Supporting Report B

HYDROLOGY AND HYDRAULICS
(Musi River Basin)

The Republic of Indonesia

THE PROJECT
FOR
ASSESSING AND INTEGRATING CLIMATE CHANGE IMPACTS INTO
THE WATER RESOURCES MANAGEMENT PLANS FOR
BRANTAS AND MUSI RIVER BASINS
(WATER RESOURCES MANAGEMENT PLAN)

FINAL REPORT

Supporting Report B : HYDROLOGY AND HYDRAULICS (Musi River Basin)

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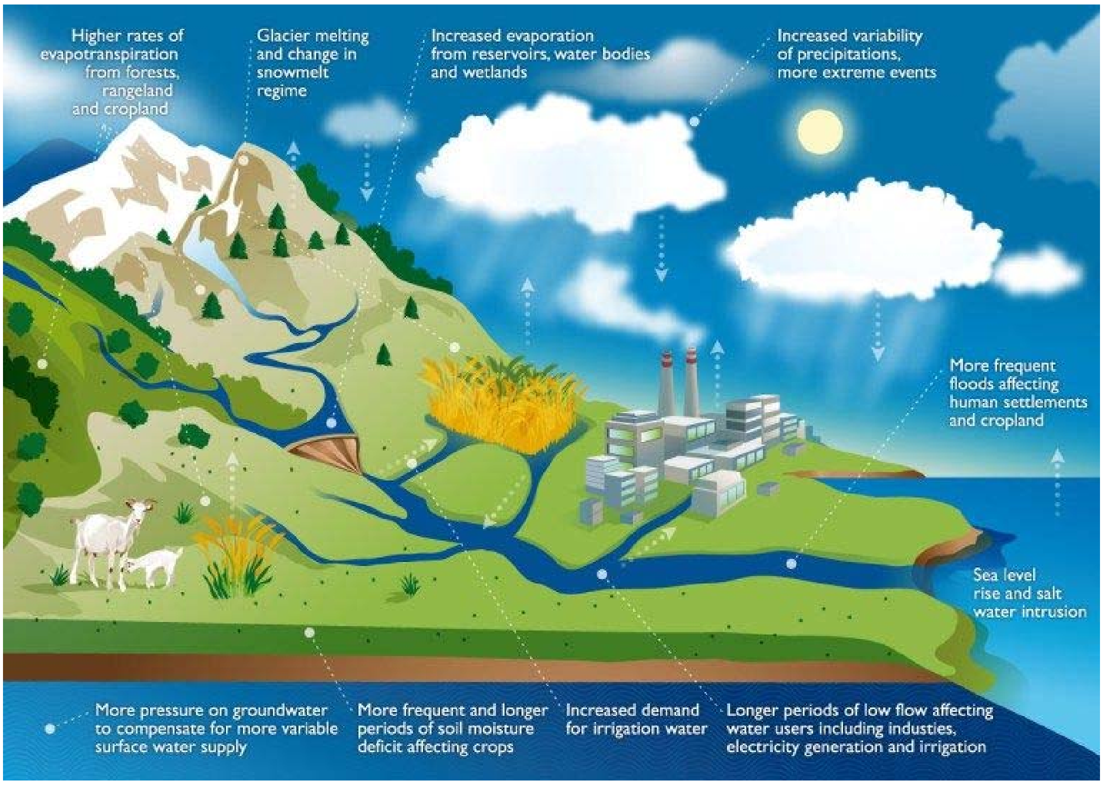
CHAPTER B1 GENERAL

B1.1 Objectives

It is almost obvious these days that surface air temperature will increase in the next decades in Indonesia. On the other hand, since climate change affects water cycles in complex ways, climate change impacts on rainfall, river discharge, etc. are difficult to forecast.

To predict future rainfall and other hydro-meteorological elements, General Circulation Model (GCM) is one of the most advanced tools to simulate climate change impact on water cycle. It is reported by the Indonesia Climate Change Sectoral Roadmap (ICCSR) Synthesis Report (2009) that "the projected climate change in Indonesia will likely impose stress on water resources. At present, the Java-Bali regions have already faced a deficit in its water balance, while for other regions like Sumatra, Sulawesi, Nusa Tenggara and the Moluccas are projected in critical conditions". The report shows some results of rainfall change in Indonesia based on GCM with SRES A2 scenario, however the results are not downscaled to river basin scale. Therefore, it is difficult to incorporate the results properly into Water Resources Management Strategic Plan (POLA) and Water Resources Management Implementation Plan (RENCANA).

In this project, JICA Project Team 1 analyzed climate change impact on rainfall, river discharge, etc. based on the Water and Energy Budget-based Distributed Hydrological Model (WEB-DHM) using downscaled outputs from GCMs. This supporting report B describes how to assess the impact of climate change on flood and drought hazards using the projected rainfall and discharge analyzed by JICA Project Team 1.



Source: Climate Change Impact on Water Cycle ©FAO 2015

Figure B 1.1.1 Examples of Climate Change Impact on Water Cycle

B1.2 Climate Change Impact

B1.2.1 Climate Change Impact on River Discharge

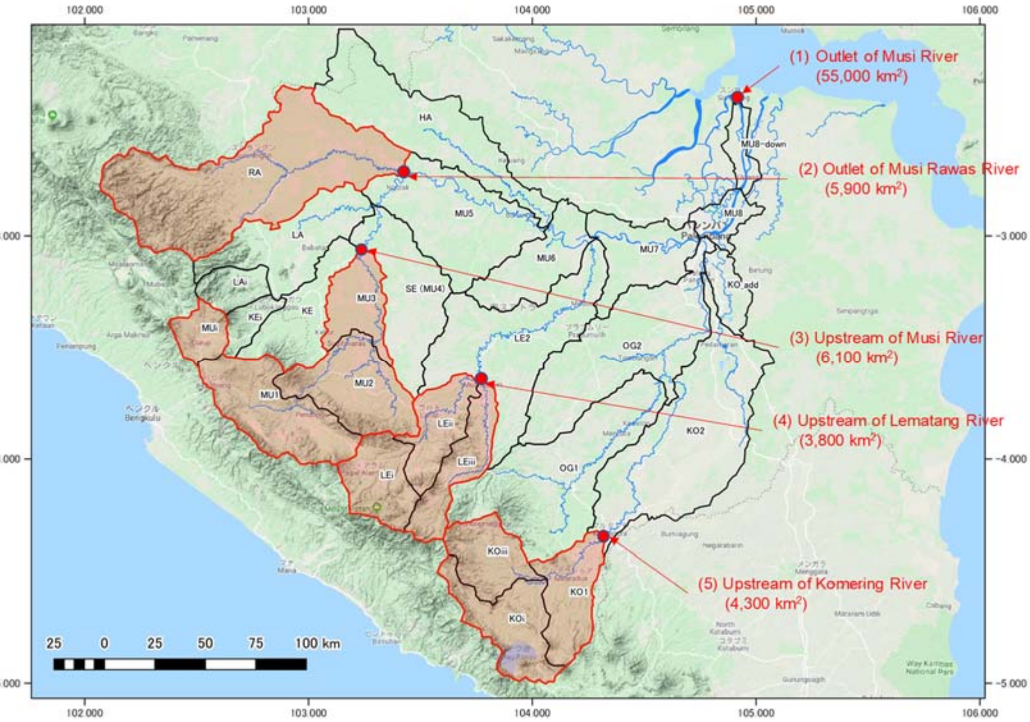
GCMs (General Circulation Models) has uncertainty and variety. At first, the 9 GCMs as shown in Table B 1.2.1 were selected which reflect the climatic characteristic of Musi river basin relatively well by screening more than 30 GCMs by JICA Project Team 1.

Table B 1.2.1 Selected 9 GCMs by First Screening

No.	GCM
1	CCCMA_CGCM
2	CSIRO_MK35
3	GFDL_2_0
4	GFDL_2_1
5	GISS_AOM
6	INGV_ECHAM4
7	MIUB_ECHO
8	MIUB_MPI_ECHAM5
9	MIUB_MRI_CGCM232A

Source: JICA Project Team 1

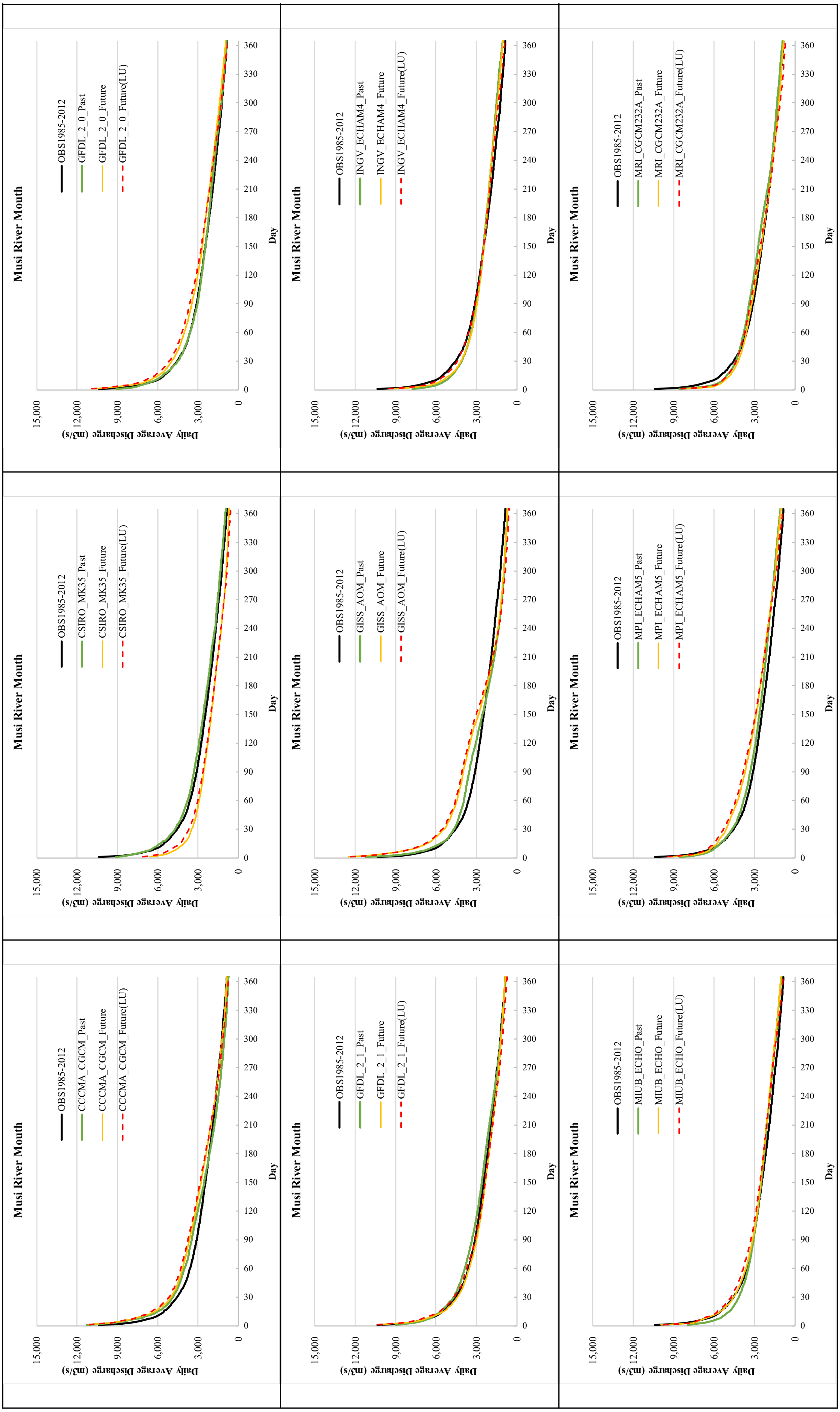
Subsequently, JICA Project Team 1 analyzed climate change impact on river discharge based on the Water and Energy Budget-based Distributed Hydrological Model (WEB-DHM) using downscaled outputs from the 9 GCMs. Based on the results of simulated river discharge, the flow duration curves were created to check the impact of climate change and land-use change on river discharge.



*Google Terrain Hybrid is used as background image
Source: JICA Project Team 2

Figure B 1.2.1 Location of Flow Duration Curve

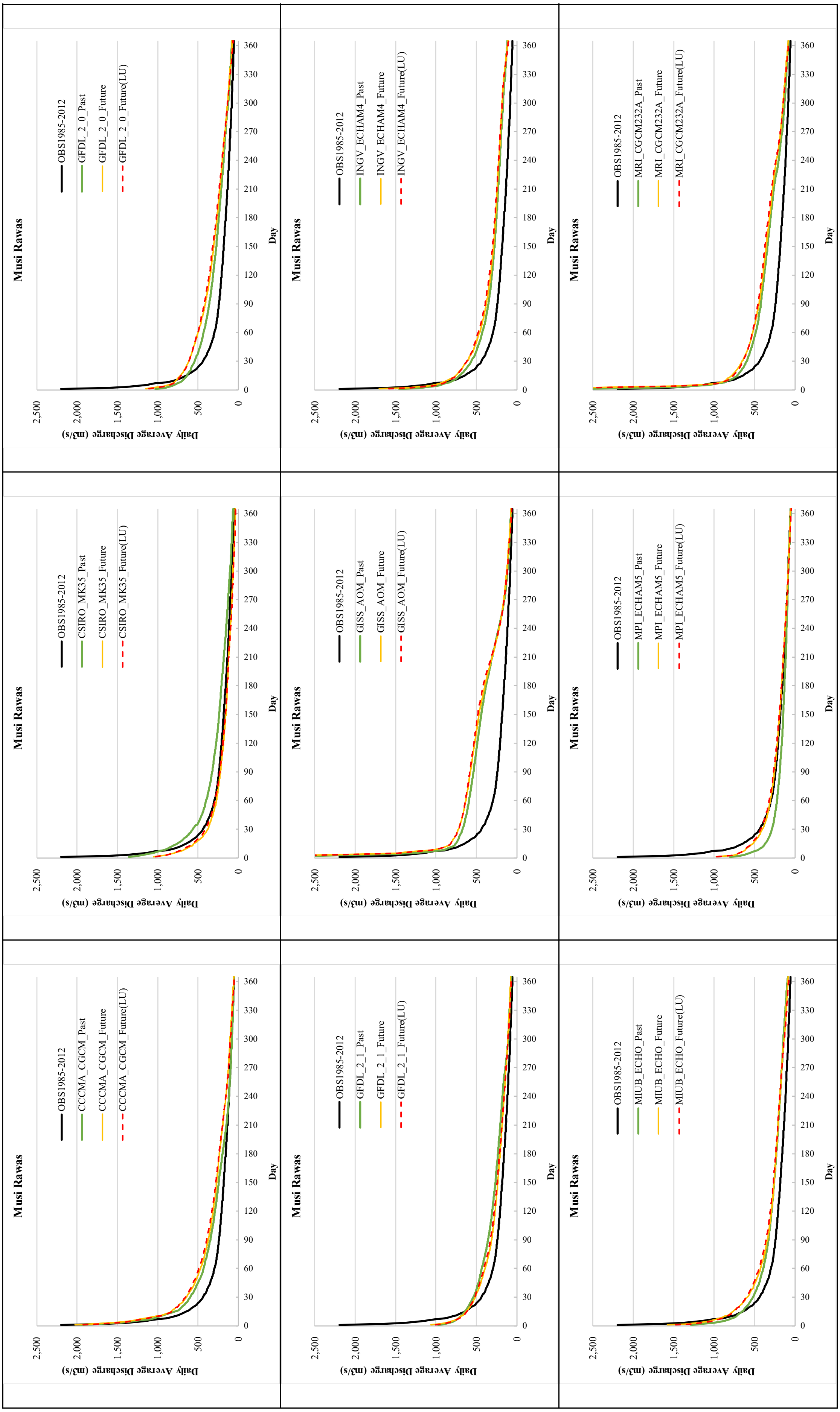
*OBS1985-2012: Observed Data from 1985 to 2012, Past: Current Climate&Current Landuse, Future: Future Climate&Current Landuse, Future(LU): Future Climate&Future Landuse



Source: JICA Project Team 2

Figure B 1.2.2 Flow Duration Curve: (1) Outlet of Musi River

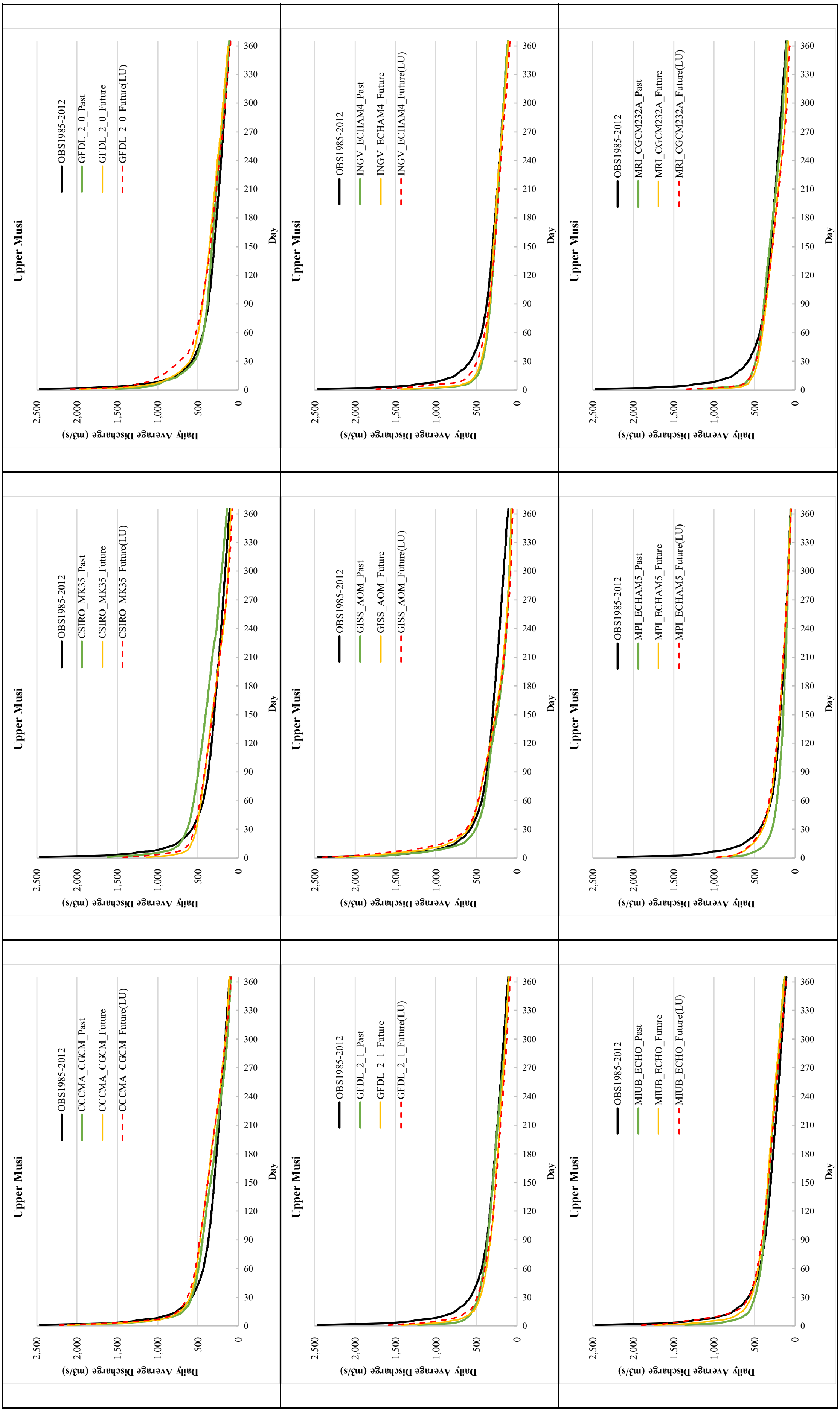
*OBS1985-2012: Observed Data from 1985 to 2012, Past: Current Climate&Current Landuse, Future: Future Climate&Current Landuse, Future(LU): Future Climate&Future Landuse



Source: JICA Project Team 2

Figure B 1.2.3 Flow Duration Curve: (2) Outlet of Musi Rawas River

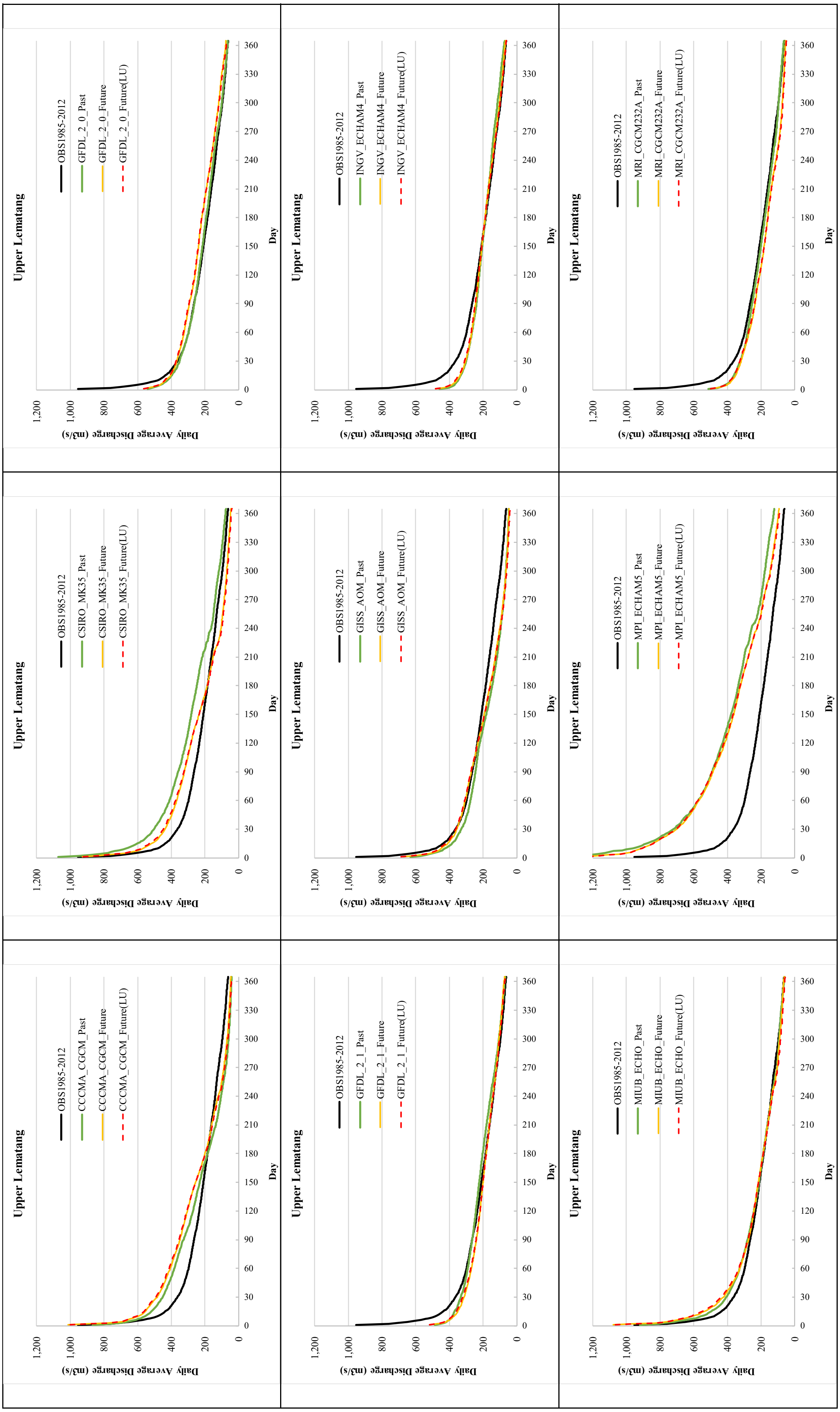
*OBS1985-2012: Observed Data from 1985 to 2012, Past: Current Climate&Current Landuse, Future: Future Climate&Current Landuse, Future(LU): Future Climate&Future Landuse



Source: JICA Project Team 2

Figure B 1.2.4 Flow Duration Curve: (3) Upstream of Musi River

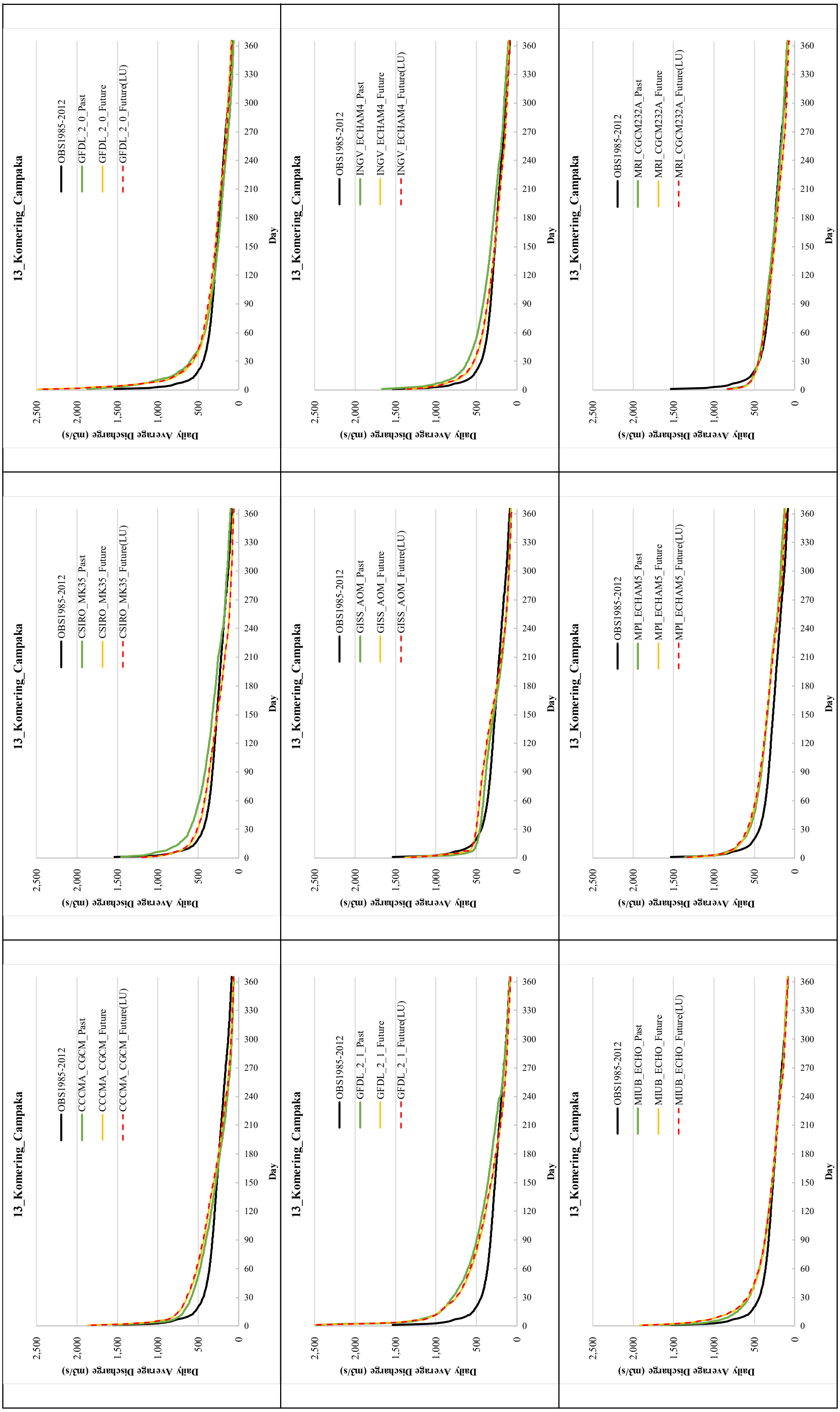
*OBS1985-2012: Observed Data from 1985 to 2012, Past: Current Climate&Current Landuse, Future: Future Climate&Current Landuse, Future(LU): Future Climate&Future Landuse



Source: JICA Project Team 2

Figure B 1.2.5 Flow Duration Curve: (4) Upstream of Lematang River

*OBS1985-2012: Observed Data from 1985 to 2012, Past: Current Climate&Current Landuse, Future: Future Climate&Current Landuse, Future(LU): Future Climate&Future Landuse



Source: JICA Project Team 2

Figure B 1.2.6 Flow Duration Curve: (5) Upstream of Komering River

B1.2.2 Summary of Climate Change Impact

Results of evaluating climate change impact by JICA Project Team 1 are summarized as below.

(1) Impact on Water Resources

(i) Annual rainfall will decrease very likely.

(ii) Monthly averaged discharge will decrease in the first-half rainy season and the second-half dry season, whereas will increase in the second-half rainy season and the first-half dry season.

(iii) Low flow discharge will likely decrease, whereas high flow discharge will likely increase.

(iv) It is very likely that the drought period will become longer in future

(v) The changes in ET and soil moisture, which are closely related with rice production, are very small.

(2) Impact on Flood Regime

The range of projected flood changes is very wide. A scenario approach is effective for adaptation planning.

CHAPTER B2 FLOOD HAZARD ANALYSIS FOR MUSI RIVER BASIN

B2.1 Setting Target for Flood Hazard Analysis

B2.1.1 Setting Target Area

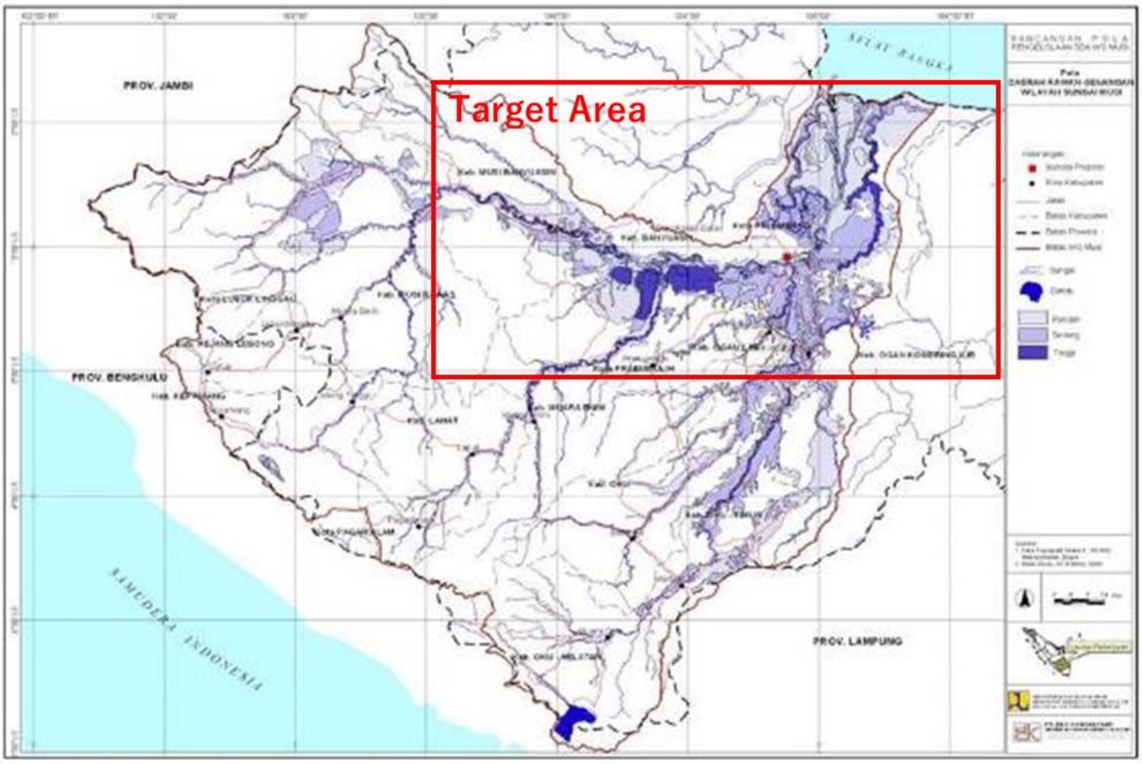
The target area for flood analysis was decided as shown in Figure B 2.1.1based on the following consideration:

(i) To evaluate the impact of sea level rise, the downstream lowland of Musi river basin should be modeled.

(ii) Musi river basin has vast natural retarding basin in middle and downstream area, which has a huge effect on flood regulation. The function of natural retarding basin should be considered.

(iii) Flood prone area is concentrated in middle and downstream area as shown in Figure B 2.1.1.

(iv) The larger the target area is, the more time is required for computation of flood simulation. It is difficult to build flood inundation model for whole Musi river basin since Musi river has huge catchment area (about 55,000 km^2).



Source: Balai PSDA Musi, Year 2007 (copied from RENCANA, Year 2017)

Figure B 2.1.1 Flood Prone Area Map

B2.1.2 Setting Target Flood

(1) Target flood type

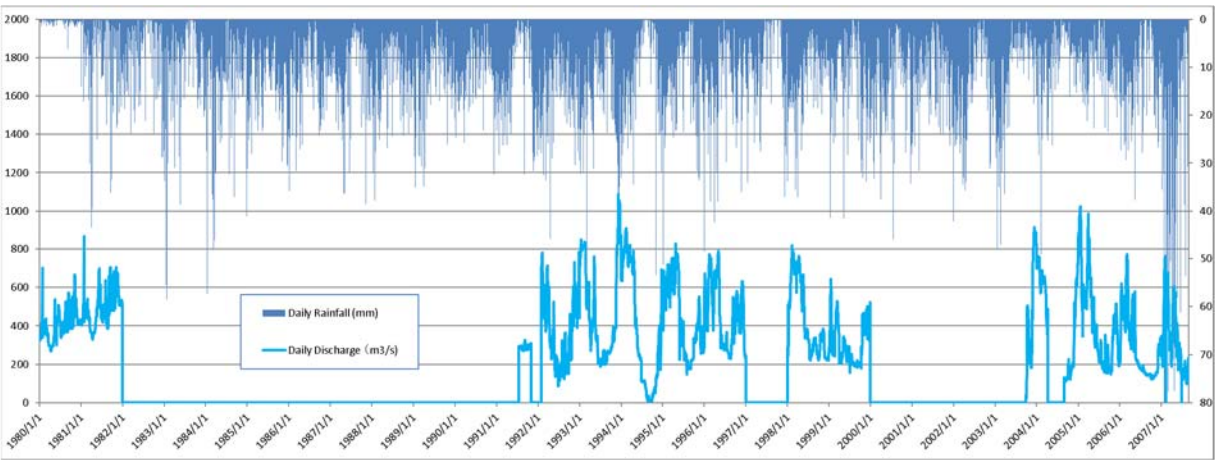
Musi river basin has vast low-lying flood plain in downstream and floods the area every year. Most of the low-lying area are used for agriculture or aquaculture, but residential area is also expanding to the area which is very vulnerable to floods. City expansion to flood vulnerable area will increase flood risk. Therefore, flood hazard analysis in this project targets flood inundation overtopping from downstream of the Musi river and its main tributaries.

(2) Target rainfall duration

The correlation between flood volume and accumulated rainfall was calculated to decide the flood duration at the Lematang Rotan Water Level Station (upstream catchment area: 7,000 km^2) which locates in the downstream area of the Musi river basin. The discharge of 300 m^3/s or more is regarded as flood. The duration of the accumulated rainfall with the highest correlation was taken as the flood duration. The condition of rainfall and water level at the station is shown in Figure B 2.1.2.

The flood volume is to be calculated for seven months from October to April, which is generally regarded as the rainy season. The analysis results are shown in Table B 2.1.1 and Table B 2.1.2. In this analysis, the runoff rates in 2004 and 2006 are excluded due to the abnormal values.

As a result, it was found that the data of five months rainfall (from November to March) has the best correlation as shown in Table B 2.1.2. Therefore, 5 months rainfall from November to March is regarded as target rainfall duration in this project.



Source: JICA Project Team 2

Figure B 2.1.2 Conditions of Daily Rainfall and Daily Discharge in Lematang Rotan Water Level Station

Table B 2.1.1 Comparison between Flood Volume and Cumulative Rainfall

Counting Terms		Total Discharge over 300m3/s (MCM)	1Month Rainfall(mm)							2Month Rainfall(mm)					
Start	End		Oct	Nov	Dec	Jan	Feb	Mar	Apr	Oct-Nov	Nov-Dec	Dec-Jan	Jan-Feb	Feb-Mar	Mar-Apr
Oct-92	Apr-93	4730	334	293	299	403	255	324	346	626	591	702	658	579	670
Oct-93	Apr-94	7119	279	476	533	404	272	336	265	755	1009	937	676	607	600
Oct-94	Apr-95	3724	58	297	294	415	229	306	325	355	592	709	644	536	631
Oct-95	Apr-96	3689	292	252	292	240	429	303	388	545	544	533	669	732	692
Oct-98	Apr-99	980	210	167	178	320	241	212	99	377	345	497	560	453	311
Oct-05	Apr-06	2258	242	169	125	327	401	268	345	411	295	452	727	668	613
Correlation Coefficient			0.297	0.962	0.934	0.495	-0.143	0.912	0.374	0.871	0.950	0.912	0.392	0.293	0.576

Counting Terms		Total Discharge over 300m3/s (MCM)	4Month Rainfall(mm)				3Month Rainfall(mm)				
Start	End		Oct-Jan	Nov-Feb	Dec-Mar	Jan-Apr	Oct-Dec	Nov-Jan	Dec-Feb	Jan-Mar	Feb-Apr
Oct-92	Apr-93	4730	1328	1249	1281	1328	925	994	957	982	925
Oct-93	Apr-94	7119	1692	1685	1544	1276	1288	1413	1209	1011	872
Oct-94	Apr-95	3724	1064	1236	1244	1275	650	1006	938	950	860
Oct-95	Apr-96	3689	1077	1214	1265	1361	837	785	961	973	1121
Oct-98	Apr-99	980	875	905	950	871	555	664	738	772	552
Oct-05	Apr-06	2258	864	1022	1120	1340	537	621	853	995	1013
Correlation Coefficient			0.963	0.983	0.988	0.549	0.944	0.938	0.981	0.711	0.352

Counting Terms		Total Discharge over 300m3/s (MCM)	5Month Rainfall(mm)			6Month Rainfall(mm)		7Month Rainfall
Start	End		Oct-Feb	Nov-Mar	Dec-Apr	Oct-Mar	Nov-Apr	Oct-Apr
Oct-92	Apr-93	4730	1583	1573	1626	1907	1919	2253
Oct-93	Apr-94	7119	1964	2021	1809	2299	2285	2564
Oct-94	Apr-95	3724	1294	1542	1569	1600	1867	1925
Oct-95	Apr-96	3689	1506	1517	1653	1809	1905	2198
Oct-98	Apr-99	980	1115	1117	1049	1327	1216	1426
Oct-05	Apr-06	2258	1264	1290	1466	1532	1635	1877
Correlation Coefficient			0.964	0.991	0.894	0.977	0.962	0.951

Source: JICA Project Team 2

Table B 2.1.2 Rank Table of Correlation Coefficient in Each Rainfall Duration

Rank Table of Correlation Coefficient	1Month Rainfall	2Month Rainfall	3Month Rainfall	4Month Rainfall	5Month Rainfall	6Month Rainfall	7Month Rainfall
No.1	Nov 0.962	Nov-Dec 0.950	Dec-Feb 0.981	Dec-Mar 0.988	Nov-Mar 0.991	Oct-Mar 0.977	Oct-Apr 0.951
No.2	Dec 0.934	Dec-Jan 0.912	Oct-Dec 0.944	Nov-Feb 0.983	Oct-Feb 0.964	Nov-Apr 0.962	
No.3	Mar 0.912	Oct-Nov 0.871	Nov-Jan 0.938	Oct-Jan 0.963	Dec-Apr 0.894		

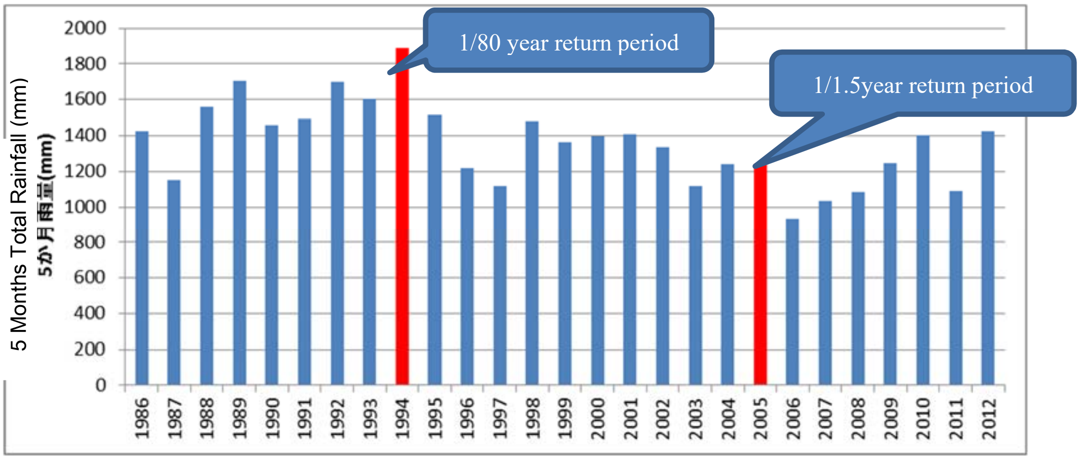
5 months rainfall during Nov-Mar showed best correlation coefficient

Source: JICA Project Team 2

(3) Selection of Representative Floods

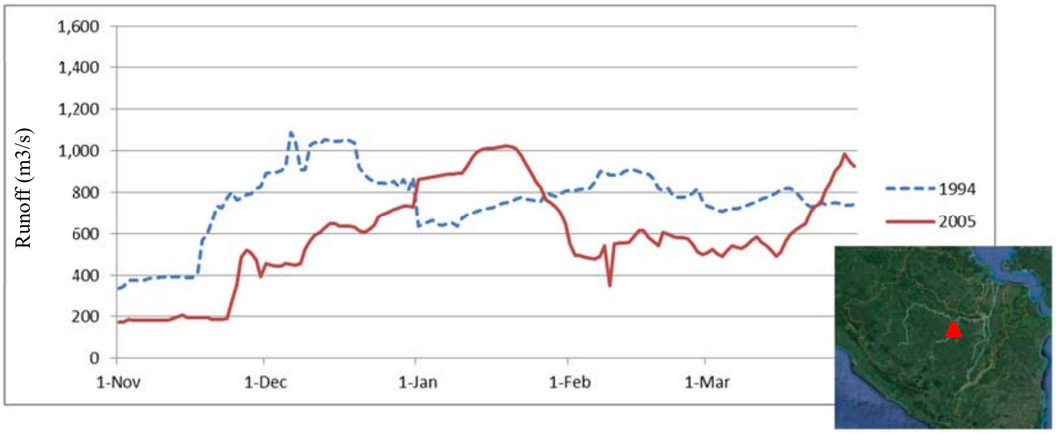
By using mesh rainfall data for a total of 28 years from 1985 to 2012 provided by JICA Project Team 1, 5 month basin mean rainfall during the rainy season (November to March) of the Musi River basin is estimated as illustrated in Figure B 2.1.3

The 5-month rainfall of about 1,900 mm in the hydrological year 1994 (from November 1993 to March 1994) is the largest among those of the 28 years. The magnitude of this rainfall corresponds to a return period of 80 years according to frequency analysis. Considering that there is no clear evidence of such a huge flood, it is assumed that the rainfall might have been smaller, actually, and the data has a problem in accuracy. However, the discharge of 1994 at Lematang Rotan Water Level Station is larger than that of 2005 when a certain flood definitely occurred as shown in Figure B 2.1.4. Therefore, the rainfall pattern of 1994 is proposed as the representative rainfall pattern for the flood inundation analysis.



Source: JICA Project Team 2

Figure B 2.1.3 Basin Average of Five Months Rainfall from November to March



※The basin upstream of the Lematang Rotan Water Level Station is 6,990m^3.

Source: JICA Project Team 2

Figure B 2.1.4 Comparison of Observation Discharge in Lematang.Rotan Water Level Station

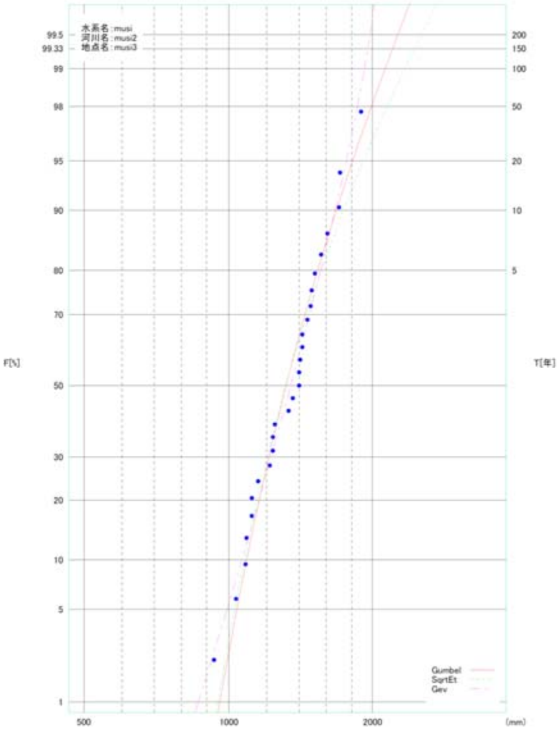
(4) Statistical Analysis for Probable Rainfall

Statistical analysis has been carried out using 5-month rainfall for 27 years (1986 to 2012). In the selection of the probability distribution model for the hydrological statistical analysis, SLSC 0.04 or less was recommended to choose from three models: (1) Gumbel distribution, (2) Gev (generalized extreme distribution), or (3) square root exponent type maximum value distribution (SQRTet). For this project, the Gumbel model which meets the above conditions was selected.

Table B 2.1.3 Result of the Statistical Analysis for Probable Rainfall

		Exp	Gumbel	SqrtEt	Gev	LP3Rs	LogP3	Iwai	IshiTaka	LN3Q	LN3PM	LN2LM	LN2PM
X-COR(99%)		0.941	0.983	0.975	0.992	0.993	—	0.993	0.993	0.992	0.993	0.992	0.992
P-COR(99%)		0.899	0.985	0.984	0.992	0.992	—	0.991	0.992	0.993	0.992	0.991	0.991
SLSC(99%)		0.067	0.035	0.046	0.027	0.026	—	0.026	0.026	0.029	0.026	0.026	0.026
Log Lilelihood		−177.4	−185.1	−185.5	−184.2	−184.2	—	−184.3	−184.2	−184.4	−184.2	−184.3	−184.3
pAIC		358.8	374.1	375	374.4	374.4	—	374.5	374.5	374.7	374.5	372.6	372.5
X-COR(50%)		0.993	0.992	0.993	0.98	0.981	—	0.986	0.984	0.98	0.984	0.987	0.987
P-COR(50%)		0.979	0.982	0.978	0.977	0.98	—	0.981	0.981	0.981	0.981	0.98	0.981
SLSC(50%)		0.087	0.057	0.084	0.047	0.051	—	0.048	0.047	0.056	0.047	0.049	0.048
Probable Hyudrological Value	Return Period	Exp	Gumbel	SqrtEt	Gev	LP3Rs	LogP3	Iwai	IshiTaka	LN3Q	LN3PM	LN2LM	LN2PM
	2	1276.6	1317.3	1314.7	1347.1	1350.5	—	1339.3	1345.1	1354.6	1345.2	1338.6	1338.6
	3	1383	1418.7	1427.8	1451.3	1450.4	—	1440.5	1444.9	1451.3	1444.9	1442.3	1440
	5	1517	1531.7	1558.9	1554.1	1548	—	1543.9	1544.3	1544.4	1544.3	1548.6	1543.8
	10	1698.8	1673.7	1731.3	1665.7	1654.5	—	1662.6	1655.7	1645	1655.7	1671.2	1663.3
	20	1880.7	1810	1904.6	1757	1743.6	—	1767.2	1751.6	1728.9	1751.6	1779.6	1768.9
	30	1987	1888.3	2007.8	1803.4	1790.3	—	1824.2	1803.1	1772.8	1803	1838.9	1826.5
	50	2121	1986.3	2140.4	1855.9	1844.9	—	1892.7	1864.1	1824.1	1864.1	1910.2	1895.9
	80	2244.3	2075.9	2265.3	1899.1	1891.6	—	1953.1	1917.4	1868.1	1917.3	1973.3	1957.1
	100	2302.9	2118.4	2325.6	1918	1912.7	—	1981.1	1941.9	1888	1941.8	2002.5	1985.5
	150	2409.3	2195.4	2437	1950.1	1949.7	—	2030.9	1985.1	1923	1985	2054.6	2036
	200	2484.7	2250	2517.4	1971.2	1975	—	2065.5	2015	1946.9	2014.9	2090.9	2071.2
	400	2666.6	2381.5	2716	2016.9	2032.7	—	2146.9	2084.5	2001.7	2084.4	2176.3	2154

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure B 2.1.5 Goodness of Fit with Probability Distribution Model

Table B 2.1.4 Extension Ratio for Each Return Period

Return Period	Extension Rate of Actual Rainfall (Nov.1993-Mar.1994)
2	0.71
5	0.82
10	0.88
25	0.94
50	0.98
100	1.01

Source: JICA Project Team 2

(5) Setting Probable Flood

JICA Project Team 1 selected the 3 GCMs for the inundation analysis. In the selection of the probability density function, the Gev Model, with the smallest SLSC of 9 GCM average, was selected. Finally, the following 3 GCM was selected as high risk scenario (GCM-GISS), middle risk scenario (GCM-CCCMA) and low risk scenario (GCM-GFDL 2.1). The GCM Scale Factor in each return period is shown in the table below.

Table B 2.1.5 GCM Scale Factor

Return Period	GCM Large	GCM Middle	GCM Small	Extension Rate of Actual Rainfall (Nov.1993- Mar.1994)
	GISS	CCCMA	GFDL_21	
2	1.11	1.03	0.96	0.71
5	1.10	1.02	0.95	0.82
10	1.10	1.01	0.95	0.88
25	1.09	1.01	0.95	0.94
50	1.08	1.00	0.95	0.98
100	1.08	1.00	0.95	1.01

Source: JICA Project Team 2

The GCM extension ratio was calculated from the following method. The GCM Extension Ratio in each return period is shown in Table B 2.1.6 as well.

GCM Extension Ratio = Actual Rainfall Extension Ratio × GCM Scale Factor

Table B 2.1.6 Extension Ratio for the 3 GCMs

Return Period	GCM Large	GCM Middle	GCM Small
	GISS	CCCMA	GFDL_21
2	0.79	0.73	0.68
5	0.91	0.84	0.78
10	0.97	0.89	0.84
25	1.03	0.95	0.89
50	1.06	0.98	0.93
100	1.10	1.01	0.96

Source: JICA Project Team 2

B2.2 Flood Inundation Modeling

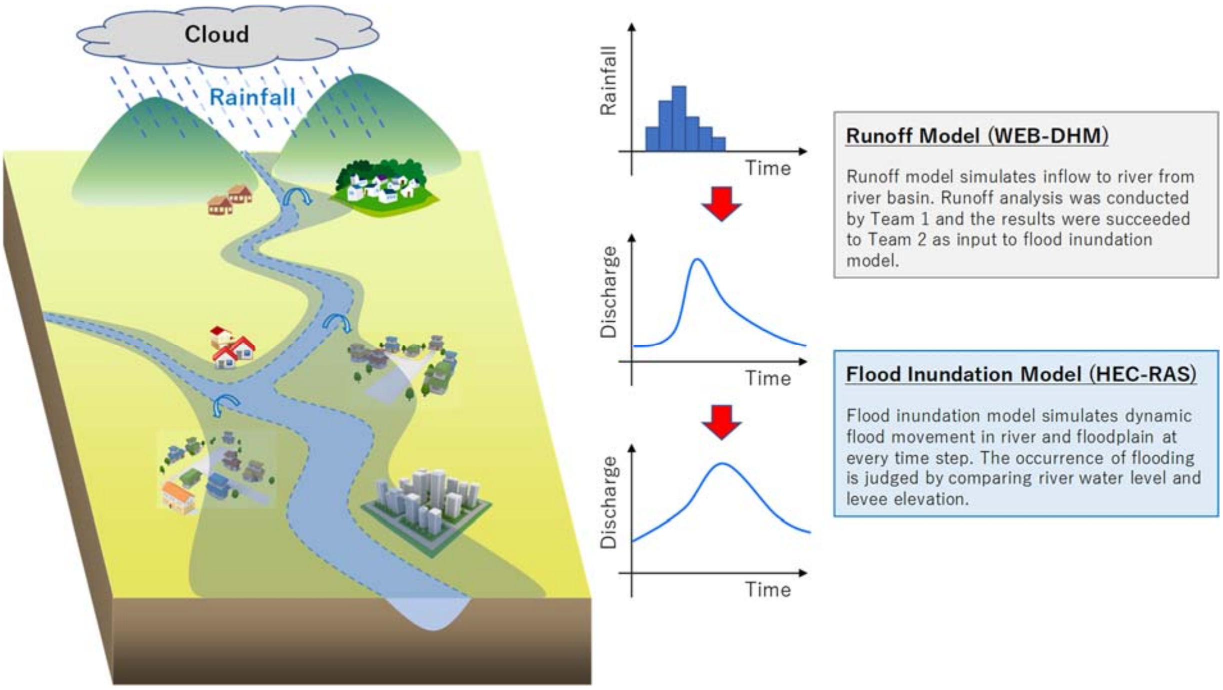
B2.2.1 Outline of Flood Inundation Modeling

The impacts of climate change (CC) are incorporated to both runoff analysis and flood inundation analysis. In runoff analysis, CC impacts were simulated in GCMs and runoff analysis was conducted for 3 GCMs regarded as high risk, middle risk and low risk. Team 2 succeeded the results of runoff analysis, thus flood inundation analysis reflected CC impacts on rainfall, temperature, etc. to input discharge hydrograph. CC impact on sea level rise was also incorporated in flood inundation model by reflecting the impact to the boundary data of river mouth. Outline of flood inundation modeling was shown in Figure B 2.2.1.

A flood inundation model was developed as combined one-dimensional (1D) unsteady-flow modeling and two-dimensional (2D) unsteady-flow routing. The main reasons are following:

(i) Floodplain would rather be modeled by 2D unsteady-flow routing model than by pond model because characteristics of flooding show spread or flow down type in some areas.

(ii) Modeling only 2D unsteady-flow routing will not make sense because there was no DEM (digital elevation map) data including river bed nor was scarce cross section data.

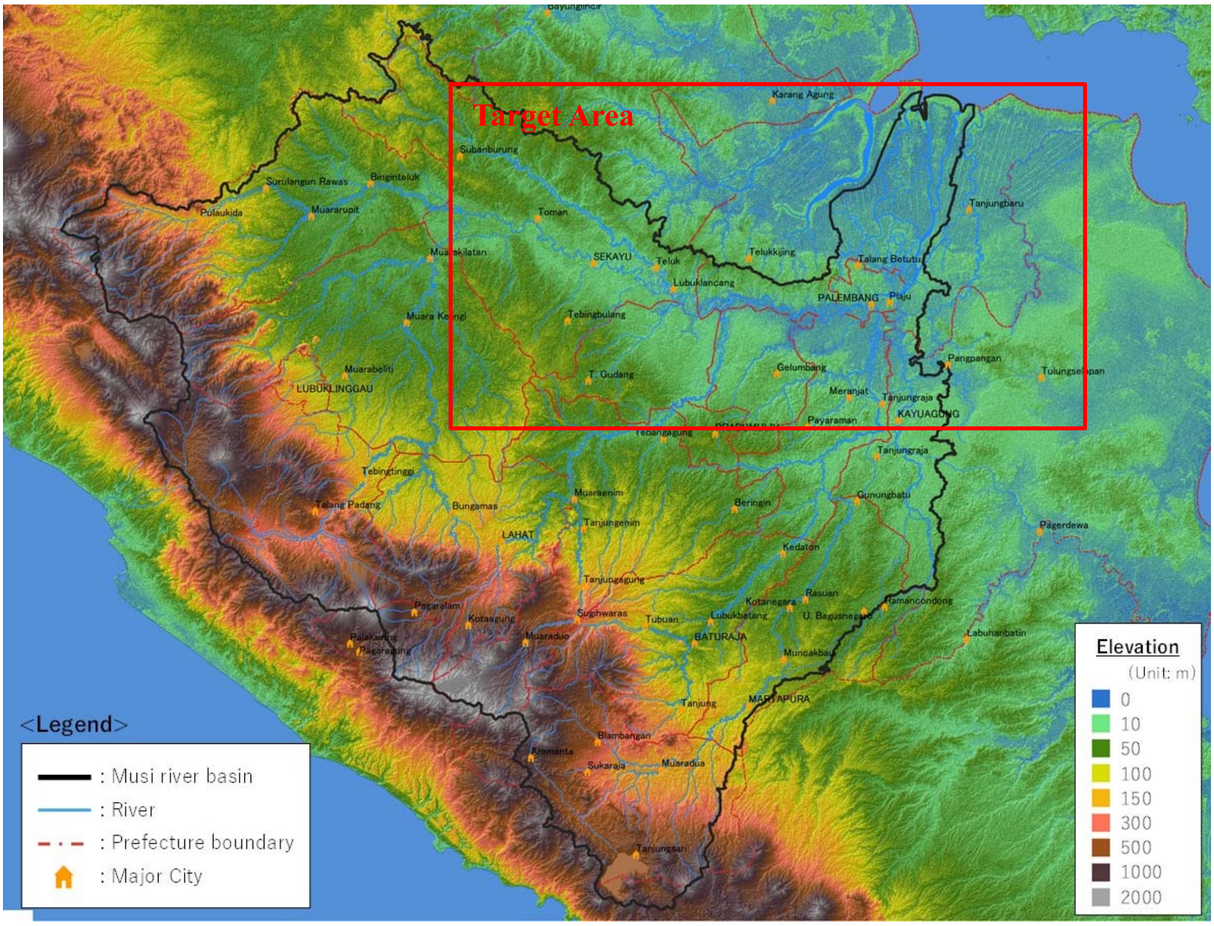


Source: JICA Project Team 2

Figure B 2.2.1 Outline of Flood Inundation Modeling

B2.2.2 Overview of the Target Area

Figure B 2.2.2 shows overview of the target area. The target area locates on midstream to downstream of Musi river and has large lowland areas.



*SRTM version 3.0 (3 arc-second mesh) was used to show elevation.
Source: JICA Project Team 2

Figure B 2.2.2 Overview of the Target Area

B2.2.3 Selection of Hydraulic Computation Software

The hydraulic computation software, "HEC-RAS (River Analysis System)", was selected for flood inundation analysis in the Project. HEC-RAS is provided by Hydrologic Engineering Center (HEC) of US Army Corps of Engineers. The followings show main reasons to select the HEC-RAS:

(i) HEC-RAS has the ability to perform one-dimensional (1D) unsteady-flow modeling, two-dimensional (2D) unsteady-flow modeling, as well as combined 1D and 2D unsteady-flow modeling, which means that any other software isn't required for flood inundation analysis.

(ii) This software is used not only in America but also all over the world and its utility is widely accepted.

(iii) This software is distributed free on the website[1] of HEC and plenty of its user's manuals and technical reference are available. Therefore, it is convenient to succeed the model by the Counterpart after the end of the Project.

The version of HEC-RAS used in the Project was shown in the table below.

[1] HEC-RAS download site: http://www.hec.usace.army.mil/software/hec-ras/downloads.aspx

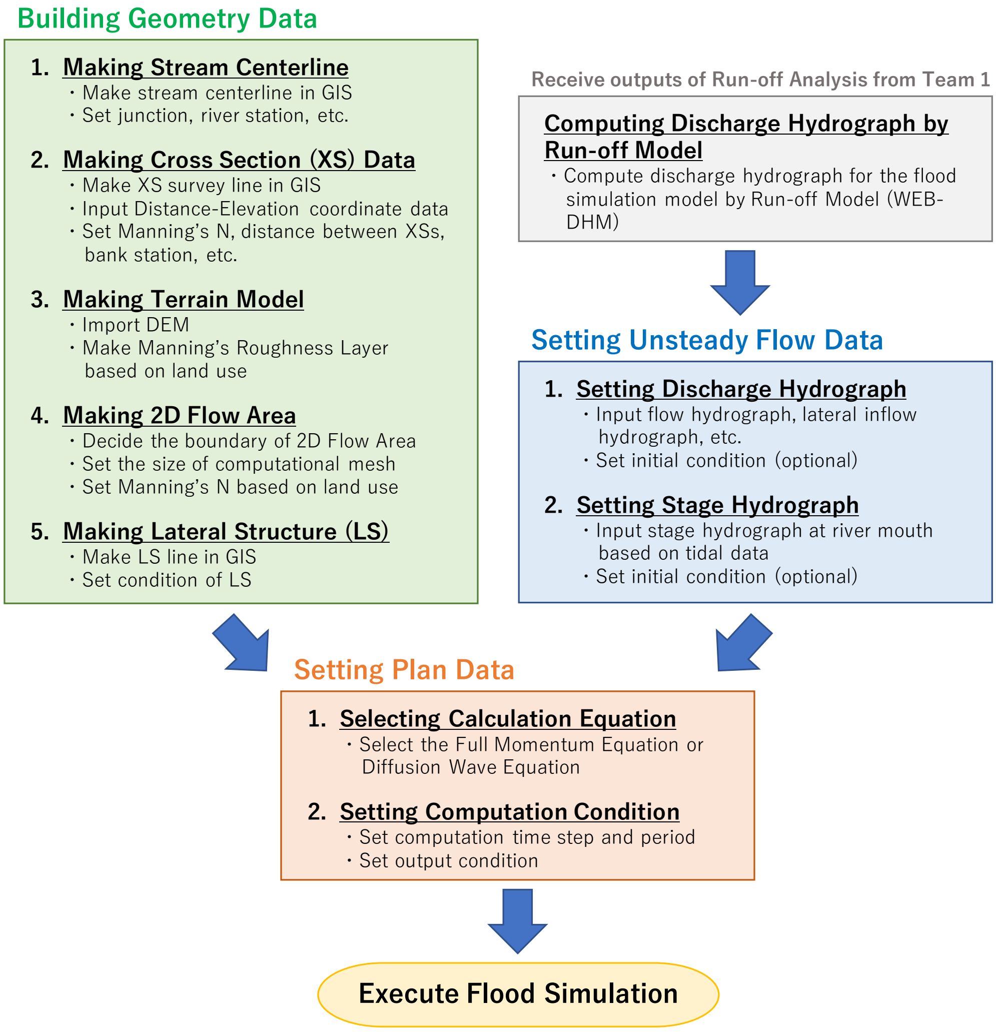
Table B 2.2.1 Hydraulic Software Used for Flood Inundation Simulation

Software Name	HEC-RAS
Version	Version 5.0.7
Release	March 2019

Source: JICA Project Team 2

B2.2.4 Workflow of Flood Inundation Modeling

Workflow of flood inundation modeling is shown in Figure B 2.2.3. HEC-RAS requires (1) Geometry data, (2) Unsteady Flow Data and (3) Plan Data to execute flood inundation simulation. Detailed work processes are explained in the following sections.



Source: JICA Project Team 2

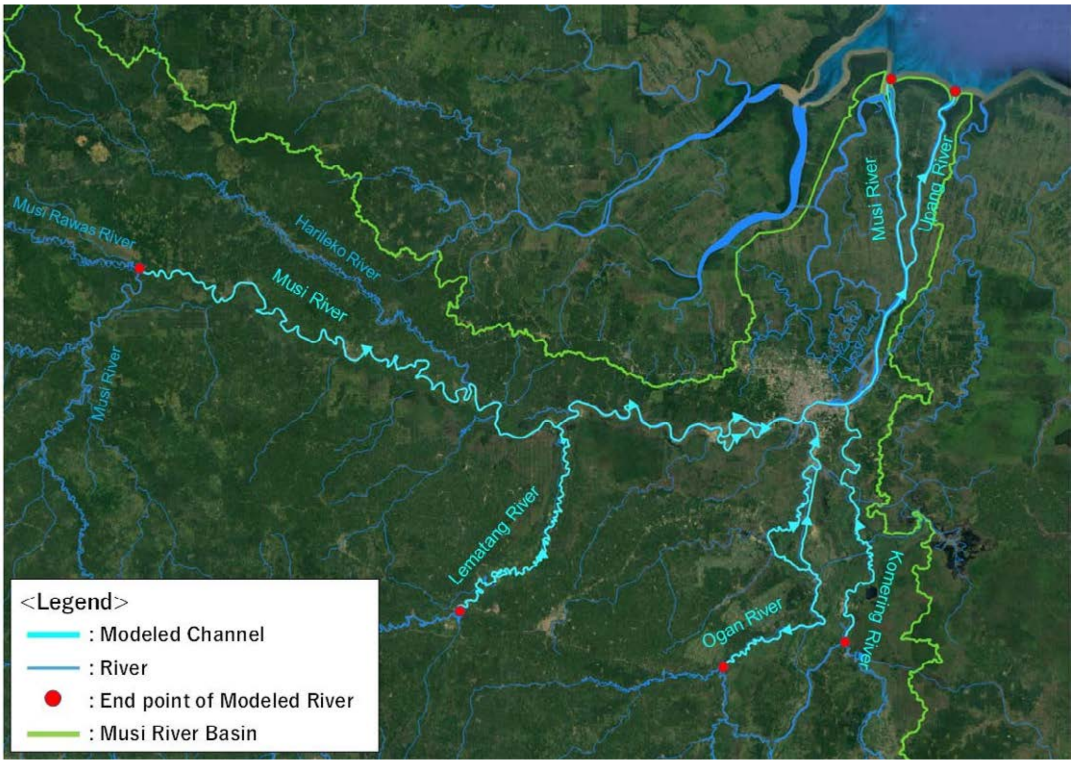
Figure B 2.2.3 Workflow of Flood Inundation Modeling

B2.2.5 River Channel Modeling

(1) Building channel network

2D Modeling and flood mapping requires river network with geological coordinate. Therefore, Stream centerlines were drawn by tracing river centerline of satellite image in GIS software. Figure B 2.2.4shows channel network drawn for flood inundation modeling. In addition to Musi river, 4 major tributaries, namely Lematang river, Ogan river, Komering river and Upang river, were drawn in the target area. Musi river starts from confluent point of Musi river and

Musi Rawas river and end at Musi River mouth. Lematang river, Ogan river and Komering river start from confluent point of tributaries and end at confluent point with Musi river. Upang river start from separate point of Musi river and end at Upang river mouth.



*The data of "River" in the legend was downloaded from the DIVA-GIS website[2].

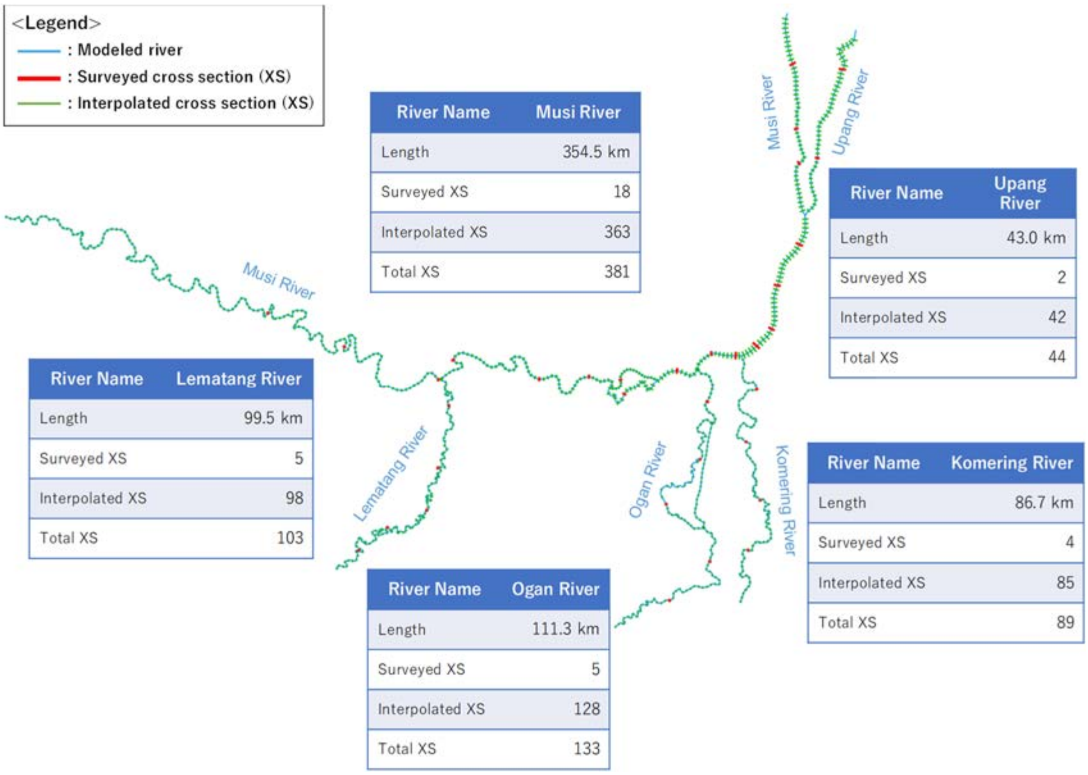
Source: JICA Project Team 2

Figure B 2.2.4 Overview of Modeled Channel Network

(2) Setting Cross Section (XS) Data

2D modeling requires (i) location of XS with geological coordinate, (ii) XS's distance – elevation (X-Y) coordinate, (iii) Manning's N value, (iv) Bank stations and (v) distance to the next XS. Firstly, location of XS and their X-Y coordinate were set based on the surveyed cross sections. Manning's N values were applied as 0.033 for channel part and 0.05 for over bank part for all cross sections because there was no reference nor few hydrological data for calibration regarding to Manning's N. Bank stations were set based on XS's shape and distance to the next XS were calculated based on the location of XS. After setting surveyed XS data, more cross sections were interpolated or extrapolated less than 1 km interval to improve computation stability as shown in Figure B 2.2.5.

[2] DIVA-GIS website: http://www.diva-gis.org/



Source: JICA Project Team 2

Figure B 2.2.5 Cross Sections set for Flood Inundation Model

B2.2.6 Floodplain Modeling

(1) Building terrain data from DEM

a) Selecting DEM for terrain data

Flood simulation model requires accurate digital elevation model (DEM) to express actual flood movement in floodplain. To select more suitable DEM for Musi river basin, the available free DEM data shown in Table B 2.2.2 were collected and compared with geodetic control points for elevation reference.

JPT (Japan Project Team) also tried to collect available DEM from Indonesian counterpart, but there was no available DEM appropriate in the target area for flood simulation model.

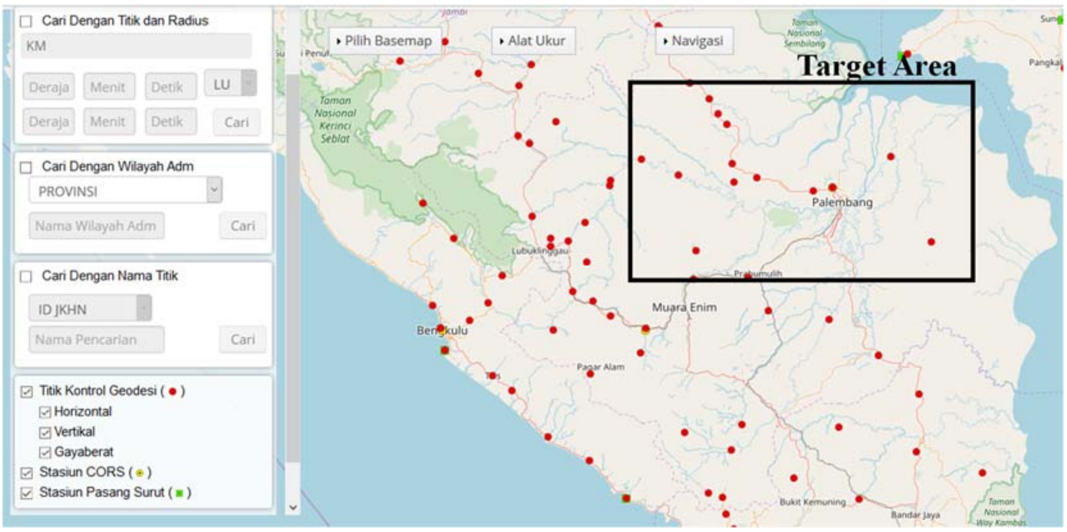
Table B 2.2.2 List of Available Free DEM Data

Name	DSM/ DTM	Reference Ellipsoid	Reference Geoid	Resolution	Source
SRTM (version 4.1)	DSM	WGS84	EGM96	3 arc-second (about 90m)	https://cgiarcsi.community/data/srtm-90m-digital-elevation-database-v4-1/
SRTM (version 3.0)	DSM	WGS84	EGM96	1 arc-second (about 30m)	https://earthexplorer.usgs.gov/
Aster GDEM (version 2.0)	DSM	WGS84	EGM96	1 arc-second (about 30m)	https://lpdaac.usgs.gov/dataset_discovery/aster/aster_products_table/astgtm
ALOS World 3D (version 2.1)	DSM	GRS80	EGM96	1 arc-second (about 30m)	https://www.eorc.jaxa.jp/ALOS/aw3d30/index_j.htm
DEMNAS	DSM	WGS84	EGM2008	0.27 arc-second (about 8m)	http://tides.big.go.id/DEMNAS/
MERIT DEM	DTM	WGS84	EGM96	3 arc-second (about 90m)	http://hydro.iis.u-tokyo.ac.jp/~yamadai/MERIT_DEM/index.html

*DSM: Digital Surface Model, DTM: Digital Terrain Model
Source: JICA Project Team 2

i) Comparing DEM with Geodetic Control Points

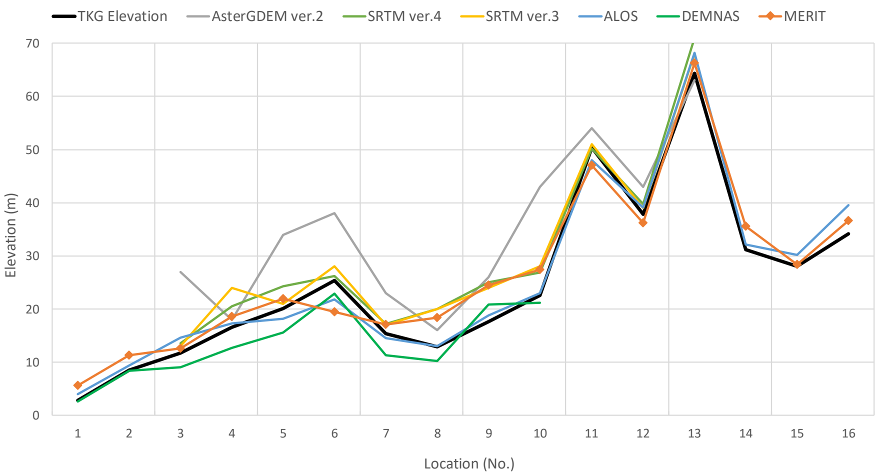
To check how the collected DEM fit the actual topography in the target area, the DEM data listed in Figure B 2.2.6 were compared with geodetic control points (TKG: Titic Kontrol Geodesi in Indonesian). TKG data were downloaded from the website of BIG (Badan Informasi Geospasial) which was established by granting more responsibility to the National Coordinating Agency for Surveys and Mapping (BAKOSURTANAL) with Law No. 4/2011 on Geospatial Information and Presidential Regulation No. 94/2011 on the Geospatial Information Agency. The compatibility with the GCPs validates the accuracy of DEMs.



Source: website of BIG (Badan Informasi Geospasial) (http://srgi.big.go.id/srgi2/jkg)

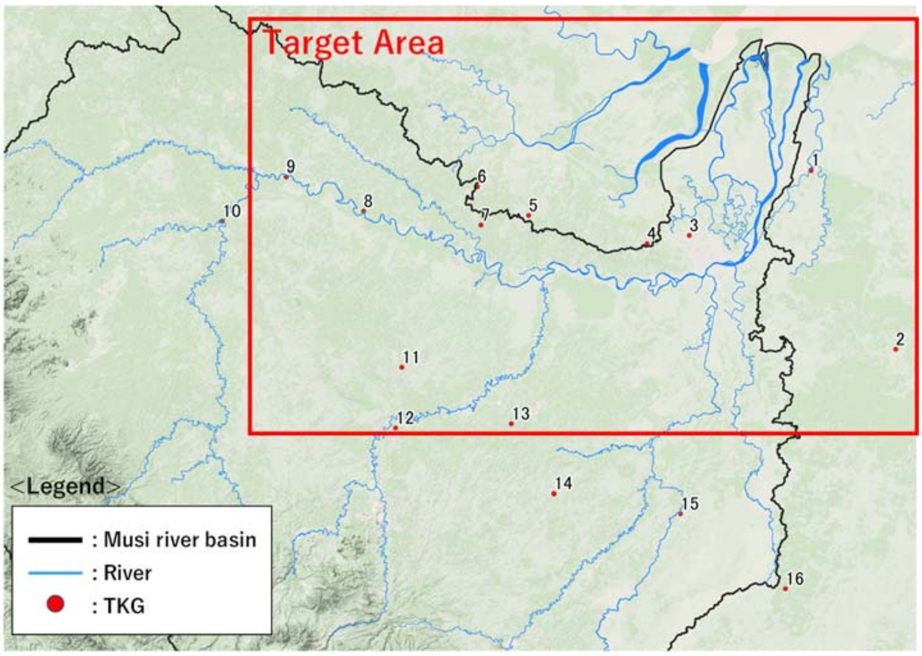
Figure B 2.2.6 Location of Geodetic Control Points (TKG)

The result of comparing DEM with TKG is shown in Figure B 2.2.7. MERIT DEM, DEMNAS and ALOS showed relatively good fitting in comparison of GCPs in the target area for flood simulation.



*Location No. is shown in the figure below.
Source: JICA Project Team 2

Figure B 2.2.7 Comparison of DEMs with TKG (GCP)



Source: JICA Project Team 2

Figure B 2.2.8 Location No. of TKG

ii) Result of the DEM Selection

As a result of comparing the DEM with geodetic control points (TKG), MERIT DEM, DEMNAS and ALOS fit well among the DEMs. In addition to that, digital terrain model (DTM), whose grids' elevations are modified from digital surface model (DSM) by removing the height of buildings and vegetation, should be applied to flood simulation model because flooded water flow through buildings and vegetation. Therefore, MERIT DEM was selected to build a terrain model for the flood simulation model.

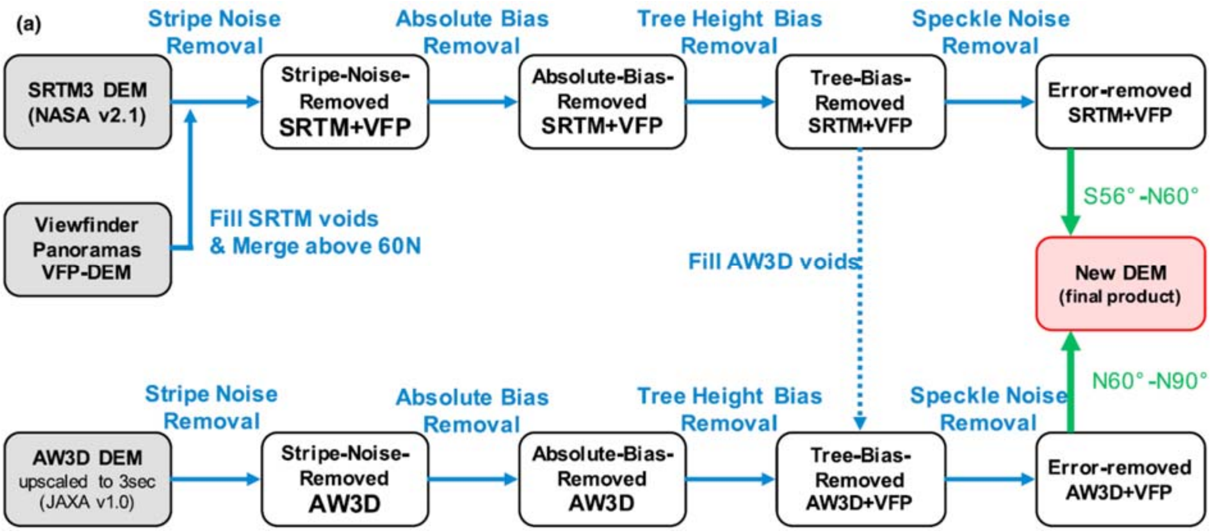
b) Building Terrain Data

i) Downloading the MERIT DEM Data

The data of MERIT DEM was downloaded from the website (http://hydro.iis.u-tokyo.ac.jp/~yamadai/MERIT_DEM/index.html) of Mr. Dai YAMAZAKI, associate professor of Institute of Industrial Sciences of the University of Tokyo. The website explains the product as follows:

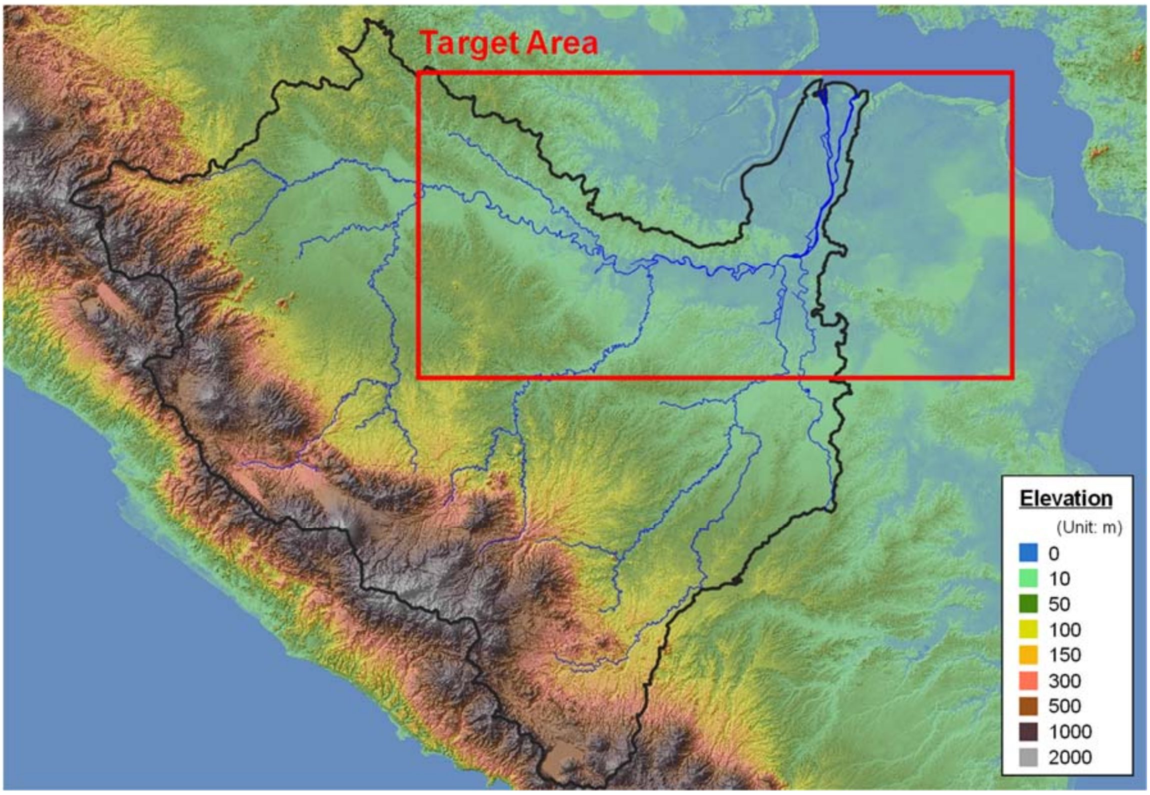
"The MERIT (Multi-Error-Removed Improved-Terrain) DEM was developed by removing multiple error components (absolute bias, stripe noise, speckle noise, and tree height bias) from the existing spaceborne DEMs (SRTM3 v2.1 and AW3D-30m v1). It represents the terrain elevations at a 3sec resolution (~90m at the equator), and covers land areas between 90N-60S, referenced to EGM96 geoid".

Figure B 2.2.9 shows schematic diagram of the procedure of removing errors to create MERIT DEM. Figure B 2.2.10 shows colored elevation map based on the downloaded MERIT DEM.



Source: Dai Yamazaki, et al. (2017) A high-accuracy map of global terrain elevations, Geophys. Res. Lett., 44, 5844–5853, doi:10.1002/2017GL072874

Figure B 2.2.9 Procedures of Error Removal for MERIT DEM. Schematic Diagram.

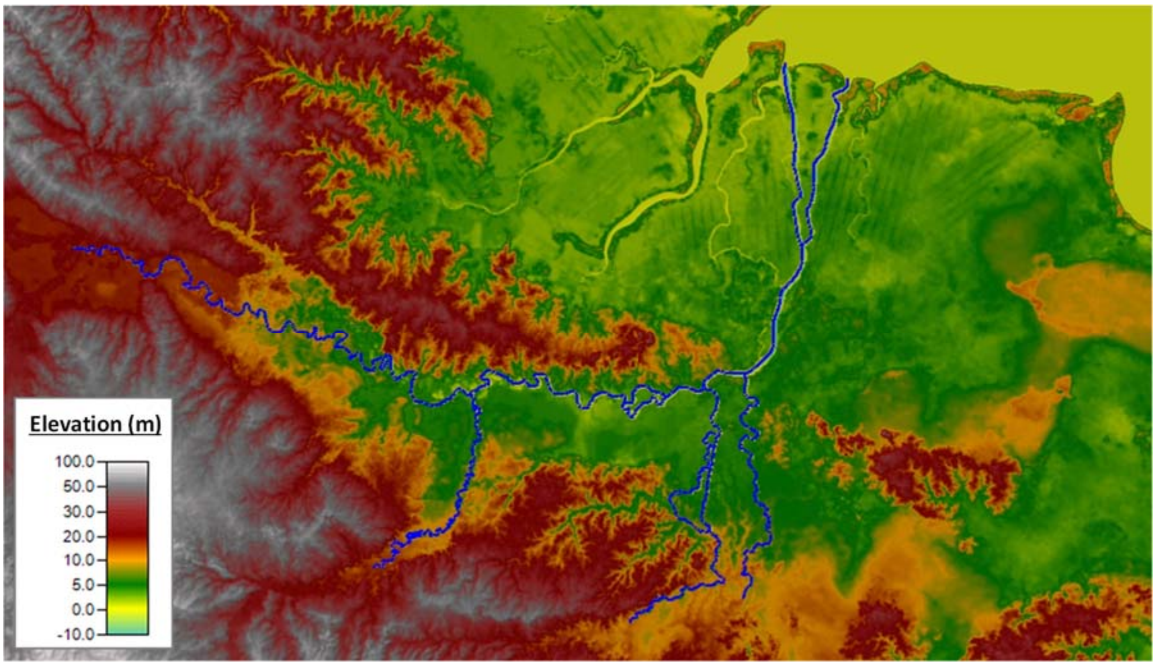


*This elevation map is made from MERIT DEM
Source: JICA Project Team 2

Figure B 2.2.10 Elevation Map Based on the Downloaded MERIT DEM

ii) Making the Terrain Model in HEC-RAS

The terrain model for flood inundation analysis was built by importing the MERIT DEM data into HEC-RAS and creating TIN (Triangulated irregular network) surface. The created terrain model is shown in the figure below.



Source: JICA Project Team 2

Figure B 2.2.11 Created Terrain Model in HEC-RAS

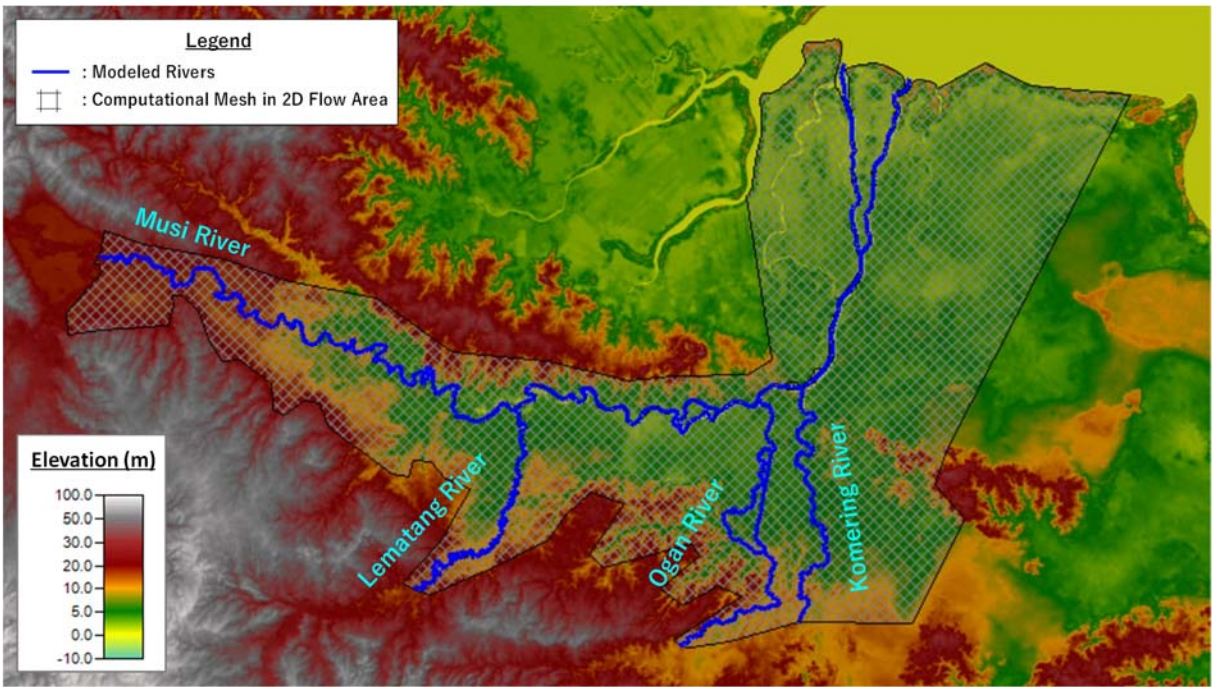
(2) Building 2D Flow Area

a) Making 2D Flow Area Boundary

2D flow area boundary was made to include maximum inundation area for the target floods considering the terrain model. The boundary along the modeled channel was drawn along the river bank.

b) Generating Computational Mesh

2D flow areas were made based on the 2D flow area boundary described in the previous section. 1 km mesh was adopted as computational mesh size of 2D flow area considering (i) 2D flow area lies on lowland and gentle slope area, (ii) characteristic of flooding and (iii) computational time. Computational mesh was automatically generated with HEC-RAS by setting computational sell size for each 2D flow area.



Source: JICA Project Team 2

Figure B 2.2.12 Building 2D Flow Area and Computational Mesh

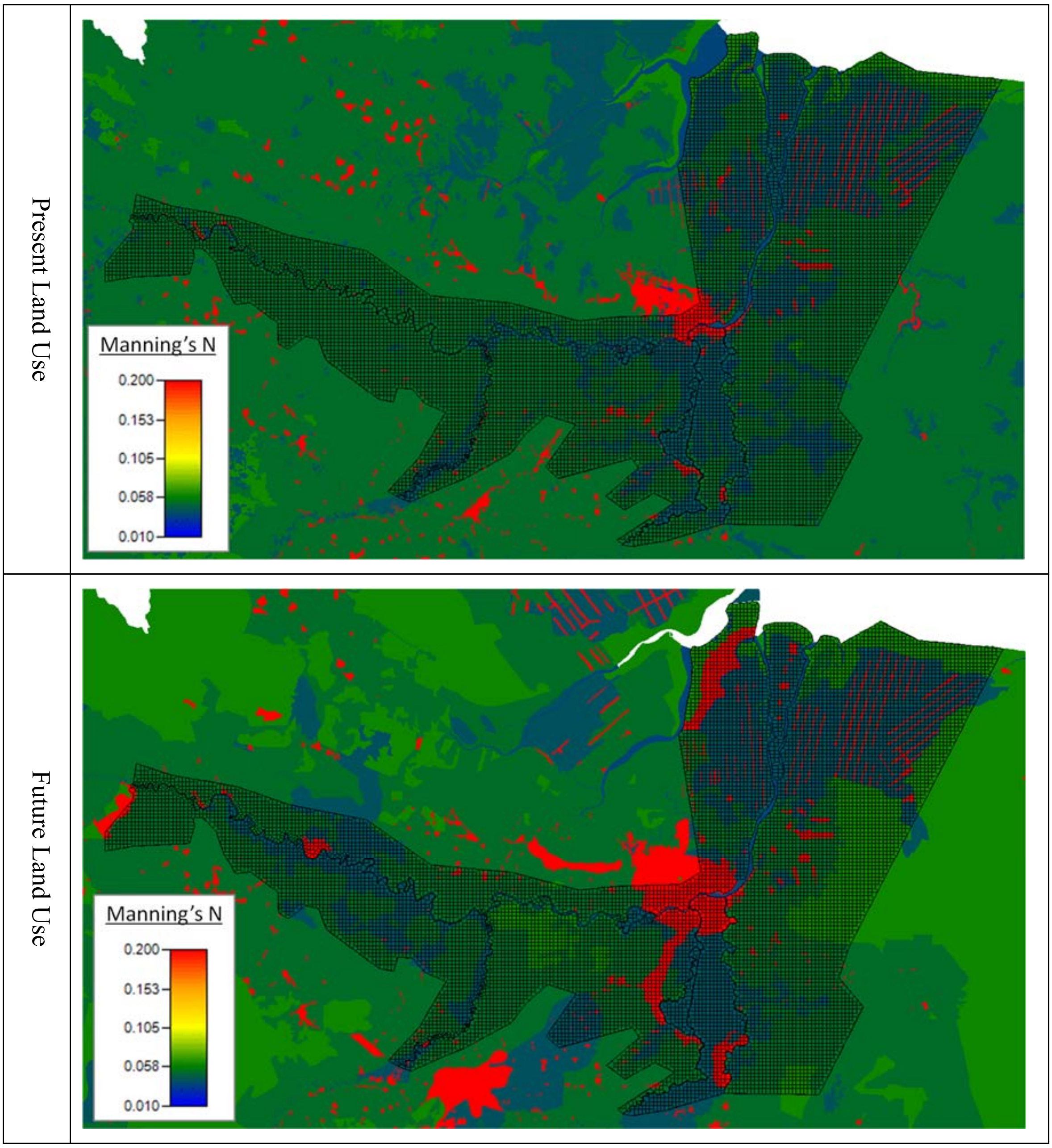
c) Setting Manning's N value from Land Use

Spatially varied Manning's roughness layers were made by importing the present land use data and the future land use data to HEC-RAS. Subsequently, reasonable Manning's N value was applied for each land use type referring to the table below. Figure B 2.2.13 shows the created Manning's roughness layers for both present condition and future condition.

Table B 2.2.3 Valid Manning's 'n' Ranges for Different Land Use Types

Land Use Type	Manning's 'n'
Residential areas – high density	0.2 – 0.5
Residential areas – low density	0.1 – 0.2
Industrial/commercial	0.2 – 0.5
Open pervious areas, minimal vegetation (grassed)	0.03 – 0.05
Open pervious areas, moderate vegetation (shrubs)	0.05 – 0.07
Open pervious areas, thick vegetation (trees)	0.07 – 0.12
Waterways/channels – minimal vegetation	0.02 - 0.04
Waterways/channels – vegetated	0.04 – 0.1
Concrete lined channels	0.015 – 0.02
Paved roads/car park/driveways	0.02 – 0.03
Lakes (no emergent vegetation)	0.015 – 0.35
Wetlands (emergent vegetation)	0.05 – 0.08
Estuaries/Oceans	0.02 – 0.04

Source: STAGE 1&2 REPORT of PROJECT 15 "Two Dimensional Modelling in Urban and Rural floodplains" (Australian Rainfall & Runoff Revision Projects) P15/S1/009 Nov. 2012



Source: JICA Project Team 2

Figure B 2.2.13 Spatially Varied Manning's Roughness Layer

(3) Building Lateral Structure (LS)

To connect 2D flow areas to 1D river reaches, lateral structures (LS) were made along the river channels. Overtopped flow from river is calculated based on water level in channel, LS elevation and connected cell's elevation. Since there was no levee in the target area, LS elevation was set same as located terrain elevation. Other condition set for lateral structures were shown in the table below.

Table B 2.2.4 Lateral Structure Condition

Weir Data	Set value/ condition
Weir Computations	Standard Weir Equation
Standard Weir Equation Parameters	
Weir flow reference	Water Surface
Weir Coefficient	0.2
Weir Crest Shape	Zero Height

Source: JICA Project Team 2

B2.2.7 Model Calibration

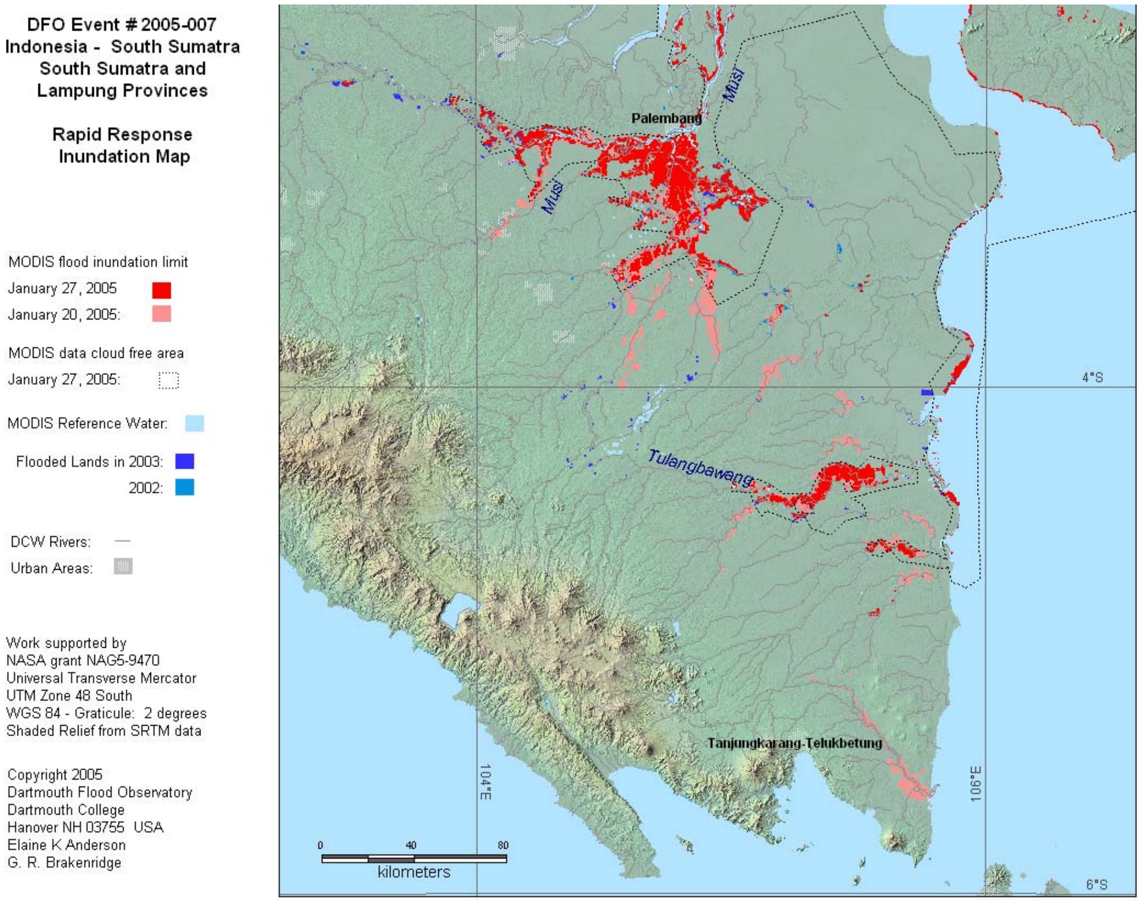
(1) Target Flood for Calibration

To improve the accuracy of flood inundation model, JPT collected hydrological station data (water level, discharge) and inundation maps. Table 2 shows the result of collected available calibration data. Actual inundation map was only available for January 2005 flood so that the flood inundation model was calibrated to the flood 2005.

Table 2.2.5 Available Calibration Data

Data	Source
Inundation map for flood 2005	Dartmouth Flood Observatory (http://www.dartmouth.edu/~floods/)
Water Level at Boom Baru Station	Pelindo II (Indonesia Port Corporation II)

Source: JICA Project Team 2



Source: Dartmouth Flood Observatory (http://www.dartmouth.edu/~floods/)

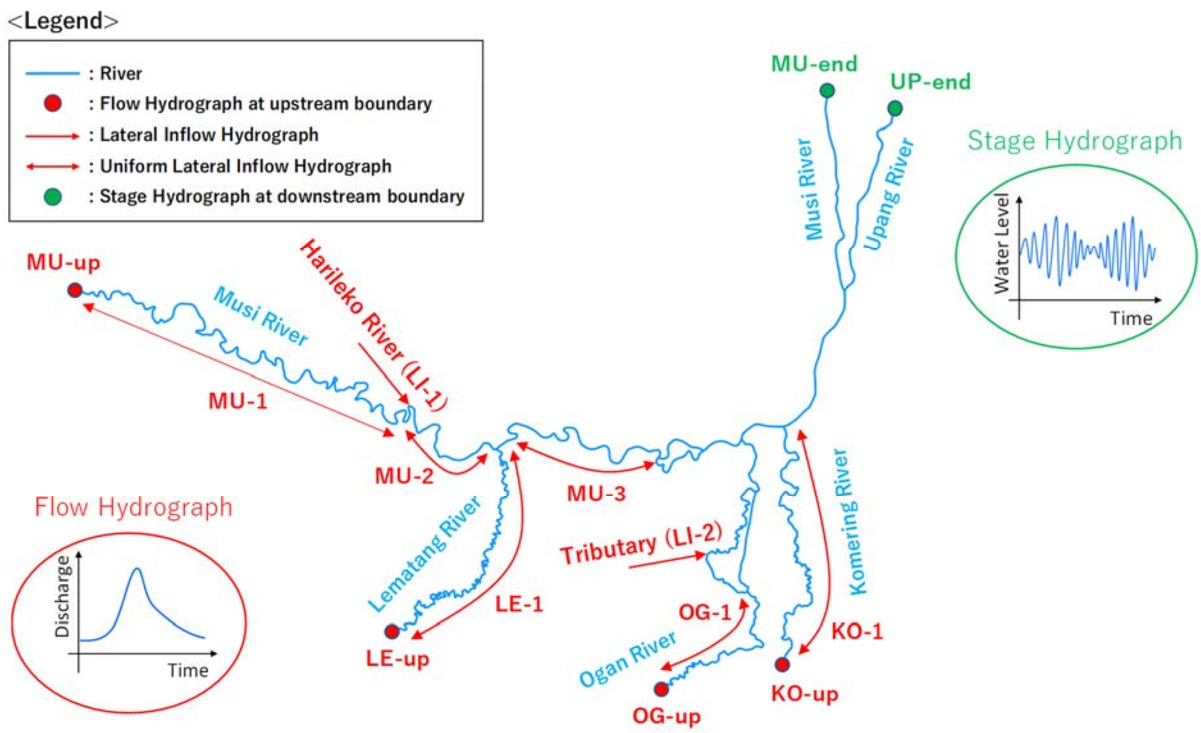
Figure B 2.2.14 Inundation Map of Flood 2005

(2) Setting Boundary Data

a) Discharge Hydrograph

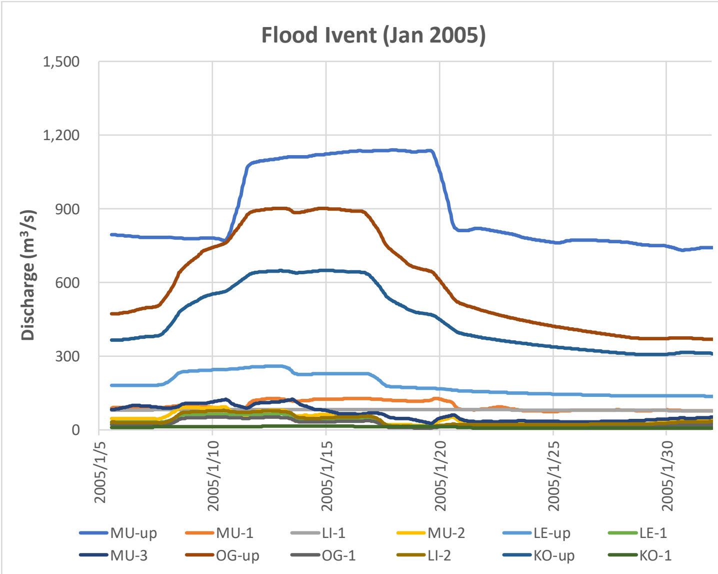
As explained in Chapter B2.2.1 of Annex C, Team 1 conducted runoff analysis and provided the discharge data to Team 2. Figure B 2.2.15 shows boundary condition of flow and stage hydrograph. Flow hydrographs were set at each upstream end. Lateral inflow hydrographs were set at confluent points of tributaries such as Harileko river. Uniform lateral inflow hydrographs were also set to input difference between upstream runoff discharge and downstream runoff discharge in the same river. Uniform lateral inflow hydrograph brings in a flow hydrograph and distribute it uniformly along the river reach between two specified cross section locations.

Figure B 2.2.16 shows boundary data of flow hydrograph for flood 2005.



Source: JICA Project Team 2

Figure B 2.2.15 Boundary Condition of Flow and Stage Hydrograph



Source: JICA Project Team 1 and 2

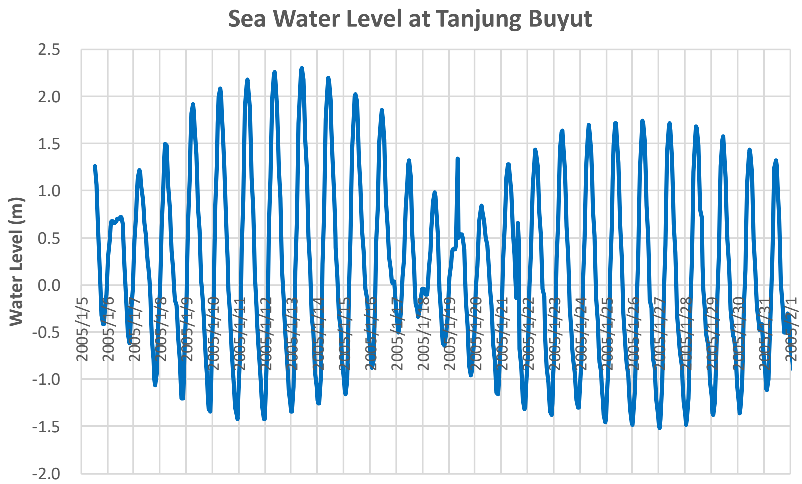
Figure B 2.2.16 Boundary Data of Flow Hydrograph for 2005 Flood

b) Stage Hydrograph at Downstream End

Stage hydrographs at downstream end of Musi river and Upang river were set based on observation data of Tanjung Buyut tidal station. Tidal data shows diurnal tidal cycle and fluctuates about 4 meters between -1.5 m and 2.5 m.

*Google Satellite is used as background image
Source: JICA Project Team 2

Figure B 2.2.17 Location of Tanjung Buyut Tidal Station



Source: the figure is prepared by JICA Project Team 2 using the data from Pelindo II (Indonesia Port Corporation II)

Figure B 2.2.18 Observed Sea Water Level at Tanjung Buyut Tidal Station

(3) Computation Condition

Table B 2.2.6 shows computation condition to simulate 2005 flood.

Table B 2.2.6 Computation Condition for 2005 Flood

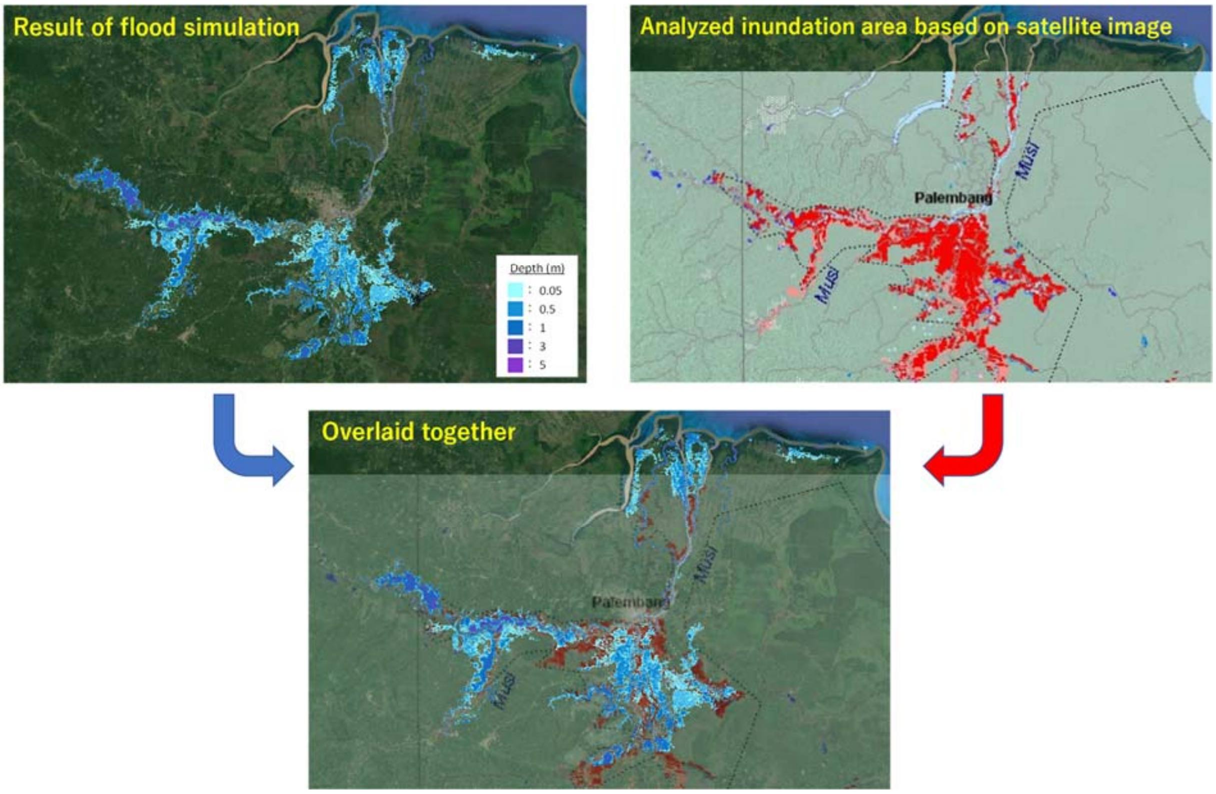
Items		Set Condition
Boundary condition		
	Flow hydrograph	2005 flood hydrograph
	Tide water level	2005 observed tide water level
Simulation period		5 Jan 2005 to 20 Jan 2005
Computational mesh size		1 km
Land use		based on present land use
Computational time step		2 minutes
Equation set in 2D flow area		the full Saint Venant Equations

Source: JICA Project Team 2

(4) Calibration Result

a) Comparison of Inundation Area

Figure B 2.2.19 compares simulated flood inundation areas with the satellite map by Dartmouth College. The simulated inundation area is larger than that of the satellite image inundation area in the downstream lowland delta but they match well in the most part of the inundation area.



Source: JICA Project Team 2

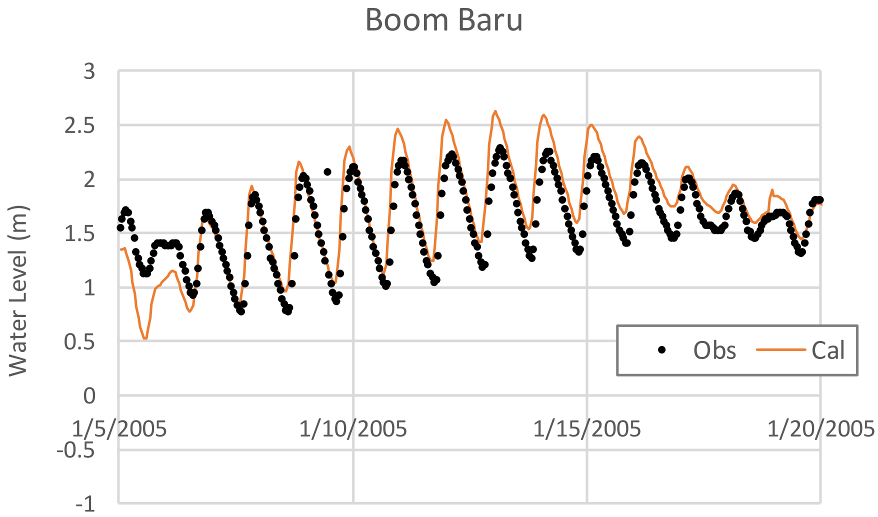
Figure B 2.2.19 Comparison of Inundation Area

b) Comparison of Water Level at Boom Baru Tidal Station

Figure B 2.2.21 compares the simulated and observed water levels at Boon Baru tide station in Palembang. Calculated water level is higher about 30 cm at peak than the observed value, but this gap can be considered as small enough taking into account the available data limitation such as rough interval of river cross section and rough resolution of DEM. The JICA Project Team 2 considers that the developed simulation model is acceptable, and that further improvement is very difficult due to the scarcity of data/information.

Source: the figure is prepared by JICA Project Team 2 using Google Terrain Hybrid as background image

Figure B 2.2.20 Location of Boom Baru Tidal Station



*Obs: Observed values at Boom Baru tidal gauge station, Cal: Calculated water level by flood simulation model
Source: JICA Project Team 2

Figure B 2.2.21 Comparison of Water Level at Boom Baru Tidal Station

B2.3 Results of Flood Simulation

B2.3.1 Evaluating the Impact of Sea Level Rise in 2050

(1) Estimation of future sea level rise in 2050

Sea level rise due to climate change has been observed at a lot of places in the world. It is necessary to assume the future sea level rise at Musi River mouth to evaluate climate change impacts on the flood conditions of the Musi River basin.

Several study reports on sea level rise were collected as summarized in Table B 2.3.1. According to the table, the rise rate ranges from 0.1 to 1.3 cm/year. In conclusion, it is proposed that the sea level rise rate of 0.5 cm/year that was estimated in the latest study focusing on South Sumatra should be employed for flood inundation analysis. Accordingly, the sea level rise in 2050 was estimated as +25cm from the current sea level.

Table B 2.3.1 References of Sea Level Rise

No.	Existing Report	Target Area	Target Year	Sea Level Rise (cm)	Rise Rate (cm/Year)	Evidence	Adoption
1	"Climate Change Risk and Adaptation Assessment, South Sumatra" sector report "Sea Level Rise and Extreme Event Projections" by MOE (GIZ & AusAID) Climate Change Risk and Adaptation Assessment, South Sumatera, Sea Level Rise and Extreme Event Projections FINAL DRAFT .p73. June 2012 Ministry of Environment (GIZ & AusAID)	South Sumatra	2000 ～ 2050	25.2cm ±11.7cm	0.5cm/year	Focusing on the SRCC (Special Report on Emission Scenario) A1B scenario by IPCC, analyzed using HYCOM (HYbrid Coordinate Ocean Model) and FVCOM (Finite Volume Coastal and Ocean Model)	✔
2	World Bank Water Management Report (2012) Water Management for Climate Change Mitigation and Adaptive Development in Lowlands – WACLIMAD. Government of Indonesia (World Bank). P16.February 2012	All Indonesia	Present (2012? ~2050)	50cm	1.3cm/year	Configuration based on estimates of sea level rise in the 21st century of the IPCC AR4 (18-59 cm / all scenarios) and estimates of sea level rise by analyzing Sofian, 2010 papers (35-40 cm in 2050, 75 cm in 2100)	
3	IPCC AR4 Report(2007) Climate change 2007: Summary for policy makers Ministry of the Environment	All World	1990~ 2090	21cm~48cm (2090~2099 year /A1B scenario)	0.4cm/ year	Analysis result by Atmosphere-Ocean General Circulation Model (AOGCM)	
4	Paper on Sea Level Rise (1994) TETSUO YANAGI and TATSUYA AKAKI. 1994. Sea Level Variation in the Eastern Asia, Journal of Oceanography Vol. 50, pp. 643 to 651.	East Asia	1985~ 2030	13cm	0.29cm/ year	Estimated from tide level data at 16 stations from 1951 to 1991	
5	Report on climate change by WWF (2007) Michael Case, Fitrian Ardiansyah, Emily Spector. 2007. Climate Change in Indonesia Implications for Humans and Nature. WWF report.	All Indonesia	21st Century	13cm (0.3cm/ year×43year)	0.1~0.3cm / year	Cruz, et al., 2007 paper cited	

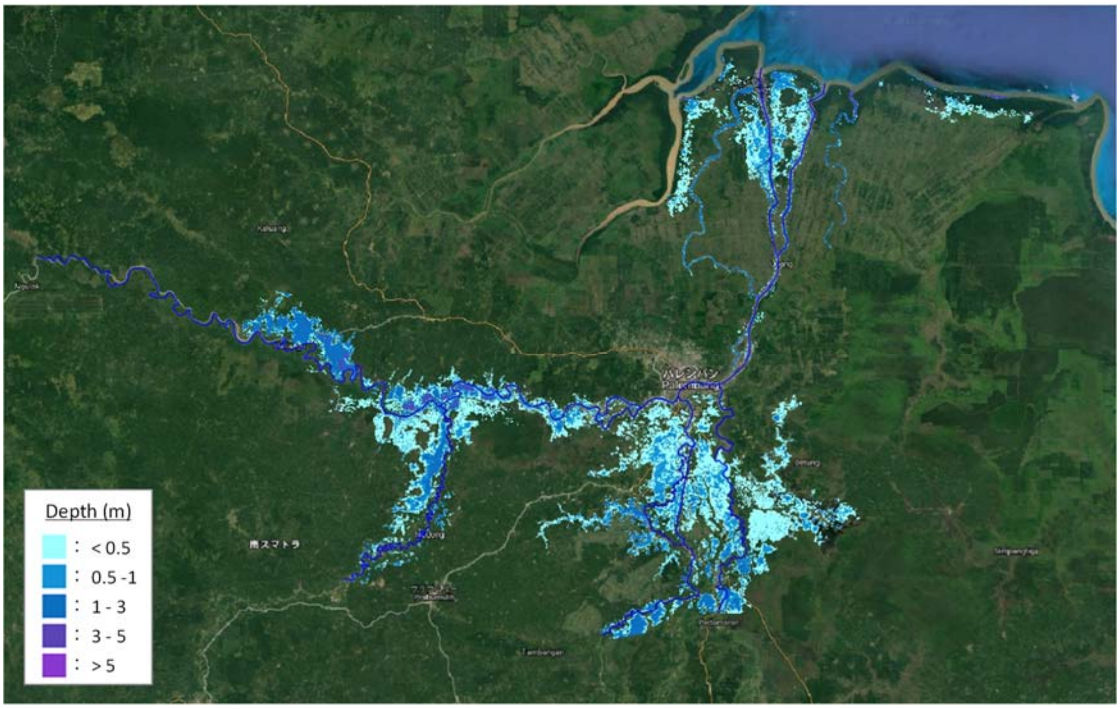
Source: JICA Project Team 2

(2) Evaluating the impact of Sea Level Rise by Flood Simulation

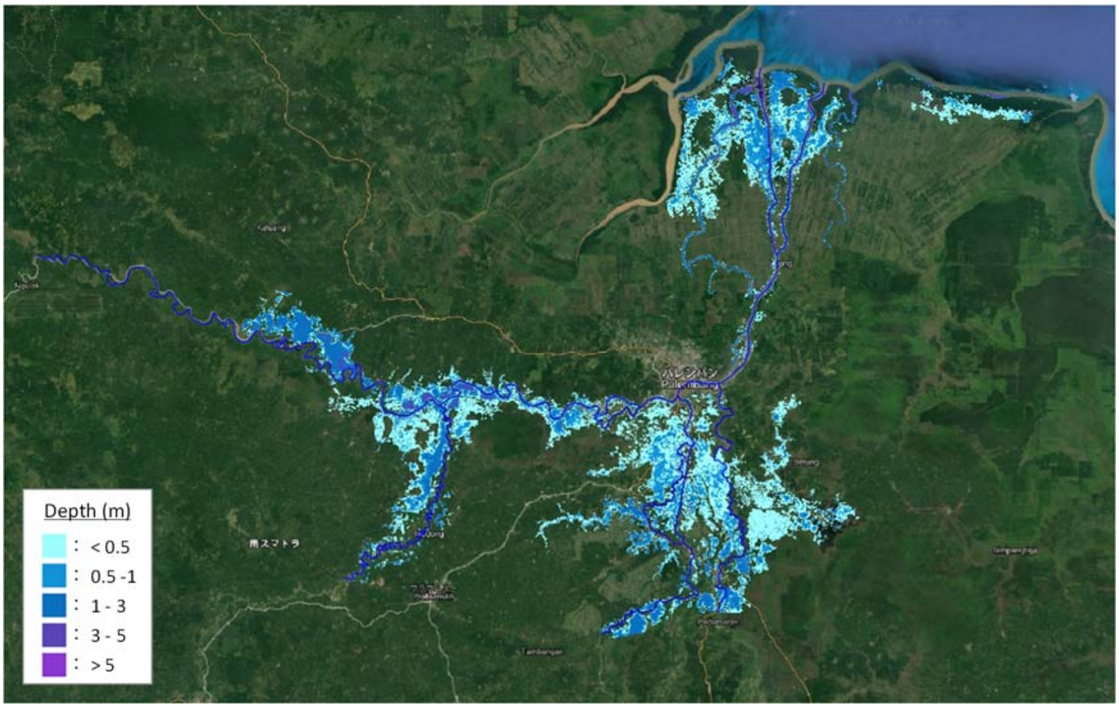
To evaluate the impact of the sea level rise, flood simulation was conducted for the 2005 flood for two cases without and with sea level rise by +25cm.

Figure B 2.3.1 shows the maximum inundation depth of the simulated results. It is clearly seen in the figure that flood inundation area is expanded to the low-lying area around the Musi river mouth.

Present Condition (Without Sea Level Rise)



Future Condition (With Sea Level Rise)



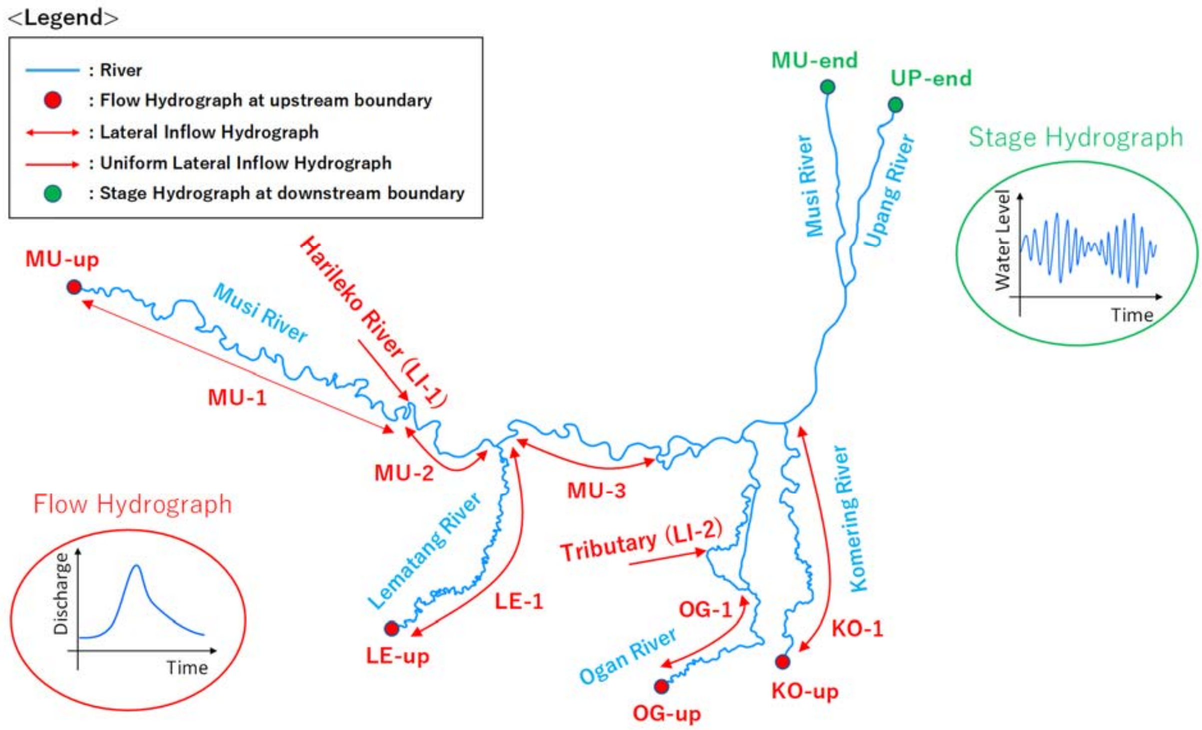
*Google Satellite Hybrid is used as background image.
Source: JICA Project Team 2

Figure B 2.3.1 The Impact of Sea Level Rise on Flood Inundation Area in 2005 Flood Condition

B2.3.2 Evaluating the Impact of Rainfall Change in 2050

(1) Flow hydrographs of the probable floods

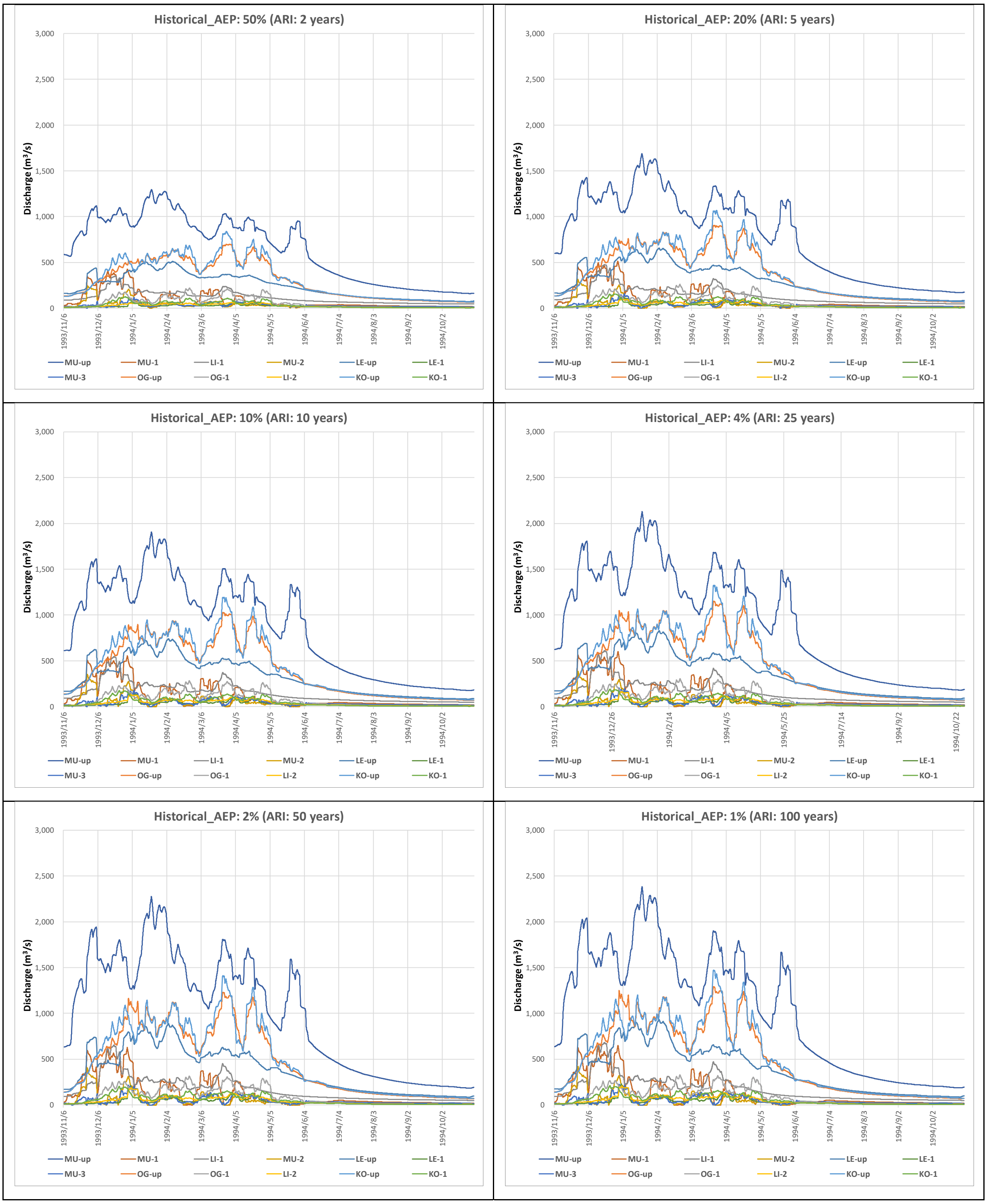
Flow hydrographs of the probable floods were created based on the 1994 flood hydrograph multiplying the extension ratio which is explained in B2.1.2(5) Setting Probable Flood. Since the three representative GCMs were selected to evaluate future flood risk as high risk scenario (GCM-GISS), middle risk scenario (GCM-CCCMA) and low risk scenario (GCM-GFDL 2.1), totally 24 hydrographs (4 cases: historical, risk-high/middle/low times 6 probable floods: 2, 5, 10, 25, 50, 100 years in return period) were created. Figure B 2.3.2 to Figure B2.3.5 show the flow hydrographs of the probable floods for 4 cases.



Source: JICA Project Team 2

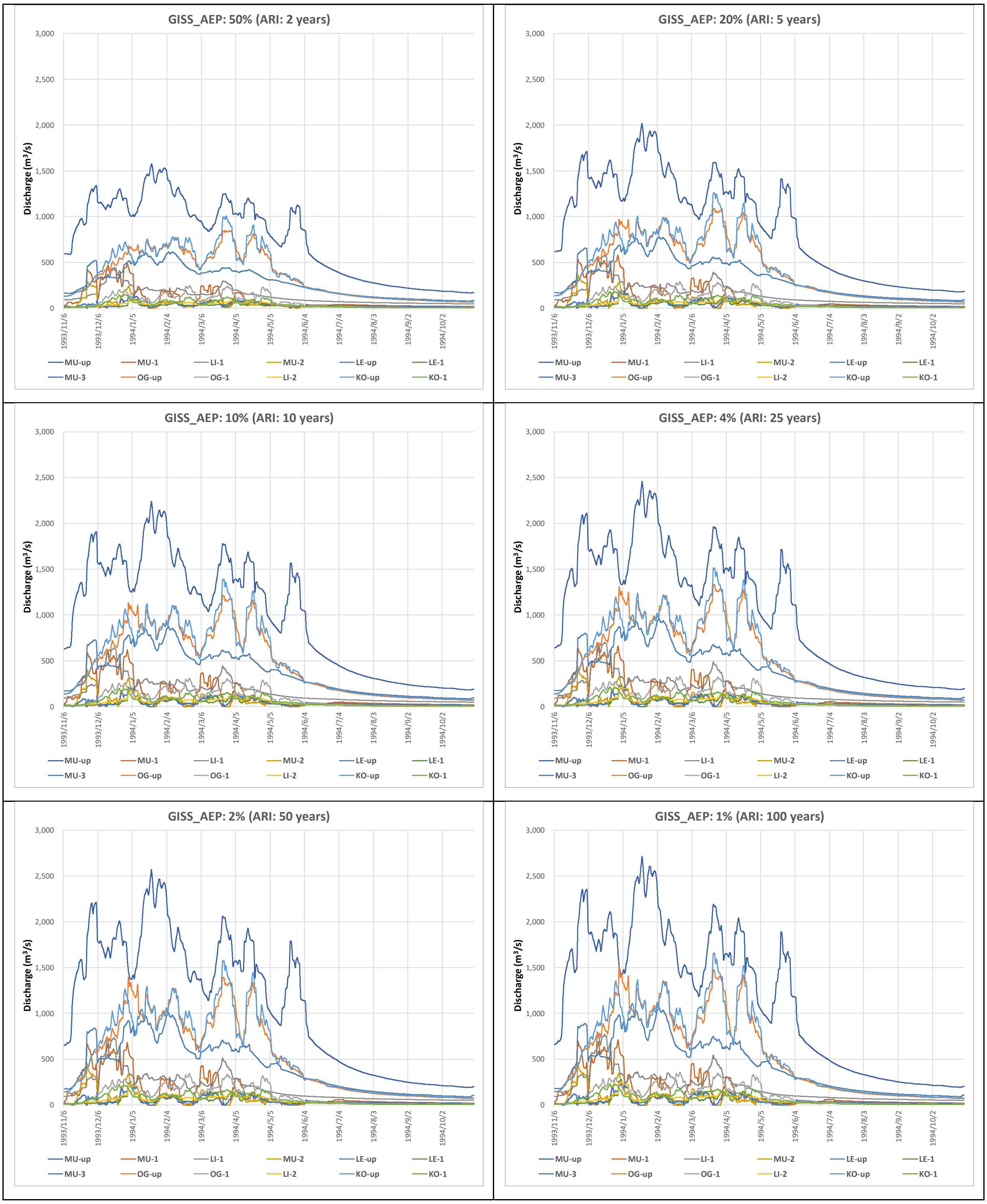
Source: JICA Project Team 2

Figure B 2.2.15 (Reprint) Boundary Condition of Flow and Stage Hydrograph



*AEP: Annual Exceedance Probability, ARI: Average Recurrence Interval
*Legends correspond to the Figure B 2.2.15
Source: JICA Project Team 2

Figure B 2.3.2 Flow Hydrographs for Flood Simulation Model (Historical)

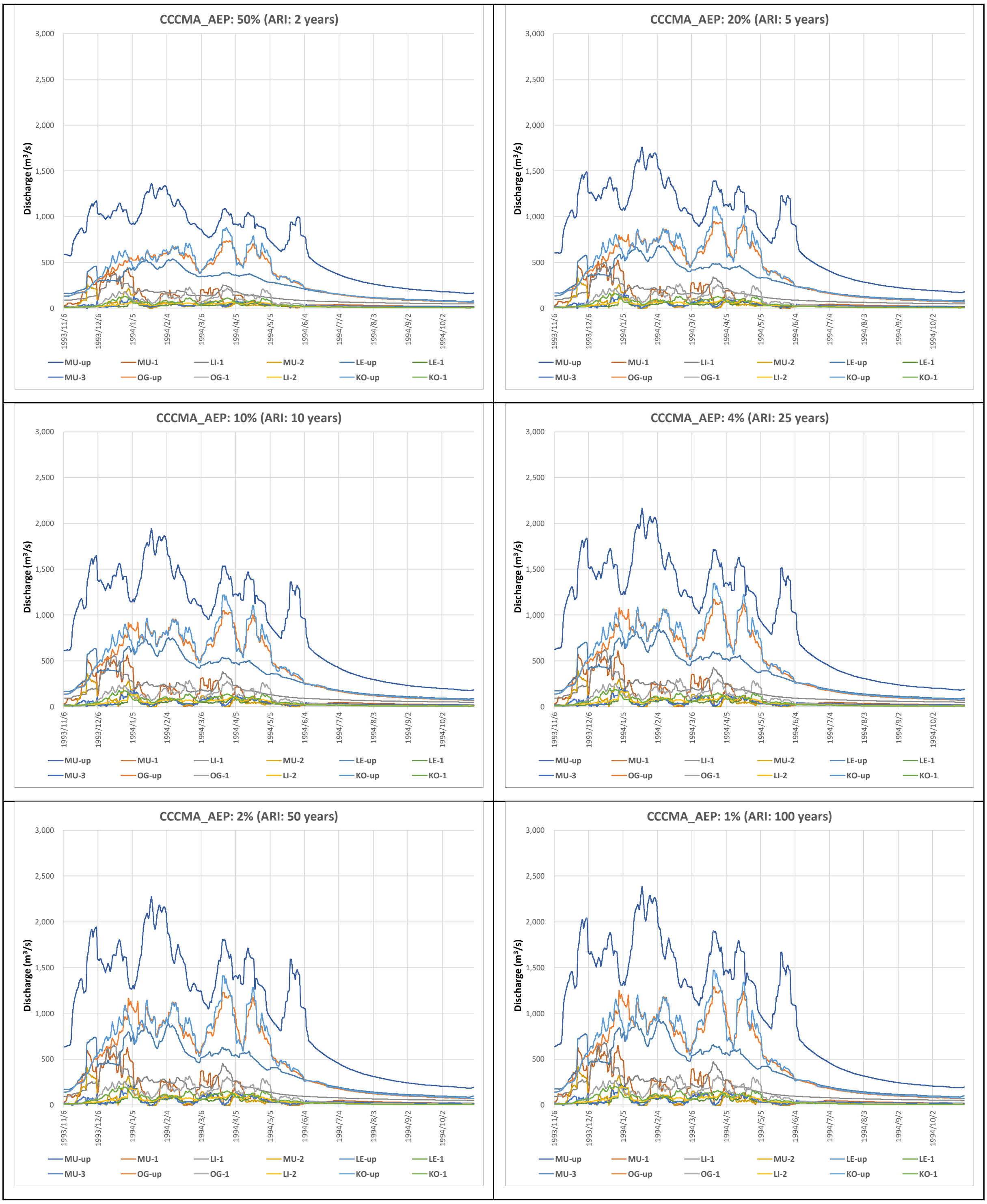


*AEP: Annual Exceedance Probability, ARI: Average Recurrence Interval

*Legends correspond to the Figure B 2.2.15

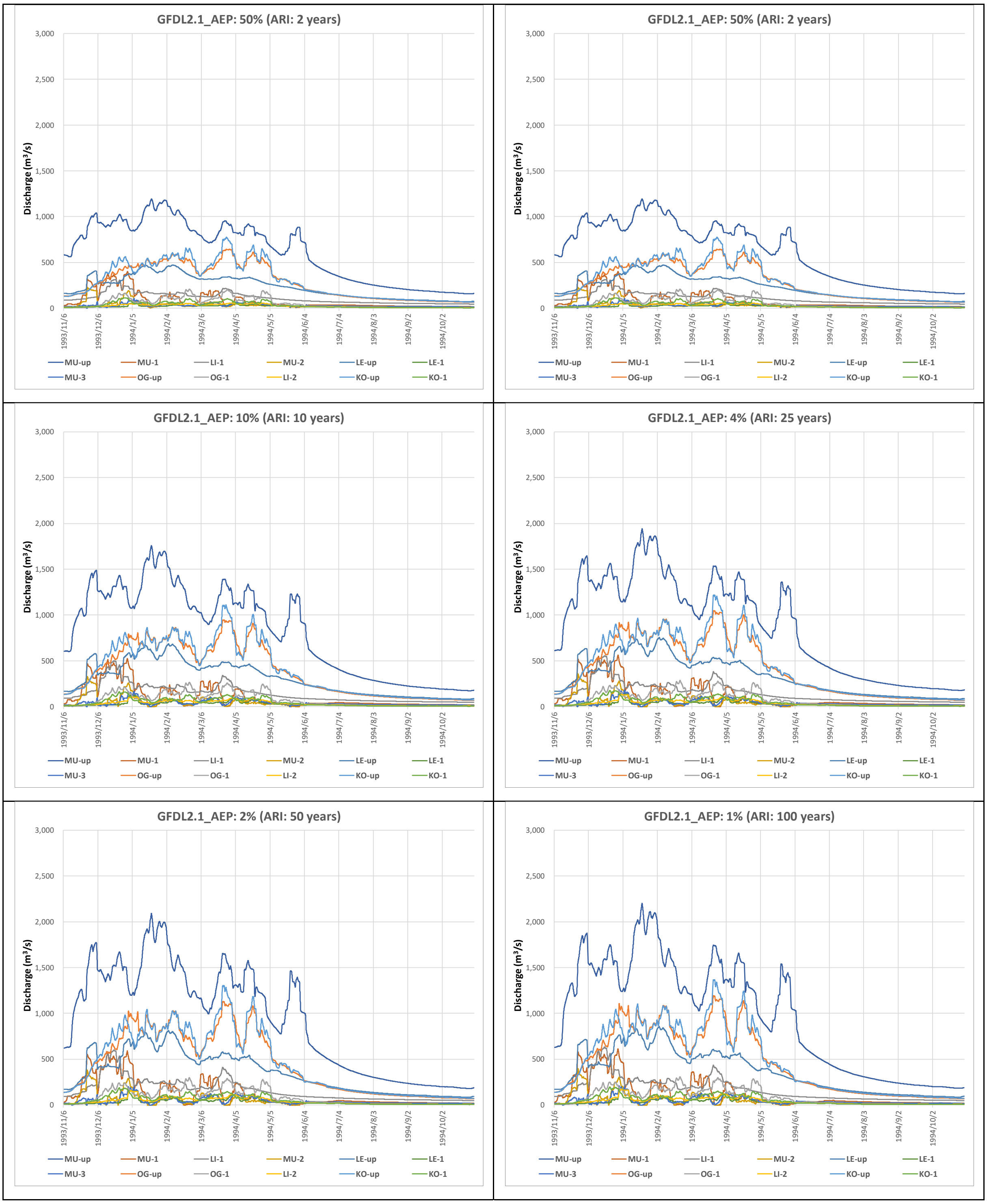
Source: JICA Project Team 2

Figure B 2.3.3 Flow Hydrographs for Flood Simulation Model (GCM:GISS, Risk-High)



*AEP: Annual Exceedance Probability, ARI: Average Recurrence Interval
*Legends correspond to the Figure B 2.2.15
Source: JICA Project Team 2

Figure B 2.3.4 Flow Hydrographs for Flood Simulation Model (GCM:CCCMA, Risk-Middle)



*AEP: Annual Exceedance Probability, ARI: Average Recurrence Interval
*Legends correspond to the Figure B 2.2.15
Source: JICA Project Team 2

Figure B 2.3.5 Flow Hydrographs for Flood Simulation Model (GCM:GFDL 2.1, Risk-Low)

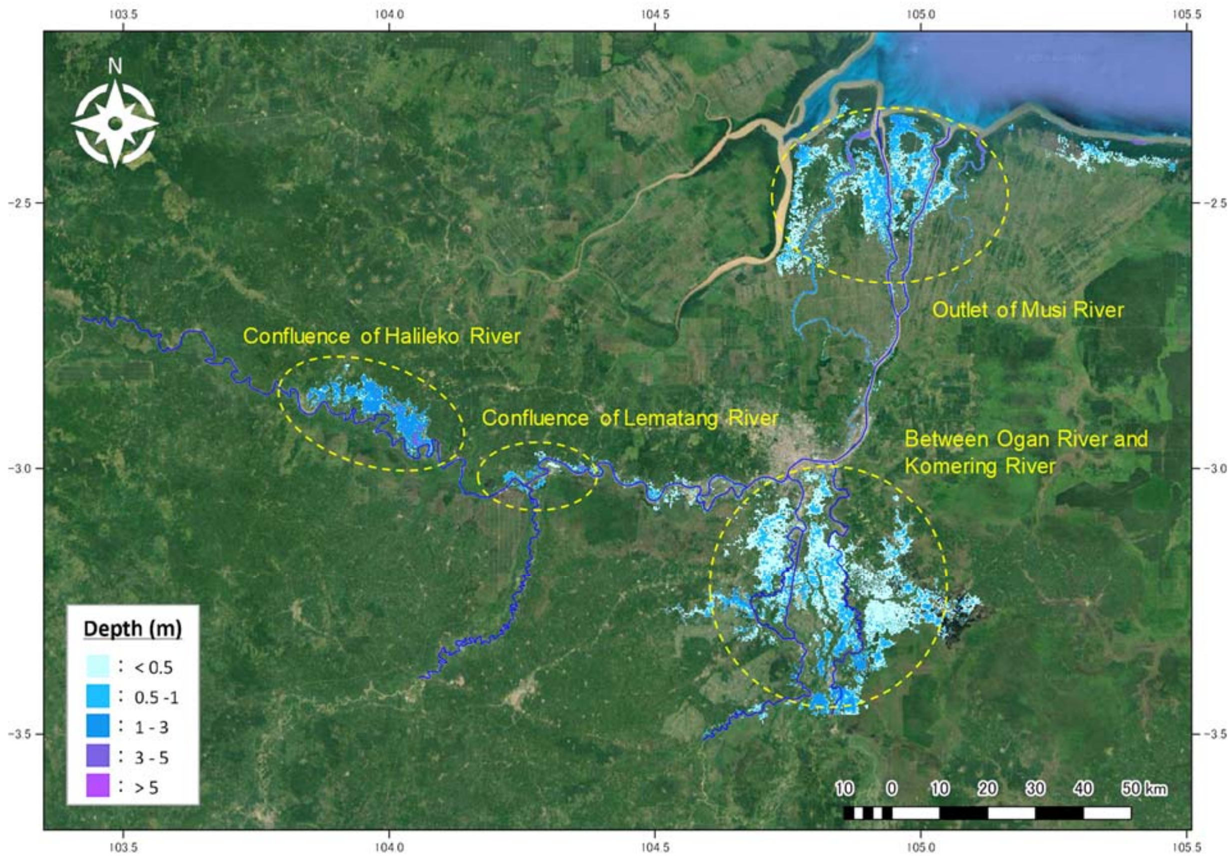
(2) Evaluating the impact of rainfall change in 2050

To evaluate the impact of rainfall change in future, flood simulation was conducted with the computation condition as shown in the Table B 2.3.2. Figure B2.3.7 to Figure B 2.3.12 show the maximum inundation depth of the simulated results. As shown in Figure B 2.3.7, the areas (i) around confluence of Halileko River, Lematang River, (ii) between Ogan River and Komering River and (iii) around outlet of Musi River are prone to be flooded.

Table B 2.3.2 Computation Condition

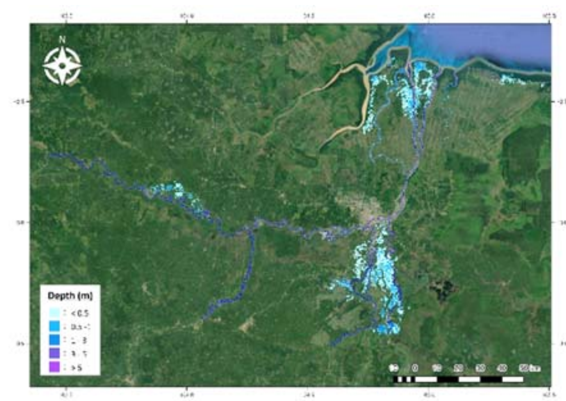
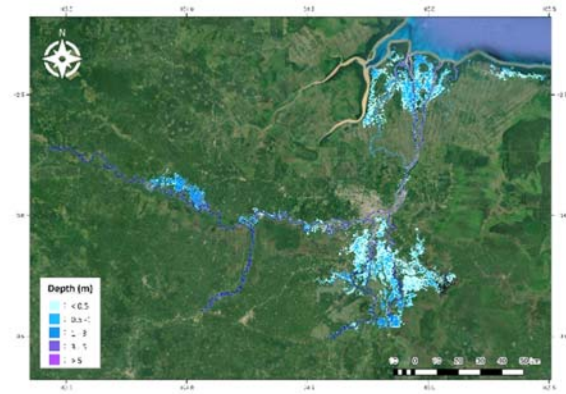
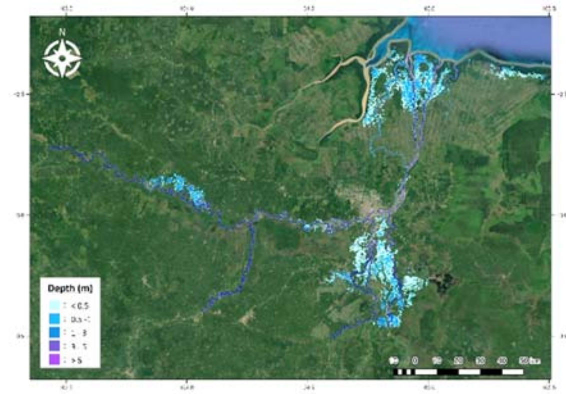
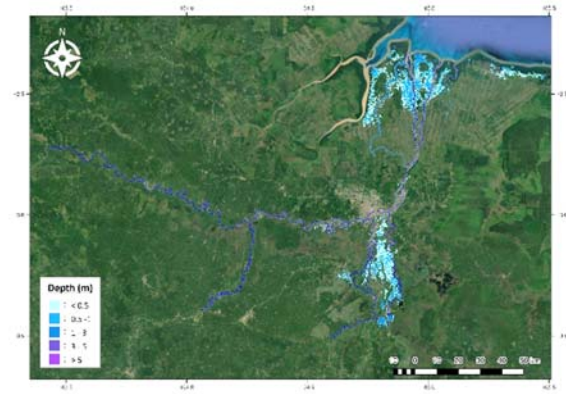
Items	Set Condition	
Simulation case	Historical	GCMs (High, Middle, Low)
Target probable flood	2, 5, 10, 25, 50, 100 years in return period	
Boundary condition		
Flow hydrograph	1994 flood hydrograph (X)	(X) times the extension ratio*
Tide water level	2005 observed tide WL (Y)*	(Y) plus 25cm
Simulation period	10 Jan 1994 to 5 Apr 1994	
Computational mesh size	1 km	
Land use	Present land use	Future land use
Computational time step	2 minutes	
Equation set in 2D flow area	the full Saint Venant Equations	

*The extension ratio is shown in Table B 2.1.4 and Table B 2.1.6
*Observed tide water level in 1994 was not available, so that 2005 observed data was used as alternative.
Source: JICA Project Team 2



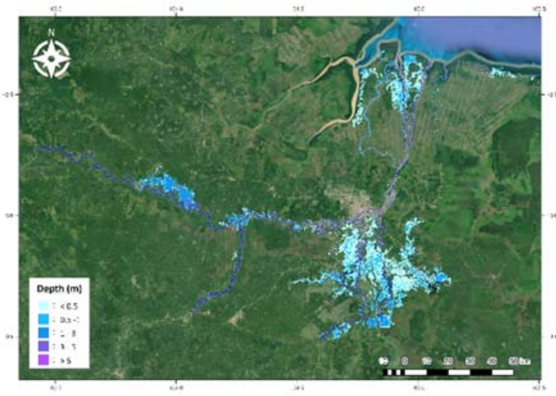
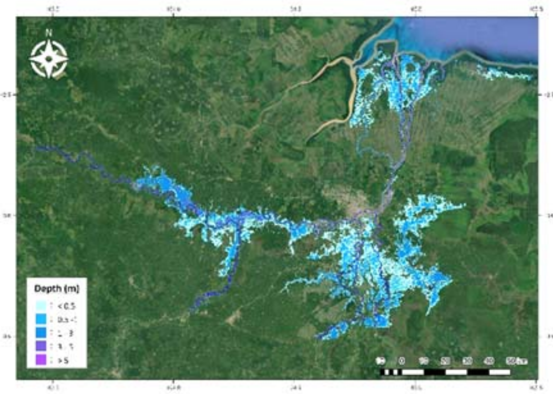
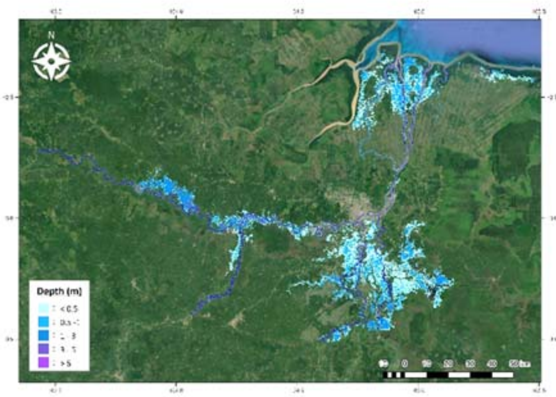
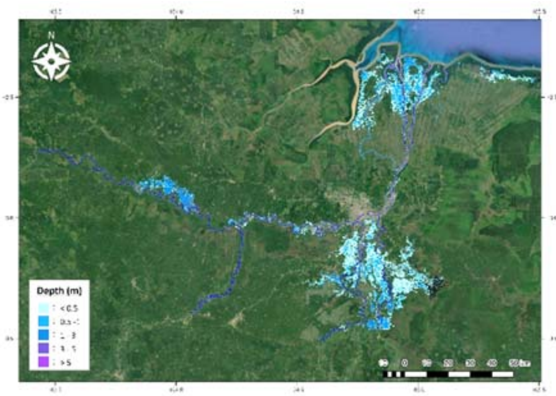
*Google Satellite is used as background image.
Source: JICA Project Team 2

Figure B 2.3.6 Simulated Flood Prone area (example of 2-year flood in High Risk Scenario)

Historical (1994 flood)	
Flood risk-High (GCM: GISS)	
Flood risk-Middle (GCM: CCCMA)	
Flood risk-Low (GCM: GFDL 2.1)	

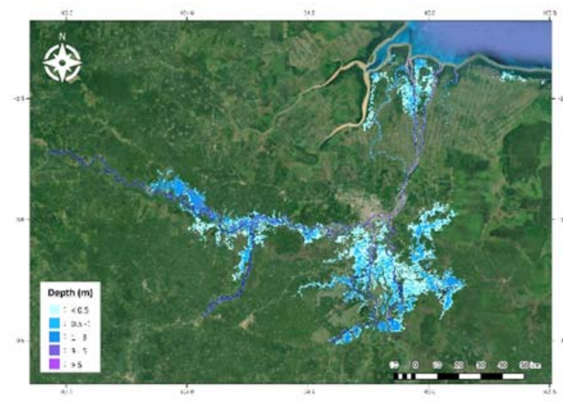
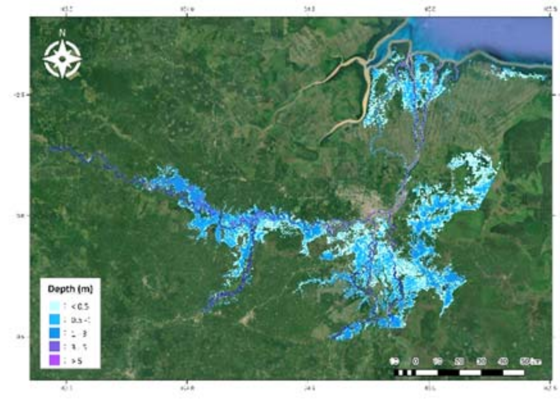
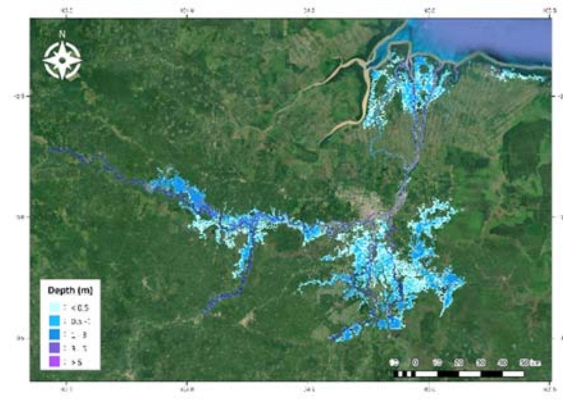
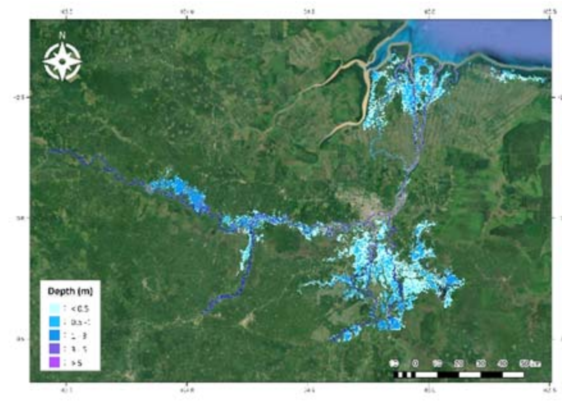
Source: JICA Project Team 2 (*Google Satellite is used as background image.)

Figure B 2.3.7 Maximum Inundation Depth of 2-year Flood

Historical (1994 flood)	
Flood risk-High (GCM: GISS)	
Flood risk-Middle (GCM: CCCMA)	
Flood risk-Low (GCM: GFDL 2.1)	

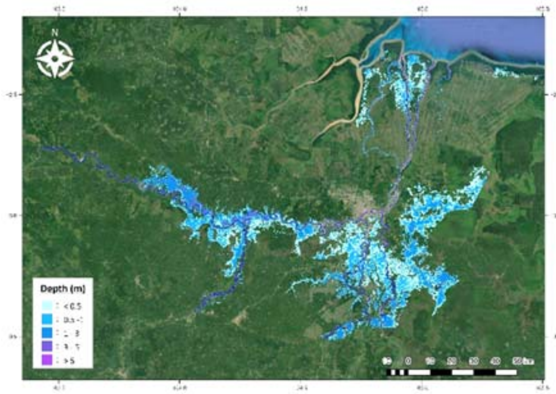
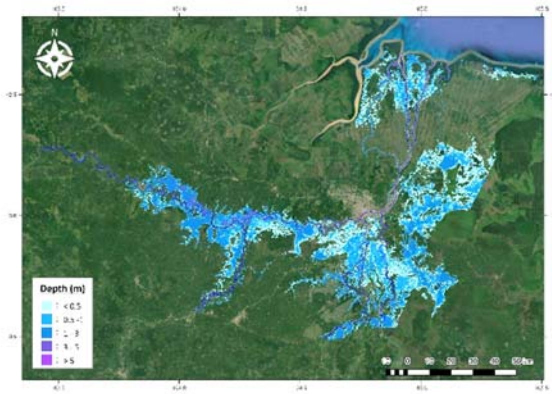
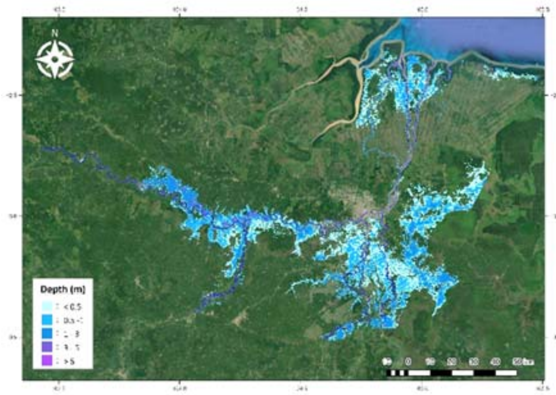
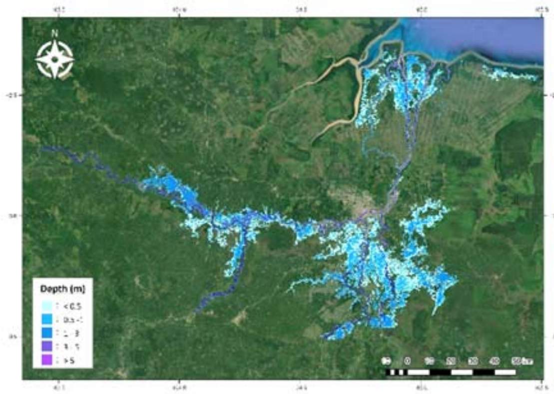
Source: JICA Project Team 2 (*Google Satellite is used as background image.)

Figure B 2.3.8 Maximum Inundation Depth of 5-year Flood

Historical (1994 flood)	
Flood risk-High (GCM: GISS)	
Flood risk-Middle (GCM: CCCMA)	
Flood risk-Low (GCM: GFDL 2.1)	

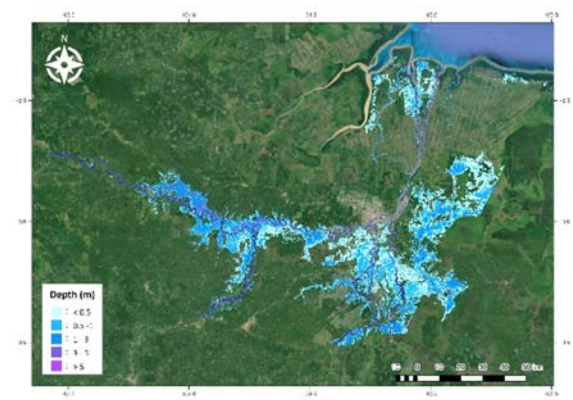
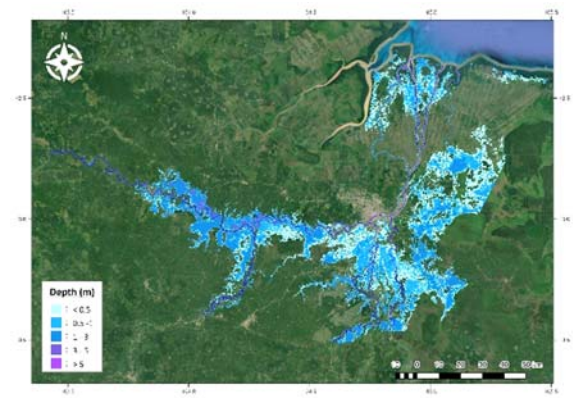
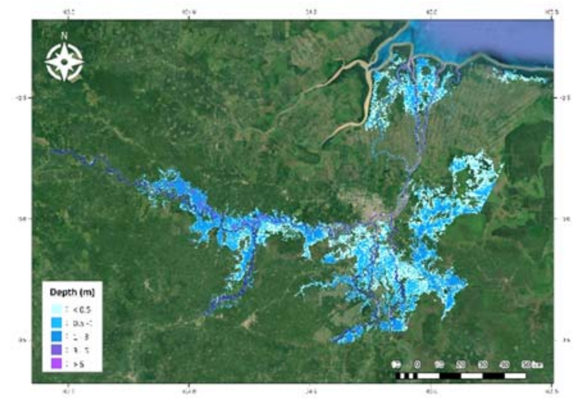
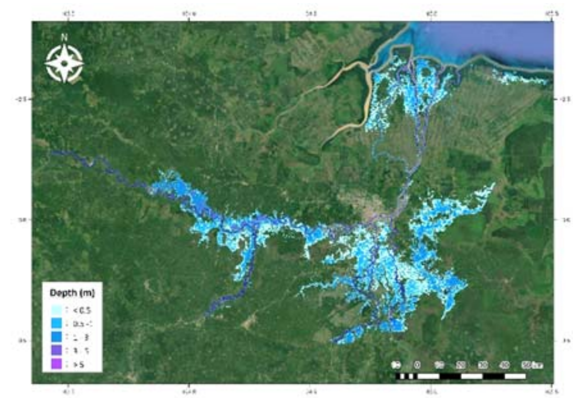
Source: JICA Project Team 2 (*Google Satellite is used as background image.)

Figure B 2.3.9 Maximum Inundation Depth of 10-year Flood

Historical (1994 flood)	
Flood risk-High (GCM: GISS)	
Flood risk-Middle (GCM: CCCMA)	
Flood risk-Low (GCM: GFDL 2.1)	

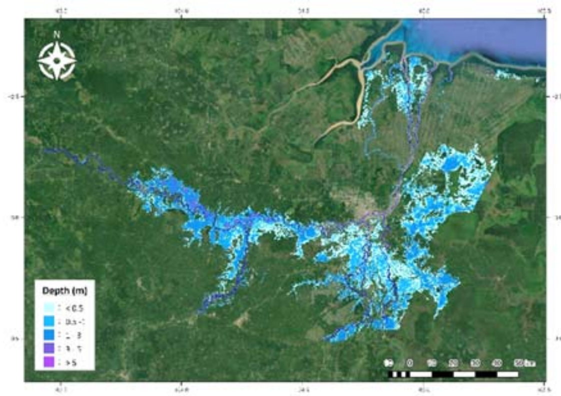
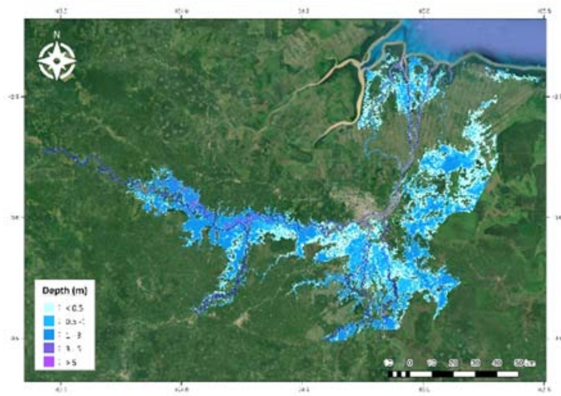
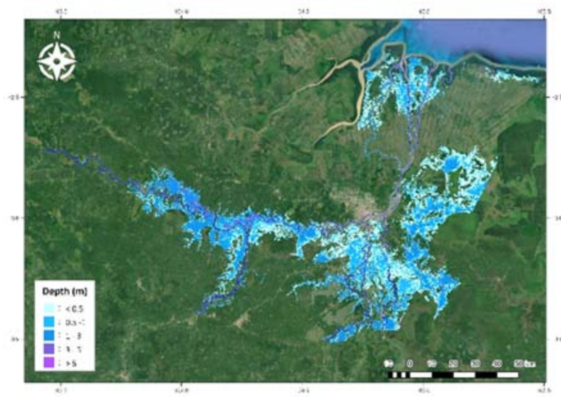
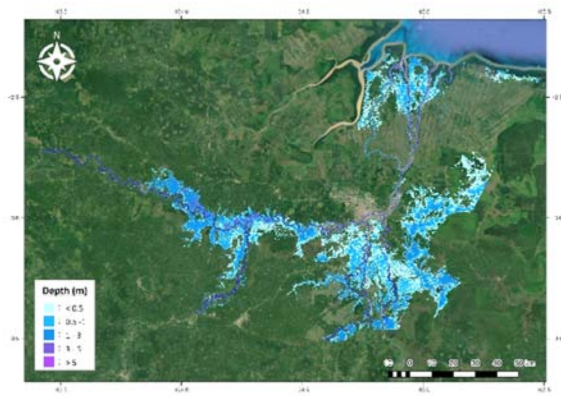
Source: JICA Project Team 2 (*Google Satellite is used as background image.)

Figure B 2.3.10 Maximum Inundation Depth of 25-year Flood

Historical (1994 flood)	
Flood risk-High (GCM: GISS)	
Flood risk-Middle (GCM: CCCMA)	
Flood risk-Low (GCM: GFDL 2.1)	

Source: JICA Project Team 2 (*Google Satellite is used as background image.)

Figure B 2.3.11 Maximum Inundation Depth of 50-year Flood

Historical (1994 flood)	
Flood risk-High (GCM: GISS)	
Flood risk-Middle (GCM: CCCMA)	
Flood risk-Low (GCM: GFDL 2.1)	

Source: JICA Project Team 2 (*Google Satellite is used as background image.)

Figure B 2.3.12 Maximum Inundation Depth of 100-year Flood

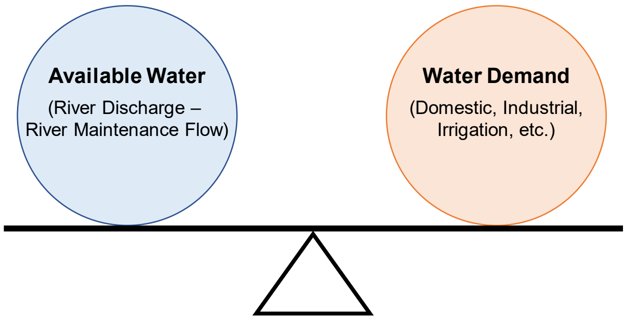
CHAPTER B3 WATER BALANCE ANALYSIS FOR MUSI RIVER BASIN

B3.1 Outline of Water Balance Analysis

B3.1.1 Concept of Water Balance Calculation

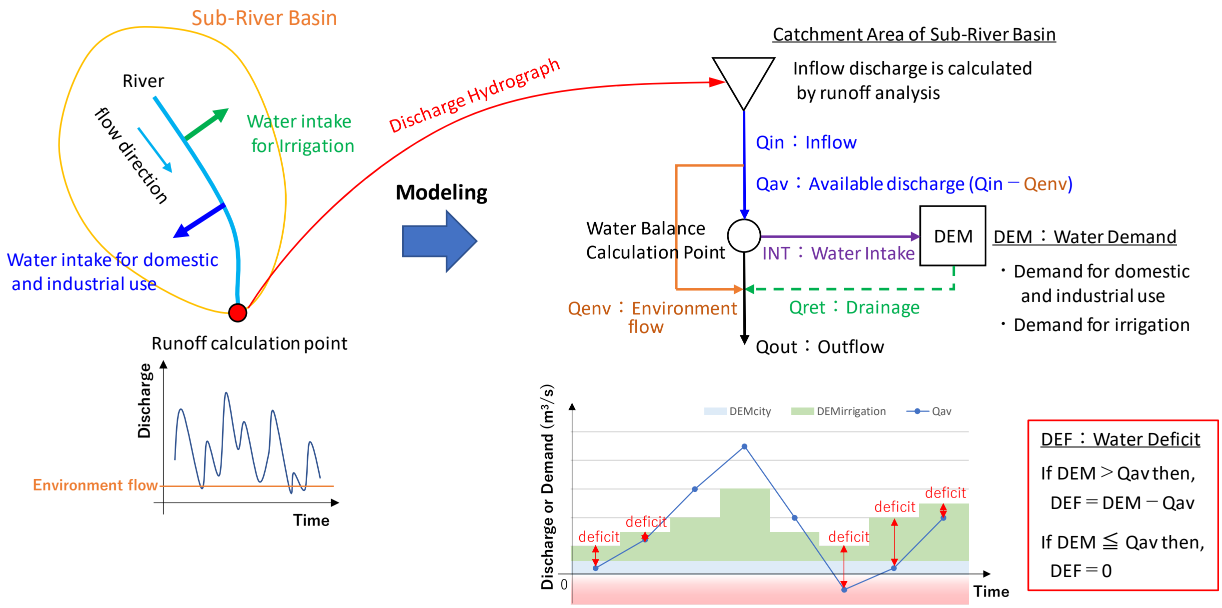
Basic concept of water balance calculation is to compare available water in river and water intake demand from the river as shown in Figure B 3.1.1. Water deficit will happen when water demand is heavier than available water. The amount of water deficit is going to be the target of future water resource development. Figure B 3.1.2 shows the image of water balance modeling and how to calculate water deficit.

Since climate change (CC) or social and economic change will affect both available water and water demand, their impacts were estimated, and water balance was calculated in multiple scenario in this project.



Source: JICA Project Team 2

Figure B 3.1.1 Basic Concept of Water Balance Calculation



Source: JICA Project Team 2

Figure B 3.1.2 Basic Concept of Water Balance Modeling

B3.1.2 Methodology of Water Balance Modeling

Methodology of water balance modeling is summarized in Table B 3.1.1. Since water balance analysis focuses low water in dry season, water balance was calculated at 10 days average discharge with Microsoft Excel. Figure B 3.1.3shows detailed procedure of water balance calculation at each sub river basin. Calculated outflow from sub river basin is succeeded as inflow of downstream sub river basin.

Table B 3.1.1 Methodology of Water Balance Modeling

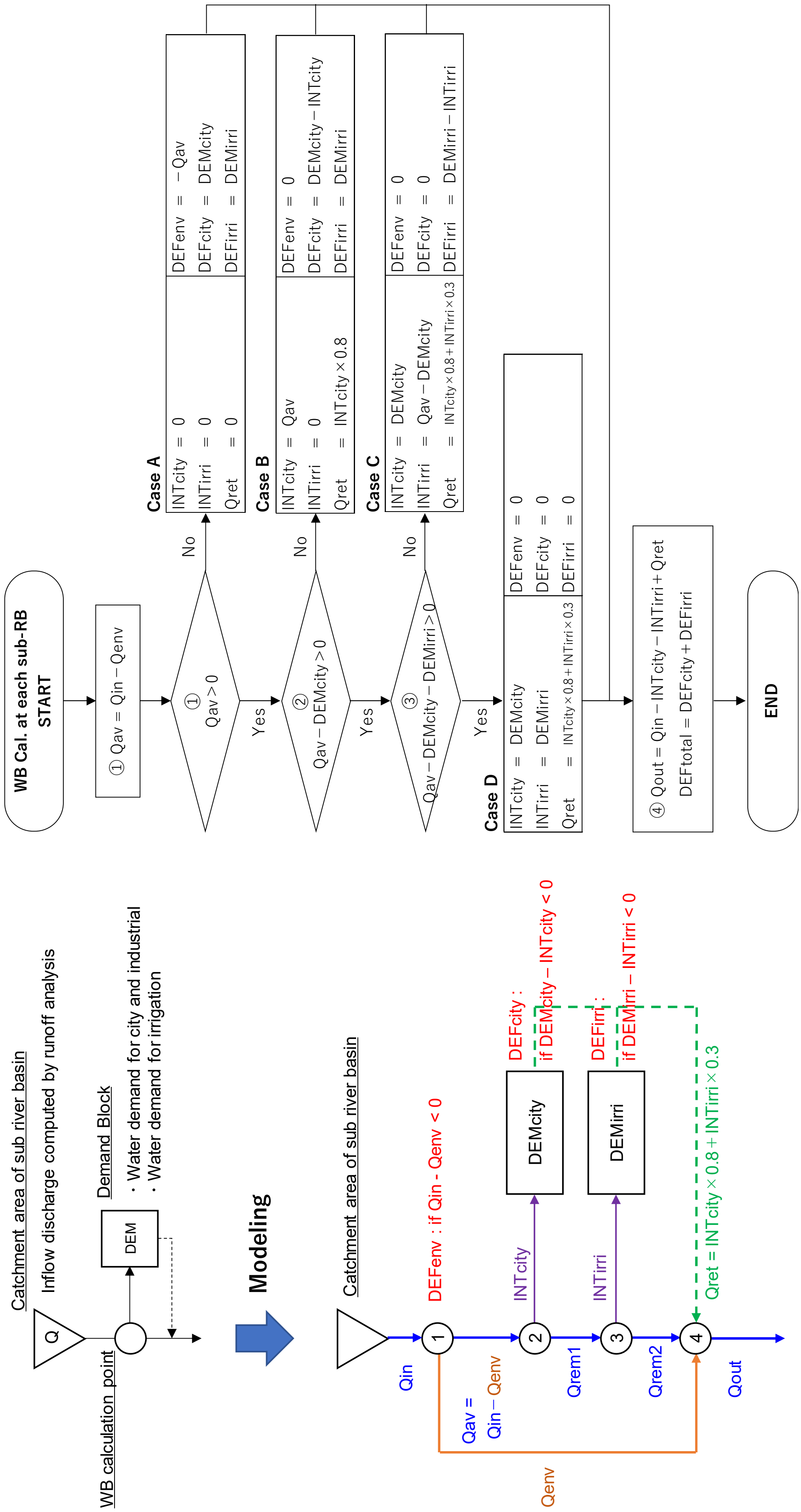
Item	Condition
Software for Modeling	Microsoft Excel
Calculation Unit	Sub river basin
Calculation Time Step	10 days
Calculation Method	- Calculating water balance at each sub river basin setting a water demand block as shown in Figure B 3.1.3. If there is a large water intake facility in a sub river basin, the sub river basin is divided two at the facility by multiplying the ratio of river basin area to calculate more accurate inflow. - Water intake priority was set as follows: (1) environmental flow (river maintenance flow), (2) water demand for city and industrial and (3) water demand for irrigation, in accordance with RENCANA 2017. - Return flow by drainage was assumed as 80% of water intake for city and industrial and as 30 % of water intake for irrigation.

Source: JICA Project Team 2

Table B 3.1.2 Explanation of Terms Used in Water Balance Modeling

Item	Notes
Qin	Inflow
Qenv	Environmental flow (Maintenance flow)
DEMcity	Demand for domestic and industrial water
DEMirri	Demand for irrigation
INTcity	Quantity of water intake for domestic and industrial water
INTirri	Quantity of water intake for irrigation
Qrem1	Remained discharge after water intake for domestic and industrial water
Qrem2	Remained discharge after water intake for irrigation
DEFenv	Deficit of environmental flow
DEFcity	Deficit of domestic and industrial water
DEFirri	Deficit of irrigation water
DEFtotal	Total deficit
Qret	Return flow after water use of domestic, industrial, irrigation etc.
Qout	Outflow

Source: JICA Project Team 2



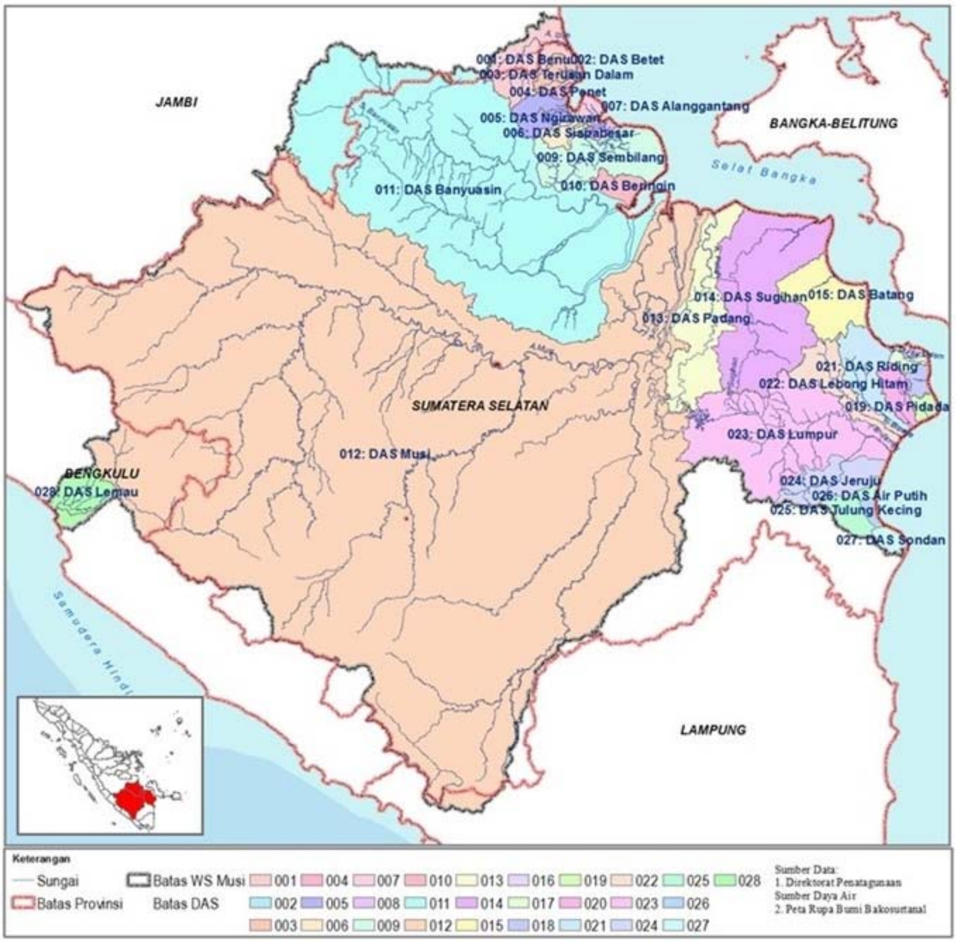
Source: JICA Project Team 2

Figure B 3.1.3 Calculation Procedure of Water Balance at Each Sub River Basin

B3.2 Water Balance Modeling

B3.2.1 Setting Target Area for Water Balance Analysis

The target area for water balance analysis was set as whole Musi river basin as shown in the figure below with orange color.

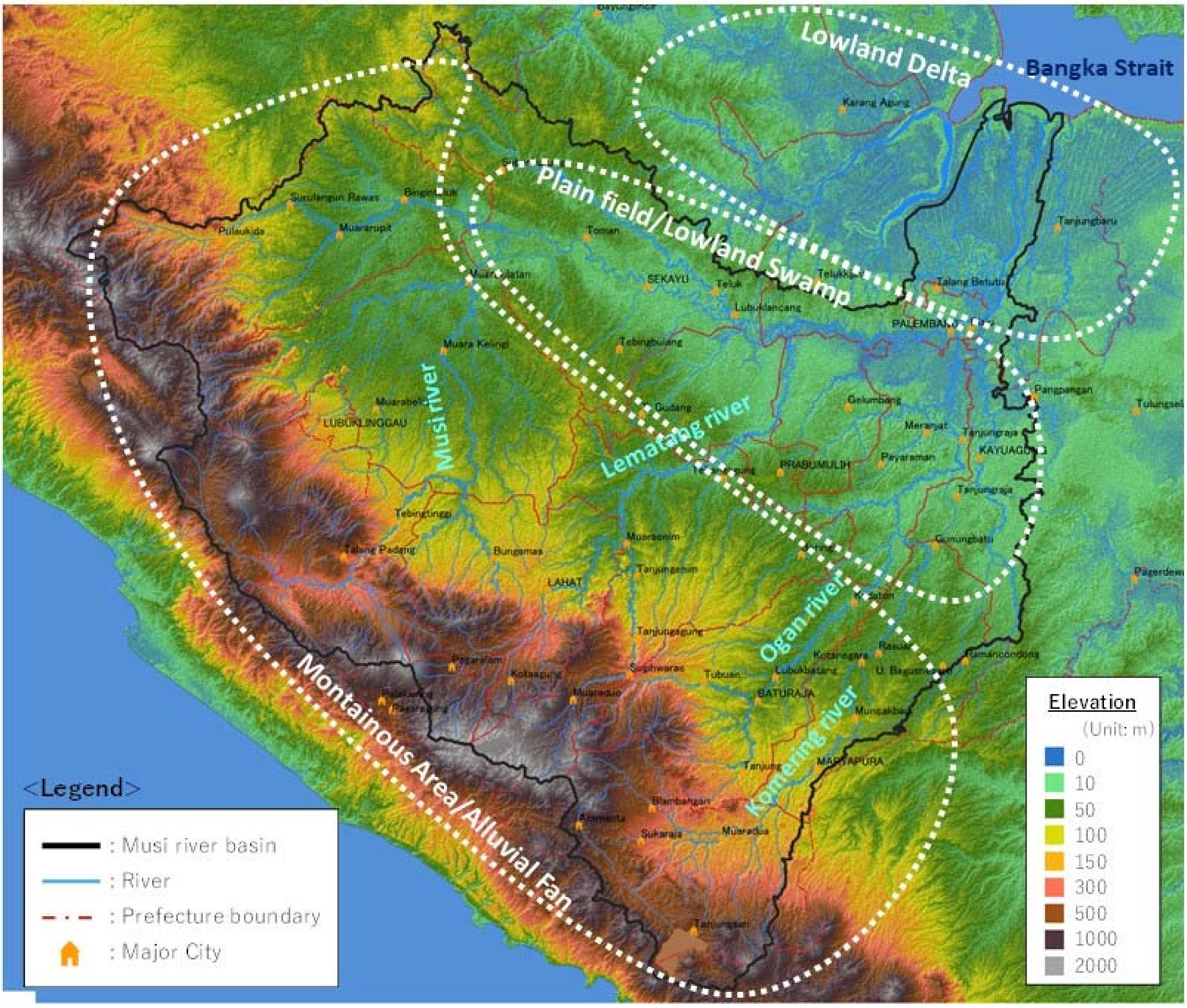


Source: RENCANA, 2017

Figure B 3.2.1 Target Area for Water Balance Analysis (012: DAS Musi)

B3.2.2 Overview of the Target Area

Figure B 3.2.2 shows overview of Musi river basin. Musi river and other main tributaries such as Lematang river, Ogan river and Komering river originate from south mountainous area. Musi river flows to North in upstream and changes the direction to East in middle stream and flows to North again and flows into the Bangka strait. From agricultural point of view, agricultural form in water use differs based on topographical characteristic. Except rain-fed cultivation area, agricultural forms can be separated to mainly 3 groups, namely (i) irrigation area with water intake from river, (ii) fresh water swamp area and (iii) tidal swamp irrigation area, and they locate in mountainous area or alluvial fan, or lowland swamp or lowland delta respectively.

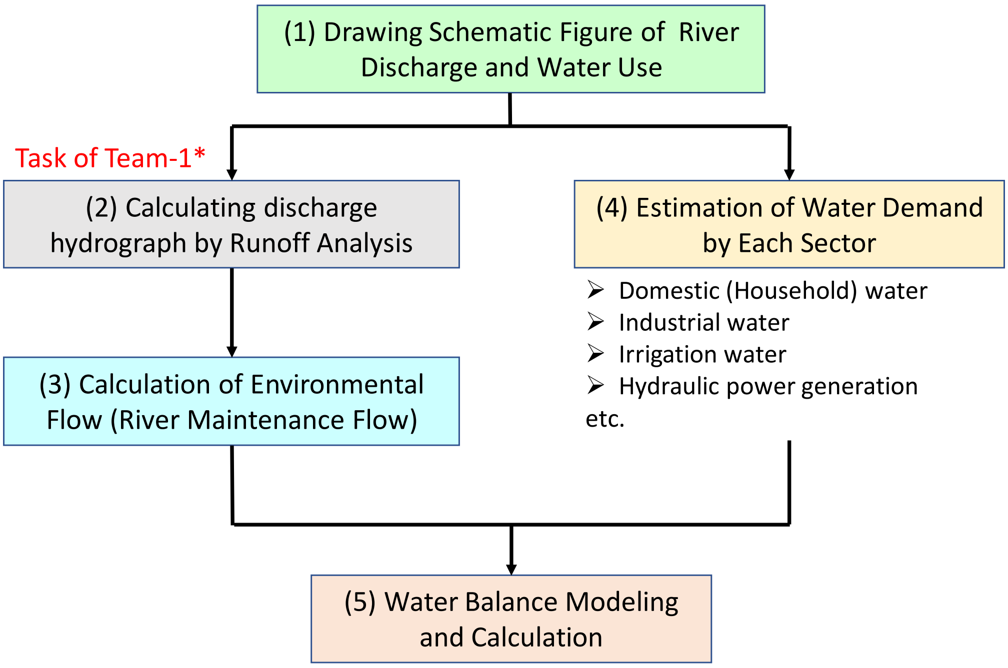


*SRTM version 3.0 (3 arc-second mesh) is used to show elevation.
Source: JICA Project Team 2

Figure B 3.2.2 Overview of Musi River Basin

B3.2.3 Workflow of Water Balance Modeling

Figure B 3.2.3 shows workflow of water balance modeling. In the workflow, the part of runoff analysis was conducted by JICA Project Team 1 and other parts were conducted by JICA Project Team 2.

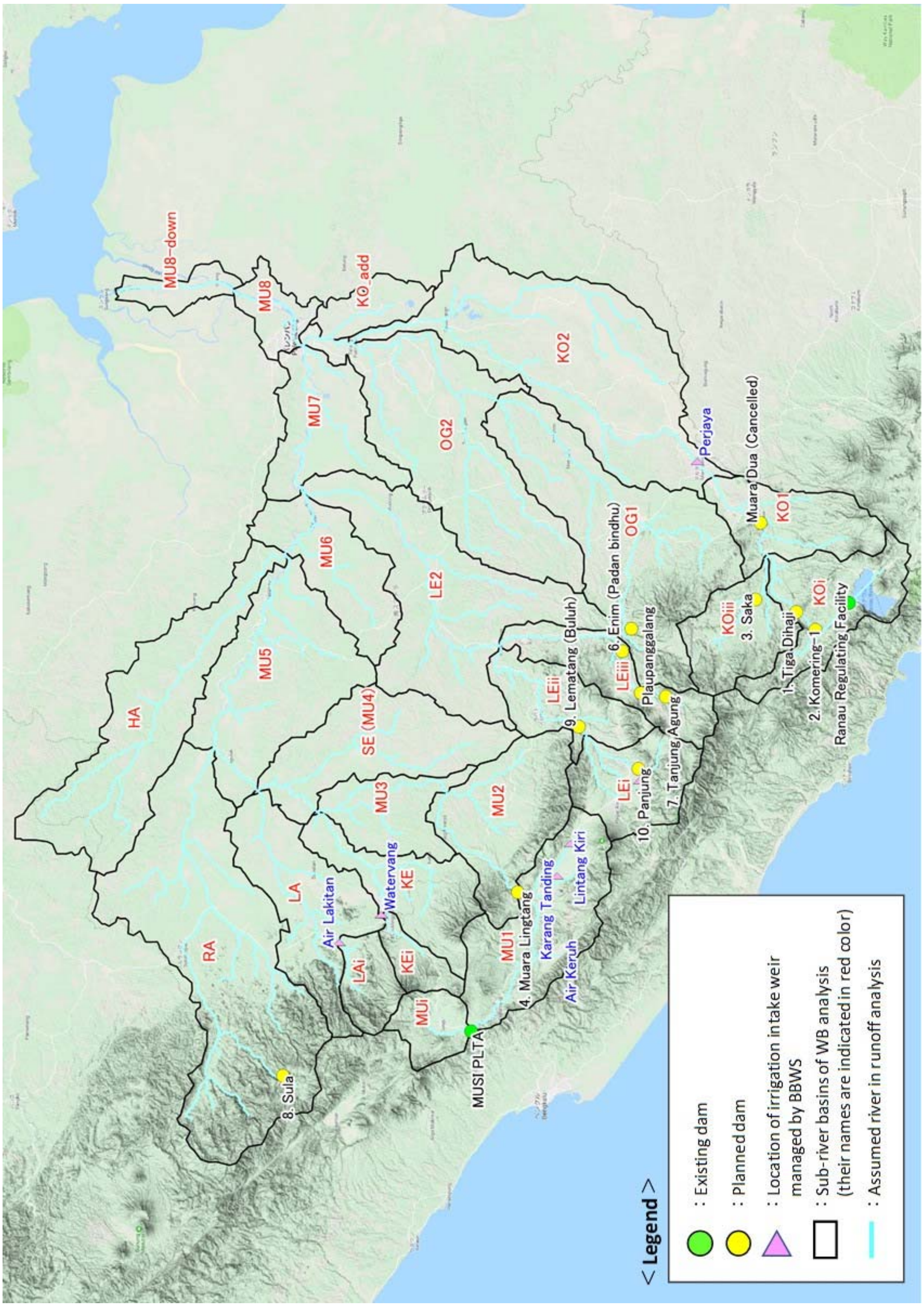


*Team-1 in the figure means JICA Project Team 1
Source: JICA Project Team 2

Figure B 3.2.3 Workflow of Water Balance Modeling

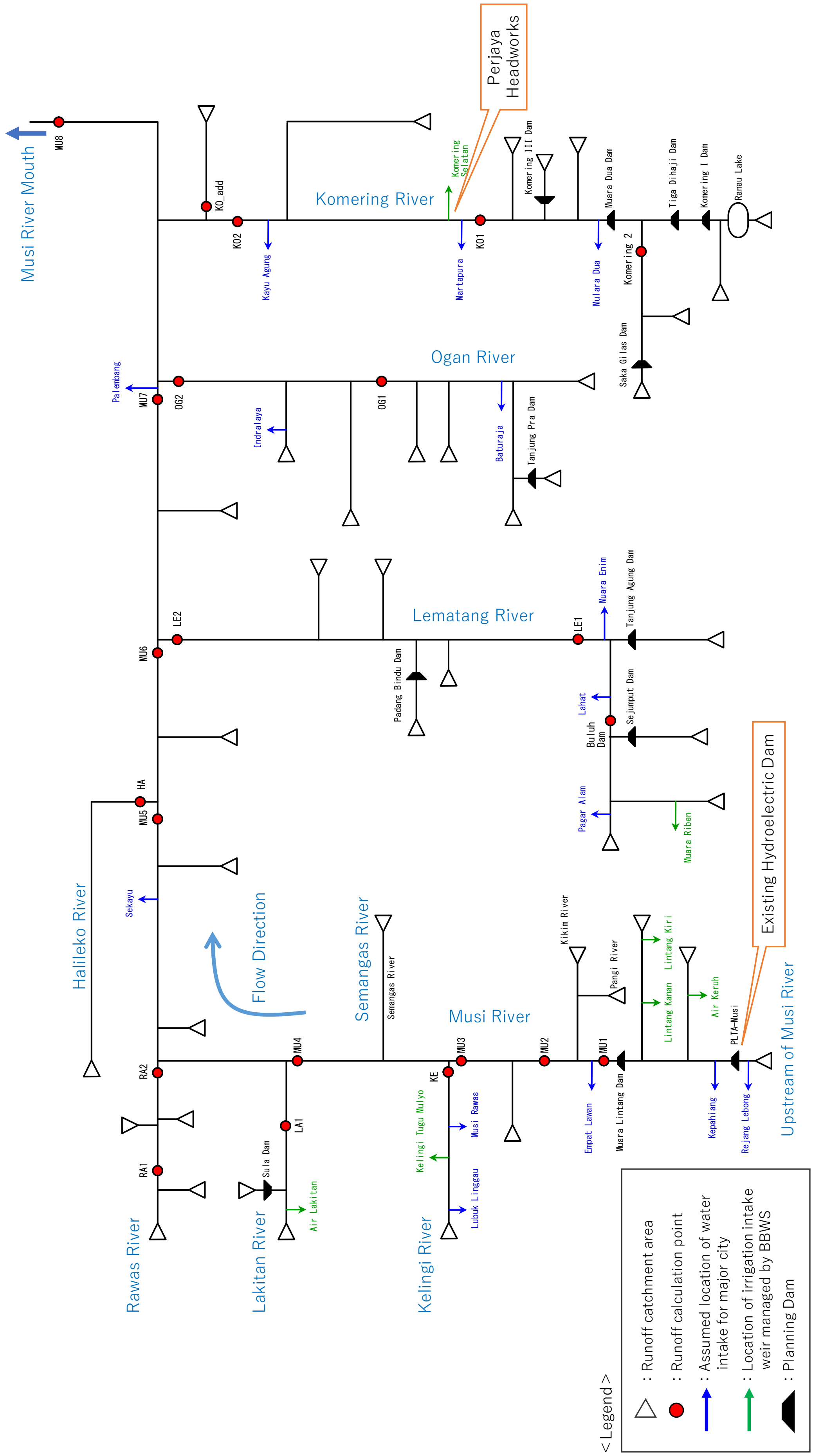
B3.2.4 Drawing Schematic Figure of Inflow and Outflow

For the purpose to grasp main inflow and outflow in whole Musi river basin, documents and data of water intake facility and water control facility were collected. Figure B 3.2.4shows sub-river basin division for water balance analysis and location of main water control facility in Muri river basin, and Figure B 3.2.5 shows created schematic figure of inflow and outflow.



Source: JICA Project Team 2 (Google Terrain Hybrid is used as background image)

Figure B 3.2.4 Sub-river Basin Division for Water Balance Analysis and Main Water Control Facility in Muri river Basin



Source: JICA Project Team 2

Figure B 3.2.5 Schematic Figure of Inflow and Outflow in Musi River Basin

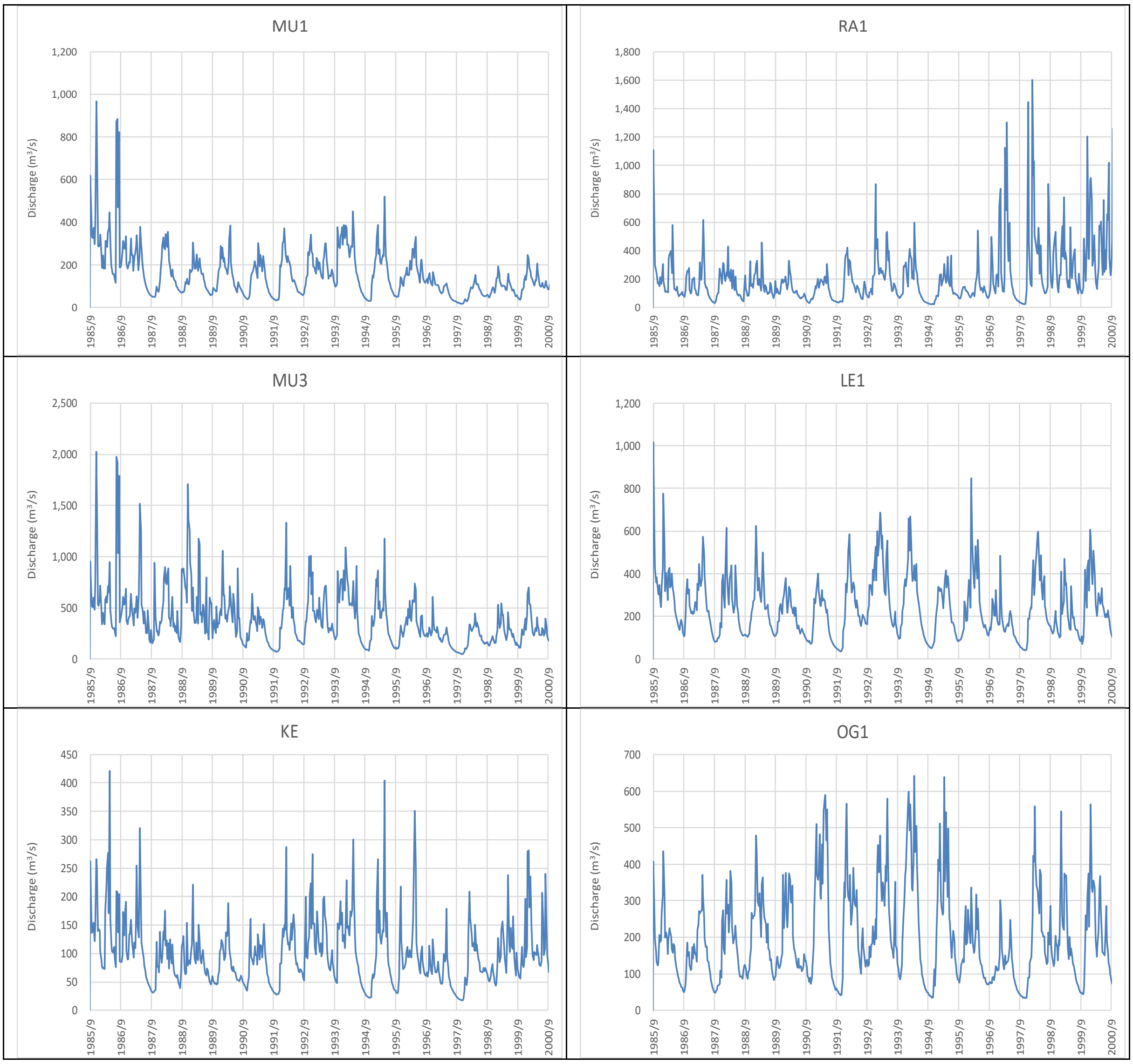
B3.2.5 Results of Runoff Analysis

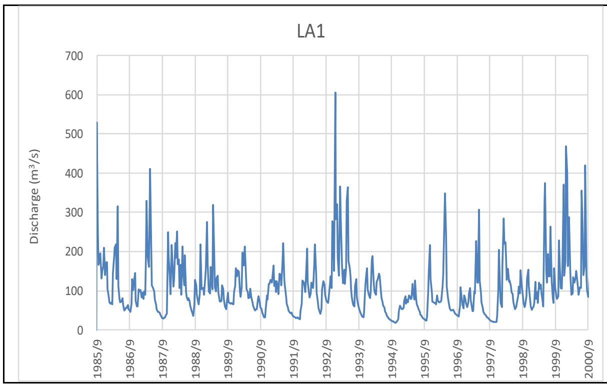
Team 1 conducted runoff analysis for totally 28 cases as shown in Table B 3.2.1 to evaluate the impact of climate change and land use change, and provided to Team 2 hourly river discharge at the points shown in Figure B 3.2.4. Figure B 3.2.6 show the part of results of runoff analysis for case 1 at 8 sub river basins.

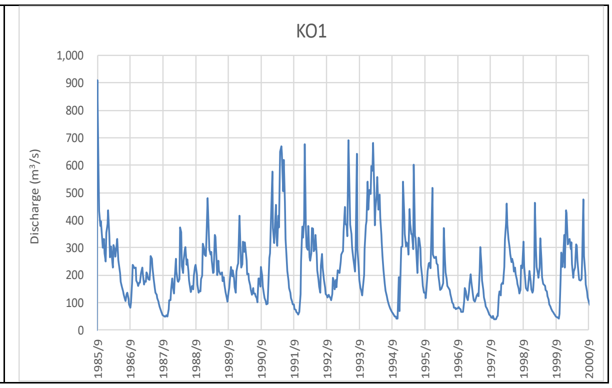
Table B 3.2.1 Study Cases for Water Balance Analysis

Case	Climate	Land Use	Number of Cases
Case 1	Observed (Past)	Past	1 Cases
Case 2	9 GCMs (Past)	Past	9 Cases
Case 3	9 GCMs (Future)	Past	9 Cases
Case 4	9 GCMs (Future)	Future	9 Cases

Source: JICA Project Team 2







*Title of each graph shows sub river basin whose location is shown in Figure B 3.2.4

Source: JICA Project Team 2

Figure B 3.2.6 Results of Runoff Analysis of Case 1

B3.2.6 Setting Environmental Flow (river maintenance flow)

Environmental flow (river maintenance flow) means the minimum discharge required for keeping river function, such as river transportation, fishing, river ecosystem and so on. In Indonesia, the article 25 in PP No.38/2011 (Sungai) rules that river discharge has to be controlled to keep 95% reliable flow. Therefore, environmental flow was set as 95% discharge of flow duration curve. Table B 3.2.2 shows calculated environmental flow in each sub-river basin, and flow duration curves are shown in Chapter B4.2.

Table B 3.2.2 Calculated Environmental Flow in Each Sub-river Basin

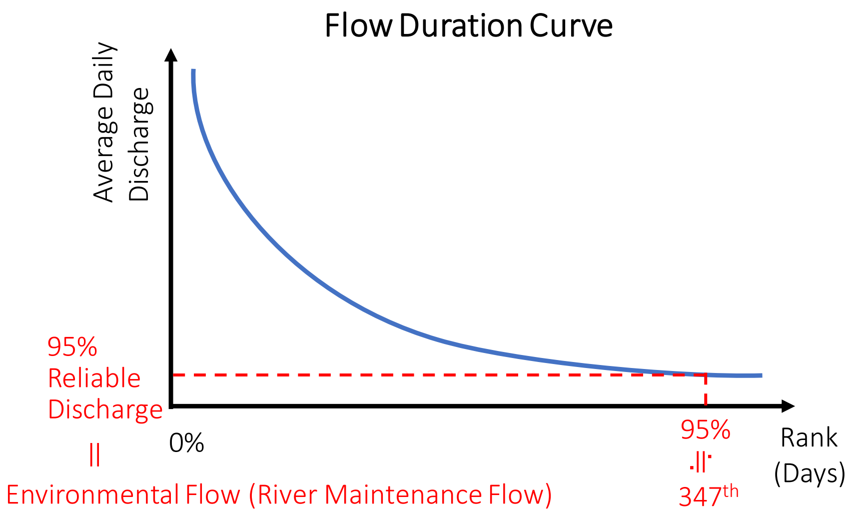
No.	Runoff Cal. Point	Environmental Flow (m^3/s)
1	MUi	11.1
—	Musi HEPP	1.1
2	MU1	55.6
3	MU2	111.2
4	MU3	140.6
5	KEi	9.6
6	KE	41.0
7	SE	50.4
8	MU4	239.0
9	LA1	9.9
10	LA2	40.7
11	RA2	71.5
12	MU5	406.4
13	HA	72.7
14	MU6	503.9
15	LEi (Buluh Dam)	32.2

No.	Runoff Cal. Point	Environmental Flow (m^3/s)
16	LEii	57.4
17	LEiii	28.6
18	LE1	85.9
19	LE2	155.6
20	MU7	690.3
21	OG1	62.2
22	OG2	272.8
23	KOi (RRF)	11.7
24	KOii	26.6
25	KOiii	20.8
26	KO1	74.0
27	Perjaya (rainy)	35.0 (25.0)
28	KO2	154.1
29	KO_add	6.9
30	MU8	1006.3

*Environmental flow at Musi HEPP (PLTA Musi), Ranau Regulating Facility (RRF) and Perjaya Headworks were set based on existing operation rule.

*The environmental flow at Perjaya Headworks is 35 m^3/s in rainy season and 25 m^3/s in dry season.

Source: JICA Project Team 2

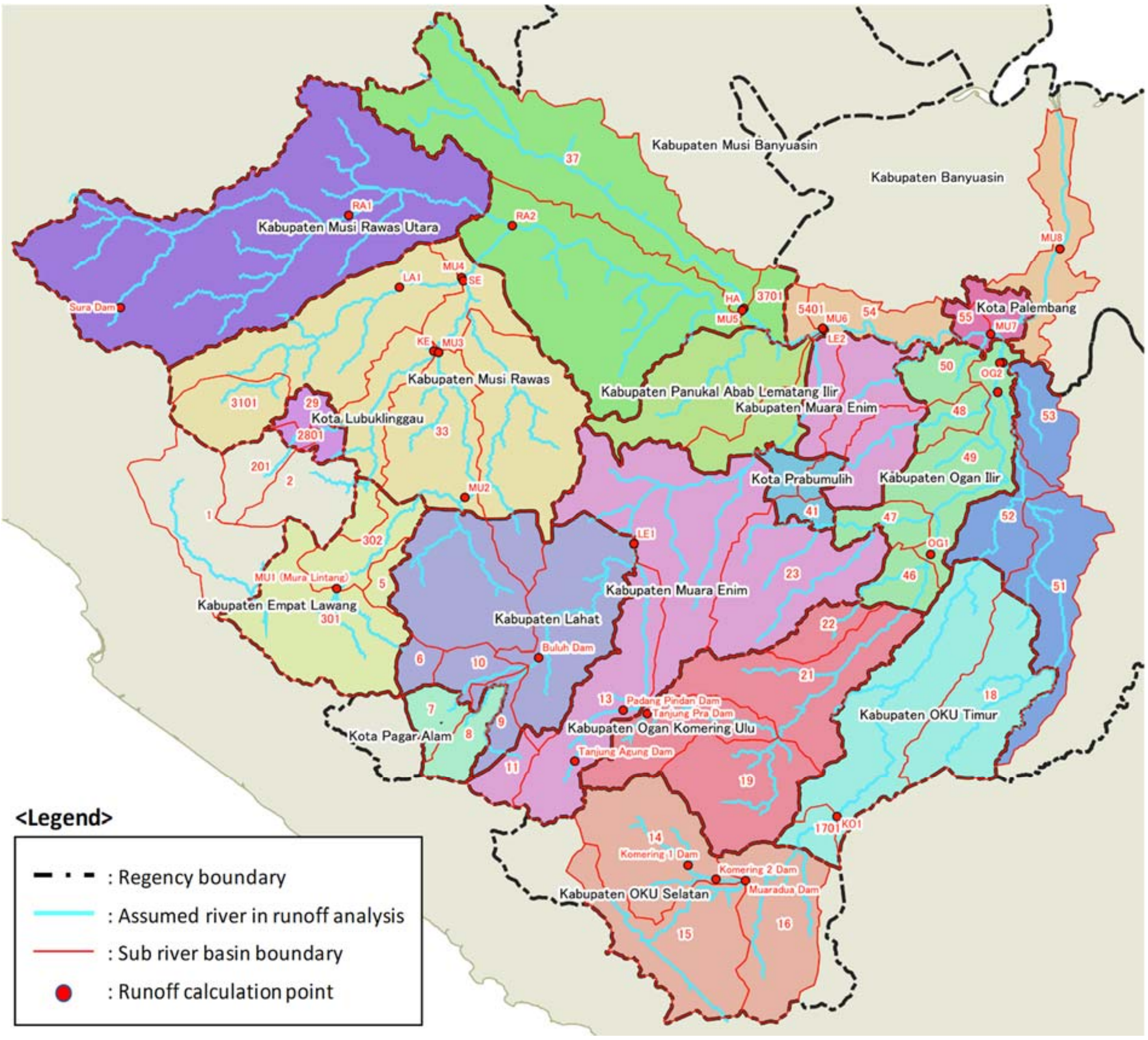


Source: JICA Project Team 2

Figure B 3.2.7 Environmental Flow as 95% Reliable Discharge

B3.2.7 Estimation of Water Demand

Methodology and results of water demand estimation is explained in the main report. Here, how to incorporate the estimated demands to water balance model is explained. Due to limitation of data availability and difficulty to identify all locations of water intake facility, water demand was estimated based on regency except for some large irrigation area. Water balance was calculated based on sub river basin as explained in the section B3.1.2, water demand based on regency was distributed to sub river basins multiplying overlaying ratio between regency boundary and sub river basin boundary. Figure B 3.2.8 shows overlaying the both two boundaries and Table B 3.2.3 shows distribution ratio based on overlapping area of the two boundaries.



Source: JICA Project Team 2

Figure B 3.2.8 Overlaying Regency Boundary and Sub River Basin Boundary

Table B 3.2.3 Distribution Ratio Based on Overlapping Area between Regency and Sub River Basin

No.	Kota/Kabpaten	Sub-Basins of Water Balance Analysis																											
		MUi	MU1	MU2	MU3	KEi	KE	SE	MU4	LAi	LA	RA	MU5	HA	MU6	LEi	LEii	LEiii	LE2	MU7	OG1	OG2	KOi	KOii	KOiii	KO1	KO2	KO_add	MU8
1	Banyu Asin	0	0	0	0	0	0	0	0	0	0	0	0	0	0.09	0	0	0	0	0.35	0	0	0	0	0	0	0	0	0.56
2	Empat Lawang	0	0.66	0.28	0	0	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Lubuklinggau City	0	0	0	0	0.20	0.35	0	0	0	0.45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Pagar AramCity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Palembang City	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.40	0	0	0	0	0	0	0	0	0.60
6	Prabumulih City	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.39	0	0	0.61	0	0	0	0	0	0	0
7	Lahat	0	0	0.36	0	0	0	0.07	0	0	0	0	0	0	0	0.17	0.40	0	0	0	0	0	0	0	0	0	0	0	0
8	Muara Enim	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.30	0.43	0	0	0.28	0	0	0	0	0	0	0
9	Musi Banyasin	0	0	0	0	0	0	0	0	0	0	0	0.48	0.52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Musi Rawas	0	0	0	0.19	0	0.09	0.27	0.08	0.09	0.29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Musi Rawas Utara	0	0	0	0	0	0	0	0	0	0	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Ogan Ilir	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.14	0.14	0.72	0	0	0	0	0	0	0
13	Ogan Komering Ilir	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.77	0.23	0
14	Ogan Komering Ulu	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	0	0	0	0	0	0	0	0
15	Ogan Komering Ulu Selatan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.13	0.23	0.33	0.31	0	0	0
16	Ogan Komering Ulu Timur	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.06	0.94	0	0
17	Panukal Abab Lematang Ilir	0	0	0	0	0	0	0	0	0	0	0	0	0	0.73	0	0	0	0.27	0	0	0	0	0	0	0	0	0	0
18	Rejang Lebong	0.39	0	0	0	0.23	0.38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	Kepahiang	0	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Source: JICA Project Team 2

(1) Water demand for domestic and industry

Water demand for domestic and industry was estimated for 2015 as present and 2050 as future based on regency as shown in Figure B 3.2.9. The demand was set as constant value per year.

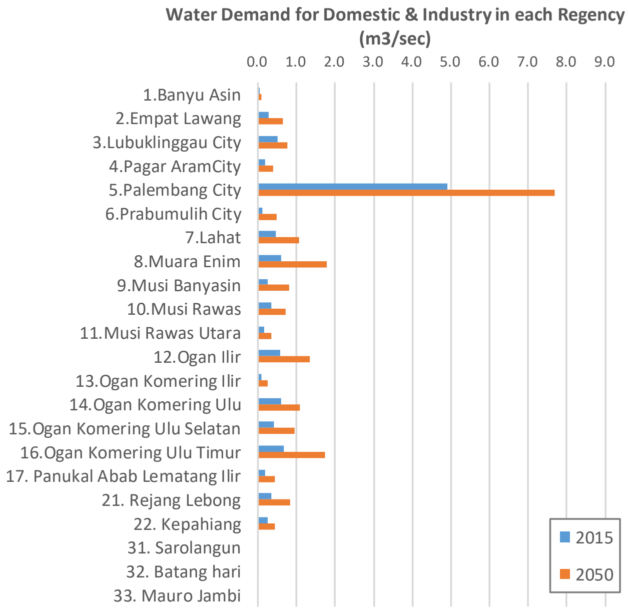


Table. Comparison in Demand Total

	Demand Total	
	(m3/s)	(MCM/year)
2015	10.9	345
2050	21.9	689
Increase Rate	200 %	

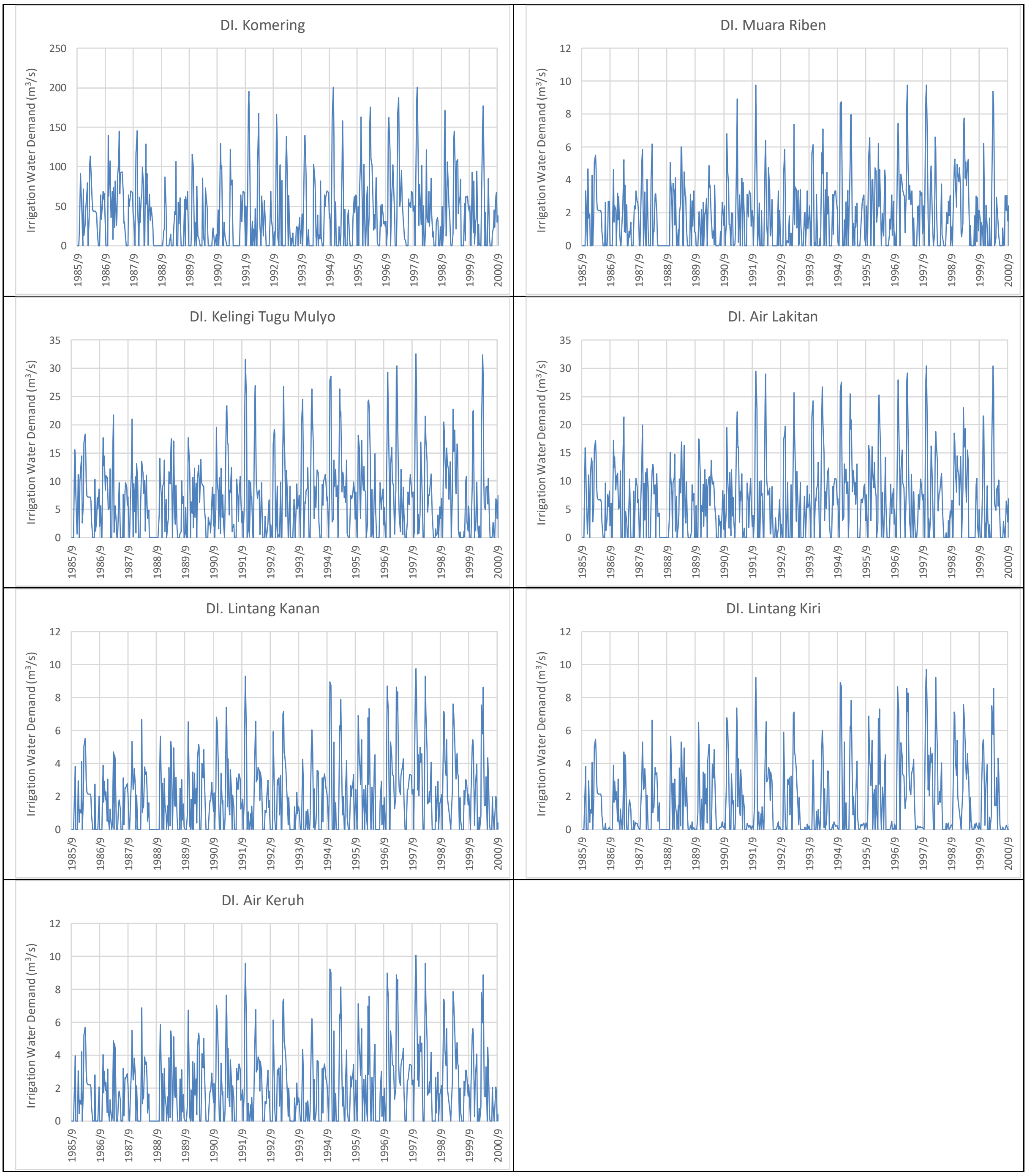
*MCM (Million Cubic Meter)

Source: JICA Project Team 2

Figure B 3.2.9 Water Demand for Domestic and Industry

(2) Water demand for irrigation

Since water demand for irrigation fluctuates reflecting cropping pattern and climate condition such as rainfall, temperature, etc., water demand for irrigation was estimated for each study cases as shown in Table B 3.2.1. Locations of water intake weir for national irrigation scheme were identified so that their demand was calculated based on their actual location in water balance analysis. However, locations of water intake points for provincial or local irrigation scheme were not able to identified so that their demand was calculated based on regency and distributed to sub river basin as explained in the section B3.2.7. Figure B 3.2.10 shows estimated water demand for irrigation of totally 7 national irrigation schemes in Case 1. DI. Komering is the largest irrigation scheme in Musi river basin and draws water from Komering river at Perjaya Headworks.



Source: JICA Project Team 2

Figure B 3.2.10 Estimated Water Demand for National Irrigation Scheme in Case 1

B3.2.8 Water Balance Modeling

(1) Operation rule of Dams

There are two dams, namely Musi hydroelectric power plant (PLTA-Musi) and Ranau regulating facility (RRF) in Musi river basin at present. Operation rules of these water control facility were reflected to the water balance model.

a) Musi hydroelectric power plant (PLTA-Musi)

PLTA-Musi locates upstream of Musi river. PLTA-Musi drew water at 38.4 m^3/s in average and drained water to another river basin in Bengkulu Province. Table B 3.2.4 shows basic condition of PLTA-Musi and Table B 3.2.5 shows operation rule in water balance model.

Table B 3.2.4 Basic Condition of PLTA-Musi

Upstream catchment area	587 km^2
Environmental flow	1.1 m^3/s
Peak water intake rate	62 m^3/s
Average water intake rate	38.4 m^3/s

Source: JICA Project Team 2

Table B 3.2.5 Operation Rule in Water Balance Model

If inflow to PLTA-Musi > average water intake rate, Water intake rate = average water intake rate (38.4 m^3/s) If inflow to PLTA-Musi < environmental flow Water intake rate = 0 If environmental flow < inflow < average water intake rate, Water intake rate = inflow – environmental flow

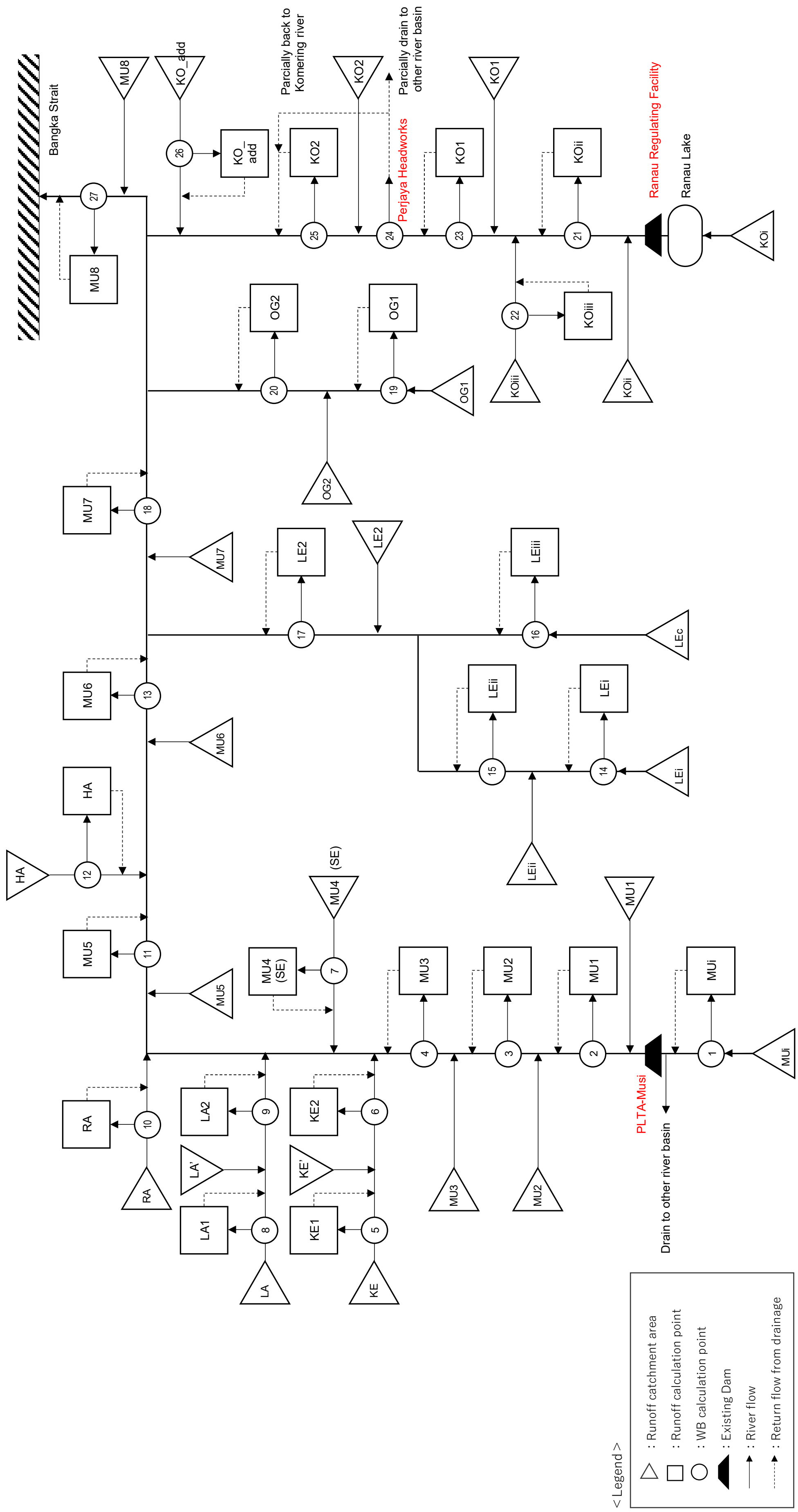
Source: JICA Project Team 2

b) Ranau regulating facility (RRF)

RRF locates upstream of Komering river and at outlet of Ranau lake. RRF has a role to supply water for Komering irrigation scheme. Effective water storage for irrigation of Ranau lake is 190 MCM between lowest water level (EL. 540.20m) and normal high water level (EL. 541.70m). RRF was modeled to supply water in response to water deficit at Komering irrigation scheme.

(2) Building water balance model

Based on the conditions above, water balance model was built as shown in Figure B 3.2.11. Water intake at PLTA-Musi is drained to another river basin in Bengkulu Province by 100% and water intake at Perjaya Headworks is drained partially to another river basin in Lampung Province.



Source: JICA Project Team 2

Figure B 3.2.11 Schematic Figure of Water Balance Model

(3) Calculation condition of water balance analysis

Calculation condition of water balance analysis was summarized in the table below.

Table B 3.2.6 Calculation Condition of Water Balance Analysis

Item	Computation Condition
Target Area	Whole Musi River Basin
Computation Unit	Sub river basin
Computation time step	10 days
Computation period	-Case for Present: Sep. 1 1985 – Aug. 31 2000 (15 years) -Case for Future: Sep. 1 2050 – Aug. 31 2065 (15 years)
Modeled River Facility	Ranau Regulating Facility and Musi Hydroelectric Power Plant
Priority in water intake	(1) Environmental flow (River maintenance flow) (2) Water demand for city and industry (3) Water demand for irrigation
Return flow back to river by drainage	-Assume 80% from water use in city and industry -Assume 30% from irrigation in agricultural field

Source: JICA Project Team 2

B3.3 Setting Target for Water Balance Analysis

B3.3.1 Selection of 3 Representative GCMs (scenarios)

(1) Procedure to select 3 representative GCMs

GCMs (General Circulation Models) has uncertainty and variety in principal. At first, 9 GCMs were selected to show the climatic characteristic of Musi river basin relatively well by screening more than 30 GCMs by JICA Project Team 1. Subsequently, JICA Project Team 2 selected 3 GCMs as high risk scenario, middle risk scenario and low risk scenario considering both GCM's characteristic and workload.

Table B 3.3.1 Selected 9 GCMs by First Screening

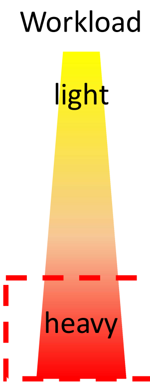
No.	GCM
1	CCCMA_CGCM
2	CSIRO_MK35
3	GFDL_2_0
4	GFDL_2_1
5	GISS_AOM
6	INGV_ECHAM4
7	MIUB_ECHO
8	MIUB_MPI_ECHAM5
9	MIUB_MRI_CGCM232A

Source: JICA Project Team 1

The purpose in selecting 3 GCMs is to grasp the uncertainty of GCMs and to study future water resource management considering future drought risk quantitatively.

Table B 3.3.2 shows indices for selecting 3 GCMs. Rainfall and Discharge can express drought risk from water supply point of view, while water deficit can express drought risk from both water supply and water demand point of view. As a result, "Water Deficit" was selected as indicator for selecting 3 GCMs.

Table B 3.3.2 Indices for Selecting 3 GCMs



Indicator	Explanation	Consideration
Rainfall	Average annual rainfall over Musi river basin	✓ Easy to understand ✓ Normally used for flood control plan as external force
Discharge	Average discharge at Musi river mouse computed by run-off analysis	✓ Discharge reflects rainfall spatial and chronological characteristics and run-off characteristics of river basin ✓ The effect of water use is not considered
Water Deficit	Total water deficit computed by water balance analysis	✓ Both surface flow and water demand are considered ✓ Workload is heavy

Source: JICA Project Team 2

Therefore, water deficit was computed for totally 28 cases as shown in Table B 3.3.3.

Table B 3.3.3 Study Case for Water Balance Analysis

Case	Climate	Land Use	Number of Cases
Case 1	Observation (Past)	Past	1 Cases
Case 2	9 GCMs (Past)	Past	9 Cases
Case 3	9 GCMs (Future)	Past	9 Cases
Case 4	9 GCMs (Future)	Future	9 Cases

Source: JICA Project Team 2

(2) Results of water balance analysis for selecting 3 GCMs

a) Water balance in total

To grasp the overview of water balance results first, average annual total of water balance calculation for whole Musi river basin (totally 27 sub basins) is summarized in the Table B 3.3.5.

Comparing total inflow at outlet of the Musi river and total water demand, water resource is abundant to fulfill the water demand. But large amount of water deficit will generate if river environmental flow has to be maintained at each sub-basin outlet.

Table B 3.3.4 Explanatory Note of the Table B 3.3.5

Item	Notes
Qin	Inflow
Qenv	Environmental flow (Maintenance flow)
Demand (City)	Demand for domestic and industrial water
Demand (Irrigation)	Demand for irrigation water
Intake (City)	Quantity of water intake for domestic and industrial water
Intake (Irrigation)	Quantity of water intake for irrigation
Deficit (Qenv)	Deficit of environmental flow
Deficit (City)	Deficit of domestic and industrial water
Deficit (Irrigation)	Deficit of irrigation water
Deficit (total)	Total deficit (*not including "Deficit (Qenv)")
Qret	Return flow after water use of domestic, industrial, irrigation etc.
Qout	Outflow

Source: JICA Project Team 2

Table B 3.3.5 Average Annual Total of Water Balance Calculation for Each Sub Basin

(Unit: MCM / Year)

Case			Water Balance (10 days Base)											
			Qin	Qenv	Demand		Intake		Deficit				Qret	Qout
					City	Irrigation	City	Irrigation	Qenv	City	Irrigation	total		
Case 1	Observed Rainfall		87,453	31,758	345	4,037	302	3,264	4,669	43	773	816	1,144	85,030
Case 2	GCM1	CCCMA_CGCM	79,910	31,758	345	3,685	265	2,219	7,114	80	1,466	1,546	679	78,105
	GCM2	CSIRO_MK35	81,724	31,758	345	3,900	286	2,575	6,320	59	1,325	1,384	768	79,631
	GCM3	GFDL_2_0	78,241	31,758	345	4,054	303	3,253	4,078	42	801	843	1,207	75,892
	GCM4	GFDL_2_1	80,555	31,758	345	3,724	286	2,709	6,369	59	1,015	1,074	988	78,548
	GCM5	GISS_AOM	77,423	31,758	345	3,879	253	2,400	8,640	92	1,479	1,571	925	75,695
	GCM6	INGV_ECHAM4	77,611	31,758	345	3,833	317	3,249	2,301	27	584	611	1,266	75,310
	GCM7	MIUB_ECHO	78,036	31,758	345	4,121	315	3,260	1,978	30	860	891	1,152	75,613
	GCM8	MIUB_MPI_ECHAM5	83,719	31,758	345	3,633	306	2,679	3,051	38	954	992	917	81,650
	GCM9	MIUB_MRI_CGCM232A	80,408	31,758	345	3,716	305	2,910	3,278	40	806	846	1,068	78,260
Case 3	GCM1	CCCMA_CGCM	85,804	31,758	689	3,753	572	2,372	4,452	117	1,381	1,499	858	83,718
	GCM2	CSIRO_MK35	60,706	31,758	689	4,625	475	2,396	11,021	214	2,229	2,443	1,023	58,858
	GCM3	GFDL_2_0	85,987	31,758	689	3,838	610	3,050	3,063	79	788	867	1,320	83,647
	GCM4	GFDL_2_1	75,017	31,758	689	4,288	546	3,183	6,689	143	1,105	1,247	1,356	72,644
	GCM5	GISS_AOM	86,423	31,758	689	3,815	511	2,399	7,992	178	1,416	1,594	1,126	84,639
	GCM6	INGV_ECHAM4	77,474	31,758	689	3,954	603	3,104	3,383	86	850	936	1,376	75,143
	GCM7	MIUB_ECHO	81,687	31,758	689	4,369	617	3,342	2,333	72	1,027	1,099	1,399	79,128
	GCM8	MIUB_MPI_ECHAM5	89,621	31,758	689	3,653	601	2,536	3,606	88	1,117	1,206	1,066	87,551
	GCM9	MIUB_MRI_CGCM232A	75,213	31,758	689	4,367	552	2,870	5,948	137	1,497	1,635	1,301	73,093
Case 4	GCM1	CCCMA_CGCM	86,938	31,758	689	4,196	556	2,633	5,682	133	1,563	1,696	953	84,702
	GCM2	CSIRO_MK35	62,053	31,758	689	5,174	476	2,706	12,427	214	2,468	2,682	1,180	60,051
	GCM3	GFDL_2_0	87,071	31,758	689	4,300	595	3,398	4,179	94	902	996	1,521	84,599
	GCM4	GFDL_2_1	75,886	31,758	689	4,748	536	3,486	8,703	153	1,263	1,415	1,514	73,378
	GCM5	GISS_AOM	87,045	31,758	689	4,329	495	2,838	10,899	195	1,491	1,686	1,313	85,025
	GCM6	INGV_ECHAM4	78,545	31,758	689	4,385	593	3,417	4,195	96	968	1,064	1,541	76,076
	GCM7	MIUB_ECHO	82,629	31,758	689	4,808	603	3,613	3,311	86	1,195	1,281	1,553	79,966
	GCM8	MIUB_MPI_ECHAM5	90,660	31,758	689	4,150	593	2,899	4,714	96	1,251	1,347	1,282	88,450
	GCM9	MIUB_MRI_CGCM232A	76,052	31,758	689	4,830	536	3,240	7,766	153	1,590	1,743	1,472	73,747

* The values are average of 15 years
* Items of the table is explained in the Table B 3.3.4
* Computing condition for Case 1 to 4 is shown in the Table B 3.3.3.
Source: JICA Project Team 2

b) Deficit in each sub river basin

To analyze in which sub basin and how much water deficit will happen, average annual deficit at each sub basin is computed as shown in Figure B 3.3.1. As the computed water deficits show large variations in 9 GCMs, figures of box plots were created as shown in Figure B 3.3.2 based on Table B 3.3.6.

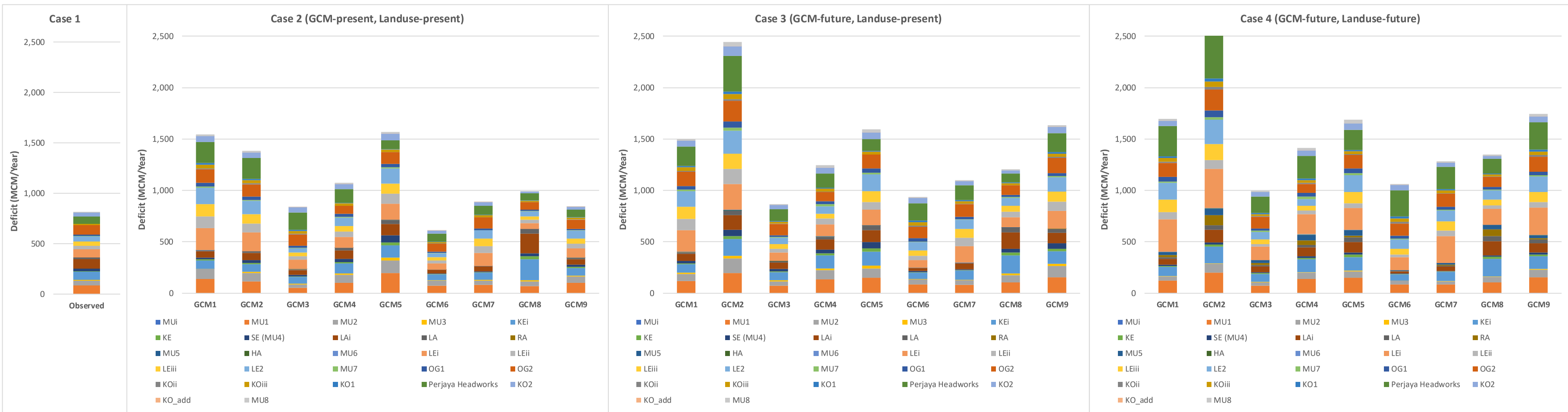
Because main irrigation schemes take surface water from upstream of Musi river and its tributaries as shown in Figure B 3.2.4, large water shortage can be seen at upstream sub basins such as upstream of Musi river (MU1), Kelingi river (KEi), Lakitan river (LAi), Lemtang river (LEi), and Perjaya headworks of Komering river.

(Unit : MCM/year)

No.	Sub-River Basin	Case 1	Case 2 (GCM-present, Landuse-present)								
		Observed	GCM1	GCM2	GCM3	GCM4	GCM5	GCM6	GCM7	GCM8	GCM9
1	MUi	0.6	0.7	0.5	0.3	0.7	1.4	0.3	0.4	0.4	0.7
2	MU1	89.2	137.6	111.2	51.5	99.6	194.0	73.9	80.7	66.0	99.8
3	MU2	46.3	95.9	82.5	33.7	76.7	123.7	46.9	42.3	47.3	59.9
4	MU3	8.8	1.3	11.2	7.0	16.0	27.5	4.8	5.6	12.2	11.8
5	KEi	76.3	83.5	76.5	65.6	96.7	119.7	58.0	69.8	206.3	72.4
6	KE	7.9	10.7	10.8	4.7	13.8	28.8	2.5	4.4	28.5	11.7
7	SE (MU4)	25.6	15.7	30.0	15.1	32.3	69.6	6.4	8.5	28.6	20.4
8	LAi	91.5	63.4	66.9	47.8	80.7	107.6	33.1	48.7	188.9	53.2
9	LA	18.3	6.6	16.7	8.1	23.2	39.4	1.5	4.6	45.5	14.0
10	RA	0.5	0.8	0.5	0.2	0.6	0.2	0.0	0.0	0.7	0.1
11	MU5	0.4	0.8	0.5	0.3	0.6	0.8	0.1	0.2	0.5	0.2
12	HA	0.5	0.9	0.8	0.2	0.6	0.3	0.0	0.0	0.0	0.0
13	MU6	0.4	0.9	0.6	0.2	0.7	0.8	0.1	0.2	0.3	0.2
14	LEi	78.7	212.0	181.8	92.8	105.2	154.2	61.2	124.4	58.2	90.6
15	LEii	36.0	117.3	87.9	30.3	51.0	101.0	29.2	68.7	30.7	46.7
16	LEiii	39.3	117.8	89.8	36.8	54.9	98.2	32.4	70.3	33.0	49.6
17	LE2	53.2	157.4	129.9	41.5	80.1	147.2	37.5	82.9	49.0	77.6
18	MU7	6.8	13.7	9.4	4.0	10.1	12.9	2.3	2.4	4.3	3.7
19	OG1	13.4	38.8	32.2	20.5	26.8	30.8	13.3	16.4	13.6	10.9
20	OG2	91.1	131.0	119.5	110.9	79.9	116.0	79.2	107.8	70.7	92.6
21	KOii	0.9	4.5	11.8	9.4	1.1	0.1	2.6	1.4	2.0	2.0
22	KOiii	12.6	39.8	27.8	21.6	21.0	23.9	13.3	19.8	11.8	15.4
23	KO1	4.0	15.9	14.1	13.2	7.3	5.0	5.0	4.5	3.9	4.6
24	Perjaya Headworks	69.8	204.4	203.6	169.9	132.5	86.1	76.1	86.5	68.6	72.9
25	KO2	35.3	57.4	52.9	49.8	48.1	61.8	27.5	36.2	16.1	29.3
26	KO_add	0.1	0.0	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.0
27	MU8	8.3	17.3	14.2	7.2	14.0	19.8	4.0	3.8	5.2	5.1
Total		816.0	1,546.2	1,384.0	842.9	1,074.1	1,570.9	611.2	890.6	992.1	845.7

No.	Sub-River Basin	Case 3 (GCM-future, Landuse-present)								
		GCM1	GCM2	GCM3	GCM4	GCM5	GCM6	GCM7	GCM8	GCM9
1	MUi	0.9	2.3	0.8	2.1	3.2	1.1	0.7	1.3	2.6
2	MU1	117.2	193.5	70.8	133.2	147.6	83.1	81.1	102.3	151.5
3	MU2	70.6	143.5	43.7	88.0	88.4	48.5	42.3	72.3	109.2
4	MU3	8.8	23.0	10.2	18.5	28.9	7.0	5.2	16.5	23.2
5	KEi	82.6	162.8	78.6	124.9	134.5	59.8	91.6	174.6	121.8
6	KE	10.8	29.1	8.8	18.6	32.2	4.6	4.9	27.6	25.1
7	SE (MU4)	23.9	63.0	21.9	37.6	64.6	10.8	7.9	38.8	51.6
8	LAi	68.3	141.3	63.5	98.5	112.9	29.3	54.5	158.0	104.6
9	LA	13.9	40.0	11.7	24.7	44.9	2.9	5.9	44.6	36.7
10	RA	0.9	2.6	0.4	1.2	0.4	0.0	0.1	1.8	0.2
11	MU5	1.6	3.3	0.9	2.5	2.2	0.6	0.5	1.7	1.2
12	HA	1.6	5.3	0.5	2.4	0.6	0.2	0.2	0.2	0.1
13	MU6	1.2	2.7	0.7	2.0	1.7	0.5	0.4	1.0	0.8
14	LEi	209.5	251.6	82.7	115.1	152.1	75.4	159.5	100.4	172.7
15	LEii	111.2	143.4	39.0	58.5	72.9	38.6	83.3	51.7	89.7
16	LEiii	118.8	149.6	42.1	45.2	106.7	54.3	88.3	55.6	95.7
17	LE2	152.7	225.7	62.5	70.7	160.3	80.3	89.4	78.7	142.4
18	MU7	12.7	28.9	7.1	20.9	19.3	5.5	4.4	9.6	10.3
19	OG1	35.9	60.7	17.7	30.9	39.4	31.3	21.6	19.3	30.1
20	OG2	136.8	198.7	109.5	89.4	134.6	112.9	124.9	92.3	147.4
21	KOii	7.5	18.2	5.0	4.4	0.9	10.3	3.6	2.4	9.4
22	KOiii	37.7	48.6	16.7	27.1	29.4	34.1	25.8	20.3	31.8
23	KO1	13.2	23.1	8.3	7.5	7.5	14.4	10.8	6.5	14.4
24	Perjaya Headworks	188.7	347.7	112.6	140.6	113.5	168.1	141.8	87.2	185.8
25	KO2	56.1	92.6	41.3	57.0	65.8	53.2	43.7	29.9	60.0
26	KO_add	0.1	0.9	0.0	0.1	0.2	0.1	0.1	0.0	0.2
27	MU8	15.6	40.8	9.8	25.7	28.9	9.0	6.5	11.1	16.1
Total		1,498.6	2,442.9	866.7	1,247.2	1,593.7	935.7	1,099.0	1,205.7	1,634.7

No.	Sub-River Basin	Case 4 (GCM-future, Landuse-future)								
		GCM1	GCM2	GCM3	GCM4	GCM5	GCM6	GCM7	GCM8	GCM9
1	MUi	1.0	2.4	0.8	2.1	3.2	1.1	0.8	1.4	2.6
2	MU1	120.5	196.1	71.2	135.2	148.4	85.1	83.9	103.7	152.4
3	MU2	41.2	86.1	34.2	62.3	59.0	34.5	30.3	52.1	74.2
4	MU3	3.8	6.3	3.3	5.7	8.2	2.6	2.0	4.9	6.7
5	KEi	90.6	162.5	78.6	124.0	133.4	58.3	89.4	173.2	121.5
6	KE	9.1	20.2	5.9	13.6	22.4	3.3	4.2	18.7	17.7
7	SE (MU4)	10.3	20.2	9.1	14.5	21.4	4.4	4.8	14.5	18.9
8	LAi	56.9	123.5	56.0	85.2	100.0	23.9	46.7	138.3	92.7
9	LA	16.4	44.1	15.3	28.0	48.0	2.6	8.4	47.6	37.5
10	RA	23.0	96.5	18.7	45.0	15.2	0.7	6.7	66.1	11.0
11	MU5	25.5	62.4	27.8	53.2	52.8	8.2	14.1	43.0	29.7
12	HA	2.2	5.2	0.9	2.6	1.1	0.4	0.4	0.4	0.4
13	MU6	1.5	2.7	1.0	2.2	2.2	0.6	0.7	1.2	1.3
14	LEi	318.2	381.7	131.5	195.9	214.7	125.9	264.2	157.3	267.5
15	LEii	67.7	86.8	24.2	34.8	44.8	24.0	49.8	31.6	53.3
16	LEiii	122.4	152.7	44.5	46.0	108.8	57.3	92.1	58.6	97.8
17	LE2	162.6	237.5	73.6	65.0	162.6	88.7	106.1	86.3	148.6
18	MU7	15.4	27.1	11.5	22.9	24.0	7.4	7.5	10.8	15.0
19	OG1	44.7	65.0	21.4	36.5	41.5	31.3	28.9	24.4	32.8
20	OG2	132.8	202.7	115.4	88.1	134.1	119.0	124.9	97.0	147.7
21	KOii	11.6	26.5	7.1	9.4	5.2	13.9	6.3	4.2	14.8
22	KOiii	39.0	49.9	17.3	28.3	30.5	34.9	27.0	21.2	32.4
23	KO1	17.5	31.7	10.0	14.4	11.9	18.1	13.3	8.2	19.3
24	Perjaya Headworks	290.7	471.6	160.0	220.9	197.8	255.4	218.1	143.8	268.8
25	KO2	52.4	81.4	43.1	52.3	60.2	50.4	39.4	26.5	56.5
26	KO_add	0.2	1.0	0.1	0.2	0.3	0.2	0.2	0.0	0.3
27	MU8	19.5	38.0	13.6	26.9	34.0	11.6	10.8	12.0	21.8
Total		1,696.4	2,681.5	996.0	1,415.3	1,685.6	1,063.9	1,281.1	1,347.0	1,743.3



* The values are average of 15 years
Source: JICA Project Team 2

Figure B 3.3.1 Cumulative Bar Chart of Average Annual Water Deficit at Each Sub-river Basin

Table B 3.3.6 Computed Water Deficit at Each Sub-river Basin and their Quartile Values

(Unit: MCM/year)

Case 2 (GCM: Past/ Land Use: Past)

GCM		1 MUi	2 MU1	3 MU2	4 MU3	5 KEi	6 KE	7 SE(MU4)	8 LAi	9 LA	10 RA	11 MU5	12 HA	13 MU6	14 LEi	15 LEii	16 LEiii	17 LE2	18 MU7	19 OG1	20 OG2	21 KOii	22 KOiii	23 KO1	24 Perjaya	25 KO2	26 KO_add	27 MU8	Total
GCM1	CCCMA_CGCM	0.7	137.6	95.9	1.3	83.5	10.7	15.7	63.4	6.6	0.8	0.8	0.9	0.9	212.0	117.3	117.8	157.4	13.7	38.8	131.0	4.5	39.8	15.9	204.4	57.4	0.0	17.3	1546.2
GCM2	CSIRO_MK35	0.5	111.2	82.5	11.2	76.5	10.8	30.0	66.9	16.7	0.5	0.5	0.8	0.6	181.8	87.9	89.8	129.9	9.4	32.2	119.5	11.8	27.8	14.1	203.6	52.9	0.2	14.2	1384.0
GCM3	GFDL_2_0	0.3	51.5	33.7	7.0	65.6	4.7	15.1	47.8	8.1	0.2	0.3	0.2	0.2	92.8	30.3	36.8	41.5	4.0	20.5	110.9	9.4	21.6	13.2	169.9	49.8	0.0	7.2	842.9
GCM4	GFDL_2_1	0.7	99.6	76.7	16.0	96.7	13.8	32.3	80.7	23.2	0.6	0.6	0.6	0.7	105.2	51.0	54.9	80.1	10.1	26.8	79.9	1.1	21.0	7.3	132.5	48.1	0.1	14.0	1074.1
GCM5	GISS_AOM	1.4	194.0	123.7	27.5	119.7	28.8	69.6	107.6	39.4	0.2	0.8	0.3	0.8	154.2	101.0	98.2	147.2	12.9	30.8	116.0	0.1	23.9	5.0	86.1	61.8	0.1	19.8	1570.9
GCM6	INGV_ECHAM4	0.3	73.9	46.9	4.8	58.0	2.5	6.4	33.1	1.5	0.0	0.1	0.0	0.1	61.2	29.2	32.4	37.5	2.3	13.3	79.2	2.6	13.3	5.0	76.1	27.5	0.0	4.0	611.2
GCM7	MIUB_ECHO	0.4	80.7	42.3	5.6	69.8	4.4	8.5	48.7	4.6	0.0	0.2	0.0	0.2	124.4	68.7	70.3	82.9	2.4	16.4	107.8	1.4	19.8	4.5	86.5	36.2	0.0	3.8	890.6
GCM8	MIUB_MPI_ECHAM5	0.4	66.0	47.3	12.2	206.3	28.5	28.6	188.9	45.5	0.7	0.5	0.0	0.3	58.2	30.7	33.0	49.0	4.3	13.6	70.7	2.0	11.8	3.9	68.6	16.1	0.0	5.2	992.1
GCM9	MIUB_MRI_CGCM232A	0.7	99.8	59.9	11.8	72.4	11.7	20.4	53.2	14.0	0.1	0.2	0.0	0.2	90.6	46.7	49.6	77.6	3.7	10.9	92.6	2.0	15.4	4.6	72.9	29.3	0.0	5.1	845.7
Max		1.4	194.0	123.7	27.5	206.3	28.8	69.6	188.9	45.5	0.8	0.8	0.9	0.9	212.0	117.3	117.8	157.4	13.7	38.8	131.0	11.8	39.8	15.9	204.4	61.8	0.2	19.8	1570.9
75%		0.7	111.2	82.5	12.2	96.7	13.8	30.0	80.7	23.2	0.6	0.6	0.6	0.7	154.2	87.9	89.8	129.9	10.1	30.8	116.0	4.5	23.9	13.2	169.9	52.9	0.1	14.2	1384.0
50%		0.5	99.6	59.9	11.2	76.5	10.8	20.4	63.4	14.0	0.2	0.5	0.2	0.3	105.2	51.0	54.9	80.1	4.3	20.5	107.8	2.0	21.0	5.0	86.5	48.1	0.0	7.2	992.1
25%		0.4	73.9	46.9	5.6	69.8	4.7	15.1	48.7	6.6	0.1	0.2	0.0	0.2	90.6	30.7	36.8	49.0	3.7	13.6	79.9	1.4	15.4	4.6	76.1	29.3	0.0	5.1	845.7
Min		0.3	51.5	33.7	1.3	58.0	2.5	6.4	33.1	1.5	0.0	0.1	0.0	0.1	58.2	29.2	32.4	37.5	2.3	10.9	70.7	0.1	11.8	3.9	68.6	16.1	0.0	3.8	611.2

(Unit: MCM/year)

Case 3 (GCM: Future/ Land Use: Past)

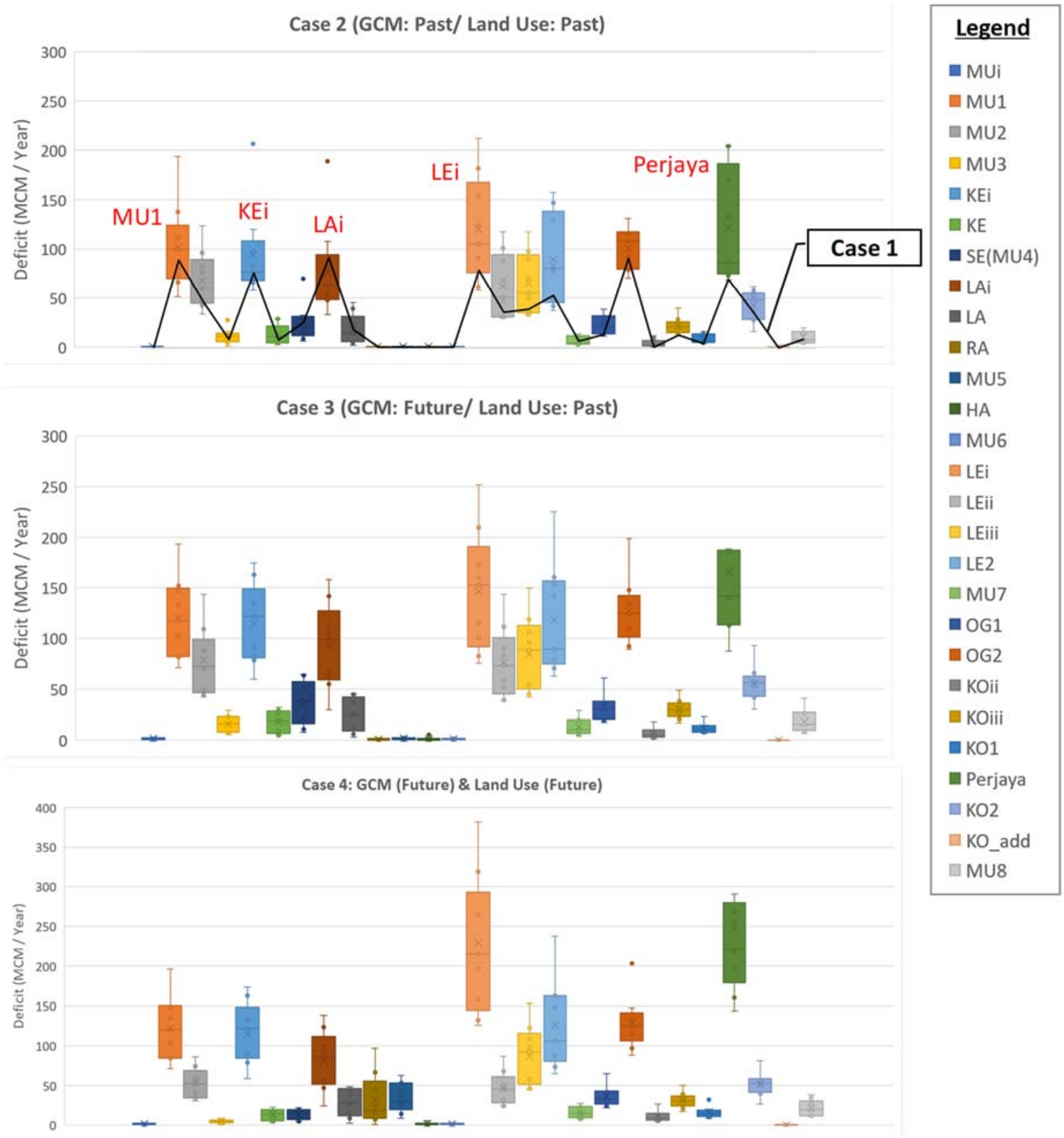
GCM		1 MUi	2 MU1	3 MU2	4 MU3	5 KEi	6 KE	7 SE(MU4)	8 LAi	9 LA	10 RA	11 MU5	12 HA	13 MU6	14 LEi	15 LEii	16 LEiii	17 LE2	18 MU7	19 OG1	20 OG2	21 KOii	22 KOiii	23 KO1	24 Perjaya	25 KO2	26 KO_add	27 MU8	Total
GCM1	CCCMA_CGCM	0.9	117.2	70.6	8.8	82.6	10.8	23.9	68.3	13.9	0.9	1.6	1.6	1.2	209.5	111.2	118.8	152.7	12.7	35.9	136.8	7.5	37.7	13.2	188.7	56.1	0.1	15.6	1498.6
GCM2	CSIRO_MK35	2.3	193.5	143.5	23.0	162.8	29.1	63.0	141.3	40.0	2.6	3.3	5.3	2.7	251.6	143.4	149.6	225.7	28.9	60.7	198.7	18.2	48.6	23.1	347.7	92.6	0.9	40.8	2442.9
GCM3	GFDL_2_0	0.8	70.8	43.7	10.2	78.6	8.8	21.9	63.5	11.7	0.4	0.9	0.5	0.7	82.7	39.0	42.1	62.5	7.1	17.7	109.5	5.0	16.7	8.3	112.6	41.3	0.0	9.8	866.7
GCM4	GFDL_2_1	2.1	133.2	88.0	18.5	124.9	18.6	37.6	98.5	24.7	1.2	2.5	2.4	2.0	115.1	58.5	45.2	70.7	20.9	30.9	89.4	4.4	27.1	7.5	140.6	57.0	0.1	25.7	1247.2
GCM5	GISS_AOM	3.2	147.6	88.4	28.9	134.5	32.2	64.6	112.9	44.9	0.4	2.2	0.6	1.7	152.1	72.9	106.7	160.3	19.3	39.4	134.6	0.9	29.4	7.5	113.5	65.8	0.2	28.9	1593.7
GCM6	INGV_ECHAM4	1.1	83.1	48.5	7.0	59.8	4.6	10.8	29.3	2.9	0.0	0.6	0.2	0.5	75.4	38.6	54.3	80.3	5.5	31.3	112.9	10.3	34.1	14.4	168.1	53.2	0.1	9.0	935.7
GCM7	MIUB_ECHO	0.7	81.1	42.3	5.2	91.6	4.9	7.9	54.5	5.9	0.1	0.5	0.2	0.4	159.5	83.3	88.3	89.4	4.4	21.6	124.9	3.6	25.8	10.8	141.8	43.7	0.1	6.5	1099.0
GCM8	MIUB_MPI_ECHAM5	1.3	102.3	72.3	16.5	174.6	27.6	38.8	158.0	44.6	1.8	1.7	0.2	1.0	100.4	51.7	55.6	78.7	9.6	19.3	92.3	2.4	20.3	6.5	87.2	29.9	0.0	11.1	1205.7
GCM9	MIUB_MRI_CGCM232A	2.6	151.5	109.2	23.2	121.8	25.1	51.6	104.6	36.7	0.2	1.2	0.1	0.8	172.7	89.7	95.7	142.4	10.3	30.1	147.4	9.4	31.8	14.4	185.8	60.0	0.2	16.1	1634.7
Max		1.4	194.0	123.7	27.5	206.3	28.8	69.6	188.9	45.5	0.8	0.8	0.9	0.9	212.0	117.3	117.8	157.4	13.7	38.8	131.0	11.8	39.8	15.9	204.4	61.8	0.2	19.8	1570.9
75%		0.7	111.2	82.5	12.2	96.7	13.8	30.0	80.7	23.2	0.6	0.6	0.6	0.7	154.2	87.9	89.8	129.9	10.1	30.8	116.0	4.5	23.9	13.2	169.9	52.9	0.1	14.2	1384.0
50%		0.5	99.6	59.9	11.2	76.5	10.8	20.4	63.4	14.0	0.2	0.5	0.2	0.3	105.2	51.0	54.9	80.1	4.3	20.5	107.8	2.0	21.0	5.0	86.5	48.1	0.0	7.2	992.1
25%		0.4	73.9	46.9	5.6	69.8	4.7	15.1	48.7	6.6	0.1	0.2	0.0	0.2	90.6	30.7	36.8	49.0	3.7	13.6	79.9	1.4	15.4	4.6	76.1	29.3	0.0	5.1	845.7
Min		0.3	51.5	33.7	1.3	58.0	2.5	6.4	33.1	1.5	0.0	0.1	0.0	0.1	58.2	29.2	32.4	37.5	2.3	10.9	70.7	0.1	11.8	3.9	68.6	16.1	0.0	3.8	611.2

(Unit: MCM/year)

Case 4 (GCM: Future/ Land Use: Future)

GCM		1 MUi	2 MU1	3 MU2	4 MU3	5 KEi	6 KE	7 SE(MU4)	8 LAi	9 LA	10 RA	11 MU5	12 HA	13 MU6	14 LEi	15 LEii	16 LEiii	17 LE2	18 MU7	19 OG1	20 OG2	21 KOii	22 KOiii	23 KO1	24 Perjaya	25 KO2	26 KO_add	27 MU8	Total
GCM1	CCCMA_CGCM	1.0	120.5	41.2	3.8	90.6	9.1	10.3	56.9	16.4	23.0	25.5	2.2	1.5	318.2	67.7	122.4	162.6	15.4	44.7	132.8	11.6	39.0	17.5	290.7	52.4	0.2	19.5	1696.4
GCM2	CSIRO_MK35	2.4	196.1	86.1	6.3	162.5	20.2	20.2	123.5	44.1	96.5	62.4	5.2	2.7	381.7	86.8	152.7	237.5	27.1	65.0	202.7	26.5	49.9	31.7	471.6	81.4	1.0	38.0	2681.5
GCM3	GFDL_2_0	0.8	71.2	34.2	3.3	78.6	5.9	9.1	56.0	15.3	18.7	27.8	0.9	1.0	131.5	24.2	44.5	73.6	11.5	21.4	115.4	7.1	17.3	10.0	160.0	43.1	0.1	13.6	996.0
GCM4	GFDL_2_1	2.1	135.2	62.3	5.7	124.0	13.6	14.5	85.2	28.0	45.0	53.2	2.6	2.2	195.9	34.8	46.0	65.0	22.9	36.5	88.1	9.4	28.3	14.4	220.9	52.3	0.2	26.9	1415.3
GCM5	GISS_AOM	3.2	148.4	59.0	8.2	133.4	22.4	21.4	100.0	48.0	15.2	52.8	1.1	2.2	214.7	44.8	108.8	162.6	24.0	41.5	134.1	5.2	30.5	11.9	197.8	60.2	0.3	34.0	1685.6
GCM6	INGV_ECHAM4	1.1	85.1	34.5	2.6	58.3	3.3	4.4	23.9	2.6	0.7	8.2	0.4	0.6	125.9	24.0	57.3	88.7	7.4	31.3	119.0	13.9	34.9	18.1	255.4	50.4	0.2	11.6	1063.9
GCM7	MIUB_ECHO	0.8	83.9	30.3	2.0	89.4	4.2	4.8	46.7	8.4	6.7	14.1	0.4	0.7	264.2	49.8	92.1	106.1	7.5	28.9	124.9	6.3	27.0	13.3	218.1	39.4	0.2	10.8	1281.1
GCM8	MIUB_MPI_ECHAM5	1.4	103.7	52.1	4.9	173.2	18.7	14.5	138.3	47.6	66.1	43.0	0.4	1.2	157.3	31.6	58.6	86.3	10.8	24.4	97.0	4.2	21.2	8.2	143.8	26.5	0.0	12.0	1347.0
GCM9	MIUB_MRI_CGCM232A	2.6	152.4	74.2	6.7	121.5	17.7	18.9	92.7	37.5	11.0	29.7	0.4	1.3	267.5	53.3	97.8	148.6	15.0	32.8	147.7	14.8	32.4	19.3	268.8	56.5	0.3	21.8	1743.3
Max		1.4	194.0	123.7	27.5	206.3	28.8	69.6	188.9	45.5	0.8	0.8	0.9	0.9	212.0	117.3	117.8	157.4	13.7	38.8	131.0	11.8	39.8	15.9	204.4	61.8	0.2	19.8	1570.9
75%		0.7	111.2	82.5	12.2	96.7	13.8	30.0	80.7	23.2	0.6	0.6	0.6	0.7	154.2	87.9	89.8	129.9	10.1	30.8	116.0	4.5	23.9	13.2	169.9	52.9	0.1	14.2	1384.0
50%		0.5	99.6	59.9	11.2	76.5	10.8	20.4	63.4	14.0	0.2	0.5	0.2	0.3	105.2	51.0	54.9	80.1	4.3	20.5	107.8	2.0	21.0	5.0	86.5	48.1	0.0	7.2	992.1
25%		0.4	73.9	46.9	5.6	69.8	4.7	15.1	48.7	6.6	0.1	0.2	0.0	0.2	90.6	30.7	36.8	49.0	3.7	13.6	79.9	1.4	15.4	4.6	76.1	29.3	0.0	5.1	845.7
Min		0.3	51.5	33.7	1.3	58.0	2.5	6.4	33.1	1.5	0.0	0.1	0.0	0.1	58.2	29.2	32.4	37.5	2.3	10.9	70.7	0.1	11.8	3.9	68.6	16.1	0.0	3.8	611.2

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure B 3.3.2 Boxplots of Deficit for 9 GCMs at Each Sub-river Basin

c) Selection of the representative three GCMs

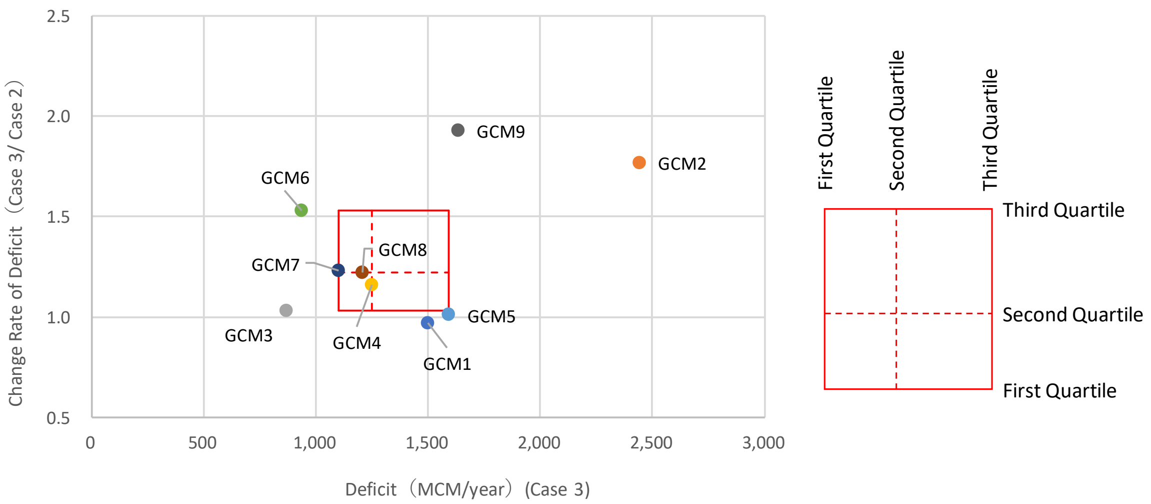
The representative three (3) GCMs were selected by the third quartile (75 percentile) as drought risk high, by the second quartile (50 percentile) as drought risk middle and by the first quartile (25 percentile) as drought risk low using box plot as shown in Figure B 3.3.3.

Table B 3.3.7 Selecting 3 Representative GCMs Based on Average Annual Total Deficit

(Unit: MCM / Year)

GCM		Case 2		Case 3		Case 4		Case 3/Case 2		Case 4/Case 2	
		Deficit	RANK	Deficit	RANK	Deficit	RANK	Rate	RANK	Rate	RANK
GCM1	CCCMA_CGCM	1546.2	2	1498.6	4	1696.4	3	0.97	9	1.10	8
GCM2	CSIRO_MK35	1384.0	3	2442.9	1	2681.5	1	1.77	2	1.94	2
GCM3	GFDL_2_0	842.9	8	866.7	9	996.0	9	1.03	7	1.18	7
GCM4	GFDL_2_1	1074.1	4	1247.2	5	1415.3	5	1.16	6	1.32	6
GCM5	GISS_AOM	1570.9	1	1593.7	3	1685.6	4	1.01	8	1.07	9
GCM6	INGV_ECHAM4	611.2	9	935.7	8	1063.9	8	1.53	3	1.74	3
GCM7	MIUB_ECHO	890.6	6	1099.0	7	1281.1	7	1.23	4	1.44	4
GCM8	MIUB_MPI_ECHAM5	992.1	5	1205.7	6	1347.0	6	1.22	5	1.36	5
GCM9	MIUB_MRI_CGCM232A	845.7	7	1634.7	2	1743.3	2	1.93	1	2.06	1
Max		1570.9	-	2442.9	-	2681.5	-	1.93	-	2.06	-
75%		1384.0	-	1593.7	-	1696.4	-	1.53	-	1.74	-
50%		992.1	-	1247.2	-	1415.3	-	1.22	-	1.36	-
25%		845.7	-	1099.0	-	1281.1	-	1.03	-	1.18	-
Min		611.2	-	866.7	-	996.0	-	0.97	-	1.07	-

* Deficit of Case 1: 816.0 MCM/year
* Case 3/Case 2 means increase ratio by the impact of climate change
* Case 4/Case 2 means increase ratio by the impact of climate change and land-use change
Source: JICA Project Team 2



Source: JICA Project Team 2

Figure B 3.3.3 Box P in Scatter Plot of Deficit Change Ratio and Deficit

As explained in B3.3.1(1), 3 representative GCMs to express drought risk high/ middle/ low were selected based on water deficit calculated by water balance analysis. Since GCM data originally have uncertainty, 3 GCMs should be selected by “change rate of deficit” rather than by “the amount of deficit”. In other words, 3 GCMs should be selected by how much deficit will increase rather than how much deficit will happen. In addition to that, drought risk “High” and “Low” were selected by 75 percentile and 25 percentile respectively to avoid evaluating future drought risk extremely high or extremely low.

Considering the above points, the 3 representative GCMs were selected as shown in Table B 3.3.8.

Table B 3.3.8 Result of Selecting Representative 3 GCMs

Drought Risk	Selected GCM	Selected Reason
High	(GCM6) INGV_ECHAM4	75 percentile of change rate of water deficit (Case 3/ Case 2)
Middle	(GCM8) MIUB_MPI_ECHAM5	50 percentile of change rate of water deficit (Case 3/ Case 2)
Low	(GCM3) GFDL_2_0	25 percentile of change rate of water deficit (Case 3/ Case 2)

B3.3.2 Setting Future Discharge Hydrograph

(1) Future water deficit

As explained in the previous section, average annual total deficit for the present condition (Case 1) was calculated as 816 MCM/year. On the other hand, environmental flow (river maintenance flow) is not considered in fact except for at the Musi hydroelectric power plant (PLTA-Musi), Ranau Regulating Facility (RRF) and the Perjaya headworks. So, if environmental flow is not considered in the water balance analysis except for the above three facilities, average annual deficit for the present condition is calculated as 168 MCM/year.

Since outputs from GCM include the errors based on uncertainty, the outputs should be used not as the values themselves but as statistically analyzed values such as change rate. Therefore, future water deficits were calculated by multiplying the change rate shown in the Table B 3.3.7 by the present water deficit as shown in the Table B 3.3.9.

As a result, future deficit volume is projected to increase, by 18% to 74%, from 816 to 963 to 1,420 MCM/year as impacts of climate and land-use changes.

Table B 3.3.9 Future Water Deficit Volumes of the Representative 3 GCMs

Scenario	Present Total Deficit (MCM/year)	Future Climate + Present Land Use		Future Climate + Future Land Use	
		Increase rate from Present to Case 3	Total deficit (MCM/year)	Increase rate from present to Case 3	Total deficit (MCM/year)
High	816 (168)	1.53	1,248 (298)	1.74	1,420 (433)
Medium		1.22	996 (207)	1.36	1,110 (275)
Low		1.03	840 (194)	1.18	963 (260)

Note: Values in the parentheses means total deficit volumes that are estimated without consideration of river maintenance flow.
Source: JICA Project Team 2

(2) Future river discharge

Repeatedly, since outputs from GCM include the errors based on uncertainty, the outputs should be used not as the values themselves but as statistically analyzed values such as change rate. However, time series of future river discharge and water demand are required for water balance analysis for future condition. Therefore, applying the time series of future water demand without any change, the time series of future river discharge was calculated by multiplying certain constant rate by future river discharge (runoff-analysis output from JICA Project Team 1) to correspond to the future water deficit shown in the Table B 3.3.9 for practical purposes.

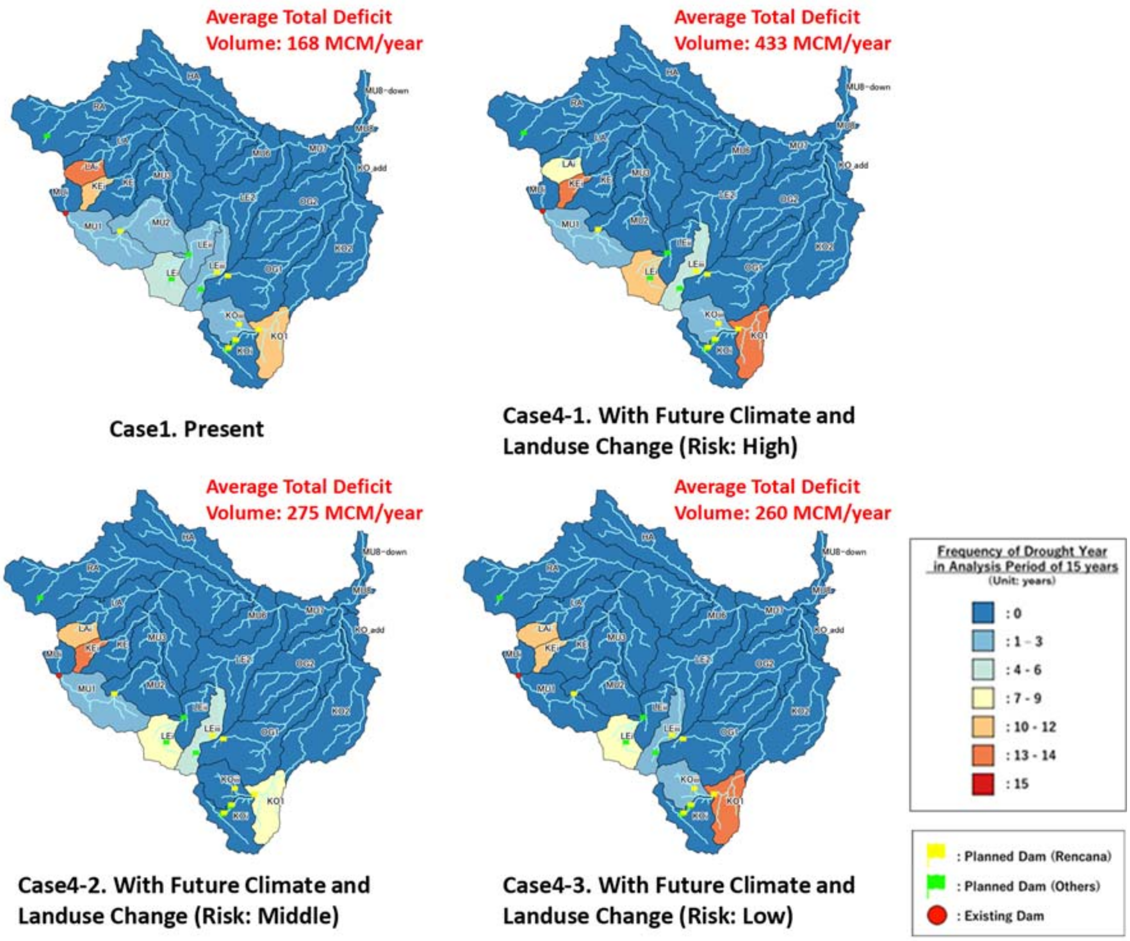
B3.4 Results of Water Balance Analysis

B3.4.1 Evaluating the Impact of Rainfall Change in 2050

In order to assess the impact of climate change on water use, the frequency of drought year[3], as an indicator of water security level, was evaluated based on the results in B3.3 as shown in Figure B 3.4.1. From the figures, considerations were made as follows:

- As shown in Figure B 3.4.1, in all the scenarios drought occurs only in upstream sub-basins, but there is no drought in middle and lower river basins. These water-short sub-basins include those of the Komering, Lematang, Kelingi and Lakitan Rivers where existing and proposed large-scaled irrigation intake facilities are concentrated.
- A few dam reservoirs have been planned/proposed for the water-short sub-basins of the Komering and Lematang Rivers. However, those of the Kelingi and Lakitan Rivers have no planned/proposed dam site.
- Water demand for domestic and industry which is prioritized more than irrigation water in terms of water security will be secured almost 100% in all the climate change scenario. however, almost all the deficit volume is for irrigation water.

[3] Frequency of drought year: Drought year is defined as the year in which water deficit occurred at least once in any kind of water demand such as domestic, industry, irrigation, etc. in this study. The frequency means the number of drought years in water balance analysis for 15 years. For example, “3” means that drought year happened 3 times in 15 years, which equals 1/5 or 20% probability.



*In preparing Figure B 3.4.1, environmental flow (river maintenance flow) is not considered except for the existing operation rules at the Musi hydroelectric power plant (PLTA-Musi), Ranau Regulating Facility (RRF) and the Perjaya headworks because the values of environmental flow at each sub-basin was set as 95% reliable flow as explained in B3.2.6, which probably results in drought occurs almost every year.
Source: JICA Project Team 2

Figure B 3.4.1 Frequency of Drought Occurrence in Sub Basin

B3.4.2 Water Balance Analysis for Climate Change Adaptation

(1) Adaptation measures against drought

Based upon the situations explained in the previous section, following adaptation measures are conceived for the Musi River Basin. A combination of these measures should be taken comprehensively to address the uncertainty of climate change impact as well as to cope with the increasing water demand.

Table B 3.4.1 Conceivable Adaptation Measures against Drought

Structural/ Non-structural	Measure	Expected effects
Structural	Dam reservoirs	Development of water resources.
	Embung	Development of water resources.
	Utilization of Groundwater	Development of water resources.
	Reduction of Leakage from irrigation canals	Saving of irrigation water.
	Reduction of Non-Revenue Water (Leakage from DMI water)	Saving of irrigation water.
	Recycling of industrial water	Saving of industrial water.
	Rain harvesting	Development of water resources.
Non-structural	Modification of Operation of RRF	Development of water resources by lowering of water level of Ranau Lake.
	Irrigation water demand management	Saving of DMI water.
	DMI water demand management	Saving of DMI water.
	Watershed Conservation	Conservation of water resources

Source: JICA Project Team 2

(2) Calculation condition with future dams

Focusing on the four river basins where water shortage is likely to occur, necessity and effectiveness of the proposed dam reservoirs are examined through water balance analysis. Each of the four river basins has a water supply target as presented in Table B 3.4.2. The water balance analysis aims to check if the target is attained or not by the proposed dam reservoirs.

Table B 3.4.2 Water Supply Targets at 2050

Period	River Basin	Catchment Area (km^2)	Irrigation Water Supply				DMI** Water Supply	
			Irrigation Area (ha)			Safety Level (%)	Water Demand*** (m^3/s)	Safety Level (%)
			MH*	MK1*	MK2*			
Present	Komering	9,725	74,717	64,221	30,847	80	0.18	90
	Lematang	7,608	50,860	16,095	4,786	80	0.31	90
	Kelingi	1,931	12,387	8,470	3,848	80	0.29	90
	Lakitan	2,784	12,634	10,786	5,237	80	0.17	90
	Total	22,048	150,597	99,573	44,718	80	0.95	90
Future Target (2050)	Komering	9,725	98,208	87,712	42,593	80	2.92	90
	Lematang	7,608	55,160	29,518	12,392	80	2.60	90
	Kelingi	1,931	15,387	11,470	5,348	80	1.04	90
	Lakitan	2,784	12,634	10,786	5,237	80	0.62	90
	Total	22,048	181,388	139,487	65,569	80	7.18	90

*MH: Paddy in rainy season, MK1: Paddy in dry season, MK2: Secondary crop in dry season
** DMI: Water demand for domestic and industry
*** Water demand: Non-Revenue Water (NRW) is included.
Source: JICA Project Team 2

There are two planned dam reservoirs in the Komering River Basin as shown in Figure B 3.4.2. Tiga Dihaji Dam of which purposes are supply of DMI and Irrigation water and hydropower generation have been under construction since 2018 and is expected to be completed in 2022. Saka Dam has been also planned for the purposes of DMI and Irrigation water and hydropower generation in the feasibility study in 2013. In addition to these two dams reservoirs, the modification of the operation of RRF (Ranau Regulating Facility) is also expected to very much contribute to the mitigation of the water shortage in the Komering river basin, although its environmental issues are yet to be cleared.

In the Lematang River Basin there are a planned dam and two proposed dam sites that might be effective for the mitigation of the water shortage in the river basin. For Padang Bindu Dam a pre-feasibility study was conducted in 2015, but almost no study has been conducted for Tanjung Agung and Panjung Dams. Their approximate locations only are indicated as potential hydropower dam sites in some documents of BBWS-S8.

In the Kelingi and Lakitan River Basins, which are also vulnerable to water shortage, there is no planned/proposed dam sites so far.

In order to evaluate the effect of these dam reservoirs and then to establish long-term strategies for the water resources development in the Musi River Basin, water balance analysis is conducted under the conditions presented in Table B 3.4.4.

Table B 3.4.3 Planned/Proposed Dams

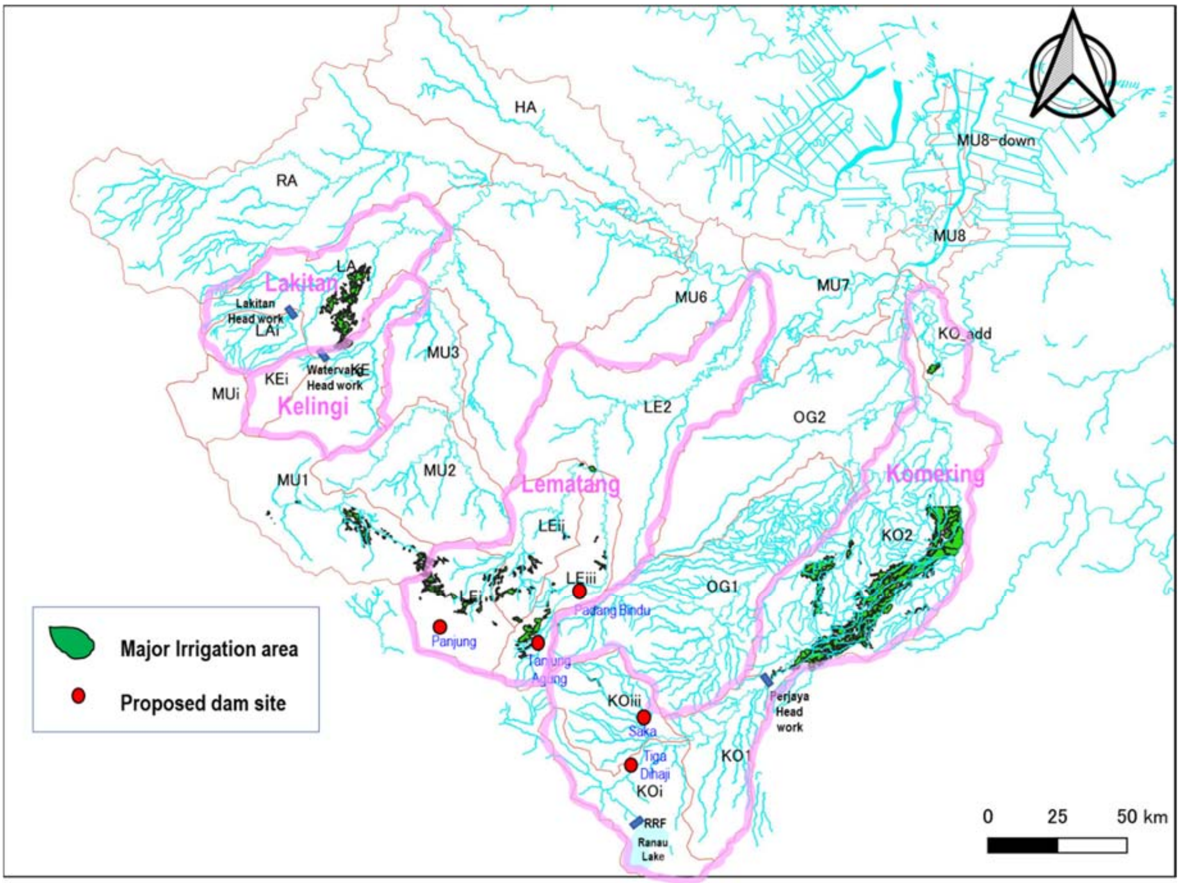
Sub-river system	Name of dam	Purpose	River	Catchment Area (km^2)	Type of Dam	Dam Height (m)	Total Storage Volume (MCM)	Effective Storage Volume (MCM)	Present Status
Komering	Tiga Dihaji	DMI water, Irrigation and hydropower,	Komering River	1,156	Rock-fill	122	106	65	Under Construction since 2018
	Saka	DMI water, Irrigation and hydropower,	Saka River	386	Rock-fill	75	43	20	F/S completed in 2013
Lematang	Padang Bindu	DMI water, Irrigation and hydropower,	Enim River	468	Rock-fill with center core	109	110	53	Pre-F/S completed in 2015
	Tanjung Agung*	Hydropower	-	226	Not Specified	130	80	43	Potential dam
	Panjung*	Hydropower	Lahat River	220	Not specified	170	150	106	Potential dam

*: The two potential dams, Tanjung Agung Dam and Panjung Dam are very roughly designed based on SRTM DEM data.
Source: BBWS-S8 and JICA Project Team 2

Table B 3.4.4 Conditions of Water Balance Analysis

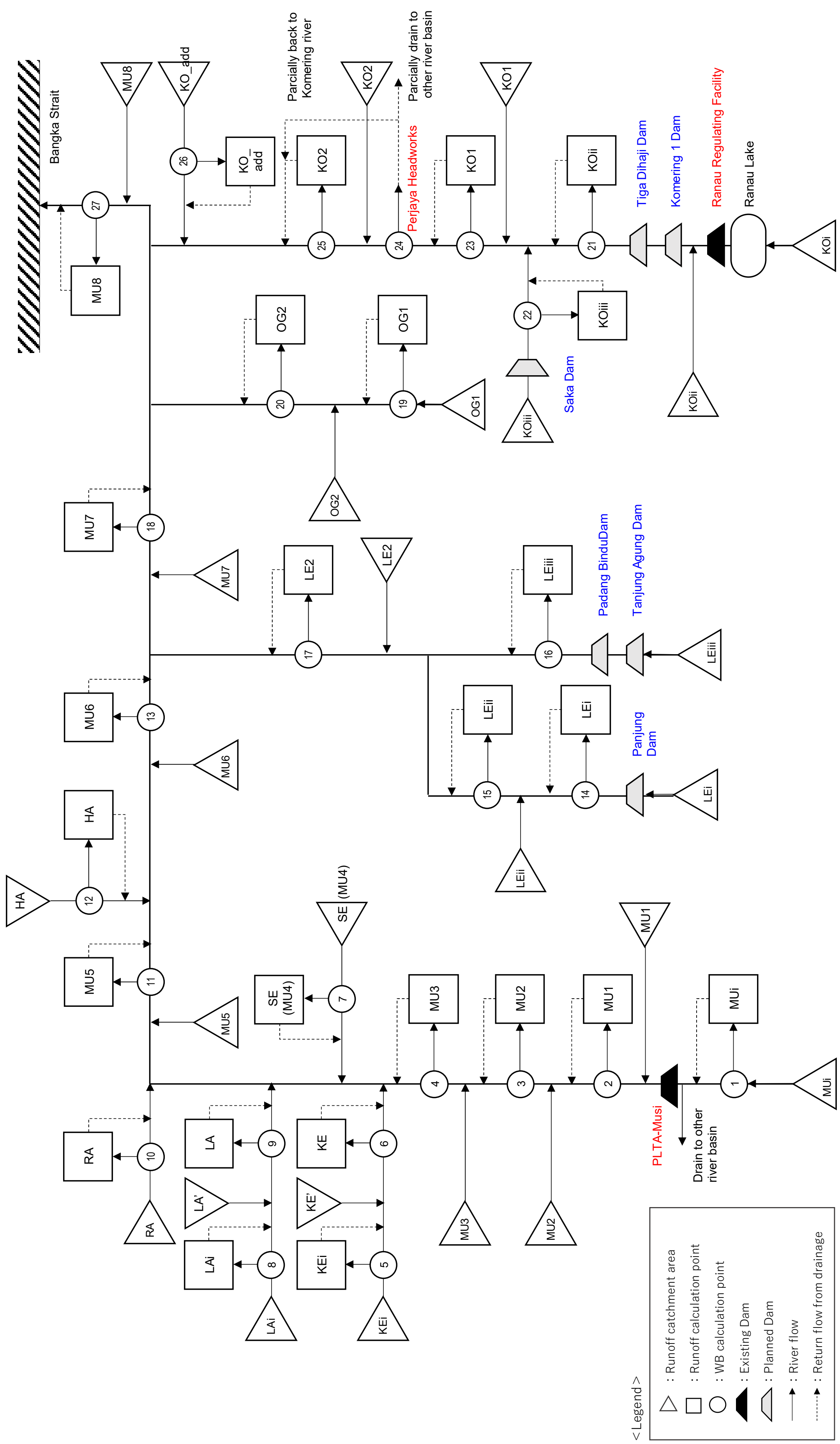
Item	Condition
Analysis Area	Komering River Basin: 9,725km^2, Lematang River Basin: 7,608 km^2, Kelingi River Basin: 1,931 km^2, Lakitan River Basin: 2,784 km^2
Calculation Period	Present Case: 15 years from (October 1985 to September 2000), Future Case: 15 years (October 2050 to September 2065)
Discharge Data	Runoff Analysis Data Provided by JICA Project Team 1 are used.
Water Demand	DMI Water Demand and Irrigation Water Demand are considered. Newly estimated irrigation demand explained in the main report are used as the Irrigation Water Demand.
Calculation unit time	10 days
River maintenance flow	Maintenance flow is set up for Downstream of RRF: 11.7m^3/s, Downstream of Perjaya Headwork:35m^3/s for rainy season and 25 m^3/s for dry season, Downstream of dam sites: 95% discharge of duration curve of natural flow.
Hydropower generation at dams	Hydropower generation is considered for Tiga Dihaji and Saka Dams and the small hydropower station just downstream of RRF but not considered for the three dams in Lematang River Basin because information is insufficient.

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure B 3.4.2 Location of Planned/Proposed Dam Sites and Major Irrigation Areas

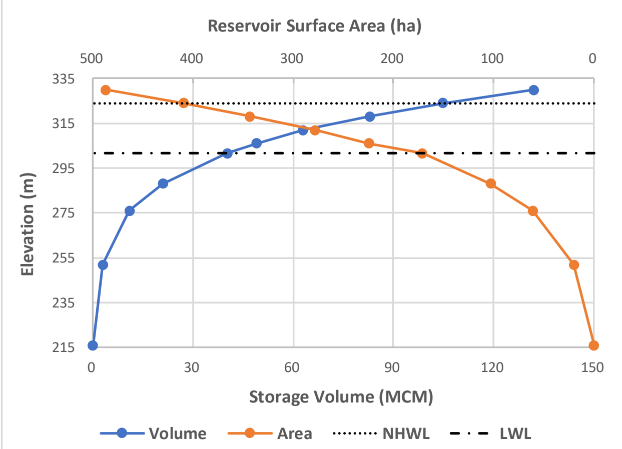


Source: JICA Project Team 2

Figure B 3.4.3 Schematic Figure of Water Balance Model with Future Dams

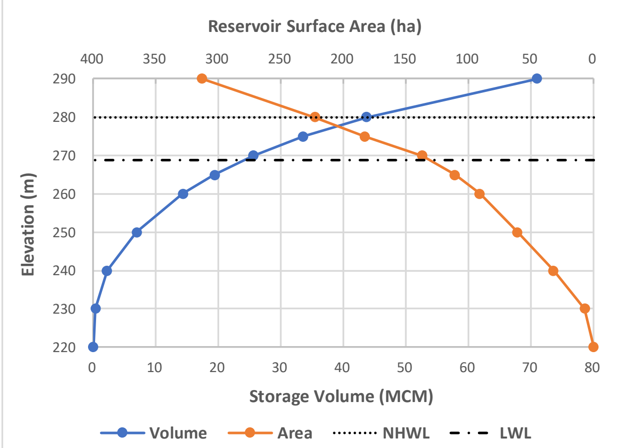
Tiga Dihaji Dam

Elevation (m)	Area (ha)	Volume (MCM)
330.0	487	132.0
324.0	409	104.8
318.0	343	83.0
312.0	278	63.0
306.0	224	49.0
301.6	171	40.2
288.0	103	21.0
276.0	61	11.0
252.0	20	3.0
216.0	0	0.0



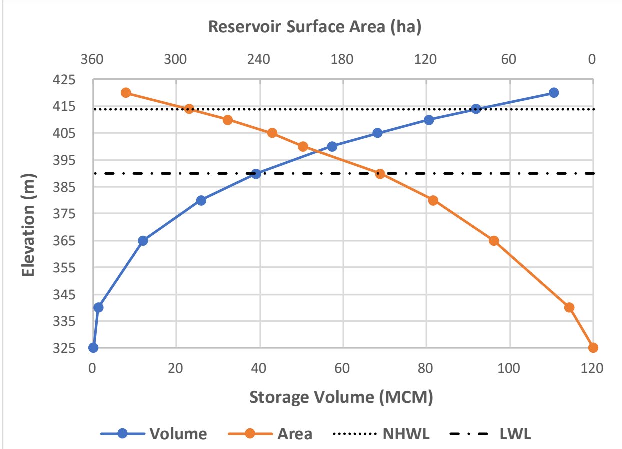
Saka Dam

Elevation (m)	Area (ha)	Volume (MCM)
290.0	313	71.0
280.0	223	43.7
275.0	183	33.6
270.0	137	25.6
265.0	111	19.4
260.0	91	14.3
250.0	61	6.9
240.0	32	2.2
230.0	7	0.4
220.0	0	0.0



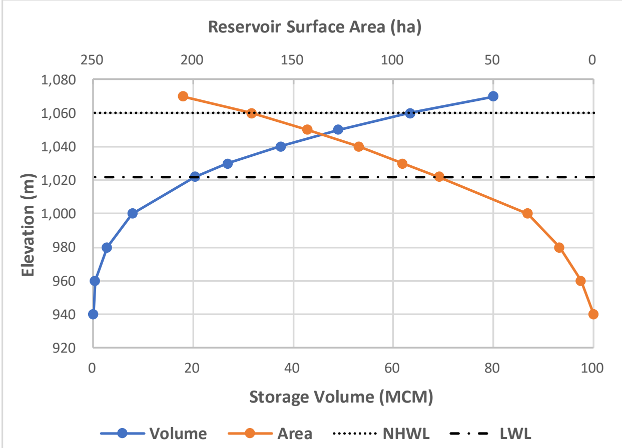
Padan Bindu Dam

Elevation (m)	Area (ha)	Volume (MCM)
420.0	336	110.5
414.0	291	91.9
410.0	263	80.6
405.0	231	68.3
400.0	209	57.3
389.9	153	39.1
380.0	115	25.8
365.0	72	11.9
340.0	17	1.2
325.0	0	0.0



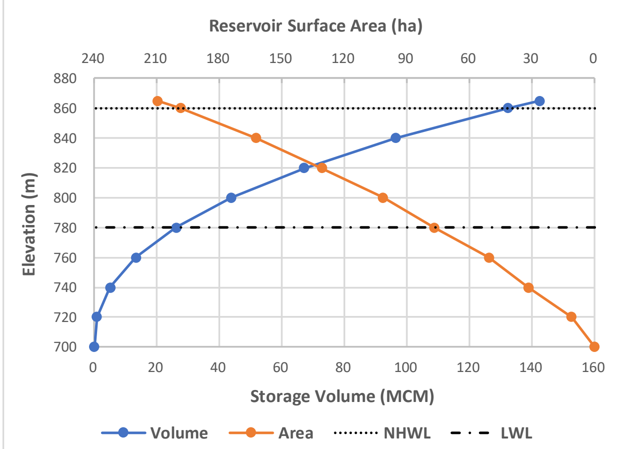
Tanjung Agung Dam

Elevation (m)	Area (ha)	Volume (MCM)
1070.0	205	80.0
1060.0	171	63.3
1050.0	143	49.0
1040.0	118	37.4
1030.0	96	26.8
1022.0	77	20.3
1000.0	33	7.8
980.0	17	2.8
960.0	6	0.4
940.0	0	0



Panjung Dam

Elevation (m)	Area (ha)	Volume (MCM)
865.0	210	142.5
860.0	199	132.3
840.0	162	96.4
820.0	131	67.1
800.0	102	43.9
780.0	77	26.2
760.0	51	13.3
740.0	32	5.1
720.0	11	0.9
700.0	0	0



Source: JICA Project Team 2

Figure B 3.4.4 H-A-V Tables Applied for the Water Balance Analysis

(3) Results of water balance analysis

a) Komering River Basin

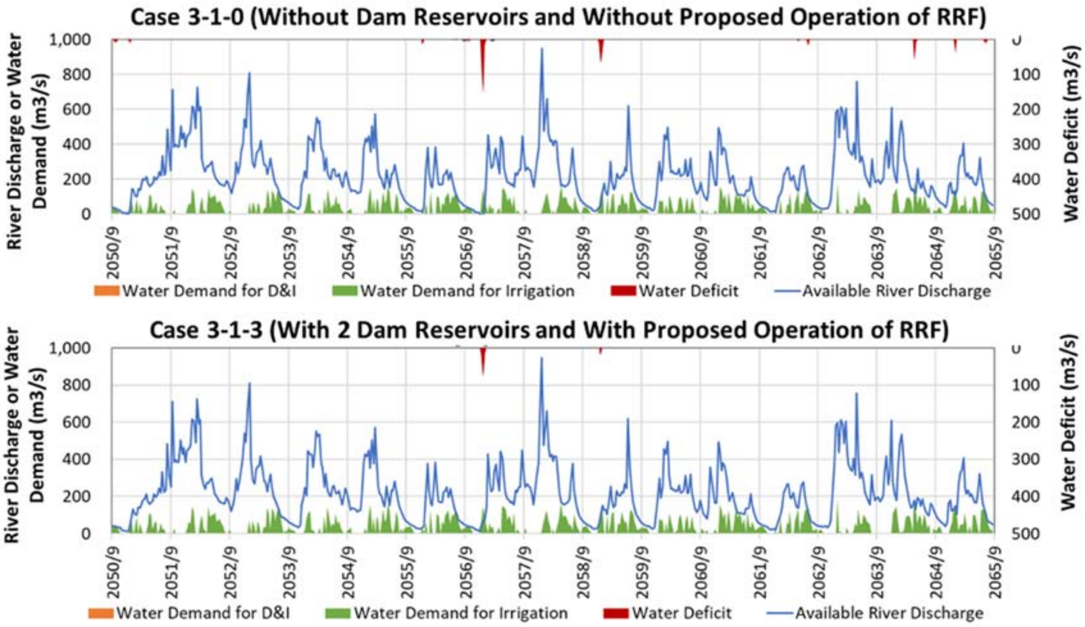
Results of the water balance analysis are summarized in Table B 3.4.5. Figure B 3.4.5 compares the water deficits at Perjaya Headwork to grasp how much the water deficit could be reduced by the two new dam reservoirs and the proposed operation of RRF, of which operations are shown in Figure B 3.4.6. From the table and the figures following considerations are made:

- The water deficit at Perjaya Headwork will be reduced considerably by the three measures, Tiga Dihaji Dam, Saka Dam and the modification of the RRF operation. However, some more measures are necessary to completely reduce it to the required safety level (90% for DMI water and 80% for irrigation water) or zero.
- Low Scenario seems to be more severe in terms of the sufficiency rates and the deficit volume than Medium Scenario.
- The water shortage affects the irrigation water, while the DMI water sufficiency rate is almost 100% in all the cases.

Table B 3.4.5 Results of Water Balance Simulation for Komering River Basin

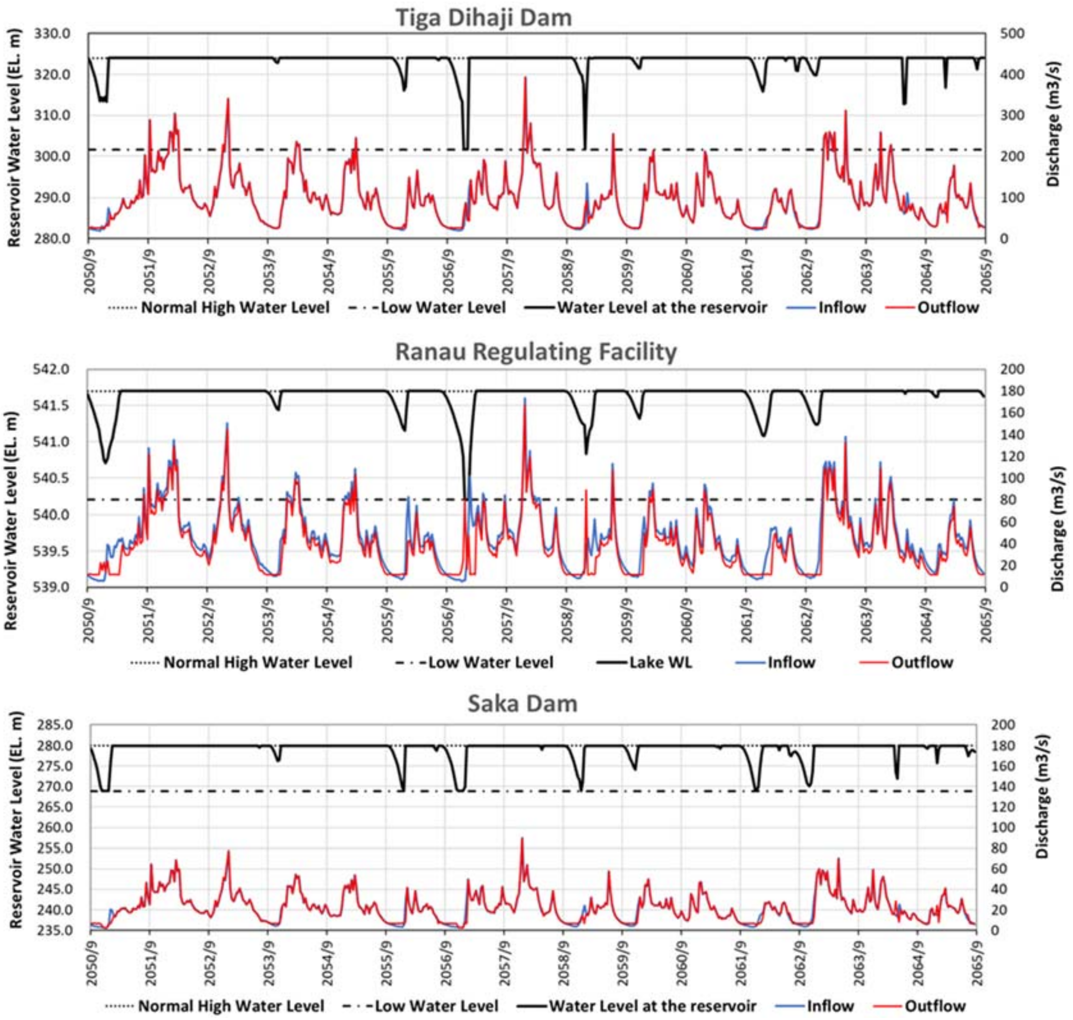
Case No.	Scenario	Irrigation Area	Dam Reservoir		RRF Operation	DMI Sufficiency Rate	Irrigation Sufficiency Rate			Deficit (MCM/yr)	Frequency of drought year	Power Generation (10^6 kWh/yr)
			Tiga Dihaji	Saka			MH	MK1	MK2			
1-1	Present	Present	No	No	No	100.0%	91.9%	92.2%	97.4%	51.4	80.0%	9.39
2-0	Low	Present	No	No	No	99.9%	92.0%	94.4%	98.7%	63.2	53.3%	30.6
2-1-0	Low	Future	No	No	No	100.0%	90.9%	87.5%	96.6%	113.3	73.3%	61.2
2-1-1	Low	Future	Yes	No	No	100.0%	90.9%	92.0%	97.5%	84.8	73.3%	543.9
2-1-2	Low	Future	Yes	No	Yes	99.9%	93.9%	96.1%	95.5%	69.4	73.3%	544.4
2-1-3	Low	Future	Yes	Yes	Yes	99.9%	93.8%	95.4%	95.5%	67.8	60.0%	631.0
3-0	Medium	Present	No	No	No	99.9%	90.0%	99.2%	100.0%	43.6	66.7%	24.8
3-1-0	Medium	Future	No	No	No	100.0%	85.6%	96.3%	97.6%	61.3	86.7%	49.6
3-1-1	Medium	Future	Yes	No	No	100.0%	91.6%	100.0%	100.0%	32.0	80.0%	448.3
3-1-2	Medium	Future	Yes	No	Yes	100.0%	95.7%	100.0%	100.0%	18.9	80.0%	448.3
3-1-3	Medium	Future	Yes	Yes	Yes	100.0%	95.9%	100.0%	100.0%	10.5	40.0%	520.1
4-0	High	Present	No	No	No	99.8%	73.7%	93.5%	97.7%	107.2	80.0%	22.4
4-1-0	High	Future	No	No	No	99.9%	70.8%	87.6%	95.9%	152.3	93.3%	44.8
4-1-1	High	Future	Yes	No	No	99.9%	79.1%	93.3%	96.8%	101.9	93.3%	404.8
4-1-2	High	Future	Yes	No	Yes	99.9%	86.0%	98.6%	93.1%	76.5	93.3%	404.9
4-1-3	High	Future	Yes	Yes	Yes	99.9%	84.8%	98.5%	94.8%	61.8	73.3%	470.5

DMI Water Sufficiency rate (%) = Supplied Water/Water Demand
Irrigation Water Sufficiency Rate (%) = Average of annually minimums of values of Supplied Water/Water Demand
Source: JICA Project Team 2



Source: JICA Project Team 2

Figure B 3.4.5 Comparison of Water Deficit at Perjaya Headwork



Source: JICA Project Team 2

Figure B 3.4.6 Operation of Tiga Dihaji Dam and Saka Dam and RRF (Case 3-1-3)

b) Lematang River Basin

Regarding the Padang Bindu Dam of which a pre-feasibility study was already conducted in 2015, basic information such as dam height, the reservoir capacity, dam dimensions was obtained and utilized for this Project. However, almost no information on the two potential dams, Tanjung Agung and Panjung except for their approximate locations. So the JICA Project Team 2 designed the two potential dams very roughly as the topographically allowably highest dams, based on SRTM DEM data only for the water balance analysis. Therefore, it should be noted that the JICA Project Team 2 cannot guarantee the viability of the two potential dam sites.

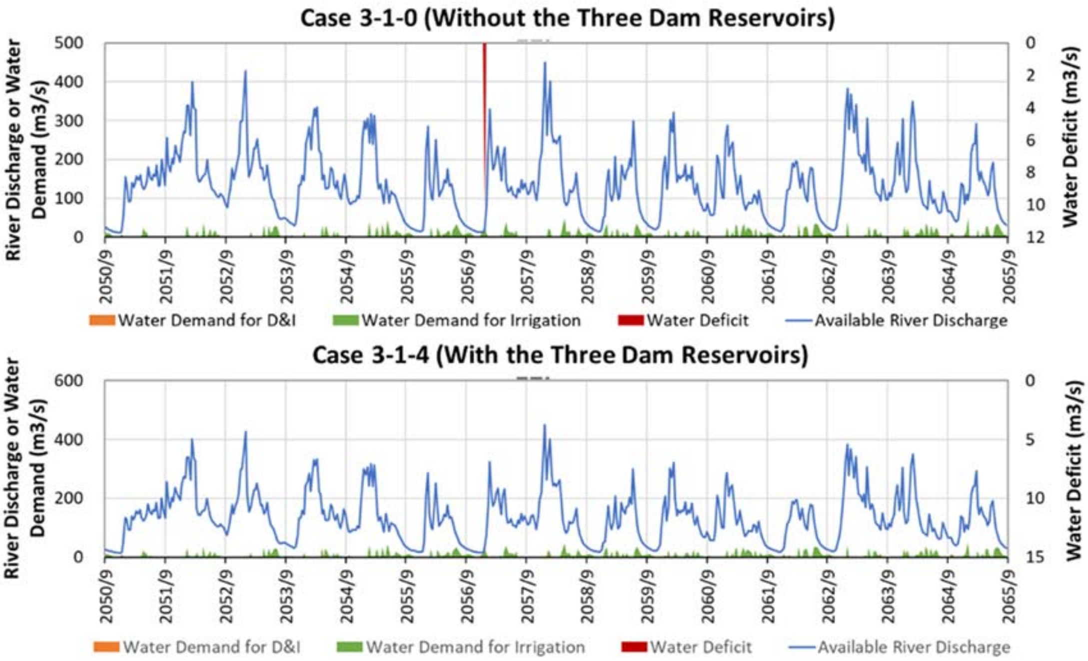
Results of the water balance analysis are summarized in Table B 3.4.6 Figure B 3.4.7 compares the water deficits in the LEi Sub-river Basin to check how much the water deficit could be reduced by the three new dam reservoirs, of which operations are shown in Figure B 3.4.8. From the table and the figures following considerations are made:

- The water deficit in the Lematang River Basin as well as at the sub-basin LEi will be eliminated by the three dams.
- As seen in Figure B 3.4.8, however, the large storage volumes of the three dams are not fully used. Their reservoir water levels have never been even once lowered to the LWLs (Low Water Levels) in the 15 years. The reservoir capacities are too large compared with the water demands. It is suggested that more realistic and effective dam reservoirs be planned based on more detail surveys including geological survey.
- Medium Scenario seems to be the most severe in terms of the sufficiency rates and the deficit volume among the three scenarios.
- The water shortage affects the irrigation water, while the DMI water sufficiency rate is almost 100% in all the cases.

Table B 3.4.6 Results of Water Balance Simulation for Lematang

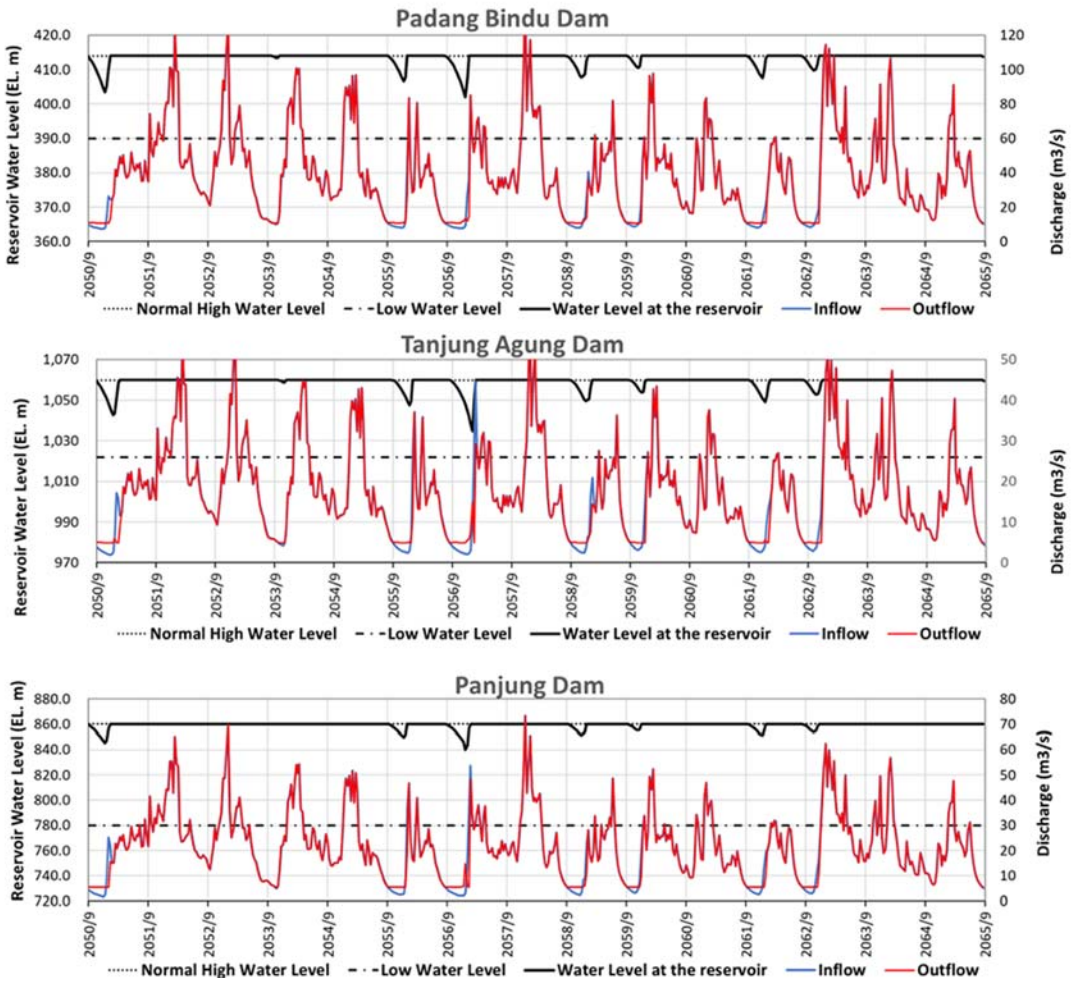
Case No.	Scenario	Irrigation Area	Dam Reservoir			DMI Sufficiency Rate	Irrigation Sufficiency Rate			Deficit (MCM/yr)	Frequency of drought year
			Padang Bindu	Tanjung Agung	Panjung		MH	MK1	MK2		
1-1	Present	Present	No	No	No	100.0%	88.2%	93.7%	98.5%	44.4	93.3%
2-0	Low	Present	No	No	No	100.0%	94.2%	97.1%	100.0%	13.9	86.7%
2-1-0	Low	Future	No	No	No	99.5%	99.9%	100.0%	99.2%	7.0	46.7%
2-1-1	Low	Future	Yes	No	No	99.6%	99.9%	100.0%	99.5%	4.5	46.7%
2-1-2	Low	Future	Yes	Yes	No	99.8%	99.9%	100.0%	99.8%	3.2	46.7%
2-1-3	Low	Future	Yes	No	Yes	99.9%	100.0%	100.0%	99.7%	1.3	33.3%
2-1-4	Low	Future	Yes	Yes	Yes	100.0%	100.0%	100.0%	100.0%	0.0	0.0%
3-0	Medium	Present	No	No	No	100.0%	93.0%	98.5%	100.0%	33.9	86.7%
3-1-0	Medium	Future	No	No	No	98.5%	97.2%	100.0%	98.6%	31.8	60.0%
3-1-1	Medium	Future	Yes	No	No	99.1%	97.8%	100.0%	99.2%	16.3	60.0%
3-1-2	Medium	Future	Yes	Yes	No	99.5%	98.5%	100.0%	99.7%	8.7	60.0%
3-1-3	Medium	Future	Yes	No	Yes	99.5%	99.3%	100.0%	99.5%	7.6	60.0%
3-1-4	Medium	Future	Yes	Yes	Yes	100.0%	100.0%	100.0%	100.0%	0.0	0.0%
4-0	High	Present	No	No	No	100.0%	81.6%	92.9%	96.5%	63.5	100.0%
4-1-0	High	Future	No	No	No	98.5%	98.3%	99.5%	98.4%	26.1	66.7%
4-1-1	High	Future	Yes	No	No	99.1%	98.7%	99.7%	99.1%	13.8	66.7%
4-1-2	High	Future	Yes	Yes	No	99.5%	99.2%	99.9%	99.6%	7.6	66.7%
4-1-3	High	Future	Yes	No	Yes	99.5%	99.6%	99.8%	99.4%	6.2	66.7%
4-1-4	High	Future	Yes	Yes	Yes	100.0%	100.0%	100.0%	100.0%	0.0	0.0%

DMI Water Sufficiency rate (%) = Supplied Water/Water Demand
Irrigation Water Sufficiency Rate (%) = Average of annually minimums of values of Supplied Water/Water Demand
Source: JICA Project Team 2



Source: JICA Project Team 2

Figure B 3.4.7 Comparison of Water Deficit in Sub-Basin LEi



Source: JICA Project Team 2

Figure B 3.4.8 Operation of Padang Bindu, Tanjung Agung and Panjung Dams

c) Kelingi and Lakitan River Basins

There is no planned/proposed dam site in the Kelingi and Lakitan River Basins, although water shortage is anticipated according to the water balance analysis in the Progress Report 4. A water balance analysis is conducted to assess the climate change impact on water use for the two river basins.

Results of the water balance analysis are summarized in Table B 3.4.7 and Table B 3.4.8. Figure B 3.4.9 and Figure B 3.4.10 compare the water deficits in the sub-rivers, KEi and LAi. From these tables and figures following considerations are made:

- For both the two river basins Medium Scenario is the most severe scenario in terms of the sufficiency rates and the deficit volume among the three scenarios.
- In the Kelingi River Basin irrigation water shortage will occur in all the scenarios.
- In High Scenario of the Lakitan River Basin no water shortage will occur. However, irrigation water shortage will occur in Low and Medium Scenario.

Table B 3.4.7 Results of Water Balance Simulation for Kelingi River Basin

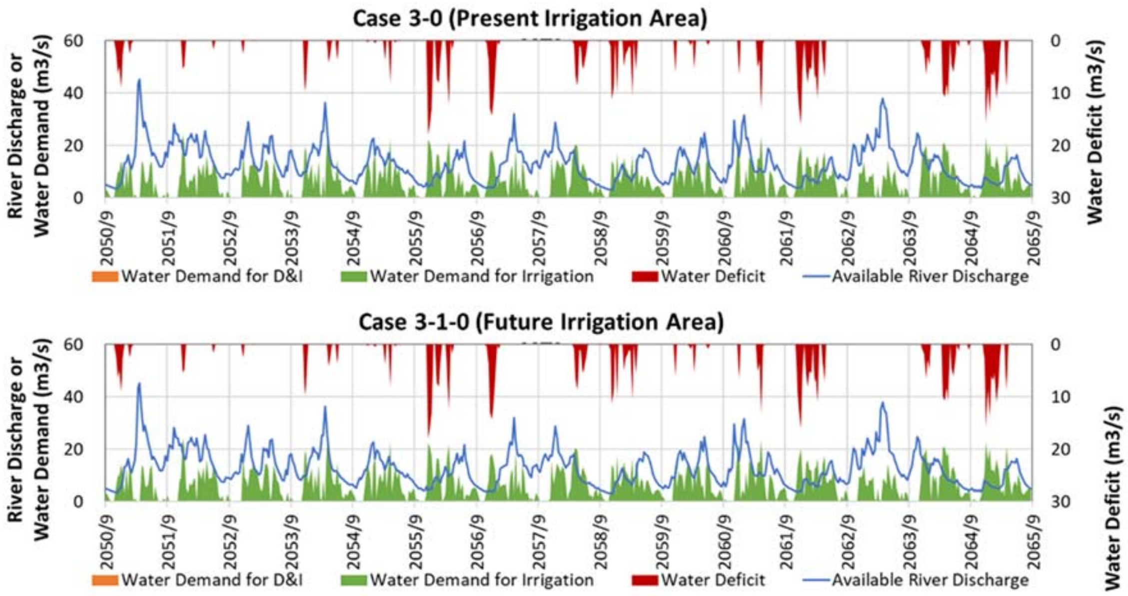
Case No.	Scenario	Irrigation Area	DMI Sufficiency Rate	Irrigation Sufficiency Rate			Deficit (MCM/yr)	Frequency of drought year (%)
				MH	MK1	MK2		
1-1	Present	Present	100.0%	88.0%	96.7%	100.0%	6.0	60.0%
2-0	Low	Present	100.0%	93.3%	100.0%	100.0%	2.1	26.7%
2-1-0	Low	Future	100.0%	94.3%	100.0%	100.0%	1.6	26.7%
3-0	Medium	Present	100.0%	58.5%	78.4%	98.0%	42.5	93.3%
3-1-0	Medium	Future	100.0%	60.7%	81.2%	98.4%	35.9	93.3%
4-0	High	Present	100.0%	94.6%	99.5%	100.0%	1.4	33.3%
4-1-0	High	Future	100.0%	95.8%	99.9%	100.0%	0.9	33.3%

DMI Water Sufficiency rate (%) = Supplied Water/Water Demand
Irrigation Water Sufficiency Rate (%) = Average of annually minimums of values of Supplied Water/Water Demand
Source: JICA Project Team 2

Table B 3.4.8 Results of Water Balance Simulation for Lakitan River Basin

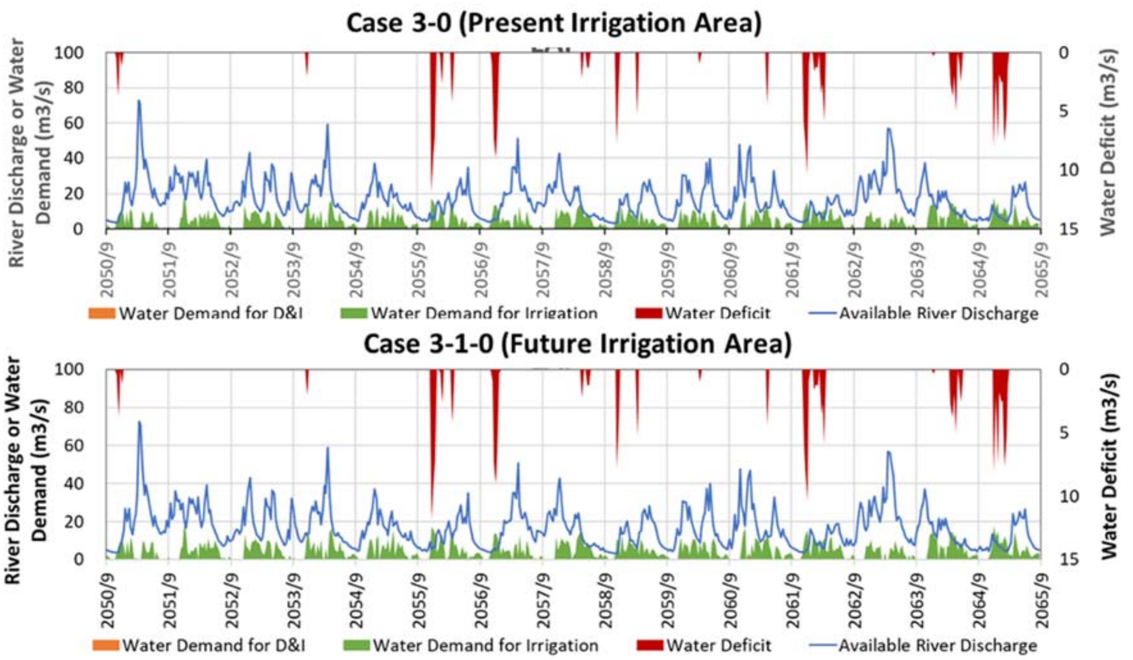
Case No.	Scenario	Irrigation Area	DMI Sufficiency Rate (%)	Irrigation Sufficiency Rate (%)			Deficit (MCM/yr)	Frequency of drought year (%)
				MH	MK1	MK2		
1-1	Present	Present	100.0%	97.4%	100.0%	100.0%	0.7	26.7%
2-0	Low	Present	100.0%	99.1%	100.0%	100.0%	0.1	6.7%
2-1-0	Low	Future	100.0%	99.6%	100.0%	100.0%	0.1	6.7%
3-0	Medium	Present	100.0%	78.9%	94.4%	100.0%	14.5	80.0%
3-1-0	Medium	Future	100.0%	84.8%	96.6%	100.0%	11.0	73.3%
4-0	High	Present	100.0%	100.0%	100.0%	100.0%	0.0	0.0%
4-1-0	High	Future	100.0%	100.0%	100.0%	100.0%	0.0	0.0%

DMI Water Sufficiency rate (%) = Supplied Water/Water Demand
Irrigation Water Sufficiency Rate (%) = Average of annually minimums of values of Supplied Water/Water Demand
Source: JICA Project Team 2



Source: JICA Project Team 2

Figure B 3.4.9 Comparison of Water Deficit in Sub-Basin KEi (Watervang Headwork)



Source: JICA Project Team 2

Figure B 3.4.10 Comparison of Water Deficit in Sub-Basin LAi (Lakitan Headwork)

CHAPTER B4 APPENDIX

B4.1 River Cross Section

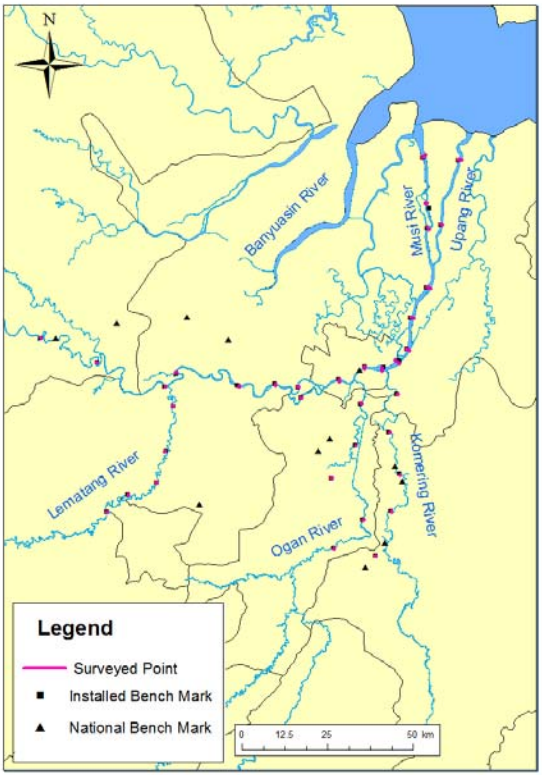
Regarding topographical information on the rivers, there were only available bathymetry survey data for the lowest Musi River stretch below Palembang. For the flood inundation analysis, river cross section data covering river banks as well as river channel are indispensable for river stretches in flood inundation areas. Under the Project, cross section survey was conducted for the Musi River and its major tributaries as shown in Table B 4.1.1 and Figure B 4.1.1.

All elevation data of the survey products have been reduced to the BAKOSURTANAL datum (referred to as "mean sea level or msl" hereinafter) that is equivalent to the average of mean sea levels at seven tide stations around Sumatra Island, namely Malahayati, Sibolga, Telukbayur Padang, Bengkulu, Long-Lampung and Dumai Stations.

Table B 4.1.1 Summary of Cross Section Survey

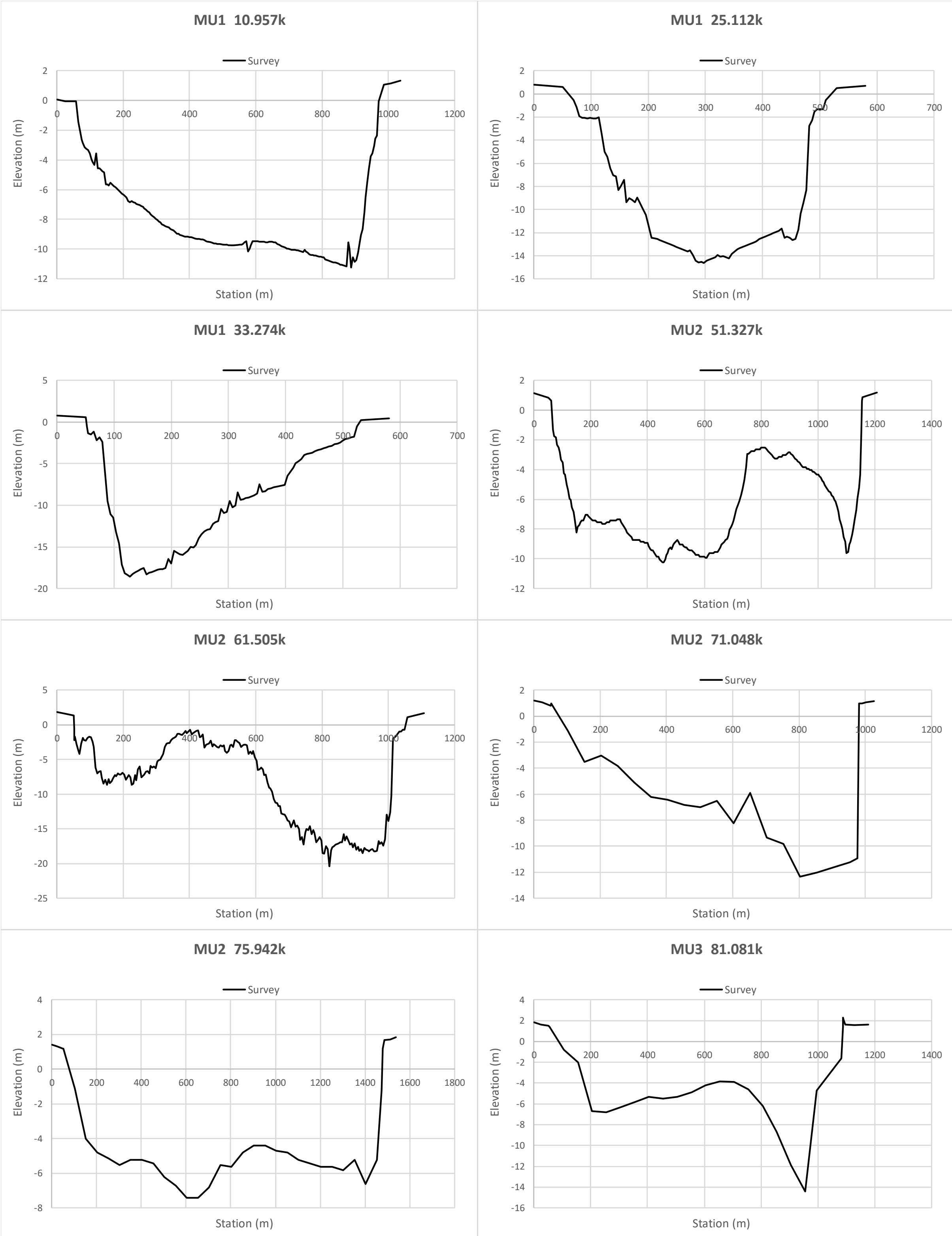
No	River	Number of Cross Section	Stretch and Interval
1	Musi River (Mid-Lower reaches)	20	Stretch: River mouth – 250km Interval: Approx. 10km
2	Komering River	5	Stretch: 50km upstream from conjunction point to Musi River (Kayu Agung) Interval: Approx. 10km
3	Ogan River	5	Stretch: 50km upstream from conjunction point to Musi River (Tanjung Raja) Interval: Approx. 10km
4	Lematang River	5	Stretch: 50km upstream from conjunction point to Musi River (Muara Enim) Interval: Approx. 10km
	Total	35	

Source: JICA Project Team 2



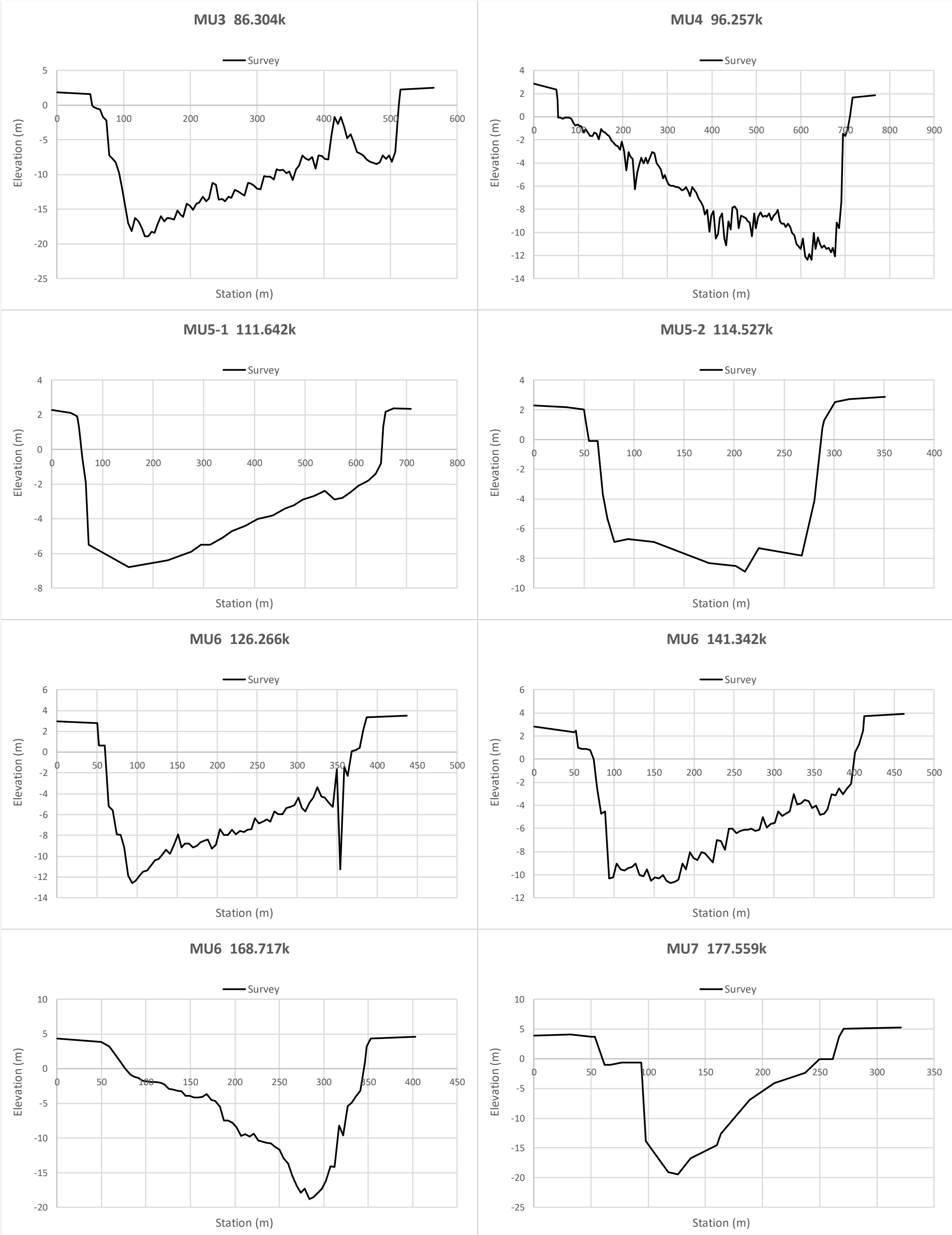
Source: JICA Project Team 2

Figure B 4.1.1 Location of Cross Section Survey



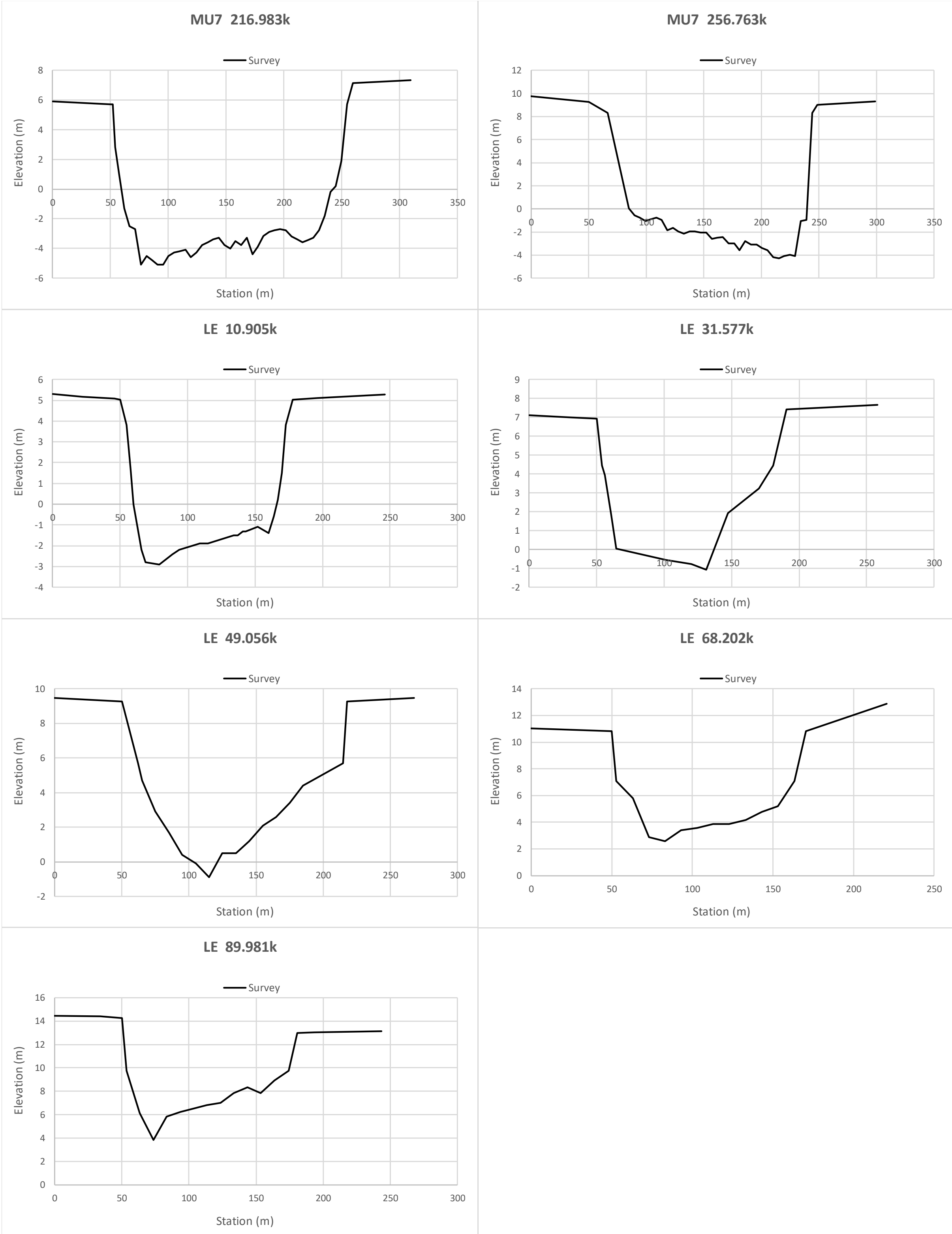
Source: JICA Project Team 2

Figure B 4.1.2 Cross Section of Musi River (MU) (1/3)



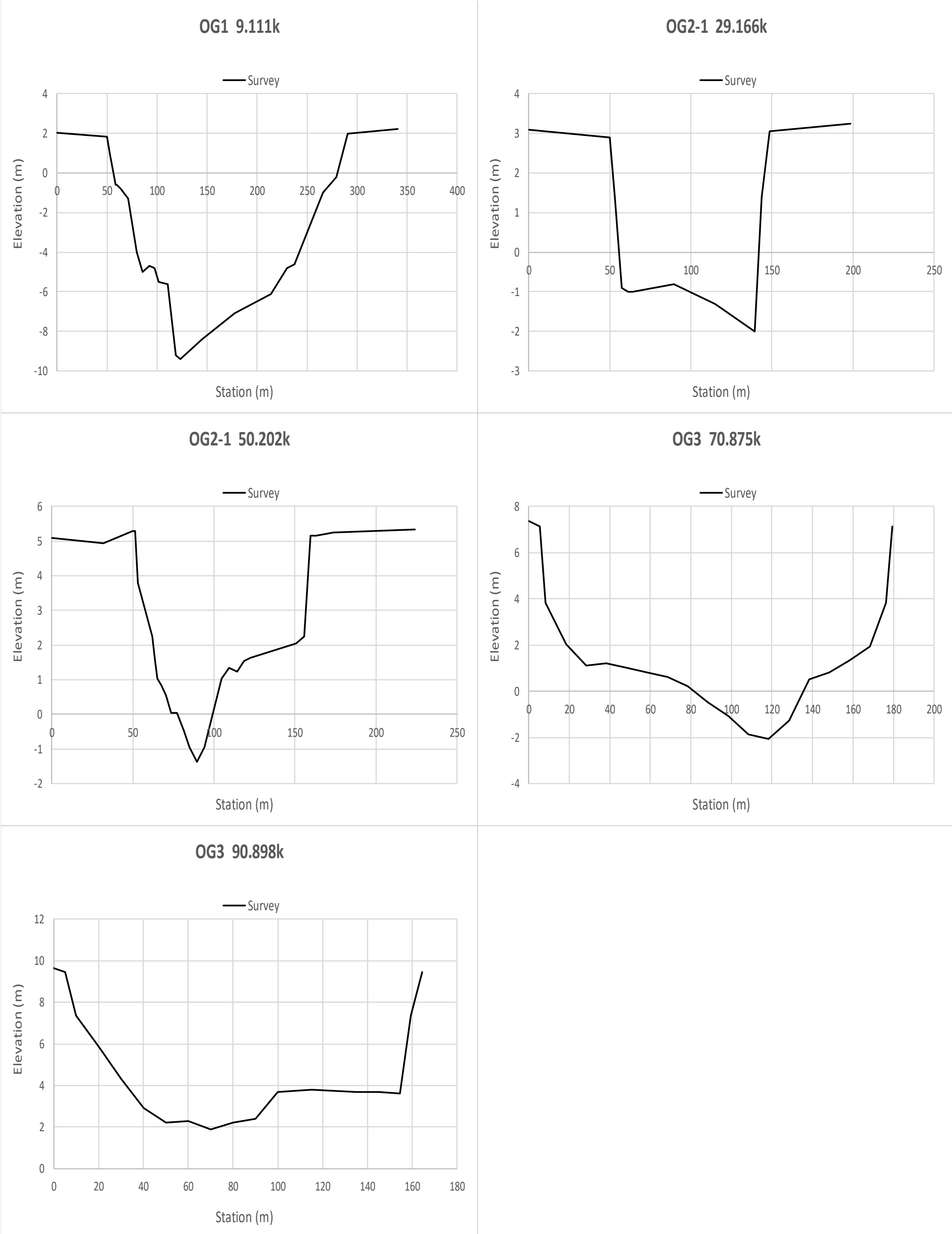
Source: JICA Project Team 2

Figure B 4.1.3 Cross Section of Musi River (MU) (2/3)



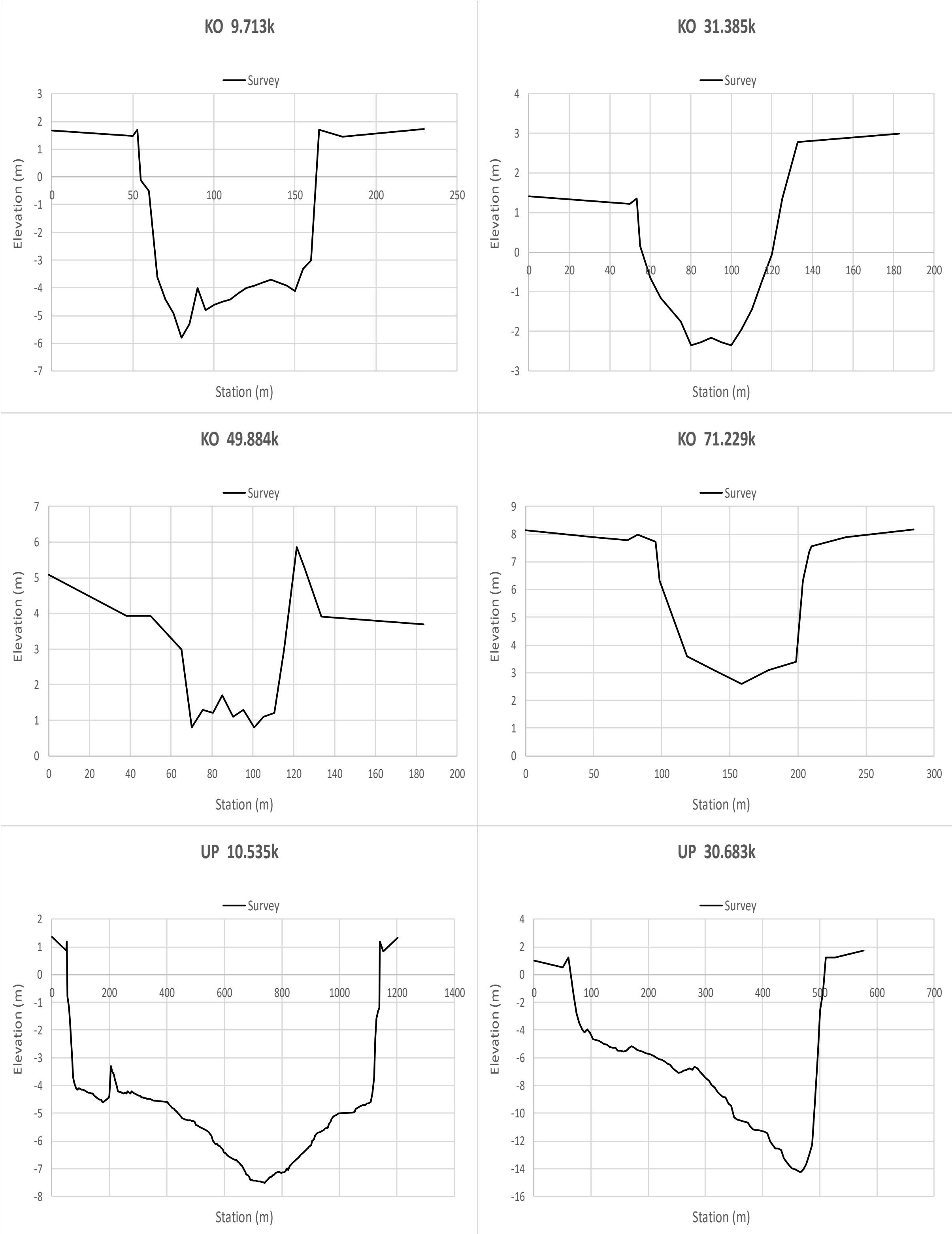
Source: JICA Project Team 2

Figure B 4.1.4 Cross Section of Musi River (MU) (3/3) and Lematang River (LE)



Source: JICA Project Team 2

Figure B 4.1.5 Cross Section of Ogan River (OG)



Source: JICA Project Team 2

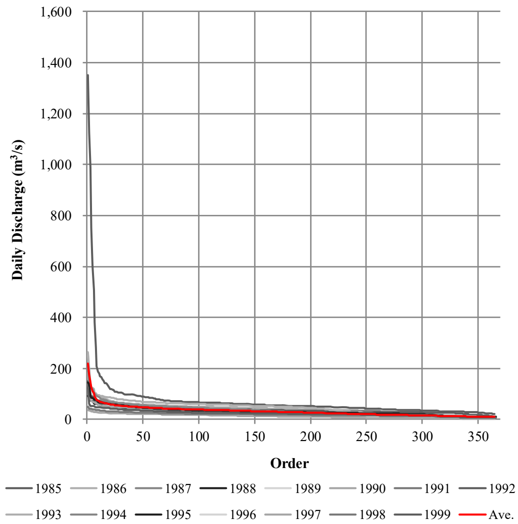
Figure B 4.1.6 Cross Section of Komering River (KO) and Upang River (UP)

B4.2 Calculated Flow Duration Curve and Environmental Flow

As explained in the section B3.2.6, flow duration curves were made to calculate environmental flow at each sub river basin.

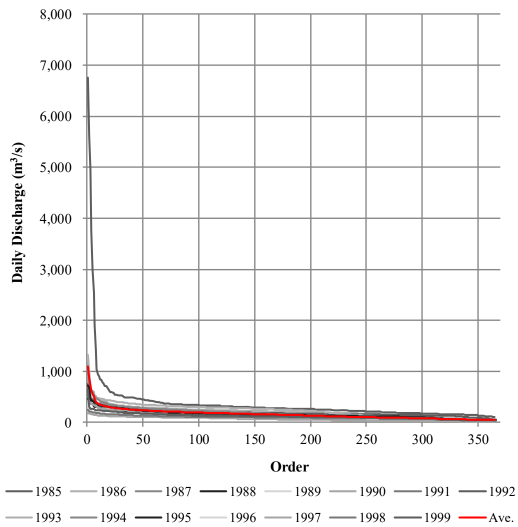
MUi

	Discharge (m^3/s)					
	D95	D185	D275	D347	D355	Ave.
1985	68.2	53.5	38.3	28.4	25.2	73.4
1986	50.6	40.9	31.0	13.2	12.2	41.9
1987	43.0	24.7	14.7	9.9	9.8	30.7
1988	34.4	24.8	16.1	12.0	11.2	27.6
1989	38.0	26.7	17.4	14.0	13.2	30.8
1990	36.6	25.9	11.0	8.0	7.6	26.1
1991	40.4	22.5	11.7	7.0	6.9	27.3
1992	44.7	34.7	29.5	19.1	15.4	38.2
1993	60.6	48.2	22.2	11.8	10.7	46.2
1994	45.8	28.4	10.8	6.1	5.9	32.5
1995	37.4	28.4	22.9	10.1	9.8	31.5
1996	22.4	20.0	12.9	6.1	5.7	18.4
1997	18.3	11.1	5.1	3.6	3.5	12.2
1998	21.8	17.9	13.4	9.8	9.3	18.9
1999	27.4	21.9	18.6	7.7	7.3	23.8
Ave.	39.3	28.6	18.4	11.1	10.2	32.0
STDEV	13.9	11.4	9.0	6.1	5.2	14.5



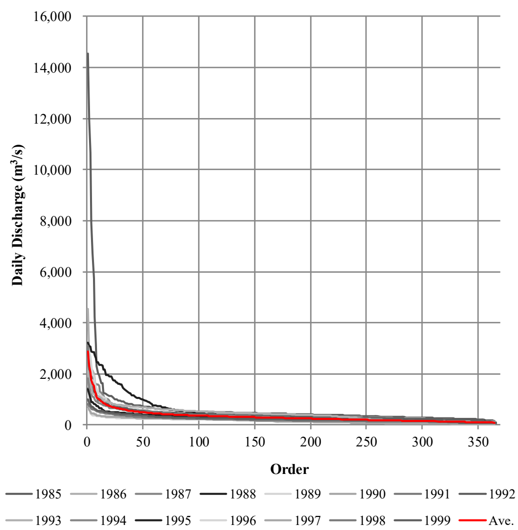
MU1

	Discharge (m^3/s)					
	D95	D185	D275	D347	D355	Ave.
1985	340.9	267.5	191.7	142.2	125.9	367.0
1986	252.8	204.6	154.7	66.0	60.8	209.3
1987	214.8	123.5	73.3	49.5	49.1	153.3
1988	172.2	123.8	80.3	59.8	56.0	138.1
1989	189.8	133.4	86.8	69.8	66.1	154.1
1990	183.1	129.4	54.8	40.0	37.8	130.5
1991	202.2	112.7	58.7	35.2	34.6	136.4
1992	223.4	173.6	147.6	95.5	77.1	191.1
1993	303.1	241.1	111.0	58.8	53.7	231.0
1994	229.1	142.2	53.8	30.3	29.3	162.3
1995	187.1	142.1	114.6	50.4	48.9	157.6
1996	111.9	99.8	64.6	30.3	28.6	92.0
1997	91.5	55.3	25.4	17.9	17.5	61.1
1998	109.0	89.5	66.7	49.0	46.7	94.5
1999	137.1	109.5	92.9	38.7	36.5	119.0
Ave.	196.5	143.2	91.8	55.6	51.2	159.8
STDEV	69.6	56.9	44.8	30.7	25.9	72.5



MU2

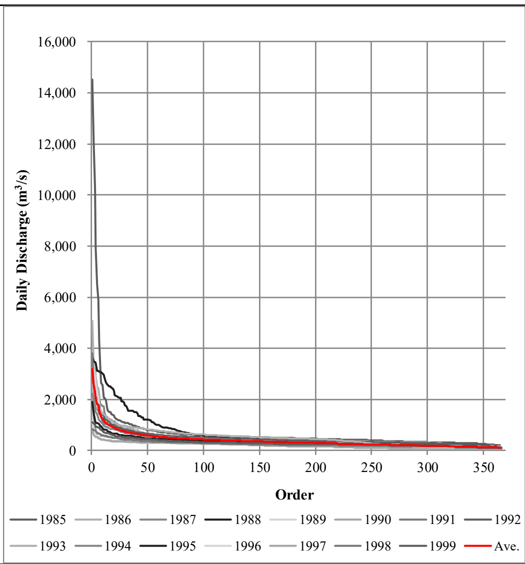
	Discharge (m^3/s)					
	D95	D185	D275	D347	D355	Ave.
1985	533.6	430.3	311.8	225.5	198.1	648.2
1986	444.4	356.0	275.0	160.4	140.8	427.3
1987	392.3	251.7	167.2	127.4	120.0	350.3
1988	484.4	311.9	237.5	159.0	146.3	538.1
1989	374.5	289.0	203.4	150.1	140.5	367.9
1990	299.1	214.9	108.2	76.8	71.5	228.2
1991	390.3	209.2	111.5	53.5	52.6	295.5
1992	433.4	327.0	254.8	192.8	144.2	387.3
1993	546.3	408.3	186.6	103.0	94.3	425.8
1994	395.5	268.0	106.0	66.4	62.8	298.6
1995	339.4	249.7	183.7	82.3	80.8	277.3
1996	213.2	179.4	126.9	58.4	55.5	174.2
1997	230.9	127.9	48.7	34.6	33.8	155.4
1998	244.7	168.1	130.7	99.1	96.3	207.3
1999	277.0	219.1	180.3	79.4	75.9	246.9
Ave.	373.3	267.4	175.5	111.2	100.9	335.2
STDEV	105.6	87.2	72.5	55.7	45.7	136.3



*"DXX" means that the discharge is higher in XX days a year. The value of D347 almost equals to 95% reliable discharge
Source: JICA Project Team 2

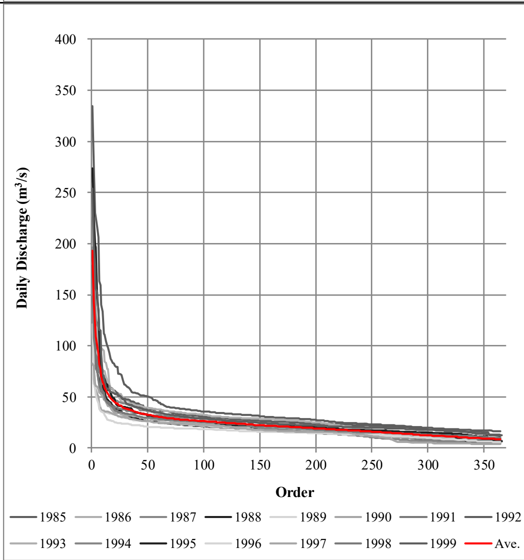
MU3

	Discharge (m³/s)					
	D95	D185	D275	D347	D355	Ave.
1985	608.6	481.9	360.8	273.1	239.5	714.9
1986	510.4	413.7	326.0	193.7	170.7	504.4
1987	470.8	310.4	218.3	156.5	146.9	421.3
1988	609.6	378.7	289.1	203.6	187.1	651.8
1989	447.2	341.1	250.0	192.2	181.7	431.7
1990	349.6	265.7	138.4	100.3	94.0	272.1
1991	457.7	248.9	145.8	72.5	71.8	349.3
1992	518.6	390.8	302.2	228.9	175.2	470.4
1993	632.7	476.3	222.0	126.5	117.0	512.5
1994	465.2	302.2	132.0	84.4	80.5	353.6
1995	394.6	296.0	218.9	101.2	99.7	334.9
1996	261.1	218.4	164.0	79.5	75.8	220.3
1997	277.6	162.4	67.1	50.6	50.0	188.0
1998	297.9	211.7	165.4	131.1	127.0	252.5
1999	329.9	266.3	218.9	114.6	110.6	304.0
Ave.	442.1	317.6	214.6	140.6	128.5	398.8
STDEV	122.0	95.2	81.3	64.8	53.3	152.6



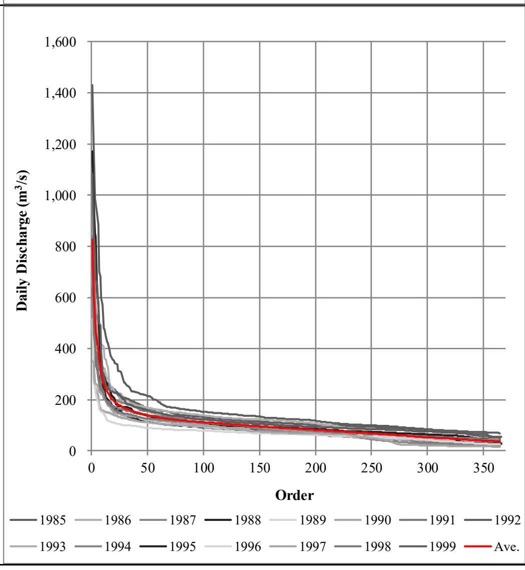
KEi

	Discharge (m³/s)					
	D95	D185	D275	D347	D355	Ave.
1985	36.6	28.7	21.8	17.1	16.8	37.0
1986	29.5	24.2	19.4	10.1	9.2	28.1
1987	21.5	16.6	10.3	7.5	7.4	19.0
1988	21.9	19.0	16.0	11.2	10.8	21.9
1989	22.2	15.7	12.5	10.7	10.5	18.8
1990	22.7	18.5	10.9	8.4	8.2	18.7
1991	29.1	20.3	14.1	6.7	6.5	22.4
1992	31.4	24.8	20.7	15.6	12.7	29.9
1993	33.1	26.7	13.6	8.8	8.1	27.9
1994	28.8	16.2	8.2	5.2	5.1	22.3
1995	24.7	20.7	16.1	7.1	7.0	25.0
1996	18.8	15.1	11.1	6.7	6.4	16.0
1997	24.2	16.1	5.8	4.1	4.0	17.8
1998	26.1	19.3	14.3	10.6	10.1	22.4
1999	29.1	22.6	19.0	13.8	13.4	28.5
Ave.	26.6	20.3	14.2	9.6	9.1	23.7
STDEV	5.0	4.3	4.6	3.7	3.4	5.7



KE

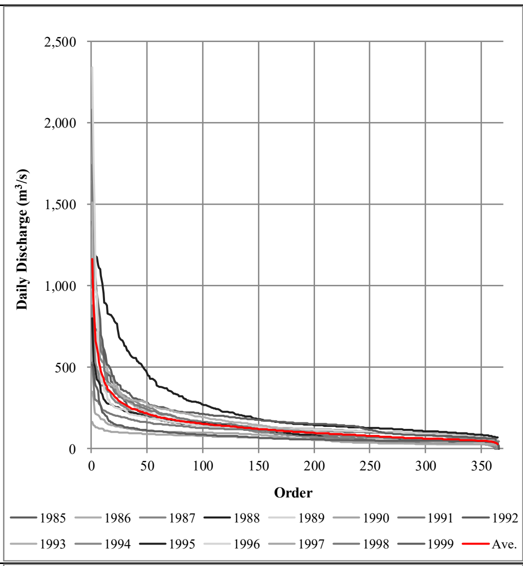
	Discharge (m³/s)					
	D95	D185	D275	D347	D355	Ave.
1985	156.5	122.9	93.4	73.3	72.1	158.2
1986	126.1	103.8	83.0	43.0	39.4	120.3
1987	92.1	71.1	44.1	32.1	31.5	81.1
1988	93.8	81.2	68.3	47.8	46.2	93.9
1989	95.2	67.0	53.4	45.9	44.8	80.4
1990	96.9	79.2	46.5	35.9	34.9	80.3
1991	124.8	86.8	60.2	28.5	27.7	95.9
1992	134.3	106.0	88.6	66.7	54.3	127.9
1993	141.6	114.3	58.4	37.4	34.6	119.4
1994	123.5	69.5	35.1	22.0	21.7	95.4
1995	105.7	88.4	68.8	30.5	30.0	107.2
1996	80.3	64.7	47.3	28.8	27.2	68.7
1997	103.4	68.8	25.0	17.7	17.2	76.2
1998	111.5	82.7	61.0	45.5	43.3	95.9
1999	124.7	96.9	81.4	59.1	57.3	122.2
Ave.	114.0	86.9	61.0	41.0	38.8	101.5
STDEV	21.2	18.3	19.9	15.9	14.6	24.2



*"DXX" means that the discharge is higher in XX days a year. The value of D347 almost equals to 95% reliable discharge
Source: JICA Project Team 2

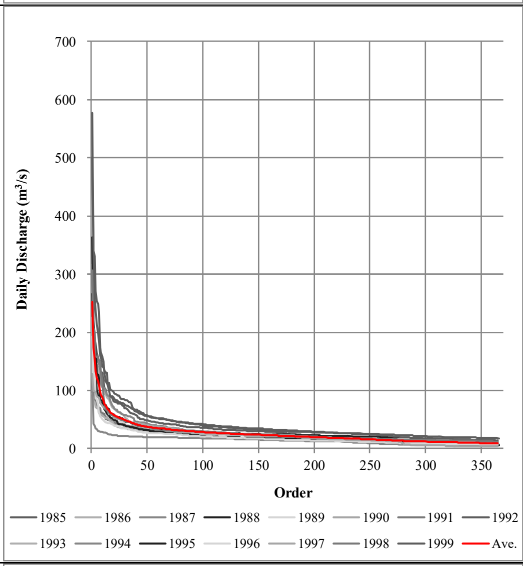
SE

	Discharge (m³/s)					
	D95	D185	D275	D347	D355	Ave.
1985	145.5	115.1	96.8	69.8	67.4	160.2
1986	158.2	125.1	101.8	71.9	65.8	169.8
1987	171.3	119.9	96.6	62.3	56.5	159.8
1988	286.7	150.9	120.3	86.9	81.9	255.2
1989	168.1	121.2	98.2	69.1	61.2	153.2
1990	97.8	61.7	42.0	35.4	33.6	75.6
1991	169.8	85.5	40.8	31.0	30.3	138.5
1992	217.3	158.2	89.4	65.8	63.7	194.0
1993	198.0	114.5	59.8	38.5	36.5	152.8
1994	150.9	79.1	37.3	27.4	26.1	113.7
1995	158.3	89.5	62.1	39.8	39.0	121.9
1996	143.3	102.9	51.4	38.1	36.6	134.9
1997	79.7	61.3	32.6	26.8	26.2	60.2
1998	129.6	107.4	66.0	48.8	46.7	109.6
1999	88.2	58.0	49.8	43.6	42.5	79.7
Ave.	157.5	103.4	69.6	50.4	47.6	138.6
STDEV	52.1	30.8	28.3	19.0	17.3	49.5



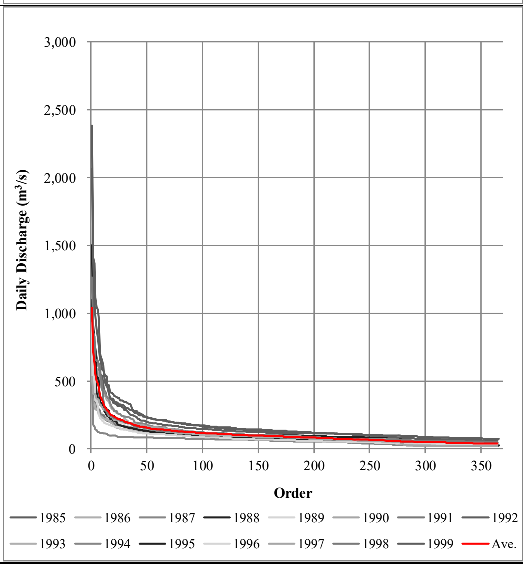
LAi

	Discharge (m³/s)					
	D95	D185	D275	D347	D355	Ave.
1985	36.5	24.5	16.4	12.1	11.8	33.2
1986	28.6	20.0	14.2	9.7	8.6	27.4
1987	30.5	21.7	11.0	7.3	7.0	28.3
1988	29.5	23.4	18.8	13.6	12.6	29.0
1989	25.9	19.9	16.2	12.5	12.1	24.2
1990	27.2	22.4	11.6	8.3	7.8	22.7
1991	27.0	21.0	10.0	7.2	6.8	21.8
1992	42.6	30.6	20.5	15.1	14.8	41.5
1993	25.8	18.5	9.8	6.8	6.4	20.1
1994	17.9	13.7	7.5	4.7	4.7	13.9
1995	22.8	16.9	12.2	6.2	5.9	22.5
1996	21.6	14.9	9.8	7.5	7.2	19.2
1997	29.2	19.6	12.1	4.9	4.7	23.5
1998	30.0	21.3	15.5	13.1	12.3	28.4
1999	41.8	28.9	23.4	18.9	18.4	41.7
Ave.	29.1	21.1	13.9	9.9	9.4	26.5
STDEV	6.8	4.6	4.5	4.2	4.0	7.7



LA

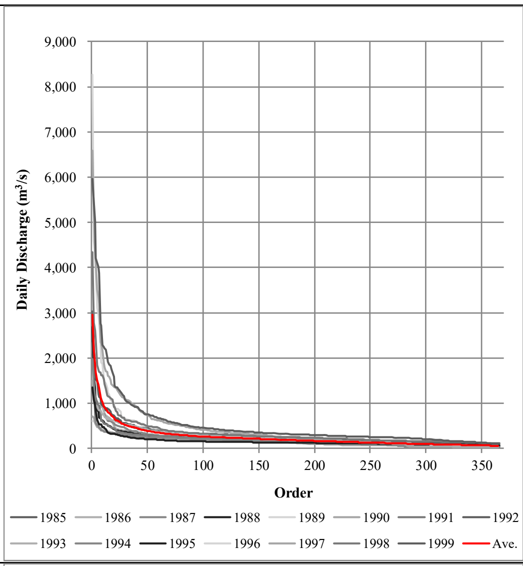
	Discharge (m³/s)					
	D95	D185	D275	D347	D355	Ave.
1985	150.6	101.0	67.7	49.9	48.7	137.1
1986	117.9	82.5	58.6	40.0	35.7	113.3
1987	125.7	89.4	45.5	30.1	29.0	116.7
1988	121.8	96.5	77.8	56.3	52.1	119.6
1989	107.1	82.1	66.8	51.5	50.0	100.0
1990	112.2	92.7	48.1	34.2	32.0	93.9
1991	111.5	86.7	41.2	29.8	28.0	90.0
1992	176.1	126.4	84.7	62.4	60.9	171.5
1993	106.6	76.4	40.3	27.9	26.2	82.9
1994	73.9	56.5	30.7	19.5	19.2	57.3
1995	94.1	69.7	50.5	25.5	24.3	92.8
1996	89.3	61.4	40.4	31.0	29.6	79.1
1997	120.7	80.9	50.1	20.2	19.5	97.2
1998	123.7	88.1	64.1	53.9	50.8	117.1
1999	172.6	119.3	96.7	78.2	75.9	172.3
Ave.	120.3	87.3	57.5	40.7	38.8	109.4
STDEV	28.2	18.9	18.6	17.2	16.7	31.9



*"DXX" means that the discharge is higher in XX days a year. The value of D347 almost equals to 95% reliable discharge
Source: JICA Project Team 2

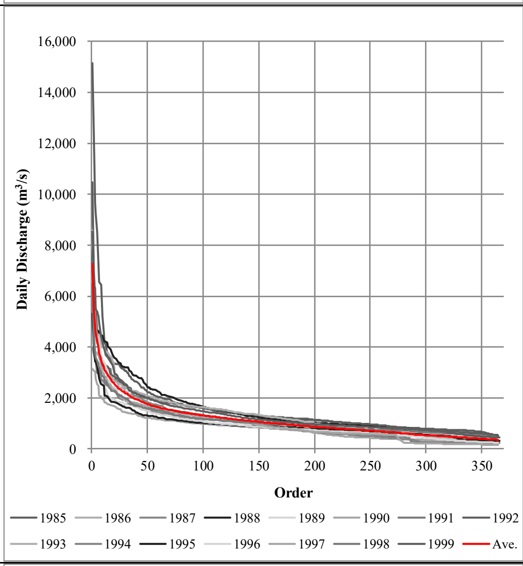
RA

	Discharge (m³/s)					
	D95	D185	D275	D347	D355	Ave.
1985	279.0	195.5	132.7	94.1	89.1	267.5
1986	190.8	149.1	104.9	54.8	49.3	197.4
1987	237.9	175.8	102.4	44.5	42.6	211.8
1988	220.5	164.6	129.8	93.8	86.5	210.1
1989	197.8	141.5	111.4	82.1	80.3	169.7
1990	203.4	122.8	66.2	46.6	42.5	149.6
1991	225.0	156.8	74.4	46.5	45.1	186.8
1992	335.5	246.6	142.9	100.7	97.6	302.1
1993	292.3	166.0	93.1	45.1	42.2	230.2
1994	210.5	130.8	65.6	29.6	28.1	161.6
1995	161.6	128.9	101.0	80.4	76.9	158.9
1996	312.6	186.2	119.6	60.4	55.0	350.9
1997	432.8	228.5	105.7	30.3	28.6	426.4
1998	335.5	243.4	172.0	127.9	119.1	352.5
1999	473.1	309.5	239.8	135.6	124.9	523.3
Ave.	273.9	183.1	117.4	71.5	67.2	259.9
STDEV	90.7	53.1	44.4	33.7	31.5	110.5



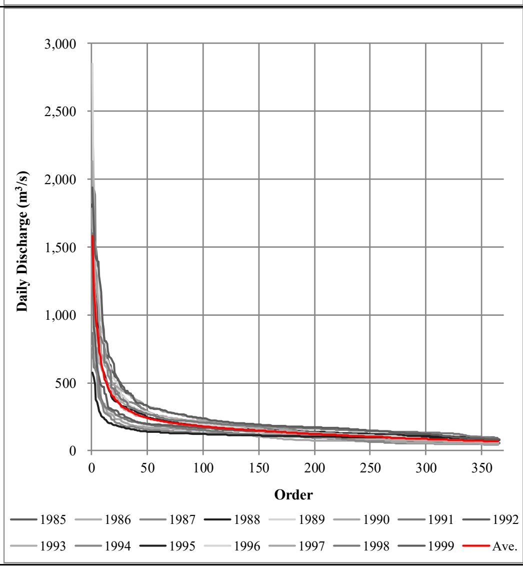
MU5

	Discharge (m³/s)					
	D95	D185	D275	D347	D355	Ave.
1985	1633.4	1165.1	851.9	688.2	617.8	1570.5
1986	1265.9	990.0	769.0	440.7	400.2	1237.5
1987	1336.2	910.5	620.7	371.6	342.6	1152.9
1988	1715.4	1047.0	836.9	572.9	540.0	1467.9
1989	1225.5	918.5	647.8	537.0	515.0	1051.0
1990	995.3	727.7	381.4	298.9	291.6	785.5
1991	1357.7	740.9	474.0	240.7	236.2	970.4
1992	1629.2	1194.7	849.6	613.5	571.4	1400.6
1993	1649.9	1122.8	540.5	315.2	292.8	1243.9
1994	1186.0	742.4	419.0	216.6	204.4	916.7
1995	1033.6	817.0	622.1	329.8	326.1	928.6
1996	1101.5	776.7	539.2	274.2	257.9	993.2
1997	1260.5	751.8	446.3	171.7	166.5	976.9
1998	1197.3	917.9	716.5	533.1	491.1	1098.1
1999	1505.1	1015.9	792.9	492.1	466.1	1330.6
Ave.	1339.5	922.6	633.8	406.4	381.3	1141.6
STDEV	235.0	161.9	163.6	159.2	143.7	227.5



HA

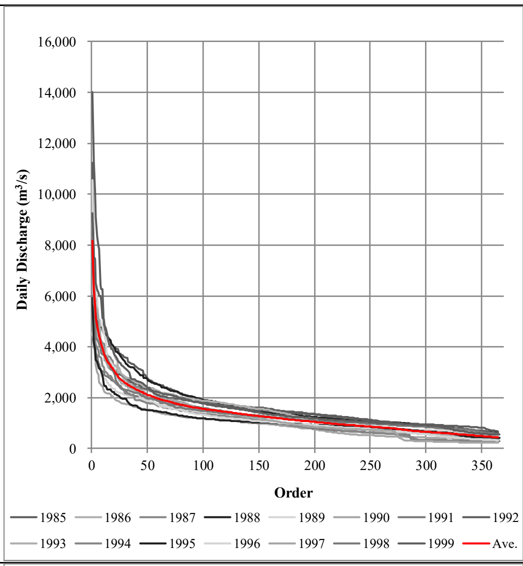
	Discharge (m³/s)					
	D95	D185	D275	D347	D355	Ave.
1985	195.4	142.6	121.5	100.9	99.1	213.4
1986	174.8	136.0	101.1	73.1	69.8	170.7
1987	207.4	149.3	89.3	64.0	63.1	205.6
1988	188.2	142.0	113.1	93.0	90.4	189.1
1989	163.4	116.5	89.9	69.9	69.6	141.3
1990	152.1	80.3	64.3	55.8	55.1	122.3
1991	155.1	104.1	75.8	57.9	57.6	129.6
1992	170.5	128.6	81.6	68.5	67.9	150.5
1993	219.9	115.7	79.7	62.6	60.5	177.0
1994	133.2	113.1	55.9	47.2	46.3	116.4
1995	124.3	106.6	95.2	84.2	82.7	120.1
1996	197.1	137.6	105.6	70.0	67.0	203.3
1997	234.0	140.3	63.2	51.9	50.9	204.2
1998	212.1	168.0	139.2	102.6	99.0	212.4
1999	245.0	177.6	133.1	88.4	85.5	242.0
Ave.	184.8	130.6	93.9	72.7	71.0	173.2
STDEV	35.7	25.3	25.2	17.5	16.8	40.7



*"DXX" means that the discharge is higher in XX days a year. The value of D347 almost equals to 95% reliable discharge
Source: JICA Project Team 2

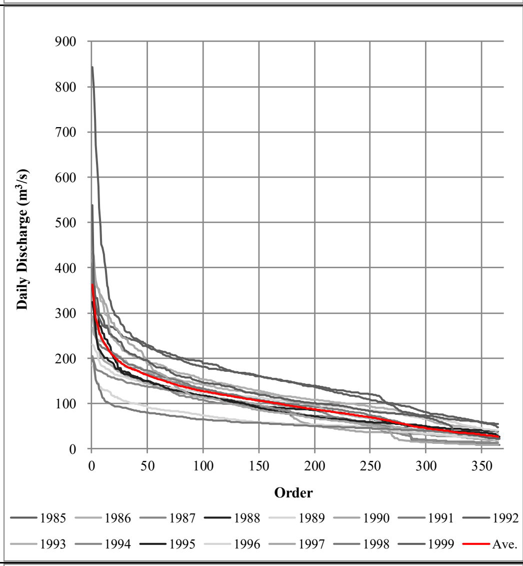
MU6

	Discharge (m^3/s)					
	D95	D185	D275	D347	D355	Ave.
1985	1988.9	1424.2	1018.6	825.8	761.9	1848.6
1986	1514.2	1174.7	926.1	536.8	488.5	1468.0
1987	1632.8	1132.3	773.0	452.8	422.9	1394.5
1988	1985.9	1308.0	1015.1	697.9	661.1	1696.3
1989	1460.6	1122.0	773.7	631.6	606.7	1247.8
1990	1194.2	842.3	467.7	379.3	368.0	951.7
1991	1608.0	896.6	571.1	314.2	311.3	1144.2
1992	1841.5	1382.2	993.1	717.4	670.9	1593.8
1993	1930.5	1257.0	641.6	399.1	373.9	1470.2
1994	1370.4	881.5	552.6	284.2	269.9	1094.5
1995	1200.4	971.7	763.7	444.9	436.5	1095.7
1996	1346.5	954.6	667.3	364.0	344.1	1253.1
1997	1566.2	942.9	471.0	238.0	233.2	1240.3
1998	1517.3	1134.8	908.4	678.4	615.6	1386.6
1999	1826.0	1236.5	970.1	594.1	572.6	1619.6
Ave.	1598.9	1110.8	767.5	503.9	475.8	1367.0
STDEV	266.7	188.2	198.2	179.3	163.1	252.3



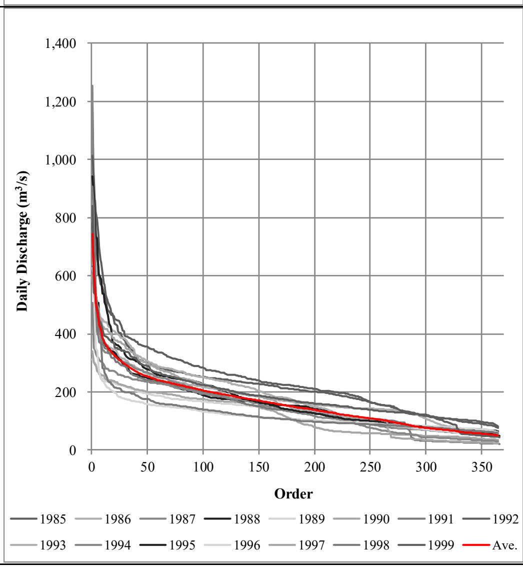
LEi

	Discharge (m^3/s)					
	D95	D185	D275	D347	D355	Ave.
1985	194.3	144.3	97.8	60.5	57.1	161.9
1986	143.9	113.3	84.5	43.8	38.2	117.0
1987	133.2	92.3	47.2	26.6	25.9	97.8
1988	117.8	88.2	57.0	41.2	40.1	98.6
1989	126.1	103.7	77.4	46.0	42.7	104.8
1990	119.0	64.2	34.9	21.7	19.9	82.5
1991	134.8	97.3	59.7	10.9	10.2	99.6
1992	184.3	144.8	87.5	59.8	55.5	149.2
1993	158.2	102.5	46.1	27.9	25.3	115.9
1994	110.7	78.2	33.6	15.2	14.3	79.2
1995	119.6	75.3	54.7	36.4	35.3	91.8
1996	76.2	54.4	37.9	24.6	23.3	61.1
1997	115.7	73.9	22.1	9.4	8.8	95.4
1998	66.0	52.4	42.7	30.7	28.5	57.9
1999	150.2	105.4	77.6	29.1	24.4	120.1
Ave.	130.0	92.7	57.4	32.2	30.0	102.2
STDEV	34.3	28.0	22.7	15.8	14.7	28.4



LEii

	Discharge (m^3/s)					
	D95	D185	D275	D347	D355	Ave.
1985	254.4	208.1	137.8	91.6	86.0	225.9
1986	219.8	161.4	136.6	69.1	67.8	182.2
1987	206.7	146.4	74.9	55.3	52.8	159.3
1988	195.9	151.8	89.4	70.7	68.3	163.6
1989	169.2	136.5	91.0	71.4	69.2	137.8
1990	176.6	97.4	53.7	40.0	37.3	119.6
1991	206.4	131.8	96.3	24.6	23.3	149.0
1992	288.7	219.3	140.0	99.1	93.7	238.4
1993	253.3	168.9	79.2	53.6	49.8	186.2
1994	198.3	127.9	58.6	34.0	32.7	138.6
1995	234.2	133.4	90.0	58.4	57.4	176.4
1996	137.0	105.4	86.3	51.0	47.8	116.6
1997	233.5	141.6	41.5	26.6	25.5	166.7
1998	143.7	101.5	83.9	64.5	62.8	125.9
1999	227.6	166.7	130.0	50.7	47.6	187.9
Ave.	209.7	146.5	92.6	57.4	54.8	164.9
STDEV	41.8	35.1	31.1	21.5	20.5	36.0

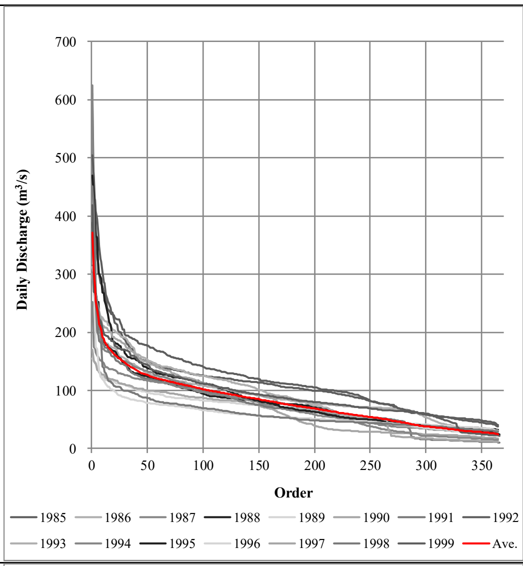


*"DXX" means that the discharge is higher in XX days a year. The value of D347 almost equals to 95% reliable discharge

Source: JICA Project Team 2

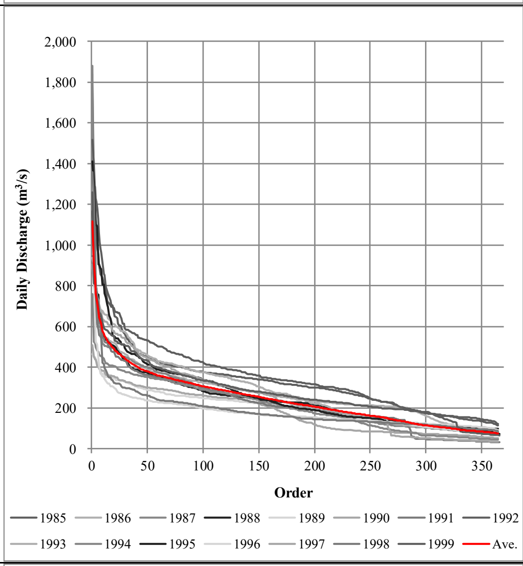
LEiii

	Discharge (m³/s)					
	D95	D185	D275	D347	D355	Ave.
1985	126.7	103.7	68.6	45.6	42.8	112.5
1986	109.5	80.4	68.1	34.4	33.8	90.8
1987	103.0	72.9	37.3	27.6	26.3	79.4
1988	97.6	75.6	44.5	35.2	34.0	81.5
1989	84.3	68.0	45.4	35.6	34.5	68.7
1990	88.0	48.5	26.7	19.9	18.6	59.6
1991	102.8	65.7	48.0	12.3	11.6	74.2
1992	143.8	109.3	69.8	49.4	46.7	118.8
1993	126.2	84.2	39.5	26.7	24.8	92.8
1994	98.8	63.7	29.2	16.9	16.3	69.0
1995	116.7	66.5	44.8	29.1	28.6	87.9
1996	68.2	52.5	43.0	25.4	23.8	58.1
1997	116.3	70.5	20.7	13.2	12.7	83.1
1998	71.6	50.6	41.8	32.1	31.3	62.7
1999	113.4	83.1	64.8	25.3	23.7	93.6
Ave.	104.5	73.0	46.1	28.6	27.3	82.2
STDEV	20.8	17.5	15.5	10.7	10.2	17.9



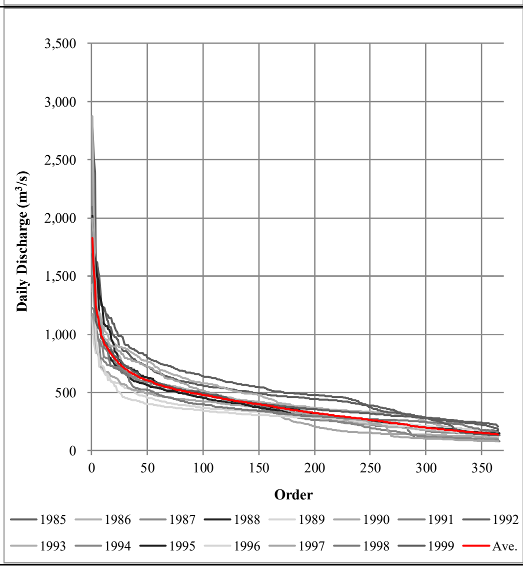
LE1

	Discharge (m³/s)					
	D95	D185	D275	D347	D355	Ave.
1985	381.1	311.8	206.4	137.2	128.8	338.4
1986	329.4	241.8	204.7	103.5	101.5	272.9
1987	309.7	219.3	112.2	82.9	79.0	238.7
1988	293.5	227.4	133.9	105.9	102.3	245.1
1989	253.5	204.5	136.4	107.0	103.6	206.5
1990	264.6	145.9	80.4	59.9	55.9	179.2
1991	309.2	197.4	144.3	36.9	34.8	223.2
1992	432.5	328.6	209.8	148.5	140.4	357.2
1993	379.5	253.1	118.7	80.3	74.6	279.0
1994	297.0	191.6	87.7	50.9	49.0	207.6
1995	350.9	199.9	134.8	87.6	86.0	264.3
1996	205.2	157.9	129.3	76.4	71.6	174.6
1997	349.8	212.1	62.1	39.8	38.2	249.8
1998	215.3	152.1	125.7	96.6	94.0	188.6
1999	340.9	249.8	194.8	76.0	71.3	281.5
Ave.	314.1	219.5	138.7	85.9	82.1	247.1
STDEV	62.6	52.6	46.6	32.2	30.7	54.0



LE2

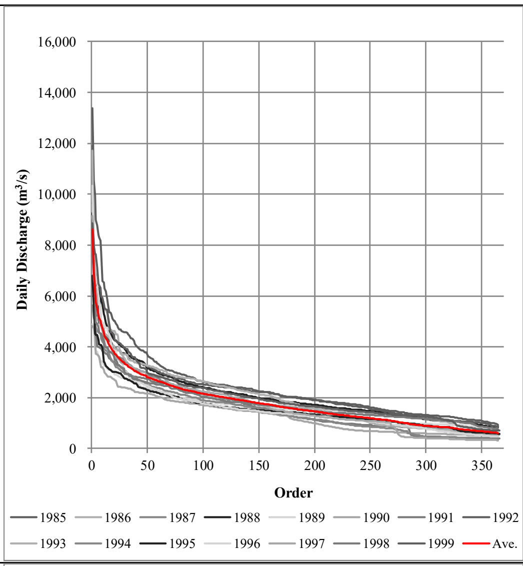
	Discharge (m³/s)					
	D95	D185	D275	D347	D355	Ave.
1985	568.1	459.4	329.8	226.0	214.7	512.9
1986	509.8	381.3	319.2	179.0	174.8	431.8
1987	463.9	342.0	203.1	146.7	141.4	369.4
1988	464.5	356.7	227.6	181.8	177.2	390.8
1989	375.5	310.4	230.1	180.8	175.6	329.9
1990	426.7	241.3	143.9	122.8	117.4	308.2
1991	498.7	309.1	235.9	88.3	85.5	371.0
1992	658.6	493.1	323.3	242.0	235.5	547.5
1993	588.1	372.2	200.2	144.4	136.6	445.4
1994	487.4	285.2	161.9	103.3	100.7	349.0
1995	499.9	323.5	220.5	158.3	153.8	406.0
1996	352.7	290.6	216.8	140.3	132.1	310.1
1997	531.3	323.8	119.1	88.4	85.6	394.5
1998	401.3	305.6	262.0	188.9	172.0	370.3
1999	508.6	369.5	298.4	142.5	135.7	420.3
Ave.	489.0	344.3	232.8	155.6	149.2	397.1
STDEV	81.0	65.5	64.6	45.4	43.6	68.0



*"DXX" means that the discharge is higher in XX days a year. The value of D347 almost equals to 95% reliable discharge
Source: JICA Project Team 2

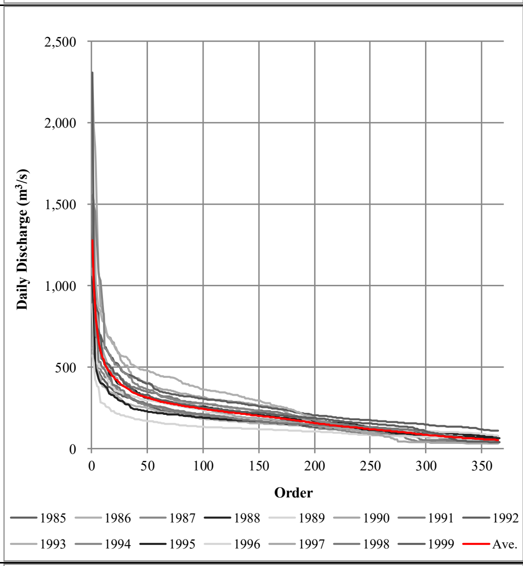
MU7

	Discharge (m^3/s)					
	D95	D185	D275	D347	D355	Ave.
1985	2666.3	2018.6	1448.1	1103.6	1044.6	2443.2
1986	2176.2	1619.7	1289.0	755.6	690.4	1958.4
1987	2181.5	1517.8	1004.1	618.0	584.3	1798.8
1988	2453.4	1793.8	1326.0	932.4	880.8	2122.9
1989	1910.2	1522.3	1032.1	852.0	804.9	1624.7
1990	1760.2	1121.8	638.6	527.6	519.5	1309.3
1991	2211.0	1224.8	861.4	420.0	416.0	1564.8
1992	2545.3	1987.5	1374.1	1027.3	966.1	2187.7
1993	2703.5	1738.0	878.1	566.3	532.4	1963.2
1994	1977.8	1225.9	744.8	410.8	386.6	1494.9
1995	1797.2	1396.4	1041.0	625.0	617.0	1561.0
1996	1830.3	1330.1	921.6	525.1	496.6	1624.1
1997	2287.2	1372.0	583.2	346.0	338.1	1688.5
1998	2125.3	1544.2	1244.0	883.1	833.5	1825.4
1999	2406.2	1708.5	1323.0	761.9	730.8	2086.4
Ave.	2202.1	1541.4	1047.3	690.3	656.1	1816.9
STDEV	309.0	271.8	276.9	233.6	216.4	306.9



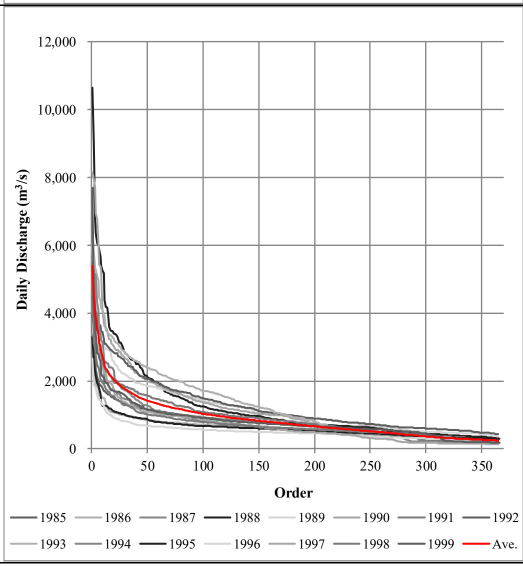
OG1

	Discharge (m^3/s)					
	D95	D185	D275	D347	D355	Ave.
1985	209.6	169.5	118.3	62.0	57.2	180.2
1986	191.5	144.4	106.2	53.9	50.7	161.9
1987	209.1	146.6	86.3	49.9	47.6	168.4
1988	260.3	182.8	119.4	83.0	80.1	213.7
1989	244.9	149.8	113.9	95.1	88.2	191.0
1990	322.2	190.1	90.7	66.0	60.2	257.1
1991	281.8	199.7	108.3	43.1	40.9	216.8
1992	312.7	223.0	162.4	124.7	116.1	265.7
1993	378.2	225.7	98.1	55.3	51.6	272.5
1994	279.4	194.0	81.8	36.0	34.8	227.3
1995	194.0	151.7	95.1	70.5	69.3	164.3
1996	137.2	110.5	77.7	53.0	49.5	121.7
1997	260.0	155.9	46.5	34.0	33.2	187.7
1998	215.0	151.8	121.6	61.6	55.7	186.7
1999	257.7	196.0	139.5	45.2	43.2	221.7
Ave.	250.2	172.8	104.4	62.2	58.6	202.4
STDEV	60.7	32.2	27.6	23.9	22.1	42.3



OG2

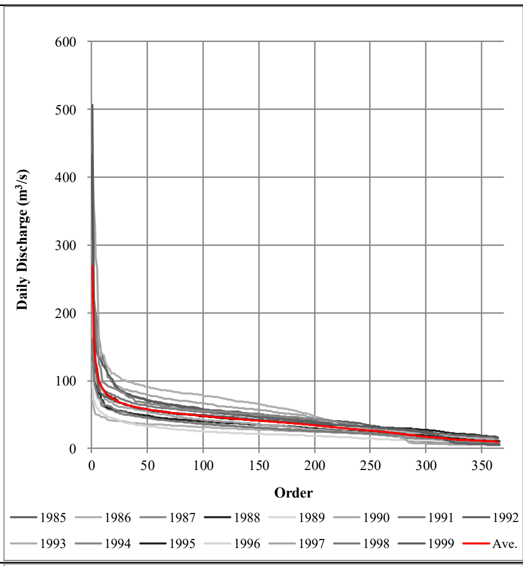
	Discharge (m^3/s)					
	D95	D185	D275	D347	D355	Ave.
1985	922.8	728.0	504.2	314.8	288.1	794.3
1986	720.4	592.5	443.6	247.7	240.8	624.9
1987	844.8	584.1	368.1	199.1	197.0	726.8
1988	1276.7	763.1	499.6	357.5	344.2	1224.2
1989	1472.5	955.6	588.6	444.9	423.0	1168.0
1990	1410.5	865.4	422.4	296.4	271.9	1181.6
1991	1107.6	772.3	447.5	195.4	189.5	925.7
1992	1539.3	961.8	646.0	488.5	469.3	1233.9
1993	1776.0	917.7	430.1	253.9	237.4	1266.4
1994	955.9	680.3	343.9	161.5	156.5	817.1
1995	680.4	539.5	409.0	307.8	304.6	612.1
1996	567.3	464.6	334.8	219.4	207.8	506.9
1997	889.1	508.6	216.7	150.8	146.7	667.2
1998	813.9	592.3	461.7	257.2	237.0	711.5
1999	923.3	691.8	530.8	196.5	189.4	811.4
Ave.	1060.0	707.8	443.1	272.8	260.2	884.8
STDEV	355.7	163.1	106.1	98.4	93.3	261.6



*"DXX" means that the discharge is higher in XX days a year. The value of D347 almost equals to 95% reliable discharge
Source: JICA Project Team 2

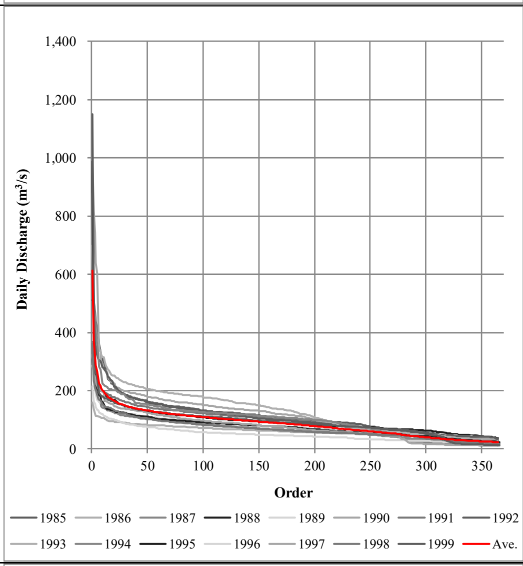
RRF

	Discharge (m^3/s)					
	D95	D185	D275	D347	D355	Ave.
1985	60.0	44.7	26.8	15.9	14.8	49.2
1986	32.1	25.5	17.8	9.2	8.4	25.6
1987	38.6	26.4	17.6	5.5	5.3	28.8
1988	48.1	37.7	29.9	19.9	18.3	41.3
1989	40.8	32.4	23.1	18.2	16.9	34.4
1990	67.5	49.7	23.6	15.7	15.1	53.1
1991	54.4	42.7	23.3	9.9	9.0	42.1
1992	58.2	41.3	27.8	18.3	17.9	47.9
1993	80.0	54.6	25.1	13.2	12.1	56.6
1994	56.5	46.1	21.3	6.5	6.2	44.5
1995	41.1	31.7	22.1	11.9	11.3	34.1
1996	25.6	19.6	12.9	9.1	8.9	21.8
1997	43.3	30.6	18.8	5.8	5.7	32.6
1998	36.7	27.8	20.0	9.5	8.6	30.3
1999	49.9	38.4	29.1	6.8	6.4	40.7
Ave.	48.8	36.6	22.6	11.7	11.0	38.9
STDEV	14.3	10.0	4.7	4.9	4.6	10.3



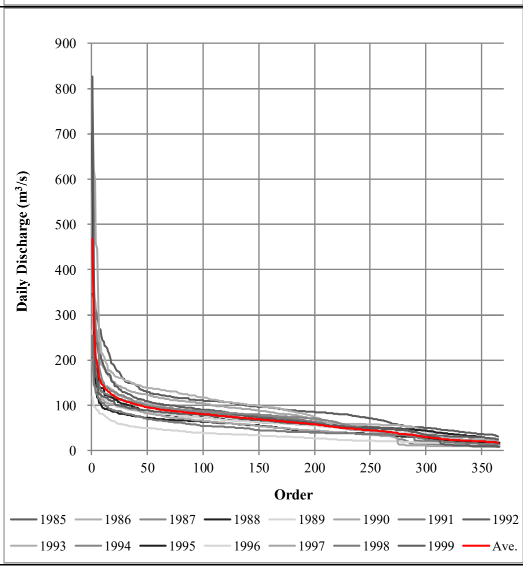
KOii

	Discharge (m^3/s)					
	D95	D185	D275	D347	D355	Ave.
1985	136.3	101.6	61.0	36.1	33.5	111.8
1986	72.9	57.9	40.5	20.9	19.0	58.3
1987	87.6	60.0	39.9	12.6	12.1	65.4
1988	109.4	85.7	68.1	45.2	41.7	93.8
1989	92.6	73.6	52.6	41.5	38.5	78.3
1990	153.3	113.0	53.7	35.6	34.4	120.7
1991	123.6	97.0	52.9	22.4	20.6	95.7
1992	132.3	93.8	63.2	41.6	40.7	108.9
1993	181.8	124.0	57.0	30.0	27.5	128.7
1994	128.3	104.8	48.3	14.8	14.1	101.1
1995	93.3	72.1	50.2	27.0	25.6	77.6
1996	58.3	44.5	29.4	20.6	20.2	49.5
1997	98.4	69.6	42.8	13.2	13.0	74.0
1998	83.4	63.2	45.5	21.6	19.5	68.8
1999	113.5	87.3	66.2	15.5	14.5	92.5
Ave.	111.0	83.2	51.4	26.6	25.0	88.3
STDEV	32.4	22.6	10.8	11.1	10.4	23.4



KOiii

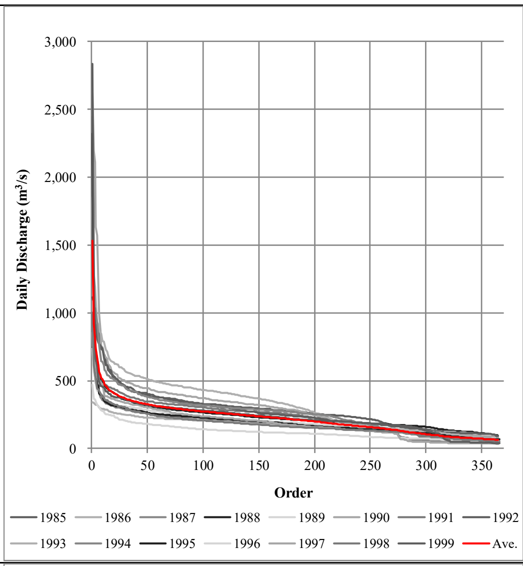
	Discharge (m^3/s)					
	D95	D185	D275	D347	D355	Ave.
1985	111.9	88.2	57.9	37.5	35.9	95.7
1986	88.0	66.4	55.8	27.4	26.5	72.0
1987	82.8	64.4	40.1	20.6	19.7	65.6
1988	74.1	58.2	48.8	30.9	27.8	64.3
1989	73.8	58.4	40.9	28.0	26.2	60.6
1990	106.0	77.7	33.9	23.9	23.4	82.6
1991	84.4	69.1	35.7	14.2	13.4	65.9
1992	92.6	64.9	47.8	29.8	28.1	76.1
1993	118.3	84.0	36.7	20.6	19.0	86.6
1994	88.1	73.6	25.0	10.4	9.8	68.9
1995	64.8	44.9	32.2	18.2	18.0	51.9
1996	39.6	29.5	20.3	15.0	14.6	33.0
1997	67.2	46.8	15.7	9.4	9.2	49.4
1998	57.1	41.4	34.3	15.5	14.4	47.3
1999	79.8	60.2	46.5	10.5	10.1	63.3
Ave.	81.9	61.8	38.1	20.8	19.7	65.6
STDEV	20.8	16.2	12.1	8.5	8.0	16.2



*"DXX" means that the discharge is higher in XX days a year. The value of D347 almost equals to 95% reliable discharge
Source: JICA Project Team 2

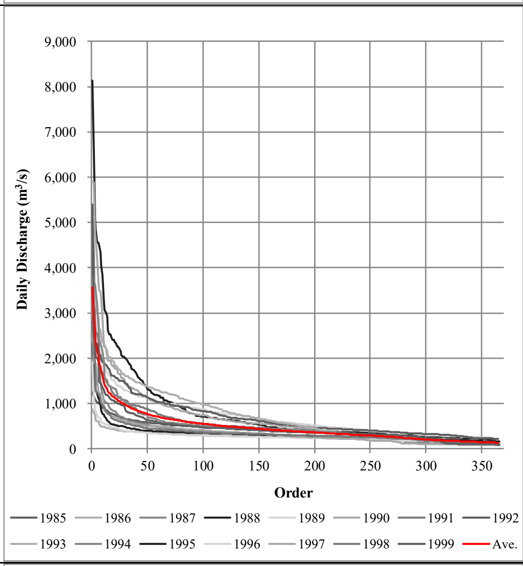
KO1

	Discharge (m³/s)					
	D95	D185	D275	D347	D355	Ave.
1985	335.9	268.9	166.2	104.8	98.5	284.4
1986	207.9	175.3	125.7	70.1	64.0	170.8
1987	225.5	172.5	119.0	48.2	47.2	177.1
1988	270.2	213.1	173.6	115.6	107.3	233.5
1989	237.4	190.1	138.9	108.2	100.3	201.4
1990	378.3	281.7	132.0	93.2	90.5	301.9
1991	306.8	246.9	135.0	59.5	56.7	240.1
1992	326.9	237.9	163.6	110.9	108.4	272.9
1993	437.6	302.8	144.6	80.3	74.2	321.0
1994	321.1	264.7	110.7	42.8	40.7	255.5
1995	231.9	173.5	127.8	74.1	70.7	193.1
1996	144.5	114.0	78.5	57.4	56.0	123.5
1997	241.0	170.5	99.9	38.5	38.0	183.2
1998	210.1	157.0	124.8	61.8	56.0	174.9
1999	284.0	215.6	172.2	44.6	42.3	232.0
Ave.	277.3	212.3	134.2	74.0	70.1	224.4
STDEV	75.3	53.6	27.1	26.8	25.1	55.8



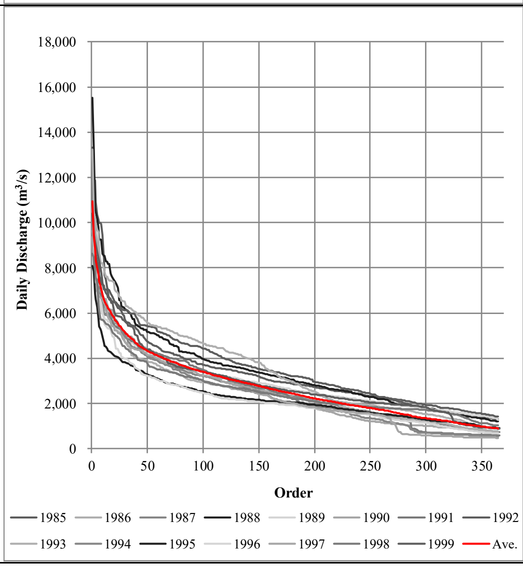
KO2

	Discharge (m³/s)					
	D95	D185	D275	D347	D355	Ave.
1985	493.4	406.6	272.4	179.1	170.8	419.1
1986	327.9	286.5	216.6	133.5	124.8	283.3
1987	406.9	302.1	222.9	99.1	97.9	368.2
1988	726.9	418.3	301.7	209.3	203.8	776.7
1989	890.9	553.5	362.9	261.6	245.8	694.4
1990	753.4	472.6	260.0	184.6	169.8	682.7
1991	570.5	423.8	257.7	120.5	115.4	520.1
1992	848.2	505.8	364.1	241.5	233.4	680.7
1993	1017.1	513.5	257.6	154.0	144.5	731.4
1994	517.4	408.4	211.9	96.4	93.6	492.7
1995	355.5	293.5	233.0	174.2	168.7	329.8
1996	293.0	243.5	180.1	131.2	124.8	266.5
1997	416.3	266.2	146.6	92.1	90.8	332.9
1998	377.4	295.1	237.6	132.2	122.2	345.7
1999	482.5	369.0	303.5	102.8	99.9	454.5
Ave.	565.2	383.9	255.2	154.1	147.1	491.9
STDEV	227.3	99.3	60.3	53.2	50.2	177.6



MU8

	Discharge (m³/s)					
	D95	D185	D275	D347	D355	Ave.
1985	3755.1	2850.2	2099.6	1458.0	1388.7	3301.7
1986	2983.8	2294.5	1756.3	1031.5	947.0	2627.9
1987	3270.9	2296.2	1420.5	837.2	797.2	2596.4
1988	4110.9	2975.1	1972.3	1374.9	1293.8	3444.3
1989	3470.4	2564.4	1929.8	1469.7	1422.5	2912.1
1990	3474.6	2174.4	1085.5	872.0	812.1	2578.2
1991	3573.9	2112.9	1367.3	630.1	617.6	2562.9
1992	4538.4	3199.6	2168.2	1581.2	1516.7	3530.6
1993	4794.0	2869.0	1365.3	834.9	783.3	3315.4
1994	3090.1	1939.7	1116.2	590.4	561.2	2368.3
1995	2556.7	2042.6	1453.8	1030.1	951.1	2218.9
1996	2529.8	1895.5	1271.7	755.4	715.3	2177.1
1997	3315.6	1968.5	810.3	507.2	498.2	2392.7
1998	3107.5	2212.6	1772.1	1160.5	1113.3	2598.6
1999	3486.5	2518.6	1950.5	961.9	937.1	2943.2
Ave.	3470.5	2394.2	1569.3	1006.3	957.0	2771.2
STDEV	637.6	414.4	411.9	339.6	324.3	445.8



*"DXX" means that the discharge is higher in XX days a year. The value of D347 almost equals to 95% reliable discharge
Source: JICA Project Team 2