Nagara-gawa

Map of River

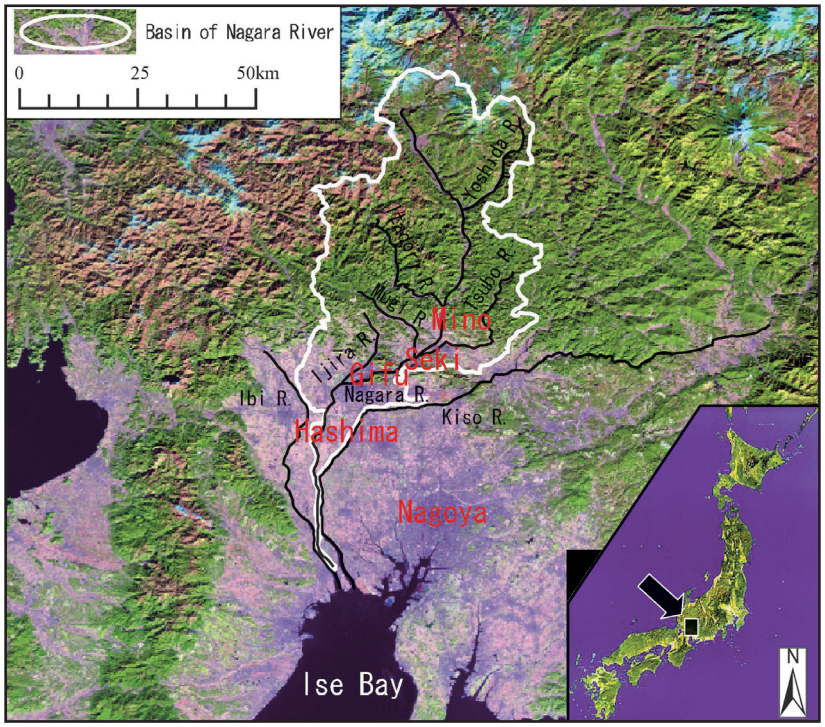


Table of Basic Data

Name: Nagara-gawa		**Serial No. :** Japan-13
Location: Central Honshu, Japan	N 34° 04' ~ 35° 59'	E 136° 36' ~ 137° 04'
Area: 1,985 km^2	**Length of main stream:** 166 km	
Origin: Mt. Dainichi	**Highest point:** Mt. Dainichi (1,709 m)	
Outlet: Ise Bay, Pacific Ocean	**Lowest point:** River Mouth (0 m)	
Main geological features: features: granite, andesite, ryolite, gneiss		
Main tributaries: Yoshida River (181 km^2), Itadori River (298 km^2), Mugi River (154 km^2), Tsubo River (269 km^2)		
Main lakes: None		
Main reservoirs: Nagara Estuary Barrage (1995), Atagi Dam (2.55 × 10^{6}m^3, 1988)		
Mean annual precipitation: 1,915.3 mm (1979~2000) at Gifu		
Mean annual runoff: 1,16.5 m^3/s (1954~2001) at Chusetsu		
Population: 915,100 (1995)	**Main cities:** Gifu, Seki, Mino, Hashima	
Land use: Mountainous area (75.3%), Urban area (6.5%), Cultivated area (18.2%)		

1. General Description

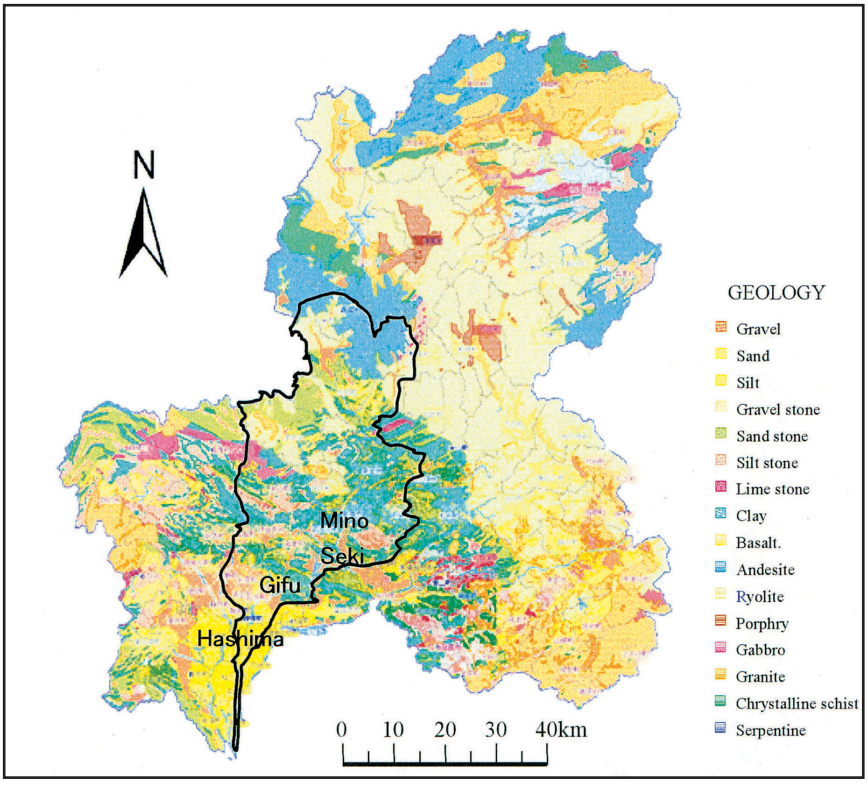
The Nagara River is one of the three rivers, the Kiso, the Nagara and the Ibi, that flow through the Nobi Plain, located at the center of the Chubu Economic Region. In the past, these three rivers named the Three Kiso Rivers (Kiso-sansen) flowed as one turbulent river. However, it was divided into the three rivers as we know today by the improvement project from 1887 to 1911 during the Meiji Era.

The Nagara River (Nagara-gawa) originates from the Kamasu Valley at the Mt. Dainichi in Takasu Village, Gifu Prefecture. It flows to the southeast and merges with tributaries such as the Yoshida, the Itadori, the Mugi, and the Tsubo flowing in the mountainous area and the cultivated area in the central part of Gifu Prefecture. In the its lower reaches the Nagara River it merges with the Ijira River running across the cultivated area and the urban area of Gifu City and flows southward in the Nobi Plain. The separation levees force the river to run parallel to the Kiso River from Naruto, Kaizu Town located in the southern part of Gifu Prefecture. And then, it flows through Kuwana in Mie Prefecture, and merges with the Ibi River before flowing into the Ise Bay as one river.

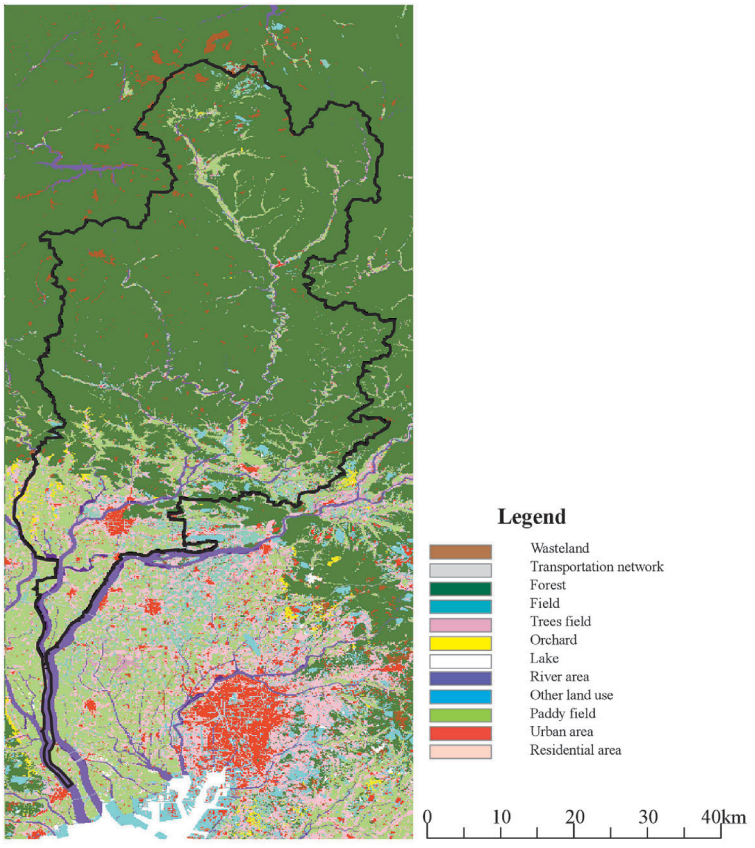
Its catchment area is 1,985 km^2 and the length of its mainstream watercourse is 166 km. Its abundant waters are used for irrigating an area of 80 km^2 and for hydroelectric power generation at five stations with a maximum output of about 17,000 kW. The water of its lower reaches satisfies the population demand for water in the cities of Tokai and Handa in Aichi Prefecture, and supplies industry in the North Ise district.

2. Geographical Information

2.1 Geological Map



2.2 Land Use Map

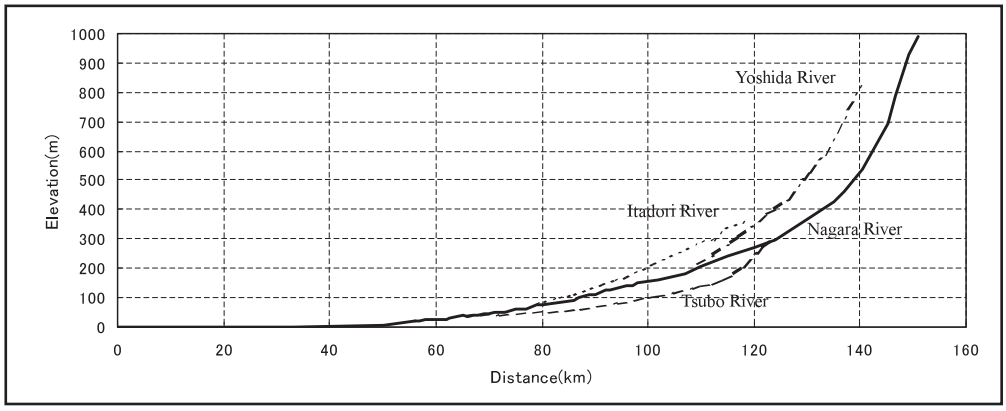


2.3 Characteristics of River and Main Tributaries

No.	Name of river	Length [km] Catchment area [km^2]	Highest peak [m] Lowest point [m]	Cities Population	Land use [%]
1	**Nagara** (Main river)	166 1,985	Mt. Dainichi 1,709 River mouth 0	Gifu 402,748	M (75.3) U (6.5) C (18.2)
2	**Yoshida** (Tributary)	36 187	Mt. Eboshi 1,625 Confluence 215	Hachiman-cho 17,262	
3	**Itadori** (Tributary)	44 314	Mt. Heike 1,442 Confluence 78	Mino 24,662	
4	**Mugi** (Tributary)	13 164	Mt. Hinaga 1,216 Confluence 40	Mugi-gun 17,621	
5	**Tsubo** (Tributary)	37 292	Mt. Omae 701 Confluence 31	Seki 74,438	
6	**Ijira** (Tributary)	14 159	Mt. Kama 696 Confluence 10	Gifu, Ijira-mura 32,871	

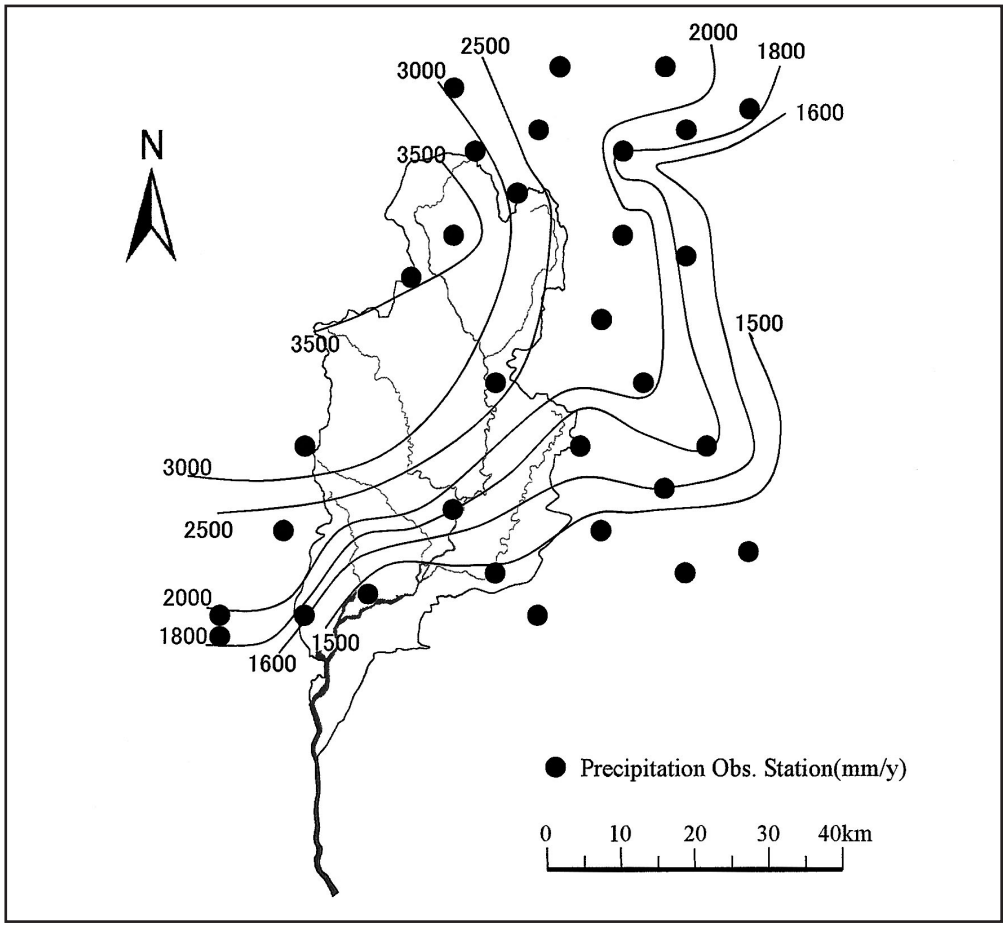
M: Mountainous area U: Urban area C: Cultivated area

2.4 Longitudinal Profiles



3. Climatological Information

3.1 Annual Isohyetal Map and Observation Stations



3.2 List of Meteorological Observation Stations[1)]

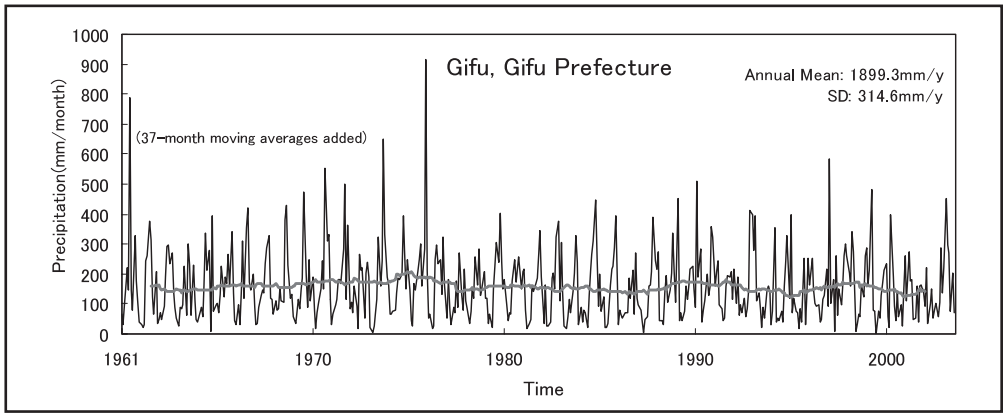
No.	Station	Elevation [m]	Location	Observation period	Mean annual precipitation [mm]	Observation items[4)]
52181[2)]	**Mumai**	1,015	N 36° 03' 36" E 137° 02' 00"	1979 ~ present	2,451.0 1979 ~ 2000	DS, P, T, W
52221[2)]	**Nagataki**	430	N 35° 55' 30" E 136° 49' 54"	1979 ~ present	3,019.5 1979 ~ 2000	DS, P, T, W
52331[2)]	**Hachiman**	250	N 35° 45' 30" E 136° 58' 48"	1979 ~ present	2,682.2 1979 ~ 2000	DS, P, T, W
52461[2)]	**Mino**	68	N 35° 33' 24" E 136° 54' 36"	1979 ~ present	2,162.2 1979 ~ 2000	DS, P, T, W
52586[2)]	**Gifu**	13	N 35° 24' 00" E 136° 41' 42"	1961 ~ present	1,899.3 1971 ~ 2000	DS, P, T, W
53041[2)]	**Kuwana**	3	N 35° 03' 00" E 136° 41' 36"	1979 ~ present	1,605.0 1979 ~ 2000	DS, P, T, W
10509 **12855** **02480**[3)]	**Kuzuhara**	160	N 35° 35' 57" E 136° 42' 36"	1918 ~ present	3,022.0 1960 ~ 2002	P
10509 **12855** **02500**[3)]	**Chusetsu**	10	N 35° 25' 42" E 136° 44' 58"	1950 ~ present	1,971.0 1954 ~ 2002	P

1) 7 rainfall observation stations managed by Japan Meteorological Agency and 21 stations managed by Ministry of Land, Infrastructure and Transport are operated in the Nagara River basin. Part of the stations are listed here.
2) Serial Number used by Japan Meteorological Agency
3) Serial Number used by Ministry of Land, Infrastructure and Transport
4) DS: Duration of sunshine, P: Precipitation, T: Air temperature, W: Wind velocity and wind direction

3.3 Monthly Climate Data (Observation station: Gifu)

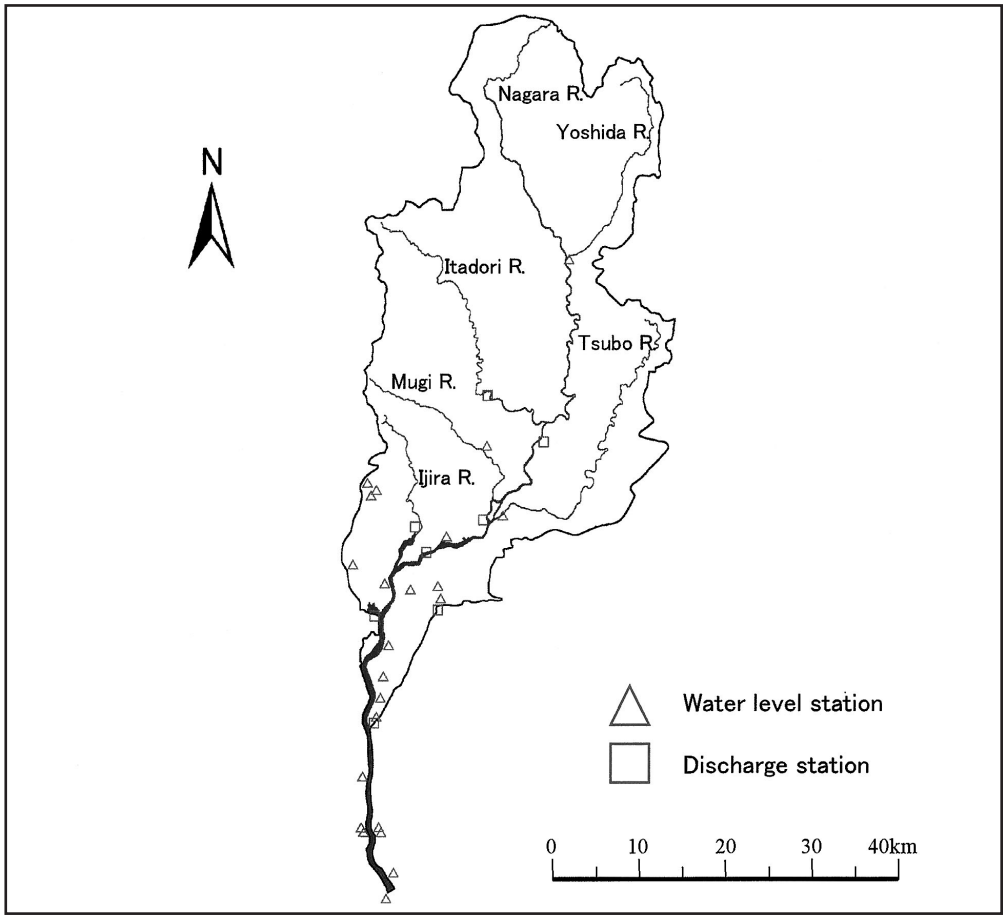
Observation item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Period for the mean
Temperature [°C]	4.3	4.7	8.2	14.1	18.6	22.5	26.2	27.5	23.5	17.7	11.9	6.6	15.5	1971 ~ 2000
Precipitation [mm]	62.4	83.5	142.6	186.6	206.3	253.7	273.4	172.0	269.0	124.1	94.6	47.3	1,915.3	1971 ~ 2000
Solar radiation [$MJ/m^2/d$]	8.7	11.3	14.6	16.3	18.7	17.1	17.1	17.8	13.8	11.7	9.1	7.7	13.7	1961 ~ 1990
Duration of sunshine [hr]	163	162	193	192	204	157	171	200	152	174	157	163	2,086	1971 ~ 2000

3.4 Long-term Variation of Monthly Precipitation



4. Hydrological Information

4.1 Map of Streamflow Observation Stations



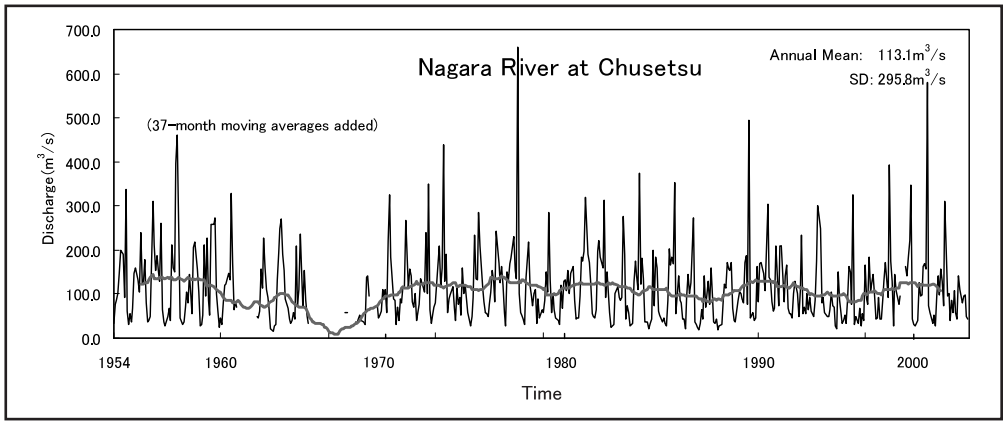
4.2 List of Hydrological Observation Stations[1)]

No.[2)]	Station	Location	Catchment area (A) [km^2]	Observation period	Observation items[3)]
305091285502190	**Sunomata**	39.4 km from the river mouth	1,914.0	1939 ~ present	H, Q
305091285502170	**Chusetsu**	50.2 km from the river mouth	1,606.8	1954 ~ present	H, Q
305091285502150	**Akutami**	59.4 km from the river mouth	1,598.0	1964 ~ present	H, Q
305091285502140	**Mino**	74.5 km from the river mouth	1,076.0	1966 ~ present	H, Q
305091285502250	**Furukawabashi**	51.0 km from the river mouth	121.0	1975 ~ present	H, Q

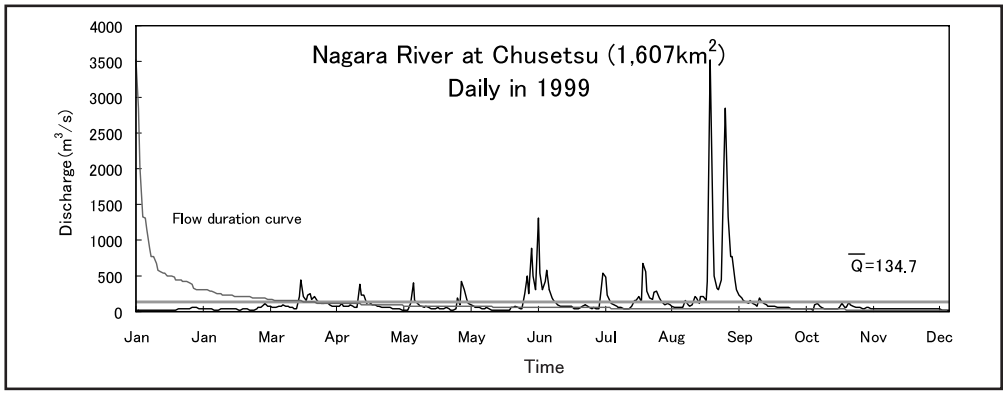
No.[2)]	$\overline{Q}$[4)] [m^3/s]	Qmax[5)] [m^3/s]	$\overline{Q}$max[6)] [m^3/s]	$\overline{Q}$min[7)] [m^3/s]	$\overline{Q}$/A [m^3/s/100km^2]	Qmax/A [m^3/s/100km^2]	Period of statistics
305091285502190	130.10	6,852.90	2,922.30	27.70	6.80	358.04	1939 ~ 2001
305091285502170	116.49	6,713.10	1,853.43	17.75	7.25	417.79	1954 ~ 2001
305091285502150	112.52	6,550.24	3,263.66	19.69	7.04	409.90	1976 ~ 2001
305091285502140	88.71	5,497.14	2,662.38	15.37	8.24	510.89	1966 ~ 2001
305091285502250	6.90	448.95	203.64	0.70	5.70	371.03	1979 ~ 2001

1) 15 water stage stations and 17 discharge stations are operated in the Nagara River basin.
2) Serial Number used by Ministry of Land, Infrastructure and Transport
3) H: water level, Q: discharge, Q is obtained from rating curve.
4) $\overline{Q}$: Mean annual discharge
5) Q max : Maximum discharge
6) $\overline{Q}$ max: Mean annual discharge
7) $\overline{Q}$ min: Mean minimum discharge

4.3 Long-term Variation of Monthly Discharge



4.4 Annual Pattern of Discharge



4.5 Unique Hydrological Features

Since the upstream region of the Nagara River is mostly unsuitable for constructing dams, one of the problems of providing flood protection is that the river course itself needs to be made to cope with larger discharge volumes. The basic plan for the Three Kiso Rivers Project therefore involves to cope with the design flood of 8,000 m^3/s using an upstream dam, allowing 7,500 m^3/s to flow down safely through the river course. The Nagara Estuary Barrage was constructed at the river mouth in 1995 for the purpose of flood protection, prevention of saltwater inflow and water use.

Although it is necessary to extend the cross-sectional area of the river course to achieve the above plan, raising the levees or moving the levees backward are not possible in the downstream region of the Nagara River where valuable land and a large number of houses are located along the river. The remaining alternative is dredging the riverbed. The downstream region of the Three Kiso Rrivers facing the Ise Bay has been invaded by saltwater for a long period, and the inhabitants have suffered saline deterioration of both their drinking water and agricultural water. In order to achieve reliable prevention of damage caused by the saltwater inflow resulting from the dredging operations, and to exploit the water resources that are needs for the development of local communities, the estuary barrage was constructed.

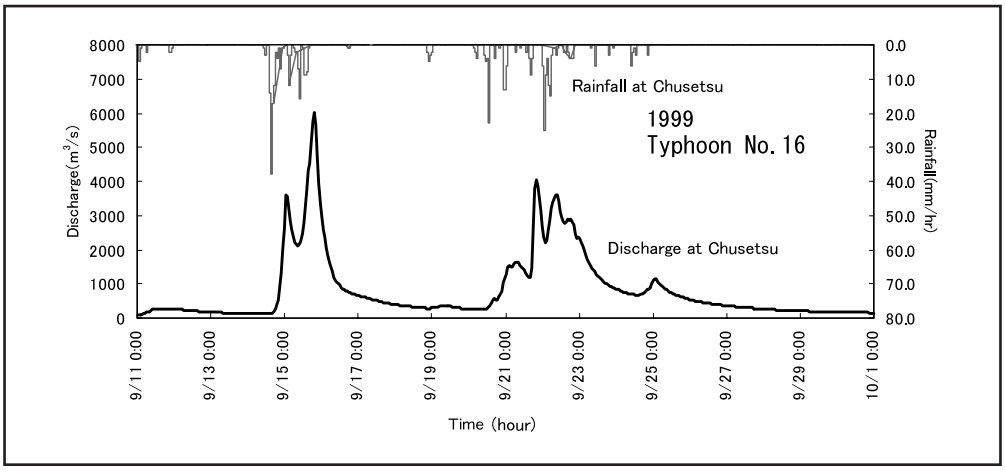
4.6 Annual Maximum and Minimum Discharges

At Chusetsu [1,607 km^2]

Year	Maximum[1)]		Minimum[2)]		Year	Maximum[1)]		Minimum[2)]	
	Date	[m^3/s]	Date	[m^3/s]		Date	[m^3/s]	Date	[m^3/s]
1954	9.2	1,634	11.15	15.8	**1978**	6.21	943	9.3	18.1
1955	8.31	1,722	12.15	27.7	**1979**	6.29	1,357	6.7	10.1
1956	3.17	2,090	11.30	8.6	**1980**	7.8	1,211	4.2	27.2
1957	8.8	2,423	10.27	16.1	**1981**	7.13	1,792	12.19	20.8
1958	8.26	2,797	11.30	11.3	**1982**	8.16	989	2.11	16.6
1959	9.27	5,560	12.29	12.8	**1983**	9.28	1,495	6.12	17.7
1960	8.13	6,713	10.28	12.8	**1984**	4.20	951	1.25	18.2
1961	-*	-*	-*	-*	**1985**	7.1	1,740	8.29	24.3
1962	6.10	1,308	12.14	10.5	**1986**	7.13	1,260	11.24	13.3
1963	6.4	1,030	1.29	21.1	**1987**	7.17	765	12.30	14.8
1964	9.25	1,820	6.14	12.1	**1988**	9.25	918	1.3	14.4
1965	-*	-*	-*	-*	**1989**	9.6	2,025	1.6	22.8
1966	-*	-*	-*	-*	**1990**	9.20	2,424	8.9	21.1
1967	-*	-*	-*	-*	**1991**	9.19	828	8.28	26.8
1968	-*	-*	-*	-*	**1992**	8.13	1,528	9.22	19.9
1969	6.30	2,144	11.15	22.5	**1993**	9.9	1,124	6.12	24.3
1970	6.16	2,097	1.28	24.1	**1994**	9.30	1,718	8.18	7.4
1971	9.7	1,748	11.22	19.9	**1995**	7.3	1,308	8.26	14.9
1972	7.13	2,054	8.9	14.2	**1996**	8.29	1,107	1.3	22.0
1973	8.26	664	6.17	17.9	**1997**	7.12	1,399	11.12	13.3
1974	8.26	2,110	2.3	20.9	**1998**	-*	-*	-*	-*
1975	8.23	2,022	9.14	23.1	**1999**	9.15	3,519	6.15	13.5
1976	9.12	3,822	1.17	24.4	**2000**	9.12	2,260	9.6	16.0
1977	8.18	527	10.31	17.2	**2001**	6.20	872	5.22	19.2

1), 2) Instantaneous observation by recording chart
*: missing data

4.7 Hyetographs and Hydrographs of Major Floods



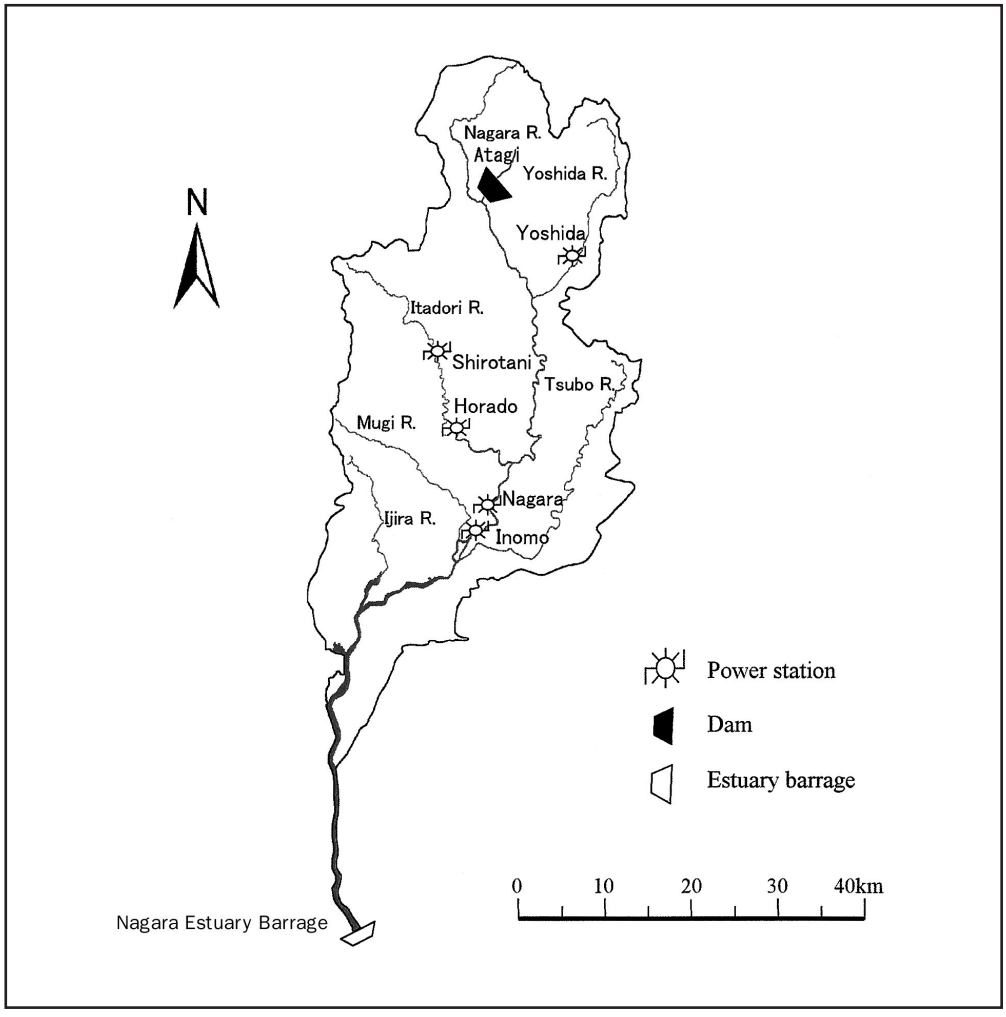
5. Water Resources

5.1 General Description

There are no dams with the purpose of water use in the Nagara River because the topography along the river is flat and the geological features is not suitable for constructing dams. The river is therefore used mainly as a source of irrigation water in the small tributaries and waterways.

On the other hand, the water of the Nagara Estuary Barrage is supplied to the Chubu urban district, which is one of three major urban districts in Japan. The maximum amount of water for city and industrial use is 22.5 m^3/s. The Nobi Plain, which is a main region of the Chubu urban district, is suffering from extensive ground subsidence caused by exploitation of ground water. It is now the largest zero-meter zone in Japan and a serious problem for the nation's disaster prevention measures. It is therefore impossible to rely on ground water as a new water resource, and positive steps need to be taken to switch from ground water to surface water use in order to prevent ground subsidence. As that mean, the expectations to the Nagara Estuary Barrage have been great in this district.

5.2 Map of Water Resource Systems



5.3 List of Major Water Resources Facilities

Major Reservoirs

Name of river	Name of dam (reservoir)	Catchment area [km^2]	Gross capacity [10^6m^3]	Effective capacity [10^6m^3]	Purpose[1)]	Year of completion
Nagara	**Nagara Estuary Barrage**	169	16.9	14.3	F, N, W	1994
Atagi	**Atagi**	16	2.6	2.1	F, N	1987

1) A: Agricultural use F: Flood control I: Industrial use N: Maintenance of normal flows P: Hydro-power
W: Municipal water supply

5.4 Major Floods

Major Floods

Date	Peak discharge at Chusetsu [m^3/s]	Rainfall [mm] Duration / Nagara River	Meteorological cause	Dead and missing	Major damages (Districts affected)
1959. 9.26	3,257	104 / 2 days	Typhoon No.15 (Ise Bay Typhoon)	104	Houses completely destroyed: 3,909 Houses partly destroyed: 12,337 Houses washed away: 2,400 Houses inundated: 8,875
1960. 8.13	3,239	204 / N. A.	Low pressure front and Typhoon No.11 and 12	10	Houses completely destroyed: 23 Houses partly destroyed: 333 Houses washed away: 2,053 Houses inundated: 6,233
1961. 6.27	-*	210 / N. A.	Low pressure front	15	Houses completely destroyed: 5 Houses partly destroyed: 26 Houses washed away: 4,374 Houses inundated: 19,721
1976. 9.7	3,822	250 / 3 days	Low pressure front and Typhoon No.17	8	Houses completely destroyed: 6 Houses partly destroyed: 14 Houses washed away: 11,363 Houses inundated: 30,079
1990. 9.11	2,424	375 / 10 days	Low pressure front and Typhoon No.19	44	Houses completely destroyed: 240 Houses partly destroyed: 816 Houses washed away: 8,333 Houses inundated: 58,029
1999. 9.14	3,519	170 / 3 days	Low pressure front and Typhoon No.16	1	Houses completely destroyed: 9 Houses partly destroyed: 22 Houses washed away: 308 Houses inundated: 3,006

*: missing data

5.5 Groundwater and River Water Quality

River Water Quality[1] at Nagara-oohashi[2] in 2001

Date	1/16	2/7	3/7	4/11	5/9	6/12	7/4	8/1	9/5	10/3	11/7	12/5
pH	7.1	7.1	7.2	7.4	7.3	7.4	7.4	7.5	7.3	7.2	7.3	7.2
BOD [mg/l]	0.5	0.6	0.6	1.2	0.9	0.8	0.7	0.9	0.7	0.5	0.5	0.7
COD_{Mn} [mg/l]	1.5	2.0	2.0	2.7	3.1	2.7	2.0	2.6	2.4	2.1	2.4	2.3
SS [mg/l]	2	3	5	5	9	4	3	2	2	1	3	1
Discharge[3] [m^3/s]	74	72	95	95	94	45	125	51	88	81	90	39

1) Observed once a month on a dry day normally several days after rainfall.
2) Located near Gifu City 33 km upstream from the river mouth.
3) Discharge on the water quality observation date.

6. Socio-cultural Characteristics

In the past, the area downstream from the Three Kiso Rivers was formed by flow nets of the Kiso, the Nagara and the Ibi rivers, the courses of which changed whenever the area was flooded.

In 1609, early in the Edo Era, a great embankment was built on the left bank of the Kiso River, surrounding the Owari Province. This embankment, some 50 km in length, was called “the Enclosure Levee.” The Enclosure Levee was intended to protect the province from floods. It also had a military role as a defensive wall against invaders from western Japan. However, restrictions with it, such as that “levees on the opposite bank in the Mino Province (Gifu Prefecture) should be 91cm lower than the Enclosure Levee,” resulted in frequent flooding in Mino, and prompted the formation of “ringed land communities” in this region.

The ringed land community is a communal society bounded by a levee (the ring levee), built to enclose a colony and its cultivated land entirely for the purpose of protecting them from floods. The levee was built by the inhabitants themselves, and the history of the development of ringed land communities is a history of the way in which these communities fought the ever-present threat of flooding.

In the mid-Edo Era (1603~1866), the Shogunate assigned a flood control work (known as the Horeki period flood control) to the Shimazu Clan, who constructed the Aburajima cofferdam and other works during only two years from 1754.

During the Meiji Era, the government made an improvement plan, aiming at full diversion of the Three Kiso Rivers. Large-scale river improvement work, involving expenditure of about 12% of the contemporary national budget, was carried out for the period from 1887 to 1912. The work brought the downstream region of the Three Kiso Rivers substantially into its present form.

The Meiji improvement reduced flood damage at the downstream of the Three Kiso Rivers considerably. However, the Ise Bay Typhoon, which hit the Tokai district in September 1959, damaged Gifu, Aichi and Mie prefectures severely, with fatalities numbering more than 5,000, including the missing. In August 1960, the flood resulting from the typhoons No. 11 and 12 broke the banks of the Nagara and devastated the river. In June 1961, heavy rain produced by a rainy season and by typhoon No. 6 again caused the banks to collapse, and the Nagara River flooded a vast area of Gifu City and Ogaki City. These floods, together with the flood caused by the Ise Bay Typhoon, are known as the three major flood of the Showa Era (1926~1988).

More recently the Nagara River also flooded heavily when typhoon No. 17 combined with a rain front in September 1976. A week of heavy rain caused severe damage in various regions, including the

collapse of the right bank in the area lying beyond Moribe in Anpachi Town, Gifu Prefecture.

In order to reduce the flood risk, the Nagara Estuary Barrage has been in operation since 1995. It prevents the inflow of seawater and enables large-scale dredging of the river course to safety allow the planned high-water discharge of 7,500 m^3/s to flow. Through the desalination of water upriver of the barrage, the water of the Nagara River is supplied to the inhabitants and industries of Aichi and Mie Prefectures. This helps to reduce excessive use of groundwater, which is the main cause of the ground subsidence in the Nobi Plain.

On the other hand, various river environment maintenance projects have been implemented to harmonize flood control projects such as the construction of the barrage to include waterfront environments. Some of the projects are for hydrophilic bulkheads such as, Sendohira Riverside Park, the Kiso-sansen Park, and promenades at Sembon Matsubara (a riverside planted with 1,000 pine trees), created to improve the landscape.

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