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Environmental Damage Assessment of the Aral Sea Disaster

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1

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2

Executive Summary

In the 1960's Soviet planners made a conscious decision to divert most of the water flowing in the Amu Darya and Syr Darya to irrigate nearly 3 million hectares (ha) of formerly arid lands. Some 50 billion cubic meters (50 km^3) of water no longer flowed to the Aral Sea each year, with the consequence that the Aral Sea began a steady decline. From a volume of over 1,000 km^3 in 1960, the sea now occupies a volume of well under 300 km^3.

By now it is widely understood that the environmental consequences of the water diversions are very serious. Human health, agricultural activity, living conditions, recreation and tourism, the once-abundant fisheries, flora and fauna, and the local climate have all been affected adversely.

This study develops a preliminary estimate of the economic value of the damages: some $1.25 to $2.5 billion annually. Future work can and probably should be conducted to refine this estimate, for the magnitude of some of the categories of damage is highly uncertain.

The damage estimate indicates what water is worth to the Aral Sea as the sixth consumer of water in the region (in addition to the five republics in the basin). Each cubic meter of water is worth on average the damage figure ($1.25 to $2.5 billion) divided by the quantity lost (50 billion m^3) or 2.5 to 5.0 cents per m^3.

At present many users of water in the basin pay nothing for water, and those that do pay typically pay very little. As a result, water is wasted on a huge scale. Consumptive users actually should be paying base-level charges equal to the value of water to the Aral Sea as a user, plus the additional costs of building and operating delivery systems.

If such water charges are implemented in the region, the revenues would be substantial and could be used to help restore the environment and for other governmental purposes. While many users would complain that they could not afford to pay such charges, it is largely a problem of current excessive levels of consumption and price controls imposed on the output of agricultural enterprises.

The principles of damage assessment described in this paper can be applied to other regional issues, such as the level of charges to be used when an upstream republic sends polluted water to a downstream republic, or when a point source discharges polluted waste water to surface waters.

Contents

Section **Page**

Acknowledgments ii

1 Introduction 1-1
2 Policy Context 2-1
3 Economic Principles of Damage Assessment 3-1
4 Review of Previous Estimates of Damage 4-1
5 Preliminary Damage Assessment for the Pre-Aral Region 5-1
Human Health 5-1
Agriculture 5-8
Living Conditions 5-11
Recreation and Tourism 5-12
Fisheries 5-12
Flora and Fauna 5-14
Existence of the Sea 5-14
Regional Climate 5-15
Transportation on the Sea, Power Generation and Other Issues 5-16
6 Conclusion 6-1

Appendix A: References A-1

List of Tables

Number **Page**

1-1 Aral Sea Parameters 1-1
5-1 Death by Cause 5-5
5-2 Infant Mortality 5-6
5-3 Spontaneous Abortions 5-7
5-4 Noninfectious Diseases 5-7
5-5 Dietary Indicators 5-7
5-6 Agriculture in the Central Asian Republics 5-8
5-7 Livestock Morbidity and Mortality 5-10
6-1 Probable Annual Damage 6-1

List of Figures

Number **Page**
5-1 Typhoid 5-3
5-2 Dysentery 5-4
5-3 Acute Intestinal Infections 5-4
5-4 Aral Sea Fisheries Catch 5-13

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Comments and criticism of this paper are welcome, especially via e-mail: boba@erols.com

6

Section 1
Introduction

As recently as 1960, the Aral Sea, a large freshwater lake in Central Asia, occupied an area of 66,000 km^2, including 2,200 km^2 of islands, and a volume of approximately 1,060 km^3. Its maximum water depth was 69 meters, though most of the sea was less than 30 meters deep. Historically, the Aral Sea supported a thriving commercial fishery and was a popular recreational destination. The sea and surrounding areas long have been important to migratory waterfowl.

During the 1950s, water resource planners in the former Soviet Union sought to increase cotton production in the region. By diverting most of the flow of the Amu Darya and the Syr Darya, two rivers that flow to the Aral Sea, irrigated acreage was expanded from 5 million hectares to 7.9 million ha. As a consequence, water levels in the Aral Sea fell, exposing large areas of the former sea bottom (see table 1-1). Rising salinity levels have eliminated the commercially-valuable fish in the sea. Highly saline irrigation water in the downstream provinces and wind-blown sediments from the former sea bottom have decreased the productivity of irrigated lands. Human health and welfare also are adversely affected by increased pollution and salinity of water supplies and exposure to wind-blown sediments. The 3.5 million people now living in the oblasts nearest the Aral Sea (often referred to as the pre-Aral or "disaster zone") currently have an unemployment rate of about 25%; in the districts nearest the sea the rate reaches 50%. Life expectancy in the region is reported to be 1.8 years less than the average for the surrounding nations (World Bank). In some districts closest to the sea, life expectancy averages 59.5 years, some 9 years below the average for the surrounding nations. Per capita incomes in the region are only about 60% of corresponding national averages.

Table 1-1
Aral Sea Parameters

Year	Elevation above m.s.l.	Volume in thousand km^3	Area in thousand km^2	Dry area in thousand km^2	km^3 from Amu Darya	km^3 from Syr Darya
1960	53	1062	66.09	---	37.9	21
1989	39.33	354	38.4	27.03	1	4.4
1990	38.51	323	36.4	29.04	9	3.5
1991	37.75	299	34.8	31.34	12.5	4
1992	37.26	286	33.9	32.31	28.9	4.6
1993	36.94	278	33.3	33.02	18.8	7.9
1994	36.94	278	33.3	33.02	21.7	8.9

Source: World Bank

In a very real sense, the Aral Sea competes for water with irrigated agriculture (91.6% of consumptive use) and to a much lesser extent diversions for other uses: municipal (3.6%), industrial (1.9 %), rural water supply (1.6%), fisheries (0.8%) and miscellaneous uses (1%). Depending upon the amount of rain and snowfall, in some years the Aral Sea receives almost no water, and in other years as much as 15% of the total available, but in no case more than one-third of what it received in 1960. Soviet-era planners viewed the Aral Sea as having limited

economic value compared to irrigated agriculture. The decision to divert water for agricultural use was deliberate, made with full expectation that the sea would diminish to a tiny fraction of its former size. What was not well-anticipated was the widespread economic and environmental damage that would accompany this decline.

The Aral Sea is by no means the only environmental problem of the newly-independent Central Asian Republics (CAR). Soil erosion, toxic mine drainage, agricultural drainage, industrial effluents and untreated human wastes all threaten water supplies, including important rivers that do not drain into the Aral Sea. In the larger cities, the air is polluted by industrial, municipal, and mobile sources. Radioactive tailings at abandoned uranium mines and toxic runoff from other mining operations also pose risks to health and the environment.

The purpose of this study is three-fold: (1) to illustrate how the technique of damage assessment might be applied in the CAR, (2) to develop a very preliminary estimate of the economic loss that has resulted from the decline of the Aral Sea, and (3) to show how an estimate of the environmental losses in the Aral Sea region can be used to set a base level for consumptive uses of water in the entire Aral Sea basin against which values in other uses may be compared. The numerical estimates of damage reported in this study are subject to considerable uncertainty and should be used with caution. Future research can refine these estimates as well as apply the tools of damage assessment to other environmental problems of the region, for example the charge rates for implementing the "polluter pays" principle to industrial discharges or polluted transboundary water flows.

The study is divided into several components of damage, described below. At the outset, three components were viewed as likely to provide most of the total damage: human health, agriculture, and existence value. The remaining categories of damage -- fisheries, tourism and recreation, flora and fauna, and regional climate effects -- were viewed as likely to be small and treated less exhaustively since resources for the study are quite limited. First, though, it is useful to review the policy context for damage assessment, that is how the concept is used as an instrument of governmental policy, particularly outside the CAR. The basic economic principles of damage assessment are outlined next, before turning to the actual assessment.

7

Section 2
Policy Context

Natural resource damage assessment became an instrument of US environmental policy with the passage of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). The Act, otherwise known as Superfund, established a mechanism for funding the cleanup of abandoned hazardous waste disposal sites. In addition, the Act provides for liability for damage to natural resources caused by the release of hazardous substances. Damage is expressed in terms of the costs of restoration, plus the economic value of lost services from natural resources prior to complete restoration. Human health effects are not included as part of natural resource values, Congress' view being that individuals had other remedies in court for obtaining compensation for harms that they might experience from exposure to hazardous substances. By 1996, the Department of the Interior and the National Oceanic and Atmospheric Administration had obtained settlements against responsible corporations totaling well in excess of $800 million dollars for natural resource damages. States have collected additional tens of millions under separate causes of action. Cases currently being pursued by the federal and state governments could add over one billion dollars to this total.

The State of Parana in Brazil uses the principle of damage assessment to reward upstream municipalities for sending clean water to downstream municipalities (see von Amsberg). About 75% of the value added tax collected by the state is redistributed to municipalities based on where value was added. The remaining 25% is redistributed based on other factors, one of which is the quality of water in the streams leaving the municipality. The payments are meant to compensate for the cost of providing clean water - or conversely to serve as an assessment for downstream damage caused by the release of polluted water.

Kazakstan recently passed a law establishing liability for damage to the environment caused by releases of toxic or hazardous substances. In order to make a claim under this statute, the state would have to estimate the actual damage to the environment. To date no claims have been filed. All of the republics also use a formula approach for damage assessment, under which polluters pay fines for discharges based upon schedules that assign higher rates for exceeding certain norms.

Section 3
Economic Principles of Damage Assessment

The basic economic principle of damage assessment is to determine how much compensation would be required to restore individuals to the economic condition they were in prior to the damage-causing incident. For example, if one's home were destroyed, one way to estimate damage is the cost of building the home plus the value of interim lost use. However, the owner might be willing to accept a lesser sum if the original structure were valued by the owner at less than the cost of construction. Conversely, an owner might value his home at more than the cost of rebuilding it. Many factors could contribute to a difference between the compensation demanded and the cost of restoring the structure. The owner might have planned on moving; the structure might have had defects in design; or the neighborhood may have changed such that the owner would rather have a lesser sum of cash than a replacement home. Conversely, the home may have sentimental or other values that a replacement home would not have.

The previous example illustrates the damage function approach, in which damage is calculated in physical terms and the physical effects then valued in monetary terms. Once physical effects are known, economics has a variety of valuation techniques. One method is the cost of replacement, where that is possible. A second asks individuals what compensation they require to accept the damage. Other techniques also appear in the literature, such as assessments based on lost wages and the costs of treating an illness (which do not necessarily restore an individual to the pre-damage condition), and hedonic analysis (which uses statistical analysis to estimate implicit prices for characteristics of market commodities).

Other than the damage function approach, one could ask individuals directly what they would be willing to do to reduce releases of pollution or improve environmental quality, without actually quantifying damage in physical terms. One might also analyze averting behavior to estimate the value of changes in environmental quality.

This study will rely on the damage function approach. While the damage function approach is the most commonly used technique, it has definite limitations, particularly in terms of its ability to measure losses to the flora and fauna or to determine the existence value of the Aral Sea. These categories of loss are best measured through a survey instrument that asks individuals (1) what they would be willing to pay to have or protect such resources, or (2) the compensation they demand to accept the loss, the so-called "willingness to accept". Future research might be directed, among other things, at improving estimates of damage for these categories. The principal advantage of the damage function approach is that damage for most categories of loss can be estimated relatively easily using existing data, particularly when the physical effects are valued in monetary terms with the technique of benefits transfer (the use of value estimates generated outside the study area, after adjusting for differences in price and income levels between the study area and the region where the estimates were originally made).

Section 4
Review of Previous Estimates of Damage

Several early attempts to assess the economic value of damages associated with the sea's recession date to Soviet times and are summarized by Micklin. A 1983 report by Gerasimov and others estimated that the annual damages in the delta of the Amu Darya totaled about 92.6 million rubles (probably in the range of $40 million, though there is no reliable ppp dollar/ruble exchange rate for that time), distributed among agriculture (42%), fisheries (31%), hunting and trapping (13%), river and sea transport (8%), and living and working conditions (6%). Without offering any explanation for the estimate, Kovalev suggested the annual losses in the entire Aral Sea region were 1.5 to 2 billion rubles ($600 to $800 million). Dukhovny and Razakov, apparently basing their estimate on the earlier work of Gerasimov et al., reported the social product losses in the Amu Darya delta were 100 million rubles per year due to lower groundwater levels, reduced productivity in agriculture, fisheries losses and the like. In 1990 Glazovsky argued that the economic losses were equal to the costs of restoration, or a total of 37 billion rubles (about $15 billion).

No comprehensive assessments of damage have appeared since, though the World Bank, UNDP, state agencies in Uzbekistan and Kazakstan, and others have examined several types of physical damage, water supply and drainage costs, restoration costs, and the like for parts of the region. These reports along with earlier Soviet assessments provide the starting point for the present study.

The Soviet damage assessments are useful in terms of identifying many of the principal categories of damage. It should be recognized, however, that the Soviet methods for calculating benefits are inconsistent with currently-accepted techniques of benefit-cost assessment, within which damage assessment is simply an estimate of foregone benefits. Prices were administered in the Soviet system, not determined by supply and demand in markets. In some cases world market prices and administered price levels differed by much more than one order of magnitude. Some valuable resources were totally unpriced (e.g., water). Adverse health effects, when they were valued, were in terms of the discounted value of future earnings, not willingness to pay to avoid. Thus, lives of the elderly, the very young, and housewives all would have low or negligible value under Soviet-style valuation techniques. Willingness-to-pay gives much different (and higher) results.

Section 5

Preliminary Damage Assessment for the Pre-Aral Region

5.1 Human Health

5.1.1 Basic Approach

With the damage function approach, generally it is necessary to go through five steps to obtain a monetary estimate for human health effects:measure the release of pollutants; determine the resulting impact on ambient environmental quality;

- measure the release of pollutants;
- determine the resulting impact on ambient environmental quality;
- estimate exposure;
- quantify health effects;
- estimate the economic value of the health effects.

In the following analysis, data generally are entirely lacking or very deficient concerning the first three steps. Nonetheless, by comparing health status observed in the disaster zone with health status outside the zone, one can roughly estimate the likely impacts. The main problem with this approach is that there could be confounding factors that affect health differently within the disaster zone and in the neighboring countries as a whole. For example, within the disaster zone incomes are lower, which probably leads to poorer health, other things equal. Of course, the Aral Sea disaster may be largely responsible for the lower incomes in that zone, so the health attribution may still be appropriate.

Some morbidity problems in the area may be attributable to natural and man-made radioactivity or other factors that have nothing to do with water diversions. For example, cesium 137, a potential carcinogen which may be a result of nuclear weapons testing, has been detected in Aral Sea water in concentrations ranging from 0.33 to 0.72 *u*Cu/l and in the former sea bed at concentrations ranging from 740 to 1140 *u*Cu/l.

A number of studies have attempted to identify the principal health effects in the region that might be linked scientifically to the decline of the Aral Sea. In large part these studies are based on official health statistics reported by each of the Central Asian republics, which may be used in conjunction with known or suspected mechanisms of disease causation to attribute some observed health effects to the sea's decline. For example, wind storms are known to blow sediments from the former sea bottom into areas of human habitation. Inhaling such airborne particles might be expected to increase the incidence of bronchial diseases, something that is reflected in official health statistics. Poor sanitation and hygiene are often associated with outbreaks of acute infectious diseases such as typhoid and dysentery.

Once excess incidence of certain diseases is identified and a plausible medical mechanism given, the next step is valuation. For both mortality and morbidity effects, three valuation techniques appear widely in the literature: cost of illness, cost of illness plus foregone earnings, and willingness to pay to avoid risks. The cost of illness approach was popular two or three decades ago and is still used to some extent today. It values morbidity and mortality in terms

11

of the economic outlays for treatment, such as hospitalization and drugs. While this approach has a number of advantages such as ease of measurement, it also has some very serious deficiencies. It does not incorporate any amount for the loss of economic output when a person is sick, nor does it measure non-economic contributions to the family and community, nor does it incorporate any sum for pain and suffering on the part of the ill person. Under this valuation system, a traffic fatality would have very little cost, for example.

The present value of lost future earnings is a technique frequently used to value mortality effects. Future earnings can be estimated with some reliability and understood by juries; consequently the method has been widely used to settle claims from airplane accidents and related incidents. A problem for the method comes when one attempts to value the lives of individuals who have no visible future income stream. The method also is not very democratic, for it places a much higher value on well-paid middle aged individuals than on low-paid workers, children, housewives, or those near or in retirement. The method also makes no allowance for pain and suffering before death.

A third method, willingness-to-pay, uses surveys (interviews) or indirect methods to determine what individuals would pay to avoid adverse health outcomes. Direct surveying is self explanatory; one simply describes an adverse health outcome and asks a randomly-drawn sample of individuals what they would be willing to pay to avoid the outcome. Results tend to be more believable if the sample is predominantly individuals who have experienced the effect in question. Indirect (hedonic) methods based on statistical analysis of wages paid in occupations of varying risk have been used to estimate what individuals receive in compensation for accepting small increases in the risk of death. While the range of estimates in US and Western European studies is fairly large, a consensus has developed that a one in one thousand chance of death is valued in those regions at $1,500 to $7,000, implying that a the probability of one death (sometimes termed a "statistical life") is worth between $1.5 million and $7 million, with a mid-range estimate of about $3 million. In fairness, it should be pointed out that some agencies use higher (as well as lower) values. For example, the US EPA recently used a mid-range estimate of $4.8 million in its retrospective examination of the benefits of the Clean Air Act. While there is not general agreement yet among economists on this next step, single life years could be valued by dividing this amount by life expectancy, yielding an average value for one additional year of life of about $40,000. An additional adjustment would recognize that the value of life studies typically focus on workers in the prime of life -- with average life expectancy of about 30 years. Consequently, the value of a life year (at least to healthy workers) might better be approximated as $3 million divided by 30 years, or $100,000. Some studies continue to use a value of several million dollars for any premature death, but surely the age of death should matter to the individual and to society. The death of someone who has most of their life in front of them seems much more significant, and consequently more worthy of preventing, than the premature death of someone in the last weeks or days of life.

Estimates for the willingness to pay to avoid risk and the associated value of one life year could be developed separately every time this concept is applied in a new geographic part of the world. An alternative and much less expensive approach is to adjust US and Western European estimates for differences in ppp incomes, a technique termed "benefits transfer." For example, ppp incomes in Kazakstan are now reported to be the equivalent of approximately $3,000, about one-eighth the level of the US and Western Europe. Consequently, the loss of

one life year in Kazakstan would be valued at one-eighth of $100,000, or $12,500, and a statistical life would be valued at $375,000. In the immediate region surrounding the Aral Sea, home to 3.5 million people, ppp incomes in Qyzylorda are about $1,800, implying a value for one life year there of about $7,500 and a value for one "statistical life" of about $200,000. In Karakalpakstan ppp incomes are about $1,200, implying a value for one life year of about $5,000 and a value of one statistical life of $150,000, based upon the life expectancies in the respective areas.

5.1.2 Discussion of Potential Impacts on Health

Diversion of water for upstream agricultural uses could lead to several types of health effects in the pre-Aral region. Upstream diversions affect the quantity and quality of water received by downstream users. Reduced quantities could lead to serious health consequences in a number of ways: inadequate water supplies for basic human consumption needs; inadequate water supplies to dilute and carry wastes safely; and fine-particle dust storms whipped up from the dry seabed. In the pre-Aral region there is evidence that as water supplies diminished in the 1960s and 1970s, sanitation deteriorated and infectious disease increased. People washed themselves less frequently; washed food less before cooking and eating it; and had less water to carry wastes away from human settlements. With the decline in sanitation came major adverse impacts on human health.

Bacterial contamination is a recognized problem in waters of both the Syr Darya and the Amu Darya. Only about 10% of potable drinking water requirements, where approximately 30 liters/day are considered "required" for basic human needs, are available in rural areas near the Aral Sea. Until very recently, over 90% of the population in the region relied on irrigation water for drinking water supply at least part of the year. Though declining in all of the Central Asian Republics, the incidence of typhoid and hepatitis in the oblasts bordering the sea remains five times the average for all of Uzbekistan or all of Kazakstan.

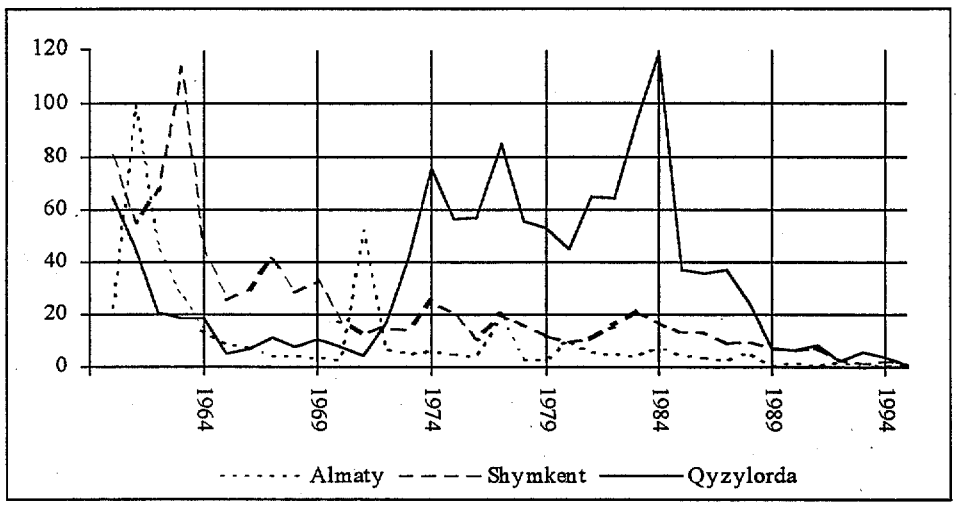

Figure 5-1. Typhoid. Rate per 100,000.

Decreased water deliveries to downstream republics were followed by sharp increases in the rates of infectious disease. Figure 5-1 portrays the incidence of typhoid in three regions: Almaty, Shymkent and Qyzylorda. In the early 1960s, the incidence of typhoid was higher in Almaty and Shymkent than in Qyzylorda. During the 1970s and well into the 1980s the inci-

dence of typhoid soared in the downstream republic of Qyzylorda while it was being brought under control in Almaty and Shymkent. By the 1990s, the rate had fallen to very low levels in all three areas, indicating that the disease had been brought under control. Whatever adverse impact that downstream water deliveries had on the incidence of this disease had been counteracted by health department actions.

During the period 1960 to 1995, the incidence of dysentery fell by about 90 percent in Almaty and by about 80 percent in Shymkent and Qyzylorda (figure 5-2). All three areas have comparable rates for the disease today. As was the case for typhoid, dysentery peaked in Qyzylorda in the mid-1970s. In the 1960s, the rate of acute intestinal infection was about twice as high in Qyzylorda as in Almaty and Shymkent (figure 5-3). While the incidence of acute intestinal disease has declined markedly in all three areas, by the 1990s the rates in Qyzylorda and Shymkent were between 3 and 4 times the rate observed in Almaty.

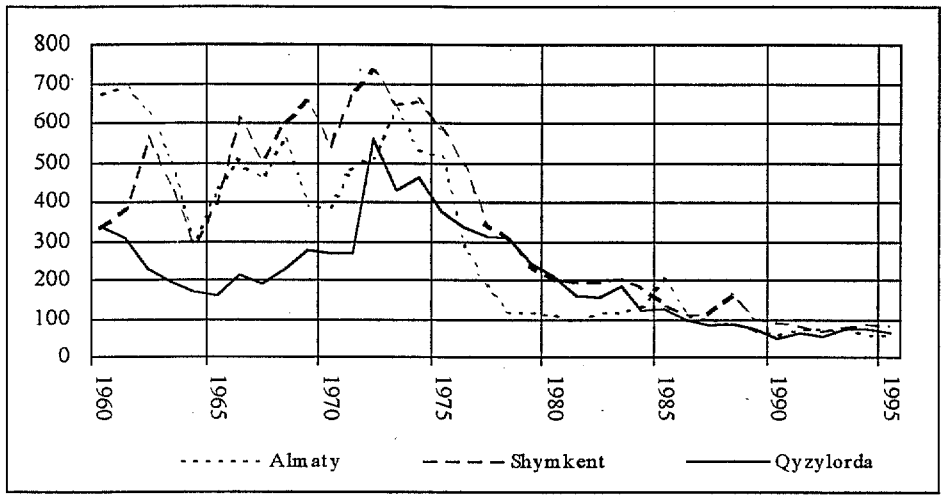

Figure 5-2. Dysentery. Rate per 100,000.

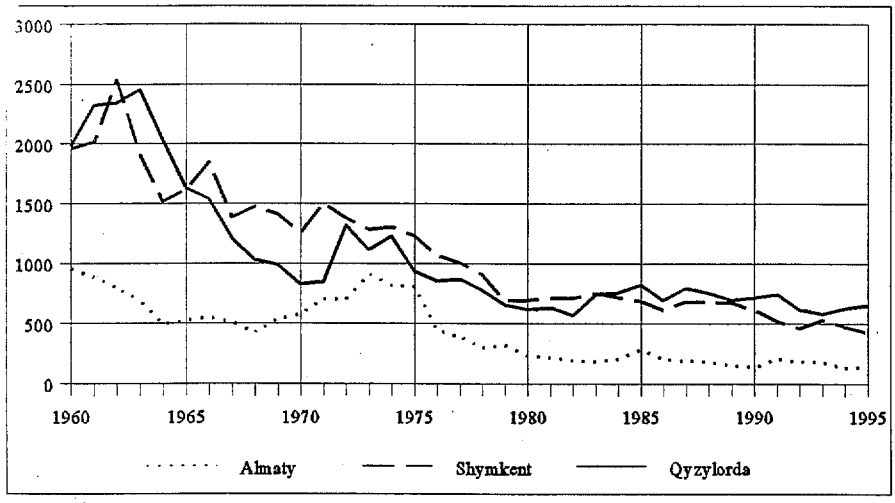

Figure 5-3. Acute Intestinal Infections. Rate per 100,000.

The cumulative evidence presented in figures 5-1 through 5-3 shows that a great deal of progress has been made in dealing with infectious diseases. While the incidence of some of these diseases rose during the 1970s and may be attributable to the water diversions, public health officials have responded successfully to the threat. The primary impact of the water diversions today may be more in terms of expenditures for health care than in terms of continuing adverse impacts from infectious disease.

Noninfectious disease is also a concern, but it is much less well studied. Water that is contaminated with agricultural runoff containing salts, pesticides, herbicides and fertilizer residues could potentially cause a range of diseases. While the mechanisms for noninfectious disease are not well understood, public health statistics in the pre-Aral region suggest a range of adverse effects.

The following table presents a comparison of death rates by cause for Qyzylorda and all of Kazakstan. While the health statistics show a lower crude death rate per 100,000 people in Qyzylorda than in Kazakstan as a whole, birth rates in Qyzylorda have been much higher than for the country as a whole, leading to a younger age distribution. In 1989, life expectancy in Qyzylorda was 66.9 for both sexes, 62.9 for males, and 70.8 for females. For Kazakstan the corresponding figures, also for 1989, were 68.7, 63.9, and 73.1. In Qyzylorda diseases of the respiratory system stand out as an anomaly that likely is explained by environmental conditions.

Table 5-1
Death by Cause

	Kazakstan (per 100,000)	Qyzylorda (per 100,000)	Qyzylorda as % of Kazakstan rate
All causes	955.3	798.1	83.5
Diseases of circulatory system	459	337.4	73.5
Accidents, murder, etc.	125.6	75.1	59
Malignant neoplasms	134.3	95.8	71.4
Diseases of respiratory system	87.9	130.2	148.1

Although DDT use in the CAR had been discontinued by 1988, soil pollution continues to be a problem. Some root crops in the early 1990s reportedly contained 12 times the DDT concentration allowed. Water in the lower Syr Darya contains high concentrations of copper and zinc (over 10 times the average in Kazakstan), likely the result of upstream mining activities.

Downing reports that the documented health consequences from the decline of the sea include high rates of cancer, stillbirth and genetic abnormalities, impaired immune function, chronic gastritis and cardiovascular disease. Available oblast data only partially support this contention, though, so the economic analysis in this paper will be limited to a subset of these effects.

In Nukus, cancer of the esophagus, which may be linked to diet as well as environmental factors, is about six times the average in Turkmenistan. Infant mortality, which could have many causes, was greater than 50 per 1,000 live births during the 1970s in the oblasts bordering the sea. With a US infant mortality of 9.1, a rate of 17.8 in the Russian Federation, and rates as low as 7 common in Western Europe, some authors have cited high infant mortality as one consequence of the sea's decline, with acute infectious diseases the principal cause of infant death.

Infant mortality rates in Qyzylorda oblast, which contains the lower Syr Darya and its delta, have historically been higher than in the Republic of Kazakstan as a whole. Within the Aral and Kazalinsk rayon, nearest the sea, the infant mortality rate was more than 50% above that of the country as a whole as recently as 1976. Recent trends show improvement in infant

mortality in all regions, with the difference between the rayons nearest the sea and the rate for Kazakstan as a whole narrowing to about 10%.

Infant mortality in the autonomous republic of Karakalpakstan, while showing improvement since 1985, remains about 40% above the rate for Uzbekistan. The data support the contention that infant mortality is related to proximity to the Aral Sea. The crude birth rate in the Aral Sea region is approximately 30 per 1000 population, indicating some 105,000 births annually among the 3.5 million inhabitants. With an excess infant mortality of 12.6 per 1000 in Karakalpakstan and 2.7 per 1000 in Qyzylorda, approximately 900 infant deaths could be considered "excess." These lives lost are valued along with other causes of premature death as part of a life expectancy calculation later in this section. The Dashkovsky region, though not physically bordering the sea, is the closest part of Turkmenistan to the sea; while it might be expected to show some effects in terms of infant mortality, it has a high rate, but less than that of the rest of Turkmenistan.

Table 5-2
Infant Mortality
(children under one year of age, rate per 1000)

	1978	1985	1990	1993	1994
Kazakstan	36	30.1	26.4	28	26.8
Qyzylorda	48.4	32.7	31.7	30.6	29.5
Aral	62.1	32.1	35.4	N/A	29.9
Kazalinsk	68.2	34.2	29.7	N/A	28.6
Uzbekistan	45.6	43.5	34.6	32	N/A
Karakalpakstan	45.8	59.2	49.1	44.6	N/A
Turkmenistan	45.9	58.4	55.9	57.8	N/A
Dashkovsky	58.1	59.2	55.6	52.1	N/A

source: Ministry of Health, Oblast Health Management Committee

Other health indicators also suggest possible links to the decline of the sea. From 1985 to 1994, the rate of spontaneous abortion (miscarriage) in Qyzylorda increased by approximately 70%, with the highest rates observed in Aral and Kazalinsk Rayon. In those districts, spontaneous abortion rates were more than twice the birth rate, whereas in Qyzylorda, which includes both Aral and Kazalinsk, the spontaneous abortion rate was only about 10% higher than the birth rate.

Table 5-3
Spontaneous Abortions
(per 1,000 women of child-bearing age)

	1985	1990	1994
Kazakstan	N/A	N/A	48.2
Almaty Municipality	N/A	N/A	71
Qyzylorda Oblast	21	30.3	35
Kazalinsk Rayon	40.3	76.4	72.7
Aral Rayon	42.5	37.4	65.6

source: national health statistics cited in Church and Koutanev

Patterns of some non-infectious disease suggest the decline of the sea may be a causative factor. Heart disease, gastroenteritis, circulatory disease, gallstone, ulcer and hypertension reportedly all showed large increases from 1970 to 1993 in the area near the sea (note, however, that changes in reporting methods and coverage may be responsible for much of this measured increase in disease incidence). Throat cancer exhibits a remarkable correlation with location. In 1993, the incidence per 100,000 was 13.6 in Kazakstan, but 65.2 in the Aral Rayon and 32.3 in the Kazalinsk Rayon.

Table 5-4
Noninfectious Disease (rates per 10,000 population)

	DISTRICT	1970	1993
Heart disease	Qyzylorda Oblast	33.8	116.9
Gastroenteritis	Qyzylorda Oblast	14.3	65.5
Circulatory disease	Aral Rayon	258	2217
Gallstone	Aral Rayon	6.3	378
Ulcer	Aral Rayon	6.3	188
Hypertension	Aral Rayon	128	1331

Certain public health indicators suggest diet is a contributory cause of poor health. In Aral and Kazalinsk, 40% of pregnant women are reported to be below ideal weight, with as many as 70% of pregnant women suffering from anemia. Total protein consumption in Qyzylorda is well below recommended limits, as is consumption of vegetable products and many vitamins. Excessive salt consumption (from contaminated drinking water supplies) may be linked to hypertension and circulatory disease. Poor diets may be linked indirectly to the decline of the sea through job loss (60,000 jobs directly or indirectly connected to the Aral Sea fishery have been lost, 50% unemployment in the disaster zone) and worsening economic conditions.

Table 5-5
Dietary Indicators (percent of recommended daily intake)

	Kazakstan	Qyzylorda	Kazalinsk	Aral
Total protein	88	79	69	66
Vegetables	N/A	41	30	30
Vitamin A	71	73	30	17
Vitamin B2	73	73	55	50
Vitamin C	47	67	13	19

Mortality Valuation. The shorter life expectancy of the 3.5 million people living in the Aral Sea region (some 1.8 years less than the national averages for Kazakstan and Uzbekistan) may be caused by a number of factors, but it appears that directly or indirectly the decline of the sea is the root cause of much of the change in life expectancy. This study assesses a range of one-half to all of decline in life expectancy as attributable to water diversions and the decline of the Aral Sea.

The economic loss is valued in terms of willingness to pay, some $100,000 per life year in the US and an estimated $6,500 in the Aral Sea region (a regional average of the earlier calculation). Using the figure of 1.8 fewer years of life expectancy, each resident of the region loses $11,700 in life years over a lifetime, or $180 per year. The upper bound estimate of regional

mortality losses is $11,700 x 3.5 million = $600 million per year, and the lower bound one-half of that, or $300 million per year.

Morbidity Valuation. A number of potentially important morbidity effects were described above. As was the case for mortality, the damage function approach first quantifies the effects in physical terms then values these effects in economic terms. The principal morbidity effects noted by other analysts who have surveyed the region include spontaneous abortion, heart disease, certain cancers, ulcers, gallstones and hypertension. While it is difficult to quantify the incidence of these effects and how incidence rates were affected by the water diversions for irrigation, the data certainly suggest that effects are real and significant. Most economic evaluations of complex health phenomenon suggest that mortality effects have a greater significance than morbidity effects, often two to five times as much. Consequently, morbidity effects will be valued at what is viewed as a lower bound estimate of $100 million annually (about $30 per inhabitant of the region and one-sixth of the estimated mortality effect).

5.2 Agriculture

About 7.9 million hectares are now under irrigation in the Aral Sea basin, up from approximately 5 million hectares in 1960. To irrigate this additional area required a near-doubling of water withdrawals. Lands brought into cultivation since 1960 typically have been lower in quality and have required more water per ha. Agriculture accounts for a significant share of total GDP in each of the five CAR republics, though its relative importance is declining. Irrigation clearly is important in the CAR: except in Kazakstan, most agricultural activity is heavily dependent upon receiving supplemental water.

Table 5-6
Agriculture in the Central Asian Republics

	Kazakstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan
Arable area (M ha)	39.6	1.4	0.8	1.27	4.5
% Irrigated	6.1	76.4	86.3	100	93.3
1990 GDP ag. share	41.8	43.1	36.7	47.9	37.2
1993 GDP ag. share	20.8	32.7	15.4	11.3	22.9

source: World Bank publications

Annual agricultural withdrawals from the Syr Darya, Amu Darya and their tributaries in 1960 were approximately 60 km^3, an amount that in average years gave the Aral Sea about 55 km^3, and sustained it at 53 meters above sea level. In years of average rainfall, withdrawals now total more than 105 km^3 per year, leaving the sea less than 10km^3. The World Bank observes that current irrigated agricultural activities are not sustainable. Three key factors contribute to the lack of sustainability: excessive water consumption in the upper and middle reaches of the Amu Darya and Syr Darya; increasing salt concentrations in the upper layers of agricultural soils; and disposal of drainage water.

The increased diversions of water for agricultural use have direct effects on the agricultural sector (increased agricultural output) and indirect effects (excess watering that brings saline groundwater close to the surface; saline return flows applied to downstream fields resulting in salt accumulation, lower productivity and eventual abandonment of some lands; associated

pesticide, fertilizer and herbicide use that contaminates soils and return flows; wind-blown sediments from the former sea bed that contaminate agricultural lands in the region nearest the sea). Several of these indirect effects result in damages to the agricultural sector and therefore are of interest for this study.

Throughout the Aral Sea basin water historically was used quite efficiently. With the large scale water diversions of the 1960s, water use efficiency began a major decline. Water use efficiency is important, for it explains the rise of groundwater levels, contamination of groundwater, the increase in soil and water salinity, and the significant abandonment of land due to secondary salinization. Water use efficiency has several components: the efficiency with which water is conveyed via canals to farms, estimated at 73% basin-wide; the efficiency with which irrigation water is applied to fields; seepage losses from on-farm canals; and the efficiency with which salts are leached from soils after the growing season. Reported field application efficiency ranges from 60 to 85%, with values in the 62-73% seen in World Bank country reports.

High water tables draw salt from lower levels to the surface through capillary action. Unless the accumulating salts are flushed or leached from the soil, agricultural productivity will fall and the land eventually will no longer be usable for agricultural purposes.

Irrigation water quality is a source of concern, with salinity of critical importance. Mg is the dominant cation in river water, with both Na and K levels high during the summer growing season. During years of low river flow, Na is likely to be toxic to crops, particularly if water is applied by sprinkler. In many of the downstream agricultural areas, natural river flows are mixed with agricultural drainage water. In some fields, drainage water is the most important source of irrigation water. Salt and chemical-laden irrigation water can contaminate formerly productive agricultural lands. Without adequate leaching (which in turn can adversely affect downstream users), land can become unfit for agricultural use.

Impacts on agriculture from wind-blown sediments from the former sea bottom are an issue of potential concern. Impacts can be observed in livestock as well as in crops. The following table, developed from official government statistics, shows that while livestock in the immediate vicinity of the sea have what seem to be high morbidity and mortality rates, virtually the same rates are observed throughout Kazakstan. From these data it is difficult to argue that the health of livestock has been measurably affected by the loss of the Aral Sea. Other analysts cite open sores in animals' mouths caused by excessive salt consumption and assert that eating habits and weight gain are adversely affected.

In Uzbekistan some 25,000 to 30,000 ha of former agricultural lands might be officially classified as abandoned, as they are in an "ameliorative reconstruction" stage awaiting leveling, rebuilding of canals and flushing of accumulated salts. A resolution from the cabinet ministers is required to officially take land out of production. Since such a resolution is not easily obtained, the classification "ameliorative reconstruction" understates the extent of the problem; a total of 100,000 ha might be termed "not productive." The cost of reconstructing lands, borne by the government, typically averages between 15,000 and 20,000 sum ($300 to $400) per ha. Each year the government tries to reconstruct 50,000 ha, (indicated cost: $15 to $20 million). Some portion of this cost could be attributed to agricultural water diversions.

Table 5-7 Livestock Morbidity and Mortality (annual rates per 1000)								
	1970		1980		1990		1994	
	Morb.	Death	Morb.	Death	Morb.	Death	Morb.	Death
Cattle:								
Kazakstan	32	2	30	2	30	3	41	5
Qyzylorda	35	2	29	3	37	5	34	5
Aral	N/A	2	50	4	49	2	77	9
Kazalinsk	N/A	4	53	5	41	4	41	6
Sheep:								
Kazakstan	26	5	34	8	38	9	62	18
Qyzylorda	26	6	27	7	30	8	43	15
Aral	N/A	5	20	6	14	4	41	19
Kazalinsk	N/A	4	29	7	19	9	56	23
source: Ministry of Agriculture								

A more significant effect is the declining productivity of agricultural lands caused by saline drainage flows from upstream fields. Productivity of grazing lands in the Aral basin has dropped to between one-half and one-third of 1960 levels (Batalova). In the 1960s, the 350,000 ha then under cultivation in Karakalpakstan produced cotton yields ranging from 2.7 to 2.8 metric tons per ha, while the 200,000 ha then under cultivation in Khorezm yielded between 3 and 3.2 metric tons per ha. Productivity in Karakalpakstan has since fallen to between 1.9 and 2 metric tons per ha, while in Khorezm yields now range between 2.4 and 2.5 metric tons per ha.(Ministry of Agriculture, Uzbekistan). The decrease in productivity ranges from 20% to 25%. If one uses world prices to value the crops grown in the two provinces, the total decline in agricultural productivity is about $350 million per year in Uzbekistan. Perhaps one-half of that amount also is lost in Kazakstan due to declining agricultural productivity; a much lesser amount is lost in Turkmenistan. Based on these calculations, total regional damages for the agricultural sector probably range from $500 million to $600 million per year.

TACIS (1995) provides an alternative and equally rough estimate of the potential losses in agriculture due to improper use of water: $400 million annually in the piedmont regions and $800 million annually in the plains (lower reaches of the Amu Darya and Syr Darya). The TACIS estimate includes losses of water due to low efficiency, nutrient losses due to leaching, drainage and pumping costs, yield losses due to salinity, and credits for subsurface irrigation due to higher water tables. TACIS suggested that yield losses due to salinization in the lower reaches of the two rivers could be in the range of $700 million annually.

5.3 Living Conditions

The 3.5 million inhabitants of the disaster zone experience adverse health effects, lower incomes and unpleasant living conditions as a consequence of the upstream water diversions. Health effects are valued separately. Most income impacts should be indicated in the agricultural and fisheries losses. There remain a number of impacts on living conditions, however, that are not indicated by either income statistics or as health effects. Among these effects are the need to travel greater distances for potable water, the need to consume water with inferior taste or smell (apart from any health considerations), unsanitary living conditions (apart from

any impacts on health), the frequent dust storms that must be endured, and local climate changes (especially hotter summers).

While salt-laden dust storms have been recorded in the vicinity of the Aral Sea since the beginning of this century, and probably have been a feature of central Asia long before humans arrived, recession of the sea and drying delta areas exposed large areas with deposits of chloride and chloride-sulphate salts and increased the transport of salt and other chemicals. Wind-blown aerosols contain from 1 to 10% salt, with lower salt contents associated with higher velocity winds. Higher velocity winds pick up larger particles that are only partially covered with salt; at lower wind velocities the salt concentration of aerosols tends to rise.

Between 1960 and 1980 the region experienced a high frequency of dust storms and movement of surface soil layers. An initial estimate developed by researchers in Leningrad of 15 million metric tons of transported aerosols was subsequently revised upward to as much as 65-108 million metric tons by scientists in Kazakstan and 43 million metric tons by scientists in Uzbekistan. From 1980 to 1995, wind storms have been less frequent and top layers of soil more stable. While some traces of salt-bearing aerosols may be detected more than 1,000 km from the sea, only land up to 300 to 500 km from the sea and covering an area of approximately 500,000 km^2 is affected to any meaningful extent by salt deposition. The region where measurable economic impacts from saline deposition may be expected probably is limited to 30-50 km from the former shoreline. Salt-laden dust storms clearly affect living conditions near the Aral Sea. Losses of wildlife and vegetation also make the area a less pleasant place to live.

Experiences of foreign missions that have brought potable water supplies to the area indicate that individuals are willing to pay 2% to 5% of their income to have accessible supplies of relatively pure water. Clearly much of this is for perceived health benefits, but other values attach to not having to travel as far and avoiding unpleasant tastes.

Outside the area most severely affected by dust storms, living conditions are better, but still clearly affected by the sea's decline. This study assumes that eliminating these adverse effects on living conditions in the entire disaster zone would be worth between 10 percent and 20 percent of ppp incomes of the 3 million inhabitants in that area, or some $250 million to $500 million annually.

5.4 Recreation and Tourism

While not presently important as a destination for foreign travelers, the many historic structures in the Aral Sea basin could be developed as such if some of the environmental problems were addressed (UNEP, 1992). The sea, as well as the wetlands and areas immediately adjacent to the sea were important recreation areas before large-scale water diversions lowered the level of the Aral Sea. Historic measures of recreational use of the area (for hunting, fishing, and bathing, etc.) are a starting point. With increasing population in the CAR and (perhaps) income and the opening of the entire CAR region to foreign visitors, recreation and tourism should have increased from historic levels (the study must make a projection, possibly guided by expert opinion). Of course, recreation and tourism now are almost nil, due to the serious environmental problems near the Aral Sea (and possibly other factors). Tourism and recre-

ation can be valued in terms of unit day values based on expenditures (though this is an imperfect measure, better measures such as contingent valuation and travel cost probably would not be feasible given the time and budget limitations for the study).

The city of Aral was an important tourist destination until the 1960s. Trains brought vacationers from Moscow, who enjoyed sunbathing, swimming, and locally-grown fruits and vegetables. The basin has considerable potential for recreational and tourist development. Impressive monuments of international repute are located in Bukhara, Khiva, Kun Urgench, Samarkand, and Turkestan. Numerous fortresses and ruins of past civilizations lining the ancient Silk Road are of great historic and scientific interest. Mineral spas and medicinal muds that might alleviate certain ailments are to be found at Nukusskoe, Andreevskoe, Sultan Sandisar and Goek Ata Lake. With an abundance of sunshine and 200 warm days each year, these destinations have the potential to become regionally as well as internationally important tourist destinations. However, access, both at international borders and in terms of local infrastructure would have to be improved, and the environmental situation at the Aral Sea resolved, for this to become a reality.

While there currently is some very limited tourist activity in the region, resolving the Aral Sea crisis is likely to be a key factor if those numbers are to increase. How much the Aral Sea crisis depresses tourism relative to other factors is very difficult to assess. The potential economic value of tourism and recreation is undoubtedly large but very difficult to determine. While other analysis may wish to use different assumptions, there appears to be very little upon which to base an estimate of how much the Aral Sea crisis affects tourism other than informal interviews and personal impressions. If one assumes the crisis reduces annual visitation by 100,000 tourists from the five Central Asian Republics (and values each visit at $250) and another 10,000 international tourists (valuing each visit at $2,500), the potential value of losses to tourism would be $50 million annually.

5.5 Fisheries

In 1960, the Aral Sea was best described as a slightly saline fresh water lake. Freshwater species of fish from the two tributaries to the Aral Sea adapted to the mildly saline environment. Historically, the Aral Sea supported an active commercial fishery, with the catch ranging between a low of 25,000 and a high of 45,000 tons per year between 1930 and 1963. Over 500 small fishing boats operated out of Aral and several hundred more out of Muynak. Directly or indirectly the fishery accounted for 60,000 jobs.

Due to the decline of the sea but also in part due to poor fisheries management, the catch had declined to 15,000 tons per year by 1970 and by 1982 commercial fishing ceased when salinity

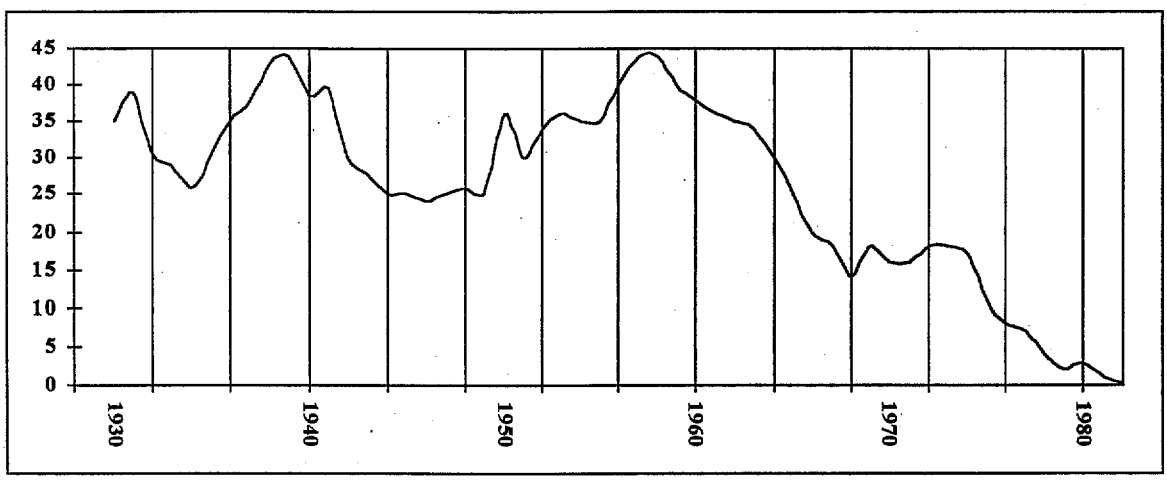

Figure 5-4. Aral Sea Fisheries Catch. Thousands of Metric Tons.

reached the range of 18 g/l (which may be compared to present level of 35-40 g/l), and eliminated all of the freshwater species. In the 1970s several species of saltwater fish were introduced to the sea; many of them including Black Sea flounder and bullhead are in abundance today and occasionally pursued by sport fishermen.

Not only harvests in the Aral Sea were affected; the delta regions of both the Amu Darya and the Syr Darya, which once constituted important fisheries in their own right, have declined though not disappeared. Major fish farms once existed on the lakes in and around the deltas of both rivers. Many of the fish farms subsequently were reorganized at least in part around livestock.

The lost catch, averaging over 35 million pounds annually, in itself would probably be worth today between 20 and 50 cents per pound (ex-vessel) at the dock, with much of this value attributable to the cost of catching fish. If access to the fishery were restricted, the cost of harvesting fish would fall and the fish in the water could represent a significant part of the ex-vessel price. Value added in the fishery could raise the total economic contribution of the fishery. For example, valuing the 60,000 jobs at the average per capita income for the region would suggest a potential economic value of the fishery of approximately $90 million annually. If the workers who lost their jobs could easily find other sources of employment, much of the lost value added in harvesting and processing would be offset by gains elsewhere, suggesting that $90 million is much too high an estimate. However, the unemployed fishermen and processors did not find work easily; for several years frozen fish was brought in at high cost by railroad from the Baltic and Caspian Seas and the Atlantic to be canned at Aral and Muynak. With the breakup of the Soviet Union, frozen fish was no longer imported to support the canneries, which now operate at very reduced capacity, processing fish from the local fish farms, delta lakes and rivers. Based on these observations, the fishery probably was worth in the range of $50 million annually.

5.6 Flora and Fauna

The regions in and around the deltas of the Amu Darya and Syr Darya once supported abundant wildlife - in the Syr Darya delta at least 71 species of mammals, 319 species and sub-species of birds, 7 species of reptiles, and two amphibian species. The flood plains once supported large stands of trees and bush, termed tugai forests. The tugai forest included poplar, willow and other trees, providing wildlife habitat, stabilizing the flood plains against erosion, and filtering suspended solids. The tugai forest has declined severely due to decreasing groundwater levels, fires, changes in the microclimate and winds, and sheep raising and other agricultural activities. Some of the tugai forests have been succeeded by ecologically less valuable salt tolerant species, while other areas are now barren.

In the delta regions the state once operated several muskrat farms that collectively produced some 5-6 million skins per year. The muskrat farms have all closed due to the deterioration of muskrat habitat. (At some point it may be possible to value these pelts. A very tentative estimate is $5 each.) Reeds that once grew in abundance in the delta region were important to the local economy. Growing up to 15 meters in height, mature reeds were used as reinforcing materials in construction and for fencing, and the young shoots fed to cattle.

In the Syr Darya delta, the area of wetlands decreased from 245,000 ha in 1955 to 40,000 by 1986. The former wetlands have declined to meadow or desertified classifications, which have far lower economic and ecological significance. Before the 1960s the Amu Darya delta contained nearly 800,000 ha of wetlands, but this has been reduced to no more than 100,000 ha today. Wetlands are recognized worldwide as valuable for the wildlife habitat they provide, for controlling surface flows and limiting floods, for recharging groundwater, for water purification and other services. In most industrialized nations, wetlands are protected by public policy (Stein). Depending upon the context, wetland protection often costs $10,000 per acre or more, a sum that appears justified by the few studies that have attempted to estimate values for wetlands. For example, a 1991 review of the literature by Anderson and Rockel revealed that average U.S. values for flood conveyance were about $5,000 per acre; fish habitat about $900 per acre; waterfowl habitat $4,500 per acre; mammal and reptile habitat $300 per acre and recreation a minimum of $150 per acre (all expressed in 1994 dollars).

The economic loss of wetlands and associated flora and fauna could be estimated through the technique of benefits transfer. First observe that $10,000 is a capitalized value, whose annual value may be 7% or $700. Next, convert this to a ppp equivalent for the Aral Sea region, coming up with an estimate of about $35. If one converts this to a value per hectare, the result is about $83. This suggests a value for the lost flora and fauna in the range of $75 million annually ($83 times 900,000 ha).

5.7 Existence of the Sea

Existence value of a resource is what people would be willing to pay to know the resource exists, even though they have no plans to use it. The people who attribute existence values to the Aral Sea could live anywhere, so identifying who these people are and how large are their existence values is a daunting task.

One possible technique is to tally what the World Bank, the European Union, the U.S. Agency for International Development and other donors have agreed to spend (and seem obligated to spend) to ameliorate some of the problems. This is at least $450 million. Of course, much of this expenditure is directed at reducing some of the observed health damage, so this method is not entirely satisfactory for estimating existence value. The items that clearly double-count should be eliminated. One also should recognize that this approach provides very much a lower limit, since most people who might be willing to pay something would not participate in World Bank decisions.

Another possible option would be to have a small panel of experts rank this issue relative to other issues whose existence has been valued (e.g., visibility in the Grand Canyon, existence of the whooping crane, etc.) Still better as a means of estimating existence value is a contingent valuation survey that sampled individual WTP throughout the world to protect the Aral Sea. This approach is not feasible though (due to both time and budget considerations) in this preliminary study.

Protecting visibility in the Grand Canyon was estimated to be worth around $10 billion, and protecting the whooping cranes from extinction some $5 billion. The Aral Sea, once the fourth largest inland sea in the world, in 1960 occupied an area equivalent to that of the state of West Virginia. Clearly, if the Aral Sea were in the US or Western Europe its existence could well be worth several tens of billions of dollars. Its remote location in a poor part of the world suggests that its existence would not be that highly valued. Nonetheless, the disaster caused by the decline of the sea has caused widespread attention outside the region and several international agencies have offered technical and financial assistance totaling hundreds of millions of dollars.

The World Bank recently announced plans to provide total assistance of $380 million by the year 2000 to help the region. Leaders of the five republics once pledged to contribute one percent of their GNP (about $500 million) toward preservation and restoration of the Aral Sea; however, collecting this sum has proven problematic. In February 1997, the presidents of the five republics pledged aid equal to 0.3 percent of their annual fiscal budgets to assist the region, or roughly $35 million per year (Clover).

For the purposes of study and discussion, this preliminary investigation uses a range of $1 billion to $10 billion for existence of the sea, implying an annual value for existence of between $70 million and $700 million.

5.8 Regional Climate

While much uncertainty surrounds this issue, there seems little doubt that the regional climate has been affected. The annual temperature range is greater without the mitigating effect of the Aral Sea. Wind-blown sea salts have been traced for more than 1,000 km. In the Pamirs and elsewhere, this salt may contribute to glacial melting.

The decline of the Sea and of lake surfaces and volumes reduced the local thermal reserve and altered the thermal balance of the region. The local micro-climate of the region became more continental with higher summer temperatures. Cooler winters, which would be expected with

a more continental micro-climate, have not materialized, perhaps due to an overall warming trend. Temperature and climate modifications in the immediate region of the Sea are measurable, but may not have tremendous economic significance. Dust storms containing salt and other residues became an issue as the sea started to recede in the 1960s. As Smith points out, it is difficult to separate climate changes due to the decline of the sea from natural climate changes and other anthropogenic atmospheric and land surface alterations such as the rise of irrigated agriculture.

5.8.1 Humidity

The monitoring station on the northern bank of the Aral Sea reports a decrease of 25 to 30% in relative humidity since 1960, while a station in the Syr Darya delta at Kazalinsk shows a decline of 15 to 20%. Contemporary humidity readings show levels never observed before 1960.

5.8.2 Temperature

In all of the monitoring stations north, east and south of the Aral Sea (north Aral Sea, Uzunkair-Bayan, Uyali, and Muynak), summer temperatures increased an average of 1.3 to 1.8 degrees Celsius between the decade of the 1950s and 1981-1985. Further from the sea in Qyzylorda and Kazalinsk summer temperatures increased to a much lesser extent. Winter temperatures show much less change over the same period, with some monitoring stations recording small increases and others small decreases. Over the past several decades the climate of Central Asia has experienced a warming trend that must be considered part of global processes and not part of the decline of the Aral Sea. The actual area whose climate is affected by the change in size and volume of the sea apparently is limited to a distance of about 30 km from the former shoreline.

The growing season has been reduced by between two and three weeks, enough to make cotton no longer viable in the northern regions near the Aral Sea. While the change in microclimate may affect cropping patterns, this is not expected to have a significant economic impact.

5.9 Transportation on the Sea, Power Generation and Other Issues

The Sea formerly provided significant transportation services between Uzbekistan and points north in the Soviet Union. Electric power generation has come to the fore as an issue; what should be a non-consumptive use of water has evolved otherwise for some peculiar reasons.

The port of Aral began operations at the beginning of the 20th century. The local shipbuilding industry, the *Mid Asia Ship Enterprise*, was established in 1910. Most of the infrastructure, including houses, factories and storage depots, were built between 1925 and 1930. Approximately 5-8 large cargo vessels of 250 to 550 tons capacity and 20 medium cargo vessels of 80 to 150 tons capacity transported cargo between Aral and Muynak in Uzbekistan to the south. Aral sent fish, food and construction materials south, while Uzbekistan shipped fruit and other agricultural products, tissue, and cotton to Aral, and from there via railway to Moscow and other destinations in the Soviet Union.

While the Aral Sea has been lost as a transportation corridor, it is not clear that the alternatives now available are necessarily more costly. Consequently, no damage is attributed to the loss of transportation services of the sea.

Hydroelectric power generation in upstream republics is leading to net water withdrawals from the Aral Sea basin and adding to the losses. Winter power generation results in water flows that cannot be accommodated in the present channels of the Amu Darya and Syr Darya in the winter. The fault lies partly with downstream weirs built to divert water for agricultural uses. The weirs slow flows, causing the rivers to freeze and choke with ice. Water that would have made its way to the Aral Sea must be diverted into desert depressions to avoid flooding downstream settlements. Dams may also increase water surface area and evaporative losses

To the extent that winter hydroelectric power generation acts as a consumptive user of water, it should pay for all water it causes to be diverted from the Aral Sea. How to apportion "consumptive use" between the operation of dams and the downstream users is not obvious. But consumptive use is apparent in evaporation from reservoirs.

Section 6
Conclusion

The separate components of damage are listed in the table below. Despite the very great uncertainties associated with this analysis, it appears quite likely that damage to resources and health total at least $1.345 billion annually, and could be more than $2.5 billion annually. Increased water diversions since 1960, the proximate cause of the estimated damage, amounting to roughly 50 km^3 per year, suggests that the average damage per cubic meter of water lost to the sea could range from about 2.5 cents to 5.0 cents.

Water that is consumed in the Amu Darya and Syr Darya basins is lost to the sea, suggesting a base charge for consumptive uses of water between 2.5 to 5.0 cents per cubic meter. That a charge of this magnitude is not completely implausible can be confirmed by the estimated cost of water conservation measures, which in several sources is estimated to be in the range of $1 billion per km^3 or about $1.00 per cubic meter. That most such conservation measures have not been undertaken, nor the massive collector drain projects built along the Amu Darya that would improve downstream water quality, suggest that conservation and water quality projects are difficult to justify economically. One dollar per cubic meter may simply be too much to pay for water.

Table 6.1
Probable Annual Damage
(in millions of dollars)

	Estimated Damage	Comments
Health	400-700	noninfectious diseases uncertain
Agriculture	500-600	possible added impacts upstream
Living conditions & incomes	250-500	survey could clarify this
Fisheries	50	
Flora & fauna	75	
Existence of the sea	70 - 700	needs follow up evaluation
Regional climate	?	probably small
Transportation	?	probably small
TOTAL	1,345-2,500	

A base charge of 2.5 cents to 5.0 cents per cubic meter for consumptive uses of water would appear to be affordable in many, if not most, cases. Basic human needs can be satisfied with about 30 liters per day. At a cost of 5 cents per cubic meter, basic human needs could be met at an annual cost of $2.50 for a family of 4. This represents much less than one percent of measured incomes in the region most heavily affected. It should be noted that while residential users in that region do pay for water, it is based on "norms," or average consumption levels. Average per person consumption in urban areas of the lower Amu Darya region is presently 500-600 liters per day, a very high figure by world standards and indicative of huge waste.

Many agricultural users of water would appear to be in a position to pay charges in this range if prices for their inputs and outputs were freed from state control and set by market forces. For example, cotton uses about 12,000 m^3 per ha and yields output worth about $2,000 (at world prices) per ha in Karakalpakstan. Charges of 2.5 cents per m^3 would increase production costs

by $300 per ha, a sum that could be paid from profits if output prices were not regulated by the government. Even at 5 cents per m^3 cotton would appear to be profitable. Rice, wheat and alfalfa might not fare quite so well, but each appears able to withstand charges of 2.5 cents per m^3. Similar conclusions were reached by Burns & Roe in a recent report.

A necessary condition for agriculture to be able to pay such water charges is that governments cease setting prices of inputs and outputs (and lower the effective rate of taxation on cotton). While the Uzbekistani government currently is dependent upon cotton for a large share of tax revenues, and is understandably reluctant to have international agricultural markets dictate domestic prices for agricultural inputs and outputs, water charges could more than offset the loss if agriculture were privatized and prices allowed to find world levels.

Appendix A
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