Module 1, Investigation 2: Briefing
What is happening to the Aral Sea?

Background
Lakes become salty when they form in interior basins in arid areas. Water contains salts, and when water evaporates, the salts remain to accumulate. Without a continuing inflow of fresh water, these lakes become smaller and saltier. The Great Salt Lake in Utah and the Salton Sea and Mono Lake in California are examples of lakes that have no outlets and have become salty. These salt water lakes are more prone to pollution problems than are fresh water lakes. This is especially true when the amount of water flowing into them is severely reduced. The Aral Sea, in arid central Asia, is the world's leading example of a shrinking salt lake that is suffering from pollution problems. In 1973, it was the fourth largest lake in the world, but by the 1990s it was only the sixth largest lake. In this investigation, you will be a geographer on a NASA team finding out what is happening to the Aral Sea, and why the changes threaten entire ways of life for millions of people.

Objectives
In this investigation you will
- locate the Aral Sea and describe its physical characteristics,
- use satellite imagery to identify and measure recent changes in the Aral Sea,
- explain how human activities have changed the physical characteristics of the Aral Sea and its surroundings,
- discuss the consequences of human actions on the Aral Sea and how the resulting changes are affecting human populations, and
- recommend actions to reduce further damage to the Aral Sea and the human populations that use its resources.

Part 1: How can you measure changes in the size of the Aral Sea?
Imagine that you are a member of a team of geographers working for NASA to survey Earth's water resources. Your team is investigating changes to the Aral Sea over the last 40 years in order to assess the current and future condition of the Aral Sea as a resource. First, locate the Aral Sea in Figure 1, which is a map of the region made by the U.S. Geological Survey. Estimate the latitude and longitude of the sea and note the countries that surround it.

Answer questions 1 and 2 on the Log following the Briefing.

Your team will use a *time-series* of satellite images of the Aral Sea taken from 1964 to 1997 (Figures 2 and 3) to estimate the change in the size of the Aral Sea over time. The squares labeled 38.4 kilometers on a side in the lower left-hand corner of the images represent 1474.56 square kilometers (38.4 X 38.4 = 1474.56).

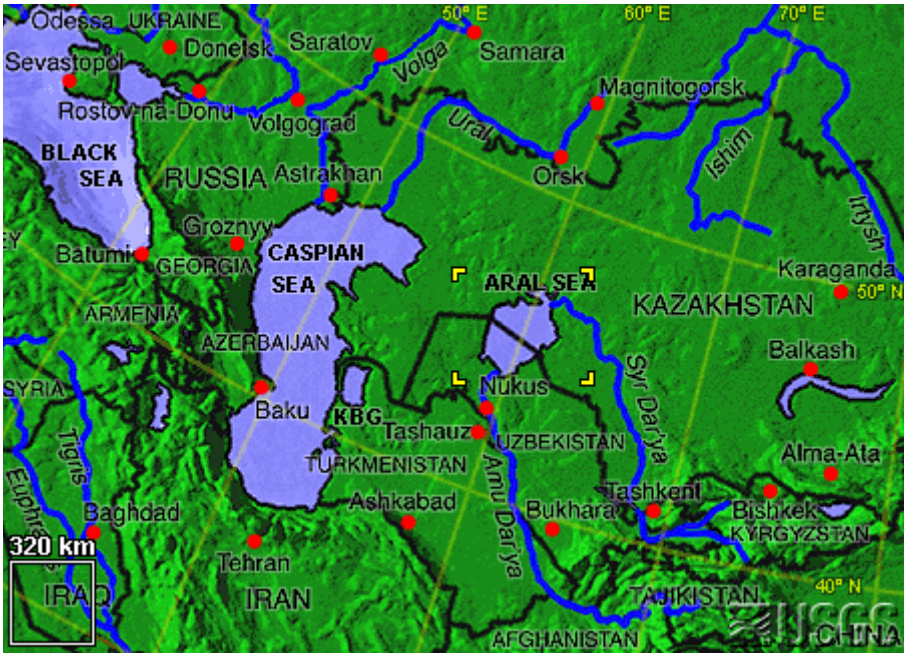

Figure 1: Map of Central Asia
Source: http://edcwww.cr.usgs.gov/earthshots/slow/Aral/Aral

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To estimate how the Aral Sea has changed in size, you will use a procedure that is part of a geographic information system (GIS). GIS is a way to store, analyze, and display many kinds of data. Most GIS procedures start by dividing an area into smaller units, much like the squares in the bottom of each image of the Aral Sea (Figures 2 and 3). A count (or inventory) GIS procedure is designed to answer questions about an entire area, such as "How large is the Aral Sea?"

Using the GIS count grid provided in Figure 4 (or a transparency), lay it on or under Figure 2 (the 1964 satellite image). Line up the bottom left square from the GIS count grid with the square on the image and then count the number of times the points in each square lie on the sea surface. If part of the point lies on the Aral Sea, count it for your estimate. Then estimate the surface area by multiplying the total number of points by the grid measure (1474.56 square kilometers).
Surface area in square kilometers = number of points in grid squares X 1474.56 square kilometers

Answer question 3 on the Log.

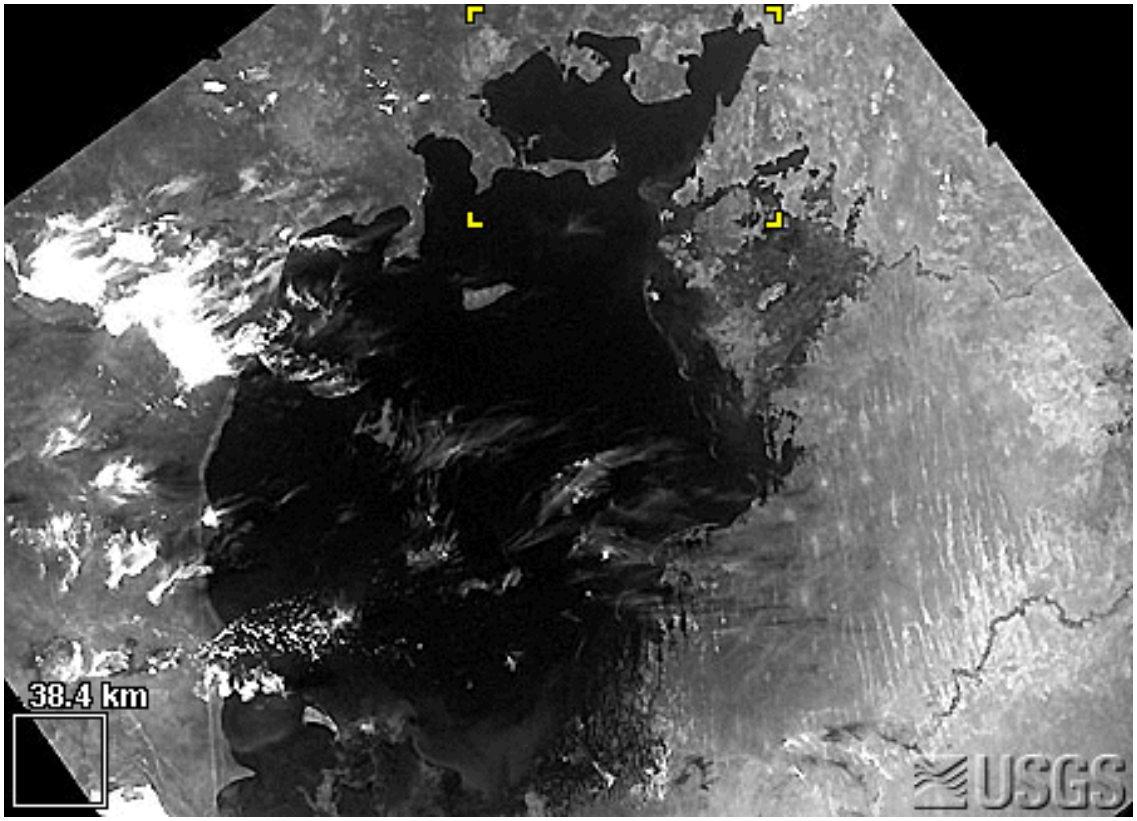

Figure 2: The Aral Sea on August 21, 1964; Argon satellite photo

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Now that you have determined the size of the Aral Sea for 1964, measure the size of the Aral Sea in 1997 (Figure 3).

Answer question 4 on the Log.

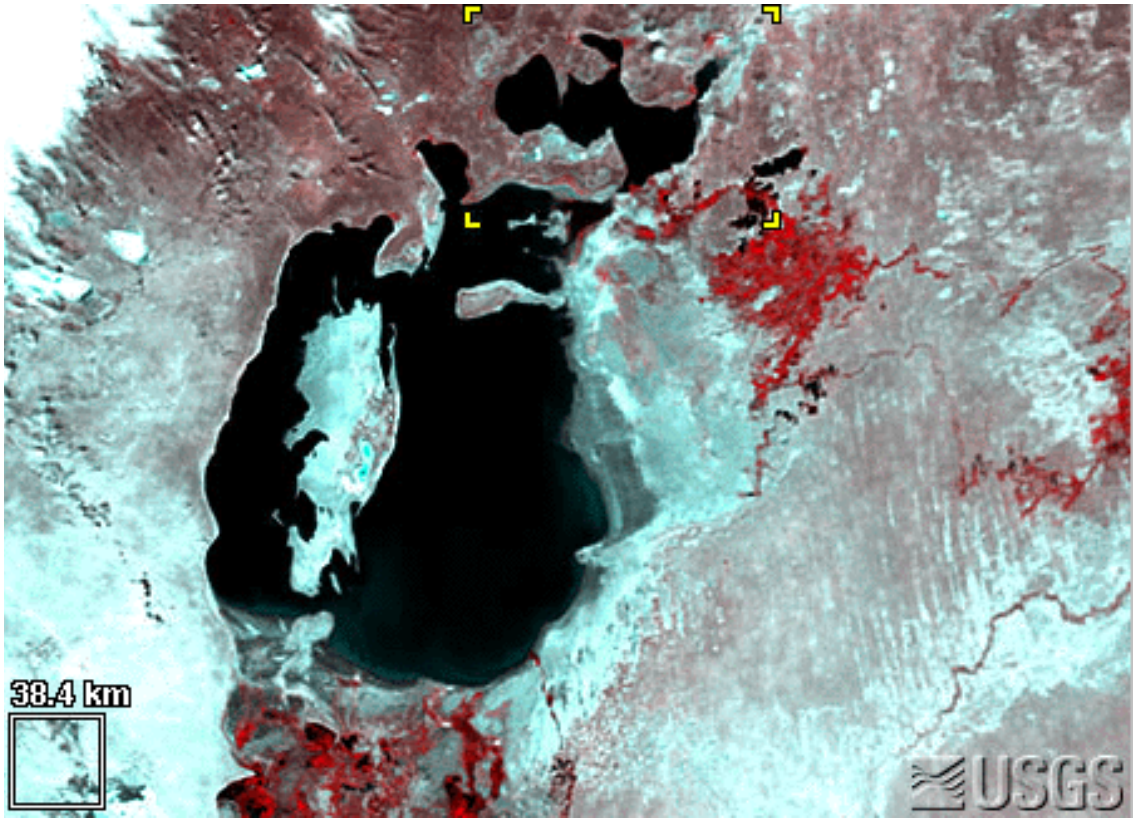

Figure 3: The Aral Sea on July 11, 1997; NOAA 14 AVHRR bands 2 1 1

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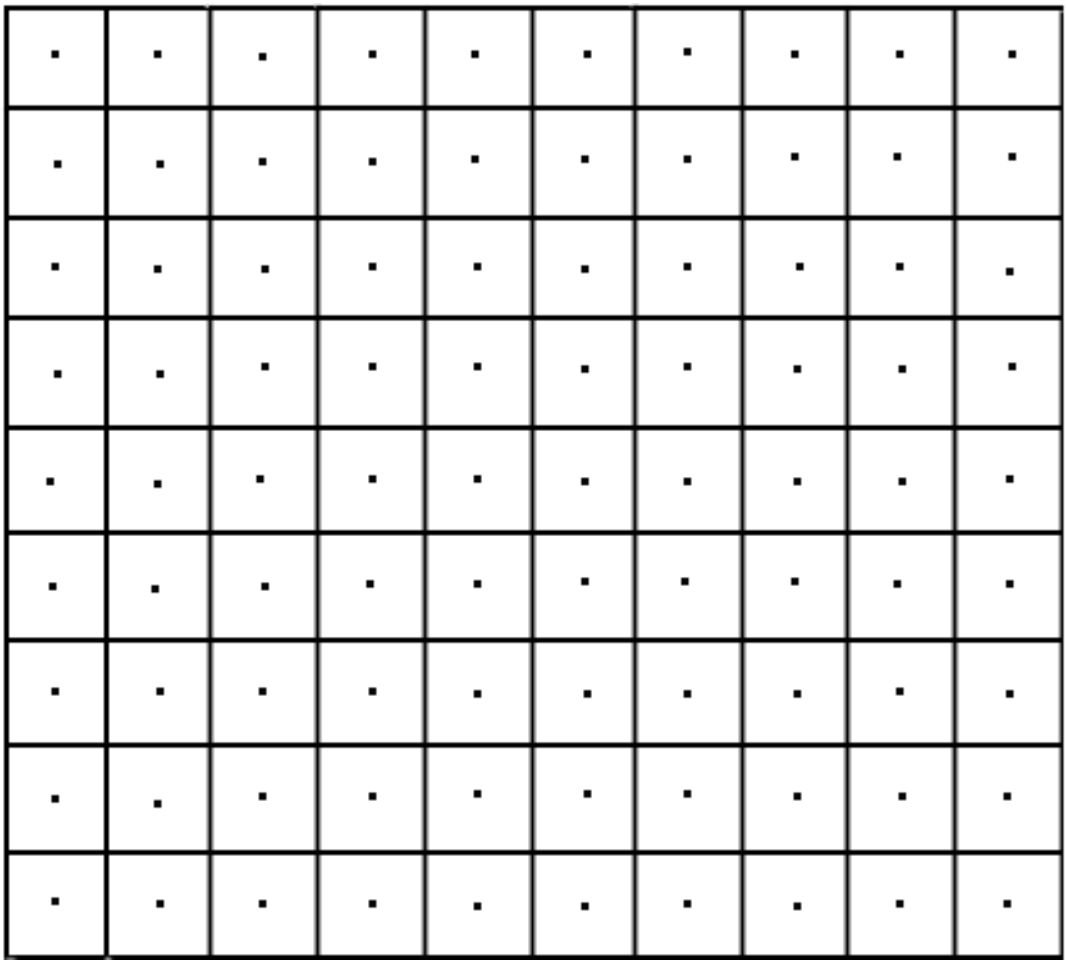

Figure 4: GIS count grid for Aral Sea

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Next, compute the *percentage change* in the size of the surface area of the Aral Sea from 1964 to 1997. To do this, use the following mathematical procedure:

$$\text{Percentage change} = \frac{\text{square km in 1964 - square km in 1997}}{\text{square km in 1964}} \times 100$$

For example, if your 1964 estimate is 20,000 square miles and your 1997 estimate is 10,000 square miles, subtract 10,000 from 20,000 and divide by 20,000 to get 0.5. Multiply that by 100 to get the percentage, or 50 percent.

Answer question 5 on the Log.

Now that you have your estimates for the change in the size of Aral Sea over time, consider how satellite imagery helped you to draw conclusions about changes in the Aral Sea. What does satellite imagery allow you as a geographer working for NASA to accomplish?

Answer question 6 on the Log.

Part 2: Why has the Aral Sea been shrinking?

Government agencies are interested in reducing the loss of the Aral Sea and need to know the major causes of its decline. Use Table 1 to determine the sources of the Aral Sea's water supply.

Answer question 7 on the Log.

Consider the possible causes of the shrinking of the Aral Sea. A key step in scientific research is to *hypothesize*—to suggest explanations for the things you observe. Your team should make two lists of hypotheses to explain the shrinking of the Aral Sea. On the first list, identify causes that are physical processes. For example, the sea might be shrinking because the rate of evaporation has increased (but what would cause this?). Label the second list human processes. For example, in-migration has caused a rapid rate of population increase in the region, which has made increasing demands on the water supply that flows into the sea.

Answer questions 8 and 9 on the Log.

Your team should now begin to test its hypotheses about the causes of the Aral Sea's decline. Use the information in Table 1 and Table 2 to help you do this.

Answer questions 10, 11, and 12 on the Log.

Table 1: Aral Sea surface elevation, precipitation, evaporation, river inflow, and volume, 1950-1990.

	Surface elevation above sea level (meters)	Precipitation (cubic kilometers)	Evaporation (cubic kilometers)	Annual river inflow (cubic kilometers)	Volume (cubic kilometers)
1950	52	9	66	63	1,083
1960	53	9	66	56	951
1970	51	8	65	43	628
1980	45	6	55	17	329
1990	38	5	39	4	282

Sources: P. Micklin and W. Williams, *The Aral Sea Basin*, NATO, 1996

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Table 2: Population, irrigated area, and water use, Aral Sea region, 1930-1990.

	Population (millions of people)	Irrigated area (millions of hectares)	Water withdrawals for irrigation (cubic kilometers)
1930	7.3	3.8	NA
1940	10.9	4.2	46.3
1950	10.6	4.3	39.1
1960	13.8	5.0	51.5
1970	19.9	5.5	83.5
1980	26.1	5.8	110.5
1990	33.0	6.8	110.0

Sources: D. Glasgow in W.S. Ellis and D.C. Turnley. "A Soviet Sea Lies Dying" in *National Geographic*, February 1990, and P. Micklin and W. Williams, *The Aral Sea Basin*, NATO, 1996.

Part 3: How has the region's landscape changed?

The Amu Darya and Syr Darya Rivers empty into the Aral Sea, which lies in an interior basin. The development of irrigation projects in the region, especially to grow cotton beginning in the 1950s, captured the river waters so that little fresh water reached the Aral Sea. Withdrawal of water from the Amu Darya and Syr Darya, primarily for irrigation, is the most important factor reducing water flows into the Aral Sea. This has caused the Aral Sea to shrink in size. How do you think the irrigation projects and the shrinking Aral Sea have affected the human populations that depended on it? Figure 5 offers some clues.

Answer question 13 on the Log.

Increases in population, coupled with a demand for agricultural products, have resulted in a specific type of landscape (the entire set of human and physical features on Earth's surface that characterize a particular area or region) surrounding the Aral Sea. Figure 6 is a map of the Aral Sea. The rectangle to the east of the sea locates the image found in Figure 7. This image, a recent photograph taken from NASA's Space Shuttle, depicts land use surrounding the Syr Darya River. How does Figure 7 help you assess how human populations have affected the Aral Sea region?

Answer question 14 on the Log.

Figure 5: Abandoned Aral Sea fishing boats

Source: http://kidsat.jpl.nasa.gov/kidsat/photogallery/aral_ships.gif

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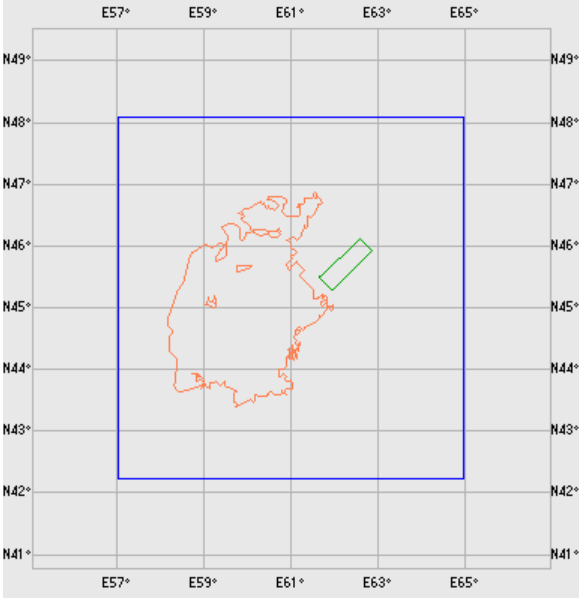

Figure 6: Aral Sea on geographic grid

Source: USGS—http://edcww.cr.usgs.gov/landaac…02086/lrlon=66.636154/result=13042

Figure 7: Land use east of the Aral Sea

Source: USGS—http://edcww.cr.usgs.gov/landaac…02086/lrlon=66.636154/result=13042

Part 4: What are the human consequences of the shrinking Aral Sea?

The shrinking Aral Sea has had both positive and negative human consequences. Agricultural production and irrigation increased, which improved the economy of the region. On the other hand, contaminated soil and water resulted from the use of chemical pesticides, herbicides, and fertilizers. Also, soils became saltier (salinization) and less suitable for agriculture. In addition, as the waters of the sea retreated, salty soil remained on the exposed lake bed. Dust storms blow away up to 75,000 tons of this soil annually, dispersing its salt particles and chemical residues into the air. This air pollution has caused widespread nutritional and respiratory ailments.

Government planners concerned with the human consequences of the shrinking Aral Sea have collected data for your team to analyze. Information on the fishing industry, health, and salinization have all been submitted for your consideration. In addition, predictions about the future size of the sea were submitted. Your team has been asked to make recommendations on how to address these problems and reduce the negative effects on populations in the region. You should make recommendations to regional governments for each type of effect listed below. Your recommendations should be based upon your hypotheses about why the sea has been shrinking.

Destruction of the Fishing Industry

As the Aral Sea has receded and the quality of the water reaching the sea has declined, there has been a sharp reduction in fisheries production (Table 3).

Table 3: Aral Sea Fish Catch, 1960-1990

Year	Metric Tons of Fish
1960	43,430
1965	31,040
1970	17,460
1975	2,940
1980	0
1985	0
1990	0

Source: M. Glantz, ed., *Creeping Environmental Problems and Sustainable Development in the Aral Sea Basin*, 1999, Cambridge University Press.

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Table 4: Major Health Problems and Causes, Aral Sea Region

Disease/Affliction	Major Cause
Respiratory problems	Blowing salt and dust
Viral hepatitis	Contaminated water
Typhoid fever	Contaminated water
Cancer	Blowing salt and dust, toxic contaminants
Intestinal disorders and infections	Contaminated water, blowing salt and dust
Birth abnormalities	Toxic contaminants
Plague	Explosion of rodent population on dry sea bottom

Source: P. Micklin and W. Williams, *The Aral Sea Basin*, NATO, 1996

Today, no fish are caught commercially in the sea. Former ports to the south (Muynak) and the north (Aralsk) of the sea are stranded many miles from the receding shoreline. The loss of the Aral Sea's fisheries sparked the collapse of the entire industry, causing unemployment and the decline of economies of former coastal towns.

Health Problems

The dependence of countries surrounding the Aral Sea on cotton production and irrigation using the waters bound for the Aral Sea has had a major impact on human health. Large-scale pesticide and fertilizer use has resulted in groundwater contamination, and many fertilizer and pesticide residues have been blown from the exposed lake bed across the landscape. The widespread regional health effects include dramatic increases in many types of health problems (Table 4).

Salinity Increases

The shrinking size of the Aral Sea has also increased the *salinity* (salt content) of the waters of the sea (Table 5). In the 1960s, the water was drinkable and supported a wide variety of fresh water animals and plants used by humans. Today, the sea water is undrinkable: it is saltier than the open ocean.

Table 5: Salinity of the Aral Sea, 1960-1995.

Year	Average Salinity (grams per liter of water)
1960	10
1970	11
1980	22
1990	37
1995	50

Source: P. Micklin and W. Williams, *The Aral Sea Basin*, NATO, 1996

Size of the Aral Sea

Figure 8 gives a chronology of the size of the Aral Sea from 1960 to 2010.

Your team should conclude its investigation by summarizing what it has learned about the Aral Sea and by making recommendations in a final report to NASA on the Log.

Answer question 15 on the Log.

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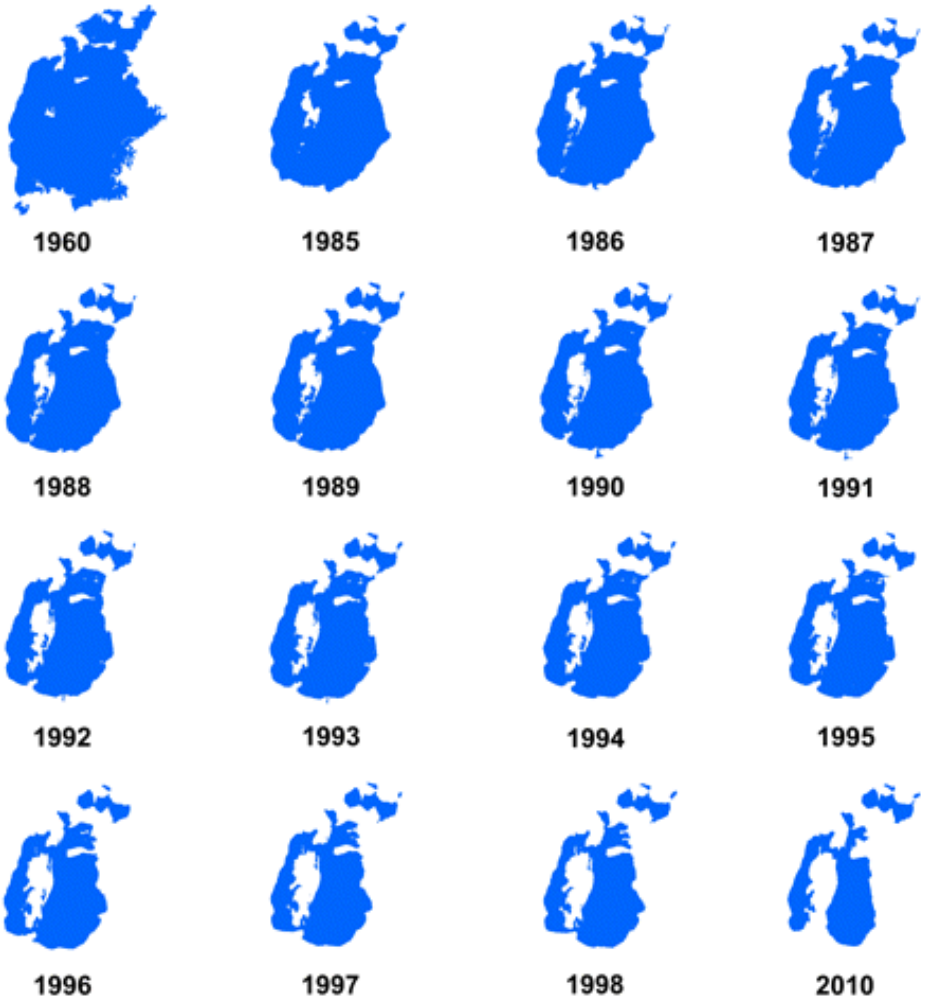

Figure 8: Chronology of the size of the Aral Sea
Source: German Department of Defense (http://www.dfd.dlr.de/app/land/aralsee/chronology.html)

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USGS Earthshots: Satellite images of environmental change http://edcwww.cr.usgs.gov/earthshots/slow/tableofcontents

USGS SIR-C browse, coverage map, and scene metadata http://edcwww.cr.usgs.gov/landaac…02086/lrlon=66.636154/result=13042