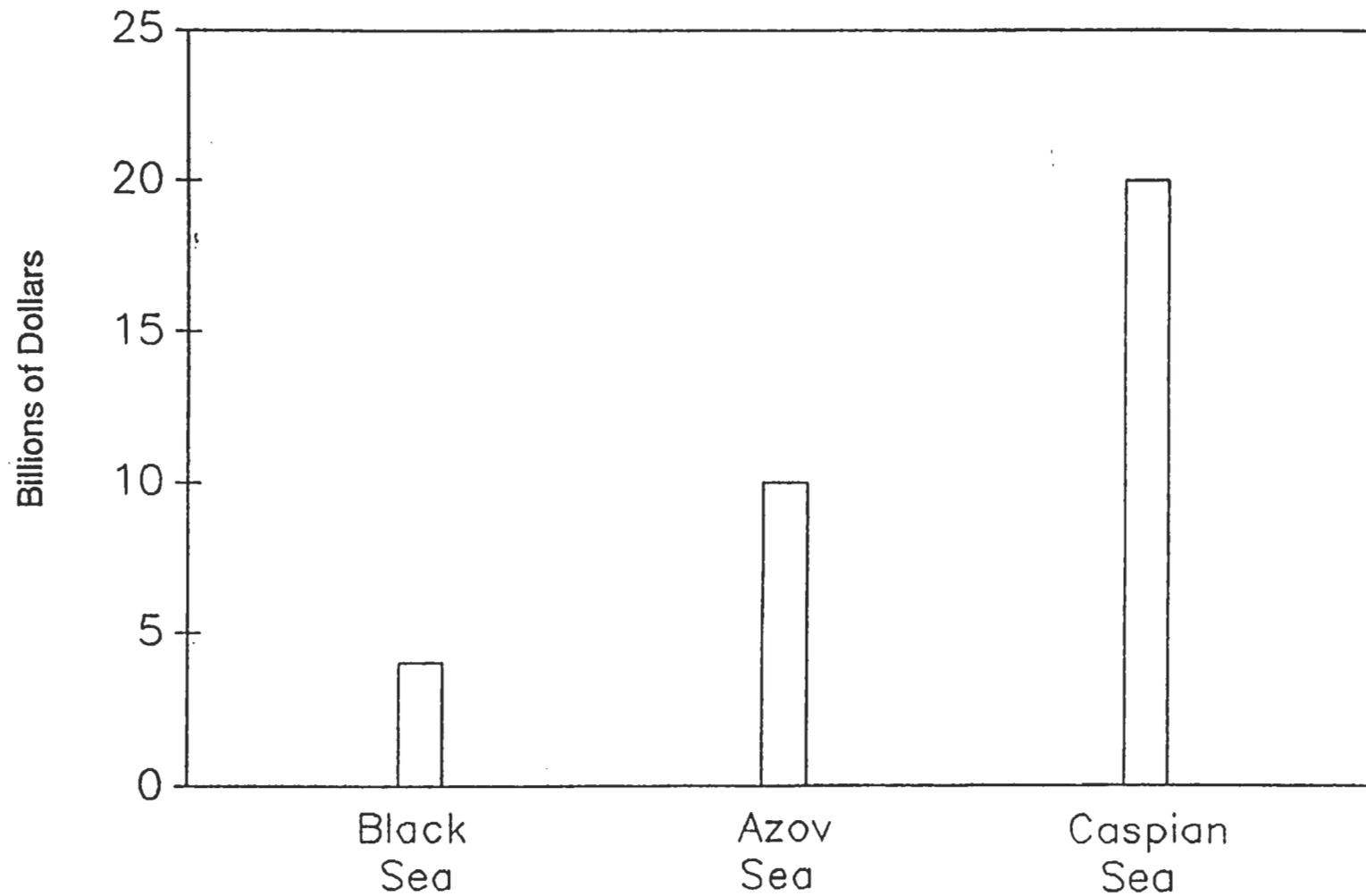


Figure 6. The capitalized losses sustained by the fisheries of the Southern Seas because of river impoundments for the period 1977 to 1987.

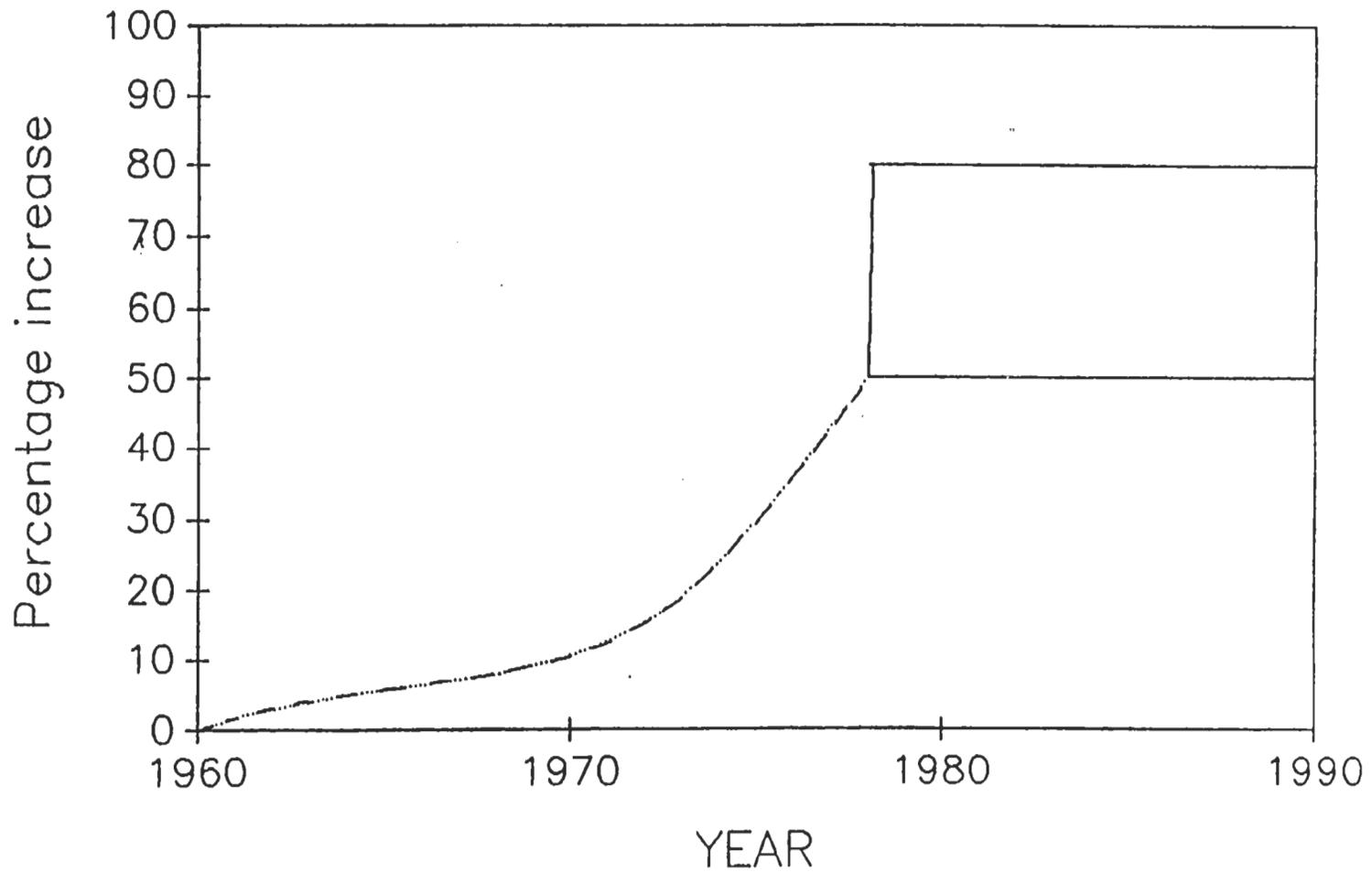


Figure 7. The range of percentage increase in birth defects as a result of unsuitable water quality in the Low Volga, Central Asia and South Kazakhstan.

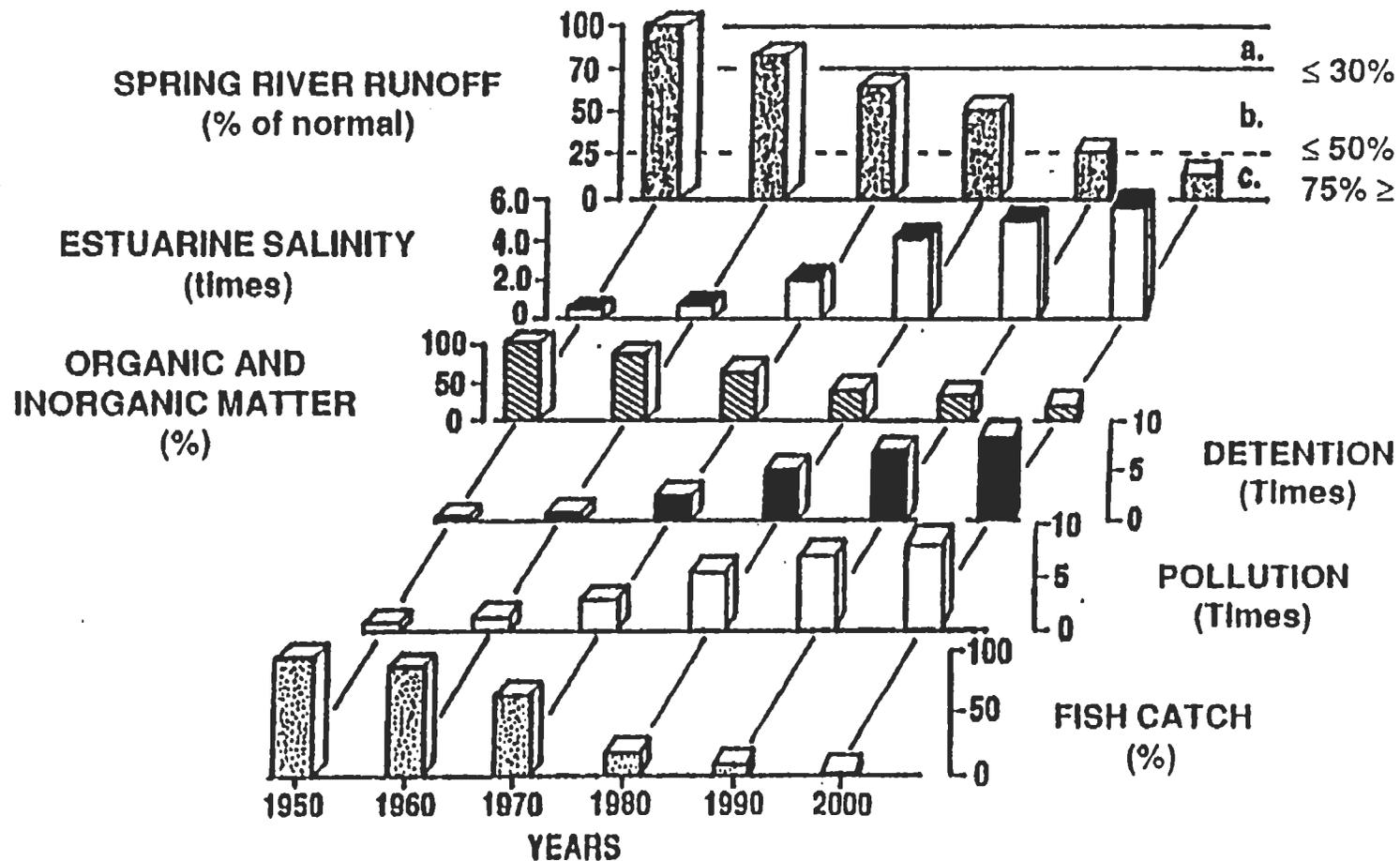


Figure 8. Conceptual chain reaction between spring river runoff and some major chemical, physical and economic parameters in the delta-estuary-sea economy.

a. Range of natural limitations in spring fresh water diversions  $\leq 30\%$  of normal.

b. Detrimental range of spring diversions for living and non-living resources  $\leq 50\%$  of normal.

c. Range of residual spring runoff irrevocably damaging to environment and economics of ecosystems  $75\% \geq$  of normal.

contamination of surface water has reached appalling proportions. As a result, the approximate estimates of economic losses for local, national and international tourism account for several hundred million dollars per year. About 3 to 5 million people per season visit the seaside resorts of the Black Sea alone.

25. It should be emphasized that to some extent similar tainted water problems and chronic deficit in drinking water supply are the major environmental issues for the South Moldavian and Ukrainian (Dniester and Dnieper) and the lower Don and Kuban (South Russia and North Caucasus) authorities. Here, the most pervasive damage stems from agricultural drainage of rice fields. The former is considered to be the major cause of unsuitable water quality in the lower river ecosystems.

26. Meantime, the current gradual poisoning of the remnants of the life-sustaining surface layer (50 to 100 meters depth) of the Black Sea (5% of sea volume) by hydrogen sulphide rising from the abyss poses a pending economic and ecological crisis for millions of people inhabiting the South of the USSR and surrounding Middle East and southern European countries. The lethal concentration of 2 mg/l to 9 mg/l is enough to wipe out the very existence of living organisms in the surface layer of the sea. This phenomenon, undocumented in the past, is intimately linked to the role of runoff depletion upon changes of physical and chemical properties of the Black and Sea of Azov basins. Note that its spatial and temporal developments are of the greatest concern to Soviet oceanographers and central authorities.

**In sum, the single-minded approach to unlimited freshwater withdrawals, which significantly exceeded the natural threshold of normal runoff deviations of  $\pm 30\%$ , has led to the development of intricately negative chain reactions whose entangled feedback interaction of ecological, economic and societal elements have started to shatter the very existence of environmental and political institutions of the USSR.**

In light of said, some major elements of this chain reaction are the following (Figure 8): Reduction of runoff through river impoundment ---> increase in salinity ---> decrease in organic and inorganic material and sediment load ---> increase in detention time ---> increase in pollutants load ---> significant decrease or elimination of spawning grounds and commercial and recreational valuable fish catch and harvest of other shelf zone products (mollusks, seaweed), and invasion and mass mortality of horrendous amounts of jellyfish or other foreign organisms that exacerbated negative conditions in the shallows of the Black and Azov seas, etc.

Thus, "all purpose" unrestrained resources development has had a disastrous effect on:

- The surface and ground water quantity and quality in river watersheds and estuaries;
- Chemical properties of the irrigated lands and acceleration of waterlogging and soil erosion;
- Agricultural production of formerly fertile croplands within the river valleys and deltas;

- Hydrophysical and hydrochemical regime of estuarine-southern seas ecosystems, intensity of desertification of deltas and arable land ;
- Climatic features over a thousand square kilometers of the Soviet Central Asia and South Kazakhstan;
- Contamination of the troposphere by millions of tonnes of coarse and fine salty suspended particulates;
- Riverine-estuarine and seas fishery and living conditions and drinking water supply for over 100 millions of people;
- Economic and political situation in neighboring republics of Uzbekistan, Kirgizstan, Tadzhikistan and Kazakhstan, South Ukraine and Moldavia, South Russia and North Caucasus, where competition for scarce residual runoff has brought about racial riots.

These conflicts inherited from the previous rulers have become the economic and political issues of great importance for the European South and Soviet Muslim Republics. In other words, all of the much touted gains in economic growth, energy production and irrigation and reclamation of 37 million hectares of land have been undermined by the above discussed problems.

An additional cost now being borne, and which will accelerate over at least the next two decades, is the cost to the Soviets for imports of cereals and other foodstuffs to supplant declining agricultural output and feed a growing population, particularly those non-European citizens whose restiveness is already concerning authorities in Moscow. Hence, to correct inherent ecologic degradation and decline in agricultural production will require more funds than the original investments.

Since 1987, the Soviet leaders have begun publicly recognizing the full scale of impending ecological and economic disaster. It was widely admitted that the major cause of the destruction of water quality, surface and ground freshwater intakes in river-delta ecosystems, arable land in their flood plains, and fisheries in the estuarine-sea basins is excessive river impoundment and water diversion.

In the foreseeable future, the Soviet government must spend between \$70 and 100 billion on restoration, at least partial, of water quality and fisheries of the major river-estuarine-coastal zone ecosystems of the Black, Azov and Caspian Seas. In addition, nearly \$80 to 100 billions have to be spent over the next two decades on reclamation of 7-10 million hectares of currently barren lands and to overhaul the nearly four-fifths of million kilometers of irrigation systems in South Moldavia, Ukraine, South RSFRS, Central Asia and South Kazakhstan. This expenditure does not include billions of dollars needed to relocate millions of people of the Karakalpakia Autonomous Republic and some other areas because the water they drink and the land on which they live can no longer support them. The cost in the quality of life is incalculable.

The current federal and republic environmental policy placed much emphasis toward better recognition of environmental costs and more holistic analysis on managing water quality and land in designated regions, namely: (1) the construction of new or completion of previously started projects had

been "frozen" until thorough risk assessment analysis of alternatives are available for scientific and public discussion, (for example, Danube-Dniester-Dnieper water conveyance and irrigation facilities, Volga-Chogray and Second Volga-Don canals); (2) special water releases from reservoirs, particularly when normal or above normal years of precipitation are followed by years of subnormal precipitation or dry conditions. This artificial regeneration of spring flood, even with shorter duration and truncated peaks, is considered to be of paramount importance in respect to ensuring reasonable water quality and to revive, to some extent, the aquatic life of ecosystems in question; (3) recycle treated water on suburban farmlands; (4) recycle effluent discharges in a closed industrial cycle; (5) rotation or substitution of highly water-dependent crops in semi-arid and arid zones by less water demanding crops; and (6) lining canals and using drip irrigation combined with a reasonable use of fertilizers.

However, it is not clear how these problems can be solved when under current conditions of water quality and supply, much worse than predicted ten years ago, agricultural production is now lower than at the beginning of the 1980s, and water management of hundreds of reservoirs and many hundred thousand kilometers of irrigation networks are badly maintained.

Meantime, the Soviet experience may serve as a warning signal for those of us in the free world who prefer to ignore the fact that the linear approach to water and other resources development will result not only in their depletion and contamination, but also in threatening the lives of millions of people and economic and political instability. In this regard, the water war may become the new political reality in semi-arid and arid regions worldwide.

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