TITLE: Reflections on Coastal Damage from River Mismanagement: A USA/USSR Comparison

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PROJECT INFORMATION:

CONTRACTOR: United States Global Strategy Council

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COUNCIL CONTRACT NUMBER: 804-22

DATE: March 10, 1993

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The work leading to this report was supported by contract funds provided by the National Council for Soviet and East European Research. The analysis and interpretations contained in the report are those of the author.
Reflections on Coastal Damage from River Mismanagement: A USA/USSR Comparison

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Table of Contents

Executive Summary ........................................ ii
Introduction ............................................... 1

1. The Effects of Freshwater Discharges on the Coastal Environment ........................................ 3

   Some general peculiarities of runoff alterations . 4

   Implication of Alteration of Freshwater Inflows to Estuarine and Coastal Systems of the USSR ...... 5

2. Ecological and Economic Impact of River Impoundment in the USA ........................................ 6

   San Francisco Bay ........................................ 6

   Columbia River .......................................... 9

   The Gulf of Mexico ..................................... 10

3. The Murray River Regulated System (Australia) .......... 10

4. The Nile River-Delta-Sea Ecosystem (Egypt) .......... 11

Conclusion ............................................... 13

References .................................................. 17
EXECUTIVE SUMMARY

Riverine-estuarine systems are the parts of the shelf zones of the world's oceans where contact and interaction between plants and animals and their environment occur tens to hundreds of times faster than in other areas of land and water. The influences of these changes on the physical characteristics and biological productivity of coastal areas of oceans and inland seas have been recognized by an international community of hydrologists and oceanographers both in the Northern and Southern hemispheres. Historically, the river inflow/delta outflow repels salt water intrusion, flushes the natural and humanly introduced pollutants from the delta and provides a rich supply of nutrients to the estuarine-coastal ecosystem.

Over half the global population lives within 200 kilometers of a coast. Eighty percent of the world's fish catch (about 70% in the USA and the former USSR) comes from continental shelves where valuable fisheries are composed of species directly or indirectly dependent on a volume of freshwater runoff and the timing of its discharges to the adjacent estuaries for at least part of their life cycles.

Estuaries may be defined as the intermediate, dynamic and cumulative link within the river-delta-estuary-sea ecosystem where continual variable confluence, interaction and mixing processes between river flow and seawater takes place. The inter- and intra-annual interaction of hydrophysical and biological factors in estuary-sea ecosystems has its visible climax in reaches known as frontal zones. These fronts are the most important regime-shaping phenomena and are the basis for the organic and inorganic enrichment of coastal shallows.

Water withdrawals superimposed on natural climatic abnormalities can have severe runoff depletion consequences. Inarguably, since the mid-1970s the riverine-estuarine ecosystems have experienced just that gradual water starvation. The estuaries and the southern seas of the former USSR have sustained formidable, cumulative, irreversible losses in annual freshwater supply, sediment load, organic and inorganic matter, oxygen, etc. to the detriment of flora and fauna and migration and spawning activities of semi-anadromous and anadromous fish.

Environmental degradation reached such a state across the southern portion of the former USSR, from Romania to the Chinese border, that destruction of the habitat became the Achilles heel of Soviet society which, through economic, political and social consequences, helped bring it down. The dictatorial administrative "mafia" in the USSR, coupled with unscrupulous conformists in the water management establishment, failed to integrate balanced economic planning and alternative projects into long-term ecological and economic benefits of riverine-estuarine-coastal
zones ecosystems.

This failure has triggered a 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 of over 120 million people in the south agro-industrial belt of the Black, Azov, Caspian and Aral Seas' basins. Conditions are particularly intolerable in South Kazakhstan and the Soviet Central Asian republics where ecological concerns were suppressed by the inflated economic requirements of the local ruling elite.

Comparing the ecological and economic impact of river impoundment on San Francisco Bay, one can say that this largest and most productive estuary of the Pacific coast shows similar signs of deterioration. The scale of change is only slightly less ominous than that of the northwestern Black Sea and Sea of Azov. The abnormally modified intra-seasonal runoff is similar to that in the south of the former USSR.

Unfortunately, the negative effect of freshwater losses on coastal dynamics is only part of a myriad of subtle and gross problems which follow. Some of these include the millions of tons in cumulative reduction of oxygen, sediment, organic and inorganic load lost to the system, which has triggered dramatic changes in biological productivity and fishery. Arguably, the lack of a strictly defined, environmentally and economically balanced water policy, and the use of erroneous water classification, paved the way for the current damage.

The excessive damming of rivers, coupled with irreversible water withdrawals, accompanied by irrevocable losses of enormous amounts of oxygen, organic and inorganic matter etc. are gradually throwing valuable estuarine-dependent species into oblivion. In the Gulf of Mexico, the multi-billion dollar fishery and tourism industries have sustained enormous economic losses.

River-delta-estuarine-coastal zone ecosystems are very vulnerable to disturbances by man. Salinization of estuarine ecosystems inevitably has been accelerated as in-stream flows are reduced, leading to sea water intrusion. A single-minded approach to unlimited fresh water withdrawals has eliminate balanced responses of estuaries to natural runoff fluctuations and has developed intricately negative chain reactions among many ecological, economic and societal elements of estuarine watersheds, to the detriment of seas and populations.

"All purpose" unrestrained water development in the USSR and the USA have had a common disastrous effect on water quality and quantity, waterlogging and soil erosion of delta croplands, the hydrophysical and hydrochemical regime of estuarine-sea ecosystems, fisheries quality, drinking water supply, and the living conditions of millions of people.
In Uzbekistan, Kyrgyzstan, Tadzhikistan and Kazakhstan, South Ukraine and Moldova, South Russia, and the northern Caucasus competition for scarce residual runoff has contributed to race riots. These conflicts have become economic and political issues of great importance for the European south and Soviet muslim republics, as well as for California and states bordering the Gulf of Mexico.

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

Riverine-estuarine systems are the parts of the shelf zones of the world's oceans where contact and interaction between plants and animals and their environment occur tens to hundreds of times faster than in other areas of land and water. The influences of these changes on physical characteristics and biological productivity of coastal areas of the oceans and inland seas have been recognized by an international community of hydrologists and oceanographers both in the Northern and Southern hemispheres. Historically, the river inflow/delta outflow repels salt water intrusion, flushes the natural and human introduced pollutants from the delta and provides a rich supply of nutrients to the estuarine-coastal ecosystem.

Here the micro- and macro-processes of mixing and renewal take place at time scales from a split second to days, months, and years. Man's works on land have had a substantial influence on the spatial and temporal course of these events and have thereby altered the outcome on both the short- and long-term.

Freshwater runoff and wind- and tide-induced mixing are the major factors which control the interaction of shelf surface, subsurface and deepwater masses of the coastal ecosystems. Some additional energy fluxes governing physical properties of the coastal zone are associated with short- and long-term climatic cycles of air temperature, precipitation, and evaporation over this zone. From year to year the hydrologic and climatic significance of these regime-forming factors may differ. But, in general, the variable coinfluence of these factors determines the spatial and temporal transport of sediment and nutrient load, oxygen enrichment, respiration, photosynthesis, and flushing of natural or man-induced contaminants. There is some indication that all natural variability is encompassed by a set limit of 25-30% for the parameter of interest. This work examines the consequences of exceeding this natural limit in the former USSR and the USA, especially through the acts of the last three decades.
Over half the global population lives within 200 kilometers of a coast. Eighty percent of the world's fish catch (about 70% in the former USSR and USA) comes from the continental shelf where valuable fisheries are composed of species directly or indirectly dependent on the volume of freshwater runoff, and the timing of its discharges to the adjacent estuaries, for at least part of their life cycles (salmon, shad, striped bass and sturgeon, oysters and shrimps, etc.).

According to Peters and Shaaf (cited by Mann, 1982), "about two-thirds of the total US commercial fish landings are taken within five miles of shore." This was attributed to the high density of organic matter per square meter which, in turn, is due to the maximum of macrophytes and phytoplankton biomass concentrated there.

Thus, the rich bioproductivity of this area is based on four major components: (1) volume of flow and timing of its discharges to estuaries and bays and coastal areas with their nutrients and sediment load; (2) seasonal offshore (upwelling) and alongshore transport of mixed water; (3) spatial density of microorganisms (phyto- and zoo-plankton); and (4) spatial and seasonal food limitation for larval growth.

Numerous detailed field observations and published results provided ample evidences that the mixed riverine-estuarine/riverine-inlet discharges spread far beyond the boundaries of the estuaries themselves (Almazov, 1962; Mann, 1982; Ketchum, 1983). Moreover, in the coastal zones, similar to California, where predominant wind-induced surface currents move alongshore (for example, in the spring), these water masses exert an additional dragging pressure on the mixed outflow bodies, and transport them in the same direction.

It has been found that the outflow of freshwater rivers entrains and mixes estuarine and coastal waters, resulting in a combined volume which may exceed 10 to 100 times the volume of the direct runoff discharges (Pritchard, 1967; Michailov, 1969; Baydin, 1980). The Coriolis force acting on this plume further
stimulates the vertical mixing and development of a secondary compensatory upwelling (Tolmazin, 1985) which involves a succession of large scale water and salt exchange between inland coastal basins and the deep waters of the shelf. In practice, this implies that the estuarine (lagoons) –coastal zone ecosystems experience nearly instantaneous processes of refreshment and enrichment. Consequently, the highest nutrient inputs and richest biological communities occur there. The studies of Duxbury, 1979; Hedgpeth, 1967, 1983; Kennish, 1989; Ketchum, 1983; Mann, 1982; Rozengurt and Haydock, 1981; Rozengurt and Herz, 1981; Rozengurt and Hedgpeth, 1989; Simonov, 1969 and many others support this simplified explanation.

1. The Effects of Freshwater Discharges on the Coastal Environment

Estuaries may be defined as the intermediate, dynamic and cumulative link within the river-delta-estuary-sea ecosystems where continual variable confluence, interaction and mixing processes between river flow and seawater take place. These processes result in the development of specific mixed water masses and, related to them, spatio-temporal distribution of their regime and biochemical characteristics, which provide for the unique biological productivity of estuarine organisms.

The inter- and intra-annual interaction of the hydrophysical and biological factors in the estuaries-sea ecosystems has its visible climax in reaches known as frontal zones (Bowden, 1983; Officer, 1976; Lauff, 1967; Rozengurt, 1971, 1974; Vinogradov, 1967).

The California coast is known for its pronounced seasonal upwelling, satellite photographs showing varying gyres, and for river plumes of mixed, brackish estuarine waters and shallow coastal fronts. These fronts are the most important regime-shaping phenomena and are the basis for the organic and inorganic enrichment of coastal shallows. This, in turn, has maintained the rich stock of commercially valuable fish and
shellfish. At least 75 to 85% of the historically valuable commercial catch has been related directly or indirectly (through the food chain) to these natural regime features (Skinner, 1962; Moyle, 1976).

The ability of estuarine characteristics to resist or to adjust to the temporary impact of natural external regime disturbances is based on four major fundamental principles: (1) the stochastic and stochastic-periodic nature of estuarine environment, including but not limited to, runoff and water/salt balance fluctuations, induced by tides, winds, or both; (2) dynamic equilibrium of the ecosystem's water masses and their salt content; (3) ecological continuity of the river-estuary-sea ecosystem, and (4) the biological tolerance of the living resources of estuaries. The condition of these principles is governed by runoff.

Some general peculiarities of runoff alterations

It is imperative to underscore the fact that under natural conditions the deviations of average annual or spring freshwater supplies for successive five year periods does not exceed plus or minus 25 to 30% of normal (as averaged for 55-60 years). As a rule of thumb, the unimpaired spring runoffs exceed by several times the summer or fall runoffs. (This held true for European and American rivers). Today, due to impoundment of rivers, these natural factors have ceased to exist (Rozengurt et al., 1967 a, b; Rozengurt and Hedgpeth, 1989).

The annual natural runoff of the South European and Central Asian rivers has been reduced to 60% (Volga), 40 to 50% (Dniester, Dnieper and Don), 15 to 20% (Kuban) and down to 0.5 to 3% (Amu-Darya and Syr-Darya) of normal (Rozengurt, 1991).

Since the commencement of runoff regulation, subnormal, dry and drought-like conditions have occurred 60 to 95% of the time. However, in years of subnormal or critical, natural conditions, the regulated annual runoff can be much less. In other words, water withdrawals superimposed on natural climatic abnormalities
can aggravate runoff depletion to exceed by 3 to 5 times its natural probability (the same is true for spring regulated runoff). Inarguably, since the mid-1970s riverine-estuarine ecosystems have experienced just that gradual water starvation. Hence, estuaries and the southern seas of the former U.S.S.R. have sustained formidable, cumulative, irreversible losses in annual freshwater supply, sediment load, organic and inorganic matter, oxygen, etc., to the detriment of flora and fauna and migration and spawning activities of semi-anadromous and anadromous fish. Moreover, the natural intensity and duration of the spring flood, of up to 40 days in the lower river-delta-estuary ecosystems, dropped by 2 to 3 times. In some rivers it almost ceased to exist, except in rare and unusually wet years.

In general, inverse, intra-annual runoff alteration and sanitary and agricultural releases caused a new phenomenon, namely, the current late summer-fall regulated runoff is almost equal to or higher than the spring regulated runoff.

Implication of Alteration of Freshwater Inflows to Estuarine and Coastal Systems of the USSR

Environmental degradation reached such a state across the southern portion of the former U.S.S.R. from Romania to the Chinese border that destruction of the habitat became an Achilles' heel of the Soviet society, which, through economic, political and social consequences, helped 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 U.S.S.R. 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 among 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 zone ecosystems. Four decades later this failure triggered a 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 South Kazakhstan and the Soviet Central Asian Republics (especially in the Southern part of the Aral Sea Basin) where ecological concerns were suppressed by inflated economic requirements. At present, this results in unrest among the people living in these despoiled lands and drinking polluted surface and ground waters. These and other impacts of unlimited water development and land use on the environment and economy, and, related to them, societal problems of the southern USSR, were summarized in several studies prepared for the National Council for Soviet and East European Research, Washington, DC.

2. Ecological and Economic Impact of River Impoundment in the USA

San Francisco Bay.

This largest and most productive estuary of the Pacific Coast shows similar signs of deterioration, in scale only slightly less ominous than that in the northwestern Black and the Azov Seas. Here, since the late 1960s, more than 100 dams and delta conveyance facilities have eliminated 80 to 100% of migration and spawning areas of several species of salmon, striped bass, shad, etc. Besides, unbalanced water withdrawals depleted the Sacramento and San Joaquin Rivers by up to 70% and 90% of normal spring runoff, respectively. This abnormally modified intra-seasonal runoff is similar to that in the south of the former USSR (spring runoff equal or less than summer-autumn). In California, the network of dams and extensive water diversions
for agricultural and municipal usage have withdrawn cumulatively since 1945 500 cubic kilometers (km³), or roughly 600 million acre feet, of freshwater.

Overall, if one assumes that the California coastal zone is one inseparable ecosystem (for simplicity, further discussion about the similar Oregon coastal zone is excluded) whose estuarine regime is controlled primarily by runoff and induced circulation patterns, then the following partially hypothetical calculation may shed some light on the cause of the present precipitous decline of commercial and recreational fishery in this area.

1. Since 1945 the central California coastal zone has been deprived of over 600 million acre-feet of fresh water due to diversions from the Sacramento-San Joaquin Delta system.

2. This implies that at least 5000 km³ of coastal waters have not been subjected to the former natural mixing (one part of freshwater entrains, in mixing, at least 10 parts of estuarine-coastal waters).

3. Other sources of freshwater along the coast down to Mexico ceased to exist over this same period due to construction of flood control dams and water storage facilities; for example, on the upper reaches of the Los Angeles, San Gabriel, and Santa Ana Rivers. Roughly, these losses may account for 2 km³ per year (the US Geological Survey computed that average unimpaired runoff from the northern and central California tidal inlets was nearly the same, or about 1 km³ per year each). Hence, average losses of these small streams in freshwater supply may account for approximately 90 km³ for the period of 1945-1990. By analogy with the above entrainment computation, this implies that nearly 900 km³ of coastal zone waters were not subjected to mixing and transport, and oxygen and organic and inorganic enrichment, because of river impoundment.
4. Therefore, by reasonable approximation (taking into account several dry periods and especially the drought periods of 1976-1977 and 1986-1990), the combined freshwater deficit has amounted to 600 km$^3$. Correspondingly, had these losses not taken place then at least 6000 km$^3$ of coastal water would have participated in salt and water and gaseous exchanges between the California estuarine-tidal-inlet-marine ecosystems. In light of the above, it is worth relating these "lost" volumes to the amount of water contained in the five mile coastal zone where some 90% of commercial and recreational catch has taken place (Mann, 1982).

5. The volume of the most productive water masses between the Golden Gate and Newport Bay, California, amounts to approximately to 320 km$^3$ (the straight length of coastline = 800 km, the average width = 10.0 km, and the average depth = 0.04 km). Now, if one compares this 320 km$^3$ volume of the fishery zone with the 6000 km$^3$ volume which was deprived of natural mixing processes, then the following conclusions may be drawn: the cumulative, precipitous decline of valuable fishery for the last four decades in the California coastal zone is intimately related to inland river impoundment which has not only reduced the functionality of the estuarian-sea ecosystems but also obliterated over 90% of the rich wetland and marsh habitats.

Unfortunately, the negative effect of freshwater losses on coastal dynamics is only part of a myriad of subtle and gross problems which follow. Some of these include the million tonnes in cumulative reduction of oxygen, sediment, organic and inorganic load lost to the system. Water withdrawals superimposed by the severe drought of 1987-1991 further aggravated water quality in San Francisco Bay. Needless to say, salinity in the delta alone increased 5 to 15 times. This
salinization of a formerly freshwater pool jeopardizes the current water quality supply for hundreds of thousands of human beings in Contra Costa County and may effectively shut off the agricultural delta intakes and other facilities transferring water to the Central Valley and South of California. Arguably, the lack of a strictly defined, environmentally and economically balanced water policy, and the use of erroneous water-year classification paved the way for the current agony of the Delta-San Francisco Bay ecosystem (Rozengurt et al., 1987; Chambers, 1991). As a result, salmon, striped bass, and shad all but vanished and estuarine fishery ceased to exist. Cumulative economic losses for fisheries alone in the San Francisco Bay exceeded $3.0 billion for the 1960s, 1970s and 1980s.

Columbia River (Pacific Northwest of the USA)

About 69 large dams built in the Columbia River watershed have left slightly less than four percent of the river's 1985 km length undisturbed by hydropower plants. In addition, Oregon, Washington and Idaho share over 40% of the Columbia watershed runoff. Such a scale of runoff use has curtailed migration and reproduction of sockeye, coho and chinook salmon down to less than 1 to 20% of their averages in the preceding half century (Netboy, 1981; NW Power Planning Council, 1986). Thus, the number of natural or wild salmon migrating to spawn has become dangerously low. Hatcheries could not prevent this precipitous decline in numbers of natural fish, or mitigate the fading strength and high mortality of the limited diversity of artificially reared anadromous fish. Under such conditions, neither ladders nor special elevators can lure the salmon to migrate to upper rivers to spawn. Therefore, here, as in the Dniester, Dnieper, Don, Kuban, Volga, Sacramento, San Joaquin and other rivers, the impoundment of water by the cascade of dams transformed freely running rivers and their tributaries to intermittent chains of water storages. Arguably, the excessive
damming of rivers, coupled with irreversible water withdrawals, accompanied by irrevocable losses of enormous amounts of oxygen, organic and inorganic matter, etc., are gradually throwing salmon, sturgeon, shad, and other valuable estuarine-dependent species into oblivion.

**The Gulf of Mexico (Atlantic Coast of the US)**

Similarly, the Gulf of Mexico is presently deprived of up to 40 to 90% of spring runoff from 44 rivers. At the same time Alabama, Mississippi, Louisiana, Texas and Florida discharge in summer and fall a significant volume of returning agricultural water saturated with toxic chemicals. This and industrial discharges from oil refineries and six of the nation's top seaports further aggravate the gulf's environment. About 30 estuaries provide 98% of all commercial fish caught in and beyond the gulf's rim. Note that fishery and shellfish in the region have experienced a drastic, steady decline since the late 1970s. By that time cumulative losses in freshwater had reached a hundred cubic kilometers. Today, the distortion of natural coastal dynamics has resulted in anoxia of over 3,000 square miles of bottom waters off the Louisiana and the southeastern Texas coast. Nearly 3.4 million acres (60% of the gulf's shellfish-growing areas) are off-limits to harvest because there is no runoff to flush out natural and man-induced contaminants accumulated in the gulf (Duke and Sullivan, 1990). As a result, the multi-billion dollar fishery and tourism industries have sustained enormous economic losses (Duke and Sullivan, 1990).

**3. The Murray River Regulated System (Australia)**

The Murray empties into the sea via two large shallow silted lakes, Alexandria and Albert, separated from the sea by a narrow sand dune. The average annual natural runoff amounts to 22.3 km³. The irrigation of arable land along the 2570 km Murray
River and its tributaries consumes nearly 91% of the available water. The Murray has a complex network of dams, channels, barrages, and weirs, some of which are used to deter salt water intrusion to the lower river and lakes. Here, as elsewhere, the substantial water withdrawals during the late winter-spring have significantly truncated flood peaks; the runoff decreased to 10 to 30% of normal, while the summer flow has increased (Collet, 1978). However, neither hydrotechnical complexes nor runoff redistribution were able to prevent the salinization of the lower river and delta, or regulate their erosion and siltation. Also, seasonal reduction in turbidity accompanied by increase in nutrient load triggered nearly instantaneous eutrophication. This event and temperature fluctuations (temperature shock being a typical development in any of the impounded rivers) further exacerbated deterioration of the Murray River aquatic environment.

The immediate consequence of this was the lack of oxygen (hypoxia) in layers underlying the surface water, as sluggish water circulation adversely affected intensity of renewal and the quality of residual outflow. Consequently, severe die-off occurred and made survival of fishery impossible (Cadwallader, 1978). Some attempts to mitigate the despoliation of this estuary through artificial introduction of some species appeared to be fruitless. Hence, the commercial and recreational fishery nearly ceased to exist.

4. The Nile River Delta-Sea Ecosystem (Egypt)

Before introduction of the Aswan High Dam, Nile water had been detected in the Levantine Sea as far north as the coast of Lebanon and Israel and to the south of Cyprus. The flood season usually began in mid-August, reached its climax in mid-September at a rate of 640 million cubic meters per day (m³/day) or up to 35 km³ in average until December. Several dozen miles off the Nile Delta a sharp demarkation line, known as a hydrofront,
distinguished this water from the adjoining seawater. The salinity on either side of the Nile hydrofront differed by up to 14 to 20%. The water masses within the hydrofront were also characterized by high temperature (24.2° to 26.6°) and oxygen supersaturation (120-130%) in comparison with the Mediterranean water (Aleem, 1972; Ben Tuvia, 1973). The total annual landing of pelagic and demersal fish from the Nile estuarine-coastal area was about 120,000 tonnes. Among them the annual landings of famous Mediterranean Sardinella ranged between 10,000 to 20,000 tonnes, while prawn fishery yielded up to 12,000 tonnes.

According to Aleem, 1972, Mancy, 1979 and others, such a harvest was due to a strong relationship among runoff, river-borne detritus and dissolved organic materials and fish stock. However, since the Aswan High Dam became operational in 1965 it has accumulated over 121 km³ through annual impoundment of flood waters (up to 95% in a drought). The cessation of Nile runoff was accompanied by accumulation behind the dam of 60 to 180 million tonnes of silt annually. This jeopardized the capacity of the reservoir and, at the same time, evoked downstream scouring erosion of the river bed because of intra-annual abnormal water releases from the hydropower plant and related modification of runoff velocity. A billion tonnes in cumulative losses of silt spelled the demise of the famous Nile hydrofront and facilitated the erosion of the 200 km Delta seaside perimeter and surrounding coast. In addition, the Nile Delta-coastal ecosystem has lost a million tonnes of natural organic matter which, in connection with other factors, significantly diminished the living resources of this region (Mancy, 1979; Shanin, 1985).

There has been a 96% and 99% decrease, respectively, in the catch of Mediterranean Sardinella (Aleem, 1972) and shrimp. In general the Nile runoff depletion down to 10 to 20% of normal destroyed entirely the North Africa and Near East coastal zone fishery, including 29,000 tonnes of demersal fish.

During the last decade sanitary releases of 4 to 5 km³ of Nile runoff per year to the sea has managed to support fish
yields in the range of 600 to 4,000 tonnes and several hundred tonnes of prawn. However, the delta fishery nearly ceased to exist. The delta water quality and supply are at the edge of collapse. Poisonous mixtures of salt water and agricultural and municipal discharges are an urgent problem to the Egyptian authorities responsible for the health of more than 14 million people settled in the Nile Delta alone.

**Conclusion**

River-delta-estuarine-coastal zone ecosystems are very vulnerable to disturbances by man. These are caused by upstream withdrawals of water for agricultural, industrial and domestic purposes, or pollution by industrial and sewage discharges, or agricultural drainage carrying nutrients, pesticides and herbicides from the fields, or all three. Salinization of estuarine ecosystems inevitably has been accelerated as in-stream flows are reduced, leading to sea water intrusion. The result is the current alarming deterioration of freshwater intakes in deltas and estuaries, accompanied by drastic declines in commercial and recreational fish and shellfish catch. This effect also carries over to the coastal zone where the cumulative losses of sediments and organic and inorganic nutrients are felt in the eventual destruction of coastal dependent fish and invertebrate species in areas even hundreds of kilometers from the estuaries.

In sum, the single-minded approach to unlimited freshwater withdrawals, which significantly exceeded the natural threshold of normal runoff deviations of 30%, has eliminated balanced response of estuaries to natural runoff fluctuations and has developed intricately negative chain reactions among many ecological, economic and societal elements of estuarine watersheds to the detriment of seas and population.

Reduction of runoff through river impoundment (Figure 1) ---> increase in salinity ---> decrease in organic and inorganic
WATER DIVERSION
CASCADE OF ENVIRONMENTAL EFFECTS

Figure 1
material and sediment load ---> increase in detention time --->
increase in susceptibility of estuarine-marine ecosystems to
pollutants ---> significant curtailment or elimination of
migration routes and spawning grounds and commercial and
recreational catch of semi-anadromous and anadromous fish and
harvest of other shelf zone products (shrimp, prawns, mollusks,
seaweed). Invasion and mass mortality of horrendous amounts of
foreign organisms aggravate negative conditions in many
estuaries.

Thus, "all purpose" unrestrained water development in the
USSR and USA has had a common disastrous effect on:

(1) Surface and ground water quantity and quality,
particularly in lower river watersheds;
(2) Waterlogging and soil erosion of delta croplands and
intensity of decertification of deltas;
(3) The hydrophysical and hydrochemical regime of estuarine-
southern seas ecosystems;
(4) Riverine-estuarine- marine fishery quality, drinking
water supply, and living conditions affecting millions of people;
(5) Troposphere contamination by millions of tonnes of coarse
and fine salty suspended particulates;
(6) The climatic features of more than one thousand square
kilometers of Soviet Central Asia and South Kazakhstan, and
(7) The economic and political situations in Uzbekistan,
Kirgizstan, Tadzhykistan and Kazakhstan, South Ukraine and
Moldavia, South Russia, and North Caucasus, where (for example)
competition for scarce residual runoff has contributed to ethnic
violence.1

These conflicts have become economic and political issues of
great importance for the European South and Soviet Muslim

1 (Points 1 through 4 have been addressed in detail in
Hedgpeth, 1977; Duke and Sullivan, 1990; Micklin, 1979; and
Rozengurt, 1991.)
Republics, as well as for California and states bordering the Gulf of Mexico.

Since the mid 1970s, scientific communities world-wide have begun publicly recognizing the full scale of negative modifications of estuaries and impending ecological, piscatorial and economic disasters. Many of the academic and ministerial institutions in the former USSR widely admitted that the most pervasive damage to water quality, surface and ground freshwater intakes in river-delta ecosystems, arable land in their flood plains, and fisheries in the southern estuarine-sea basins stems from excessive river impoundment compounded by runoffs from agricultural drainage networks. The municipal discharges, especially in deep waters of the shelf, are considered to play a much more limited role in despoliation of estuarine and coastal marine ecosystems.

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

In my view, any statement claiming that it is possible to restore a historical population of estuarine-dependent fish should be considered erroneous, for neither historical (unimpaired) runoff discharges, nor historical migration routes are available for spawning and fish maturity. Examples of such losses include the Columbia and Sacramento-San Joaquin River network as well as the Gulf of Mexico. Hatcheries may create the illusion of preventing the extinction of estuarine species but they cannot restore the historical level of natural fish populations.

Therefore, only economically and ecologically balanced water management can adequately guard the estuarine environment in the USA as well as in the former USSR, and protect the interests of
their water users. We cannot restore but we can preserve, and even partially enhance, the estuarine habitats if the following take place: (1) a halt in construction of new water projects until thorough risk assessment analyses and examinations of alternatives are available; (2) an artificial partial regeneration of the spring flood to revive the aquatic life of ecosystems; (3) recycling of treated water for farmlands; (4) recycling of effluent discharges in a closed industrial cycle; (5) rotation or substitution of highly water-dependent crops in semi-arid and arid zones with less water demanding crops; (6) lining of canals and use of drip irrigation coupled with a reasonable use of water and fertilizers; and (7) use of the capacities of dry creeks as retaining basins off the main river bed, to accumulate some part of excess late winter - early spring runoff in wet years for release (not for export) in dry years to provide a residual runoff to repel salt intrusion. Thereby adequate water quality in the river-delta-estuary ecosystems and optimal conditions for migration and reproduction of unique and valuable estuarine fishery could be assured.
References


