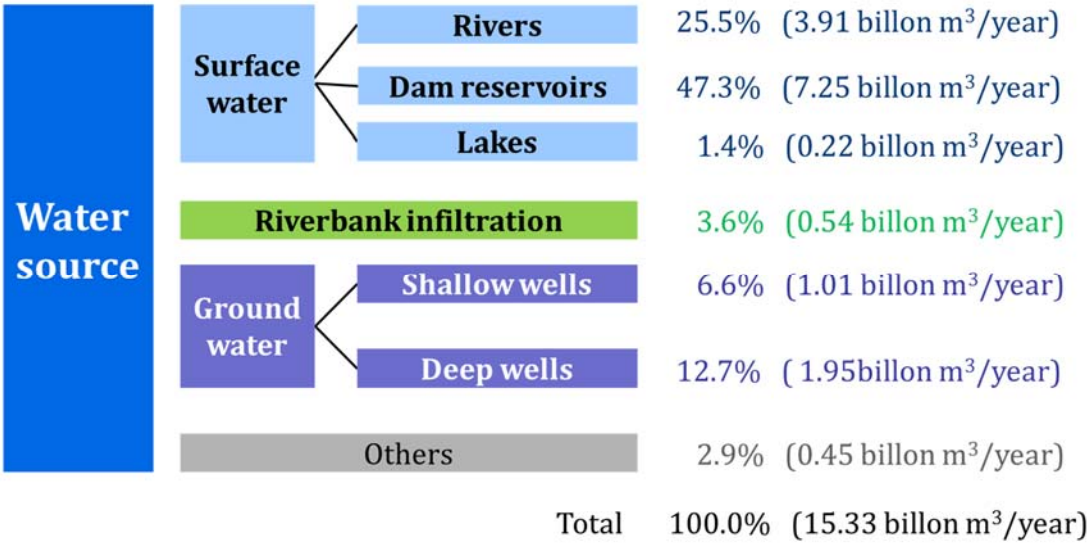
Case Study 2. Water Resources Development: Yodo River System, Okinawa Prefecture and Fukuoka City

Contents

1. Introduction

Water sources for drinking water supply include rivers, dam reservoirs, lakes and groundwater. In Japan, 70% of the water supply is drawn from surface water (e.g. rivers, reservoirs and lakes) and the rest from riverbank infiltration and groundwater.



Source: Japan Water Works Association, *Statistics on Water Supply in Japan 2014*

Figure 1. Water Sources in Japan

This module summarizes the background of water resources development in Japan and illustrates this with some practical examples. It covers intends to answer the question which is frequently asked by the participants of water supply training courses; how Japan secured water resources in response to rapid increase in demand.

2. Background of Water Resources Development

Surface water is a suitable source for large scale utilities that require a large amount of water. Drinking water supply competes with other uses such as irrigation and hydro-electric power generation. Therefore, surface water withdrawal should be coordinated among various stakeholders.

(1) Water Rights

In Japan, the necessity of fair water resource allocation was recognized a long time ago as it went through historical conflicts concerning irrigation water use. Laws and regulations were developed to ensure fair allocation of water rights.

Growing rice in paddy fields requires significant amounts of water and is a well-known fact for more than 2,000 years in Japan. Even today, after industrialization, agriculture accounts for approximately 70% of water use. Allocation of water has been an important issue since the old times when conflicts concerning water use were not uncommon.

This circular water distribution facility was built in 1938 for dividing water accurately. The water is siphoned into the central cylinder and flows to the outer cylinder. The 180 orifices on the outer cylinder distribute the water correctly. The volume of water that is distributed is decided based on the area served. The service area includes rice paddies (877 ha) in 3 municipalities.

Source: Akita prefectural government, *Nanataki Waterway and Mt. Nanataki*, http://www.pref.akita.jp/fpd/tuchi/nanataki.htm

Photo 1. Circular Water Distribution Facility at Rokugou Town, Akita Prefecture

After the 19th century, settling conflicts concerning water resources became very important, because the policy of national prosperity and the drive for modernization was based on reclaiming farm land and increasing food production. The concept of water rights was included in the promulgation of the River Act in 1896 and the system of water rights was almost fully developed by 1961. The granting of water rights prevents unauthorized use because withdrawal of river water is not allowed without a license from the river administrator. However, water rights granted prior to the establishment of the River Act are exempt and deemed as customary water rights that would not compromise usage of water in a practical way.

(2) Comprehensive River Development

Japan has promoted comprehensive river development to deal with flood control and water utilization since 1930s.

The Comprehensive River Development approach had its origin in the "River Water Control Plan" proposed by the Home Ministry [1] in the 1930s which aimed to integrate the implementation the efforts for flood control, irrigation and power generation. Comprehensive management mitigates the risk caused by rainfall variation, stock and utilize the water effectively by building dams and river facilities.

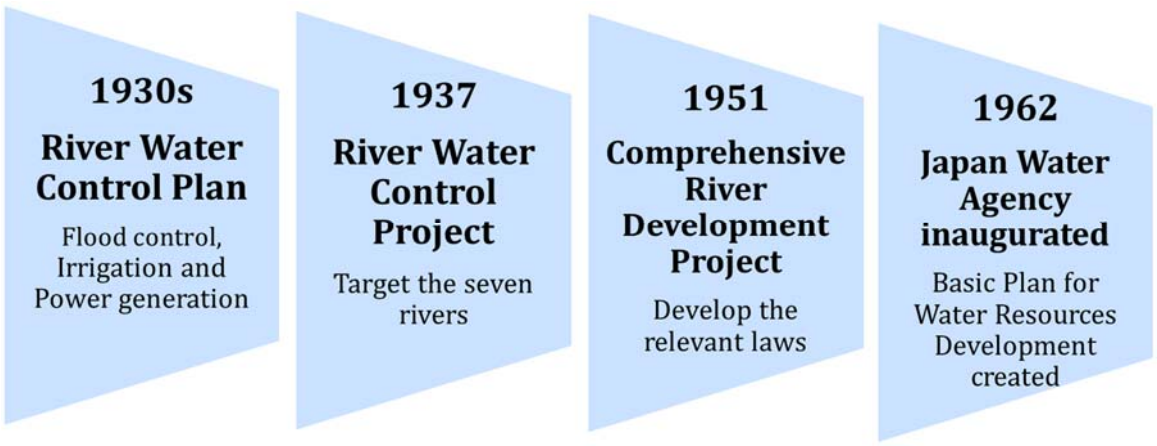


Figure 2. History of Comprehensive River Development

[1] The Home Ministry was changed into the Ministry of Home Affairs in 1947, then it was merged into the Ministry of Internal Affairs and Communications in 2001.

The plan for comprehensive river development targeted 7 rivers of the principal rivers identified in the 1937 survey, following the example of the work of the Tennessee Valley Authority (TVA) in the USA. The Comprehensive River Development Project was implemented in 1951, replacing previous development plans. River development related laws were established soon after.

Under the Act on Advancement of Water Resources Development promulgated in 1961, the Minister of Land, Infrastructure, Transport and Tourism designates water systems where water resources management in a wide area is necessary to meet the needs of industrial development and urban population growth. The Minister determines "the Basic Plan for Water Resources Development" (as known as the "Full Plan") targeting designated water systems.

(3) High Economic Growth and Drought in Urban Areas

During the period of high economic growth between the 1950s and 1970s, Japan experienced frequent droughts in urban areas. The national government adopted several approaches: water resources development by construction of multipurpose dams, promotion of efficient water use, adjusting water rights and coordination among stakeholders from water source areas and downstream to deal with water shortages.

High economic growth in the 1950s to 1970s brought rapid increase in population and water demand in major cities. Drought conditions exacerbated the pressure on water resources.

There is a limit to how much water can be extracted from the rivers. Dam construction can increase the capacity of water resources but is expensive. Therefore, to utilize this high cost investment efficiently the dam must serve multiple purposes, such as flood control, irrigation and hydropower generation and river maintenance.

The government also has to distribute the limited resource effectively. During drought events, irrigation water may have to be shifted to urban use.

In addition to resource distribution issues, there is also the challenge of balancing the burden to be borne by water source areas and the benefits to users. Lengthy negotiations are often necessary to reach agreement among stakeholders. Sometimes development projects are suspended pending the intervention by the Water Resources Development Public Corporation (established in 1962). In some cases, ways have been found for downstream users to contribute to development activities in the water source areas.

(4) Act on Advancement of Water Resources Development and Water Resources Development Public Corporation

In 1961, the Act on Advancement of Water Resources Development was established for comprehensive development of water resources and rationalization of water usage. The Act defines the principle of multipurpose dam development. The Water Resources Development Public Corporation was established as to promote water resources development.

There must be adequate water supply to meet the growing demand of industry and urban population. In 1961, the Act on Advancement of Water Resources Development was established for comprehensive development of water resources and rationalization of water usage. The Act designates water systems for water resources development and specifies the requirement of basic plans. The Water Resources Development Council was established and project leaders were appointed. In 1962, the Water Resources Development Public Corporation (now Japan Water Agency) was established to conduct projects for the development and use of water resources.

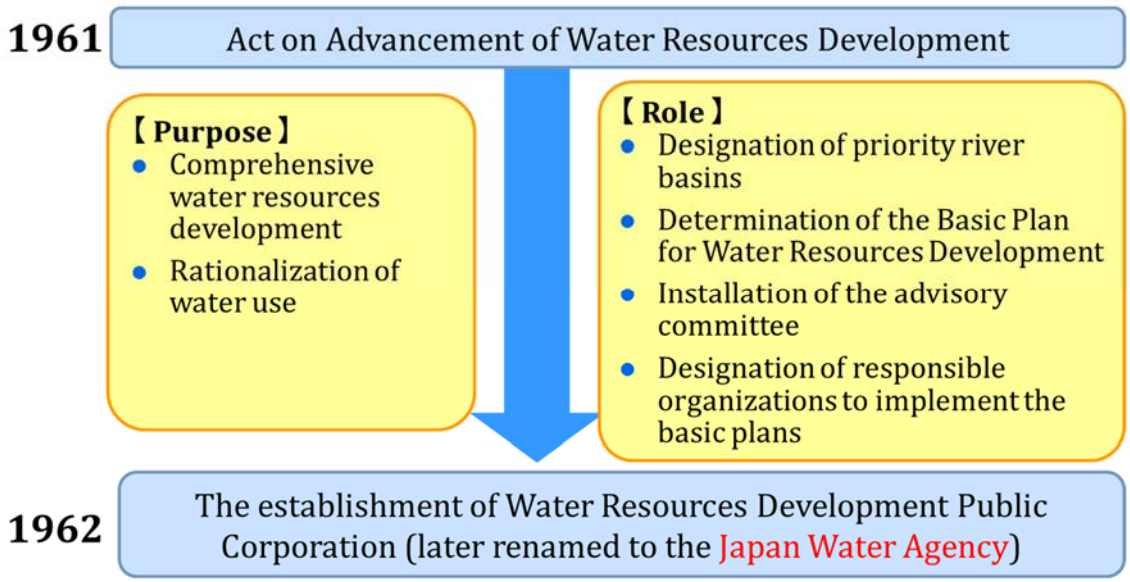


Figure 3. Act on Advancement of Water Resources Development and Water Resources Development Public Corporation

The Water Resources Development Public Corporation constructs and manages dams, barrages and canals. It is also responsible for the development of lakes and ponds as specified under the “Basic Plan for Water Resources Development” for Tone River, Arakawa River, Yodo River, Chikugo River, Kiso River, and Yoshino River water systems.

The basic plans for dam developments must integrate flood control with effective water utilization. One of the important characteristics of Japanese dam development is balancing the capacity required to handle a large 100-year flood event (or in some cases 50 to 200 year flood event depending on the importance of the river) and the capacity required to provide stable water supply during 10-year drought event.

(5) Bulk Water Supply

Utilities are run individually by municipalities, making it challenging to pursue regional collaboration to gain efficiency by broadening the coverage with integrated operations. Bulk Water Supply was developed to solve the problems of water resources development and to provide stable water supply for municipalities.

Bulk Water Supply is more than a means to secure water resources for the utilities. Several utilities, i.e. a broad area, can be served by the bulk supply thus improving the management efficiency and levelling out the capacity of the utilities. Integrating the operations of utilities for better efficiency is not easy because of their many differences in capacity, operation and management under local governments. Bulk Water Supply dealt only with securing water resources, while leaving the time consuming integration process aside.

Bulk Water Supply involves large scale water resources development and thus has the advantage that the huge development cost is shared among a number of users, who can count on a stable water supply. There are also savings in maintenance costs. However, this arrangement leaves the distribution of water to customers as a diminished operation that can run into financial difficulties because of fixed amount of water supply for long term and inefficient use of facilities, reduced operational scale, budget and personnel, while not benefitting from the cost savings from the Bulk Water Supply. Based on the experience, it is encouraged to collaborate water supply and distribution in developing water supply system in pursuing regional integration.

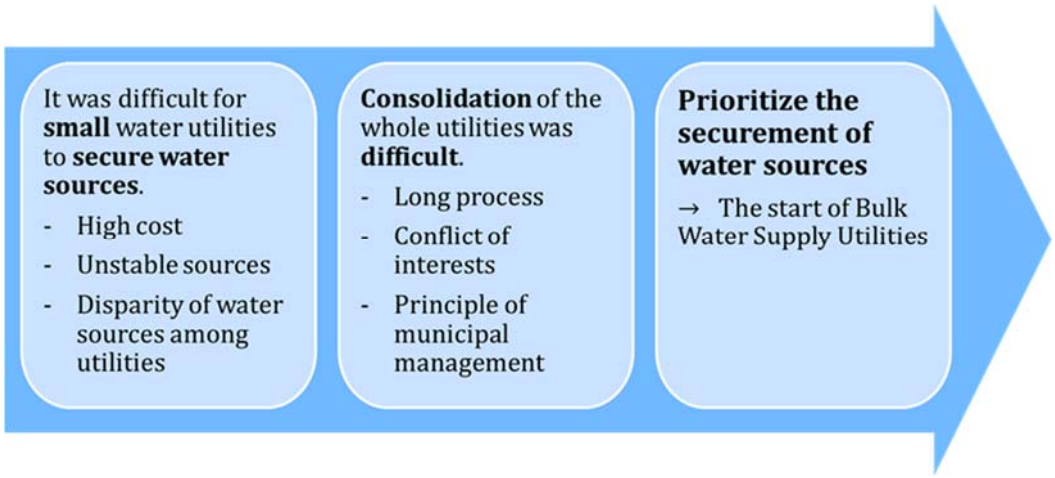


Figure 4. Background of the Bulk Water Supply in Japan

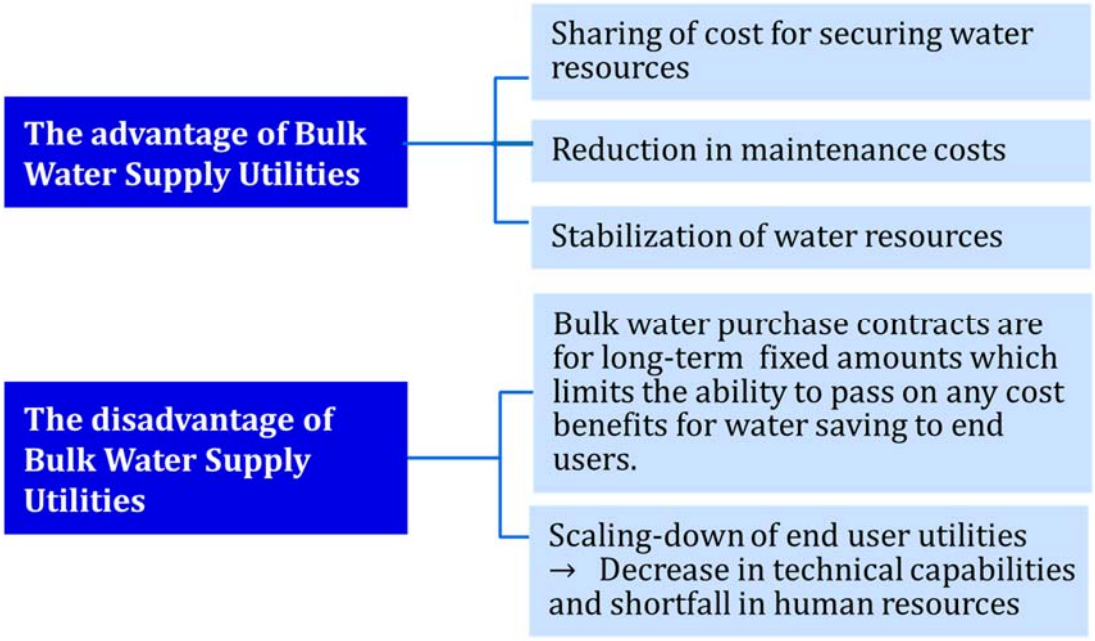


Figure 5. Concepts of Water Source Development

(6) “New” Water Sources

Japan promotes effective water use such as leakage reduction and water conservation. Unconventional water resources such as recycled water and seawater desalination are also introduced in the areas where drought occurs frequently.

In Japan, excessive groundwater withdrawal is restricted. Water resources development has been mainly focused on surface water. Other efforts to secure more water resources are turning to efficient water use, including recycling of industrial water, leakage reduction, and changing water use habits to conserve the resource. In areas where drought occurs frequently, water utilities engage in rainwater utilization, recycling and seawater desalination.

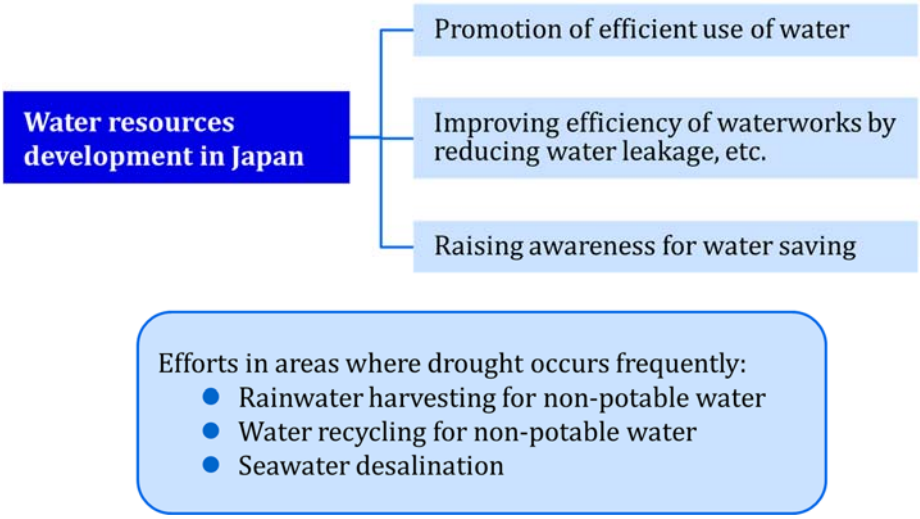
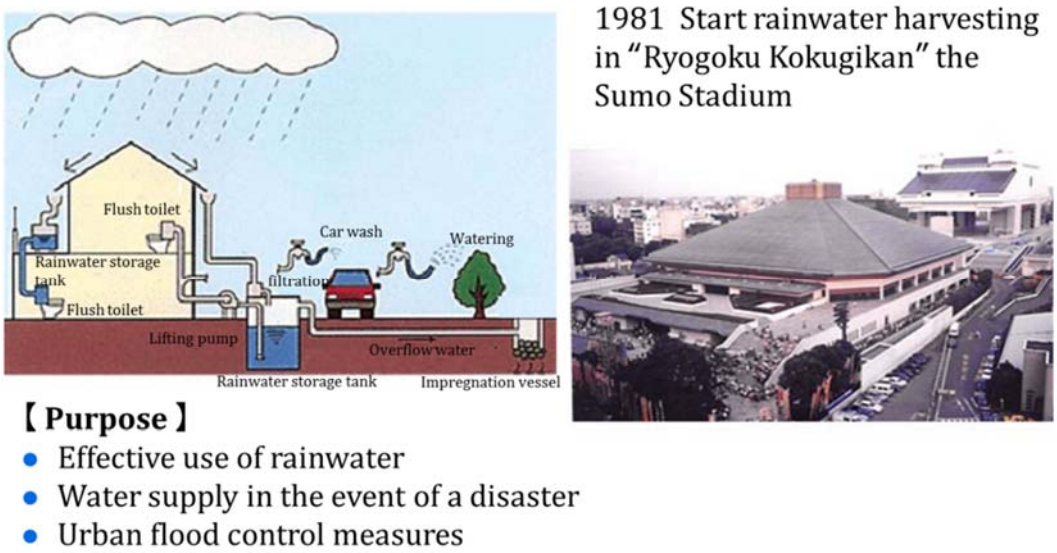


Figure 6. Concepts of "New" Water Sources



Source: Sumida City, *What is rain water use*?
https://www.city.sumida.lg.jp/kurashi/kankyou_hozen/amamizu/whats_amamizu/index.html

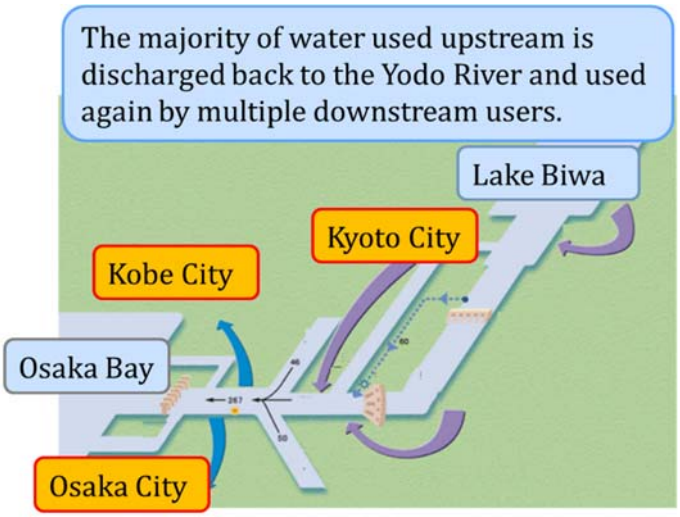
Figure 7. Rainwater Utilization in Sumida City

3. Case 1: Yodo River System Water Resources Development

(1) Background on Development of Yodo River System

Osaka City, Kyoto City and many other cities are located in the Yodo River watershed. The Yodo River water system serves different water usages in highly populated areas. Several pioneering projects for water resources development were conducted in the area because the origin of Yodo River is Lake Biwa, the biggest lake in Japan which has important environmental conservation issues.

Yodo River is the main water source for Osaka Prefecture. The river system starts at Lake Biwa, the largest freshwater lake in Japan, and flows through the valley in Otsu in Shiga Prefecture, continues south through the Kyoto Basin, merges with the Kizu and Katsura Rivers, before flowing south and west through the Osaka Plain. From the three river confluence the river is called Yodo River. It splits into the Kanzaki and Okawa Rivers before reaching Osaka Bay. The flow is stable and the large catchment area of 8,240 km^2 has a population of 12.09 million (Lake Biwa-Yodo River Water Quality Preservation Organization in 2010). There are many cities in the watershed with Osaka City being a major urban center and Kyoto City upstream. The environmental conservation of Lake Biwa has been a big issue. The need to provide water to multiple users and the high population density is making future developments of this river system the focus of special attention. Many pioneering projects have been launched in this system for water control and utilization.



Source: Ministry of Land, Infrastructure and Transport Yodogawa River Office, *Water use along the Yodo River*, http://www.yodogawa.kkr.mlit.go.jp/know/data/use/index.html

Figure 8. Water Use along Yodo River

(2) Securing Water Resources for Downstream Water Utilities

One of the issues for water utilities in the Yodo River basin was how to secure water resources. They succeeded to do this by sharing the cost for the development of Lake Biwa and the Yodo River system. The development considered all aspects of flood control, water utilization and environmental protection. The utilities managed to secure the long-term water rights and a stable water source.

Securing stable water resource had long been a challenge for the Osaka area. Many water utilization and flood control developments along the Yodo River, the only large water system for the region, were implemented and operated independently. They did not achieve the most efficient and effective outcomes. The Yodo River Control Project carried out from 1943 to 1952, was the first time that water utilization and flood control operations were planned and implemented in a comprehensive manner. The weir and facilities on the shores of Lake Biwa were rebuilt for water level control to manage water utilization and electric power generation. When the weir at Lake Biwa was operated for flood control only, approximately 50% of the annual discharge was wasted. The comprehensive development gained 15.157m^3/s of new water for the Yodo River Basin, enough to meet the demand at the time. Utilities shared the development costs, with 3/4 of the costs covered by beneficiaries of the project.

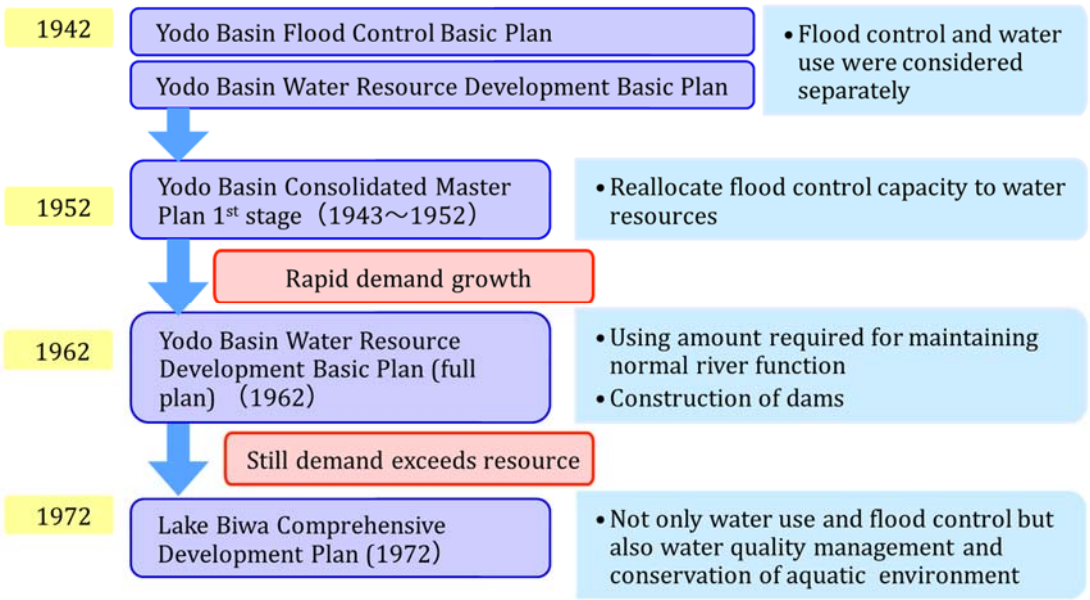


Figure 9. History of Utilization of Yodo River

After the mid 1950's, securing new water resources was urgently required as the population and water demand increased significantly. In 1961, the Act on Advancement of Water Resources Development was promulgated and the Water Resources Development Public Corporation was established. The Basic Plan for Water Resources Development for the Yodo River was determined the year after. The Water Resources Development Public Corporation led the efforts on the construction of dams in the water system and the allocation of water use to minimize any environmental impact.

At that time, although the water supply facilities had enough treatment capacity to meet the demand in the Osaka area, they did not have the water rights. To get around this problem, many projects were launched to use water from Lake Biwa. The Act on Special Measures concerning Development of Lake Biwa was enacted in 1972. Lake Biwa Comprehensive Development Project was launched to allow the withdrawal of water to 2.0 meters below the normal level, for water control and utilization in the Yodo River watershed. Shiga Prefecture, where Lake Biwa is located, insisted that withdrawal should be limited to 1.5 m below the normal level to protect the industries and environment around the lake. The final agreement allowed facilities to be built for water intake below 2 m, but any intake that would bring the water level below 1.5 m would require the approval of the Minister of Construction.

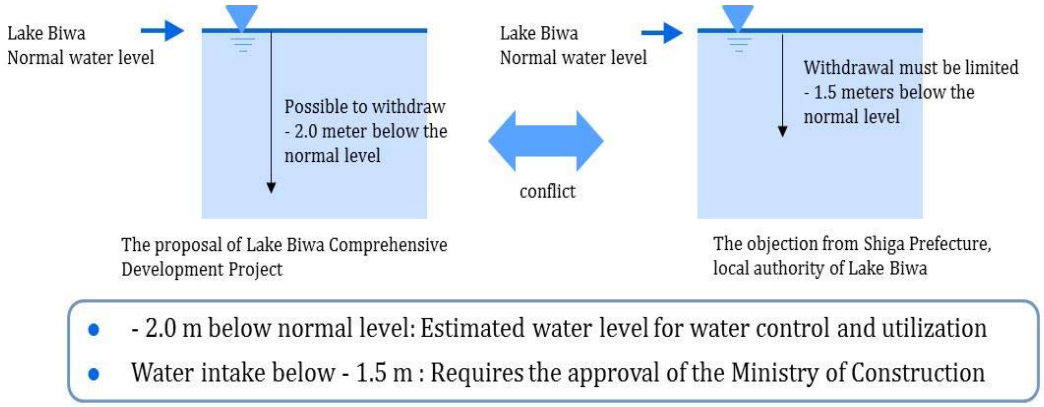


Figure 10. Lake Biwa Comprehensive Development Project

Maintaining water quality and preservation of the environment of Lake Biwa are also important objectives in the Lake Biwa Comprehensive Development Project. Eutrophication had been observed in the lake since 1950s, musty odor for the first time in 1969, and freshwater red tide occurred in 1977. Water quality improvement of the lake became a big issue. Projects such as construction of sewage treatment plants, livestock industry's environmental improvement facilities were promoted. These efforts reduced the pollution load even while the

population in catchment areas increased. The water quality of the river flowing into the lake improved and eutrophication was suppressed.

When the River Act was revised in 1997, improvement and conservation of river environment was added to the original objectives of flood control and water utilization. Consequently, the "Basic Policy for River Improvement" and "River Improvement Plan" were developed. The latter was prepared reflecting extensive opinions from local governments, academic experts and residents. The Yodo River Water System Committee was established in 2001, led by the Kinki Regional Development Bureau of the Ministry of Land, Infrastructure, Transport and Tourism. They discussed a wide range of issues, including flood prevention, water resources development, adjustment of water utilization, and conservation of the watershed. The committee accommodated the interests of stakeholders in the river basin.

Treated wastewater effluent from upper catchment cities including Kyoto, is discharged into the Yodo River, and is reused by Osaka and other downstream cities. The River Administrator and water utilities are actively engaged in water quality management in the watershed. There are regulations concerning the preservation of water quality of the Seto Inland Sea into which the Yodo River eventually flows.

With these efforts, the Hanshin area including Osaka secured enough water to meet the demand. By the time the water rights were issued, the demand for water supply began to decrease. The allocated volume and the nominal capacity of the treatment plants is enough to provide the daily maximum supply. There has been no need to seek the approval from the Construction Minister to draw water below 1.5 meters.

4. Case 2: Securing Water Resources in Okinawa Prefecture

(1) History of Okinawa Prefecture and its Water Shortage

Okinawa Prefecture consists of several islands and the watersheds are typically small. There are frequent water shortages because fresh water resources are scarce.

Okinawa Prefecture consists of 160 large and small islands that were governed by the USA from 1945 to 1972. Although the annual rainfall in Okinawa's main island exceeds that of the national average, the amount of available water resources per capita (area x [precipitation – evaporation] ÷ population) is about 60% of the national average. Water resources are very difficult to utilize because the rivers in Okinawa are short and steep, the watershed is small, runoff goes immediately into the sea and there is a big difference in the flow between the wet and dry seasons.

Since the USA relinquished the control of Okinawa in 1972, water supply facilities had been developed without much success in keeping pace with the increased demand until 1990's. From 1981 to 1982, Okinawa's main island experienced 326 days of water restrictions, the longest in Japanese history. There were frequent water supply disruptions until 1994, when the water resources developments described below were initiated.

(2) Dam Development

Okinawa Prefecture developed dams to ease water shortage with the national government's active involvement based on the Act on Special Measures concerning the Promotion and Development of Okinawa. Okinawa Prefecture installed transmission pipelines bringing water from the dams to the cities across the main island and manages the Bulk Water Supply for the municipalities.

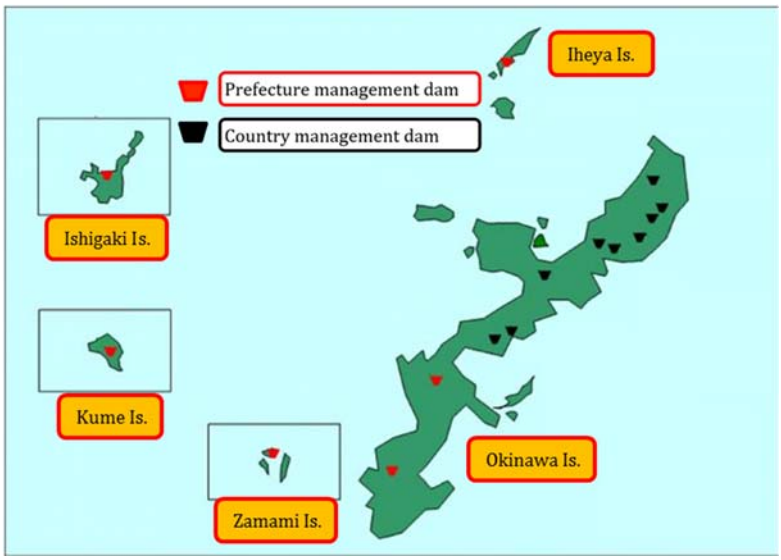
Fukuchi Dam is the largest dam on Okinawa's main island, with an effective storage capacity of 52 million m^3. When Okinawa was returned to Japan, securing stable water resources was one of the most important issues in promoting regional development. However, under the system at the time, the national government could only construct and manage multipurpose dams on Class A rivers that span several prefectures. Since Okinawa only has Class B rivers which are administered by the prefectural governors, special provisions had to be set under the Act on Special Measures concerning the Promotion and Development of Okinawa, to allow the

national government to be actively involved. The national government took over the construction of the Fukuchi Dam, which was half-finished by the US Army Corp of Engineers, and completed the project in 1974.

Later on, the national government constructed ten dams mainly in the northern area of the main island. Nine of them are managed by the national government after their completion. The prominent feature of Okinawa's water resources development is the active involvement of the national government which lessened the burden on local governments and addressed the urgency of water resources development.

The water sources developed in the northern area of Okinawa's main island are located far away from the water-consuming area in the south. About 100 kilometer of water distribution and conveyance pipelines had to be installed. Ryukyu Domestic Water Corporation (established in 1958 and reorganized as Okinawa Prefectural Enterprise Bureau in 1972) draws water from the dam reservoirs, manages the water treatment plant and supplies water to the residents. Ryukyu Domestic Water Corporation provides technical support for the development of the water utilities. The corporation has a strong relationship with the Okinawa Prefectural Enterprise Bureau.

Areas in the northern mountains have their own water source, and are not included in the bulk supply coverage. In these areas, the Foundation for Water Sources supported the development of water source forest. The Foundation (now dissolved) was organized by the national and prefectural governments and the water supply utilities.



Source: Okinawa Prefectural government, http://www.pref.okinawa.jp/site/doboku/damu/kanri/ken-damu.html

Figure 11. Dams in Okinawa Prefecture

(3) Rainwater Utilization

Rooftop tanks were used to store tap water and utilize rainwater to deal with frequent droughts in Okinawa.

Okinawa used to suffer from frequent water shortages because of droughts. Houses were built with roof top tanks to store tap water, collect and utilize rainwater. These are no longer needed after March 1994 when stable water resources were developed but residents still install tanks as an entrenched custom from the early days.

Photo 2. Rooftop Tanks in Okinawa Prefecture (December 28, 2016)

(4) Seawater Desalination

Seawater desalination is pursued as a stable water source when the usual water source is in short supply during frequent droughts.

From the 1980s to 1990s, Okinawa's main island suffered from repeated droughts. While dam development was on-going, construction of a seawater desalination facility was also taking place as an alternative measure to fill the gap between demand and supply capacity. The facility was completed in 1996. As the demand stabilized and dam developments completed, the facility does not need to operate at its full capacity of 40,000m^3/day. The system is fully established to

provide a stable supply of water if needed or if an emergency arises.

Photo 3. Seawater Desalination Facility in Chatan Water Treatment Plant (February 25, 2016)

(5) Promoting Water Conservation in Times of Drought

Okinawa, where people suffer from frequent droughts, promotes water conservation in various ways.

Okinawa residents are used to water shortages. Many public outreach activities are carried out to encourage people to save water during droughts. For example, electronic bulletin boards display “Conserve water during drought” at road sides. In 2014, when rainfall was extremely low, newspapers published daily information on falling water level at dams and appeals for water conservation were broadcasted on radio and TV.

5. Case 3: Water Resources Development and Developing Fukuoka into Water Conservation-Conscious City

(1) History of Various Water Resources Development

Fukuoka City does not have abundant water resources. In fact, it is the only city with no Class A river (designation by government ordinance). The city promoted 19 water resources development and water supply expansion projects. Water is brought from the Chikugo River outside of the city. The city also has one of the largest seawater desalination facilities in Japan.

Fukuoka City started operating a water supply system in 1923, with the planned service population of 120,000 and the maximum treatment capacity of 15,000m^3/day. Water demand kept increasing because of the merging of municipalities, economic growth and urbanization. The city has been making efforts to secure water resources since the 1950s, but water restrictions still occurred every two years in the 1960s. The city had to take further measures such as dam construction in rivers near the city, reducing irrigation water losses by replacing open channels with iron pipes and using the recovered losses for potable water supply, and developing the transmission system from Egawa Dam located at the branch of the Chikugo River.

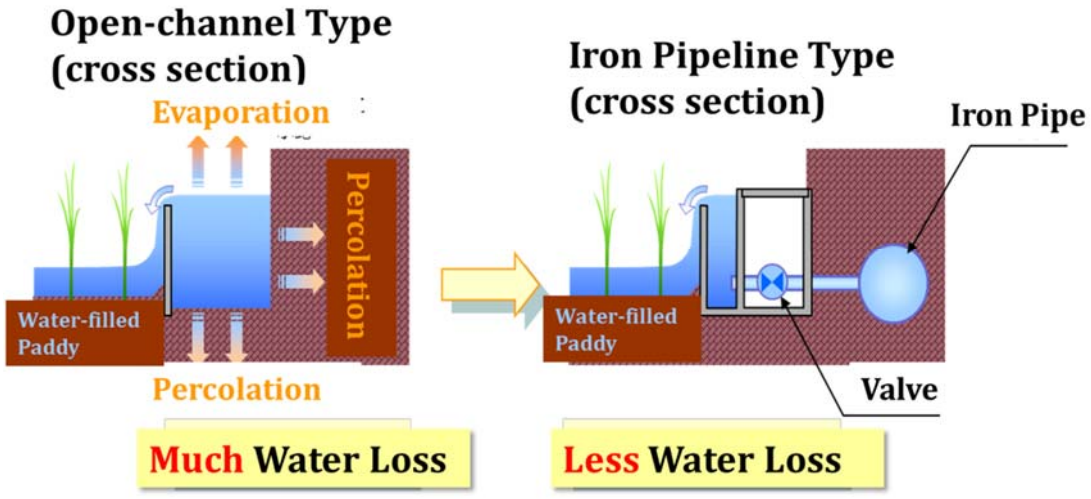


Figure 12. Efficient Use of Agricultural Water

The historic drought of 1978 brought a long period of water restriction that lasted 287 days. This experience convinced citizens that “water is a valuable and limited resource” and the city started to implement various policies based on the concept of “stable water supply” and “Water

Conservation-Conscious City”

In 1983, the city completed the inter-basin water transmission project from the Chikugo River system, which is away from the city and runs not only Fukuoka Prefecture but also different prefectures. This project had been envisioned since the water supply system was first established. Its achievement was the result of the understanding and cooperation of residents and other stakeholders in the watershed. The city also implemented several other projects such as: constructing various types of dams, increasing the capacity of existing dams by dredging, increasing the water abstraction rights for drinking water use by recharging rivers with treated wastewater and reallocating other water rights and river maintenance flows. The city participated in the construction of the Uminonakamichi Nata Sea Water Desalination Center to secure stable water supply even in times of drought. The city has been receiving water from the facility since 2005. (The facility’s maximum treatment capacity is 50,000 m^3/day including 16,400 m^3/day allocated to Fukuoka City.)

Photo 4. Uminonakamichi Nata Sea Water Desalination Center

The city is constructing the first dam for emergency water supply during extraordinary drought events in Japan. Water will be stored upstream of a river near the city and only distributed during extraordinary drought events which occur less than once in a decade. Ordinary dams for water shortage are normally dedicated to deal with drought once every ten years.

(2) Water Conservation-Conscious City

Fukuoka City not only actively developed water resources, but made extraordinary efforts to promote Water Conservation-Conscious City with the cooperation of its citizens, after experiencing two severe droughts in 1978 and 1994. Thus, water consumption per capita is the lowest among large cities in Japan and its leakage rate is one of the lowest in the world.

The 287-day water restriction in 1978 occurred because of extraordinary low precipitation which persisted since the previous year. Residents and the municipal government recognized the value of water and the difficulty in securing water source in Fukuoka City. In 1979 the city enacted the "Guidelines on Water Use and Conservation" to secure stable water supply. Water conservation efforts to promote Water Conservation-Conscious City were also needed because of the unreliable rainfall and increasing population. In 2003 the city revised the Guidelines and enacted the "Ordinance on the Promotion of Water Conservation," the first ordinance of this kind in Japan. The city enforces policies on "effective and reasonable use of limited water resources." Residents understand and support the initiative on "water use with care."

1) Promotion of Water Reuse

Fukuoka City promotes various water reuse systems to emphasize its goal of becoming a "Water Conservation-Conscious City." Individual reuse system is installed in a building for treating effluent to be reused for toilet flushing. A wide-range reuse system treats sewage water for watering gardens in parks and roadsides, and toilet flushing around large building complexes and housing developments. Rainwater collection is also practiced. It is obliged to install individual reuse system to flushing toilet for the building with the floor larger than reference area in Fukuoka City.

2) Introduction of Water Distribution Control

During the severe drought in 1978, Fukuoka City was not able to maintain water pressure evenly for different elevations. There was also the problem of uneven water distribution caused by the difference of water sources. In 1981 Fukuoka City established the Water Management Center which controls water pressure and flow from treatment plants to taps, aiming to fill the gap in the quality of water supply service.

3) Promotion of Leakage Reduction

Since 1956, Fukuoka City has actively promoted leakage reduction to save water and avoid accidents such as sinkhole along roads caused by leakage through the following measures:

Basic measures: The investigation plan for leakage reduction is reviewed every four years. The review analyzes the collected data and studies the causes of leakage, as well as evaluates the investigation methods and considers implementation of new technologies.

Corrective measures: Leakage risk in each area is regularly analyzed for early detection and quick repair. Leaks are investigated in an efficient and effective way by using sound listening rod, acoustic leak detector, and leak noise correlator. Repairs are carried out immediately 24 hours a day.

Preventive measures: Old distribution and service pipes which reached or exceeded its lifespan are replaced according to a planned schedule. Adjustment is made to prevent excessive pressure or fluctuations which can cause leakage.

4) Improvement of the Water Distribution System

Fukuoka City modifies its water distribution system systematically to achieve stable water supply based on the following principles:

Improvement of pipelines: to improve water flow by replacing or upgrading old pipes and by rearranging pipes to make loops to decrease stagnation.

Water as a lifeline in emergencies: to reconstruct or reinforce facilities to enhance their earthquake-resistance to ensure that there is a continuous water supply in case of emergencies.

Balanced distribution and efficient operation: to control water distribution from five treatment plants in response to water consumption in each area, to develop distribution reservoirs for provisional storage.

Full coverage by the distribution system: to install distribution pipelines in the areas not covered by the existing network, in order of priority.

In addition to the above measures, Fukuoka City aims to survive droughts with the cooperation of its citizens. If every resident in Fukuoka City saves 10 liters of water a day, it will result in savings of approximately 5.5 million m^3/year, which is an amount larger than the capacity of the Nagatani Dam, the water source of the city. If everyone bears in mind the need to "use water with care" this will be as effective as any effort in water resources development. It

will be like having a virtual dam built by the residents and it supports to promote Water Conservation-Conscious City.

5) Public Relation Activities

Fukuoka City carried out many public relation campaigns for water conservation since 1979. The city designated a period for “water saving days” and created the “water saving logo” to commemorate the 1978 drought event as well as recognizing it as an opportunity for appreciating the value of the resource. The “careful water use” campaign is conducted during the “water saving days” from June 1st to August every year, when water demand is high. During the campaign, the Waterworks Bureau distributes “Mizu-dayori (Water News)” to all households and publishes educational material, “Mizu to Watashi tachi (Water and Us),” for 3rd and 4th grade students. Water treatment facilities are open for public tours year-round. The city’s efforts to become Water Conservation-Conscious City are very successful in fostering the notion of water as a limited and valuable resource and the need to use it carefully.

6) Diffusion of Water Saving Devices

Fukuoka City encourages its citizen to install a “water saving tap washer” which is replaced with usual washer in tap and it can reduce water flow compared to the normal one. The city also advocates the usage of water saving toilets (approximately 4 liters/flush) and similar devices.

Fukuoka City has succeeded in reducing its non-revenue water to less than 5.1% during 20 years, and as low as 3.9% in 2015. Residents of Fukuoka City are highly aware of the need for water conservation. The 2015 survey found that approximately 86% of residents are conscientious about water conservation. They use the least water (FY 2015: 194 l/person/day) among large cities in Japan.

6. Lessons Learned

The following Japanese experience could be useful for other countries.

- **(Comprehensive River Development)** While securing water resources is a top priority for utilities, the use of river water must be well planned and controlled in a fair and equitable manner. The Japanese system makes great efforts in this regard, by allocating water rights and implementing comprehensive river development. The Water Resources Development Public Corporation (now Japan Water Agency) balances the needs for flood control and water utilization.

- **(Multipurpose Dams)** Dam construction is expensive but effective for water resources development. Therefore, dams are constructed with a multi-purpose concept to be cost effective. In Japan, reasonable cost sharing among users and coordination among government organizations and dam reservoir users have been emphasized in dam development.

- **(Bulk Water Supply)** Water utilities can cooperate to utilize Bulk Water Supply as their water source. They also benefit from integrated management by joining efforts from resource development to water distribution to end users.

- **(Other Means to Secure Water Resource)** Dam construction takes a long time to complete; therefore, other means to secure water resource must be implemented at the same time. The combined efforts in rainwater utilization, leakage reduction, reuse and water saving campaign have all helped to make lower water consumption in Fukuoka City than the national average. Seawater desalination is much more expensive than the use of surface water, so it is still only a supplemental method to obtain additional water resources.