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FLOOD WATER LEVEL RECORDS FOR 320 YEARS AND THE SAFETY LEVEL OF FLOOD CONTROL IN HIJI RIVER

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SYNOPSIS

In the Hiji River, flood water level records for 320 years have been collected. These long term records are rare and valuable in Japan. By analyzing these records, we calculated the probabilities of floods in each period and studied the safety levels of flood control by examing the changes in improvements of embankment dam construction and other flood control measures. The main findings of this research are as follows: 1) Flood water level records show that the safety levels of flood control has been improvedalong with flood control measures. 2) The safety level data based on flood water levels almost agree with those based on rainfall.

INTRODUCTION

Modern hydrological observations in Japan started when the water level gauges were placed in Sakai-machi along the Tone River and in Kema along the Yodo River in 1872 under the supervision of Dutch engineers, Cornelis Johannes van Doorn and Isaac Anne Lindo. It is said that, discharge is better than rainfall; that water level is better than discharge," and that water levels directly reflect actual flood phenomena, Thus, it is important to obtain hydrological data with the least errors. Some valuable historical data of such water level observation have been madein the Hiji River flowing through Ozu City in Ehime Prefecture (Shikoku).

The flood water level records of the Hiji River come from observations made by the Ozu Clan for 173 years from the first year of the Genroku period (1688) to the first year of the Manen period (1860). Then, such observations were made by the prefectural officials from the Meiji period to Taisho and Showa periods, and then were undertaken by the national government since 1954. Such flood water level data for 320 years have not been recorded in any other rivers in Shikoku, and they are also extremely valuable on the national level. It is known that old flood water level records were compiled during the Hansei (feudal clan's government) period in the Hiji River, but the relationship between these records and the water level currently observed at the Hiji River Bridge was not known because various different theories about water level observation sites during the Hansei period made it difficult to identify the location. Also the information about water levels before World War II when the construction was started by the former Ministry of Home Affairs had not been used. For these reasons, the flood water level observation records before the early Showa period were not used as data for flood control measures. However, the results of a detailed study on the changes of the observation locations and river channel conditions in the past 320 years starting from the Hansei period led to the judgment that they do not have much influence on the water level at the observation points. Therefore , in this paper we consider the safety level of flood control of the Hiji River by utilizing the water levels observed from the past, which have not been utilized before. Although Sho and Tominaga's study[1)] analyzed flood frequency for lake Biwa by using historical flood information, few studies have ever tried to analyze the safety level of flood control by means of historical flood information. Therefore, it is important to examine the safety levels of flood control with data of flood levels for the past 320 years

COLLECTION AND ANALYSIS OF FLOOD WATER LEVEL RECORDS FOR 320 YEARS IN HIJI RIVER

Identification of the observation site of flood water levels during the Hansei period

Water level observation records of the Hiji River during the Hansei period are retained in the manuscripts of the family record of the Kato clan[2)] (Photo-1). The History of Ozu City is based on this family records which indicate that the lord of the Ozu Clan had "two water observers in the status of 5 ninbuchi (a lower warrior class) observe the water level by day and night shifts at the Hakari-iwa (measurement rock) at Jizobuchi in Shiro Yamashita (the foot of Ozu Castle) [3)].

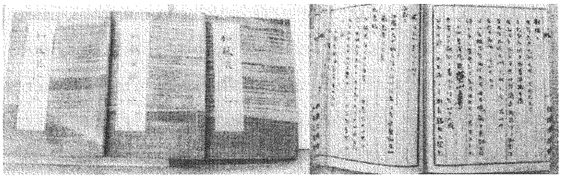


Photo-1 Manuscripts of the family record of the Kato clan

Locating this observation site was very challenging, but the information which enabled us to identify the site was found over a period of two years, (see Figure-1). A Map of the Ozu Castle [4)] drawn during the Edo period clearly shows the letter of "measurement rock " which is considered to be the observation site, and this corresponds to the description in the History of Ozu City that says, "observed at the "measurement rock " at Jizobuchi in Shiro Yamashita." It is thought that the present Ozu post office was located at the letter "Bori (moat) in the Kara-Bori (dry moat) in this map and that the water channel on the west side of the post office might have been the site of the moat running into the measurement rock in the drawing. Similarly, the location of the street under the Karabori in the drawing is considered to be the present Masugata, and that the present streets of Honmachi 1-chome, Nakamachi 1-chome, Suehiromachi 1-chome are located from the Hiji River side, in that order. Therefore, the location of the measurement rock can be identified to be the bank of Hiji River at the exit of the present Tsuchibori (soil moat) drainage sluiceway (photo in Figure-1).

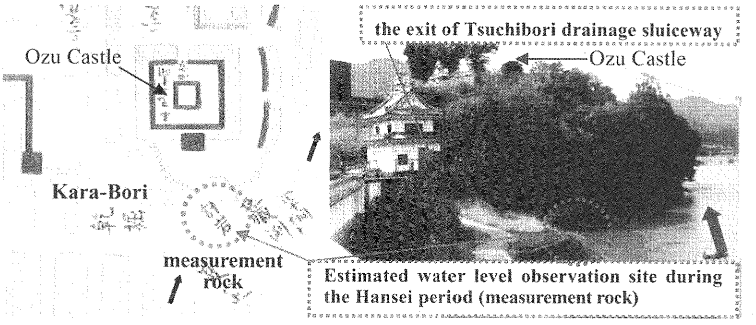


Fig-1 Map indicating the letter "measurement rock" and photo of its nearby area

"Jimu Hikitsugi (handover of paperwork)[5], documents kept permanently by Kocho (officials) in the Ozu village in the early Meiji period say that there were four Watashi (boat ports) in those days to transport people and goods from the opposite shore to the castle town as, "there were six water level gauges at the levee of Masugata Tatami Ishi (considered to be the measurement rock), and they sailed boats at the departure and increase the fares according to these water level gauges." It seems that in those days different boat fares were charged according to the water level differences in shaku (about 30 cm) from the normal water level. Family records of the Kato clan can be considered as records of the water levels as well as the damages caused by floods in the area using these water level gauges.

Changes of water level observation sites at the Ozu point

After 1886, the water level observation were made using the prefectural water gauges in Masugata near the measurement rock. Also, since 1954, the national government has been making water level observations at the present Hiji River Bridge (Photo-2).

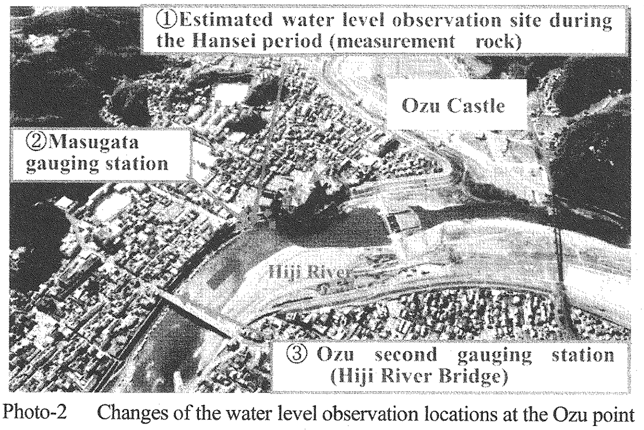


Photo-2 Changes of the water level observation locations at the Ozu point

Findings show that the water level observation sites at the Ozu point changed from (1) measurement rock → (2)

Masugata water gauges → (3) Hiji River Bridge.

The flood records between 1886 and 1943 illustrated in the table were extracted from the chronology of the Kato clan in "Showa 18-nen Kita-gun Suigai-ki, Areru Hijigawa (flood damage record in Kita-gun in 1943, raging Hiji River)"[6] reported in November 1944 by Katsushige Takagishi. He worked at the Kita local office, and was in charge of keeping records occurrence dates of floods, recording water increases in flood water levels in units of shaku-sun, and recording the amount of the damage caused by floods in a similar manner. The handling of such water level data and the description of the water level gauges at the levee of Masugata Tatami Ishi in the early Meiji period (as mentioned earlier) led to an estimation that Masugata water gauges used from the Meiji period also measured the flood water levels based on the water levels during normal times as in the Hansei period.

Flood water level observation records at the Ozu station in the Hiji River

Observations made during the Hansei period continued for 173 years from the first year of the Genroku period (1688), and the family record of the Kato clan recorded 76 floods during this period. Among these records, there are 58 floods whose dates of occurrence and increases of water levels were both recorded. Since some of these floods occurred in the same year, 48 floods which were recorded are said to have reached the annual maximum flood water level. There was no record between 1861 (Manen 2) and the early Meiji period. From 1886 to 1935, 11 annual maximum flood water levels are recorded in the materials at the Chugoku and Shikoku civil engineering branch office of the former Ministry of Home Affairs. After 1936 when the former Ministry of Home Affairs started conducting the surveys, and 69 annual maximum flood water levels were recorded. Table-1 shows the list of flood water levels at the Ozu station (annual maximum water levels during the period of the 320-year record) that was newly created by converting the units of these 128 floods into meters.

Table-1 List of flood water levels at the Ozu point in the Hiji River

Observation site	Flood month/year	Water level (m)	Observation site	Flood month/year	Water level (m)	Observation site	Flood month/year	Water level (m)
(1) measurement rock point	1688.5	6.97	(1) measurement rock point	1849.6	7.42	(3) Hiji River Bridge point	1966.9	3.44
	1689.7	7.24		1850.1	6.97		1967.7	4.00
	1702.8	7.58		1852.8	7.88		1968.7	6.66
	1704.7	4.55		1855.7	8.33		1969.7	6.14
	1707.8	6.64		860. unknow	8.39		1970.8	5.50
	1714.8	5.91	(2) Masugata point	1886.9	9.82		1971.8	3.96
	1715.6	6.97		896. unknow	9.70		1972.7	3.47
	1721.7	8.94		905. unknow	7.58		1973.5	3.50
	1722.6	7.27		908. unknow	7.24		1974.9	3.45
	1729.9	6.67		911. unknow	6.06		1975.6	3.50
	1735.4	7.88		912. unknow	8.03		1976.9	4.75
	1739.4	6.06		1921.10	5.33		1977.6	2.57
	1741.7	4.85		1928.8	7.58		1978.8	1.98
	1742.8	5.15		1932.7	4.58		1979.6	4.16
	1743.7	3.94		1934.9	5.27		1980.7	4.56
	1744.8	6.67		1935.9	5.85		1981.6	2.39
	1748.9	6.51		1936.9	4.55		1982.8	5.41
	1757.7	5.30		1937.9	4.85		1983.6	2.90
	1765.8	6.36		1938.8	7.43		1984.6	3.06
	1773.5	7.58		1939.10	5.77		1985.6	2.70
	1783.8	8.48		1940.10	2.73		1986.7	3.10
	1787.4	9.00		1941.7	5.17		1987.7	5.30
	1788.9	8.42		1942.9	5.91		1988.6	5.21
	1793.7	8.33		1943.7	8.60		1989.9	4.86
	1796.8	8.54		1945.9	8.79		1990.9	4.54
	1801.8	7.27		1946.7	5.46		1991.7	3.53
	1804.8	8.79		1947.7	6.09		1992.8	3.31
	1815.7	7.33		1948.8	5.30		1993.7	5.30
	1816.8	7.42		1950.9	6.24		1994.7	1.69
	1821.8	7.73		1951.7	5.24		1995.7	5.84
	1822.6	8.33		1953.6	5.58		1996.7	4.58
	1825.8	5.45	(3) Hiji River Bridge point	1954.9	6.85		1997.9	3.95
	1826.5	10.03		1955.9	4.92		1998.10	5.20
	1827.6	7.58		1956.9	3.52		1999.6	3.71
	1828.7	7.06		1957.6	3.92		2000.6	3.31
	1829.5	7.45		1958.4	4.80		2001.6	2.92
	1831.5	8.48		1959.8	3.98		2002.5	2.01
	1832.6	8.06		1960.6	4.84		2003.8	3.27
	1835.5	6.06		1961.9	4.44		2004.8	6.85
	1836.7	6.67		1962.6	2.74		2005.9	6.49
	1838.7	8.18		1963.8	5.00		2006.6	3.87
	1846.6	7.88		1964.6	4.01		2007.7	3.98
	1848.6	7.42		1965.9	5.60	Total: 128 floods		

* Water level reference point: Water level observation sites were changed from (1) to (2), and then to (3):
(1) Observed at the measurement rock point (1688 to 1860), (2) Observed at the point (1886 to 1953),
(3) Observed at the Hiji River Bridge point (1954 to 2007)

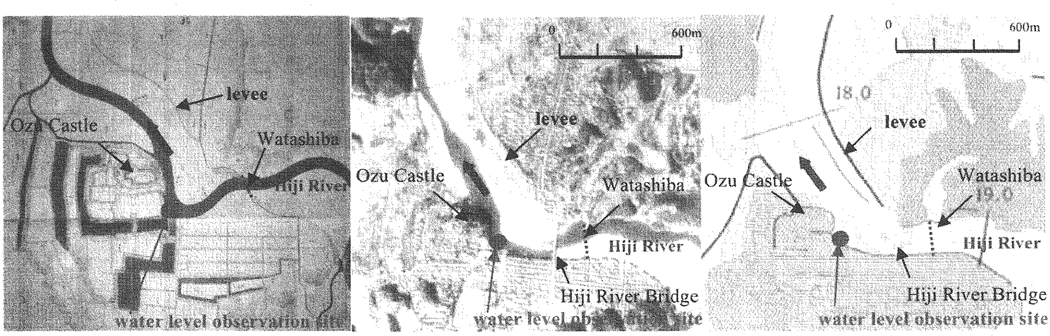
Comparison of flood water level records of each period

a) Preconditions for comparing observed water levels

To compare major flood water level data compiled for 320 years in Table-1, it is necessary to study the impacts on water level from various types of information because water levels changes depending on observation sites (observation locations), river channel topography (e.g. river channel shapes, river bed height), and facility conditions (improvement conditions of levees and dams).

[Observation locations]: As previously mentioned in the changes of water level observation sites at the Ozu point above, the Hakari-iwa and the Masugata water gauges are located in almost the same place. The location of the present gauging station has been located at the Hiji River Bridge, about 200 m upstream, since 1954, but it is still near them.

[River channel topography]: As shown in the topography classification map for flood control of the Hiji River in Figure-2, these observation locations are at the core point of the fan shape of the alluvial fan in the alluvial plain where floods are discharged to the Ozu basin at a burst from between mountains, and the river channel shapes do not change largely. Furthermore from the Ozujo Shoho Ezu (Map of the Ozu Castle) compiled during the Hansei period, a map compiled by the Japanese Land Survey Department (Rikuchi Sokuryobu) in 1904, and from an aerial photograph taken by the US force after the war (photo of Figure-2), we determined that the course of the river channel shape hed almost remained unchanged since the Hansei period.



Oozu Castle"Shoho Shiro Ezu" map (1644)

Mountainous land / Hilly □ Flood plain □ Natural levee

Fig-2 Ozu Castle "Shoho Shiro Ezu" map and Landform classification map for flood control of the Hiji River and aerial photograph taken after the war at the water level observation site

Furthermore, the current river bed height around the Ozu Castle where groundsill was constructed has become slightly lower since the end of the war, but the sand bar shape has almost remained unchanged.

The "Jimu Hikitsugi" transferred from the Tocho (officials) in the Ozu village to the Ozu town office in the early Meiji period says about the river width, "the Hiji River has a width of about 100-ken (about 180 m), and the flow is rapid. After passing the halfway Watashi [...], the three Watashi: the Garyu Watashi, the Masugata Watashi, and the Shiroshita Watashi…"[5] as the landscape of the Hiji River, and from this data, it can be determined that the river width of the halfway Watashi (Watashiba), which is near the present Hiji River Bridge, was about 180 m in these days, which is almost same as the current river width (180 m).

[Facility conditions]: Since the end of the war, the embankment along the river channel was improved from the Ozu point down the river, and the Ozu plain has been repaired without closing the West and East Ozu districts so that the Ozu point will not have an increase in the flood water level as much as possible. In addition, the Kanogawa Dam was constructed in 1960 at a point about 20 km upstream of the Ozu point in the Hiji River, and then the Nomura Dam was constructed in 1982, about 20 km upstream of Kanogawa Dam. Since then, the effects of their flood control facilities have been reflected to the flood water level at the Ozu point, and the outflow conditions have changed compared with those before the dams were constructed As mentioned above, observation locations and river channel topography have almost remained unchanged between the Hansei period and the present, and on facility conditions the embankment along the river channel have been improved keeping the balance between the upstream and the downstream of the river although the outflow conditions have been changing along with the construction of the dams; therefore, it is possible to compare the water levels observed for about 320 years side by side.

b) Appropriateness of water level comparison from the past to the present

As mentioned above, it is considered that the water level was observed based on that at normal times during the Hansei period. This section considers the appropriateness of making comparisons with the current water level observation values from the relationship between the flood water level in 1715 (Shotoku 5) and the current ordinary water level. The flood that occurred on June 21 in 1715 is described in the family record of the Kato clan that it had a 23-shaku (about 6.9 m) water level, and the damages are described as, "114 houses had inundation above floor level with a depth of 2-shaku (about 60 cm), which has never occurred before[2]." Since the ground height in the left bank during this period and today has been almost unchanged, the ground height of the street in front of the present Ozu post office which is located at the site of the Ozu castle town is about TP (Tokyo Peil) 16 m from the plan view of Figure-3, and the normal water level of the present Hiji River is about TP10 m from the cross section of Figure-4. When calculating the water level during this period under these conditions, it is calculated to be a flood with a height of "TP10 m + 23-shaku × 0.3 m = TP16. 9 m." When considering that the houses in those days their height was of about 30 cm to 40 cm from the ground it would cause an inundation with a height of about 90 cm (3-shaku) from the ground as shown in the cross section, which almost corresponds to the description of "inundation above floor level with a depth of 2-shaku" in the family record of the Kato clan.

As a result of the above, using the ordinary water level as the reference surface for water level may have a fluctuation of about 30 cm due to the unit of "shaku", but the water level can still be compared without difficulty between the Hansei period and the present within the range of the fluctuation.

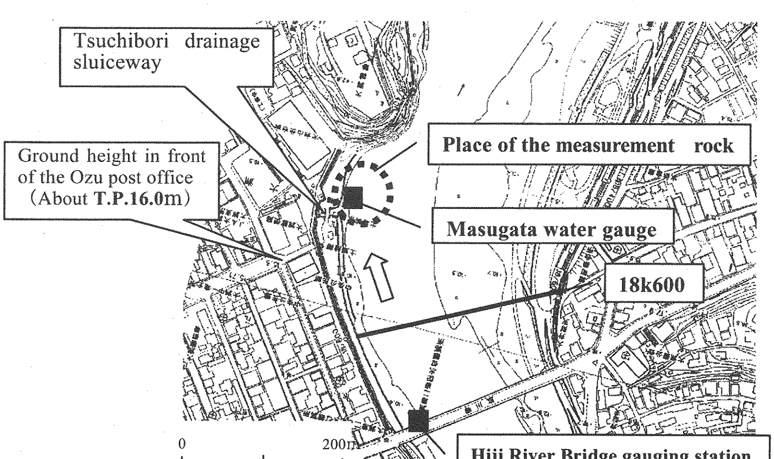


Fig-3 Present plan view of the Ozu area

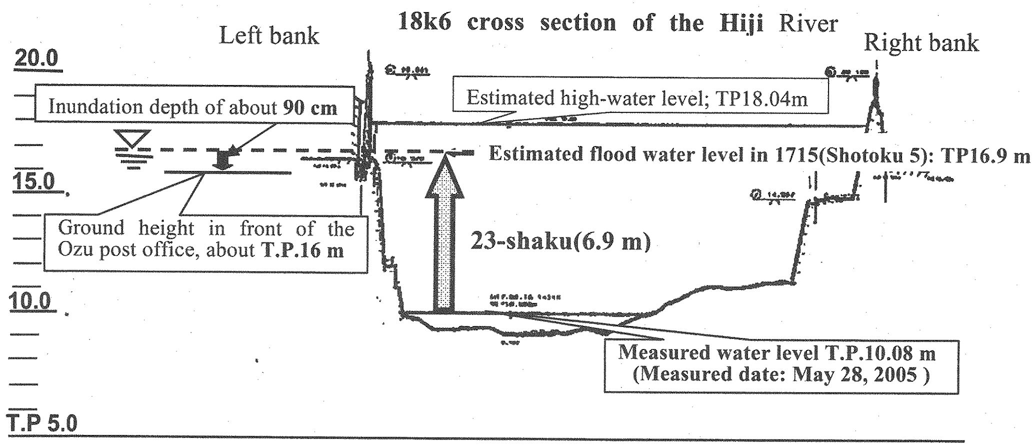


Fig-4 18k6 cross section of the distance mark of the Ozu area

c) Comparison and consideration of water level for 320 years

Figure-5 shows a graph in which the water level data measured with different observation conditions and frequencies at the Ozu point in the Hiji River for about 320 years from the first year of the Genroku period (1688) to today (2007) are compared under the same conditions based on the results as described above.

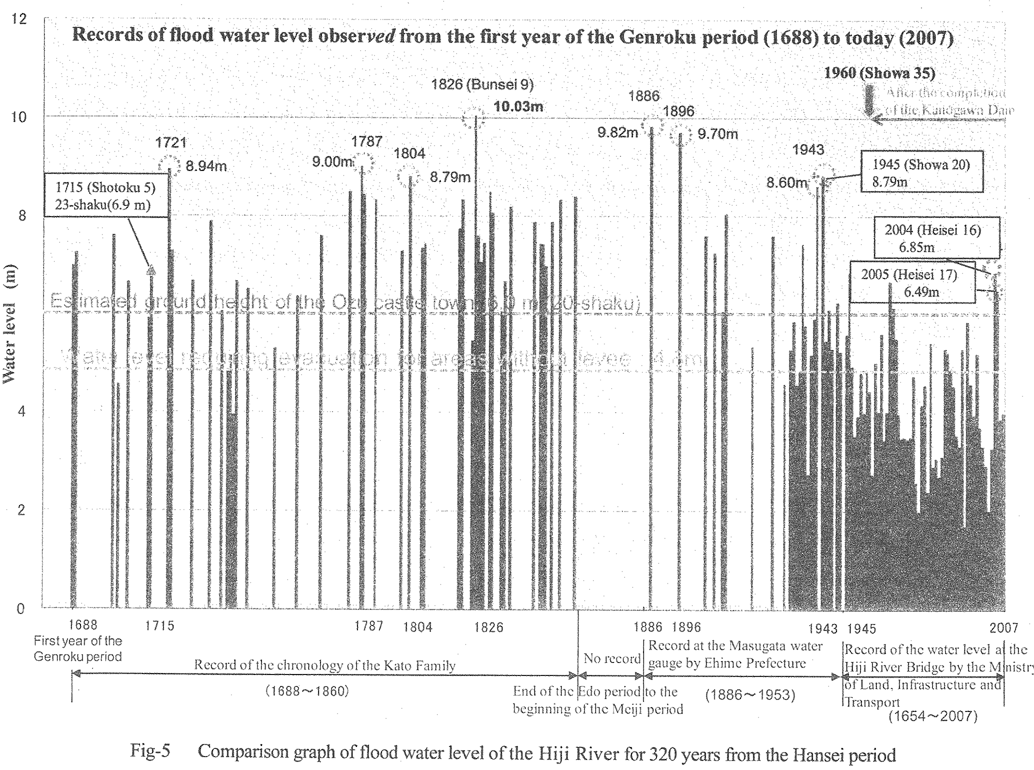


Fig-5 Comparison graph of flood water level of the Hiji River for 320 years from the Hansei period

This graph shows that 41 floods which exceeded 6.0 m (20-shaku) occurred in the 173 years during the Hansei period when there were no large levees as seen today. It is estimated that the Ozu castle town was damaged with a high frequently (about 41 times over 173 years). The graph also shows that flood water levels equivalent to or higher than that in 1945, which was the largest flood after the end of the war and became the target level of river improvement plan in the Hiji[7], occurred eight times in about 320 years including in 1826 (Bunsei 9) and in 1886 (Meiji 19). This shows that floods of the target scale of the river improvement plan occurred "8 times ÷ 320 years = 1/40 (times/year)."

Though the flood in 1826 (Bunsei 9), which was the largest one in recorded history, cannot be compared in a simple manner because the observation sites and the improvement conditions of the levees are different, but the water level of the flood was 1.2 m higher than the flood occurred in 1945, and the unprecedented devastation caused by the flood has been handed down to date as the Yoshu Ozu Kozui Banashi (story about the Yoshu Ozu flood) [8]. The flood was so large that it may have reached the current levee crown.

EXCEEDANCE PROBABILITY OF FLOOD WATER LEVEL OF HIJI RIVER FOR EACH PERIOD

Creation of a flood water level probability chart

When hydrological values such as annual maximum daily rainfall, annual maximum flood discharge, and annual maximum water level have been accumulated over a long period without missing data, hydrological values of the target return period can be obtained using these values. The occurrence probability of these hydrological values can be analyzed using various calculation methods such as the estimation using probability paper, the Iwai method, the Ishihara-Takase method, and the Gumbel method, but annual maximum values for each year weren't obtained for the water level observed in the Hiji River during the Hansei period. Therefore, "observed water levels" and "order/observation period (number of years)" were plotted for each period on the same semilogarithmic paper to ease a relative comparison. The procedure was to obtain the water level of the target return period from the water level data and consider the flood water level probability that changes with the improvement of flood control facilities such as levees and dams based on the assumption that all the flood water levels when the floods occurred were recorded.

Specifically, we considered the method to equally compare the data in which annual maximum values of each year before 1935 are not available and the flood water level data in which almost all annual maximum values since 1936 are available. They were examined based on a concept by which we arranged the flood water levels for each period (each term) in Table-2 in descending order, calculating each flood probability (order / observation period) using the order as the numerator and the term as the denominator, and plotting the "order / observation period" on the vertical axis and the observed water levels on the horizontal axis of the semilogarithmic paper, each approximate equation of the plot would represent the flood water level probability.

Table-2 Cases to consider flood water level

Statistical processing period	Period and number of data
(1) Hansei years	1688 to 1860 (173 years): 48 floods
(2) Before 1935	1688 to 1935 (248 years): 59 floods
(3) From 1936	1936 to 1959 (24 years): 21 floods
(4) After the completion of the dam	1960 to 2007 (48 years) :48 floods

Flood water level probability change chart

All four cases from (1) to (4) were plotted and compared in the semilogarithmic paper as shown in Fig-6 "Flood water level probability change chart at the Hiji River Ozu point.

The appropriateness of this chart was examined by comparing the approximate equation of (4) with the values obtained using nine probability methods including the Gumbel distribution and the Iwai Method. Among the probability methods whose SLSC (standard least-squares criterion), goodness-of-fit criteria, is 0.04 or below, two straight lines drawn from the probability water levels based on the Iwai Method with the SLSC of 0.021 and the Gumbel distribution with the SLSC of 0.038, have an approximate equation of (4). From this data, the water levels of the target return period can be calculated for the current river channel condition using Equation (4). The plotted dots of (1) and (2) represent only the data of the Hansei period when floods occurred, and so they have some errors in sections with low water levels.

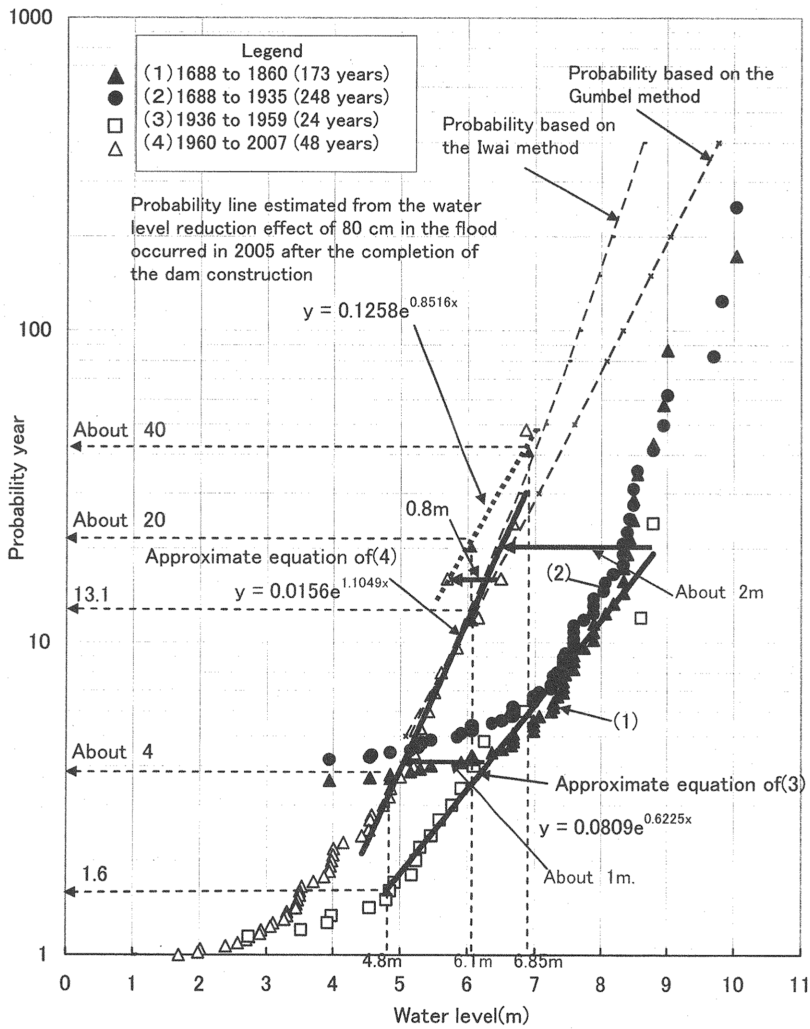


Fig-6 Probability change chart of flood water level at the Hiji River Ozu point

The water level probability during the Hansei period can be represented by plotting the 48 floods of Case (1); Case (2) represents the water level probability obtained from the 59 floods that occurred during the period before 1935 when annual maximum water levels were not recorded every year; Case (4) represents the flood water levels from 1960 when the Kanogawa Dam construction was completed.

To estimate the flood control effects of the dam, an approximate equation of the top 16 floods that can be interpreted as the changing point of the data of the 21 floods of (3) in which data before the Kanogawa Dam construction was completed are available almost every year was created; an approximate equation of the top 20 floods that can be interpreted as the changing point of the data of the 48 floods of (4) recorded from 1960 when the Kanogawa Dam construction was completed until 2007 was created. The difference in the approximate equations of (3) and (4) almost represents the water level reduction amount by flood control of the dam. From Figure-6, the water level reduction effects of about 1.0 m to 2.0 m can be seen on the probable flood scale of 3 to 20 years. This value is a little larger than the water level reduction amount of 70 cm and 1 m of the calculation results of the flood caused by Typhoon No. 16 and Typhoon No. 23 in 2004[9], respectively.

This indicates that it is difficult to estimate large-scale floods using Approximate Equation (3) alone, hence it would also be necessary to estimate the flood probability before the dam construction was completed checking large-scale data of (2). In addition, it is considered that the flood probability that is larger than the planned scale to which the dam cannot exert its effects fully would converge to the upper points of (2).

If the upstream Kanogawa Dam is renovated or the Yamatosaka Dam is constructed in the future, estimating that they can reduce about 80 cm of water level from the calculation results of the flood caused by Typhoon No. 14 in 2005[10], the future water level probability will move in on horizontal axis direction by the water level reduction amount by the dam.It is estimated that the approximate water level probability in the future will be shown like the estimated probability line.

Approximate equations of (3) and (4), and equation of estimated probability line are as follows.

y=0.0809*exp(0.6225*X) Approximate equation of (3)

y=0.0156*exp(1.1049*X) Approximate equation of (4)

y=0.1258*exp(0.8516*X) Equation of estimated probability line

CHANGES IN SAFETY LEVEL OF FLOOD CONTROL ESTIMATED FROM WATER LEVEL PROBABILITY

The safety levels of flood control (water level probability) during the Hansei period and that of the present and the future were calculated from Figure-6, in which the water level requiring evacuation for areas without levee (water level with a danger of inundation) used for the present flood forecast in the Hiji River, the overflow/inundation water level of the provisional levee in East Ozu, and the water levels of the latest floods were shown. The results are shown in Table-3.

Table-3 Estimation results of the safety level of flood control in the Hiji River

Period		Evaluated water level	Water level probability	Remarks
Hansei period		4.8 m	About 1/4yr or below	Estimated from the plot of (1).
Present		6.1 m	About 1/13yr	Estimated from Equation (4).
Future	Mid-term plan (15 years later)	6.1 m	About 1/20yr	Estimated from the estimated probability line
	Iimprovement plan (30 years later)	6.85 m	About 1/40yr	Estimated from the estimated probability line

a) Safety level of flood control during the Hansei period

It has long been said that the Hiji River caused inundations once or twice a year in the Ozu area when the rainy season started during the Hansei period. The current water level at which houses near the junction area between the Hiji River and the Kume River without levees start to be inundated is 4.80 m (water level with a danger of inundation for areas without levee). Considering that the land height during the Hansei period was also under the same condition as what it is today, it is estimated that the safety level of flood control (flood water level probability) is about 1/4 (25% probability in one year) or below from the plotted dots of (1). Figure-6 shows the probability of about 1/4. The data of (1) converges to about 1/4 because they are only available for about 1/4 of the observation period, and therefore it must be expressed that the safety level of flood control is about 1/4 or below. However, while the water level is unknown, another record [11] indicates that "106 wind and flood damages were recorded in about 200 years from 1666 (Kanbun) to 1866 (Keio 2)" in the Hiji River, and the probability obtained from the approximate equation of (3) whose outflow conditions are relatively close to those during the Hansei period without a dam was 1/1.6, and from this, it is inferred that the actual safety level is about 1/1 to 2.

b) Current safety level of flood control

The water level when the Hiji River actually overflowed from the provisional levee in East Ozu was about 6.1 m as the Ozu station water level from the average of the actual flood records of 2004 and 2005. The probability of the water level is about 1/13.1 from Equation (4). Therefore, the current safety level of flood control is estimated to be about 1/13. This safety level of flood control is slightly lower than the current safety level of flood control of 1/15, which was obtained from the rainfall of the improvement plan (created in May, 2004) in which the statistical processing for floods in 2004 and 2005 is not made. If the Kanogawa and Nomura Dams had not been constructed the safety level of flood control would have been 1/3.6 when the probability was obtained from Approximate Equation (3) with the water level of about 6.1. This suggests that the improvement of the levee (provisional levee) alone would have improved the safety level of flood control to only about 1/4.

c) Safety level of flood control after the mid-term of the improvement plan in the future

If the construction of the Yamatosaka Dam and the renovation of the Kanogawa Dam had been carried out during the mid-term of the improvement plan[7] (15 years later), the water level could have been reduced by about 80 cm from the flood water level of about 6.49 m caused by Typhoon No. 14 in 2005 due to the dam flood control effects[9] as shown in Figure-7, hence overflow from the provisional levee in East Ozu will not occur. When the evaluated water level of 6.1 m is evaluated from the estimated water level probability line after the improvement of the dam construction, it is found that the safety level of flood control will improve to 1/20 or higher.

d) Safety level of flood control after the improvement plan in the future

The height of the provisional levee in the East Ozu region and others will increase 30 years from now, which is the target year of the improvement plan, after the height of the housing areas is increased and downstream measures for the levee construction are taken[9] to achieve the "discharge for the river channel improvement " as shown in Figure-7. In the East Ozu region, the height will be increased higher than the flood water level of 6.85 m in 2004 as shown in Figure-8, hence the flood in 2004 will not overflow from the provisional levee. Moreover, we found that, when the height is increased, the safety level of flood control evaluated from the estimated probability line after the development of the dams in Figure-6 will improve to about 1/40. This corresponds to the improvement plan which set the safety level of flood control at about 1/40 based on the rainfall probability aiming to safely discharge any flood having the same peak discharge as that of the flood in September, 1945, which was the largest flood after the war.

To interpret the analysis results of the safety level of flood control based on the observed water level, it is necessary to note that it differs slightly from the calculation results of the safety level of flood control based on the outflow analysis obtained from the conventionally used rainfall probability. This research work has considered the safety level of flood control setting the zero elevation of the water level as the regular river water surface (reference surface), but in this case, the paper assumed that the water surface of the present river channel has been unchanged since the Hansei periods. However, as Figure-6 shows, even if the river water surface changed slightly, the water level probability has tended to decrease in each period since the Hansei years. For this reason, it is still important to utilize and to explain the long-term historical hydrological data in this paper to understand the progress in the improvement of the flood control facilities and the changes in the safety level of flood control, even after taking the ambiguous handling of the reference surface into consideration.

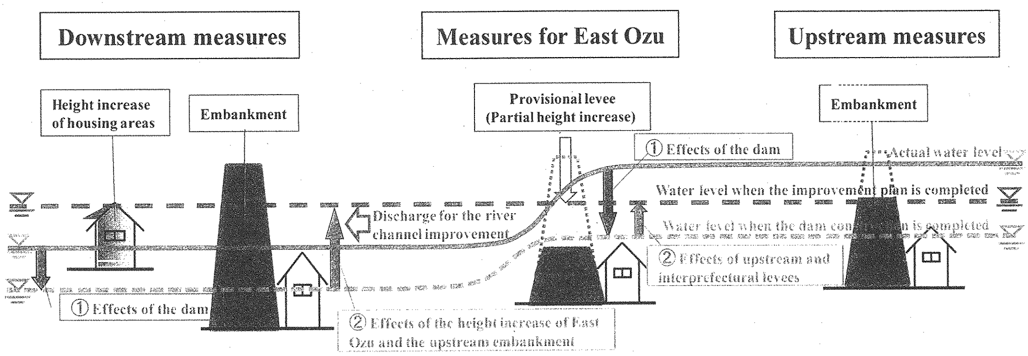


Fig-7 Image of flood control countermeasures for balancing the upstream and the downstream of the Hiji River

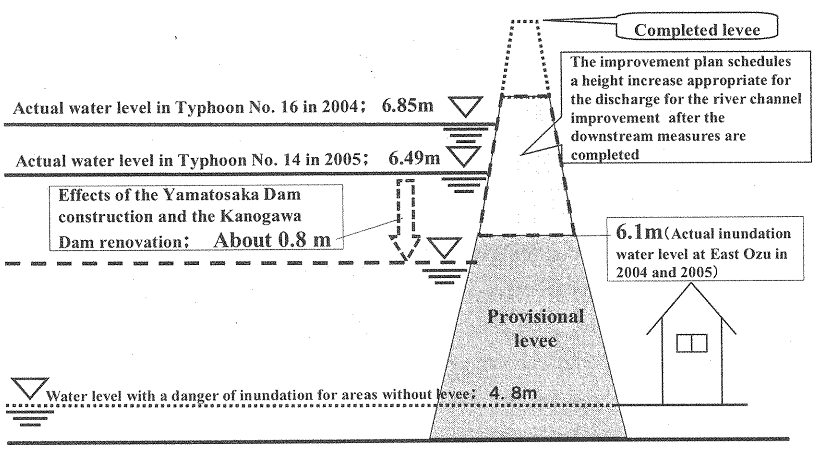


Fig-8 Relationship between the water level at the Ozu station in the Hiji River and the height of provisional levee

CONCLUSION

This paper restores the water level data recorded during the Hansei period remaining in the Hiji River which had never been used before, and compiled these huge flood observation records for about 320 years. We analyzed valuable historical hydrological data, obtained the flood probability for each period, estimated the safety level of flood control during the Hansei period, and considered the necessary changes in the safety level of flood control which changes with the improvement of the flood control facilities or other measures.

Findings of our research can be summarized as follows:

1) It was found that the safety level of flood control during the Hansei period was 1/4 or below (practically 1/1 to 1/2),

which was extremely low.

2) With the collection and analysis of historically valuable water level data, improvements in the safety levels of flood control by the improvement of the flood control facilities such as levees and dams were found to be necessary

3) The numerical values of the safety level of flood control obtained from the water level data almost correspond to those of the river improvement plan based on rainfall data.

.However, this study has added various estimations to the data of the missing areas during the Hansei and Meiji periods, and cannot be precise compared with the safety level of flood control of the improvement plan.

This requires further consideration as an issue to be solved.

In addition, it will also be necessary to reveal the long-term flood occurrence fluctuation characteristics using these long-term water level observation data.

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