INFORMATION

# Nagara River Estuary Barrage

# History of flood control along the Nagara River

## 1 Ring-levee communities of *waju*

The Nagara River empties into Ise Bay through the downstream basin it has shaped together with the other two of the Kiso Three Rivers, namely the Kiso River and Ibi River. The mesh-like pattern of intertwined streams has shifted during each flood.

In 1609, at the dawn of the Edo period (1603–1868), a great levee was constructed on the left bank of the Kiso River to protect the domain of Owari. This nearly 50-km-long levee called *okakoi zutsumi*, literally a levee enclosure, served as a bulwark against other clans from western Japan as well as floods. Unfortunately, the domain of Mino on the opposite side of the river suffered frequent flooding because of the restriction imposed to keep their levees at least 91 cm lower than the levee enclosure of *okakoi zutsumi*, a fact that prompted further development of ring-levee communities called *waju*.

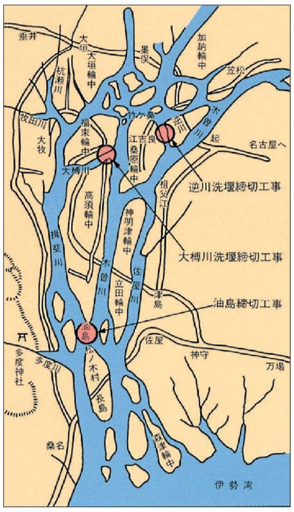
Each *waju* community is encircled by a levee to protect settlements and farmland from floods. These ring levees, constructed by local residents, are witnesses to united struggles of community members against the ever-present threat of flooding over their long history.

## 2 Horeki Flood Control Works

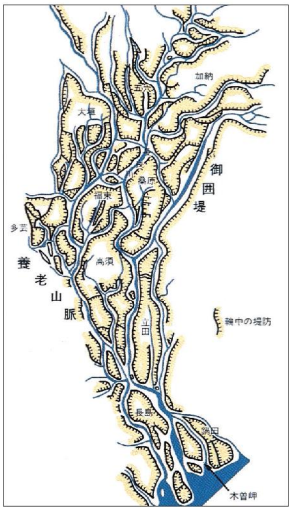
In the mid-Edo period, the ruling Tokugawa shogunate assigned so-called Horeki Flood Control Works to divert the courses of the Kiso Three Rivers. The Shimazu clan duly fulfilled the duty by constructing the Aburajima cofferdam and other works between 1754 and 1755.

## 3 Improvement works during the Meiji period (1868–1912)

In 1887, the fledging Government of Meiji Japan embarked on major improvement works with an ambitious plan to completely divert the Kiso Three Rivers. The works lasted until 1912, and costed about 12 percent of the national budget to shape the downstream basin close to what it is today.




Sketch map of downstream basin (1755) and target sections of the Horeki Flood Control Works




Distribution map of *waju* communities before improvement works during the Meiji period

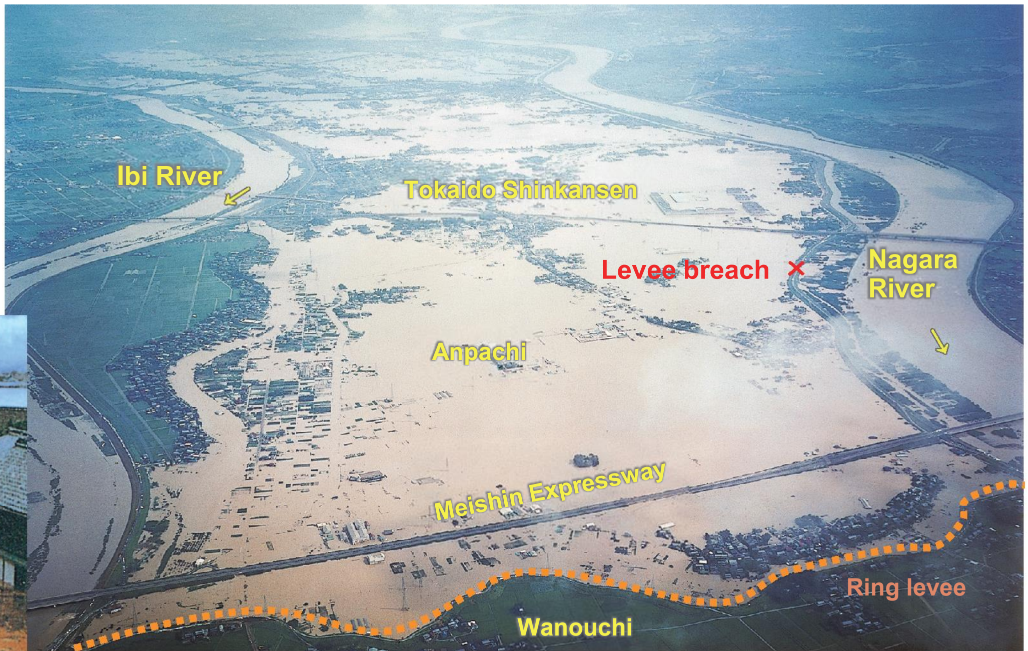
Plan drawing of improvement works by the Meiji government

## 4 Disasters in recent years

The improvement works during the Meiji period have considerably mitigated risks of flooding in the downstream basin of the Kiso Three Rivers. Notwithstanding that, Typhoon Vera hit the Tokai Region in September 1959 and devastated the three prefectures of Gifu, Aichi, and Mie. With other affected prefectures included, over five thousand people were killed or went missing. In August of the following year, Typhoons Virginia and Wendy caused serious flooding damage, such as levee breaches on the Nagara River. Later, in June 1961, intense rainfall from a seasonal rain front and Typhoon No. 6 caused yet another major flood that breached a levee along the Nagara River and inundated a vast area extending across the cities of Gifu, Ogaki, and beyond. These floods, including the one caused by Typhoon Vera, are known as the three major floods of the Showa period (1926–1989).

Later, in September 1976, an unlucky combination of a rain front and Typhoon Fran caused a week of heavy rain that led to major flooding of the Nagara River. Consequent severe damage in various parts of the basin included the collapse of the right bank in the area lying beyond Moribe in Anpachi, a part of Anpachi District in Gifu Prefecture.

People crossing an inundated area on a boat in September 1976 (Anpachi, Anpachi District, Gifu Prefecture)




Inundation following the collapse of the Nagara River's right bank in the area lying beyond Moribe in Anpachi (Anpachi and Sunomata (today's Sunomata in the city of Ogaki) in Anpachi District, Gifu Prefecture, September 1976)

# Sound water resource development and prevention of salt damage induced by dredging

## ●Dredging the Nagara River and preventing the associated seawater intrusion

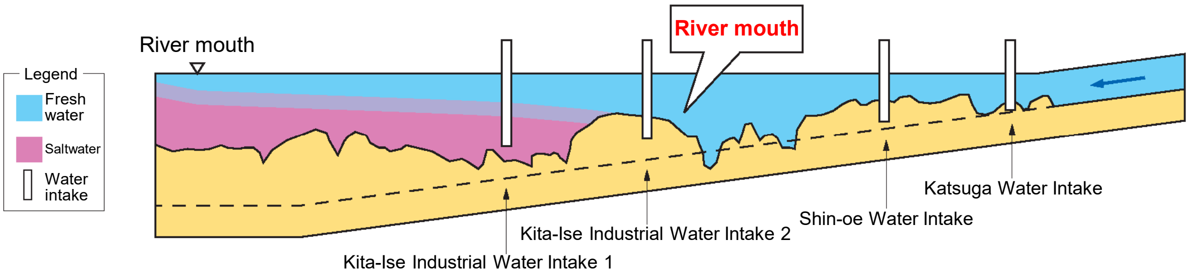
Prior to construction of the estuary barrage and dredging works, a relatively elevated strip of the riverbed, known as the mound in the section between roughly 14 and 18 km from the river mouth, had somehow managed to hold back seawater intrusion even when the river carried little water.

Dredging carried out according to the plan to deepen the riverbed across the board would have let seawater advance to about 30 km from the river mouth, further upstream of the mound that held it back. Resulting salination would thus render river water unfit for use in the hitherto unaffected upstream areas. Over time, both groundwater and soil would suffer salt damage and become unfit for farming and significantly limit other land use.

The Nagara River Estuary Barrage holds the tide back so that dredging works can be carried out while preventing salt damage. It has desalinated the upstream area, which led to further water resource development.

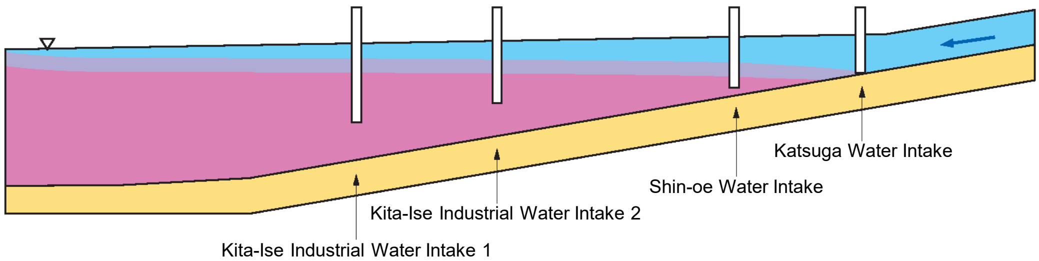
Dredging works of the section with the mound began a day after the barrage was put into full service on July 6, 1995 and ended in July 1997.

### ◆ Before barrage construction and dredging works

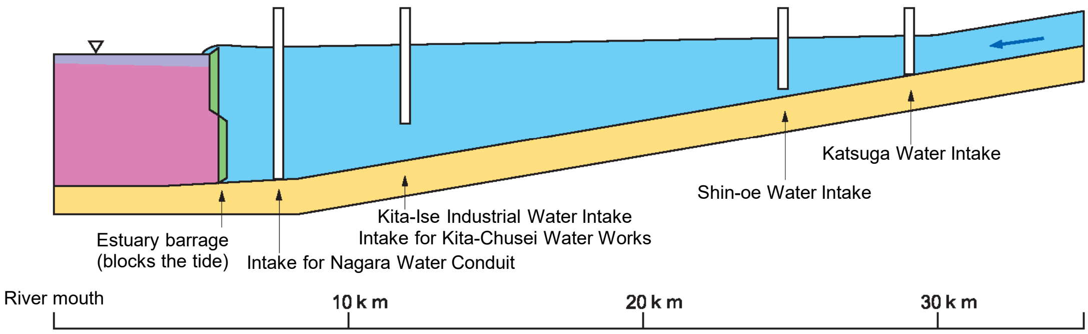



### ◆ Saltwater intrusion that would result from dredging works without barrage construction

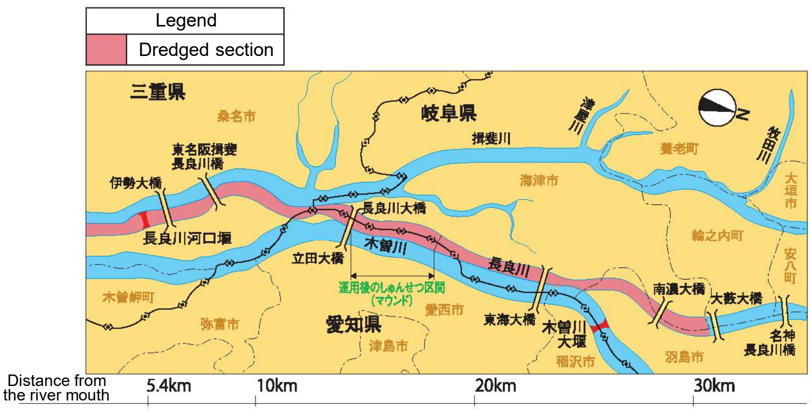
(water becomes unfit for intake and groundwater is contaminated by salt)




### ◆ Dredging works carried out after barrage construction to block saltwater




## ●Dredged section in the Nagara River




## ●Mound in the section 14–18 km upstream of the river mouth

Mound exposed above the water at low water during a spring tide

# Benefits of the Nagara River Estuary Barrage

## 1 Robust flood control

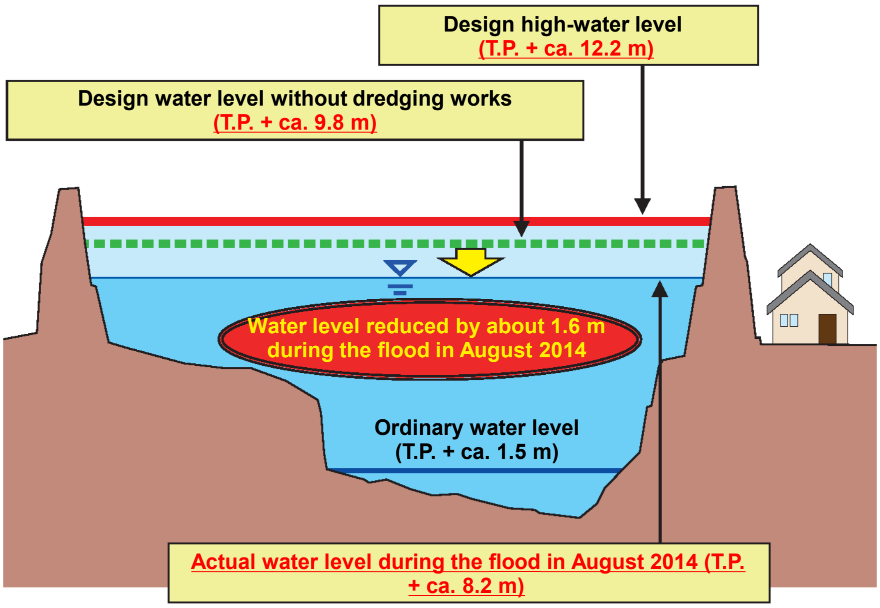
Construction of the Nagara River Estuary Barrage began in fiscal year 1971. With understanding and support from local community members, such as stakeholders in the fishery and farming sectors, the permanent works were completed in fiscal year 1994 for gate operation to begin in July 1995. Subsequent dredging works of the section with the mound that lasted until July 1997 has significantly improved the discharge capacity of the river downstream when it swells. Operating the barrage has reduced the risk of levee breaches and proved very effective in flood control. For instance, during major floods of the river above the flood-watch water level in October 1998, September 1999, September 2000, July 2002, October 2004, and August 2014, the water level was reduced by one to two meters compared to the level that would have resulted without the barrage.

During the flood of the Nagara River on August 17, 2014 caused by heavy rain from a front that remained over the area from August 14 to 18, dredging works are estimated to have reduced the water level by about 1.6 m at the Sunomata gauge station 39.2 km upstream of the river mouth compared to the level that would have resulted before the works. As a result, the high water could be safely conveyed downstream.

**Reduced water level during flood**
(Sunomata gauge station, 39.2 km upstream of the river mouth)

### ●Reduced water level at peak flow

* T.P. is short for the mean sea level of Tokyo Bay (Tokyo Peil) that serves as the altitude reference point in Japan.




### ●Reduction in water level during major floods

| Date | Peak flow rate at the Sunomata gauge station | Reduced peak water level at the Sunomata gauge station |
|---|---|---|
| October 18, 1998 | ca. 4,300 m³/s | ca. 1.2 m |
| September 15, 1999 | ca. 5,900 m³/s | ca. 1.1 m |
| September 22, 1999 | ca. 4,400 m³/s | ca. 1.3 m |
| September 12, 2000 | ca. 4,900 m³/s | ca. 1.2 m |
| July 10, 2002 | ca. 4,400 m³/s | ca. 1.6 m |
| October 21, 2004 | ca. 8,000 m³/s | ca. 2.0 m |
| August 17, 2014 | ca. 4,100 m³/s | ca. 1.6 m |

## 2 Better water use

### (1) New water supplies

The Nagara River Estuary Barrage desalinated upstream water, which became available for water supplies and industrial use at a maximum volume of 22.5 $m^3$ per second.

In April 1998, intake of this newly developed source was initiated for the Nagara Water Conduit and Kita-Chusei Water Works.

○Nagara Water Conduit (2.86 $m^3/s$)
Water is taken in and supplied as municipal water to four cities and five towns in the Chita Peninsula in Aichi Prefecture.

○Kita-Chusei Water Works (0.732 $m^3/s$)
Water is taken in and supplied as municipal water to two cities in the Chusei area in Mie Prefecture. The facility currently delivers industrial water supplies in Kita-Ise.

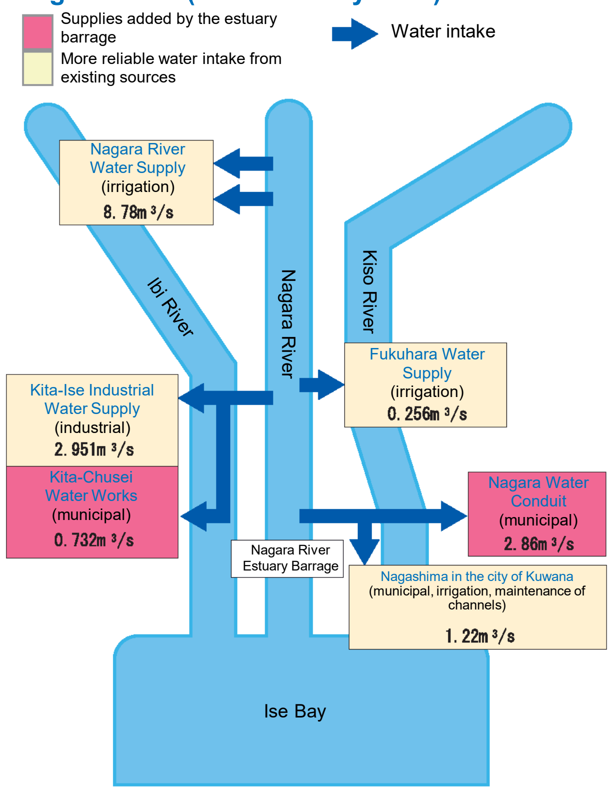
### ●Breakdown of water use (maximum amount)

(m³/s)

| | Aichi Prefecture | Mie Prefecture | Nagoya City | Total |
|---|---|---|---|---|
| Municipal water | 8.32 〈6.27〉 | 2.84 〈2.14〉 | 2.00 〈1.51〉 | 13.16 〈9.92〉 |
| Industrial water | 2.93 〈2.20〉 | 6.41 〈4.83〉 | — 〈—〉 | 9.34 〈7.03〉 |
| Total | 11.25 〈8.47〉 | 9.25 〈6.97〉 | 2.00 〈1.51〉 | 22.50 〈16.95〉 |

Top: Planned amount
Bottom: Ensured availability (during the second most severe drought in the last 20 years)

### ●Water use in the downstream part of the Nagara River (as of January 2015)



## (2) More reliable water intake from existing sources

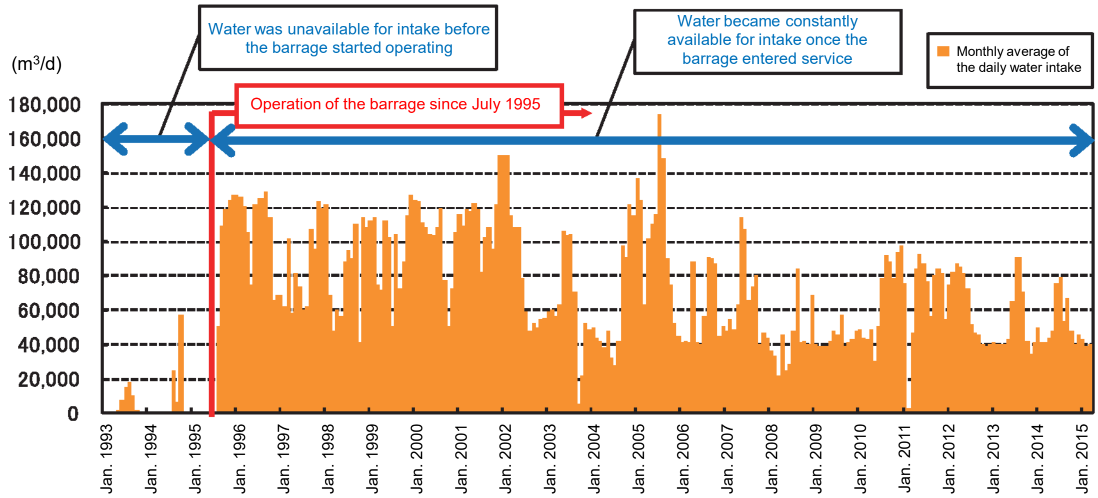
Prior to the full-fledged operation of the Nagara River Estuary Barrage, water intake from existing sources downstream of the mound was impeded by contamination with saltwater intrusion induced by subsidence of the riverbed. Intake had remained particularly unstable for the Kita-Ise Industrial Water Supply, even with the second intake constructed to cope with the problem. Once the barrage entered full service, water intake became more reliable as water upstream of the barrage was desalinated.

- O Kita-Ise Industrial Water Supply (2.951 $m^3/s$)
- O Fukuhara Water Supply (0.256 $m^3/s$)
- O Water supply to Nagashima in the city of Kuwana for irrigation, municipal use, and maintenance of channels (1.22 $m^3/s$)

In the past, Nagara River Water Supply drawn from upstream of the mound used to be affected by the tide. However, more reliable intake became possible because the full-fledged operation of the barrage stabilized the water level.

- O Nagara River Water Supply (8.78 $m^3/s$) for irrigation in the cities of Hashima and Kaizu in Gifu Prefecture

### ●Intake record of Kita-Ise Industrial Water Supply




## (3) Greater capacity to cope with drought

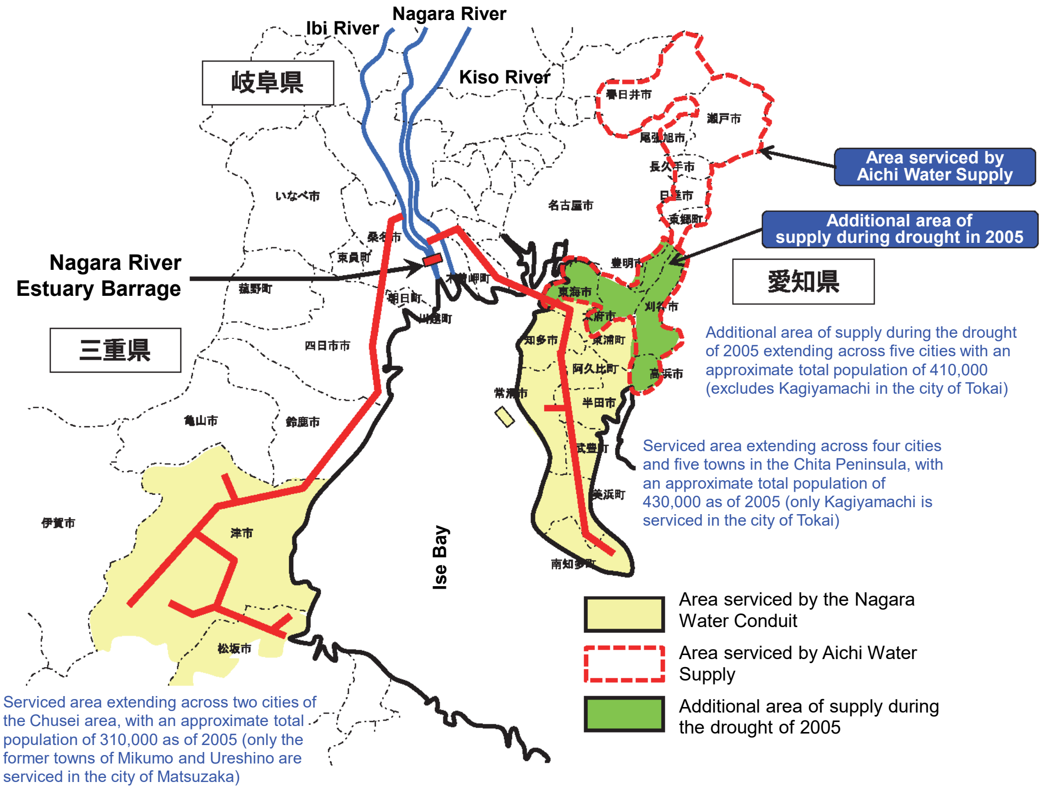
The Kiso River System was affected by drought when the amount of rainfall in July to August, 2000 fell nearly 40 percent lower than that of an average year. Still, water supplies were not disrupted owing to new sources that became available for locations such as the Chusei area in Mie Prefecture and the area serviced by Aichi Water Supply in Aichi Prefecture. This development was thanks to the Nagara River Estuary Barrage, Agigawa Dam, and Misogawa Dam.

Were it not for water delivery from the Nagara River Estuary Barrage, the Mie prefectural government estimated that about 64,000 households or 180,000 residents in serviced municipalities in the Chusei area would have suffered disruption of supply for about three to eight hours a day. Likewise, the water supply to about 1.25 million residents in the area serviced by Aichi Water Supply probably would have been curtailed or disrupted because Makio Dam would have dried up without water delivered from the barrage or other sources.

Later, from spring to summer 2005, the amount of rainfall in the Chubu region fell 20 to 40 percent below that of an average year. Water stored in dams in the Kiso River System was drawn down at a faster pace than during the recent past's most severe drought year of 1994, which raised concerns about the potential impact on water supplies. Fortunately, people in the Chita Peninsula in Aichi Prefecture were not forced to cut water use thanks to reliable supply from the Nagara River Estuary Barrage via the Nagara Water Conduit.

The unused portion of water supplied through the Nagara Water Conduit (0.66 $m^3/s$) was delivered to a neighboring area, usually served by Aichi Water Supply, to make the best use of the source developed by the Nagara River Estuary Barrage. This diversion has mitigated the impact of drought on the area served by Aichi Water Supply that happened to host Expo 2005.

### ●Better water use during the drought of 2005



# Key environmental surveys conducted in relation to the Nagara River Estuary Barrage

In the planning phase of constructing the Nagara River Estuary Barrage, a survey team known as KST studied resources in the estuarine region of the Kiso Three Rivers. Later, various kinds of studies were conducted at each milestone marked by the beginning of important construction works. They were aimed at keeping records of associated changes in the local environment and ensuring that adequate measures are taken as necessary. In fiscal year 1994 when the permanent works were completed, another study was conducted while operating the barrage gates.

From fiscal year 1995, changes in the river environment were monitored for five years to check the effectiveness of conservation measures. The survey primarily examined the following items, with advice and recommendations from experts so as to conserve the environment of the Nagara River while making sure that the barrage fulfills its original purpose.

❶ Disaster prevention
- Measures against water infiltration into *waju* ring-levee communities
- Saltwater distribution

❷ Water quality and bottom sediment

❸ Ecosystem
- Upstream and downstream migration of fish
- Habitat for plants, fish, shellfish, and other animals

This survey was publicly conducted with guidance and advice from a committee of experts to monitor the Nagara River Estuary Barrage. Each year, survey results were published in an annual report on barrage monitoring.

### ●Status of environmental surveys

KST調査 (S38–S42)　モニタリング調査 (H7–H11)　フォローアップ調査 (H12–)

| 調査項目＼年度 | S38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 植物 陸上植物 | ● | ● | ● |  |  |  |  |  |  |  | ● | ● | ● |  |  |  |  |  |  |  | ● | ● |  |  |  |  |
| 植物 水生植物 大型水生植物 | ● | ● | ● |  |  |  |  |  |  |  |  |  |  | ● |  |  |  |  |  |  |  |  |  |  |  |  |
| 植物 水生植物 付着藻類 | ● | ● |  |  |  |  |  |  |  | ● | ● |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 動物 哺乳類 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | ● | ● |  |  |  |
| 動物 鳥類 |  |  |  |  |  |  |  |  |  |  | ● | ● | ● |  |  |  |  |  |  |  | ● | ● |  |  |  |  |
| 動物 両生類・は虫類 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | ● | ● |  |  |  |
| 動物 昆虫類 |  |  |  |  |  |  |  |  |  | ● | ● |  | ● |  |  |  |  |  |  |  | ● | ● | ● |  |  |  |
| 動物 魚類 |  | ● | ● |  |  |  |  |  |  | ● | ● |  |  | ● |  |  |  |  |  |  |  | ● | ● |  |  |  |
| 動物 貝類 | ● | ● | ● | ● |  |  |  |  |  | ● | ● |  | ● |  |  |  |  |  |  |  |  | ● | ● |  |  |  |
| 動物 甲殻類 | ● | ● |  | ● |  |  |  |  |  | ● | ● |  | ● |  |  |  |  |  |  |  |  | ● | ● |  |  |  |
| 環境庁調査 |  |  |  |  |  |  |  |  |  |  | ❶ | ❶ |  |  |  | ❷ | ❷ |  |  |  | ❸ | ❸ | ❸ | ❸ | ❸ | ❹ |
| 人工種苗生産技術の開発 アユ |  | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |  |  |  |  |  |  |  |
| 人工種苗生産技術の開発 アマゴ |  |  |  |  |  |  | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |  |  |  |  |  |  |  |  |  |
| 魚道の開発及び改良 |  | ● | ● | ● | ● |  |  |  |  |  |  |  |  |  |  |  |  |  | ● | ● |  |  |  |  |  | ● |
| 漁場対策調査 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | ● | ● | ● | ● | ● |  |  |  |  |  |

| 調査項目＼年度 | H1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 植物 陸上植物 |  | ● | ● | ● |  | ● | ● | ● | ● | ● | ● |  |  | ● |  |  |  |  | ● |  |  |  | ● | ● |  |  |
| 植物 水生植物 大型水生植物 |  |  | ● | ● |  | ● | ● | ● | ● | ● | ● |  |  | ● |  |  |  |  |  |  |  |  | ● |  |  |  |
| 植物 水生植物 付着藻類 |  | ● | ● | ● |  | ● | ● | ● | ● | ● | ● |  |  |  | ● |  |  |  |  |  |  |  |  |  |  |  |
| 動物 哺乳類 |  | ● | ● | ● |  | ● | ● | ● | ● | ● | ● |  |  |  | ● |  |  |  |  |  |  |  |  |  | ● |  |
| 動物 鳥類 | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |  |  |  |  | ● |  |  |  |  | ● |  |  |  |  |
| 動物 両生類・は虫類 |  |  | ● | ● |  | ● | ● | ● | ● | ● | ● |  |  |  | ● |  |  |  |  |  |  |  |  |  | ● |  |
| 動物 昆虫類 |  |  | ● | ● |  | ● | ● | ● | ● | ● | ● |  | ● |  |  |  |  | ● |  |  |  |  |  |  |  |  |
| 動物 魚類 |  | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| 動物 貝類 |  | ● | ● | ● |  | ● | ● | ● | ● | ● | ● | ● |  |  |  | ● |  |  |  |  | ● |  |  |  |  |  |
| 動物 甲殻類 |  | ● | ● | ● |  | ● | ● | ● | ● | ● | ● | ● |  |  |  | ● |  |  |  |  | ● |  |  |  |  |  |
| 環境庁調査 | ❹ | ❹ | ❹ | ❹ |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 人工種苗生産技術の開発 アユ |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 人工種苗生産技術の開発 アマゴ |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 魚道の開発及び改良 | ● | ● | ● | ● | ● | ● |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 漁場対策調査 | ● | ● | ● | ● | ● | ● |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

(注1)　表中の●(緑)は現地調査が行われた年度を、●(青)は技術開発・改良に係わる調査・研究が行われた年度を示している。
(注2)　表中の❶、❷、❸、❹は環境庁(現環境省)による調査が行われた年度を示している。
❶ 第1回自然環境保全調査　❷ 第2回自然環境保全基礎調査　❸ 第3回自然環境保全基礎調査　❹ 第4回自然環境保全基礎調査

The monitoring committee held a total of twelve discussion sessions during the five years beginning in 1995. During their discussions, committee members provided necessary guidance and advice on monitoring plans and barrage operation to the predecessors of the Japanese Ministry of Land, Infrastructure, Transport and Tourism and the Japan Water Agency. Recommended activities included DO surveys and consideration of flushing operations to improve water quality. The monitoring committee was deemed to have mostly fulfilled its original purpose and was disbanded in March 2000. As it wound up, the committee indicated the immediate direction that should be taken on monitoring to keep the barrage operating reliably.

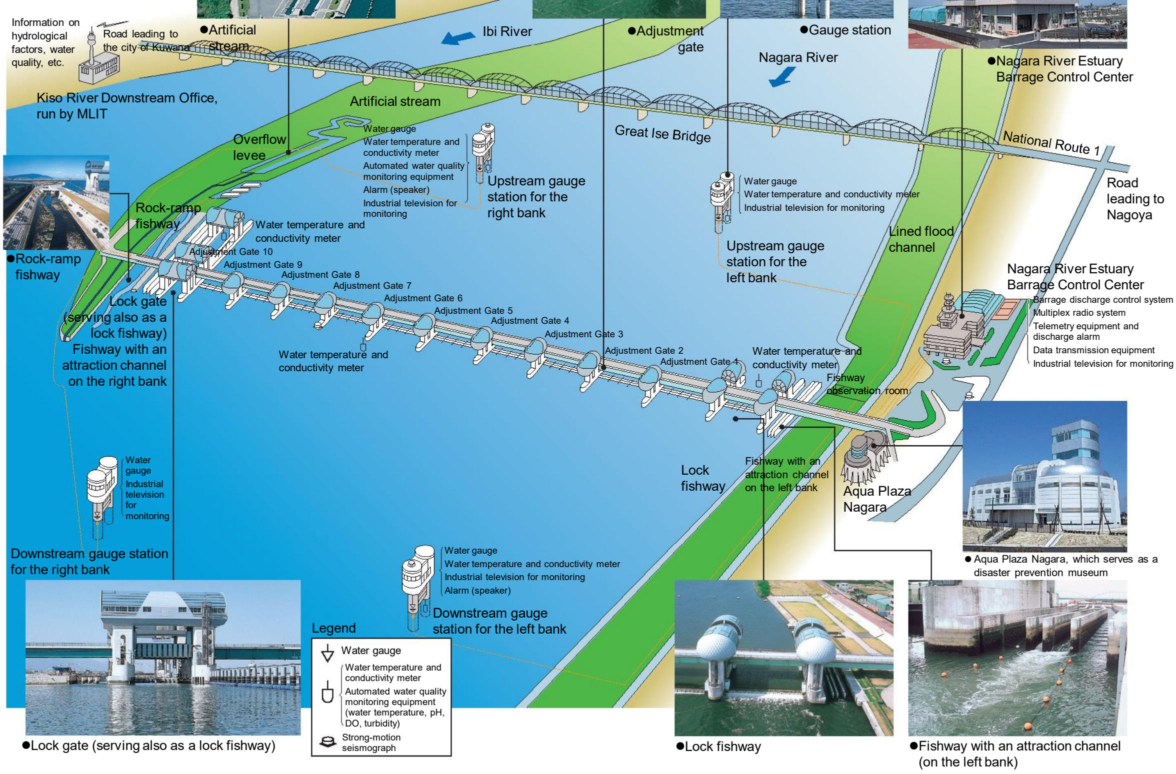
From fiscal year 2000 onward, monitoring continued in accordance with these recommendations through a follow-up survey. Findings were discussed among members of a follow-up committee for managing dams and the like in the Chubu Region and those of its subordinate barrage working group.

The follow-up committee has deliberated on analysis and evaluation findings from follow-up surveys compiled in regular reports in fiscal years 2004, 2010, and 2015. In the deliberations in fiscal year 2015—after 20 years of barrage operation—the committee acknowledged that the survey had been properly conducted; that the barrage has properly fulfilled its intended purposes to control floods and enhance water use; and that the barrage is properly managed and operated as demonstrated by the stable river environment in recent years after certain changes experienced soon before and after operation began.

# Facilities for barrage operation

## Overview

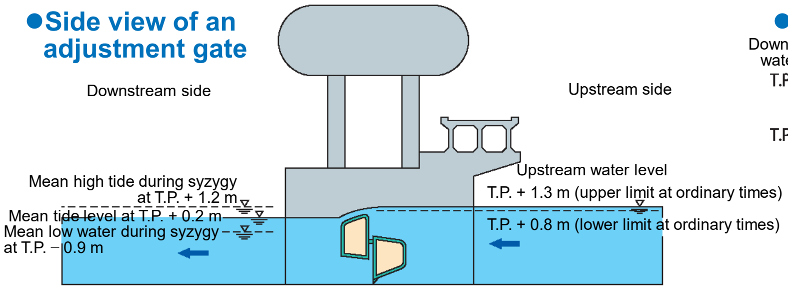
[Location]
Left bank: Nagashimacho-Tokadomo, Kuwana, Mie Prefecture
Right bank: Fukushima, Kuwana, Mie Prefecture

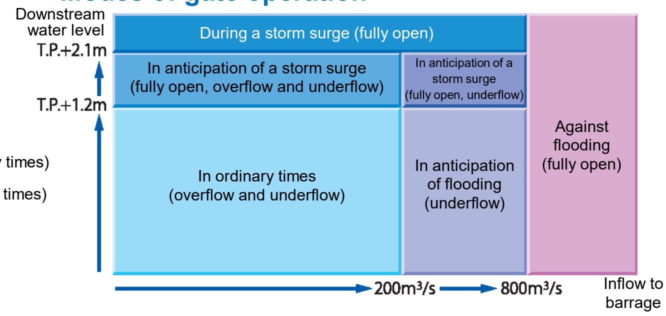
# Gate operation

All gates of the Nagara River Estuary Barrage employ an environmentally sound double-roller design to perform both overflow and underflow operations in a fine-tuned manner. These gates are operated in modes corresponding to different amounts of inflow and water levels on the downstream side in ordinary times, against flooding, against flooding combined with a storm surge, and in anticipation of a storm surge. Another type of operation is carried out in response to a tsunami. Each operation is outlined as below.

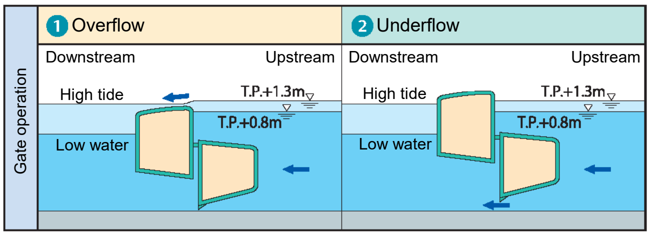
## ●Side view of an adjustment gate




## ●Modes of gate operation




## 1 Operation in ordinary times




In ordinary times, the river environment is conserved with a combination of overflow operation (❶) and underflow operation with raised lower stage gates (❷) to let water flow both over and under the gates and further down the river. The water level upstream is kept as low as possible with a given inflow to minimize the difference with the downstream level. In principle, it is kept up to 0.8 m above T.P., or the mean sea level of Tokyo Bay (Tokyo Peil), while the upper limit is assigned at T.P. + 1.3 m or the level 0.1 m higher than the mean high tide during syzygy at T.P. + 1.2 m.

Adjustment gates are operated with careful consideration to help fish move upstream or downstream. For instance, during an upstream migration season, priority is given to gates near both shores next to the fishways to lower the water level and thus lure fish into them.

As a way to safeguard its quality, upstream water is occasionally flushed, aside from being constantly sluiced in ordinary times. Since fiscal year 2011, the barrage has been operated even more flexibly to conserve and improve the river environment.

## 2 Operation against flooding

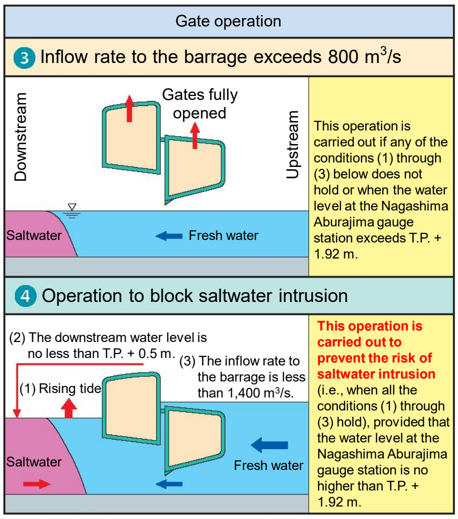
When a flood occurs, all gates (ten adjustment gates, as well as a few other lock gates and lock fishway gates) are lifted above the levee height so they do not hamper the flow of flood water.

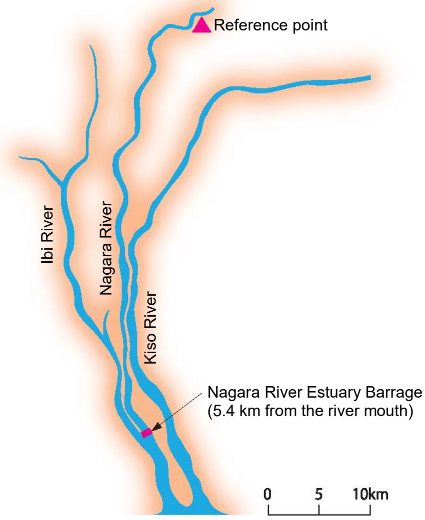
Overflow operation takes place by default until the inflow rate to the barrage reaches 200 m$^3$/s. Once that threshold is crossed and further increase is anticipated, adjustment gates are lifted for underflow operation to prepare for full opening in response to flooding.

The operation to fully open all gates against flooding is prompted by measurement of the flow rate at a reference point upstream to allow enough time before the inflow rate to the barrage reaches 800 m$^3$/s. In this manner, gates can be raised safely and reliably while avoiding sharp fluctuations in water levels both upstream and downstream of the barrage.

Once the inflow rate reaches 800 m$^3$/s, saltwater is washed downstream and eliminates the risk of saltwater intrusion further upstream. Accordingly, all gates are fully opened (❸) and their bottom edges are kept higher than the levee height (T.P. + 5.8 m) until the inflow rate subsides below 800 m$^3$/s.

Any risks of saltwater intrusion induced by a particular downstream water level or other conditions can be stemmed by maintaining the operation to block the intrusion without fully opening the gates (❹).




## 3 Operation against a storm surge

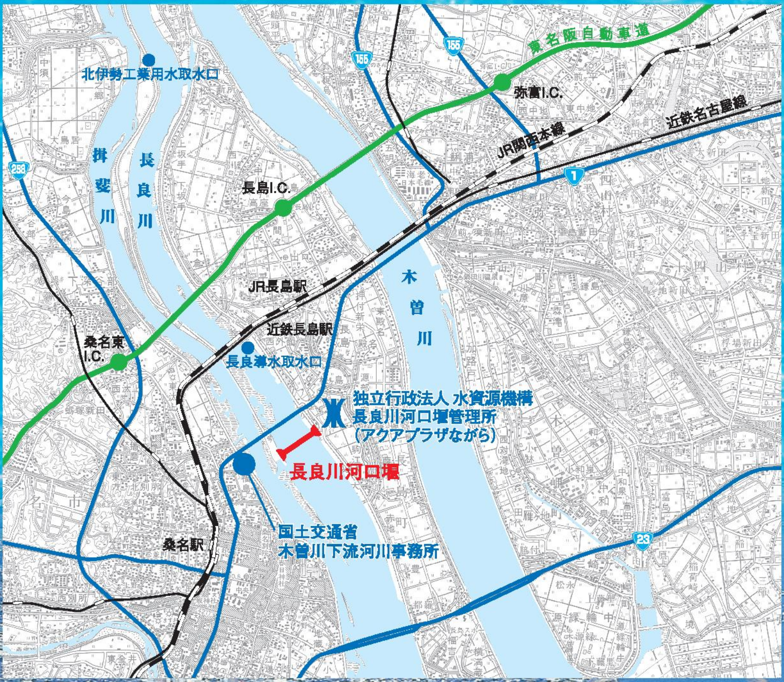
When a storm surge occurs, all gates are lifted above the levee height in the same manner as against flooding so no gates hamper the river's flow. Gates are fully opened if the downstream water level exceeds T.P. + 1.2 m and is expected to rise beyond T.P. + 2.1 m to avoid sharp fluctuations in water levels both upstream and downstream of the barrage. Once the downstream water level exceeds T.P. + 2.1 m, the bottom edges of all gates are lifted above the levee height (T.P. + 5.8 m).

Operation to block saltwater intrusion is maintained even with the downstream water level beyond T.P. + 1.2 m, as long as it is not expected to exceed T.P. + 2.1 m.

## 4 Operation in response to a tsunami

When there is a tsunami warning for the coast of Ise Bay issued by the Japan Meteorological Agency combined with a tsunami height of 2 m or greater measured at the Kamishima gauge station at the mouth of Ise Bay, which signals the advancement of a major tsunami wave from the sea into the estuary, all gates are lifted above the levee height. The gates will therefore not hamper the flow of water.

Once the gates are fully open, a siren will sound or an announcement about an approaching tsunami will be made through speakers to prompt people on boats, fishers, and other river users to evacuate the river. Relevant authorities will be notified of the response too, so patrols will take place to ensure timely evacuation.

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