PART 2 HYDRAULICS

CHAPTER A5 GENERAL

A5.1 Natural Condition in Brantas River Basin

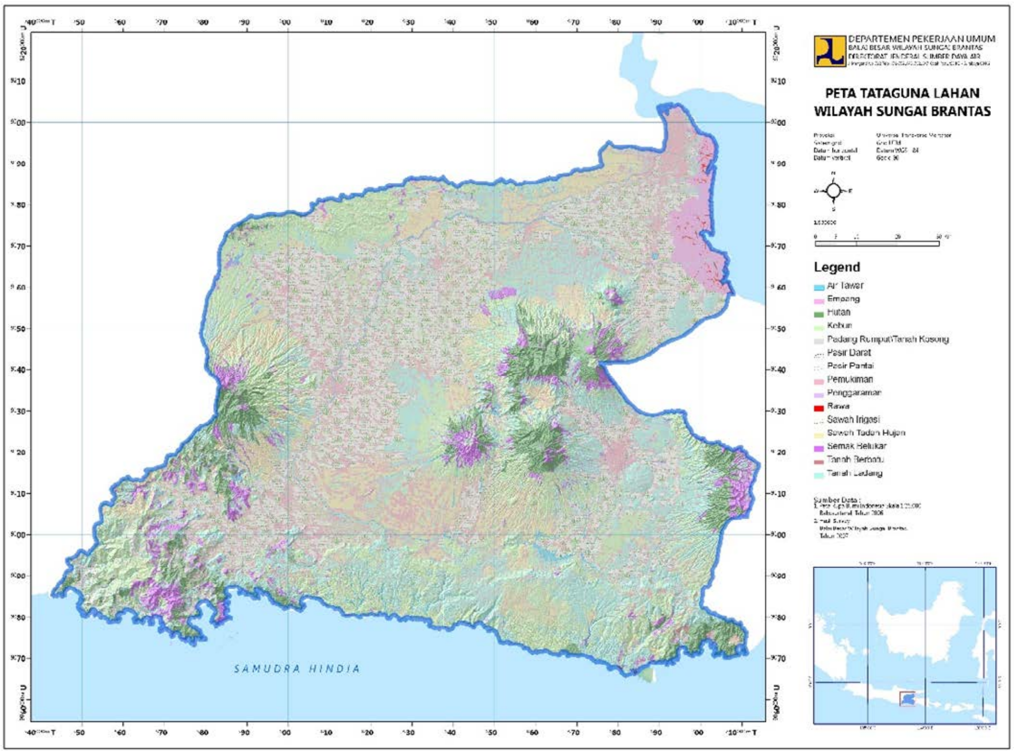
A5.1.1 Topographic Data

Topographic data is consisting of river cross section survey and digital elevation model. River cross section survey was carried out in 2013 and digital elevation model is prepared by BAKOSURTANAL.

- DEM (BAKOSURTANAL)：Inundation are (resolution 25m)
- River Cross section data（BBWS）：River area（200m interval）

A5.1.2 Land use

Land use which is prepared by PU is classified into eight types. In Brantas river basin, there are cultivation and irrigation along the river and residential area sparsely existing.



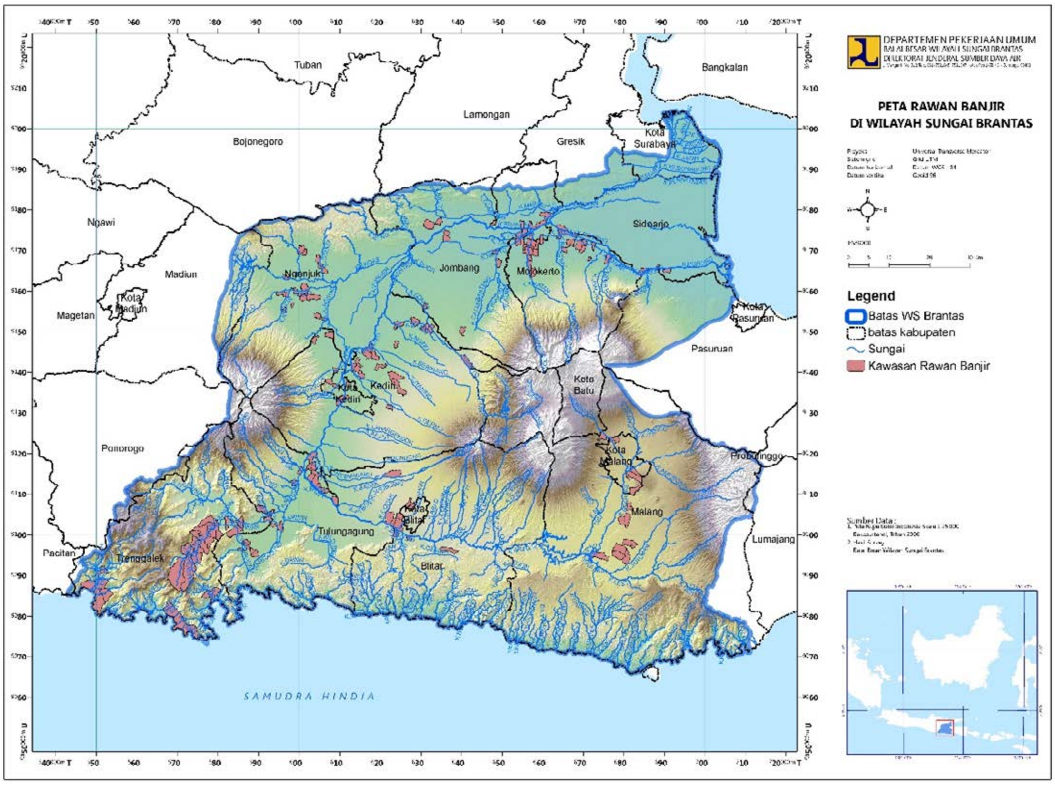
Source: Ministry of Public Works and Public Housing of the Republic of Indonesia

Figure A5.1.1 Land Use in Brantas River Basin

A5.2 Present Inundation Area

According to the inundation map in Brantas river basin prepared by PU, it can be seen that flood damage has occurred in the following places

- Brantas Main Stream: Confluence of the tributary
- Tributaries: Tawing river in Tulungagung area, Widas river, Brangkal river, and Sadar river



Source: Ministry of Public Works and Public Housing of the Republic of Indonesia

Figure A5.2.1 Inundation area in Brantas River Basin

CHAPTER A6 TARGET AREA OF FLOOD INUNDATION SIMULATION

Flood inundation simulation is carried out to the frequently inundated locations such as

1) Widas River Basin
2) Sadar River Basin (Tributary of the Porong River basin)
3) Ngotok Ring River Basin (Tributary of the Brangkal River basin)
4) Tawing River Basin (Tulungagung Area)

In addition, the mainstream from downstream of the Mrican barrage to the river mouth is checked to the possibility of overtop from the crest of dike under the present condition and the future conditions. As mentioned below, there is a possibility of overtop in Porong river, inundation analysis for Porong river is conducted.

CHAPTER A7 METHODOLOGY OF FLOOD INUNDATION SIMULATION

A7.1 Relationship between Inundation Pattern and Analysis Model

Flood inundation simulation is carried out the following analysis method and is decided from inundation pattern. The analysis models should be selected depending on the flooding form. In addition, the method should be selected according to the level of study.

Table A7.1.1 Relationship between Inundation Pattern and Analysis Model

Type	Inundation Pattern	Analysis Models
Flowing down type	Flooded water in inundation area is flowed together with flood in the river channel. Inundation area is limited along a river.	· One dimensional flow model · Two-dimensional flow model (if necessary)
Storage type	It is a flood that floods within a limited area such as a closed watershed. There is no change of inundation range by the scale of flood.	· Pond model
Diffusion type	It is a typical flood form, and flooding is influenced by topography and structures. Inundation area is diffused.	· One dimensional flow + Two-dimensional flow · Two-dimensional flow

Source: JICA Project Team 2

A7.2 Hydraulic Analysis Model

A7.2.1 1-D Non-uniform Flow Analysis

(1) Calculation Formula

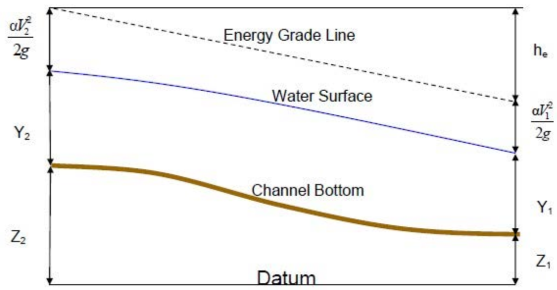
To check the possibility of overtop locations in Brantas Mainstream, one dimensional non-uniform flow is conducted by HECRAS by US Army Corps and Engineers. The governing equations, i.e., the continuity and momentum equations, for water flow are transformed from the Cartesian coordinate system to a moving boundary-fitted coordinate system due to the deformation of side banks, as shown in Fig. 1. The equations in the moving boundary-fitted coordinate system are as follows

The continuity equation refer to Figure A7.2.1:

$$Z_2 + Y_2 + \frac{a_2 V_2^2}{2g} = Z_1 + Y_1 + \frac{a_1 V_1^2}{2g} + he$$

Where:

Z_1, Z_2	=	elevation of the main channel inverts at section 1 and 2
Y_1, Y_2	=	depth of water at section 1 and 2
a_1, a_2	=	velocity weighing coefficients at section 1 and 2
g	=	gravitational acceleration
he	=	energy head loss



Source: JICA Project Team 2

Figure A7.2.1 Representation of Terms in the Energy Equation

The energy head loss (he) between the two sections is comprised of friction and contraction/expansion losses and is expressed as follows:

$$he = LS_f + C\left|\frac{a_2 V_2^2}{2g} - \frac{a_1 V_1^2}{2g}\right|$$

Where:

L = Weighted reach length

Sf = Friction slope between two sections

C = Expansion/contraction loss coefficient

The weighted reach length is calculated as:

$$L = \frac{L_{lob}\overline{Q}_{lob} + L_{ch}\overline{Q}_{ch} + L_{rob}\overline{Q}_{rob}}{\overline{Q}_{lob} + \overline{Q}_{ch} + \overline{Q}_{rob}}$$

Where:

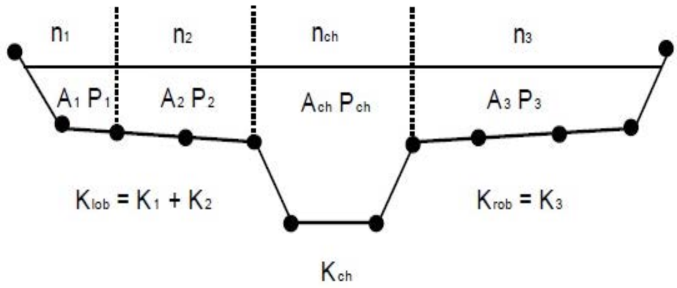
L_{lob}, L_{ch}, L_{rob}

= Reach lengths for flow in the left overbank, main channel and right overbank, respectively.

$\overline{Q}_{lob}, \overline{Q}_{ch}, \overline{Q}_{rob}$

= Arithmetic average of the flow between sections for the left overbank, main channel and right overbank, respectively

The total conveyance and velocity coefficient for a cross section requires that the flow be subdivided into units for which the velocity is distributed uniformly. The approach is to subdivide the flow in the overbank areas using the cross section n-value breakpoints (i.e., where n values change) as the basis for subdivision as shown in Figure A7.2.2



Source: JICA Project Team 2

Figure A7.2.2 Default Conveyance Method in HEC-RAS

Conveyance is calculated within each subdivision from the Manning's formula:

$$Q = K\sqrt{S_f}$$

$$K = \frac{1}{n} AR^{2/3}$$

Where:

K	= conveyance for the subdivision
n	= Manning's roughness coefficient for the subdivision
A	= flow area for the subdivision
R	= hydraulic radius (A/P) for the subdivision
P	= wetted perimeter

HEC-RAS sums up all the incremental conveyances in the overbanks to obtain a conveyance for the left and right overbank while the flow of the mainstream is computed as a single conveyance element. The total conveyance for the cross section is obtained by summing the left, channel and right subdivision conveyances.

(2) Input data

Input data for one dimensional hydraulic analysis are follows;

- River section data: River section data by river cross section survey
- Discharge data: Discharge data is come from runoff analysis result
- Upstream and downstream condition: Decided by river flow condition (normal sloop or fixed water level)
- Manning's n: Decided by river bed condition

A7.2.2 2-D unsteady flow analysis

(3) Calculation Formula

To estimate the damage from flooding, two-dimensional analysis by using Nays-2D which is developed by iRIC project is conducted. Widas River basin, Sadar River basin (Tributary of Porong River) and Ngotok Ring River basin (Tributary of Brangkal River): Diffusion type flood inundation

Nays-2D, which is packaged in iRIC (International River Interface Cooperative), is applied to estimate 2D river flow simulation. Nays2D is a plane 2D solver for calculating flow, sediment transport. Bed evolution and bank erosion in rivers.

The basic equations are as follows;

$$\frac{\partial h}{\partial t}+\frac{\partial (hu)}{\partial x}+\frac{\partial (hv)}{\partial y}=0 \text{ : Equation of Continuity}$$

$$\frac{\partial (uh)}{\partial t}+\frac{\partial (hu^2)}{\partial x}+\frac{\partial (huv)}{\partial y}=-\mathrm{hg}\frac{\partial H}{\partial x}-\frac{\tau_x}{\rho}+D^x+\frac{F_x}{\rho} \text{ : Equations of Motion in x axis}$$

$$\frac{\partial (vh)}{\partial t}+\frac{\partial (huv)}{\partial x}+\frac{\partial (hv^2)}{\partial y}=-\mathrm{hg}\frac{\partial H}{\partial y}-\frac{\tau_y}{\rho}+D^y+\frac{F_y}{\rho}$$

: Equations of Motionin in y axis

In which;

$$\frac{\tau_x}{\rho}= C_f u\sqrt{u^2+v^2}$$

$$\frac{\tau_y}{\rho}= C_f v\sqrt{u^2+v^2}$$

$$D^x = \frac{\partial}{\partial x}\left[v_t\frac{\partial (uh)}{\partial x}\right]+ \frac{\partial}{\partial y}\left[v_t\frac{\partial (uh)}{\partial y}\right]$$

$$D^y = \frac{\partial}{\partial x}\left[v_t\frac{\partial (vh)}{\partial x}\right]+ \frac{\partial}{\partial y}\left[v_t\frac{\partial (vh)}{\partial y}\right]$$

Where,

h = water depth, t = time, u = velocity in the x direction, v = velocity in the y direction, g = gravitational acceleration, H = water depth, τ_x = riverbed shearing force in the x direction, τ y = riverbed shearing force in the y direction, Cf = riverbed shear coefficient, νt = eddy viscosity coefficient, Fx is resistance by vegetation in the x direction, Fy is resistance by vegetation in the y direction, Dx is diffusion term in the x direction, Dy is diffusion term in the y direction.

(1) Input data

Input data for two-dimensional hydraulic analysis are follows;

- Therian data : Digital elevation model
- River section data : River section data by river cross section survey
- Discharge data : Discharge data of target flood
- Downstream condition : Fixed water level or normal sloop
- Manning's n : Decided by river bed condition

A7.2.3 1-D and 2-D unsteady flow analysis

(1) Calculation Formula

Porong River in Mainstream and Tawing River basin (Tulungagung Area): 1-D unsteady flow analysis to the river, 2-D unsteady flow analysis to the land area. The river area is estimated from 1-D unsteady flow to check overtop location. When overtop to the land area is occurred, the inundation analysis in the land area is carried out by using 2-D unsteady flow analysis.

1) River Model

The calculation of the river way is a one-dimensional non-constant flow model, and the formula is the following continuous equation and motion equation.

【Continuous equation】

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} + q_* = 0 \tag{1}$$

【Motion equation】

$$\frac{1}{gA}\frac{\partial Q}{\partial t} + \frac{2Q}{gA^2}\frac{\partial Q}{\partial x} - \frac{Q^2}{gA^3}\frac{\partial A}{\partial x} + \frac{\partial h}{\partial x} - ib + \frac{n^2 Q^2}{A^2 R^{4/3}} = 0 \tag{2}$$

Where,

x :axis to downstream, t :time, Q :discharge、 A :flow area、 q_* : tributary inflow、 g :gravity accretion, h:water depth, ρ :Fluid density, i_b : river bed incline, n : Manning's n, R :hydraulic radius.

The calculation method is a method in which the calculation is sequentially advanced from the downstream to the upstream. If critical flow occurs in the flow sequence, proceed with the calculation by replacing it with a uniform water depth.

2) Flood Prone Model

Two-dimensional flow calculation in floodplain are utilized flowing equation of continuity equation of motion.

【Equation of continuity】

$$\frac{\partial h}{\partial t} + \frac{\partial M}{\partial x} + \frac{\partial N}{\partial y} = 0 \tag{3}$$

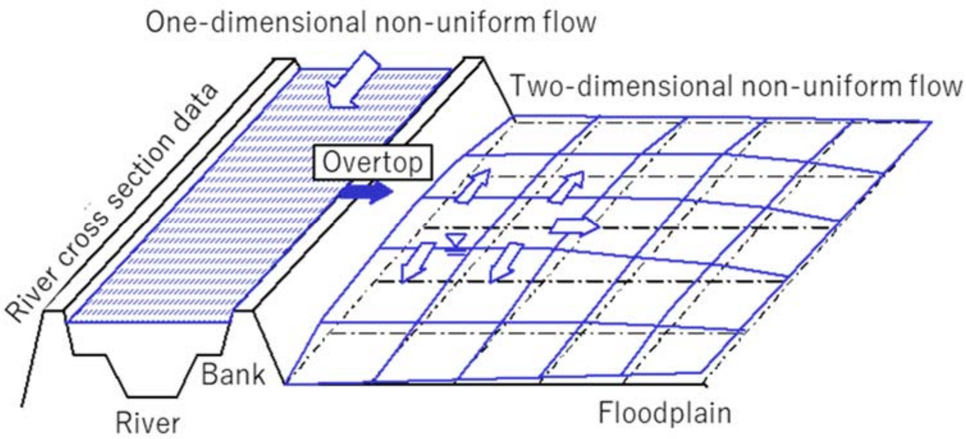
【Equation of motion】

$$\frac{\partial M}{\partial t} + \frac{\partial (UM)}{\partial x} + \frac{\partial (VM)}{\partial y} = -gh\frac{\partial (h + z_b)}{\partial x} - \frac{gn^2 U\sqrt{U^2 + V^2}}{h^{1/3}} \tag{4}$$

$$\frac{\partial N}{\partial t} + \frac{\partial (UN)}{\partial x} + \frac{\partial (VN)}{\partial y} = -gh\frac{\partial (h + z_b)}{\partial y} - \frac{gn^2 V\sqrt{U^2 + V^2}}{h^{1/3}} \tag{5}$$

Where,

h: water depth, H : water level, U,V : velocity of x and y direction, g : gravity acceleration, M: Discharge flux in x direction、 N : Discharge flux in y direction.



Source: JICA Project Team 2

Figure A7.2.3 Concept Image of Inundation Model

3) Calculation Method for Overflow Volume

Calculation condition for inundation flow volume due to the river bank break and overtopping, is based on the Inundation Simulation manual published by Public Works Research Institute in Japan on Feb. 1996.

(2) Input data

Input data for two-dimensional hydraulic analysis are follows;

- Therian data : Digital elevation model
- River section data : River section data by river cross section survey
- Discharge data : Discharge data of target flood
- Downstream condition : Fixed water level or normal sloop
- Manning’s n : Decided by river bed condition

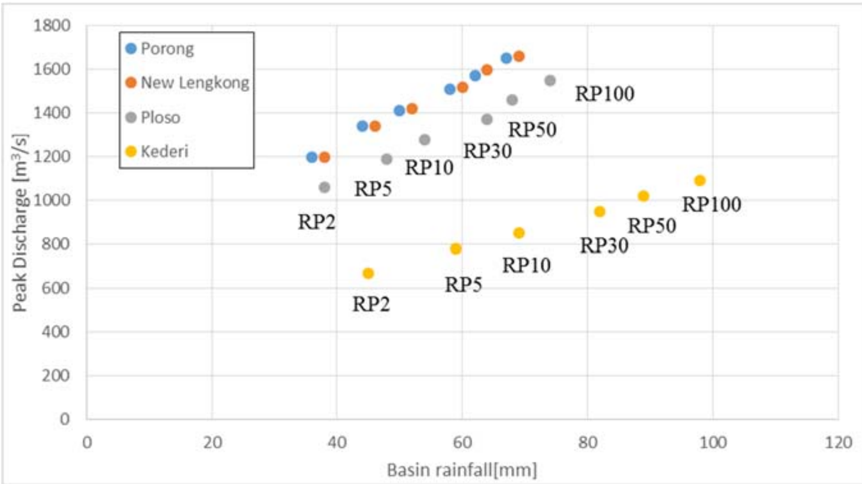
CHAPTER A8 FLOOD INUNDATION ANALYSIS FOR BRANTAS MAINSTREAM AND PORONG RIVER

A8.1 Estimation for Flow Capacity for Brantas Mainstream

A8.1.1 Setting for Calculation

(1) Peak Discharge of Mainstream under Future Condition

The probable peak discharge at the mainstream under the future conditions is required to clarify the overtop locations. The basin mean rainfall of three scenarios (Low, Medium, and High under the future conditions) is estimated by Team 1. On the other hand, the relation between the basin mean rainfall and the peak discharge was explained in “Widas Flood Control and Drainage Project, 1985”. Figure A8.1.1 shows the relation between the basin mean rainfall and the peak discharge.



Source: Widas Flood Control and Drainage Project, 1985

Figure A8.1.1 Relationship between Basin Mean Rainfall and Peak Discharge

The peak discharges under the future conditions are estimated and summarized in Table A8.1.1.

Table A8.1.1 Probable Peak Discharge under Future Conditions

Scenario		Return Period (Year)					
		RP2	RP5	RP10	RP30	RP50	RP100
1. Kediri							
Low	Basin Mean Rainfall (mm)	52	68	76	90	93	103
	Peak Discharge (m^3/s)	720	850	920	1,030	1,050	1,130
Medium	Basin Mean Rainfall (mm)	52	68	79	94	102	113
	Peak Discharge (m^3/s)	720	850	940	1,060	1,130	1,210
High	Basin Mean Rainfall (mm)	56	74	86	107	120	137
	Peak Discharge (m^3/s)	760	900	1,000	1,160	1,270	1,400
2. Ploso							
Low	Basin Mean Rainfall (mm)	44	55	59	70	71	78
	Peak Discharge (m^3/s)	1,140	1,290	1,350	1,490	1,510	1,590
Medium	Basin Mean Rainfall (mm)	44	55	62	74	78	85
	Peak Discharge (m^3/s)	1,140	1,290	1,380	1,530	1,600	1,690

Scenario		Return Period (Year)					
		RP2	RP5	RP10	RP30	RP50	RP100
High	Basin Mean Rainfall (mm)	48	60	68	83	92	104
	Peak Discharge (m^3/s)	1,190	1,350	1,450	1,660	1,780	1,930
3. New Lengkong Dam							
Low	Basin Mean Rainfall (mm)	44	53	57	66	67	72
	Peak Discharge (m^3/s)	1,300	1,430	1,500	1,630	1,640	1,720
Medium	Basin Mean Rainfall (mm)	44	53	60	69	74	79
	Peak Discharge (m^3/s)	1,300	1,430	1,530	1,670	1,740	1,820
High	Basin Mean Rainfall (mm)	48	58	65	78	86	97
	Peak Discharge (m^3/s)	1,350	1,500	1,610	1,800	1,920	2,070
4. Porong							
Low	Basin Mean Rainfall (mm)	41	51	55	64	65	70
	Peak Discharge (m^3/s)	1,290	1,420	1,480	1,610	1,620	1,700
Medium	Basin Mean Rainfall (mm)	41	51	58	67	71	77
	Peak Discharge (m^3/s)	1,290	1,420	1,520	1,650	1,710	1,790
High	Basin Mean Rainfall (mm)	45	55	63	75	84	94
	Peak Discharge (m^3/s)	1,340	1,480	1,590	1,770	1,880	2,030

Source: JICA Project Team 2

(2) Topographic data

River cross section data which was corrected in 2003, is utilized.

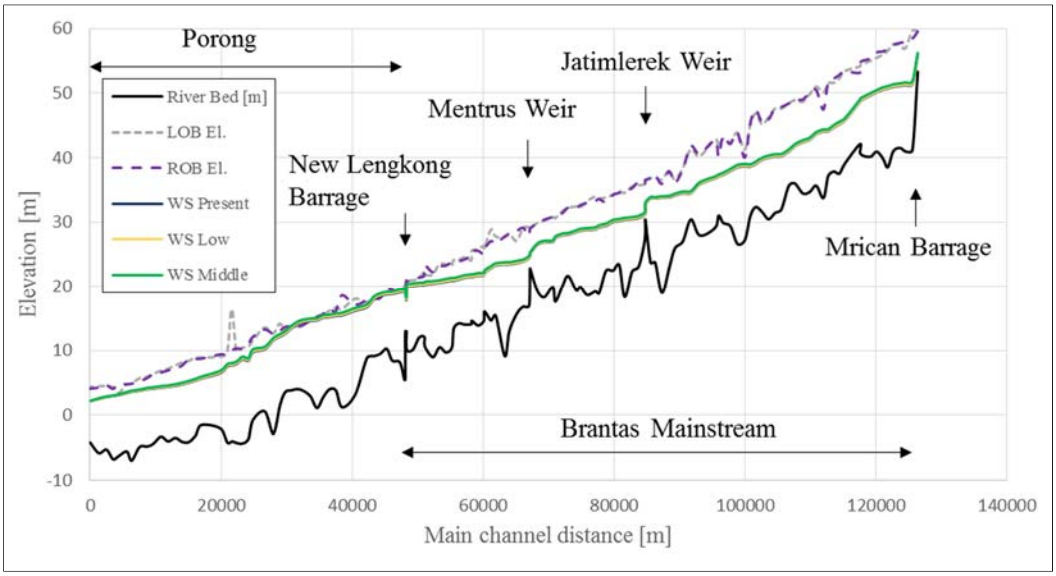
(3) Manning's n

Manning's n is settled as 0.025 which is same number of Review Master Plan Study in 1985, since the river characteristic is not changed.

A8.1.2 Assessment of Effects of Existing River Facilities in Brantas Mainstream

(1) Relation of Discharge and Freeboard of Dike along Main Stream

River profile along the mainstream from the Mrican barrage to the New Lengkong dam is show in Figure A8.1.2. Freeboard of dike along the mainstream was set at 1.0m.Table A8.1.2 shows freeboard of the present condition and future condition.



Source: JICA Project Team 2

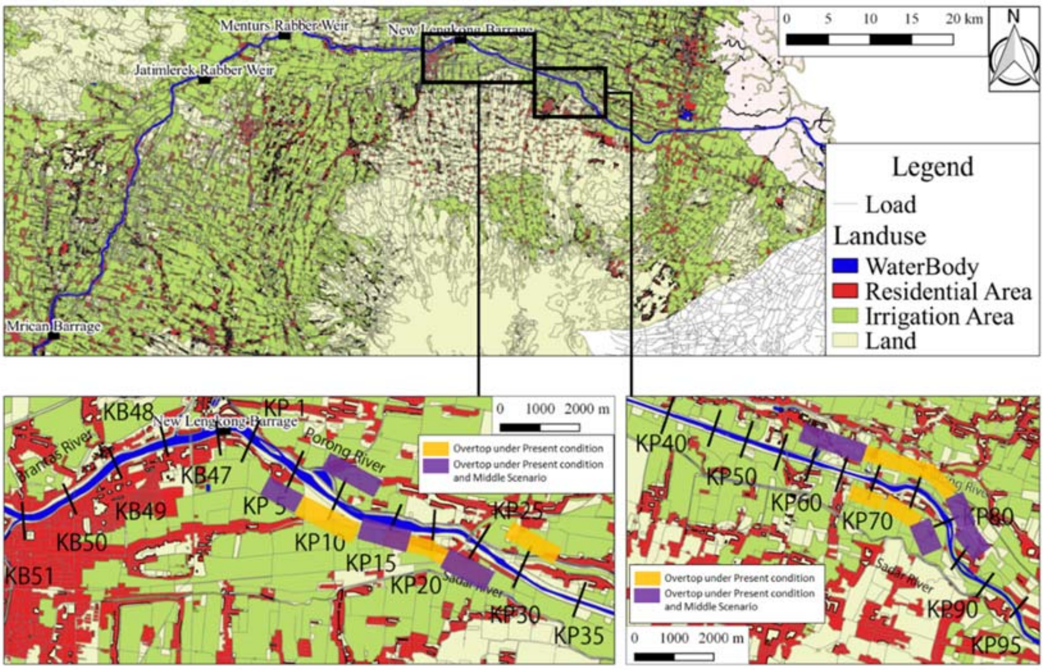
Figure A8.1.2 River Profile and Water Surface under 50-year Probable Flood

Table A8.1.2 Freeboard Comparison with Present Condition and Future Condition

Location	Main Channel Distance from River Mouth (km)	Present	Future		
			High	Medium	Low
KB125~KB99	126 ~ 101	>100 cm	>100 cm	>100 cm	>100 cm
KB98	100	>100 cm	< 100 cm	>100 cm	> 100 cm
KB97~KB52	99 ~ 53	>100 cm	>100 cm	>100 cm	> 100 cm
KB51~New Lengkong dam	52~48	< 100 cm in several section	Overtop at New Lengkong dam < 100 cm in several sections	<100 cm in several sections	<100 cm in several sections
KP1~KP15	48 ~ 45	<100 cm	Overtop	< 100 cm	< 100 cm
KP20~KP30	43 ~ 42	Overtop	Overtop	Overtop	Overtop
KP40~KP55	40 ~ 37	< 100 cm	< 100 cm	< 100 cm	< 100 cm
KP60~KP85	36 ~ 30	Overtop in Several sections	Overtop in almost sections	Overtop in almost sections	Overtop in almost sections
KP90~KP125	29 ~ 23	> 100 cm	< 100 cm	>100 cm	> 100 cm
KP130~KP195	22 ~ 9	> 100 cm	>100 cm	> 100 cm	>100 cm
KP200~KP220	7.5 ~ 3.5	< 100 cm at KP215	< 100 cm	< 100 cm at KP215	< 100 cm at KP215
KP225~River mouth	2.5 ~ 0	> 100 cm	> 100 cm	> 100 cm	> 100 cm

Source: JICA Project Team 2

As the result of relation between the peak discharge and the freeboard of dike along the mainstream, locations of overtop are shown in Figure A8.1.3.



Source: JICA Project Team 2

Figure A8.1.3 Location of Overtop Sections under 50-year Probable Flood

According to Table A8.1.2, some locations along the Porong River will be occurred overtopping from the crest of the dike. The overtop sections shall be needed to the heightening of the dike. The flood fighting team shall monitor the water level during the flood event at the locations of the overtop sections and lack of freeboard sections. And sand bags shall be stored near the identified locations in this analysis.

A8.2 Flood Inundation Analysis

A8.2.1 Simulation Model

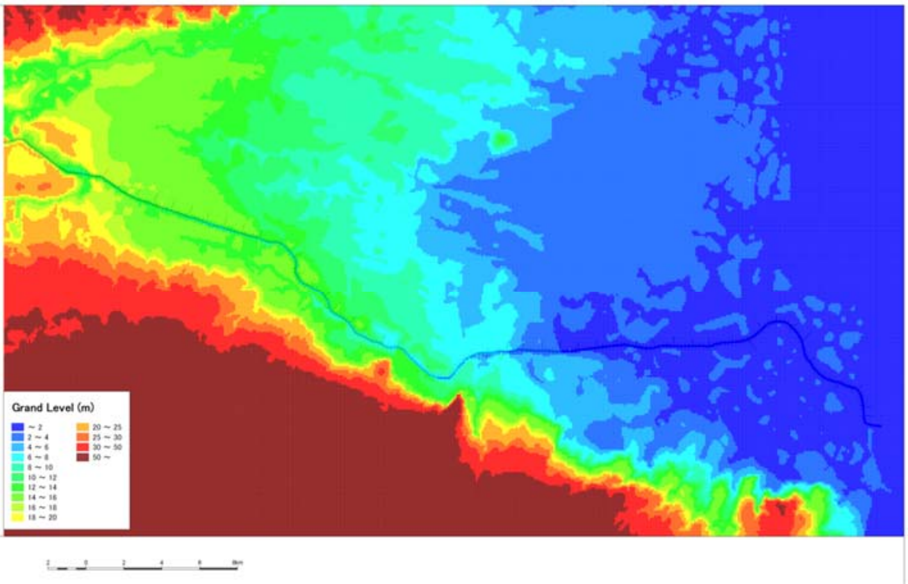
From the result of A8.1.2, in Brantas Mainstream, it was confirmed that the flood current overflowed and breached in the section of Porong River. Estimate the increase of flood damage in the future climate by conducting inundation analysis on the 50-year probability scale of each of the present climate scenario and the future climate scenario.

A8.2.2 Conditions of Analysis

Table A8.2.1 Calculation Condition for Flood Inundation Analysis on Porong River

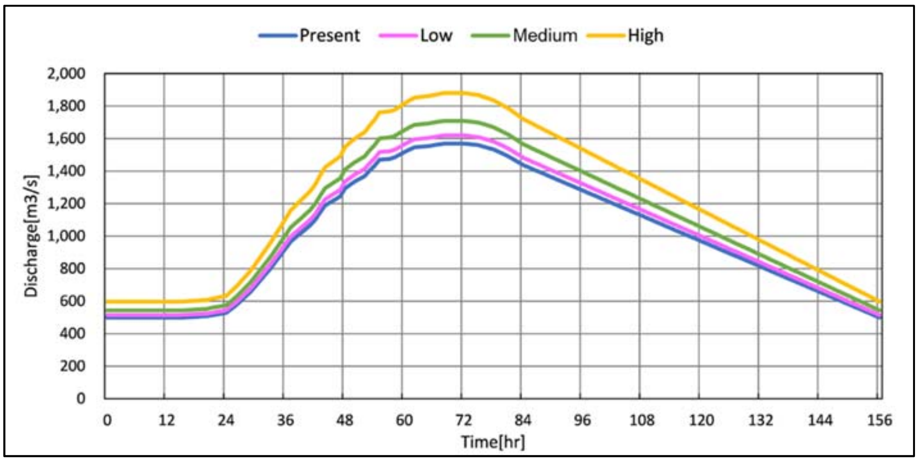
Item	Contents	Note
Method	Unsteady flow	-
Target River	from Porong river mouth to New Lenkong (KP.001-KP270)	-
Calculation Mesh	River channel 200m	-
	flood plain 100m	-
Topography	DEM (25mx25m)	BAKOSURTANAL
	River cross section data	PU BBWS Brantas 2013 survey
Manning's n	River: 0.025	Same as Master Plan 1985
	Flood plain Residential area: 0.1, Irrigation area : 0.06	-
Boundary Condition	Downstream condition: Tidal water level (present 1.53m, feature 1.72m)	-
	Upstream condition: each return period discharge	-
Case	Present condition: 1,570m^3/s	-
	Low: 1,620m^3/s	-
	Medium: 1,710m^3/s	-
	High: 1,880m^3/s	-

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure A8.2.1 Model Area of Inundation Analysis in Poring River

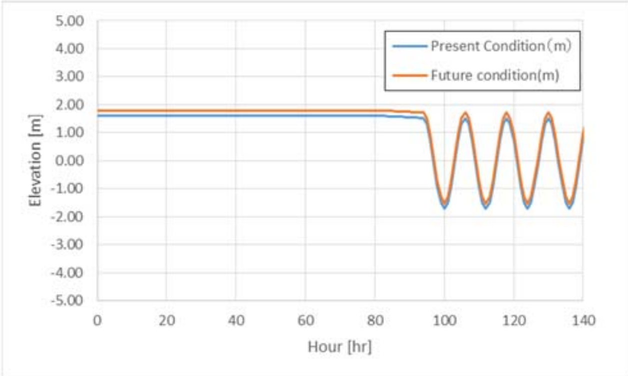


Source: JICA Project Team 2, Master Plan1985

Figure A8.2.2 Hydrograph for Porong River in return period 50 year for Each Climate Condition

According to the Project Team 1, High Water Level at Port of Tanjung Perak is 1.53m and it is estimated that sea water level will be raised 5mm/year due to the climate change. Tidal water frequency is shown in Figure A8.2.3.

- Scenario: Downstream Water Level
- Present Condition (2013) : 1.53*1
- Feature Condition (2050) : 1.72 m(≒1.53m + 0.005[m/year] x 37 [years]

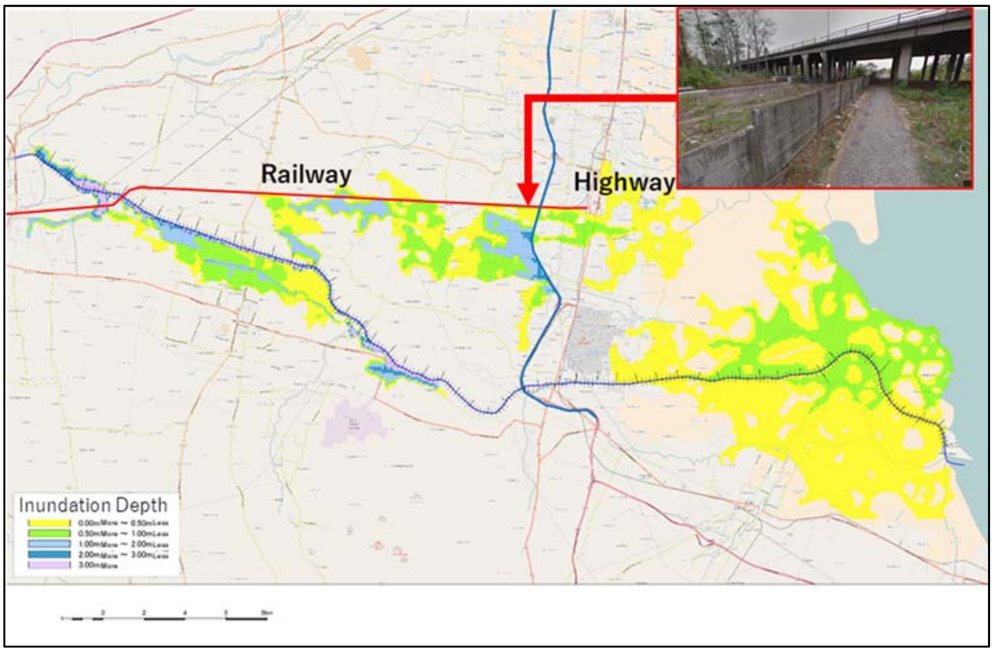


Source: JICA Project Team 2

Figure A8.2.3 Downstream Condition at Surabaya Sea Level

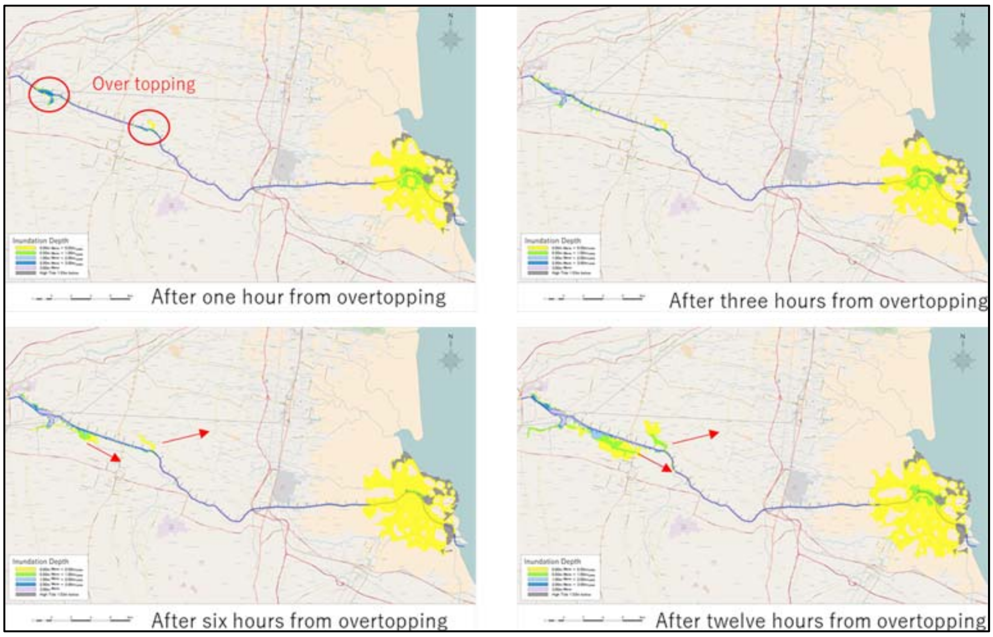
A8.2.3 Model Calibration

However, there is no available evidence of inundation from the Porong river, calibration for hydraulic analysis was conducted considering the high way road and railway. Figure A8.2.4 shows the crossing point of railway and highway. There are constructed wall along the railway, and railroad is embanked. Type of Highway at crossing with railway is flyover. For that reason, flood flow will be passed at crossing point between railway and highway.



Source: JICA Project Team 2, photo image: Google Street View, background image: Google map

Figure A8.2.4 Calibration for Porong River



Source: JICA Project Team 2

Figure A8.2.5 Time Sequence of Inundation Flow in Porong River under Present Condition

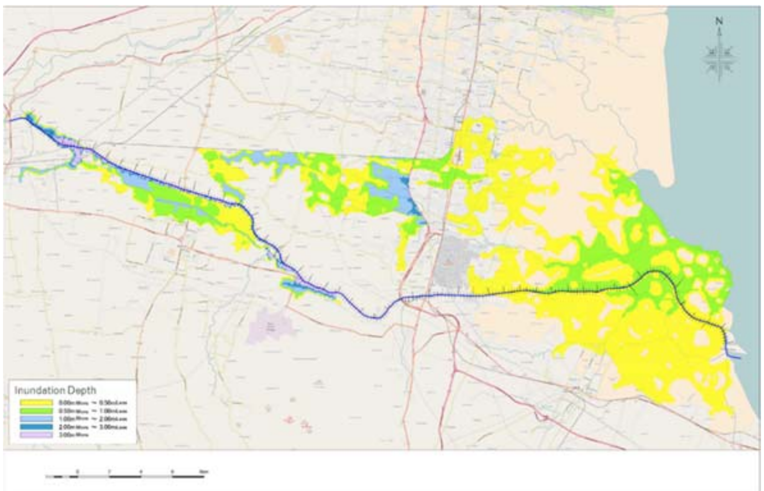
A8.2.4 Result of Calculation

Table A8.2.2 Summary of Inundation Depth and Inundated Area

Condition	Residential		Irrigation		Total
	Area (ha)	Average Depth (m)	Area (ha)	Average Depth (m)	Area (ha)
Present	888	1.2	2,390	1.2	3,278
Low	933	1.2	2,554	1.2	3,487
Medium	1,143	1.2	2,902	1.3	4,045
High	2,509	1.1	5,509	1.3	8,018

Source: JICA Project Team 2

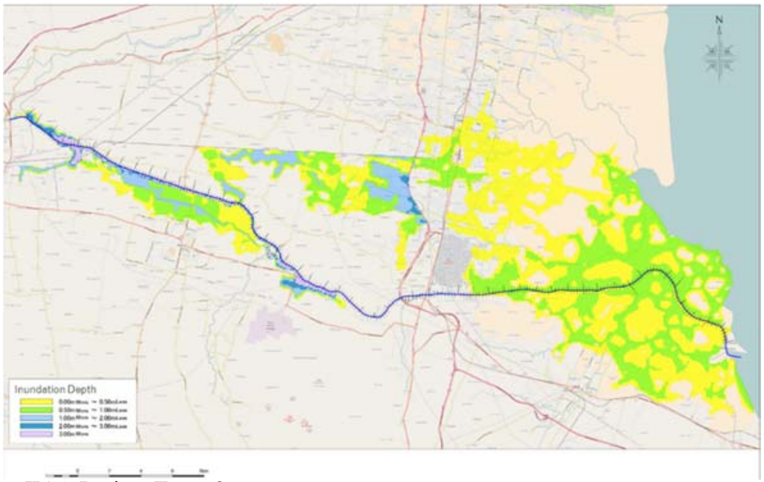
<Present>



Source: JICA Project Team 2

Figure A8.2.6 Maximum Inundation Depth and Area in Present Climate

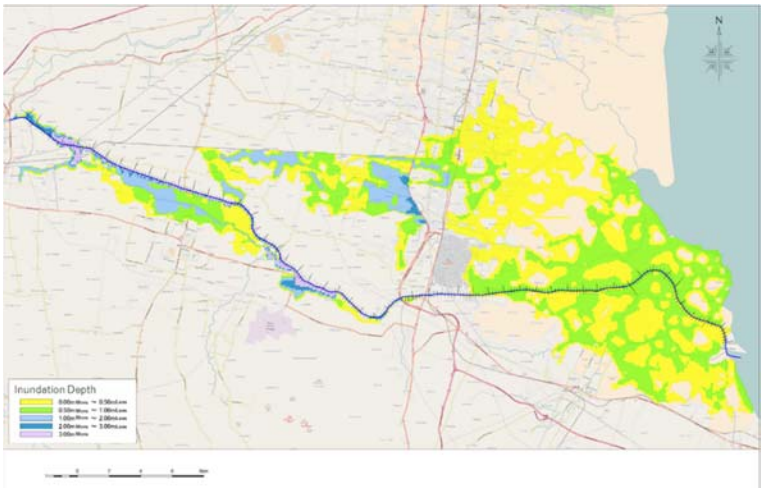
<Low>



Source: JICA Project Team 2

Figure A8.2.7 Maximum Inundation Depth and Area in Low Scenario

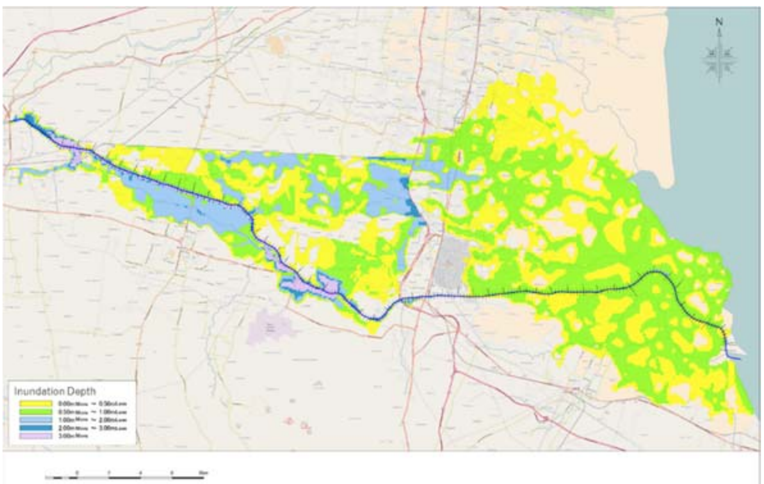
<Medium>



Source: JICA Project Team 2

Figure A8.2.8 Maximum Inundation Depth and Area in Medium Scenario

<High>



Source: JICA Project Team 2

Figure A8.2.9 Maximum Inundation Depth and Area in High Scenario

CHAPTER A9 FLOOD INUNDATION AT PRESENT AND FUTURE CLIMATE CHANGE CONDITION IN TRIBUTRIES

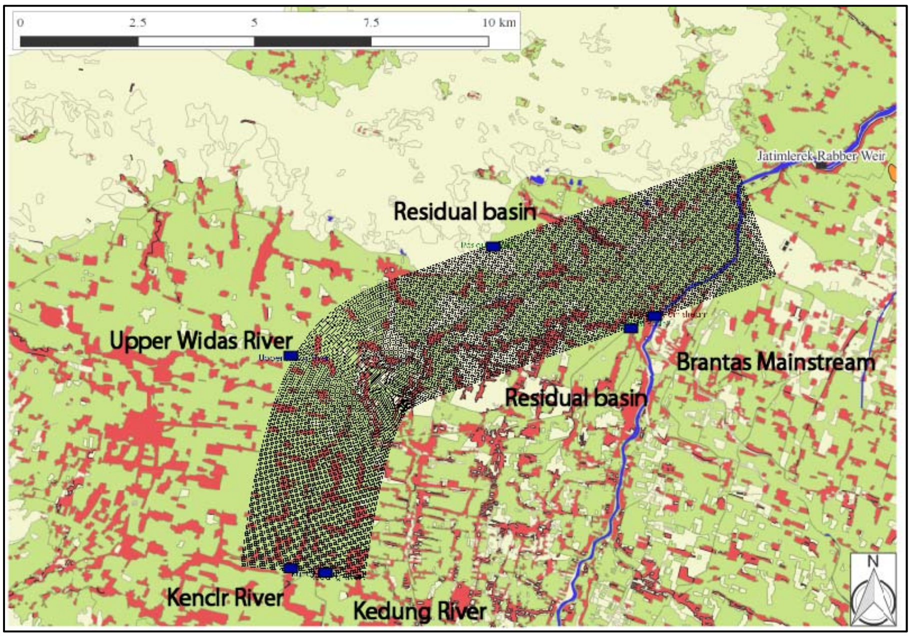
A9.1 Widas River Basin

A9.1.1 Present Condition of Widas River Basin

Flood analysis for Widas River Basin was conducted in The Study of Widas Flood Control and Drainage Project (1986), it concluded that protected target is return period 25year flood. In the study, river dike and three Returning basins were considered, but returning basin has not been constructed and the areas are used for irrigation and residential area. Here is located flat area, then the type of inundation flow is judged as diffusion type.

A9.1.2 Simulation Model

The inundation analysis in the Widas river basin is applied two-dimension unsteady flow analysis method, since this river profile is relatively flat and flooding type at this inundation area is diffusion type. The target area of analysis is shown in Figure A9.1.1.



Source: JICA Project Team 2

Figure A9.1.1 Target Area of Analysis in Widas River Basin

A9.1.3 Conditions of Analysis

The conditions of simulation are set as follows:

<u>Boundary Condition</u>

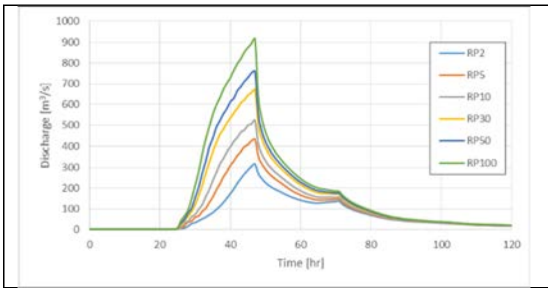
- Downstream End: The boundary condition of the downstream end is set at the water level of mainstream. The probable water levels of the mainstream are estimated from the non-uniform flow calculation by HEC-RAS. The boundary condition of the downstream end is shown in Table A9.1.1.

Table A9.1.1 Boundary Condition of Downstream End (Water Level)

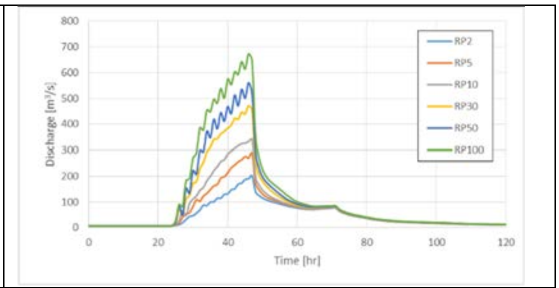
Return Period (Year)	Present	Feature		
		Low	Medium	High
2	33.4	33.6	33.6	33.7
5	33.7	33.9	33.9	34.0
10	33.8	34.0	34.0	34.1
30	34.0	34.2	34.3	34.5
50	34.2	34.2	34.4	34.7
100	34.3	34.4	34.5	34.9

Source: JICA Project Team 2

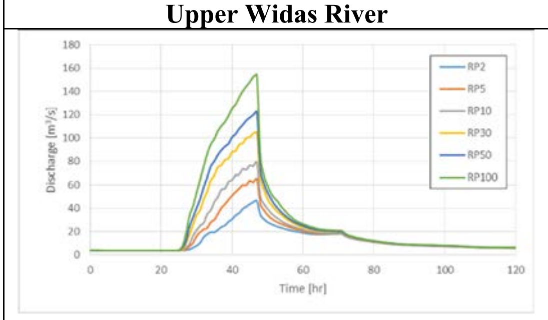
- Upstream End: The hydrographs and adjustment magnitude under the present condition and the future conditions are estimated and provided by Team 1. Table A9.1.1 shows the hydrographs at the present condition. And the peak discharge of upstream boundary conditions are shown in Figure A9.1.2.
- The hydrographs under the present and future condition are estimated by Team 1. These hydrographs are applied to the upstream boundary.



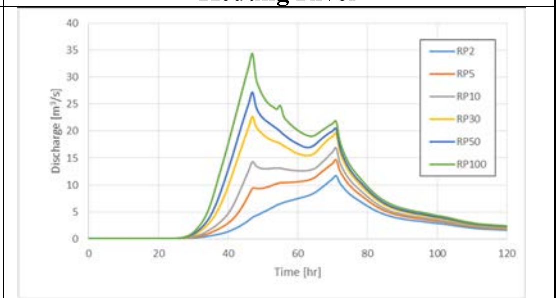
Upper Widas River



Kedung River



Kuncir River



Residual Basin

Source: JICA Project Team 2

Figure A9.1.2 Hydrograph of Each Upper End Boundary Condition (Present Condition)

Table A9.1.2 Peak Discharge of Upper End Boundary

Return Period (Year)	Peak Discharge (m^3/s)			
	Present	Low	Medium	High
1. Upper Widas River				
2	316	384	384	432
5	432	527	527	593
10	523	597	632	717
30	671	786	855	1,069
50	759	833	985	1,305
100	916	916	1,175	1,629
2. Kedung River				
2	201	248	248	279
5	289	344	344	404
10	341	403	426	511
30	471	580	637	796
50	561	621	718	1045
100	673	673	906	1387
3. Kuncir River				
2	47	57	57	66
5	65	79	79	90
10	79	91	98	113
30	105	127	142	193
50	123	136	171	253
100	154	154	219	338
4. Residual Basin				
2	12	13	13	15
5	15	17	17	18
10	17	18	20	25
30	23	28	32	42
50	27	31	38	54
100	34	34	47	73

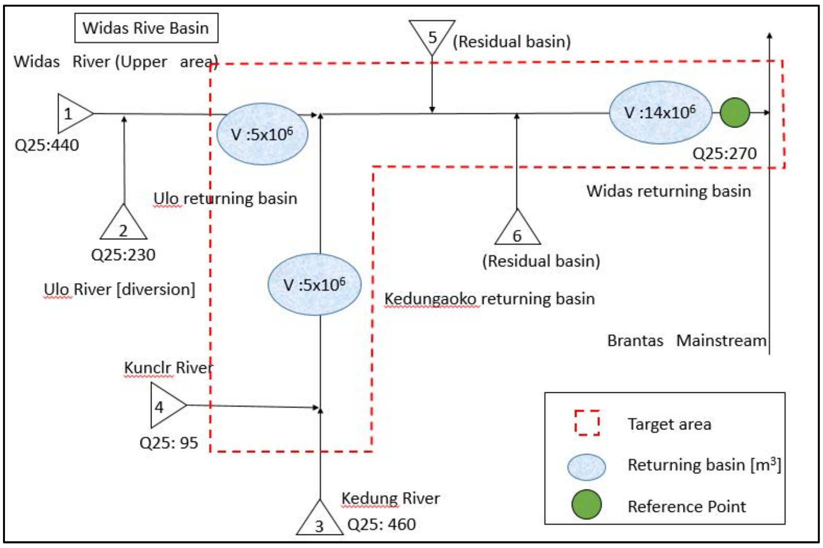
Source: JICA Project Team 2

Other Condition

- Roughness coefficient: River area (n = 0.03), Land area (n = 0.045)
- Calculation pitch: Calculation pitch: dt = 1 [sec]
- River Cross Section: River cross section survey was not carried out in this project. The trapezium shape was applied to the river section and size is decided from the discharge capacity mentioned in the past report.

A9.1.4 Model Calibration

Calibration of the parameters for the two-dimensional unsteady flow analysis is carried out to adjust the inundation volume at three returning basin which is mentioned in existing report, as shown in Figure A9.1.3.



Source: JICA Project Team 2

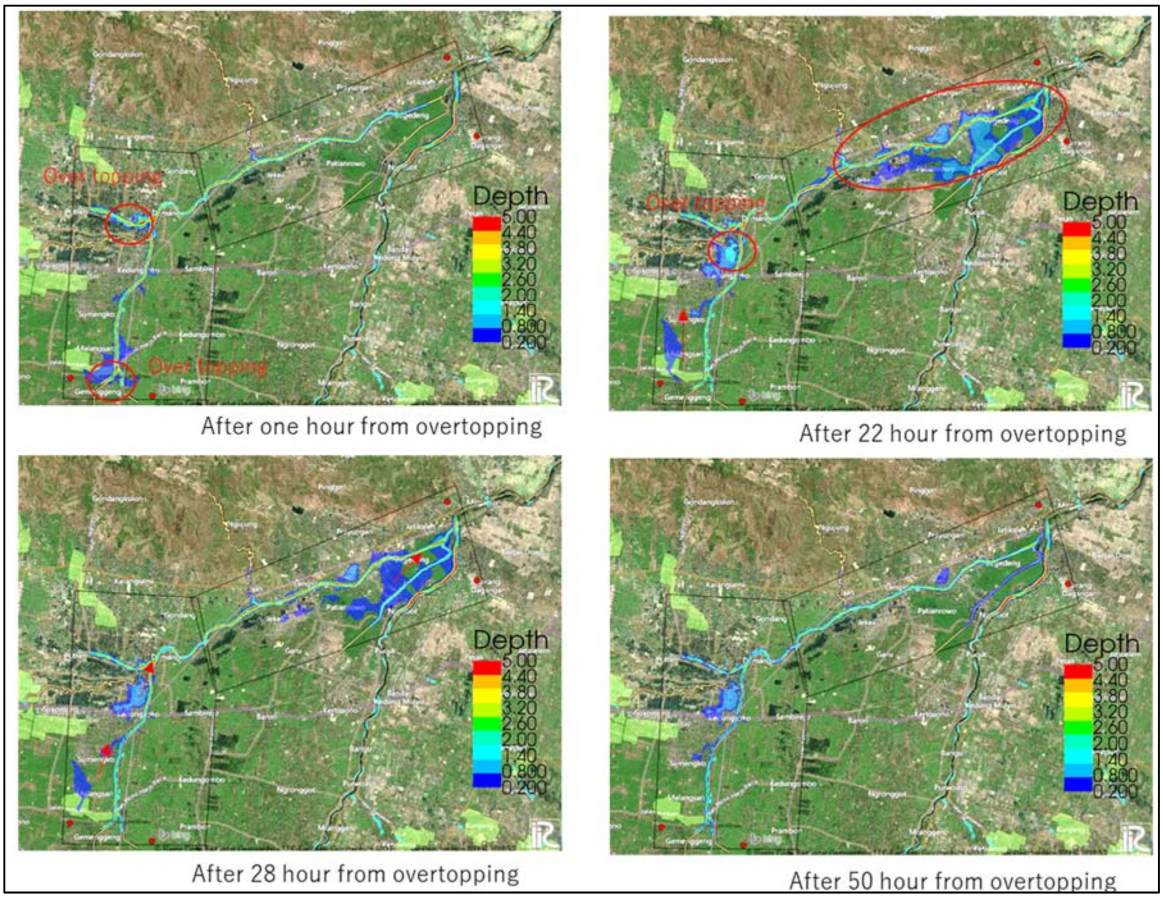
Figure A9.1.3 Design Flood Discharge in Widas River Basin

There is no flood record to grasp relation between the peak discharge and the flood damage. However, the river training works were already carried out based on "The Study of Widas Flood Control and Drainage Project (1986)". The design flood discharge is applied to return period 25-years probable flood and the design flood at reference points are mentioned in this report. The calibration of the model is considered to the design flood. In the Widas River, there are three natural retarding basins, and these basins are considered into the plan. Therefore, the inundation area in these basins for model calculation are compared with the study result of the Widas Flood Control Project. Table A9.1.3 shows the calibration result. Figure A9.1.4 shows the time sequence of inundation flood occurred. Inundation at the upstream of confluence of the main rivers flows with time, but inundation at the upstream is remain.

Table A9.1.3 Result of Calibration in Widas River Basin

Name of Retarding Basin	Inundation Volume [10^6 m^3]	
	Plan	Model
Kedungaoko retarding basin	5	5
Ulo retarding basin	5	6
Widas retarding basin	14	10

Source: JICA Project Team 2



Source: JICA Project Team 2, background image: Bing map

Figure A9.1.4 Time sequence of Inundation Flow in Widas river

A9.1.5 Results of Flood Inundation Analysis

The flood inundation analysis is carried out to the present condition and the future condition (Low, Medium, High case) under the climate change. The results of the analysis are shown in Table A9.1.4 and Figure A9.1.5 and Figure A9.1.8.

Table A9.1.4 Results of Flood Inundation Analysis (Widas River Basin)

1. Present Condition

Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	12.2	0.9	18
5	29.0	11.4	232
10	97.5	26.8	547
30	390.2	110.6	2,256
50	536.4	175.4	3,580
100	524.6	294.2	6,003

Note: Parameter of Affected Houses are applied from Japanese guideline of estimation for flood damage

2. Future Condition (Medium)

Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	22.5	7.2	148
5	106.0	27.6	562
10	309.1	73.1	1,492
30	699.0	259.0	5,286
50	880.2	335.3	6,843
100	1,347.8	474.9	9,693

Note: Parameter of Affected Houses are applied from Japanese guideline of estimation for flood damage

3. Future Condition (Low)

Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	22.5	2.4	48
5	89.2	13.9	283
10	249.0	36.8	752
30	570.7	197.4	4,030
50	627.1	242.6	4,952
100	750.8	294.2	6,003

Note: Parameter of Affected Houses are applied from Japanese guideline of estimation for flood damage

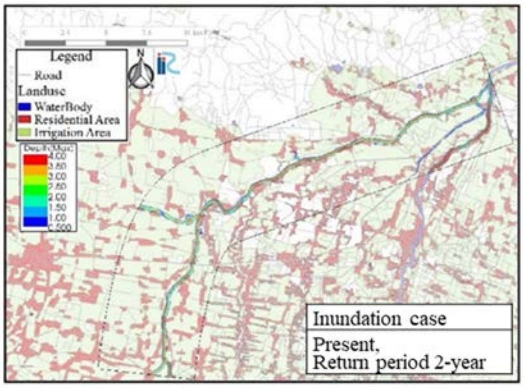
4. Future Condition (High)

Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	36.1	11.4	232
5	247.5	36.4	742
10	450.5	148.1	3,022
30	1,172.7	393.1	8,024
50	1,646.3	1,050.0	10,996
100	1,996.8	1,160.5	12,153

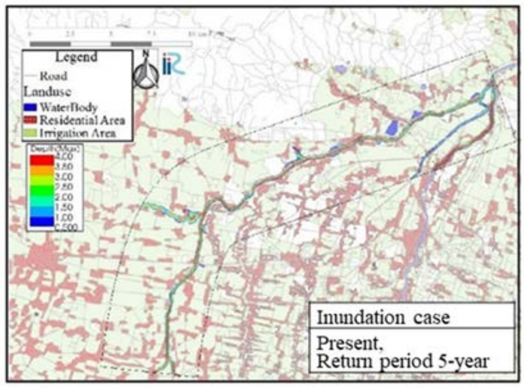
Note: Parameter of Affected Houses are applied from Japanese guideline of estimation for flood damage

Source: JICA Project Team 2

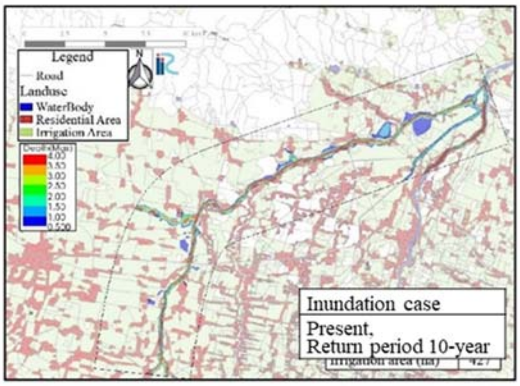
1. Present



Return period 2 year



Return period 5year



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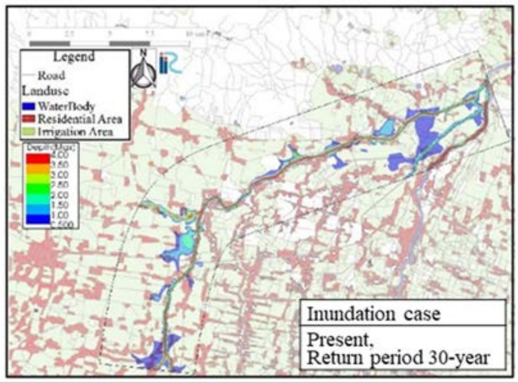
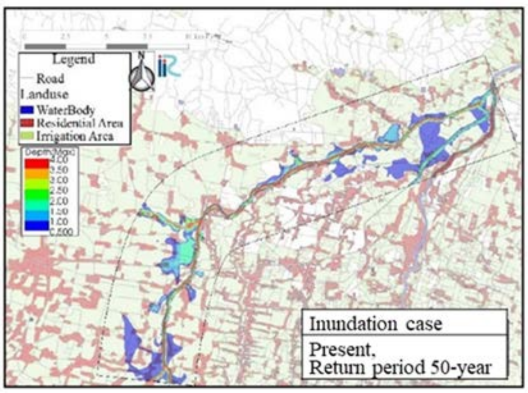
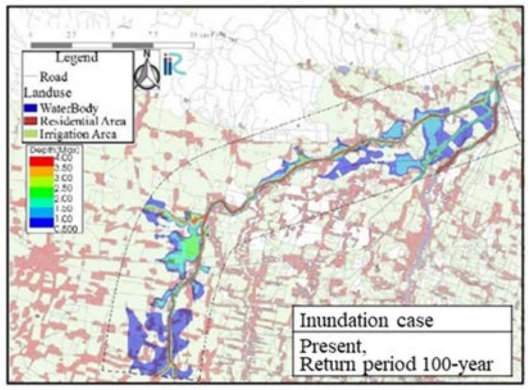


Return period 30 year



Return period 50 year

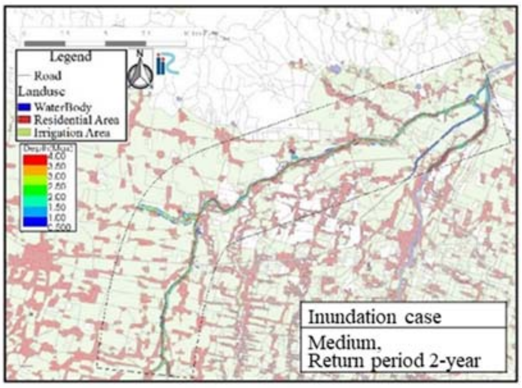


Return period 100 year

Source: JICA Project Team 2

Figure A9.1.5 Maximum Inundation Depth and Area in Widas River Basin under Present Condition

2. Medium



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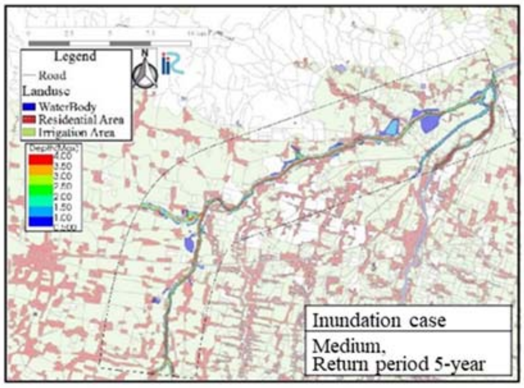

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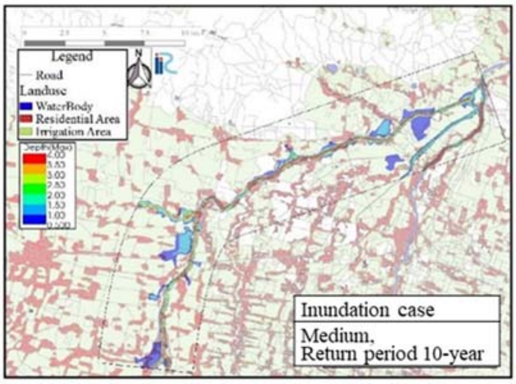
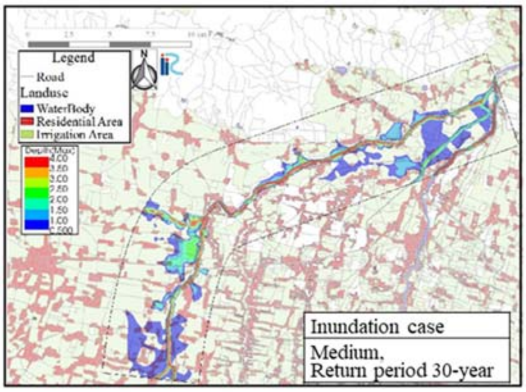


Return period 10 year



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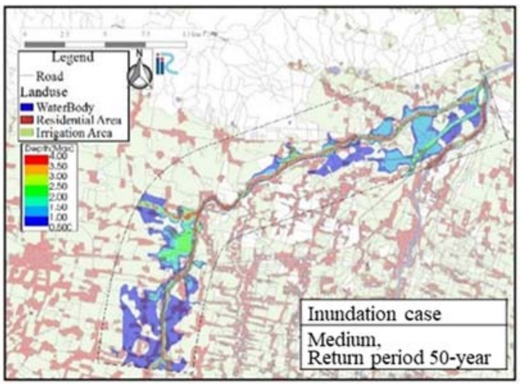
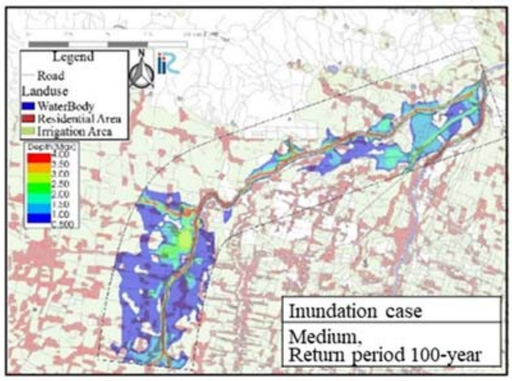


Return period 50 year

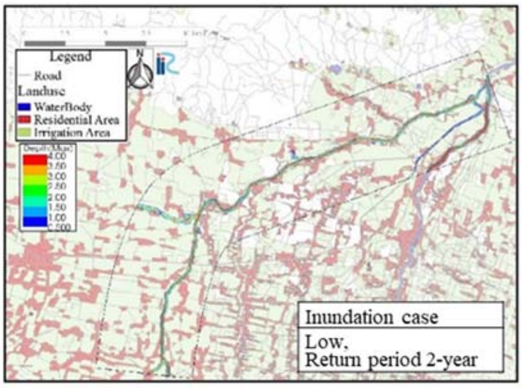


Return period 100 year

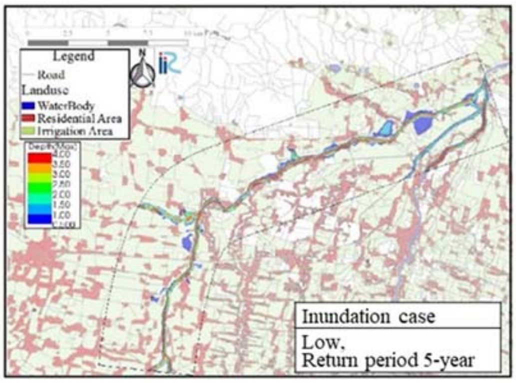
Source: JICA Project Team 2

Figure A9.1.6 Maximum Inundation Depth and Area in Widas River Basin under Medium Scenario

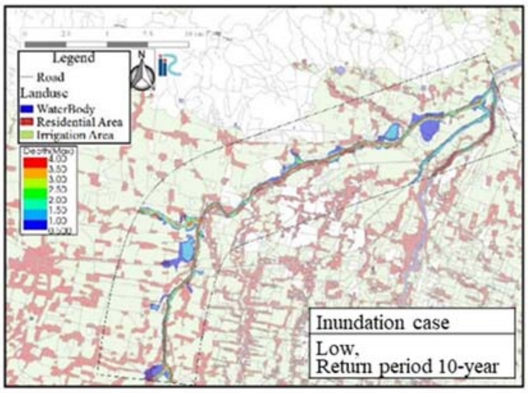
3. Low



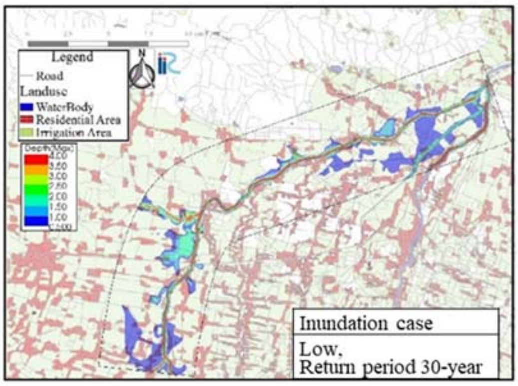
Return period 2 year



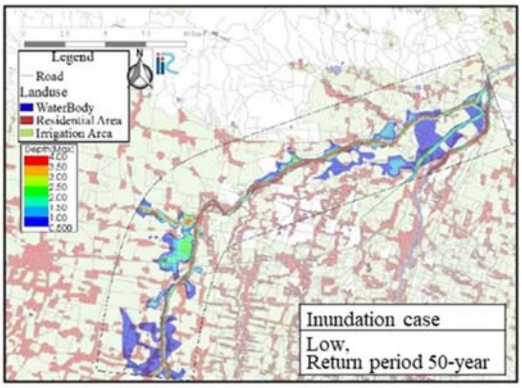
Return period 5year



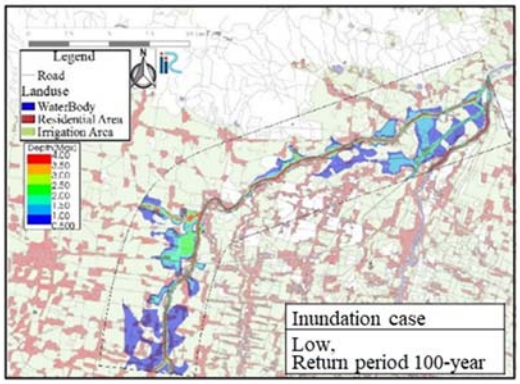
Return period 10 year



Return period 30 year



Return period 50 year

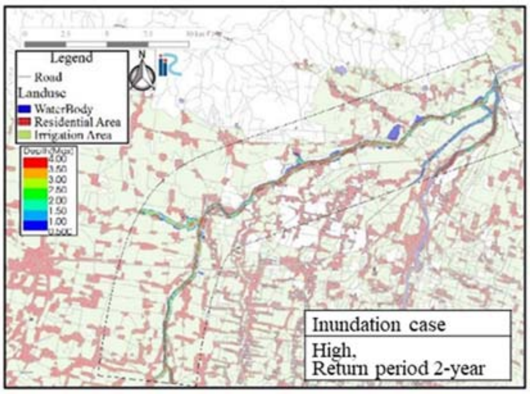


Return period 100 year

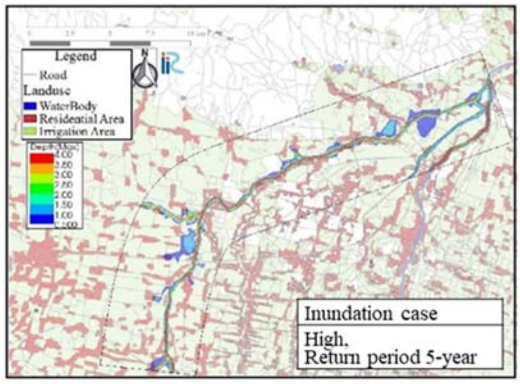
Source: JICA Project Team 2

Figure A9.1.7 Maximum Inundation Depth and Area in Widas River Basin under Low Scenario

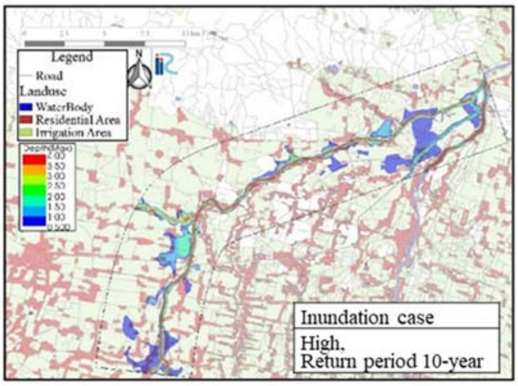
4. High



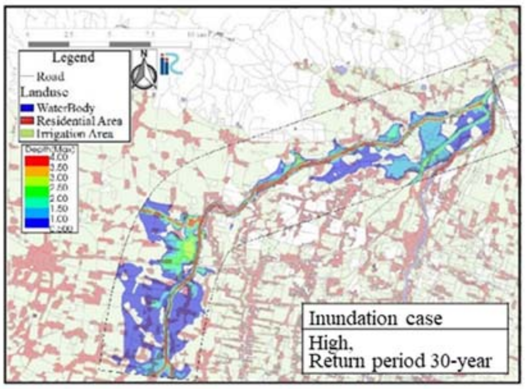
Return period 2 year



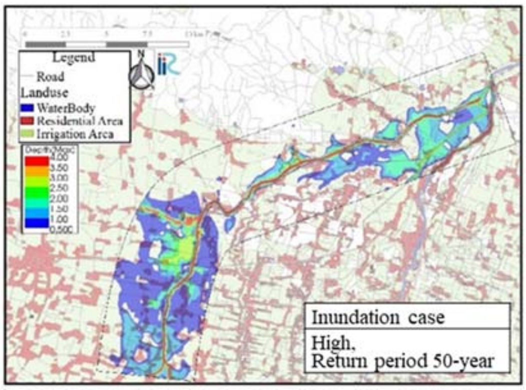
Return period 5year



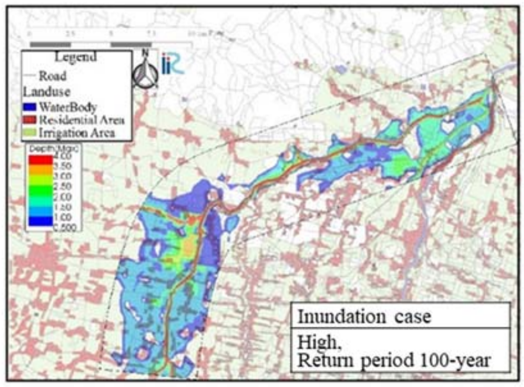
Return period 10 year



Return period 30 year



Return period 50 year



Return period 100 year

Source: JICA Project Team 2

Figure A9.1.8 Maximum Inundation Depth and Area in Widas River Basin under High Scenario

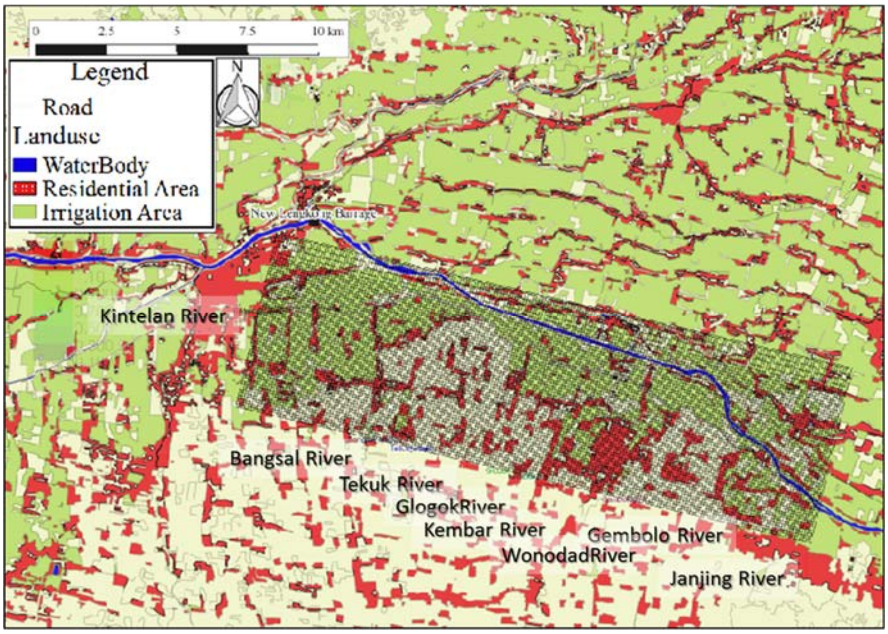
A9.2 Sadar River Basin

A9.2.1 Present Condition of Sadar River Basin

Study for flood protection in Sadar River Basin, has been conducted in "Studi Evaluasi System Pengendalian banjir kali Sadar Kabupaten and Kota Mojokerto, 2013". It is concluded pump drainage system would be applied. Small tributaries meet main stream of Sadar river and they cause flood. Here is located flat area, then the type of inundation flow is judged as diffusion type. Hence, two-dimensional model is applied this inundation area.

A9.2.2 Simulation Model

The inundation analysis in the Sadar River basin is applied two-dimensional unsteady flow analysis method. The model area is decided from the inundation area from the past flood events. The target area of analysis is shown in Figure A9.2.1.



Source: JICA Project Team 2

Figure A9.2.1 Target Area of Analysis in Sadar River Basin

A9.2.3 Conditions of Analysis

The conditions of simulation are set as follows:

<u>Boundary Condition</u>

- Downstream End: The boundary condition of the downstream end is set at the water level of mainstream. The probable water levels of the mainstream are estimated from the non-uniform flow calculation by HEC-RAS. The boundary condition of the downstream end is shown in Table A9.2.1.

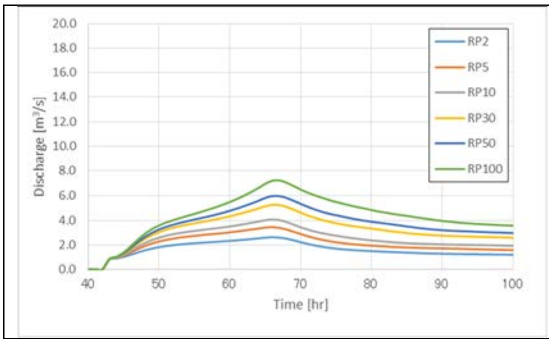
Table A9.2.1 Boundary Condition of Downstream End (Water Level: EL.m)

Return Period (Year)	Present	Feature		
		Low	Medium	High
2	4.0	4.2	4.2	4.3
5	4.3	4.5	4.5	4.6
10	4.5	4.6	4.7	4.8
30	4.7	4.8	4.9	5.1
50	4.8	4.9	5.0	5.3
100	4.9	5.0	5.2	5.6

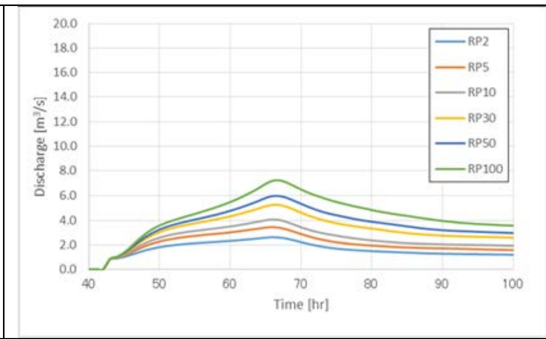
Source: JICA Project Team 2

- Upstream End: The hydrographs and adjustment magnitude under the present condition and the future conditions are estimated and provided by JICA Project Team 1. Figure A9.2.2 shows the hydrographs at the present condition. And the peak discharge of each upstream boundary conditions is shown in Table A9.2.2.

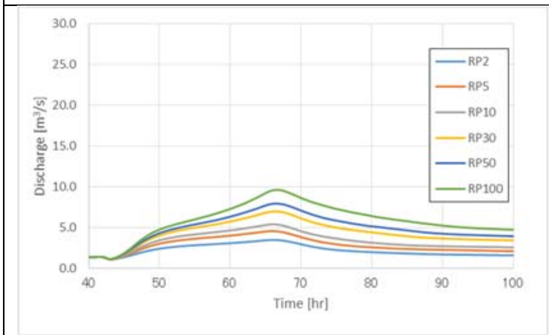
➢ The hydrographs under the present and future condition are estimated by JICA Project Team 1. These hydrographs are applied to the upstream boundary



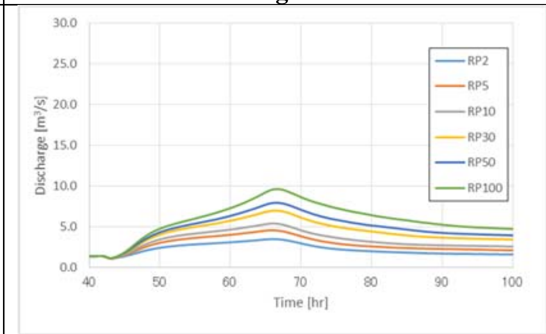
Kintelan River



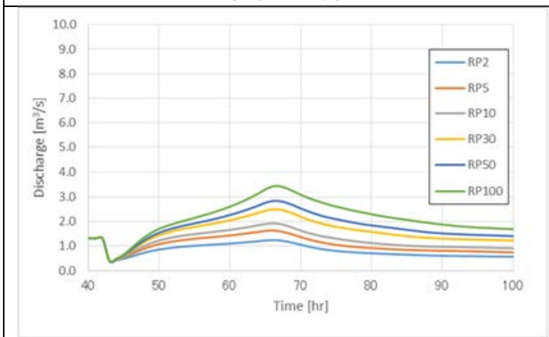
Bangsal River



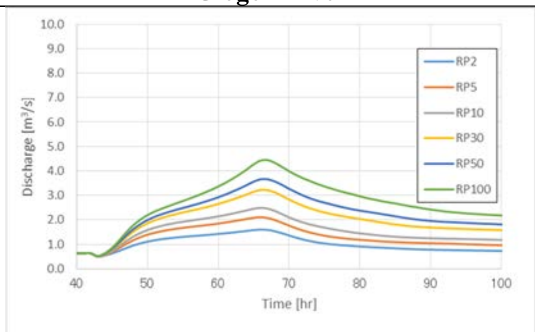
Tekuk River



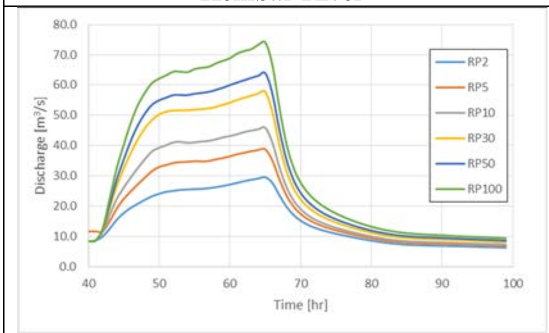
Glogok River



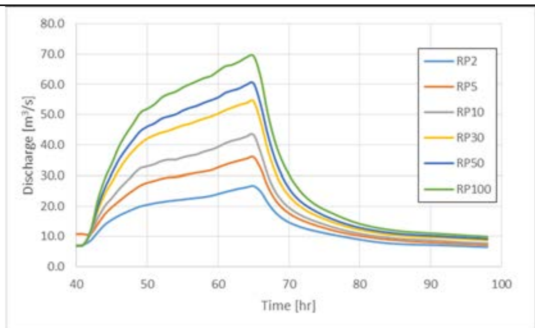
Kembar River



Wonodad River



Gembolo River



Janjing River

Source:JICA Project Team 2

Figure A9.2.2 Hydrograph of Each Upper End Boundary Condition (Present Condition)

Table A9.2.2 Peak Discharge of Upper End Boundary

Return Period (Year)	Peak Discharge (m^3/s)			
	Present	Low	Medium	High
1. Kintelan River				
2	2.6	3.0	3.0	3.3
5	3.4	4.0	4.0	4.3
10	4.1	4.5	4.8	5.3
30	5.3	6.0	6.4	8.0
50	6.0	6.4	7.6	11.3
100	7.3	7.3	10.0	20.2
2. Bangsal River				
2	5.5	6.3	6.3	6.8
5	7.2	8.3	8.3	9.1
10	8.5	9.5	10.0	11.1
30	11.0	12.6	13.4	16.8
50	12.5	13.5	15.8	23.7
100	15.2	15.2	21.0	42.4
3. Tekuk River				
2	3.5	4.0	4.0	4.3
5	4.6	5.2	5.2	5.7
10	5.4	6.0	6.3	7.0
30	7.0	7.9	8.5	10.6
50	7.9	8.5	10.0	14.9
100	9.6	9.6	13.3	26.7
4. Glogok River				
2	1.5	1.6	1.6	1.7
5	1.8	2.1	2.1	2.3
10	2.1	2.4	2.5	2.8
30	2.8	3.2	3.4	4.2
50	3.2	3.4	4.0	6.0
100	3.8	3.8	5.3	10.7
5. **Kembar River**				
2	1.3	1.4	1.4	1.5
5	1.6	1.9	1.9	2.1
10	1.9	2.1	2.3	2.5
30	2.5	2.8	3.0	3.8
50	2.8	3.0	3.6	5.4
100	3.4	3.4	4.8	9.6
6. **Wonodad River**				
2	1.6	1.8	1.8	2.0
5	2.1	2.4	2.4	2.7
10	2.5	2.8	2.9	3.2
30	3.2	3.7	3.9	4.9
50	3.7	3.9	4.6	6.9
100	4.4	4.4	6.1	12.4
7. **Gembolo River**				
2	29.5	33.9	33.9	36.7
5	38.7	44.7	44.7	48.6
10	45.8	50.7	53.1	57.8
30	57.7	63.9	67.3	78.6
50	63.9	67.6	76.0	96.6
100	74.0	74.0	90.3	122.6
8. **Janjing River**				
2	26.6	30.9	30.9	33.7
5	36.0	42.2	42.2	46.2
10	43.3	43.3	50.0	54.7
30	54.4	60.5	63.5	73.7
50	60.3	63.9	71.4	87.8
100	69.3	69.3	83.6	111.6

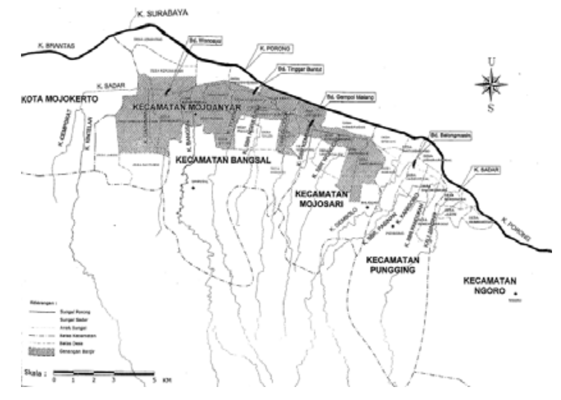
Source: ICA Project Team 2

<u>Other Condition</u>

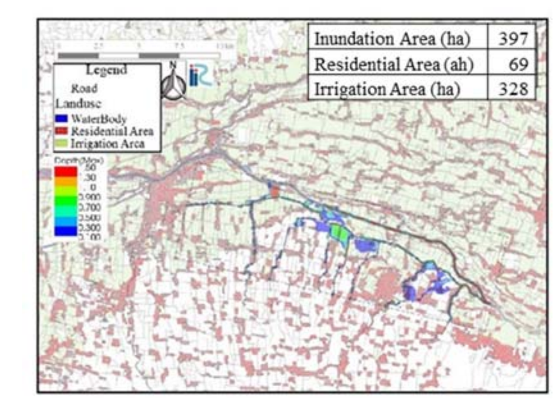
- Roughness coefficient: River area (n = 0.03), Land area (n = 0.045)
- Calculation pitch: Calculation pitch: dt = 1 [sec]
- River Cross Section: River cross section survey was carried out in this project. The grid size of the model is decided from the capacity of the computer. Even the river cross sections are surveyed, all survey points in the section are not reflected to the analysis model due to narrow river width. Therefore, some survey points and riverbed elevation are applied to the model.

A9.2.4 Model Calibration

The frequently inundated area in the administrative area was mentioned in "Studi Evaluasi System Pengendalian banjir kali Sadar Kabupaten & Kota Mojokerto, 2013" as shown in Figure A9.2.3. Figure A9.2.3 was not prepared based on the actual flood event and/or inundation analysis results. However, the planning of the flood control structures are designed to return period 25-year probable flood. The calibration of the model is carried out by using Figure A9.2.3 due to no actual inundation map. Figure A9.2.4 shows the inundation flow time sequence.



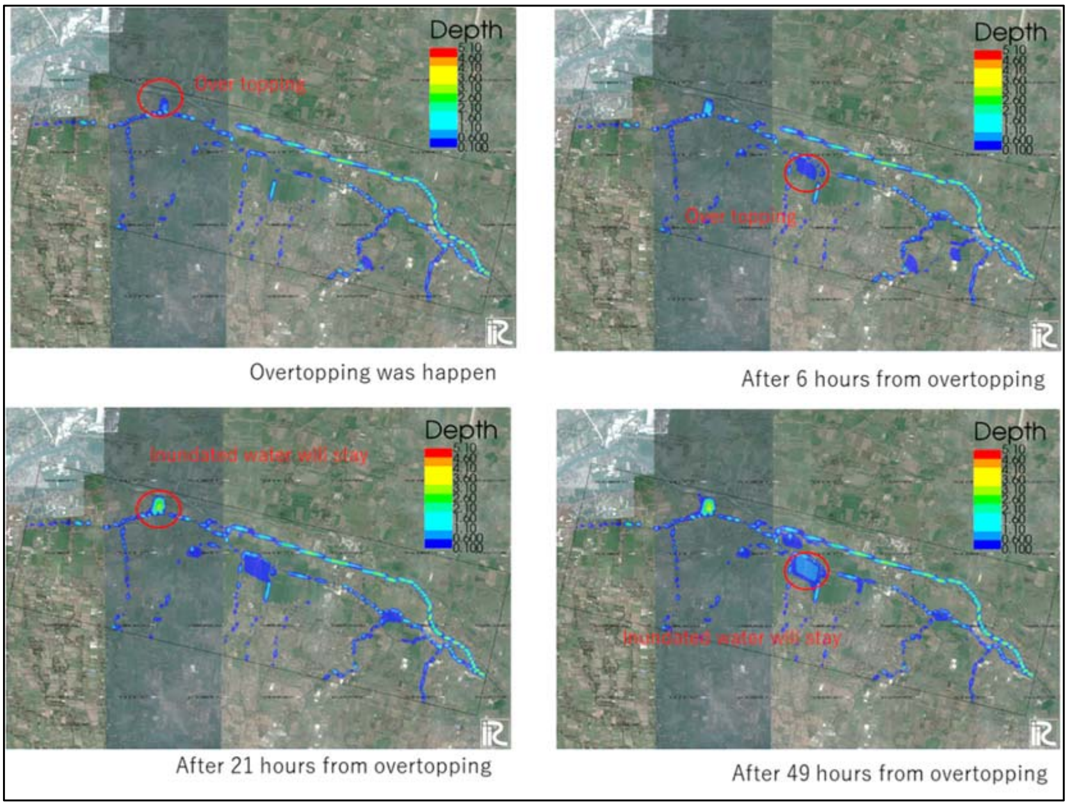
Inundation Area



Return period 30 year

Source: Studi Evaluasi System Pengendalian banjir kali Sadar Kabupaten & Kota Mojokerto

Figure A9.2.3 Calibration in Sadar River Basin



Source: JICA Project Team 2, background image: Bing map

Figure A9.2.4 Time sequence of Inundation Flow in Sadar River

A9.2.5 Results of Flood Inundation Analysis

The flood inundation analysis is carried out to the present condition and the future condition (Low, Medium, High case) under the climate change. The results of the analysis are shown in Table A9.2.3 and Figure A9.2.5 to Figure A9.2.8.

Table A9.2.3 Results of Flood Inundation Analysis (Sadar River Basin)

1. Present Condition

Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	91.1	88.2	962
5	127.1	99.5	1,084
10	149.2	105.2	1,147
30	174.3	115.8	1,262
50	186.2	120.2	1,311
100	215.1	141.5	1,543

Note: Parameter of Affected Houses are applied from Japanese guideline of estimation for flood damage

2. Future Condition (Medium)

Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	106.80	92.6	1,009
5	143.60	108.5	1,183
10	173.70	117.5	1,281
30	193.20	125.2	1,364
50	208.40	137.6	1,500
100	262.00	161.9	1,765

Note: Parameter of Affected Houses are applied from Japanese guideline of estimation for flood damage

3. Future Condition (Low)

Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	106.82	92.6	1,009
5	137.83	106.1	1,157
10	161.75	112.2	1,224
30	186.22	120.8	1,317
50	193.64	127.1	1,386
100	215.15	141.5	1,543

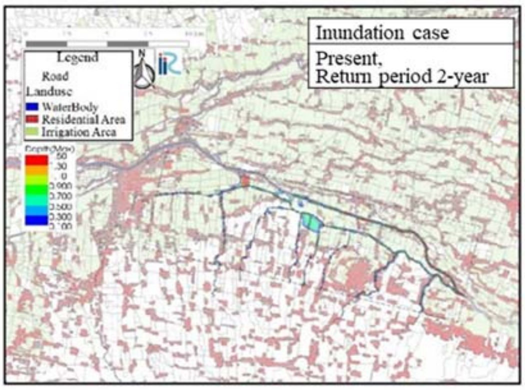
Note: Parameter of Affected Houses are applied from Japanese guideline of estimation for flood damage

4. Future Condition (High)

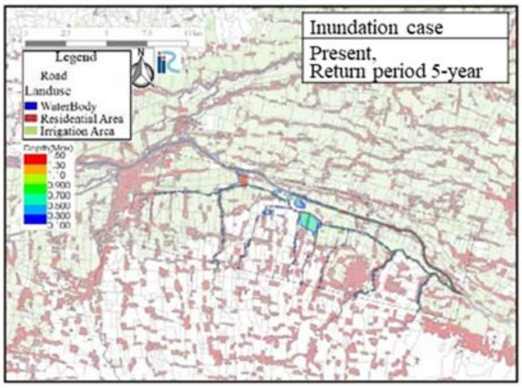
Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	113.30	95.7	1,043
5	149.42	110.9	1,208
10	180.81	120.1	1,309
30	215.17	139.4	1,519
50	268.18	162.1	1,767
100	502.81	319.8	3,486

Note: Parameter of Affected Houses are applied from Japanese guideline of estimation for flood damage
Source: JICA Project Team 2

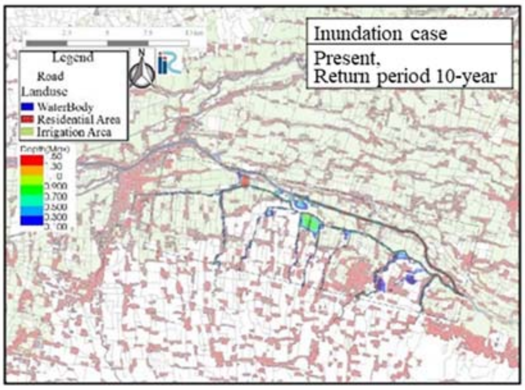
1. Present



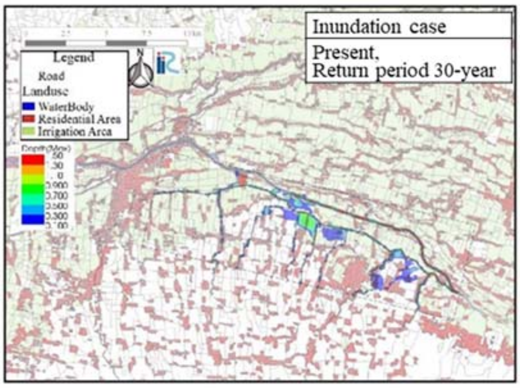
Return period 2 year



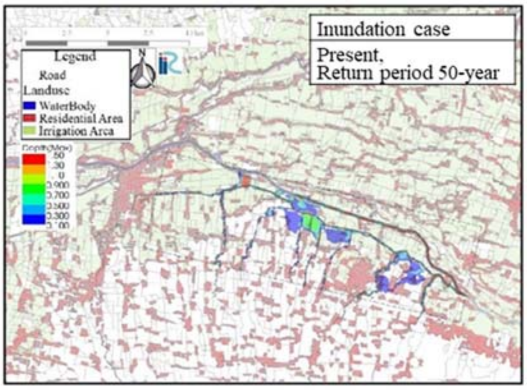
Return period 5year



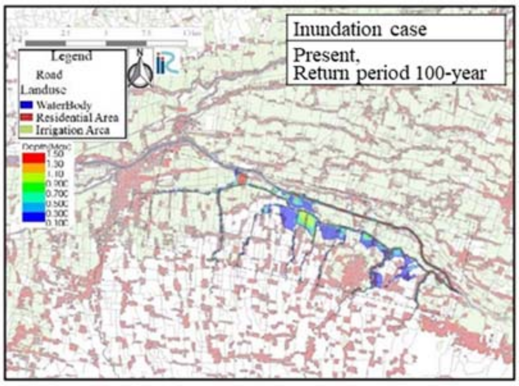
Return period 10 year



Return period 30 year



Return period 50 year

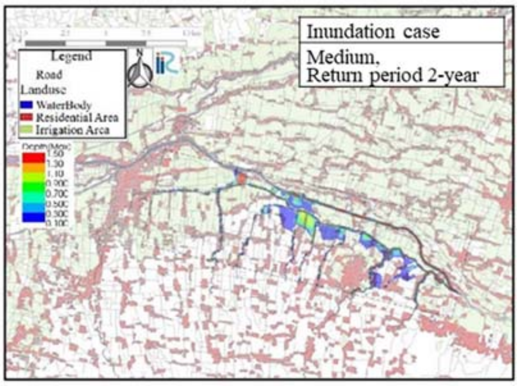


Return period 100 year

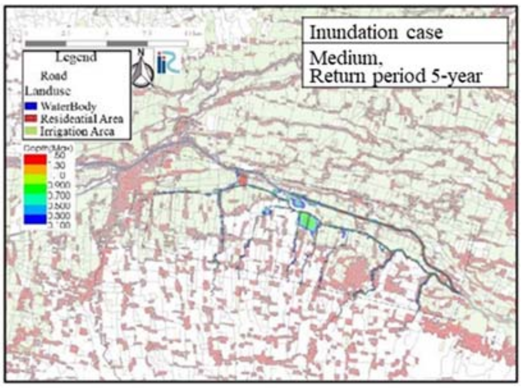
Source: JICA Project Team 2

Figure A9.2.5 Maximum Inundation Depth and Area in Sadar River Basin under Present Condition

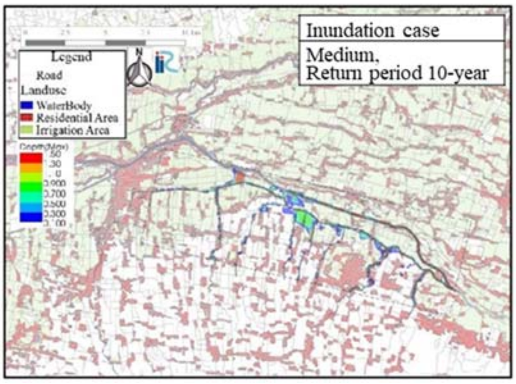
2. Medium



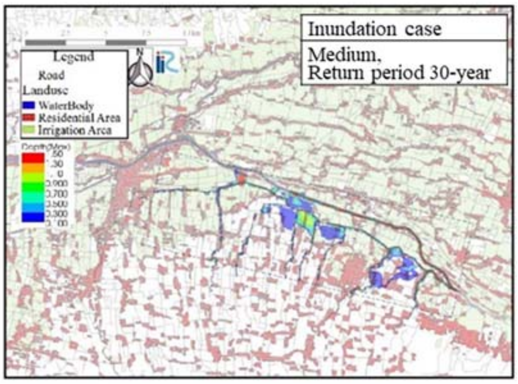
Return period 2 year



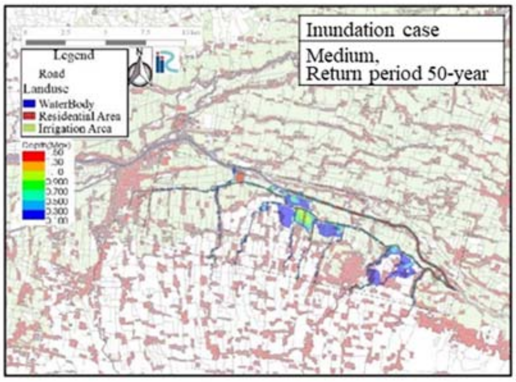
Return period 5year



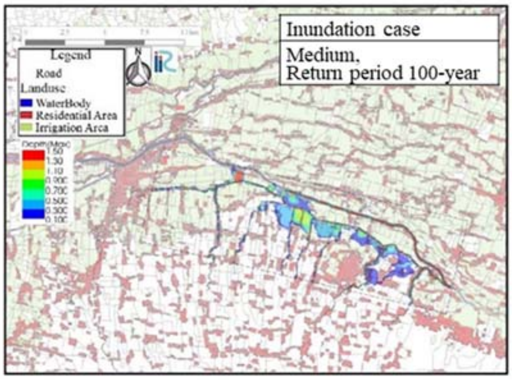
Return period 10 year



Return period 30 year



Return period 50 year

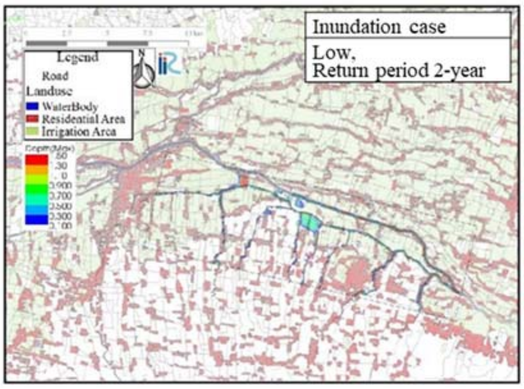


Return period 100 year

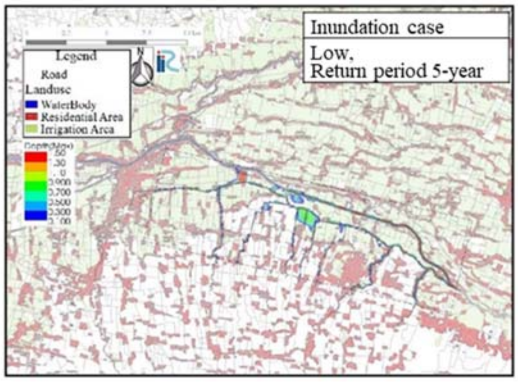
Source: JICA Project Team 2

Figure A9.2.6 Maximum Inundation Depth and Area in Sadar River Basin under Medium Scenario

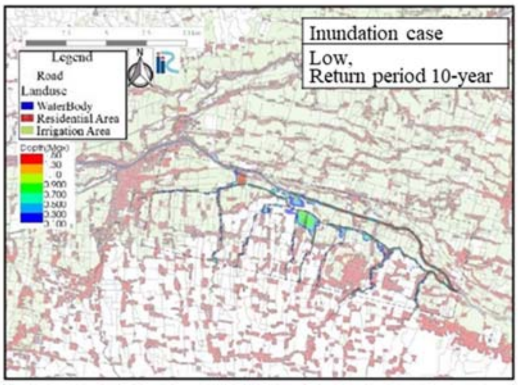
3. Low



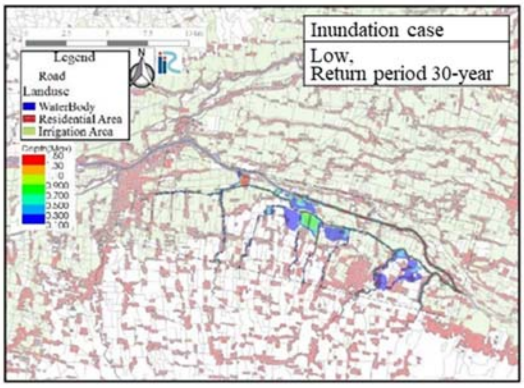
Return period 2 year



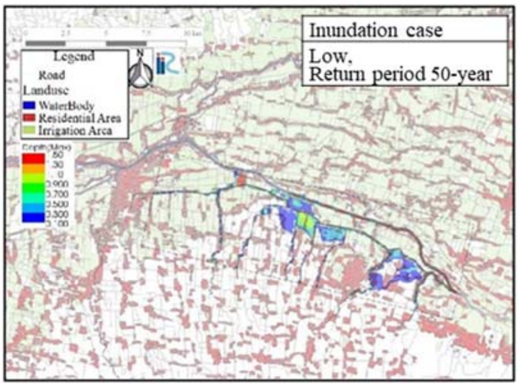
Return period 5year



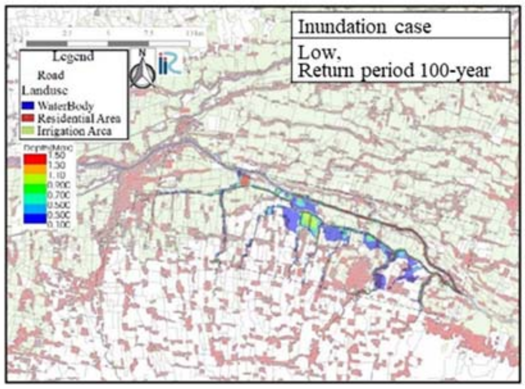
Return period 10 year



Return period 30 year



Return period 50 year

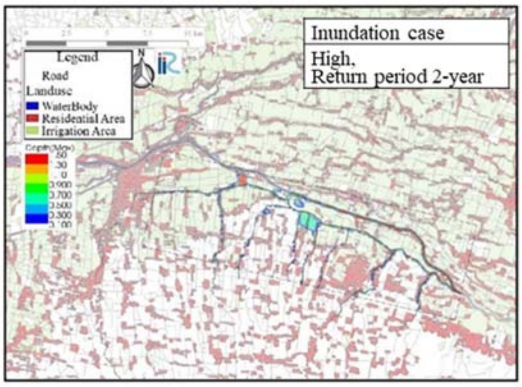


Return period 100 year

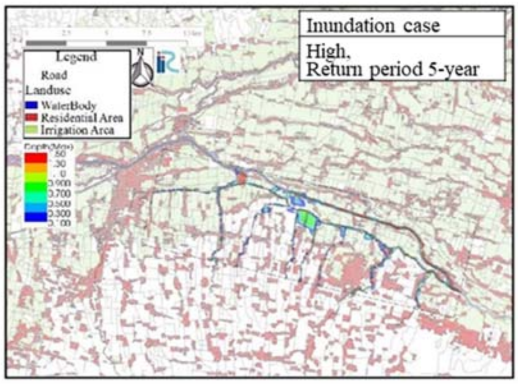
Source: JICA Project Team 2

Figure A9.2.7 Maximum Inundation Depth and Area in Sadar River Basin under Low Scenario

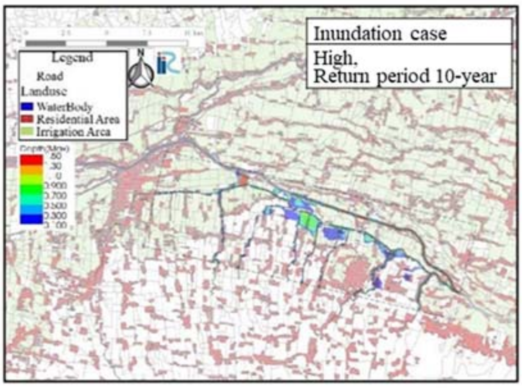
4. High



Return period 2 year



Return period 5year



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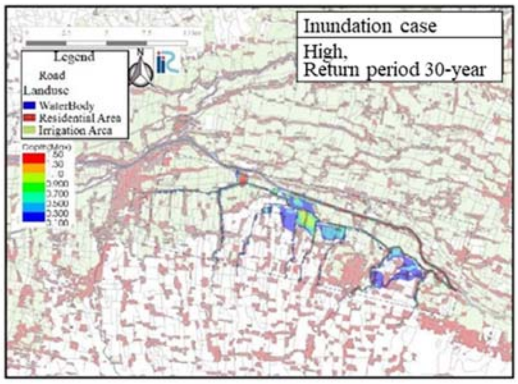
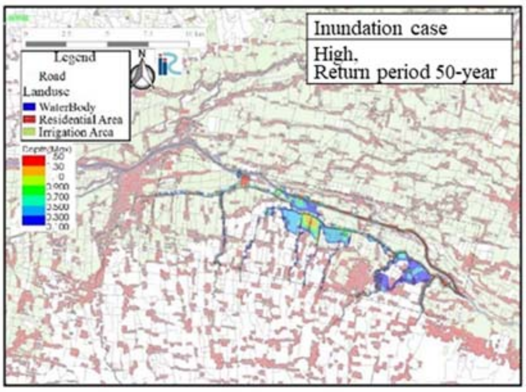
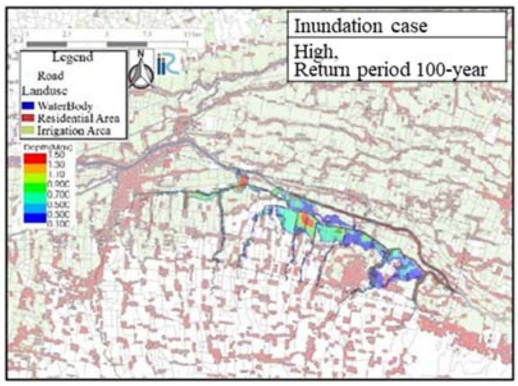


Return period 30 year



Return period 50 year



Return period 100 year

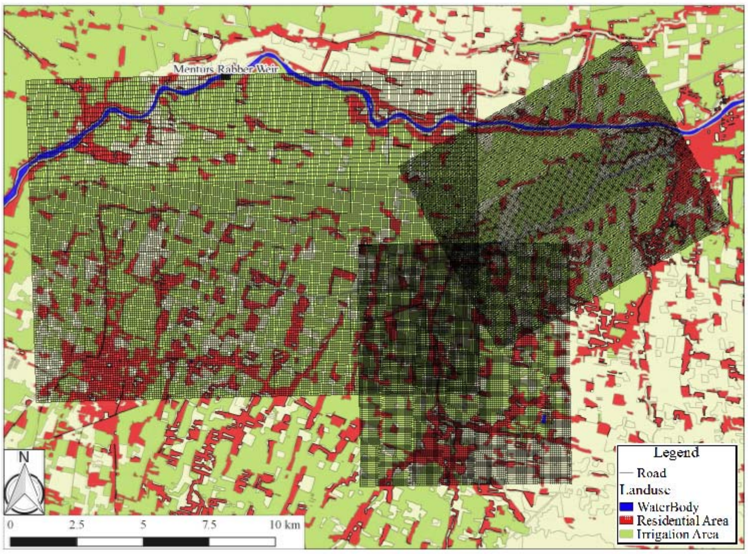
Source: JICA Project Team 2

Figure A9.2.8 Maximum Inundation Depth and Area in Sadar River Basin under High Scenario

A9.3 Brangkal River Basin

A9.3.1 Present Condition in Brangkal River Basin

Flood protection study in Brangkal River Basin was conducted and river dike construction is carrying out construction works. However damage caused by flood inundation still is occurred in Ngotok Ring River which is tributary river of Brangkal River. Based on the Study of Ngotok Ring Basin was conducted in "Sid Sistem Penanggulangan Banjir Ngotok Ring Kanal Kabupaten Mojokerto , 2008", inundation is occurred at the several points which is shown in Figure A9.3.4. The terrain type of this area is flat and to present inundation of this area, two-dimensional model is applied.



Source: JICA Project Team 2

Figure A9.3.1 Target Area of Analysis in Ngotok Ring River Basin

A9.3.2 Simulation Model

The inundation analysis in the Ngotok Ring River basin where is a tributary of the Brangkal River is applied 2-D unsteady flow analysis method. The model area is decided from the inundation area from the past flood events. Flooding area in the Ngotok Ring River was located separately along the river, so inundation model was separated into three parts. The simulation model is shown in Figure A9.3.1.

A9.3.3 Conditions of Analysis

The conditions of simulation are set as follows:

<u>Boundary Condition</u>

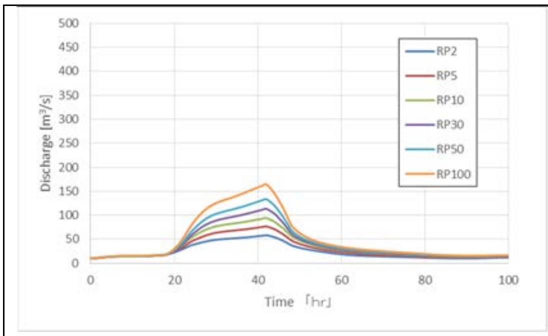
- Downstream End: The boundary condition of the downstream end at confluence point at Brantas mainstream is set the probable water levels of the mainstream witch are estimated from the non-uniform flow calculation by HEC-RAS. The boundary condition of the downstream end is shown in Table A9.3.1. And other two parts boundary condition are free flow depth.

Table A9.3.1 Boundary Condition of Downstream End (Water Level: EL.m)

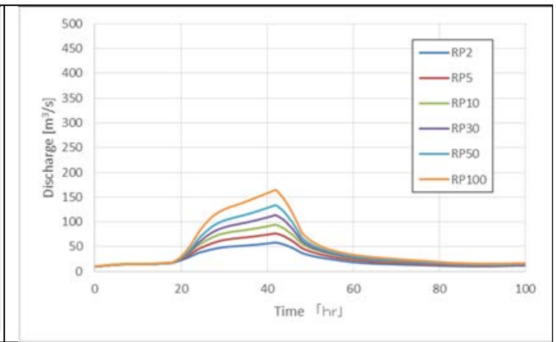
Return Period (Year)	Present	Feature		
		Low	Medium	High
2	18.6	19.0	19.0	19.1
5	19.1	19.4	19.4	19.6
10	19.3	19.6	19.7	19.9
30	19.6	19.9	20.1	20.4
50	19.8	20.0	20.3	20.8
100	20.0	20.2	20.5	21.2

Source: JICA Project Team 2

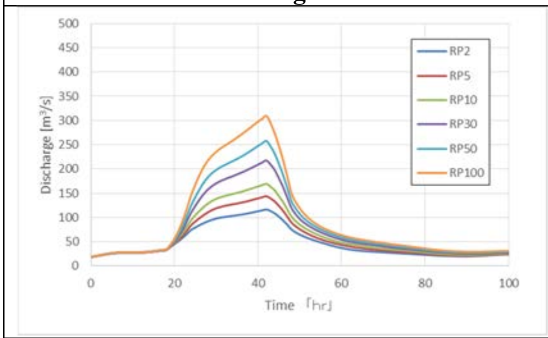
- Upstream End: The hydrographs and adjustment magnitude under the present condition and the future conditions are estimated and provided by Team 1. Figure A9.3.2 shows the hydrographs at the present condition. And the peak discharge of each upstream boundary conditions is shown in Table A9.3.2.
- The hydrographs under the present and future condition are estimated by JICA Project Team 1.



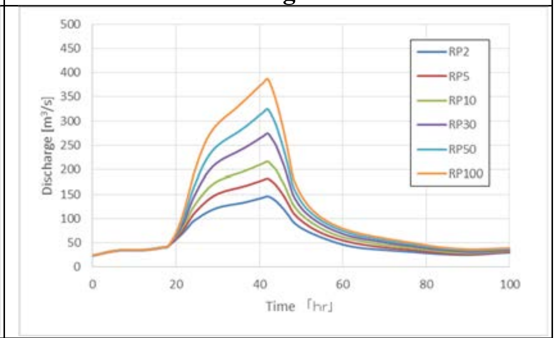
Tembelang River



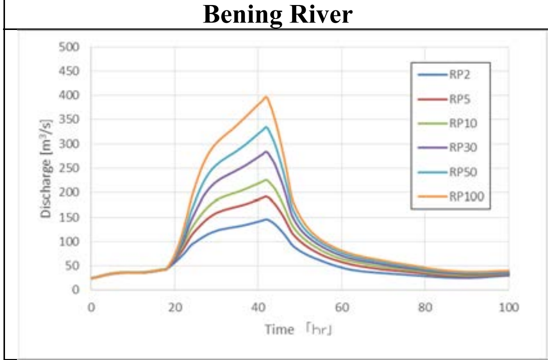
Jombang River



Bening River



Gunting River



Brangkal River

Source: JICA Project Team 2

Figure A9.3.2 Hydrograph of Each Upper End Boundary Condition

Table A9.3.2 Peak Discharge of Upper End Boundary (Ngotok Ring River)

Return Period (Year)	Peak Discharge (m^3/s)			
	Present	Low	Medium	High
1. Temblang River				
2	58	67	67	72
5	77	89	89	99
10	94	89	113	130
30	114	134	145	183
50	134	145	172	232
100	164	164	214	310
2. Jombang River				
2	68	78	78	84
5	86	100	100	111
10	94	100	113	130
30	123	146	157	198
50	143	156	184	249
100	174	174	226	328
3. Bening River				
2	117	133	133	144
5	144	166	166	185
10	170	166	204	234
30	218	258	278	350
50	258	280	332	448
100	310	309	402	583
4. Gunting River				
2	146	167	167	180
5	182	211	211	235
10	217	211	261	299
30	274	325	351	442
50	325	353	418	564
100	387	387	503	728
5. Brangkal River				
2	146	167	167	180
5	192	222	222	247
10	226	222	272	312
30	284	336	363	457
50	334	363	430	581
100	397	397	515	746

Source: JICA Project Team 2

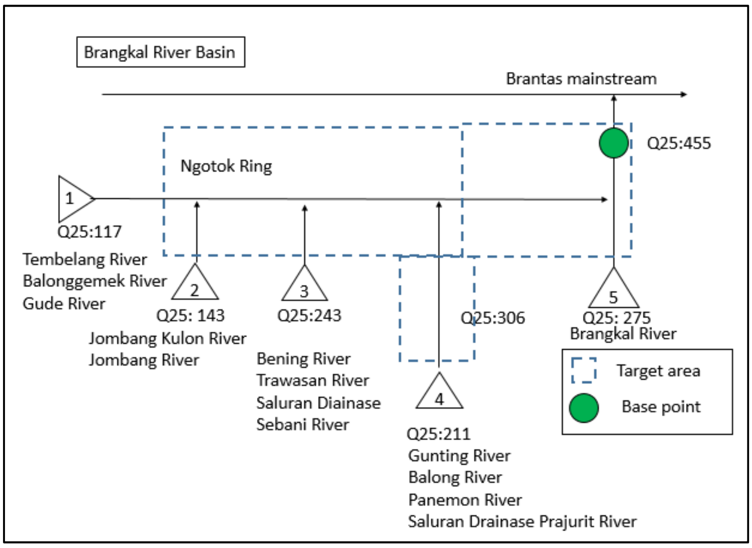
Other Condition

- Roughness coefficient: River area (n = 0.025), Land area (n = 0.03)
- Calculation pitch: Calculation pitch: dt = 1 [sec]
- River Cross Section: River cross section survey was carried out on “Sid Sistem Penanggulangan Banjir Ngotok Ring Kanal Kabupaten Mojokerto (2008)” in 2008. The shape of River cross section is represented with rectangle by reference to the survey data.

A9.3.4 Model Calibration

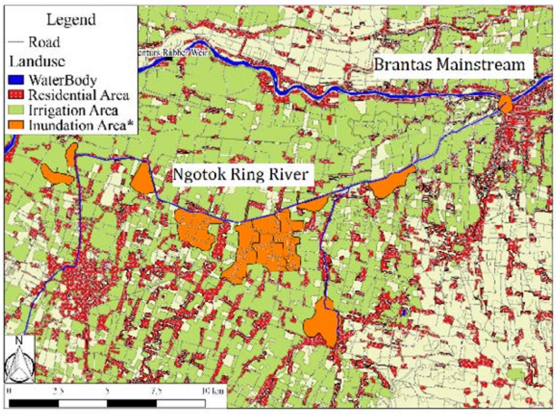
Flood inundation is frequently occurred in the Ngotok Ring River basin where is a tributary of the Brangkal River basin.

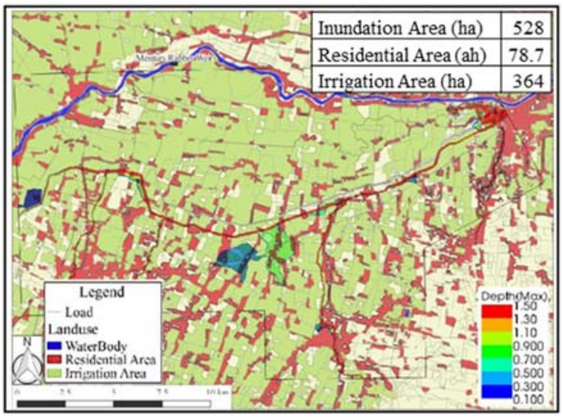
Calibration of the parameters for the two-dimensional unsteady flow analysis is carried out to adjust the design flood discharge in the Ngotok Ring River basin as shown in Figure A9.3.3. As a result of calibration, the largest inundation area at upstream of the Ngotok Ring River was expression.



Source: JICA Project Team 2

Figure A9.3.3 Design Flood Discharge in Ngotok Ring River Basin





Inundation Record by existing report	Return period 30 year

Source:

Figure A9.3.4 Calibration in Ngotok Ring River

A9.3.5 Results of Flood Inundation Analysis

The flood inundation analysis is carried out to the present condition and the future condition (Low, Medium, High case) under the climate change. The results of the analysis are shown in Table A9.3.3 and Figure A9.3.5 and Figure A9.3.8

Table A9.3.3 Results of Flood Inundation Analysis (Ngotok Ring River Basin)

1. Present Condition

Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	1	15	300
5	6	109	1,110
10	13	606	6,161
30	33	1,117	11,357
50	50	1,394	14,168
100	74	1,826	18,561

Note: Parameter of Affected Houses are applied from Japanese guideline of estimation for flood damage

2. Future Condition (Medium)

Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	8	87	1,728
5	25	259	5,133
10	41	428	8,471
30	76	1,544	15,688
50	103	2,065	20,991
100	150	2,926	29,733

Note: Parameter of Affected Houses are applied from Japanese guideline of estimation for flood damage

3. Future Condition (Low)

Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	8	87	1,728
5	25	259	5,133
10	34	355	7,031
30	70	1,415	14,384
50	80	1,619	16,451
100	91	1,840	18,704

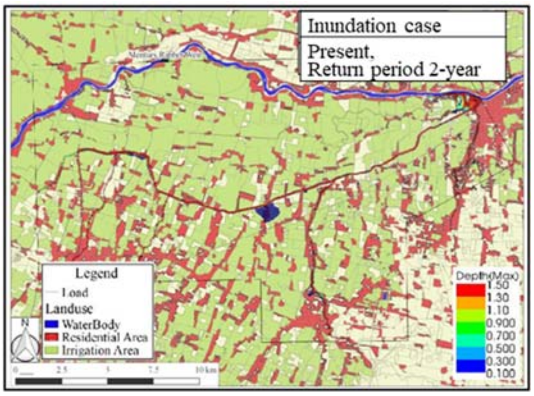
Note: Parameter of Affected Houses are applied from Japanese guideline of estimation for flood damage

4. Future Condition (High)

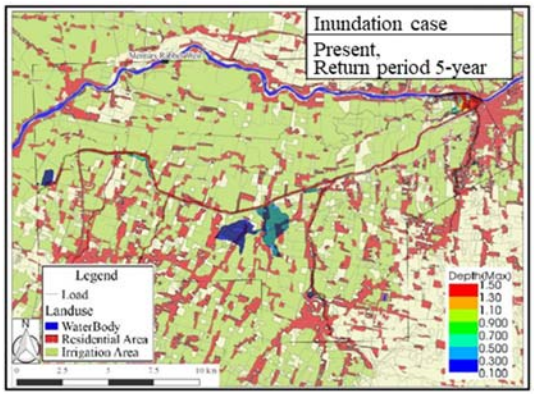
Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	15	159	1,152
5	35	364	10,080
10	63	1,279	12,499
30	127	2,512	23,421
50	182	3,496	37,522
100	250	4,648	49,418

Note: Parameter of Affected Houses are applied from Japanese guideline of estimation for flood damage
Source: JICA Project Team 2

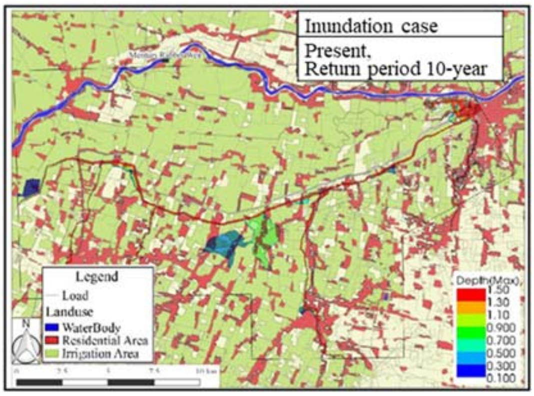
1. Present



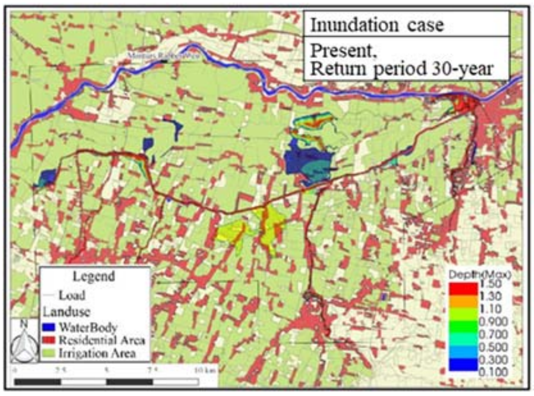
Return period 2 year



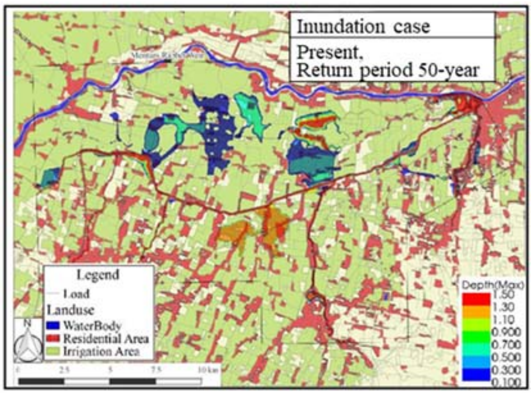
Return period 5year



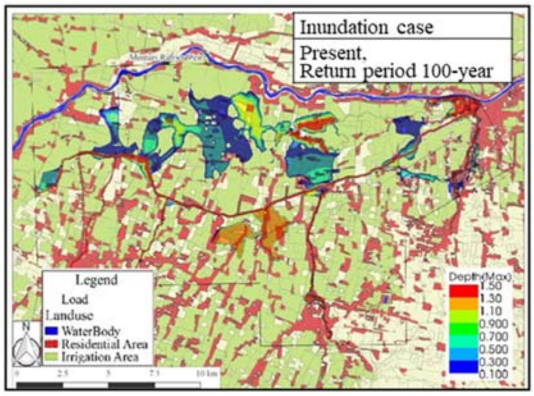
Return period 10 year



Return period 30 year



Return period 50 year

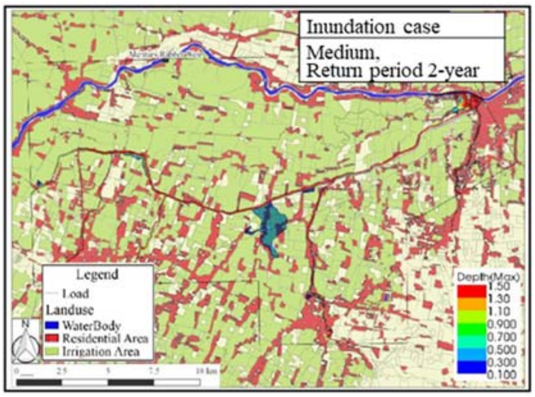


Return period 100 year

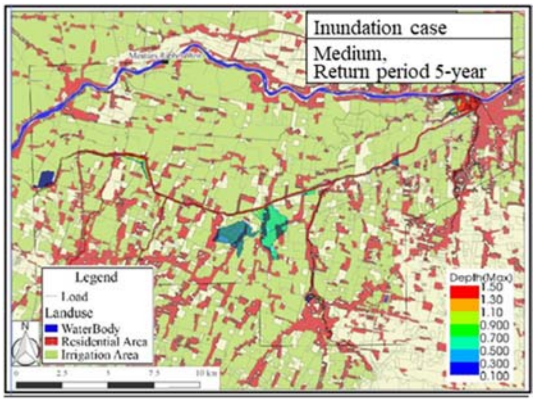
Source: JICA Project Team 2

Figure A9.3.5 Maximum Inundation Depth and Area in Ngotok Ring River Basin under `Present Condition

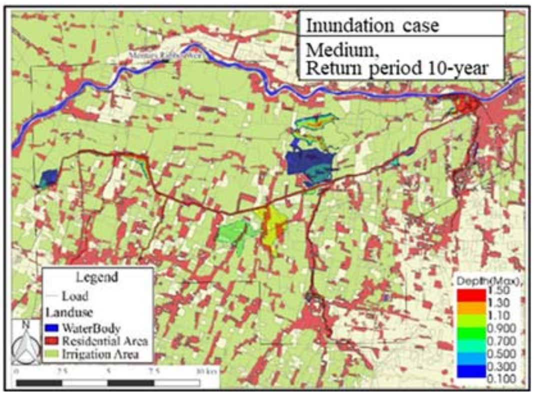
2. Medium



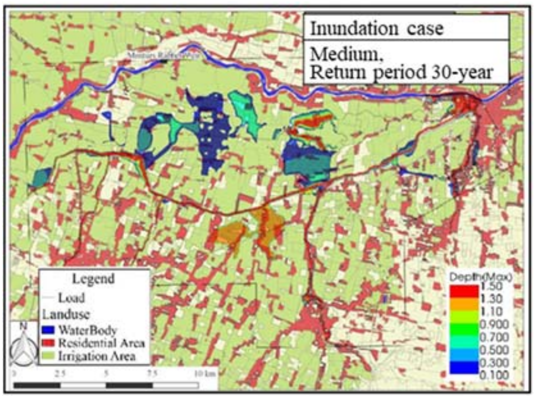
Return period 2 year



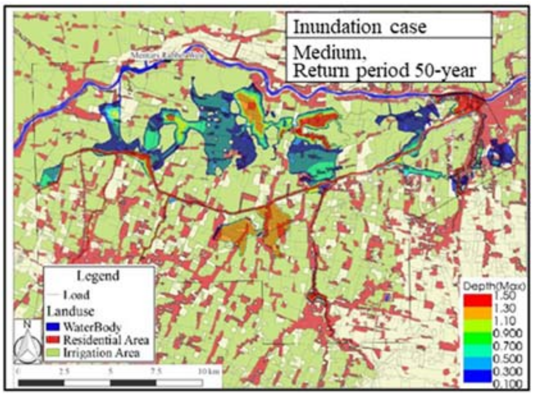
Return period 5year



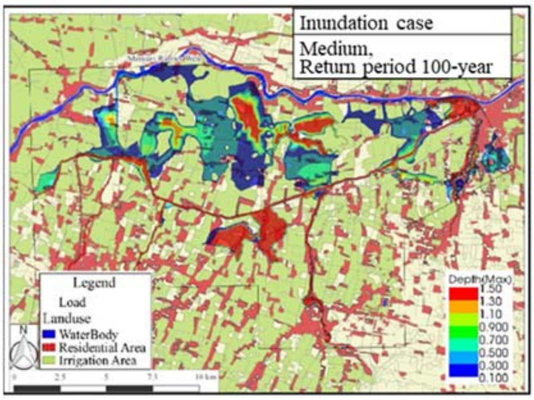
Return period 10 year



Return period 30 year



Return period 50 year

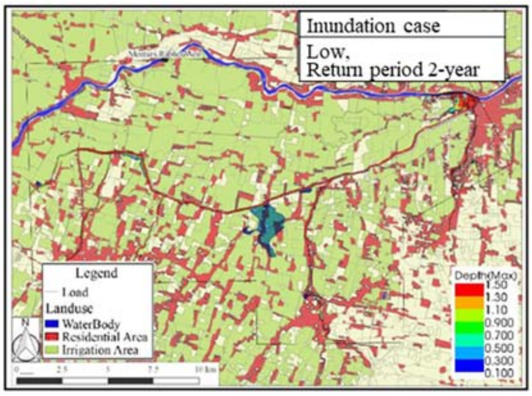
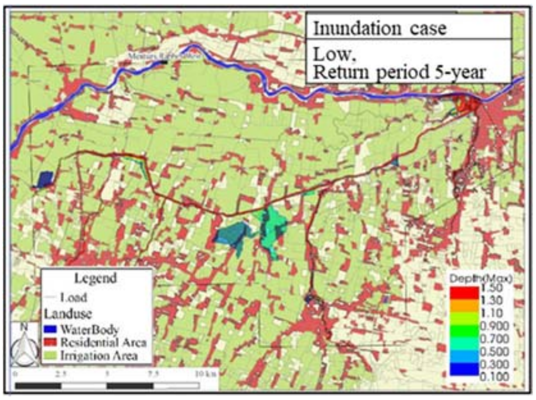
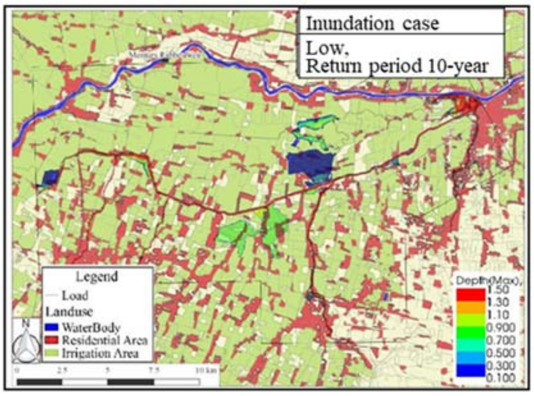
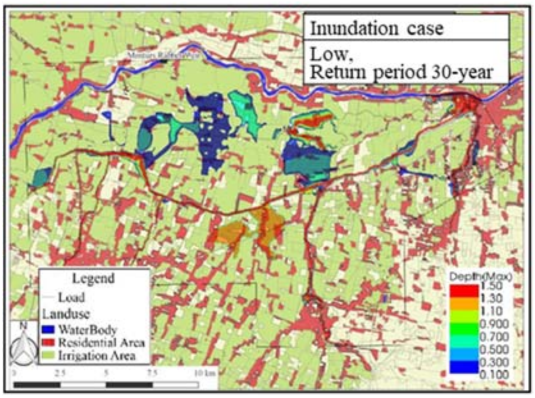
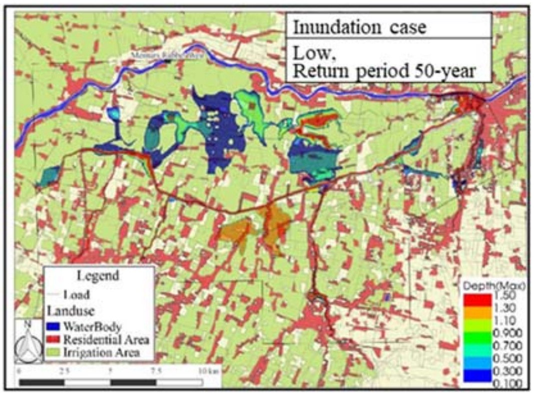
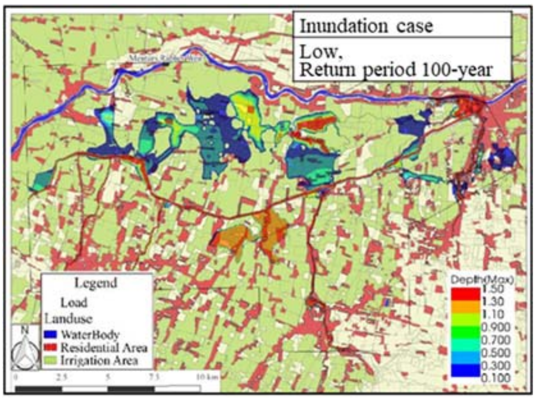


Return period 100 year

Source: JICA Project Team 2

Figure A9.3.6 Maximum Inundation Depth and Area in Ngotok Ring River Basin under Medium Scenario

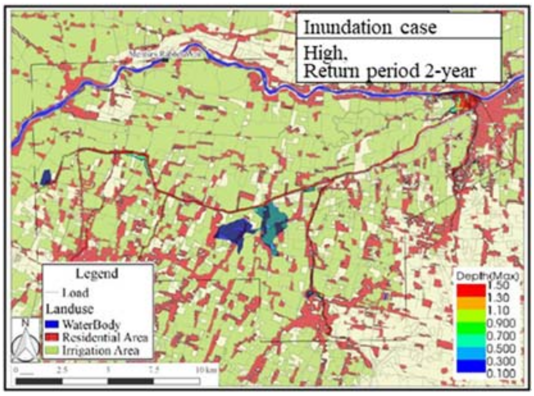
3. Low

	
Return period 2 year	Return period 5year
	
Return period 10 year	Return period 30 year
	
Return period 50 year	Return period 100 year

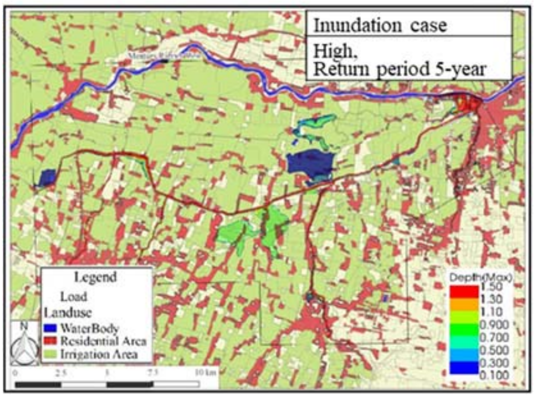
Source: JICA Project Team 2

Figure A9.3.7 Maximum Inundation Depth and Area in Ngotok Ring River Basin under Low Scenario

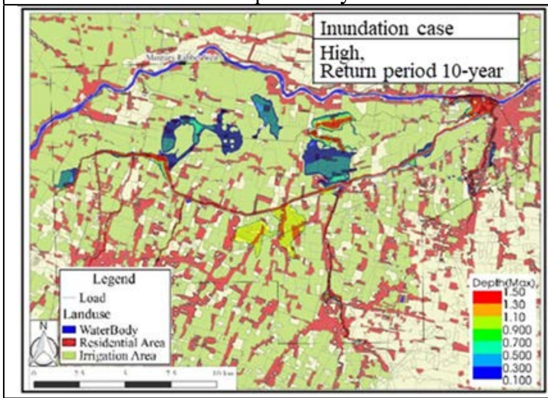
4. High



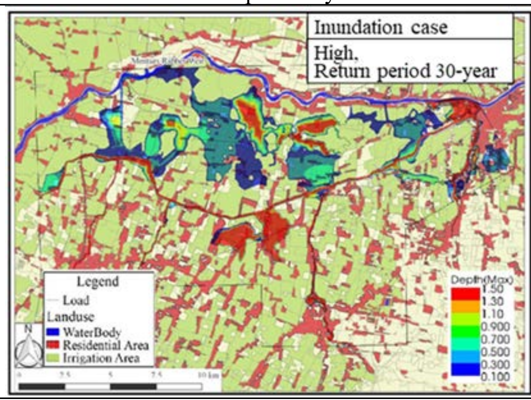
Return period 2 year



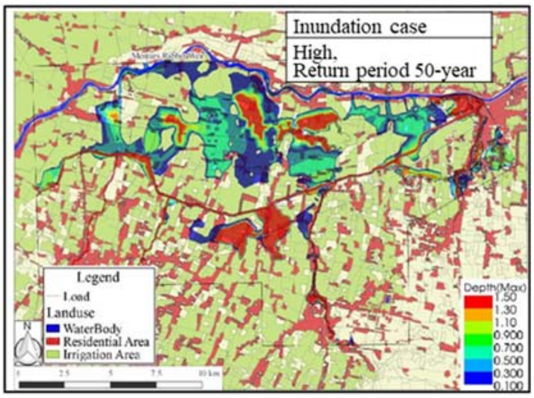
Return period 5year



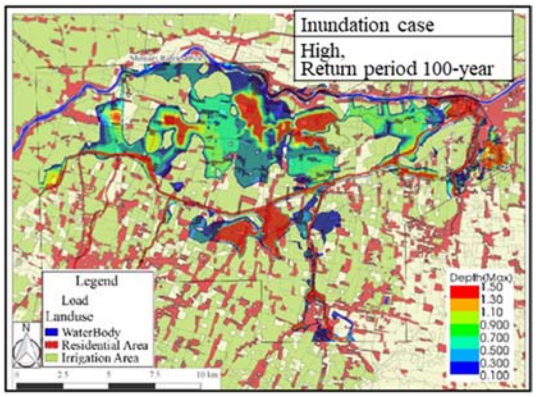
Return period 10 year



Return period 30 year



Return period 50 year



Return period 100 year

Source: JICA Project Team 2

Figure A9.3.8 Maximum Inundation Depth and Area in Ngotok Ring River Basin under High Scenario

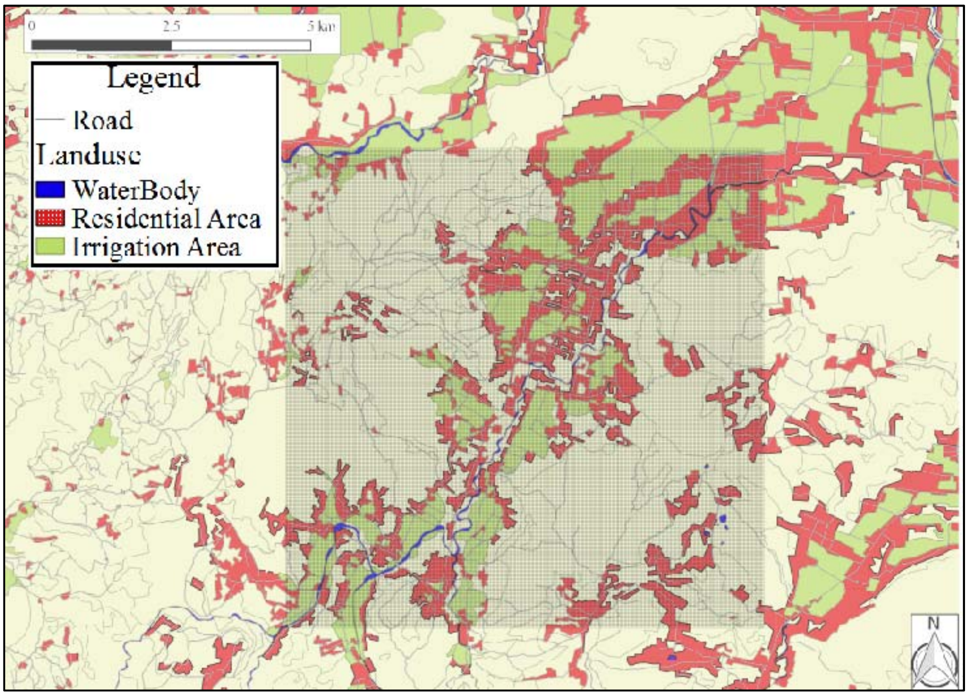
A9.4 Tulungagung Area

A9.4.1 Present Condition in Tulungagung Area

In Tulungagung area, flood protection constructions were conducted such as Neyama drainage canal. However, there is still flush flood is occurred in Tawing river, then inundation analysis is conducted in Tawing river. Tawing river is located mountain area, Therefore, floods in rivers and flood flow on the inundated area flows down together. On the other hand, downstream area is relatively flat, flood will tend to be diffused. Inundation model is applied to 1D and 2D combined model to present inundation catachrestic in Tawing River.

A9.4.2 Simulation Model

The inundation analysis in the Tawing River basin where is a small river located in Tulungagung area is applied 1-D and 2-D unsteady flow analysis method. The model area is decided from the inundation area from the past flood events. The target area of analysis is shown in Figure A9.4.1.



Source: JICA Project Team 2

Figure A9.4.1 Target Area of Analysis in Tawing River Basin

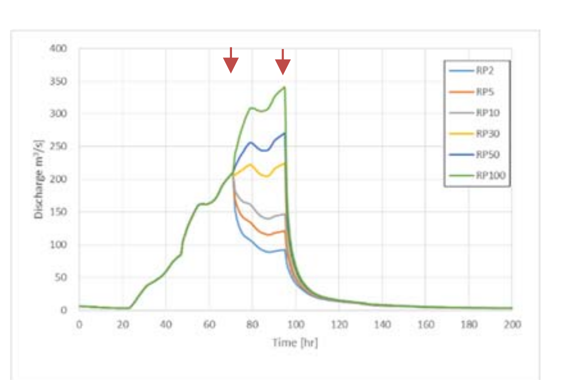
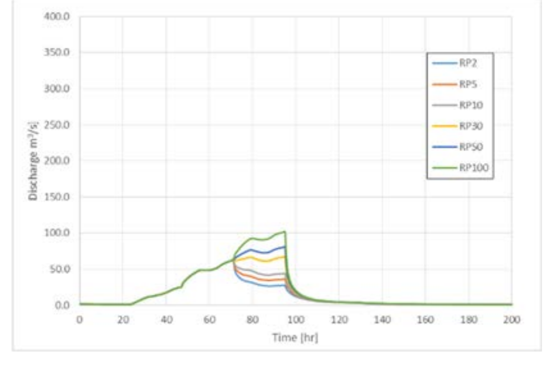
A9.4.3 Conditions of Analysis

The conditions of simulation are set as follows:

<u>Boundary Condition</u>

- Downstream End: The boundary condition of the downstream end is set at normal depth.
- Upstream End: The hydrographs under the present and the future conditions, are estimated and provided by JICA Project Team 1. Figure A9.4.2 shows the hydrographs

at the present condition in Tawing River.

	
Upper Tawing River	**Tributary of Tawing River**

Source: JICA Project Team 2

Figure A9.4.2 Hydrograph of Each Upper End Boundary Condition

As shown in Figure A9.4.2, hydrographs have two peaks, and rainfalls adjusted by JICA Project Team 1 influence second peak discharge. Peak discharge for 2-yeaer, 5-year and 10-year return period are lower than those of 1st peak discharge, then it is not be able to estimate damage caused by each return period. In consideration of flood volume, adjustment for discharge was made as follows;

1) Setting standard hydrograph is as Return Period 50-years flood and coefficient number is estimated with flood volume

Return Period 50-years flood is selected as standard hydrograph to stand out the shape of target flood. The coefficient number is calculated based on each flood volume. The modified hydrograph was created by applying the coefficient α to the hydrograph.

$\alpha = FV_{RPN} / FV_{RP50}$

$Q_{md} = Q_t \times \alpha$

where, FV : Flood Volume (m^3)

α : coefficient

RP : Return Period for 2-, 5-, 10-, 30-, 50- and 100-year flood

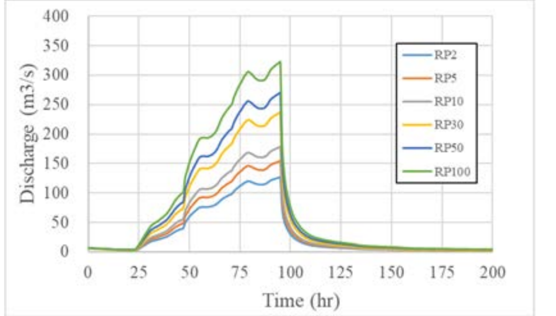
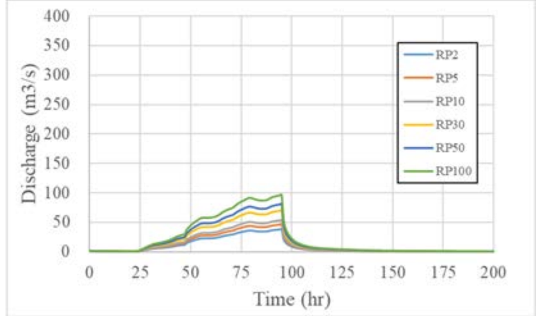
Q_{md} : Modified Discharge (m^3/s)

Q_t : Discharge of each time in hydrograph (m^3/s)

Table A9.4.1 Modified Peak Discharge under Present Condition

Return Period Flood	RP2	RP5	RP10	RP30	RP50	RP100
Flood Volume ($10^6 m^3$)	16.1	19.5	22,6	30,0	34.2	40.9
Coefficient number (α: Flood volume of Each RP per flood volume of RP 50 year)	0.47	0.57	0.66	0.88	1.00	1.19
Original Peak Flood of second flood(m^3/s)	119.5	156.6	190.2	291.3	350.7	442.2
Modified Peak Flood (m^3/s) *(Q_{md})	165.1	199.9	231.4	307.3	350.7	418.3

Note *: Peak discharge is including Tawing main stream and tributary
Source: JICA Project Team 2

	
Upper Tawing River	**Tributary of Tawing River**

Source: JICA Project Team 2

Figure A9.4.3 Modified Hydrograph of Each Upper End Boundary Condition

2) Estimation of Flood Volume and coefficient number for hydrograph of each flood in Three Future Scenarios

Calculate the flood volume for each flood probability year and set it as α.

$\alpha = FV_{RPLow/Medium/High} / FV_{RPP}$

$Q_{md} = Q_t \times \alpha$

where, α : coefficient

FV : Flood Volume (m^3)

RP($_{Low/Medium/High}$): Return Period flood under Low/Medium/High Scenario

RPP: Return Period flood under Present Condition

Q_{md} : Modified Discharge (m^3/s)

Q_t : Discharge of each time in hydrograph (m^3/s)

Table A9.4.2 Flood Volume and Coefficient Number for Hydrograph of Each Return Period under Three Future Condition

Present Condition	RP2	RP5	RP10	RP30	RP50	RP100
Flood Volume ($10^6 m^3$)	16.1	19.5	22.6	30.0	34.3	40.9
Low Scenario	RP2	RP5	RP10	RP30	RP50	RP100
Flood Volume ($10^6 m^3$)	17.1	21.2	26.1	34.4	37.5	40.9
α (Low Scenario flood volume / Present flood volume)	1.06	1.09	1.16	1.15	1.10	1.00
Medium Scenario	RP2	RP5	RP10	RP30	RP50	RP100
Flood Volume ($10^6 m^3$)	18.1	22.9	28.2	38.8	44.5	52.9
α (Medium Scenario flood volume / Present flood volume)	1.12	1.17	1.25	1.29	1.30	1.30
High Scenario	RP2	RP5	RP10	RP30	RP50	RP100
Flood Volume ($10^6 m^3$)	19.6	26.0	32.7	48.7	59.6	74.5
α (High Scenario flood volume / Present flood volume)	1.21	1.33	1.45	1.62	1.74	1.82

Source: JICA Project Team 2

3) Estimation of each Hydrograph

The modified hydrograph for three future scenarios is created by applying the coefficient α to each return period hydrograph in present condition.

Table A9.4.3 Peak Discharge of Upper End Boundary

Return Period (Year)	Peak Discharge (m^3/s)			
	Present	Low	Medium	High
1. Upper Tawing River				
2	127.1	134.9	142.7	154.3
5	154.0	167.4	180.8	205.3
10	178.2	205.9	222.0	257.9
30	236.6	271.1	305.7	384.3
50	270.1	295.7	350.9	469.8
100	322.1	322.1	417.4	587.4
2. Tributary of Tawing River				
2	38.0	40.3	42.6	46.1
5	46.0	50.0	54.0	61.3
10	53.2	61.5	66.3	77.0
30	70.7	81.0	91.3	114.8
50	80.7	88.3	104.8	140.3
100	96.2	96.2	124.7	175.5

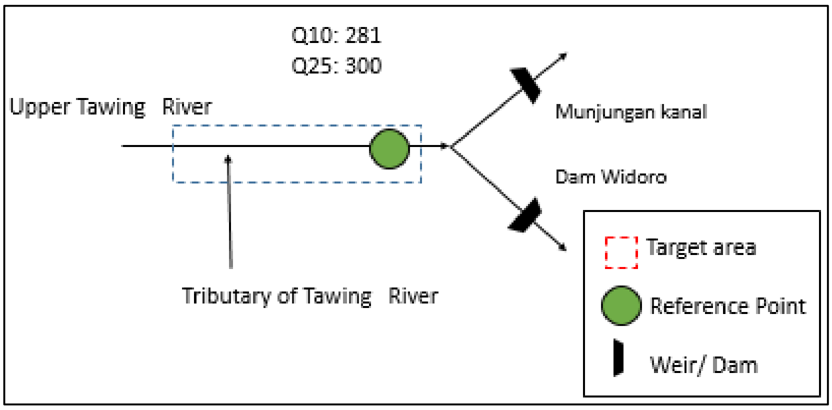
Source: JICA Project Team 2

Other Condition

- Roughness coefficient: River area (n = 0.025), Land area (n = 0.03)
- Calculation pitch: Calculation pitch: dt = 0.2 [sec]
- River Cross Section: River cross section survey was not carried out in this project. The trapezium shape was applied to the river section and size is decided from water level mentioned in the past report.

A9.4.4 Model Calibration

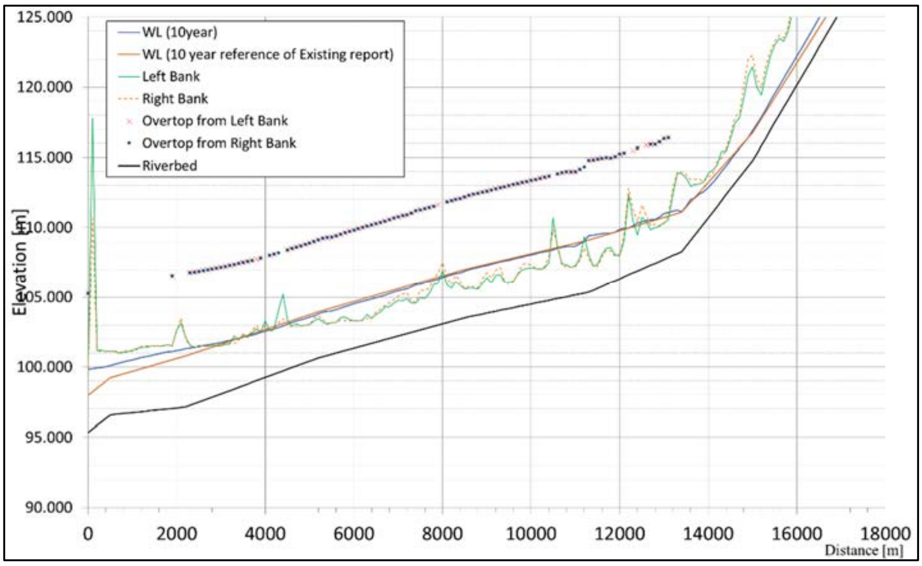
Model calibration was carried out with unsteady flow to compare with the estimated water level mentioned in "Sid Pengendalia Banjir Kali Tawing Kabupaten Trenggalek, 2013" and calculated water level in this model. The calibration of the model is carried out to 10-year probable flood because the estimated water level in the past report was mentioned to return period 10-year probable flood.



Source: JICA Project Team 2

Figure A9.4.4 Design Flood Discharge in Tawing River Basin

The calibration results are shown in Figure A9.4.5.



Source: JICA Project Team 2

Figure A9.4.5 Calibration Result in Tawing River

A9.4.5 Results of Flood Inundation Analysis

The flood inundation analysis is carried out to the present condition and the future conditions (Low, Medium, High case) under the climate change. The results of the analysis are shown in Table A9.4.4 and Figure A9.4.6 to Figure A9.4.9.

Table A9.4.4 Results of Flood Inundation Analysis (Tawing River Basin)

1. Present Condition

Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	144.3	69.6	1,378
5	237.3	165.9	1,686
10	267.3	186.0	1,891
30	317.3	204.3	2,076
50	334.2	211.0	2,145
100	352.5	224.3	2,280

Note: Parameter of Affected Houses are applied from Japanese guideline of estimation for flood damage

2. Future Condition (Medium)

Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	220.2	77.2	1,528
5	269.6	186.6	1,896
10	305.4	199.6	2,029
30	352.1	218.8	2,224
50	362.6	231.6	2,354
100	220.2	245.0	2,490

Note: Parameter of Affected Houses are applied from Japanese guideline of estimation for flood damage

3. Future Condition (Low)

Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	171.5	72.7	1,440
5	253.4	181.9	1,849
10	293.1	192.8	1,959
30	334.6	211.4	2,149
50	343.6	214.9	2,184
100	352.5	224.3	2,280

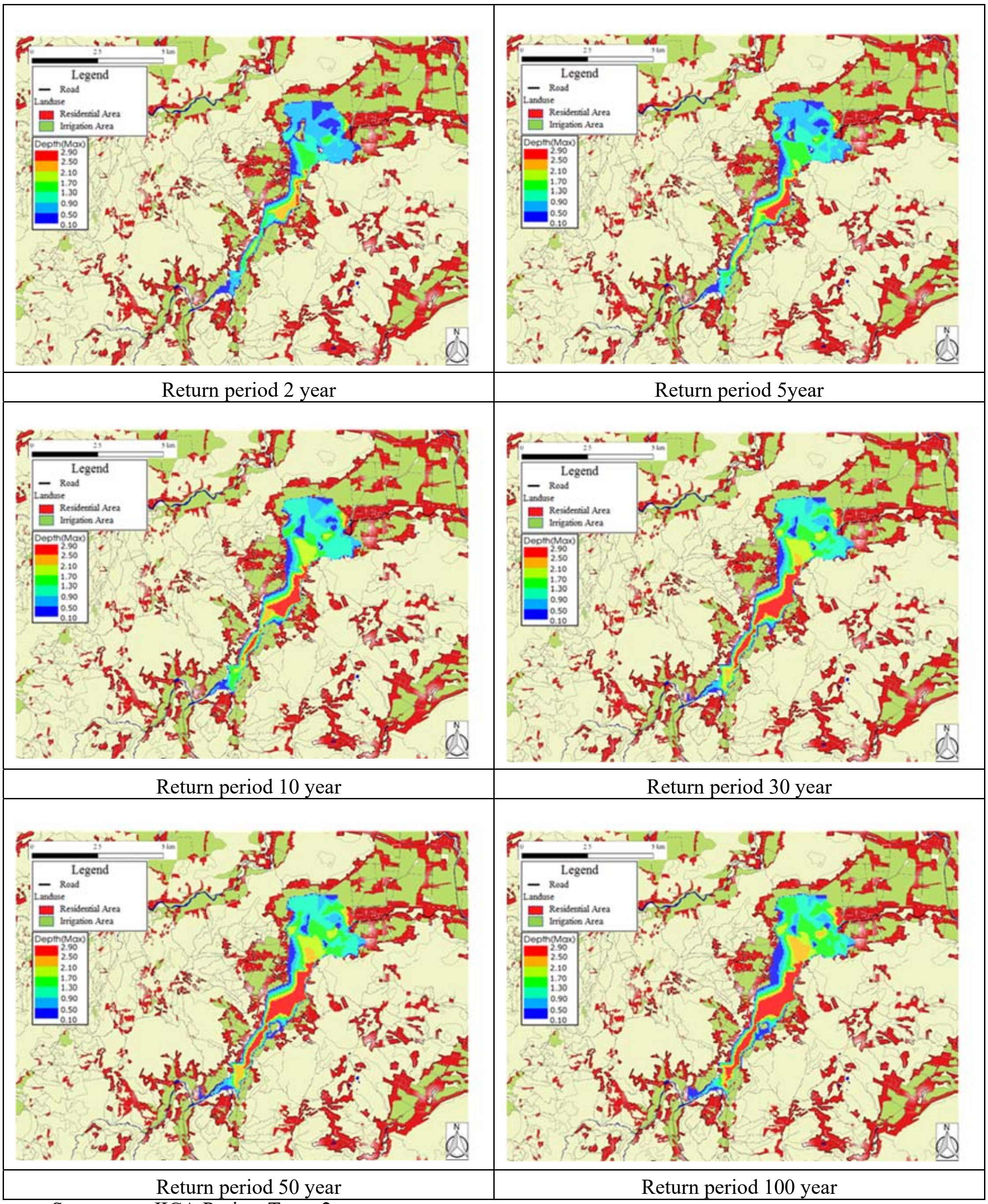
Note: Parameter of Affected Houses are applied from Japanese guideline of estimation for flood damage

4. Future Condition (High)

Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	237.7	166.1	1,689
5	292.9	192.8	1,959
10	329.2	209.0	2,124
30	379.7	239.3	2,432
50	397.7	258.3	2,626
100	426.1	269.7	2,741

Note: Parameter of Affected Houses are applied from Japanese guideline of estimation for flood damage
Source: JICA Project Team 2

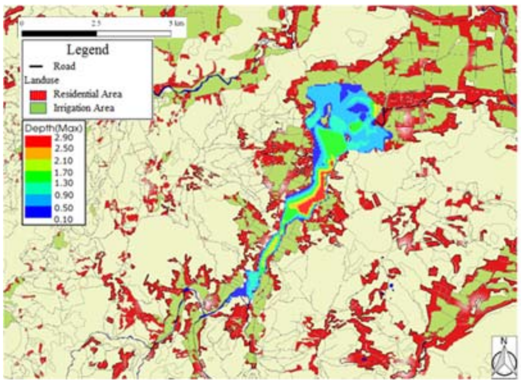
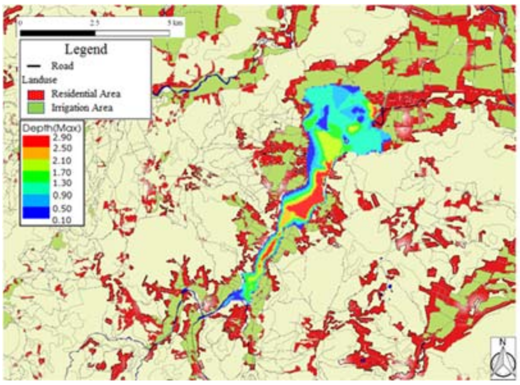
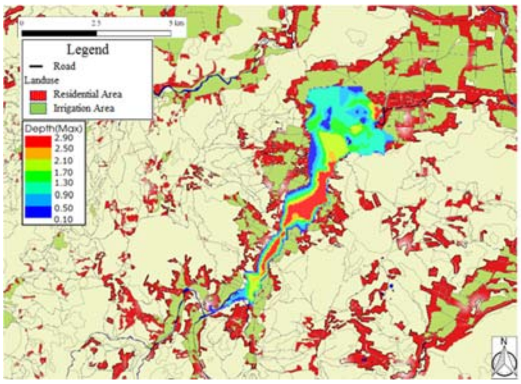
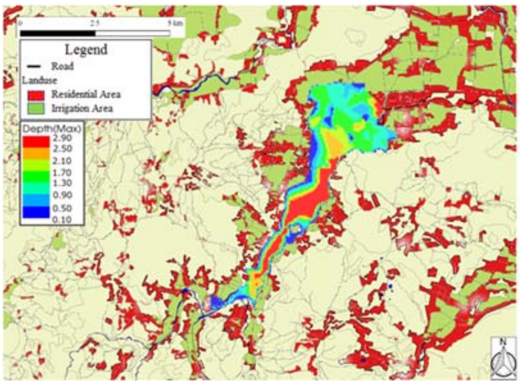
1. Present



Source: JICA Project Team 2

Figure A9.4.6 Maximum Inundation Depth and Area in Tawing River Basin under Present Condition

2. Medium

	
Return period 2 year	Return period 5year
	
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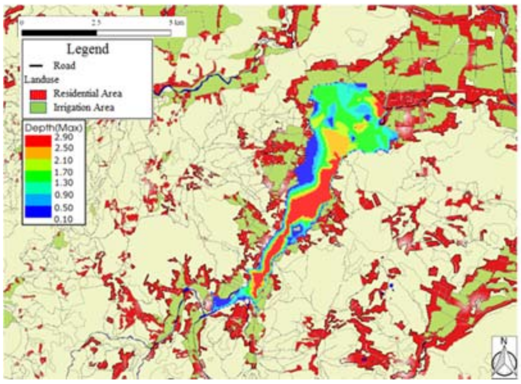
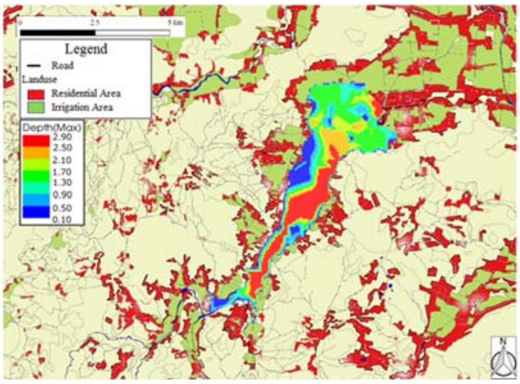
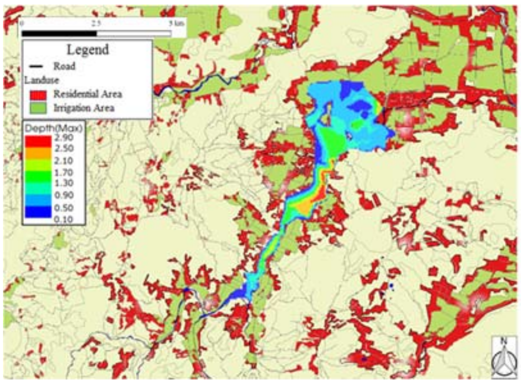
	
Return period 50 year	Return period 100 year

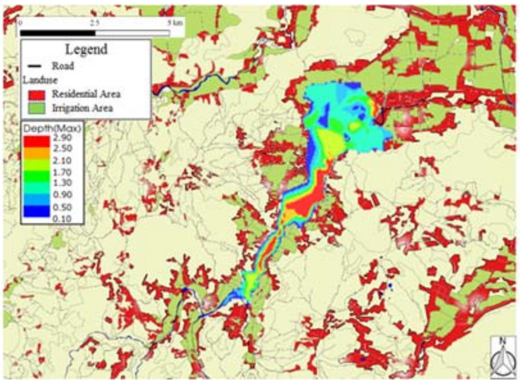
Source: JICA Project Team 2

Figure A9.4.7 Maximum Inundation Depth and Area in Tawing River Basin under Medium Scenario

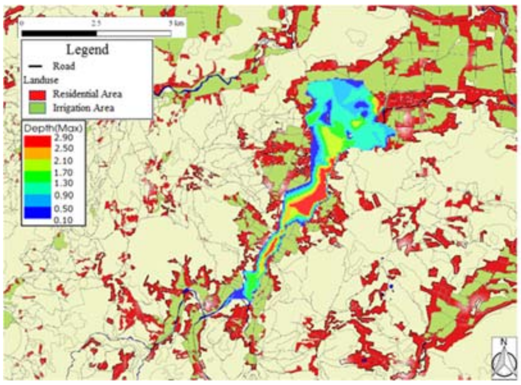
3. Low



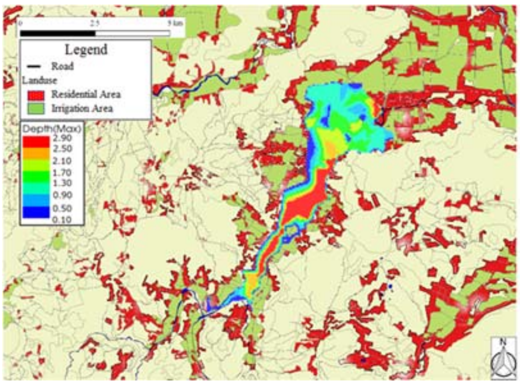
Return period 2 year



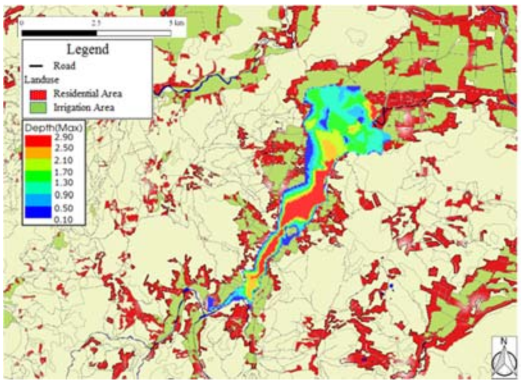
Return period 5year



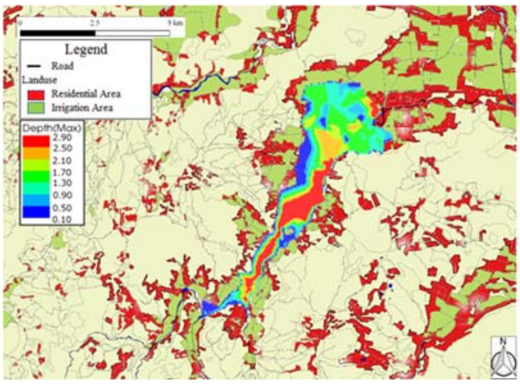
Return period 10 year



Return period 30 year



Return period 50 year

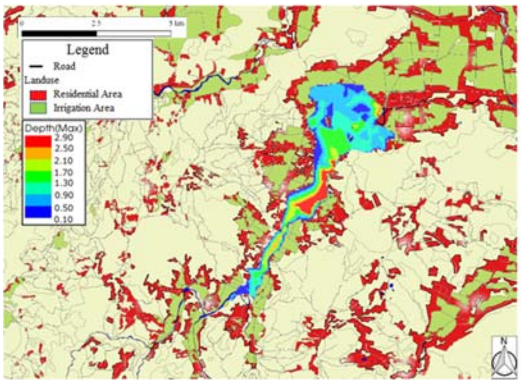


Return period 100 year

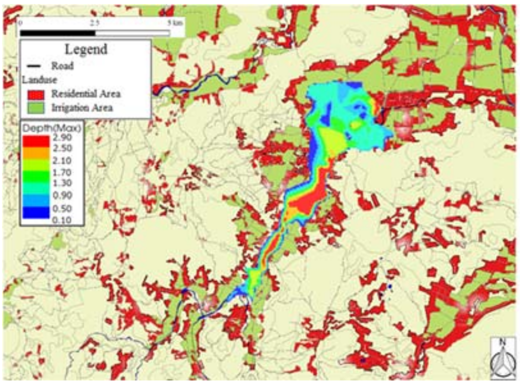
Source: JICA Project Team 2

Figure A9.4.8 Maximum Inundation Depth and Area in Tawing River Basin under Low Scenario

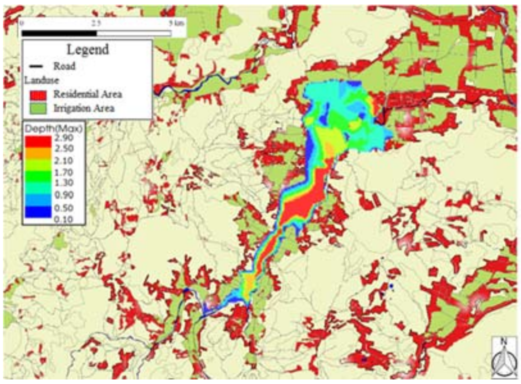
4. High



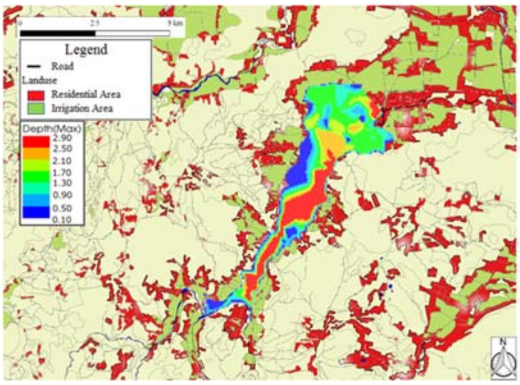
Return period 2 year



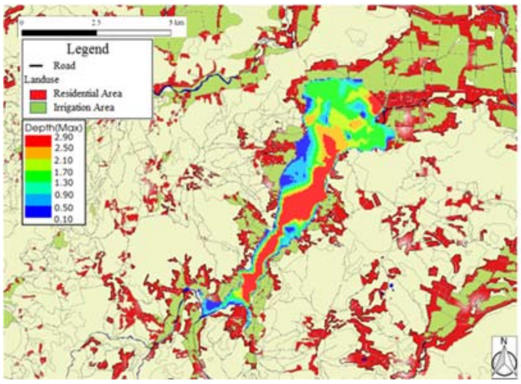
Return period 5year



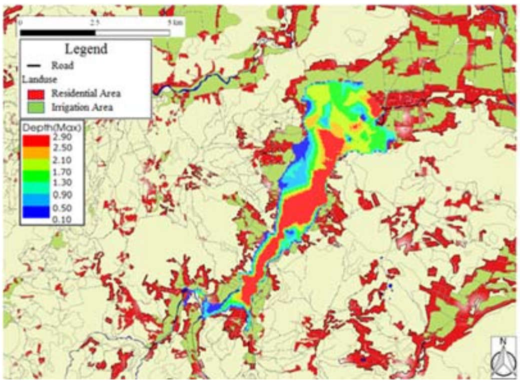
Return period 10 year



Return period 30 year



Return period 50 year



Return period 100 year

Source: JICA Project Team 2

Figure A9.4.9 Maximum Inundation Depth and Area in Tawing River Basin under High Scenario