Chapter 4
The Earth, the Water Planet
－Carry Forward Beautiful Water to Future Generations－

Section 1　Status of the Water Environment of the World and Japan

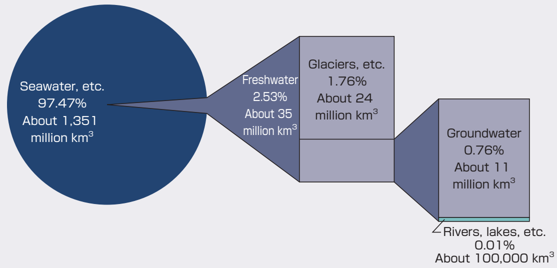
1　Water on the Earth

About 70% of the surface of the earth, often referred to as the Blue Planet, is covered with water estimated to be some 1.4 billion cubic kilometers. Of this amount, 97.5% is salt water, with the remaining only 2.5% being fresh water. Moreover, approximately 70% of freshwater is captured in glaciers and icebergs, and almost all of the remaining 30% is moisture in soil or groundwater in aquifers in deep underground. Thus, surface water in rivers and lakes easily accessible to humans is just about 0.4% of freshwater. This is equivalent to a mere 0.01% of all water on the earth, and of which only about 100,000 cubic kilometers is sustainably available as it is reproduced in the forms of rain and snowfall (Figure 4-1-1).

Thus far, in response to growing demand for water due to the population increase and economic growth, water resources, especially surface water and groundwater,

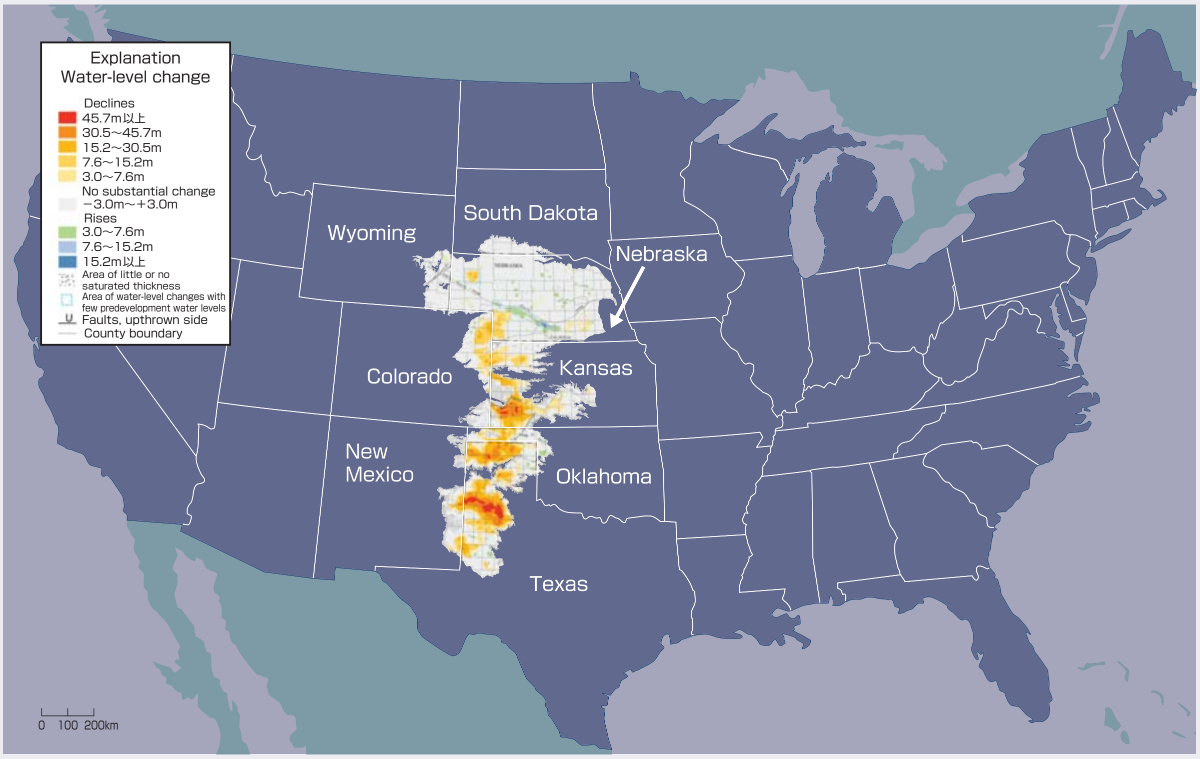
Figure4-1-1 Water Resources on the Earth

Water Resources on the earth
About 1,386 million km³



Note: Groundwater in the Antarctic Continent is not included
Source: Prepared by Ministry of the Environment based on World Water Resources at the Beginning of the 21st Century, UNESCO, 2003

Figure4-1-2 Water-Level Changes in the Ogallala Aquifer



Source: Prepared by Ministry of the Environment based on U.S. Department of the Interior, U.S. Geological Survey, "Scientific Investigations Report 2009-5019" have been developed around the world. Consequently, for example, the Ogallala Aquifer in the United States, one of the world's largest groundwater layers, has a total area of some 450,000 square kilometers, about 1.2 times Japan's land area. Since the start of irrigation agriculture, according to a survey of over 3,600 water wells, the water level has declined by an average of about 4.3 meters, with the ratio of wells whose water level dropped 3.0 meters or more standing at about 26%, that of wells with the water-level decline of 7.6 meters or more at about 18% and that with the water-level decline of 15.2 meters or more at about 11%. Wells where the water level rose 3.0 meters or more accounted for a mere 2% (Figure 4-1-2).

The annual amount of water consumed globally has increased about 2.9 times from about 1,400 cubic kilometers in 1950 to about 4,000 cubic kilometers in 2000. This amount is equivalent to 144 times the quantity of water of some 27.5 cubic kilometers held at Lake Biwa. The annual amount of water consumed is likely to come to about 5,200 cubic kilometers by 2025, a further increase of about 1.3 times from the 2000 level (Table 4-1-1).

Water resources on the earth as a whole are sufficient to satisfy human demand for water, but the geographically uneven distribution of water resources presents a major problem (Figure-Int.-2-9). The Human Development Report 2006 of the U.N. Development Program (UNDP) points out that one out of every five people living in developing countries (about 1.1 billion) is not able to satisfy the international standard of securing "at least 20 liters of safe water from a safe water source within one kilometer from his/her home," and may lose life by consuming unsanitary water near his/her home and becoming ill.

Table4-1-1 Changes in Global Water Demand

(km^3/year, million people)

	1950	1980	1995	2000	2025
Population	2542	4410	5735	6181	7877
Agriculture	1080	2112	2504	2605 (66%)	3189 (60.1%)
Industry	86.7	219	344	384 (9.7%)	607 (11.6%)
Cities	204	713	752	776 (19.5%)	1170 (22.3%)
Total	1382	3715	3788	3973 (100%)	5235 (100%)

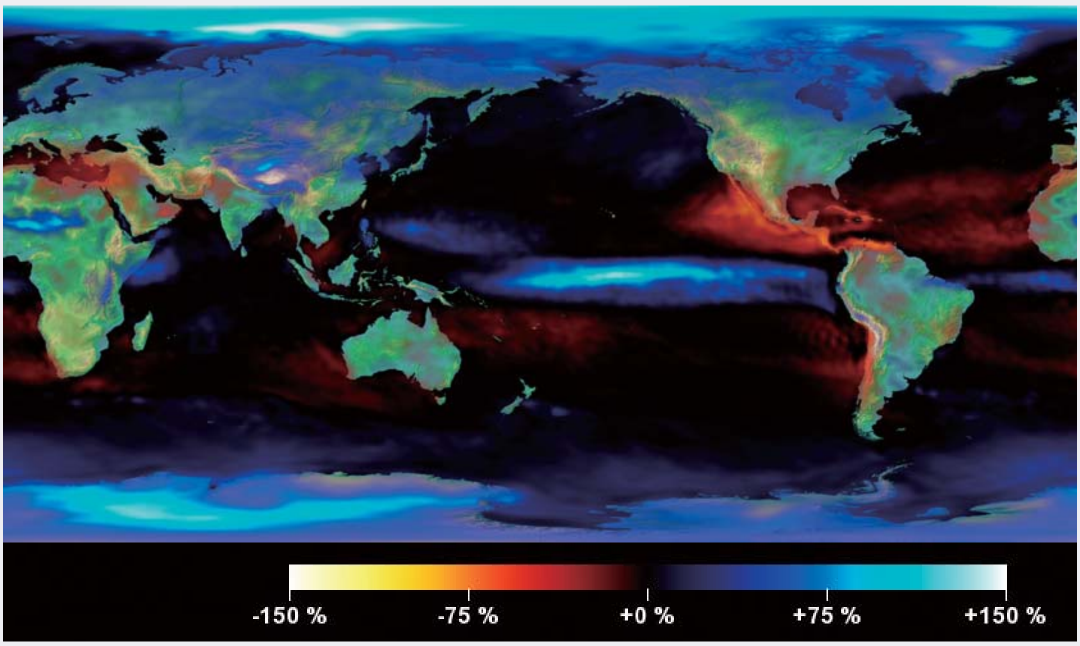
Source: State Hydrological Institute (SHI) and UNESCO (1999)

2 Impact of Global Warming

According to the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC), the progress in global warming will expose several hundred million people to increased water stress going forward, and the increased frequency of droughts and flooding is projected to adversely impact regional crop production, particularly production of subsistence crops in low-altitude regions. The rise in the global average temperature due to climate change is feared to bring about various impacts on water resources.

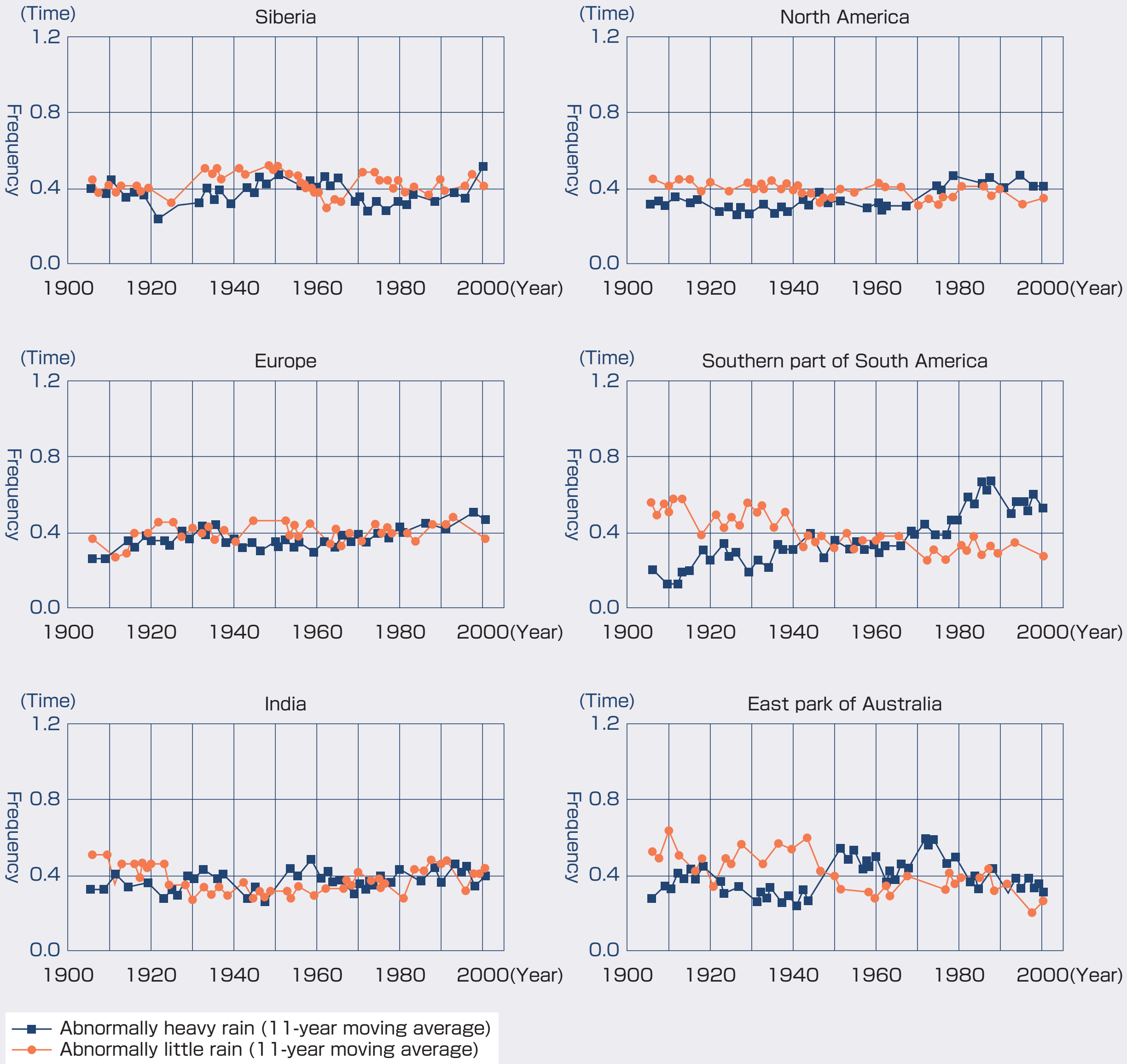
According to a global warming simulation conducted by a joint research team of the National Institute for Environmental Studies, the University of Tokyo's Center for Climate System Research (now, the Atmosphere and Ocean Research Center) and the Japan Agency for Marine-Earth Science and Technology, the global average temperature in 2071-2100 is projected to rise by 4.0 degrees C from the 1971-2000 level under a scenario that assumes the economy-focused future world will see a further progress in globalization. Precipitation, meanwhile, is projected to increase in low- and high-altitude areas and some tropical areas but decline in

Figure4-1-3 Projected Changes in Precipitation in the World in 2100



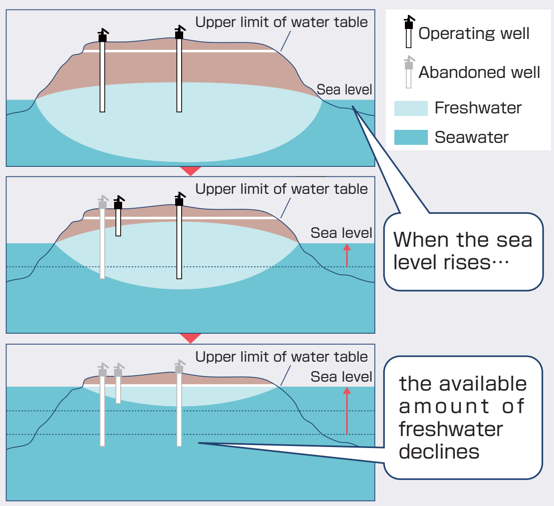
Source : National Institute for Environmental Studies, University of Tokyo, Japan Agency for Marine-Earth Science and Technology

Figure4-1-4 Interannual Changes in Frequency of Abnormally Heavy and Little Rain



Source: Abnormal Weather Report 2005 (Japan Meteorological Agency, October 2005)

Figure4-1-5 Impacts of Sea-Level Rise on Freshwater Lens



Source: National Institute for Environmental Studies, Center for Global Environmental Research (2001) Data Book of Sea-Level Rise 2000

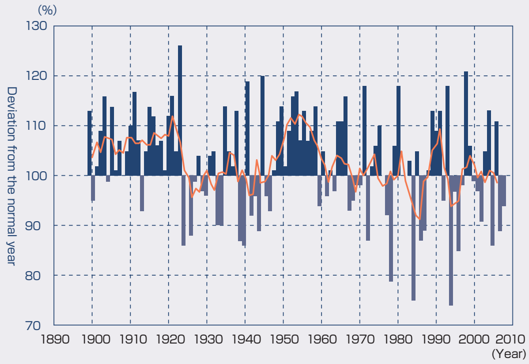
subtropical and other areas (Figure 4-1-3).

In recent years, we have seen a significant increase/decrease in the frequency of abnormally heavy rain or abnormally little rain depending on regions in the world. While the frequency of abnormally heavy rain tends to show a significant increase in Europe, North America and the southern part of South America, the frequency of abnormally little rain tends to show a significant decrease in the southern part of South America and the eastern part of Australia (Figure 4-1-4).

There also are areas where a major adverse impact on water resources is projected to emerge. For example, according to the IPCC AR4, many small islands in the Caribbean Sea and the Pacific are expected to see decreases in freshwater resources to make it hard for them to satisfy water demand during seasons of little rain. In these small island areas, not only changes in precipitation but also the rise in sea level could also trigger a decrease in freshwater resources. Below the surface of small islands made of pervious rocks, groundwater (freshwater) is floating over seawater (salt water) in the shape of lens (freshwater lens), and this freshwater lens is pushed higher by the rise in sea level, thus lowering the quantity of freshwater available (Figure 4-1-5).

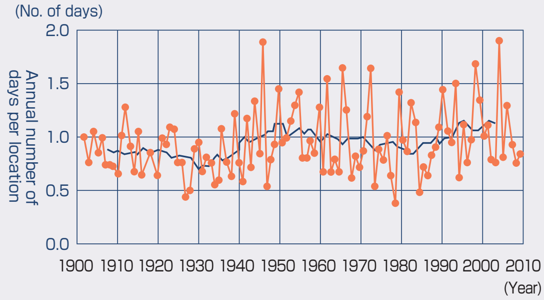
The long-term examination of annual precipitation in Japan reveals that there were periods of heavy rains until the mid-1920s and around the 1950s, and annual changes in precipitation have become larger year by year since the 1970s (Figure 4-1-6). Further, the number of days with daily precipitation of 100 millimeters or more has been on the significant rise in the long term, and comparison between the recent 30 years and the 30 years in the early 20th century shows a rise of about 1.2 times (Figure 4-1-7).

Figure4-1-6 Changes in Deviation from the Normal Year in Annual Precipitation in Japan (1898-2008)



Note: The figure shows trends in annual precipitation at 51 locations in Japan. Bar graphs show deviation from the normal year (the percentage ratio to the normal year value) in annual precipitation in each year. The red line shows the five-year moving average in deviation from the normal year. The normal year value is the 30-year average for 1971-2000.
Source: Japan Meteorological Agency, 2009

Figure4-1-7 Interannual Changes in the Annual Number of Days with Precipitation of 100mm or more

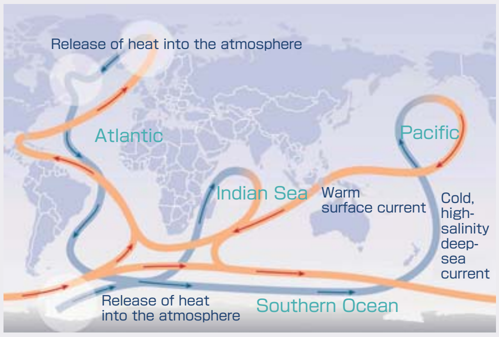


Note: The annual number of days per location obtained from the number of days of incidence at 51 locations in Japan. —●— indicates the value for each year, while ∿ shows the 11-year moving average value.
Source: "Climate Change Monitoring Report 2009" (Japan Meteorological Agency, 2010)

Column Deep Circulation in Oceans

Regarding deep circulation in oceans, the IPCC AR4 notes there is no sufficient evidence to determine where there are some tendencies in deep circulations, projecting that there is very little possibility of deep circulations showing large and rapid changes by the end of the 21st century. On the other hand, the current model-based projection points to the very high possibility of deep circulation in the Atlantic Ocean weakening during the 21st century.

Global Ocean Circulation



Source: IPPC Fourth Assessment Report

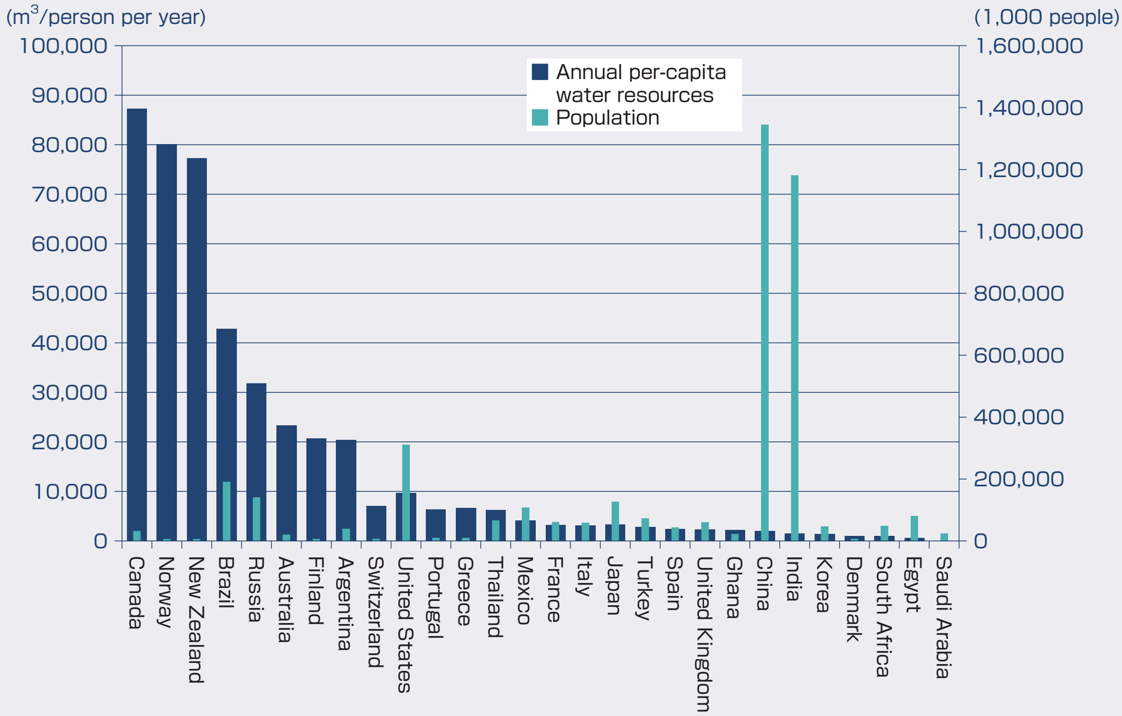
3 Various Problems Caused by Water

Due to population growth, global warming and the growth of emerging economies (which means increased demand for industrial water), it is expected that "an additional 1.8 billion people could be living in a water scarce environment by 2080," pointing to a very serious water situation in the world (Source: UNDP, "Human Development Report 2007/2008).

1) Uneven distribution of water resources and demand outlook

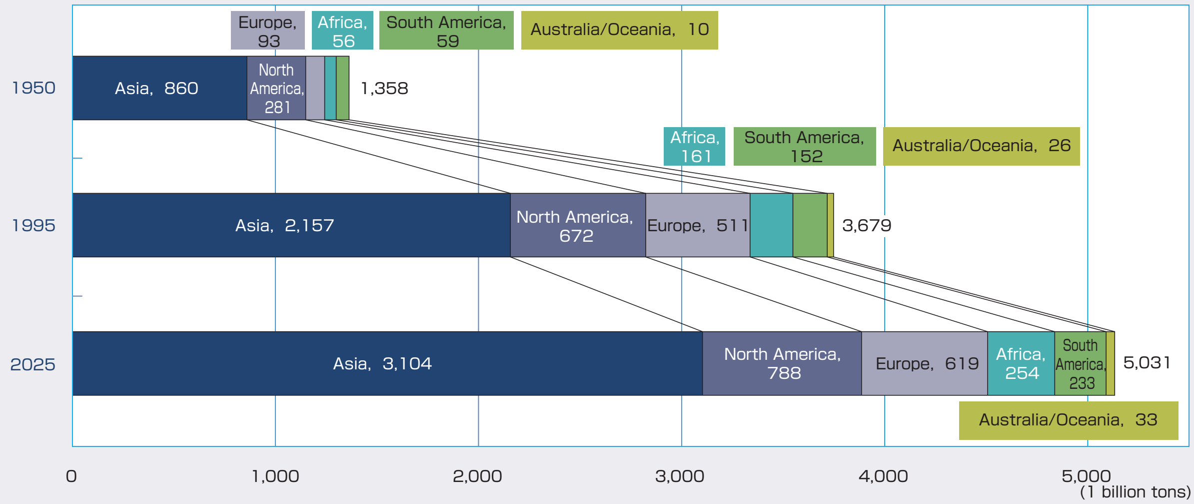
According to data provided by the Food and Agriculture Organization (FAO), there are big gaps in per-capita annual water resources among countries, and the uneven distribution of water resources is evident, with countries with relatively small water resources having relatively large populations (Figure 4-1-8). The U.N. Educational, Scientific and Cultural Organization (UNESCO) forecast a substantial increase in demand for water in Asia going forward (Figure 4-1-9). While the global population is projected to rise by about 1.4 times during a 30-year period between 1995 and 2025, domestic noncommercial use of water and water for industrial use are both expected to show sharp rises of about 1.8 times and about 1.6 times, respectively, due to population growth (Figure 4-1-10). For water for agricultural use,

Figure4-1-8 Annual Per-Capita Water Resources and Population



Source: Prepared by Ministry of the Environment based on FAO AQUASTAT

Figure4-1-9 Rapidly Increasing Water Usage



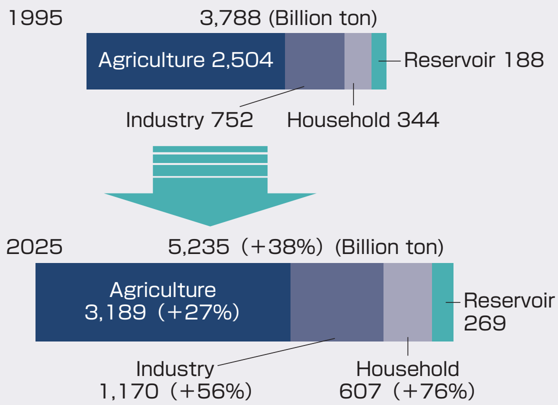
Source: Ministry of Land, Infrastructure, Transport and Tourism, "Water Resources in Japan 2007"

the amount of water pumped is likely to increase primarily due to an expansion of irrigated farmland (Figure 4-1-11). Given the geographically uneven distribution of water resources, the big issue is whether demand for water can be satisfied.

2) Use of safe and sanitary water

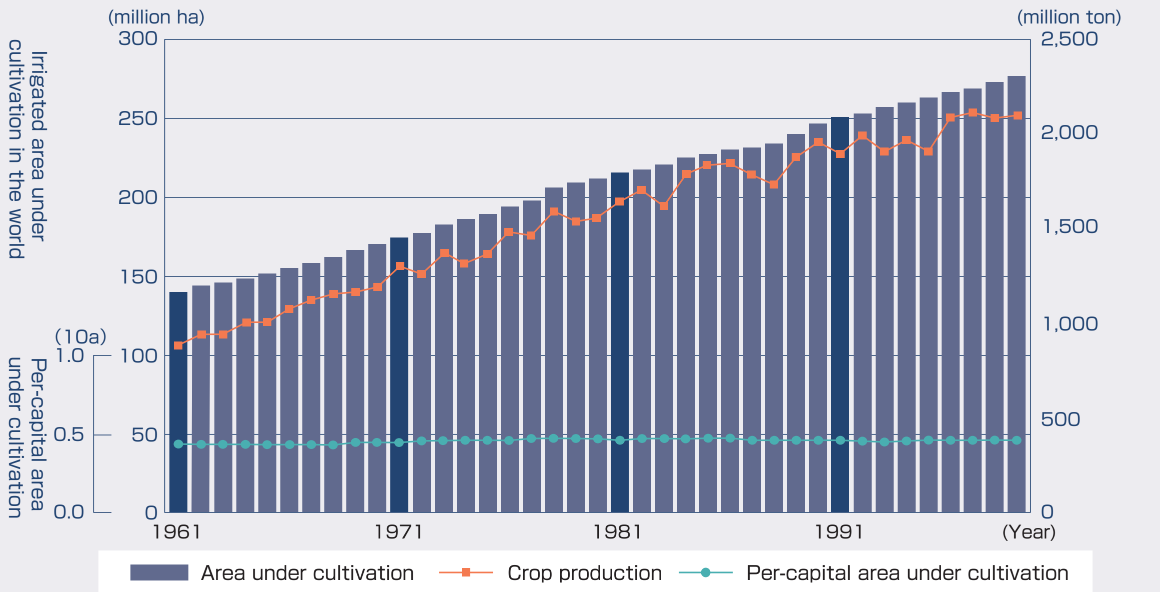
As shown in figure 4-1-8, water resources in the world are unevenly distributed and people who do not have access to safe water and sanitary facilities are concentrated in Asia and Africa. According to results of surveys conducted by the U.N. Children's Fund (UNICEF) and the World Health Organization (WHO), there are about 880 million people in the world who have no access to safe water, with Asia accounting for about 470 million people (53%) of the total (Figure 4-1-12). Also, there are about 2.5 billion people living in areas with no sanitary facilities, with Asia again accounting for a large portion of about 1.8 billion people (70%) of them (Figure 4-1-13). Because of "water" and "sanitation" problems, 1.8 million children are dying each year. These figures represent one of the biggest problems confronting mankind.

Figure4-1-10 Breakdown of Water Usage by Use in 1995 and 2025



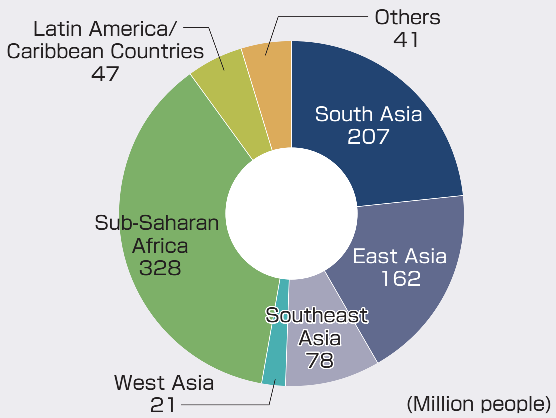
Note: Figures in parentheses show increases over 1995
Source: SHI and UNESCO (1999)

Figure4-1-11 Trends in Crop Production and Irrigated Area under Cultivation in the World



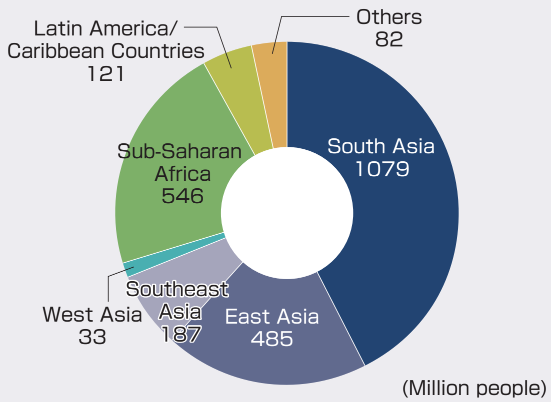
Source 1: Statistical Databases (U.N. Food and Agriculture Organization)
2: Prepared by Ministry of the Environment based on World Population Prospects: The 2000 Revision, 2001 (U.N. Department of Economic and Social Affairs, Population Division)

Figure4-1-12 Population without Continuous Access to Safe Drinking Water in Developing Countries by Region



Source: Prepared by Ministry of the Environment based on the U.N. Children's Fund (UNICEF) and the World Health Organization (WHO), "PROGRESS ON DRINKING WATER AND SANITATION : SPECIAL FOCUS ON SANITATION, 2008"

Figure4-1-13 Population without Continuous Access to Basic Sanitation in Developing Countries by Region



Source: Prepared by Ministry of the Environment based on the U.N. Children's Fund (UNICEF) and the World Health Organization (WHO), "PROGRESS ON DRINKING WATER AND SANITATION : SPECIAL FOCUS ON SANITATION, 2008"

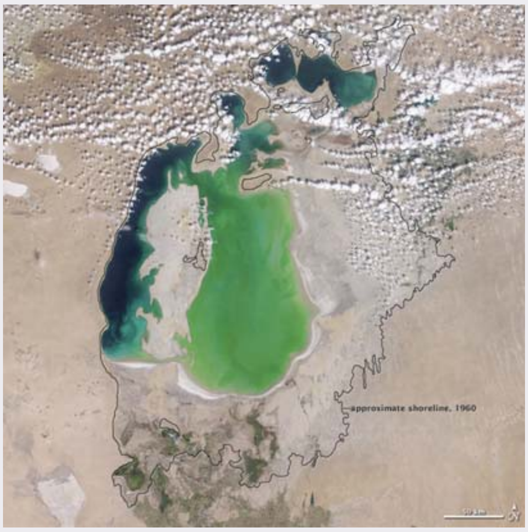
3) Various problems occurring in the world due to water

a) The shrinking Aral Sea

The Aral Sea spanning Kazakhstan and Uzbekistan in Central Asia used to be the world's fourth largest lake. Since the 1960s, vast quantities of irrigation water were withdrawn from two rivers feeding the late, the Syr Darya and Amu Darya for the cultivation of cotton and crops, causing the water level to decline and leading to the continued shrinkage of the lake surface area. In about 50 years up to 2006, the Aral Sea lost as much as about 71% of area and 91.5% of cubic volume (quantity of water) (Figure 4-1-14). Salt, sands and agricultural chemicals are being stirred up from the dried-up lake bottom, causing serious health damage to residents in surrounding areas. Remaining water has seen the rapid rise in the density of salt, which is now six times the original density. The once-rich saline lake, which used to yield 50,000 tons of fish, is now devoid of fish resources, putting fishermen out of business. With water that used to mitigate the climate in surrounding areas gone, harsher weather is said to be exacerbating growing conditions for cotton and crops.

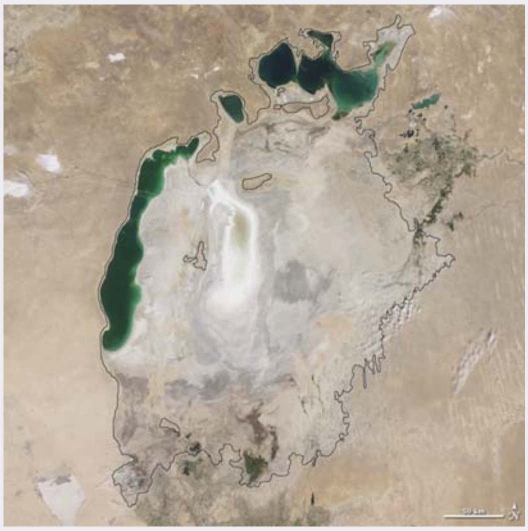
The solid line shown in Photo 4-1-1 demarcates the Aral Sea around 1960. While the Aral Sea was a single lake then, it became divided into the southern and northern parts in the latter half of the 1980s, and the South Aral Sea began to separate east and west around 2000 and continued shrinking. In August 2009, the eastern side of the South Aral Sea dried up at last (Photo 4-1-2). The North Aral Sea is beginning to recover in area after construction of the Kokaral Dam.

Photo4-1-1 Satellite Photo of the Aral Sea (August 19, 2000)



Source: NASA (http://earthobservatory.nasa.gov/Features/WorldOfChange/aral_sea.php)

Photo4-1-2 Satellite Photo of the Aral Sea (August 16, 2009)



Source: NASA (http://earthobservatory.nasa.gov/Features/WorldOfChange/aral_sea.php)

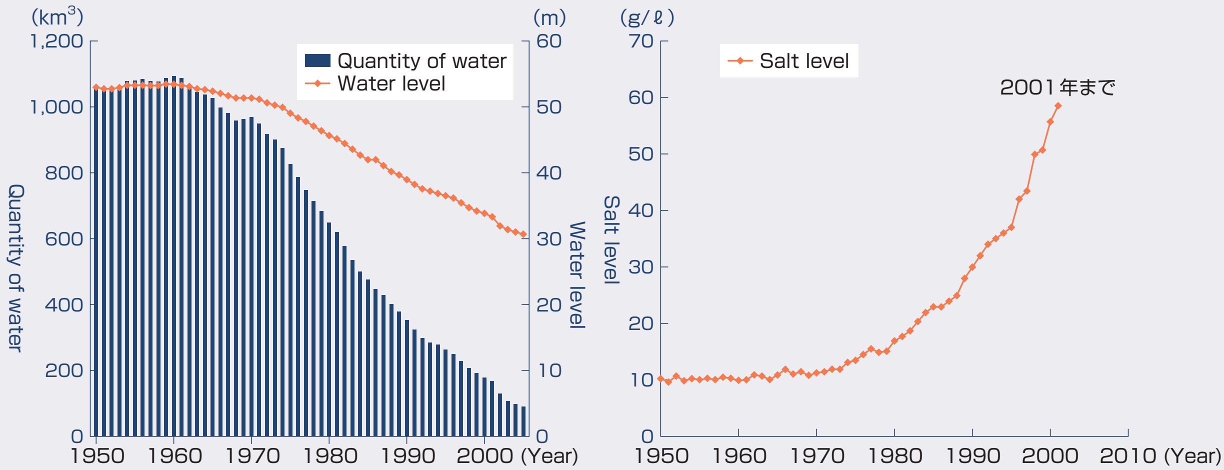
Table4-1-2 Trends in Surface Area of the Aral Sea

(km²)

	1960	1987.6～1989.9	1996.11	2003.10	2006.9～2007.10
The North Aral Sea	－	3,400	3,200	3,200	3,600
The South Aral Sea	－	42,100	31,300	17,700	13,000
Total	68,000※	45,500	34,500	20,900	16,600

※Source : Lake Biwa Environmental Research Institute, Shiga Prefecture ed., "Lakes of the World," (Jimbun Shoin, 1993)
Source: JAXA website (http://www.eorc.jaxa.jp/imgdata/topics/2007/tp071128.html)

Figure4-1-14 Trends in Quantity of Water, Water Level and Salt Level of the Aral Sea



Before shrinkage
The world's fourth largest
(Approximately 100 times the size of Lake Biwa)

1960
Water level : 53.5m
Area : 66,459km^2
Cubic volume : 1,093km^3

2006
Water level : 30.5m
Area : 19,274km^2 (29.0%)
Cubic volume : 93.2km^3 (8.5%)

Source: Database of the Aral Sea/Bathymetric characteristics (2005)

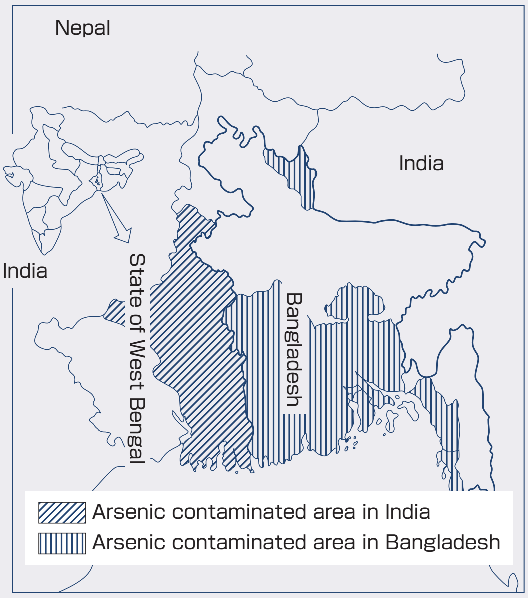
b) Arsenic contamination of groundwater in Bangladesh

In the West Bengal region straddling the border between India and Bangladesh, arsenic contamination was first officially reported in 1983, and subsequently, the contamination damage has been spreading with no halt in sight (Figure 4-1-5). Residents in the region, except for urban areas, depend on pumping wells for drinking water and domestic noncommercial water, and both countries have been promoting irrigation agriculture since the 1960s by pumping up groundwater in order to simultaneously cope with and solve the population growth and socioeconomic problems. Since it is the rice-producing region, large quantities of water for agricultural use have been pumped up with machine pumps. As a result, arsenic-contaminated groundwater has led to the high incidence of arsenic poisoning, causing skin cancer, lung cancer, keratosis, melanoderma and other diseases among poisoned patients (Photo 4-1-3). In Bangladesh, the arsenic-contaminated area extended to about 38,000 square kilometers (an area about half of Hokkaido) as of 2008, with people living in contaminated areas reaching an estimated 38 million and people who have taken arsenic-contaminated water reaching an estimated 16 million, with the number of people developing diseases unknown. In the Indian state of West Bengal on the other side of the border, the arsenic-contaminated area extended to some 37,000 square kilometers, with people living in contaminated areas reaching 34 million and people who have drunk arsenic-contaminated water reaching one million, and the number of people developing diseases totaling 200,000. In arsenic-contaminated areas, over 20% of the population suffered from arsenic poisoning, bringing about a very serious situation, with the number of patients growing at an annual rate of 8%. Under these circumstances, the government of Bangladesh carried out surveys on wells throughout the country by 2004 and launched a national arsenic mitigation policy in March 2004. Japan has provided assistance in dealing with the problem since 1998, and implemented arsenic contamination countermeasure programs since FY 2006 to reinforce the system to supply safe water to about 1.30 million residents in four zilas (prefectures) in the western part of Bangladesh.

c) Regional disputes over water

There are regions in the world where interstate conflicts are occurring over water. These disputes have been caused, among other things, by the problem of allocation of water resources, such as excessive withdrawal of water in upstream lakes and rivers as well as groundwater, and the problem of water contamination due to discharges of contaminants upstream and groundwater contamination. The disputes are over excessive use of water in the Aral Sea, water ownership in the Indus and the Jordan, and the development and allocation of water resources in the Nile and the Tigris-Euphrates basin (Figure 4-1-16).

Figure4-1-15 Arsenic Contaminated Areas around the India-Bangladesh Border

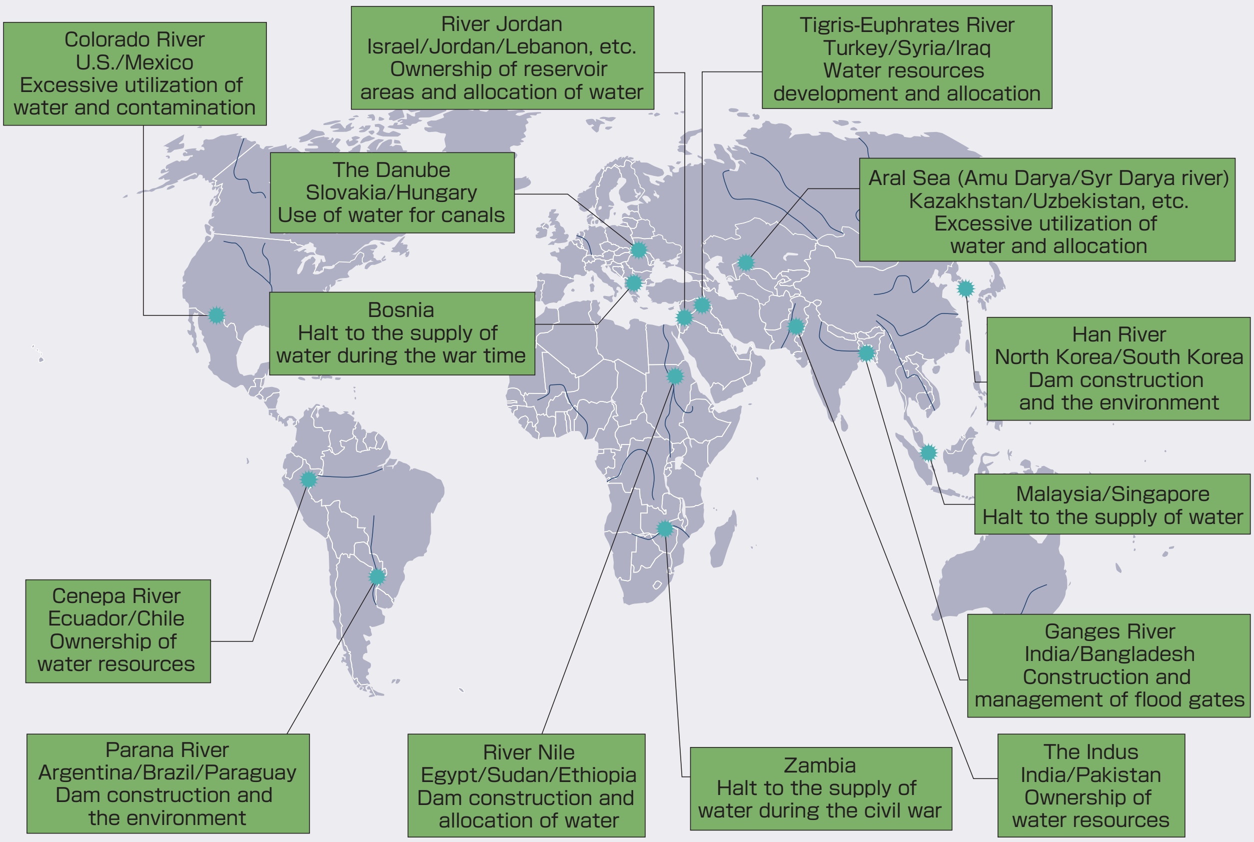


Source: Masanori Ando, Guest Professor, Musashino University

Photo4-1-3 Arsenic Poisoning (Pigmentary Anomaly)

Source : Asia Arsenic Network (Specified Nonprofit Corporation)

Figure4-1-16 Water Disputes around the World



Source: Prepared by the Secretariat of the Third World Water Forum based on Peter H. Gleick, "The World' s Water," and Marq de Villiers, "Water"

4 State of Water Demand in Japan

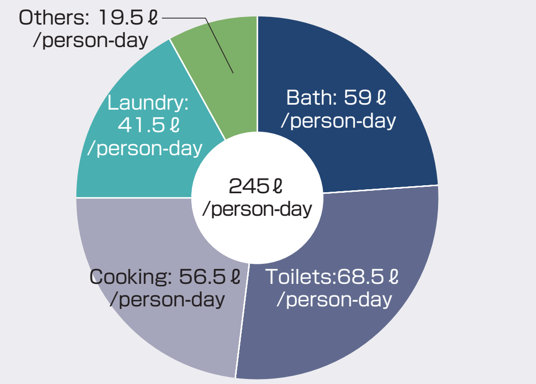
1) Amount of water consumption at households

We consume about 245 liters of water per day as "domestic water." Of the amount, water consumed as drinking water is just two to three liters, with most of the remaining portion being used for washing and cleansing, including cooking, laundering, bath, cleaning, flash toilets, water sprinkling and other purposes (Figure 4-1-17). Meanwhile, water for commercial use at such places as restaurants, department stores and hotels, water for use at business offices and water for public use, such as fountains and public restrooms in parks are collectively called "water for urban activity." Including this category of water, per-capita use of water came to an average of about 305 liters per day in FY 2006 in terms of effective volume of water.

2) Water supply-demand balance in Japan

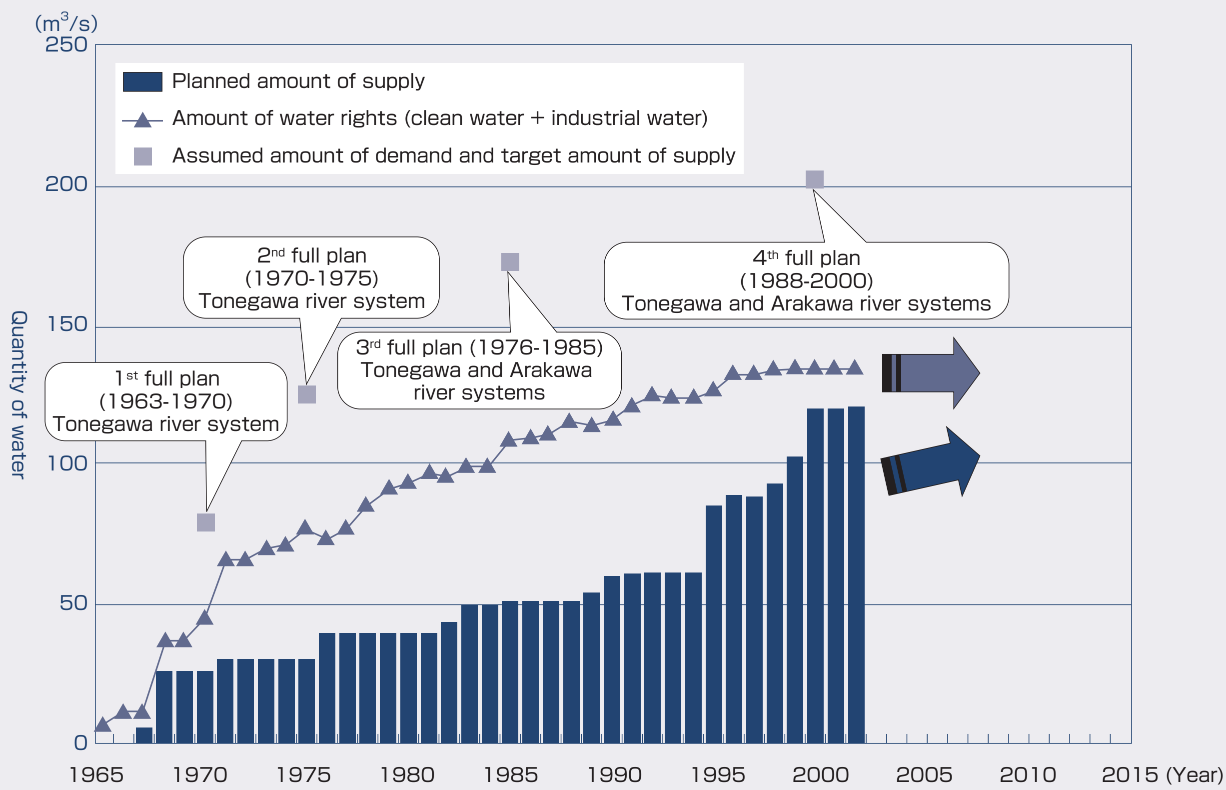
Thanks to the implementation of stable measures for ensuring water supply, Japan appears to be out of the situation where the supply of water cannot catch up with the rapid increase in demand for water (Figure 4-1-18). On the other hand, snow now melts earlier than previously due to, among other things, the decreasing amount of snowfall in part because of global warming, causing the narrowing of the supply-demand gap based on the planned supply in management of rivers, etc. and water rights, which requires the examination of an impact on facilities management.

Figure4-1-17 Ratio of Household Water by Usage



Source: Bureau of Sewerage, Tokyo Metropolitan Government, "Fact-Finding Survey on Usage of Household Water"

Figure4-1-18 Narrowing of Water Supply-Demand Gap in the Tonegawa/Arakawa River Systems



Note 1: Planned amount of supply = Amount of water under development, such as dams (facilities under construction and water diverted from agricultural rationalization projects during winter are not included)
2: Amount of water rights = The sum of water rights secured and temporary water rights
Source: Water Resources Department, Land and Water Bureau, Ministry of Land, Infrastructure, Transport and Tourism

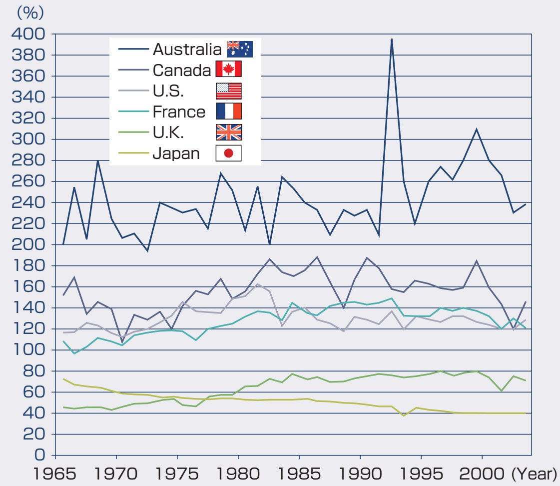
3) Japan deepening dependence on water resources abroad

Japan has safe and stable water supply systems in place for the supply of water with one of the best water quality and most sufficient amount in the world. Does this mean Japan is totally free from water stress? We must not forget that Japan consumes a lot of water around the world through imports of food. In a country that imports goods that require water in producing them (a consuming country), the amount of water estimated to be required if those goods are to be produced in the consuming country is called "virtual water."

Japan's self-sufficiency rate, on a calorie basis, stands now at around 40%, and unlike developments in other major developed countries, Japan's rate has been on the consistent decline since 1965 (Figure 4-1-19). This means Japan depends on other countries for more than half of water needed for food production and that the dependence is continuing to rise. In 2005, Japan imported 80 billion cubic meters virtual water from other countries, with the bulk of that amount stemming from food. The amount is roughly the same as the annual combined intake of water for domestic use, industrial use and agricultural use (Figure 4-1-20).

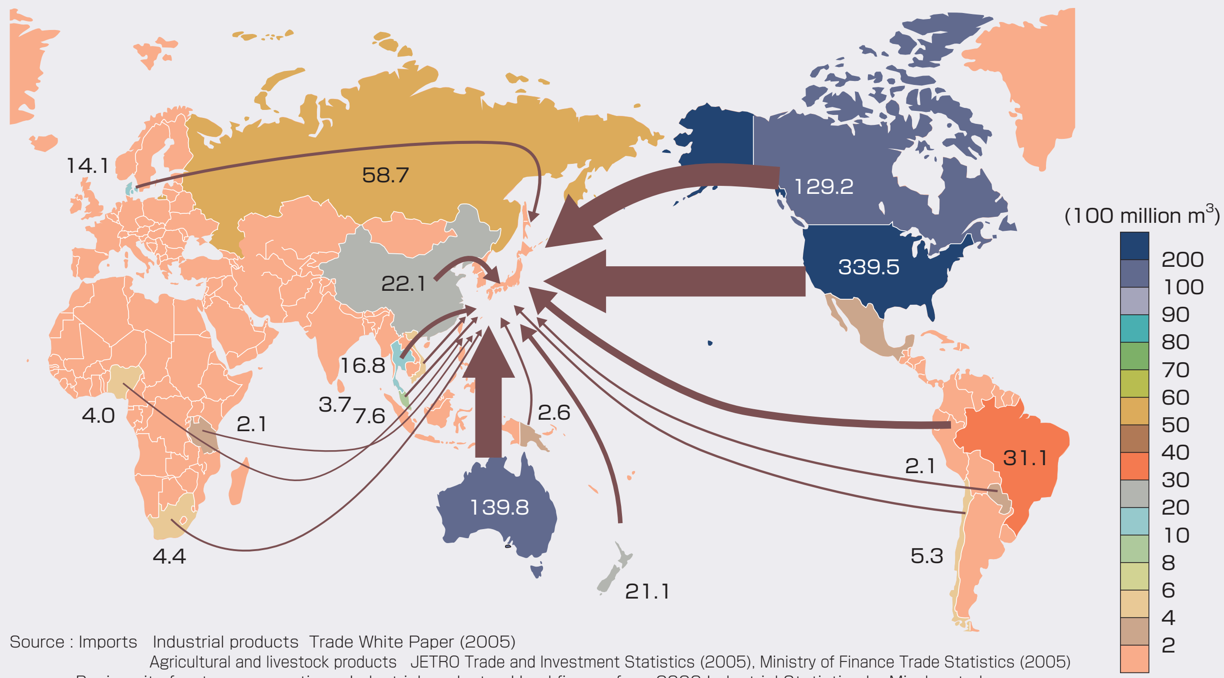
The state of water use in Japan indicates the flattening trend of demand for water for all of domestic use, industrial use and agricultural use, with no cause for alarm over possible water shortages. However, in considering the stable supply of food, we have to always bear in mind the status of water resources that support food production.

Figure4-1-19 Trends of Food Self-Sufficiency Rates of Major Countries on a Calorie Basis (1965-2003)



Source: Policy Issues of Japan in International Comparison, "Comprehensive Research Report" (National Diet Library, 2010)

Figure4-1-20 Virtual Water Imports in 2005

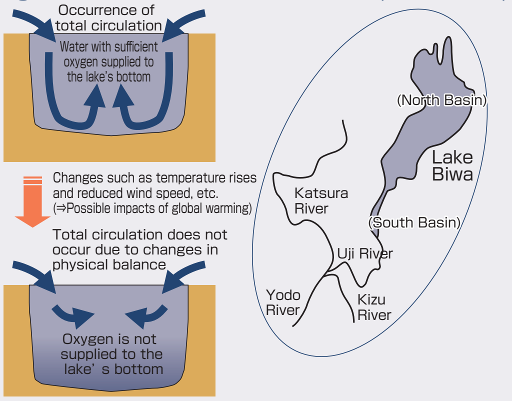


Source : Imports Industrial products Trade White Paper (2005)
Agricultural and livestock products JETRO Trade and Investment Statistics (2005), Ministry of Finance Trade Statistics (2005)
Basic unit of water consumption Industrial products Used figures from 2000 Industrial Statistics by Miyake et al.
Agricultural products Used figures from unit yields in Japan for 2000 by Sato
Round wood Used figures calculated on the basis of wood supply and demand, etc.
Source: Calculated and prepared by Ministry of the Environment based on data from Professor Oki of the Institute of Industrial Science, University of Tokyo

Column Total Circulation of Lake Biwa

In Lake Biwa, layers of water temperatures are formed in summer because of big differences between the surface water temperatures of 26-28 degrees C and deepest-part water temperatures of 6-8 degrees C. When the lake surface cools down from autumn to winter, the surface water temperatures come down and layers of water temperatures disappear, with shallow water and deep water becoming admixed. This phenomenon is called “total circulation.” However, if the lake surface does not cool down and the surface water does not sink as deeply as before because of rising atmospheric temperatures, the total circulation would decrease and oxygen is not supplied to the lake’s bottom, possibly causing a deterioration of water quality and thus giving an impact on lake ecosystems.

Image of Total Circulation of Lake Biwa (North Basin)



Source: Ministry of Land, Infrastructure, Transport and Tourism, “Water Resources in Japan 2007”

Section 2 Efforts to Solve Water Problems

1 Problems in the Use of Water Resources

As discussed in Section 1, water resources available to humans are limited and unevenly distributed geographically. On top of this, we expect to see an increase in water stress due to global warming as well as further rises in demand for water owing to population growth and economic growth. Then, are we using limited water resources effectively without wasting them? For example, in the case of water for agricultural use, which accounts for about 70% of the total water consumption, water is lost in each stage in the course of irrigation of farmland. For example, there a report that in Asia, 20% of irrigation water is lost in the stage where water is carried from reservoirs to irrigated areas, another 15% is lost when water is delivered to agricultural fields, and in addition, 25% of water is wasted in agricultural fields (Figure 4-2-1). In this case, as much as about 60% of water is lost and only the remaining 40% is actually used to grow crops. These loss problems can be improved through the averaging of agricultural fields, improvements to irrigation channels, and the “drip infusion” of irrigation water to crop roots.

In developing countries, the nonrevenue water rate (the ratio of the difference obtained by deducting water sold from water produced to water produced) is said to average at 40%. Nonrevenue water rates in major cities of Asian countries show a lot of water is wasted through water leaks, while very little water is wasted in Japan (Figure 4-2-2). Fact-finding surveys on water projects in China and Vietnam, conducted in FY 2008, found that leaks of clean water are big problems in those countries. In Zhejiang Province, China, 20 to 30% of water projects in the province are estimated to suffer water leaks. In water projects in Changxing County of the same province, the quantity of water supply is as much as 36% lower than the quantity of clean water, presenting the authorities there with a major challenge to taking measures to deal with water leaks.

Installation of sanitary facilities remains inadequate in Asian countries as a whole, though the degree of sanitation varies from country to country, standing at 44% in China, 55% in Indonesia, 72% in the Philippines, 61% in Vietnam, 17% in Cambodia, 33% in India, 59% in Pakistan and 39% in Bangladesh. Substantially more effective utilization of water resources is possible if sewage water is adequately treated for reuse as water resources. We need to further promote effective use of water resources through prevention of water leakages and adequate sewage treatment when sewage is discharged into public water areas.