Supporting Report C

HYDROGEOLOGY AND GROUNDWATER MANAGEMENT

Abbreviations

	Indonesia	English
BBWS	Balai Besar Wilayah Sengai	Large River Basin Organization
DEM	-	Digital Elevation Model
ESDM	Kementerian Energi dan Sumber Daya Mineral	Ministry of Energy and Mineral Resources
GCM	-	Global Climate Model
GCMs	-	General Circulation Models
PDAM	Perusahaan Daerah Air Minum	Indonesian Regional Water Utility Company
PP	Peraturan Pemerintah	Government regulation

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 C : HYDROGEOLOGY AND GROUNDWATER MANAGEMENT

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PART 1 GENERAL

CHAPTER C1 PROJECT OBJECTIVE, ANALYSIS METHOD AND CONCEPT OF GROUNDWATER POTENTIAL

C1.1 Objective and Analysis Method

C1.1.1 Objective

The objective is to predict and evaluate change in groundwater environment due to climate change in Brantas and Musi River, including Banyuasin River basin and the Sugihan River basin, based on the results of this project and collected data. The Project is composed of the following two components:

i) Changes in regional groundwater potential in both river basins

ii) Changes in groundwater environment in coastal peatland areas in Musi River basin

The result will be expected to apply to the future conservation and management plan of water resources in both river basins through government policy.

C1.1.2 Analysis Method

(1) Brantas River Basin

Analysis method depends on data quality and quantity, and present groundwater environment. Groundwater has been developed and is being used in Brantas River basin, and accompanying hydrogeology, survey report and groundwater data is also available. Therefore, quantitative examination of the groundwater potential using groundwater model is possible.

(2) Musi River Basin

Use of groundwater has not progressed in Musi River basin, the development of groundwater as a sustainable water resource under climate change is expected. However, hydrogeological data and groundwater information is insufficient and quantitative groundwater analysis is difficult.

C1.2 Concept of Groundwater Potential

C1.2.1 Basic Concept

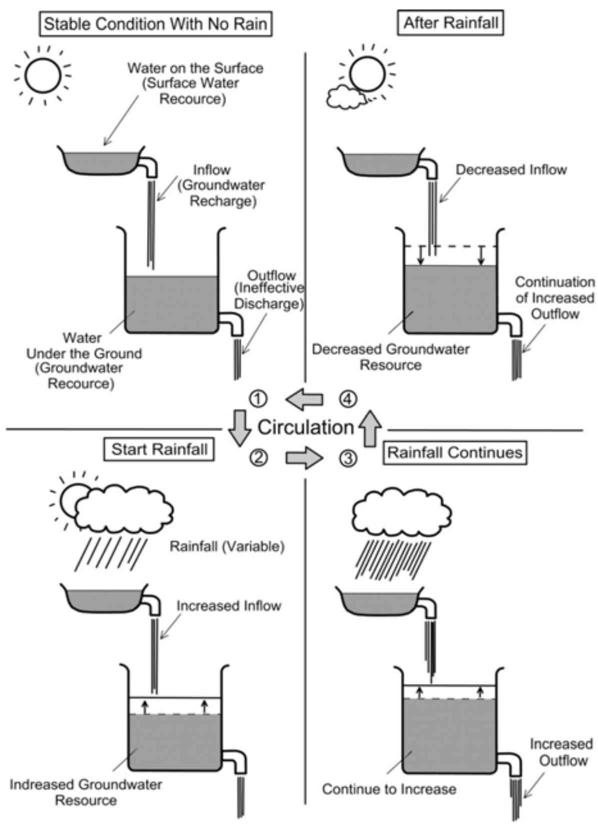
In a broad sense of groundwater use, groundwater development potential is defined as "The stored groundwater amount in the basin can be used without any consuming". Groundwater resource is always changing with time under a variety of conditions primarily weather condition, that is some of groundwater recharge, does not exist in the same amount at any time, rather than constant water resource at any time, shown in Figure C1.2.1.

Therefore, it can be said that groundwater development potential is one of the indices which is also always changing with time. To estimate groundwater development potential in present condition and evaluate the possibility of additional groundwater development in the future, appropriate definition under the site-specific groundwater condition should be needed for the Brantas River basin.

C1.2.2 Definition of Groundwater Potential in Indonesia

The Project of groundwater potential by Badan Geologi had being carried out before the Presidential Decree No. 26 of 2011 was issued. First report was published in 2005 and second was in 2010. The aquifer of the groundwater basin is divided into two kinds of aquifer; unconfined (shallow) aquifer and confined (deep) aquifer, and their groundwater potentials for respective aquifer are shown in the reports. However, the definition and evaluation process for groundwater potential has not been shown in the reports.

Subsequent investigation through interview survey revealed that the definition of the groundwater potential carried out by Badan Geologi is used simply hydrogeological aspect and rainfall data rather than advanced groundwater model, but unfortunately no one could explain the estimation procedure clearly. The procedure of groundwater potential definition estimated from the interview survey is presumed as follows:

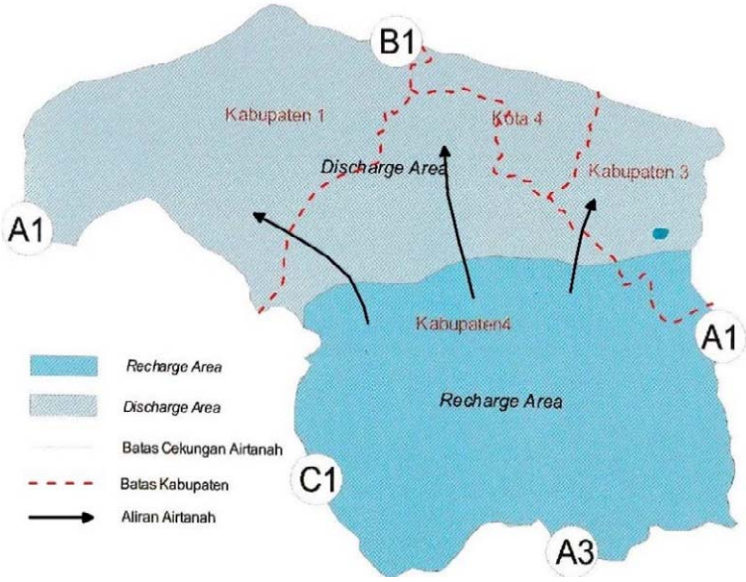


Source: JICA Project Team 2

Figure C1.2.1 Schematic Diagram of Groundwater Resource Circulation

1) Define recharge area and discharge area for each groundwater basin based on hydrogeological aspect.
2) Recharge of groundwater is defined about 10% of average rainfall, which is presumed from the value of groundwater potential.
3) Groundwater potential of confined (deep) aquifer is defined as groundwater recharge only for recharge area in groundwater basin (see Figure C1.2.2).
4) Groundwater potential of unconfined (shallow) aquifer is defined as groundwater recharge for whole groundwater basin.

The above estimation procedure of groundwater potential should be confirmed and discussed more deeply, as well as requesting to provide hydrogeological information and groundwater observation data.

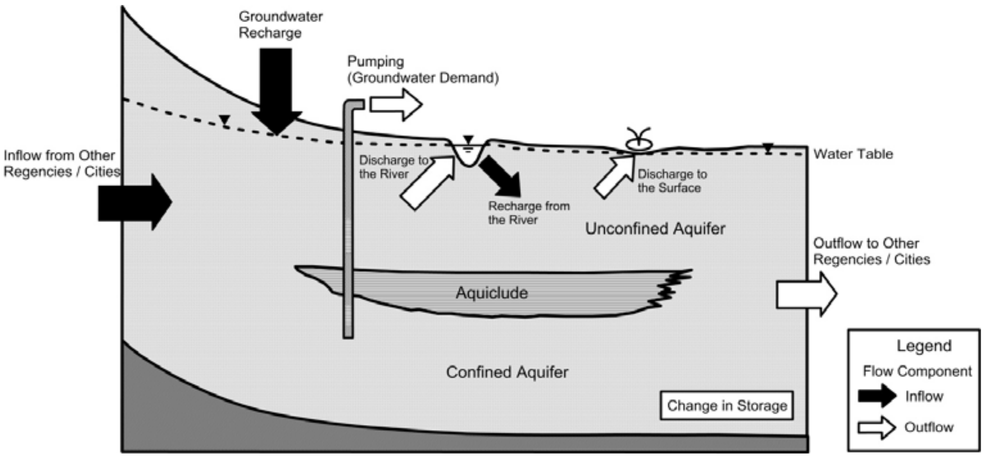


Source: ESDM (2010)

Figure C1.2.2 Example of Districts / Cities Groundwater Basin

C1.2.3 Definition of Groundwater Potential in This Project

The definition of groundwater potential in this project is more specific and rigorous than definition of Badan Geologi. Schematic diagram of groundwater balance in certain municipality is shown in Figure C1.2.3. Inflows are composed of groundwater recharge, groundwater flow from other regencies/cities and recharge from the river, and outflows are composed of pumping (groundwater demand), discharge to the river and discharge to the surface such as springs and groundwater flow to other regencies/cities. The volume of inflow minus outflow is stored temporally in aquifer as groundwater storage. Groundwater recharge is one of the main components of inflow and is often defined as the value in the safest side as groundwater potential when groundwater simulation is not implemented.



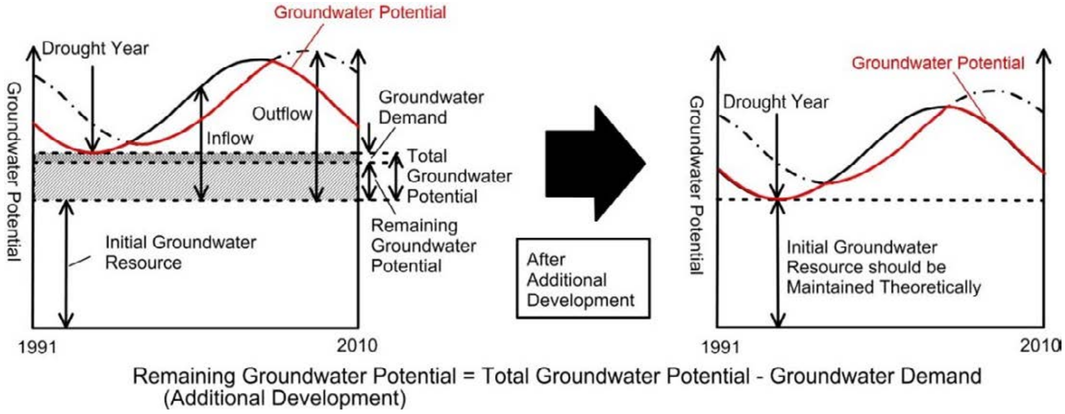
Source: JICA Project Team 2

Figure C1.2.3 Schematic Diagram of Groundwater Balance

In this project, groundwater flow model has been built and the more detailed evaluation method can be carried out in Brantas River basin. Therefore, the following concept of groundwater potential is introduced for the Brantas River basin. The concept of groundwater potential using groundwater model is shown in Figure C1.2.4. In this project, total groundwater potential is defined from the result of groundwater flow simulation using USGS MODFLOW as "**Minimum annual inflow/outflow value into/to specified area (regency/city) in 20 year's calculation under the stable condition**". Example of calculation is shown in Figure C1.2.5. Groundwater potential value from 1991 to 2010 can be calculated year by year using simulation result. Minimum value for 2010 is adopted as groundwater potential for 20 year; 886.89 million m^3/y (1997), is groundwater potential in this example.

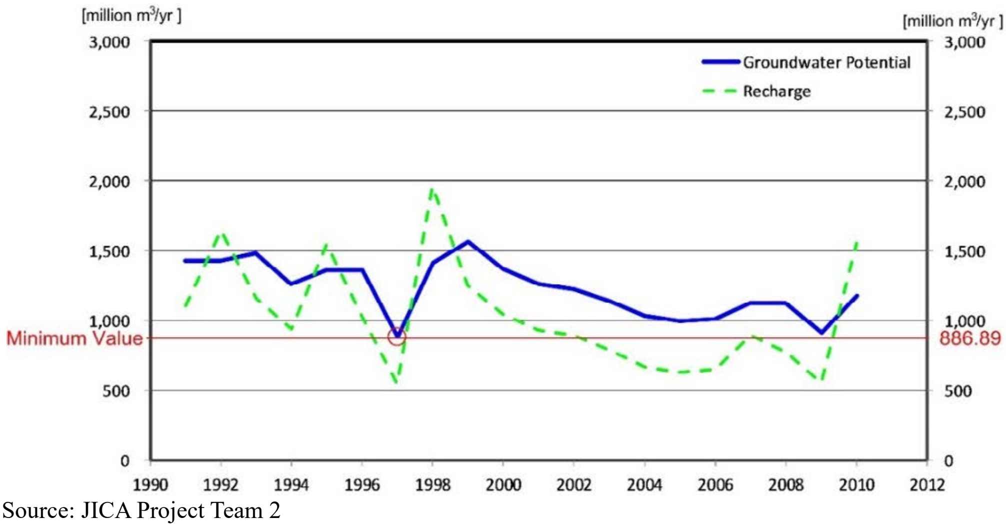
This index is absolutely defined by the calculations based on the meteorological conditions for 20 years (1991 – 2010), and it is actually supposed that much severe drought conditions may reveal except of these 20 years. In addition, it is practically impossible to pump up all inflow/outflow without any change for the amount of groundwater resource.

Remaining groundwater potential is defined as "**Total groundwater potential calculated as minimum annual inflow/outflow in 20 years minus groundwater demand.**"



Source: JICA Project Team 2

Figure C1.2.4 Definition of Groundwater Potential in Brantas River Basin



Source: JICA Project Team 2

Figure C1.2.5 Example of Definition Method of Groundwater Potential in the Project

C1.2.4 Constraints in Groundwater Potential Evaluation

To evaluate realistic groundwater potential using the result of groundwater modeling, various constraints should be taken into consideration: water balance constraint, environmental constraint, and economical constraint. In addition, region-specific constraints based on local water resource use or natural environment are also exist.

PART 2 BRANTAS RIVER BASIN

CHAPTER C2 GROUNDWATER CONDITION IN BRANTAS RIVER BASIN

C2.1 Geology

Documents and data on the geology and hydrogeology were collected and analyzed, as basic materials for evaluating the groundwater potential in Brantas River basin. Outline of the geology and hydrogeology of Brantas River basin is as follows.

Topography of the Brantas river basin, reflecting a significant geological structural feature which indicates strikes from east to west, are classified into five topographic zone extending strip in the east-west direction as shown in Table C2.1.1. These five zones are appended in the geological map shown in Figure C2.1.1.

Table C2.1.1 Topographical Zone in Brantas River Basin

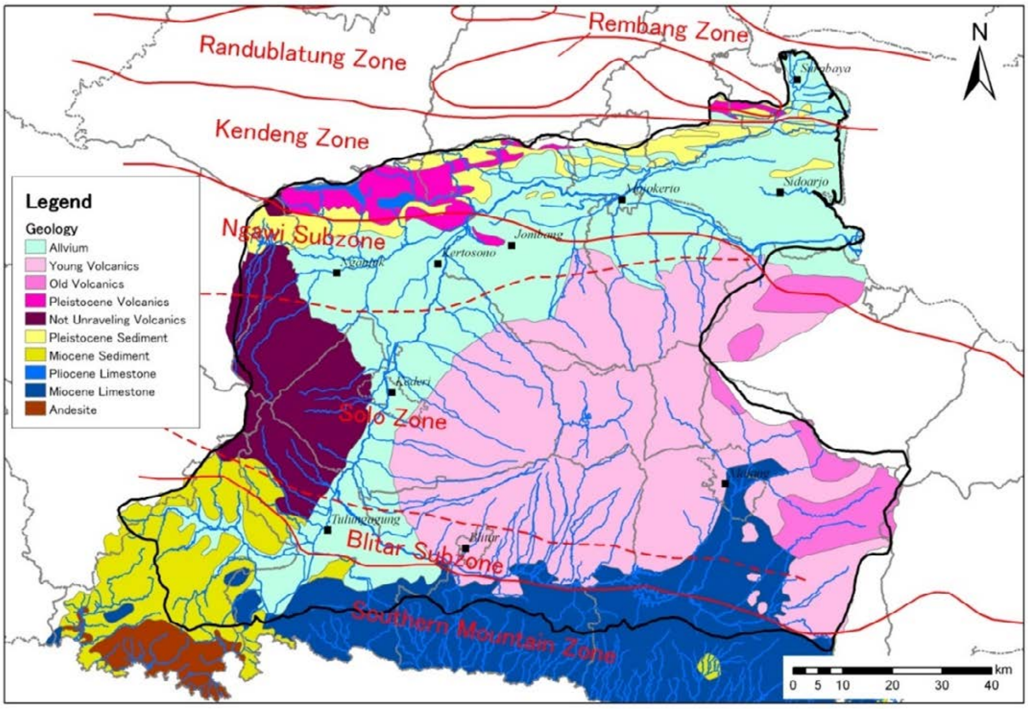
Zone	Distribution Area	Topographical Feature
Remubang Zone	Part of the Randublatung Zone	Hills consisting mainly of limestone and mudstone.
Randublatung Zone	West region of Surabaya	Depression zone composed of alluvial lowland and alluvial soft layer. The depression reaches less than 100m from original surface.
Kedeng Zone	Northern part of the basin	Hills consisting of stratified sedimentary rocks.
Solo Zone	Central portion of the basin	Mountain area consisting of quaternary volcanic chain and piedmont plains between them. There are two sub-zones: Ngawi Sub-zone in the north and Blitar Sub-zone in the south.
Southern Mountain Zone	Most southern part of the basin	Mountainous area where limestone and older volcanic rocks are distributed.

Source: JICA Project Team 2

The oldest formations of the Brantas river basin, composed of Miocene carbonate rocks, limestone, and marl in the upper-Tertiary period, are widely distributed throughout the basin. The upper Pliocene sedimentary rocks cover the oldest strata and Quaternary layer can be found at the top. Quaternary layer has been developed in Brantas River Basin as one of the productive aquifers. Basically, aquifer system in the area is composed of two-stories structure of shallow and deep aquifers.

Deep aquifers are formed in the intermountain basins, where are extensively underlain by volcanic rocks, pyroclastic rocks and their secondary sediments, and weakly cemented pyroclastic flows associated with their derived deposits and coarse sediments such as conglomerate and sandstone of the Kabuh Formation. These aquifers are widely and unconformably underlain by impervious clayey stones corresponding to the Pucangan Formation. Pleistocene volcanic rocks and sedimentary rocks are mutually interfingered containing several horizons of deep aquifers with high potential.

Moreover, shallow aquifers are developed extensively in the area, originated from fluvial washout from the surrounding volcanoes and river deposits.



Source: JICA Project Team 2

Figure C2.1.1 Geological map of Brantas River Basin

C2.2 Hydrogeology

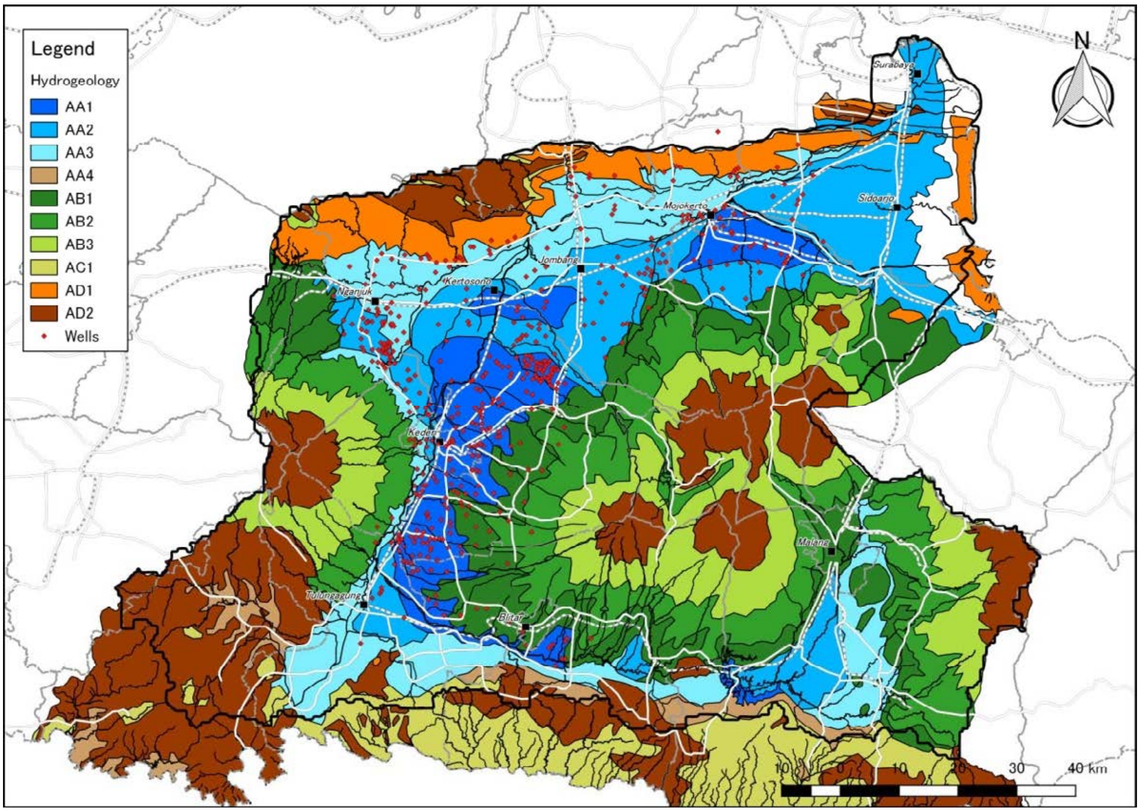
Hydrogeological map of 1/250,000 including Brantas River basin is published in 1984 by Ministry of Mines and Energy (current Ministry of Energy and Mineral Resources) as shown in Figure C2.2 1 which is extracted by Brantas River Basin. The hydrogeological classification used in the map as shown in Table C2.2.1 was used for groundwater modeling to evaluate present and future groundwater potential in Brantas River Basin. Major aquifers are distributed along Brantas River and its branch and most of pumping wells are located in the area the aquifers exist.

Table 2.2.1 Hydrogeological Classification in Brantas River Basin

Classification	Aquifer Feature	Description
AA1	Extensive and highly productive aquifers	Moderate to high transmissivity; water table or piezometric head of groundwater near or above land surface; wells yield generally 5 to 10L/s, locally more than 50L/s.
AA2	Extensive and productive aquifers	Aquifer of moderate transmissivity; water table or piezometric head of groundwater near or above land surface; wells yield generally 5 to 10L/s, in some places more than 20L/s.
AA3	Extensive, moderately productive aquifers	Aquifer of low to moderate transmissivity; groundwater table from near land surface to a depth of more than 10m; wells yield generally less than 5L/s.
AA4	Locally, moderately, productive aquifers	Mostly incoherent aquifer of low thickness and transmissivity; wells yield generally less than 5L/s.
AB1	Extensive and highly productive aquifers	Aquifers of largely varying transmissivity; depth to water table varies in wide range; wells yield generally more than 5L/s.
AB2	Extensive, moderately productive aquifers	Aquifers of largely varying transmissivity; depth to groundwater generally great; wells yield generally less than 5L/s.
AB3	Locally productive aquifers	Aquifers of largely varying transmissivity; generally, no groundwater exploitation by drilling to great depth to the groundwater table; locally small springs can be captured.

Classification	Aquifer Feature	Description
AC1	Highly to moderate productive aquifers	Groundwater flow is limited to fissures, fracture zones and solution channels; well yields and spring discharges vary in an extremely wide range.
AD1	Poor productive aquifers of local importance	Generally, very low transmissivity; locally, limited shallow groundwater resources can be obtained in valleys and weathered zones of solid rocks
AD2	Region without exploitable groundwater	–

Source: JICA Project Team 2



Source: ESDM(1984) and JICA Project Team 2

Figure 2.2.1 Hydrogeological Map of Brantas River Basin with Wells Distribution

C2.3 Wells and Springs Distribution

C2.3.1 Wells and Springs Distribution from Existing Reports and Maps

Well data are collected from report as follows:

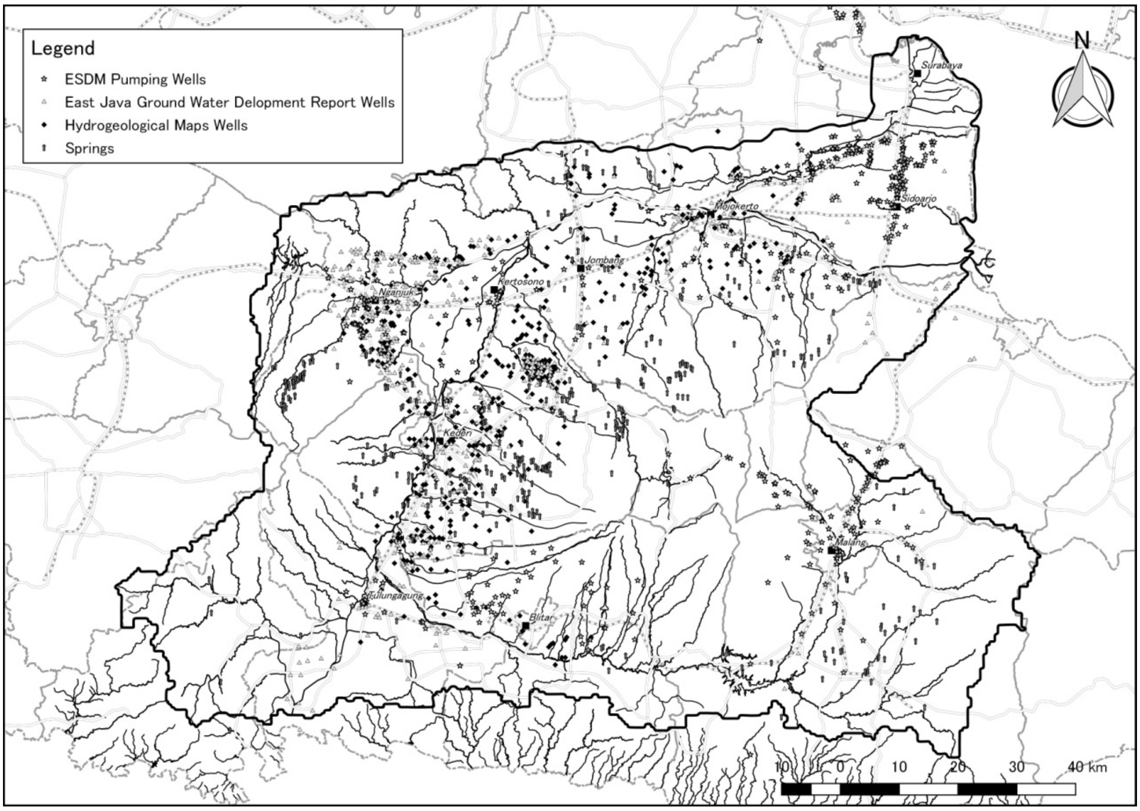
i) Dinas Energi dan Sumber Daya Mineral (ESDM) Groundwater Statistics (2012)

ii) East Java Groundwater Development Report: Ministry of Public Works, Nippon Koei Co.,Ltd., and Electrocosult S.p.A., P.T.Wiratman and Associates (1986)

iii) Hydrogeological Map: Directorat Geologi Tata Lingkungan (1984)

iv) Balai Besar Wilayah Sungai (BBWS) GIS Spring Water Area Map (2010)

All wells and springs distribution are shown in Figure C2.3.1.



Source: JICA Project Team 2

Figure C2.3.1 Wells and Springs Distribution in Brantas River Basin

C2.3.2 ESDM Registered Wells

ESDM Groundwater Statistics is disclosed on Web-site (http://esdm.jatimprov.go.id) and can be downloaded. The approximate location of the registered wells is identified from company or factory name with village name. Permit type of water source is summarized in Table C2.3.1. Total groundwater permits in Brantas River Basin are 713. The wells having most high pumping capacity are Boreholes, followed by Driven Wells. Dug Wells are so-called shallow hand dug well and almost all wells have been drilled individually. The number of wells is biggest in Sidoarjo Regency (182), but the amount of water use is not much because most of the wells are Dug Wells.

Groundwater allocation by regency/city in Brantas River Basin based on ESDM registered wells data is shown in Table C2.3.2. Largest regency/city of groundwater use is Malang Regency, followed by Mojokerto Regency and Sidoarjo Regency. In Malang Regency, most common groundwater use is Clean Water, which is so-called domestic water, but Industry is most common allocation in Mojokerto. On the other hand, groundwater use for Industry in Sidoarjo Regency is almost the same amount for Clean Water.

Figure C2.3.2 is groundwater use distribution in height for village based on ESDM registered wells data. Groundwater use in populated area such as city and the area along main road is high: Mojokerto City, Nganjuk City, Tulungagung Regency, Malang City and its surrounding area. Especially groundwater use in and around Malang City is large and the fact that dried up problem of wells in Malang City reported in newspaper due to over-pumping is supported from this data.

Table C2.3.1 Number of Groundwater Permit Type by Regency/City in Brantas River Basin

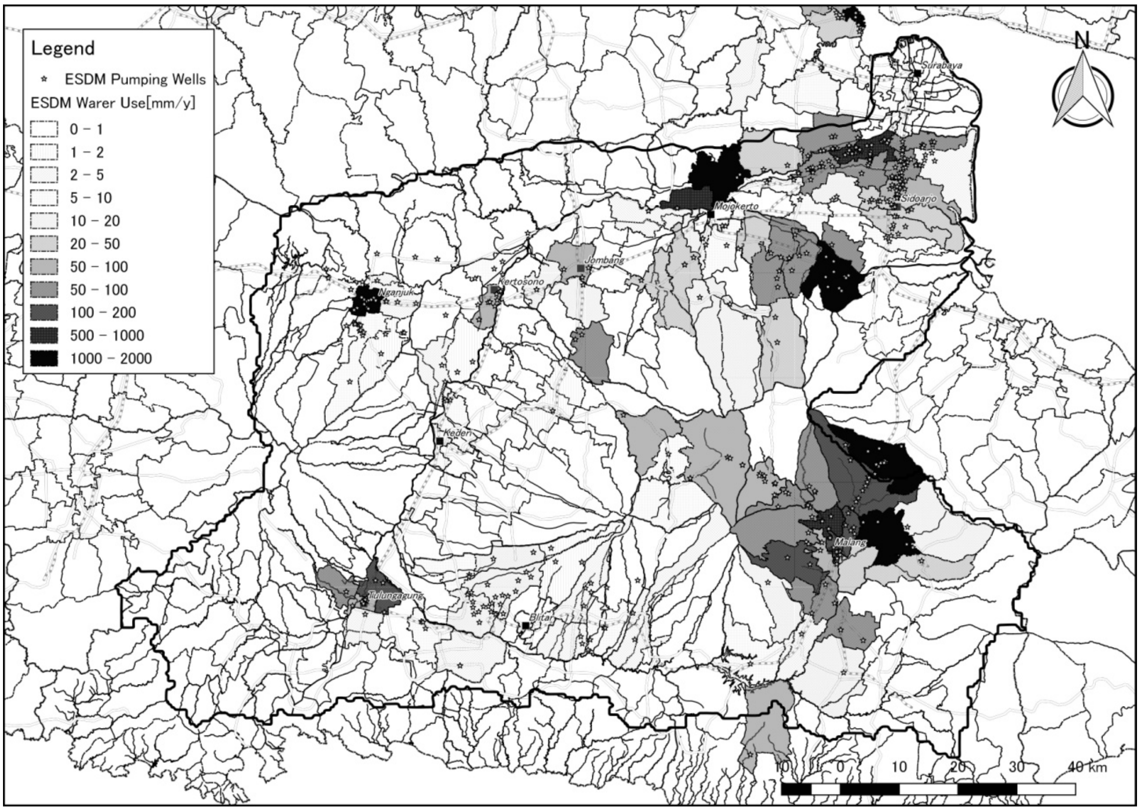
No.	Regency / City	Permit type					Total
		Boreholes	Driven Wells	Dug Wells	Water Springs	Without Information	
1	Batu City	7	5	3	-	-	15
2	Malang Regency	54	-	5	17	-	76
3	Malang City	24	6	1	-	-	31
4	Kediri Regency	2	5	-	-	-	7
5	Blitar Regency	-	-	50	1	-	51
6	Sidoarjo Regency	46	102	34	-	-	182
7	Mojokerto Regency	66	17	1	-	-	84
8	Jombang Regency	5	14	-	-	-	19
9	Kediri City	-	1	-	-	-	1
10	Mojokerto City	-	-	-	-	-	-
11	Surabaya City	-	-	-	-	-	-
12	Trenggalek Regency	-	-	-	-	-	-
13	Blitar City	73	-	-	-	-	73
14	Tulungagung Regency	4	18	2	-	-	24
15	Nganjuk Regency	24	63	-	-	-	87
16	Gresik Regency	-	-	-	-	63	63
Total		305	231	96	18	63	713

Source: JICA Project Team 2

Table C2.3.2 Groundwater Allocation by Regency/City in Brantas River Basin

No.	Regency / City	Allocation					Total	
		Industry	PDAM Water	Drinking Water	Bottled Water	Without Information	m^3/hr	m^3/day
1	Batu City	210	723	10	0	0	943	22,632
2	Malang Regency	5,692	29,458	4,627	0	0	39,777	954,648
3	Malang City	54	2,601	0	10	0	2,665	63,960
4	Kediri Regency	59	0	0	0	0	59	1,416
5	Blitar Regency	0	0	0	30	0	30	720
6	Sidoarjo Regency	3,297	2,577	0	0	0	5,874	140,976
7	Mojokerto Regency	16,486	-	-	-	7,329	23,815	571,560
8	Jombang Regency	1,518	0	0	0	0	1,518	36,432
9	Kediri City	0	10	0	0	0	10	240
10	Mojokerto City	-	-	-	-	-	-	-
11	Surabaya City	-	-	-	-	-	-	-
12	Trenggalek Regency	-	-	-	-	-	-	-
13	Blitar City	22	376	0	0	0	398	9,552
14	Tulungagung Regency	1,383	160	0	0	0	1,543	37,032
15	Nganjuk Regency	-	-	-	-	2,660	2,660	63,840
16	Gresik Regency	-	-	-	-	3,496	3,496	83,904
Total		28,721	35,905	4,637	40	13,485	82,788	1,986,912

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure C2.3.2 Groundwater Use Distribution in Height for Village Based on ESDM Registered Wells

C2.4 Groundwater Level Observation

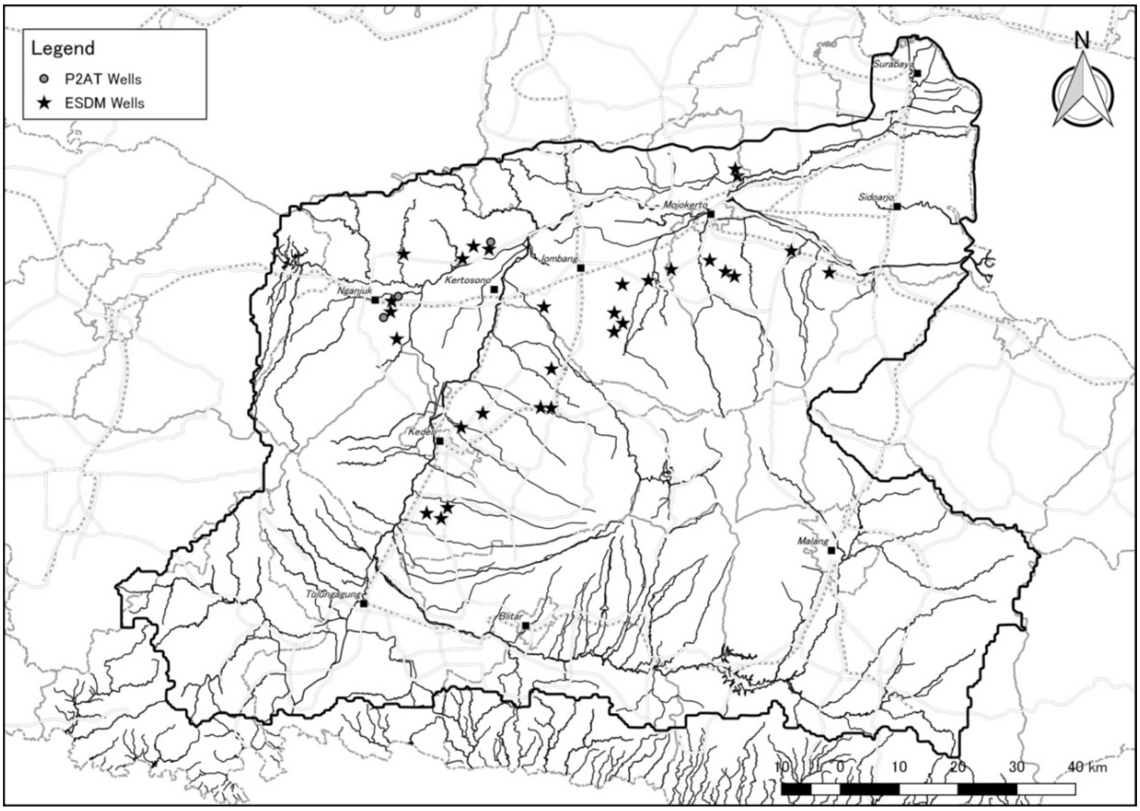
26 groundwater observation data collected by P2AT and ESDM as shown in Table C2.4.1 and Figure C2.4.1.

Since observation period and frequency of measurement are different among wells and observation wells are concentrated in the area from midstream to downstream of the Brantas River Basin where groundwater development is progressing. Groundwater level data was used as groundwater model calibration target. Detail will be discussed in Section C3.2.1.

Table C2.4.1 Groundwater Level Observation Wells

Source of Collected Data	Area	Nos. of Wells	Measurement	Period	Frequency
Pengembangum Groundwater Project (P2AT) Jawa Timur	Nganjuk	1	Automatic	1997-1998	Daily – Monthly data not constant
Ministry of Energy and Mineral Resources (ESDM) Jawa Timur Data	Mojokerto, Kediri	2	Automatic	2009-2013	Hourly data one or two year continuous
	Nganjuk, Mojokerto Jombang, Kediri	23	Manual	2004-2009	Monthly data measurement by hand
Total		26			

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure C2.4.1 Observation Wells

C2.5 Present Total Groundwater Demand by Regency/City

The groundwater demand by Regency/City was compiled for each application in the chart based on project team calculation.

Total groundwater demand is estimated as shown in Table C2.5.1 and Figure C2.5.1. Groundwater use is mainly divided into three categories by its allocation: domestic/non-domestic use, industrial use, and agricultural use. Following distribution characteristics of each groundwater use are recognized:

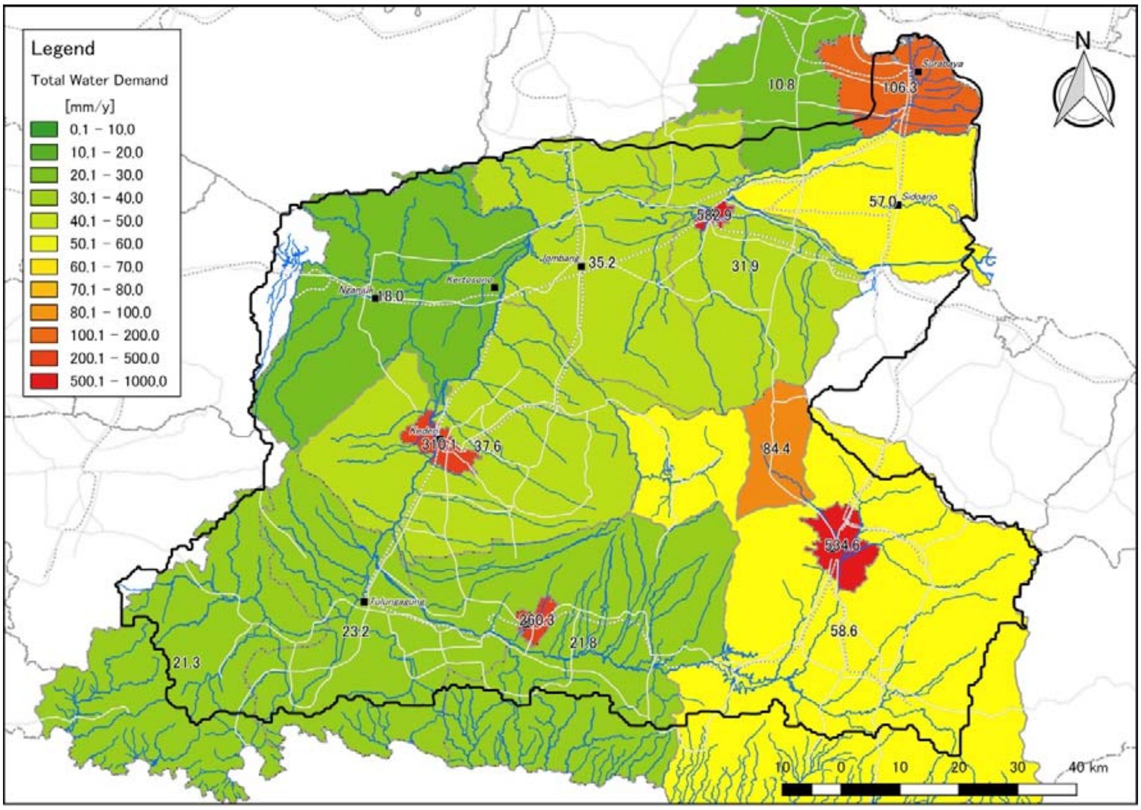
- Domestic/non-domestic use: High population density area including Surabaya City and inland urban areas such as Malang City, where stable and sufficient surface water supply is not expected.
- Industrial use: Strategic points in the traffic where industries have developed, and urban areas along the Brantas River.
- Agricultural use: Midstream - downstream of the Brantas River. Suburban farm belt.

The greatest regency/city of groundwater demand is Malang Regency (201.63 million m^3/y), followed by Malang City (58.5 million m^3/y). On the contrary, the rank of groundwater use in height is quite different, the top is Mojokerto City (582.9 mm/y), followed by Malang City (534.6 mm/y). For the further discussion of groundwater development potential, this groundwater use in height and distribution of pumping wells is heavily involved in the possibility of development.

Table C2.5.1 Present Groundwater Demand

No.	Regency / City	Area (m3)	Present Groundwater Demand				
			Domestic / Non-Domestic	Industrial	Agricultural	Total	
			(10^6 m^3/y)			(10^6 m^3/y)	(mm/y)
1	Batu City	211.9	8.66	9.23	0.00	17.89	84.4
2	Malang Regency	3,440.1	66.74	134.89	0.00	201.63	58.6
3	Malang City	109.4	52.97	5.53	0.00	58.50	534.6
4	Kediri Regency	1,521.0	32.66	13.27	11.26	57.20	37.6
5	Blitar Regency	1,753.5	31.45	6.72	0.00	38.17	21.8
6	Sidoarjo Regency	709.1	40.14	0.32	0.00	40.46	57.1
7	Mojokerto Regency	973.8	29.84	1.17	0.00	31.01	31.8
8	Jombang Regency	1,121.2	25.63	3.47	10.35	39.45	35.2
9	Kediri City	66.6	10.53	10.13	0.00	20.66	310.1
10	Mojokerto City	20.3	2.35	9.46	0.00	11.81	582.9
11	Surabaya City	327.8	34.85	0.00	0.00	34.85	106.3
12	Trenggalek Regency	1,244.6	21.13	5.32	0.00	26.45	21.3
13	Blitar City	33.4	4.17	4.53	0.00	8.71	260.3
14	Tulungagung Regency	1,152.5	25.93	0.80	0.00	26.73	23.2
15	Nganjuk Regency	1,292.3	21.36	0.00	1.95	23.31	18.0
16	Gresik Regency	1,041.6	11.26	0.00	0.00	11.26	10.8
Total		15,019.2	419.68	204.85	23.56	648.09	43.2

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure C2.5.1 Distribution of Present Total Groundwater Demand in Height in Brantas River Basin

CHAPTER C3 GROUNDWATER MODELING IN BRANTAS RIVER BASIN

C3.1 Groundwater Flow Model

C3.1.1 Basic Information

(1) Model Structure

Groundwater flow model was introduced for the evaluation of present and future groundwater potential in Brantas River basin. Model structure is summarized in Table C3.1.1. Whole model domain was discretized with a uniform quadrate basic grid cell size of 1.0km. The interpolated data from SRTM (Shuttle Radar Topography Mission), whose elevations were calculated relative to the EGM96 geoid, was imported to the top surface elevation of the model. Model bottom was defined as approximately 200m below from the ground surface based on the depth analysis of pumping well in hydrogeological map.

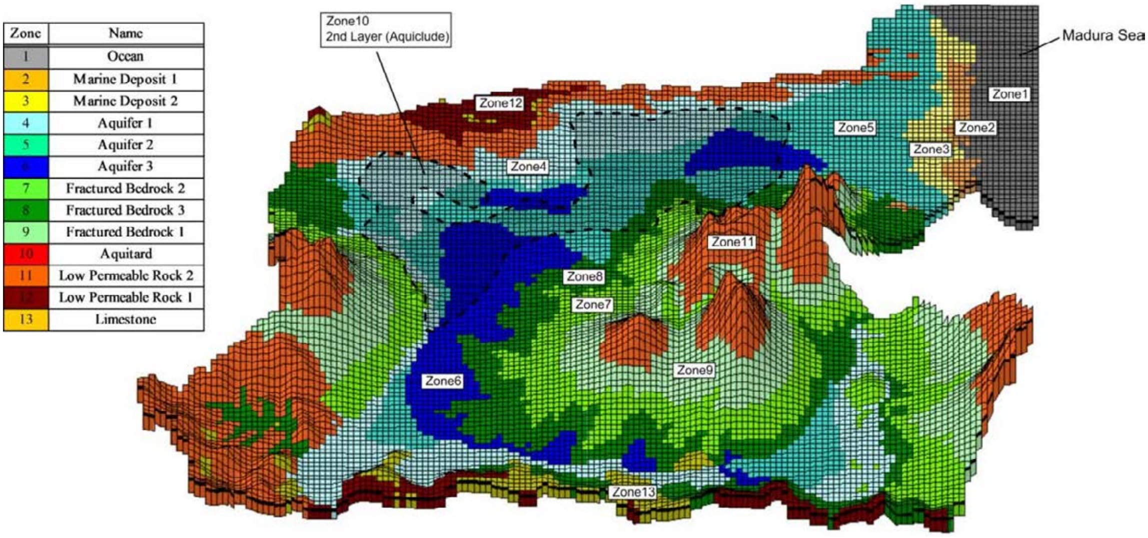
Modeling layer between ground surface and bottom was refined total 6 layers: 1 layer for shallow aquifer, 1 layer for aquiclude, and 4 layers for deep aquifer depending on their thickness. For each layer bottom, the surface elevation of aquifer and aquiclude were generated by digitizing and extrapolating from “East Java Groundwater Development Report” (see Section C2.1.1) data and imported considering their distribution limits.

3D visualization of built model grid is shown in Figure POLA.1.1. Horizontal range contains the whole region of the Brantas River basin and is along 123km in a north - south direction, and 159km in an east - west direction, respectively. Hydrogeological classification of hydrogeological map published by ESDM in 1984 is adopted for this groundwater model as explained in Section C2.2.

Table C3.1.1 Model Structure

Item	Condition
Modeling Region	19,557km^2(E-West 159km x S-N 123km)
Horizontal Analytical Area	Approximately 11,596km^2 including Brantas River Basin
Vertical Limit	Top: Ground surface Bottom: About 200m from the ground surface
Layer	6 layers (Shallow Aquifer: 1, Aquiclude: 1, Deep Aquifer: 4)
Unit Grid Cell Size	1.0km x 1.0km

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure C3.1.1 3D Visualization of Built Model Grid

(2) Analytical Method

Analytical method is shown in Table C3.1.2. The code selected to simulate was MODFLOW 2005, a modular three-dimensional finite difference groundwater flow model developed by U.S. Geological Survey. The application for pre-/post-processing is Visual MODFLOW 209.1. To recreate the present groundwater environment, monthly basis transient simulation was carried out on 1991 to 2010 (20 years) recharge data was provided.

Table C3.1.2 Analytical Method of Simulation

Item	Condition
Code	MODFLOW2005 (Visual MODFLOW 2009.1)
Calculation	Transient Simulation
Duration	1991 - 2010 (20years)
Time Steps	1 month
Calibration Target	Collected groundwater level data

Source: JICA Project Team 2

C3.1.2 Model Input

Model setting is shown in Table C3.1.3. Model setting is roughly divided into three conditions: Aquifer Constants, Boundary Conditions, and Initial Condition.

Table C3.1.3 MODFLOW Model Setting

Condition	Contents
Aquifer Constants	Material Properties (Hydraulic conductivity, Specific yield, and Specific storage coefficient)
Boundary Conditions	Groundwater Recharge Rate, Constant Head Boundaries, River Boundary, Drainage Boundaries, and Pumping Rate
Initial Condition	Groundwater Potential Distribution at the Beginning of Calculation

Source: JICA Project Team 2

(1) Aquifer Constants

Aquifer constants are composed of hydraulic conductivity, specific yield, and specific storage coefficient in this model. Initial aquifer constants are assigned by hydrogeological map published by ESDM, "East Java Groundwater Development Report" and general value from text book based on hydrogeological feature. The values of aquifer constants are varied in the calibration process and fixed finally.

(2) Boundary Conditions

Boundary conditions are summarized in Table C3.1.4 and the setting location of boundary conditions are shown in Figure C3.1.2. Boundary conditions are composed of recharge, constant head boundary, river boundary, drain boundary, and pumping wells.

Constant head boundaries were used for the cells of ocean with elevation of equal to mean sea level based on existing average Surabaya tidal data which is about -0.05m. Since it is said that the sea level is rising at a speed of 5 mm/year in Surabaya, this sea level rise effect is taken into account in future prediction model. River boundaries were assigned as the main stream including the Brantas River.

Recharge from surface of the ground is a provided daily recharge on a drainage basis as shown in Figure C3.1.3. Recharge rate is high in mountainous drainages and low in drainages facing coastal area proportional to rainfall increased with the elevation.

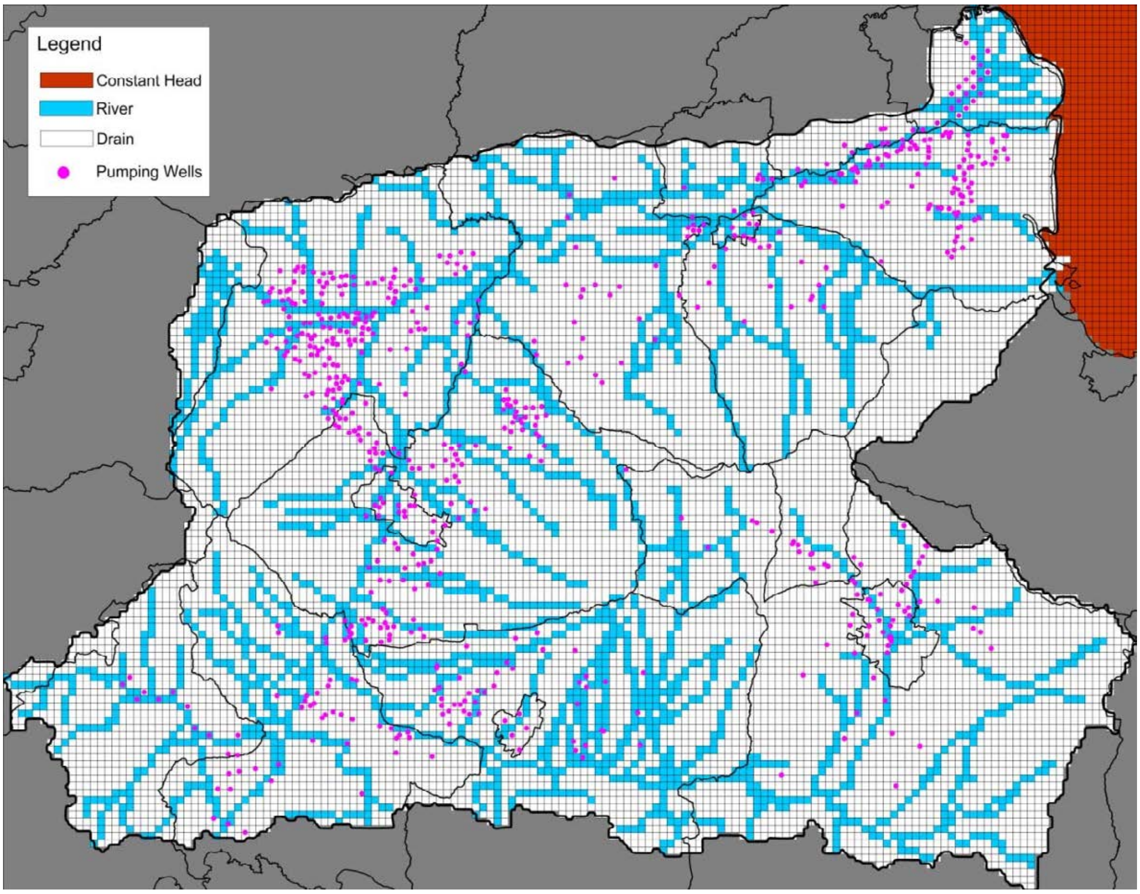
Table C3.1.4 Boundary Conditions

Setting Position	Contents	
Ground Surface	Groundwater Recharge: Provided data	
Ocean	Constant Head Boundary (Sea Water Level)	-0.05m: for present model 0.05m: for near future (2030) prediction model 0.15m: future (2050) prediction model
River	River Boundary	
Ground Surface except for Main River	Drainage Boundary	
Pumping Wells	Pumping Rate: Aggregated total groundwater demand by regency/city	

Source: JICA Project Team 2

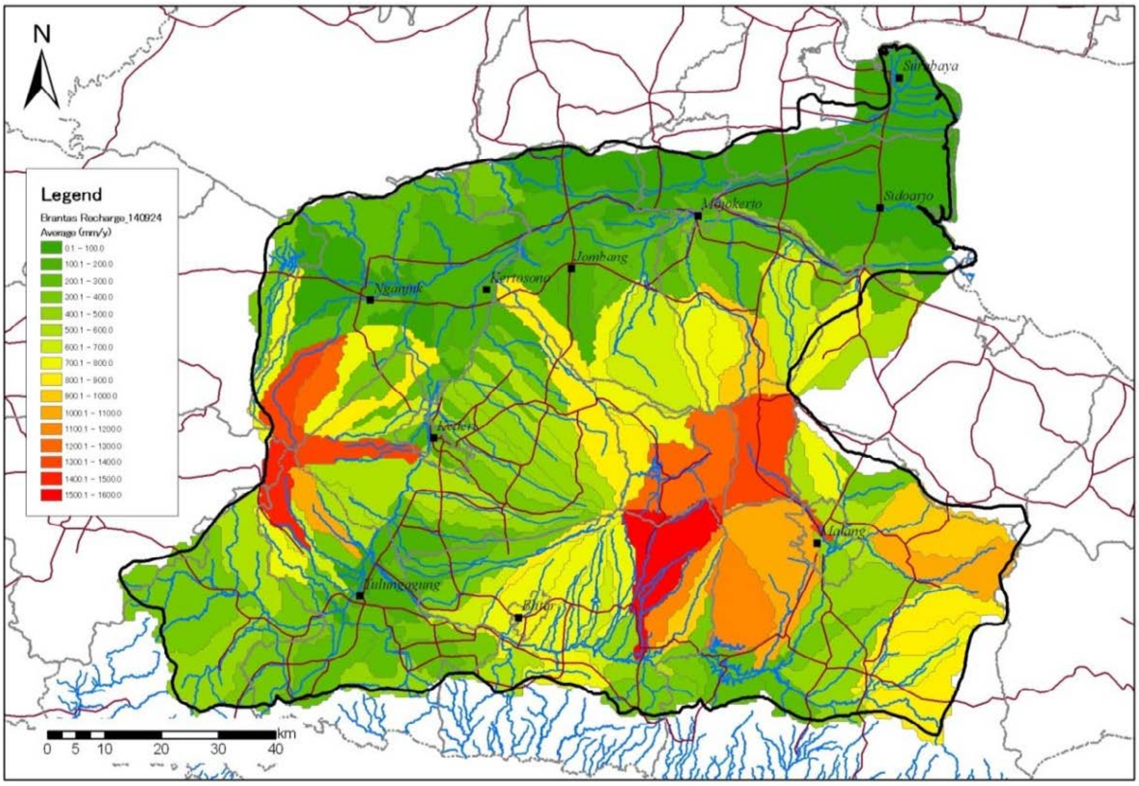
(3) Initial Condition

Steady-state simulation for making initial condition was carried out with initial aquifer constants and special constant head boundaries assigned the value of the ground surface elevation for each cells of surface layer in whole model domain. The hydraulic heads of steady-state simulation were used 1st transient simulation as initial condition. Transient simulations were carried out at least three times using the hydraulic heads of previous simulation result to minimize the effect of the initial conditions.



Source: JICA Project Team 2

Figure C3.1.2 Boundary Conditions



Source: JICA Project Team 2

Figure C3.1.3 Distribution of Average Recharge Rate for Present Simulation

3.2 Groundwater Flow Simulation for Present Groundwater Condition

3.2.1 Calibration Target

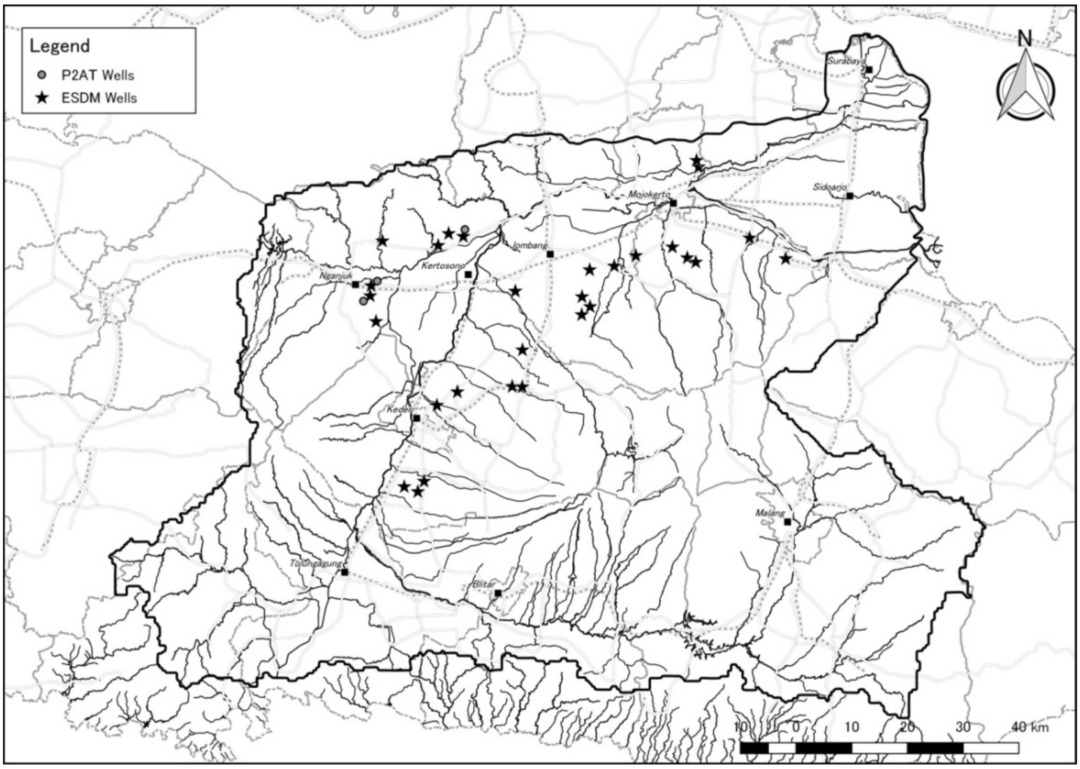
Calibration targets for the spatial distribution of hydraulic heads were 26 groundwater observation data collected by P2AT and ESDM as shown in Table C3.2.1 and Figure C3.2.1.

Since observation period and frequency of measurement are different among wells, it was decided to use the average observed water level for the calibration. In addition, observation wells are concentrated in the area from midstream to downstream of the Brantas River Basin where groundwater development are progressing. The quantitative calibration for remaining areas such as coastal area or upstream area is difficult, in the current situation, it is only confirmed whether groundwater flow and water balance are reasonable or not base on the experience.

Table C3.2.1 Calibration Target Wells (Re-posting)

Source of Collected Data	Area	No. of Wells	Measurement	Period	Frequency
Pengembangum Groundwater Project (P2AT) Jawa Timur	Nganjuk	1	Automatic	1997-1998	Daily – Monthly data not constant
Ministry of Energy and Mineral Resources (ESDM) Jawa Timur Data	Mojokerto, Kediri	2	Automatic	2009-2013	Hourly data one or two year continuous
	Nganjuk, Mojokerto Jombang, Kediri	23	Manual	2004-2009	Monthly data measurement by hand
Total		26			

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure C3.2.1 Calibration Targets of the Model (Re-posting)

3.2.2 Result of Simulation

(1) Fixed Aquifer Constants

Fixed aquifer constants are shown in Table C3.2.2. In general, the hydraulic conductivities of each hydrogeological unit become smaller with depth. Therefore, hydraulic conductivities of deep aquifer from 3 to 6 layers except for Ocean (zone1) and Aquiclude (zone10) were set 1 order smaller than hydraulic conductivities of shallow aquifer (1 and 2 layers). In addition, hydraulic conductivities have anisotropic feature. Hence, vertical hydraulic conductivities are assigned to be about 1 order smaller than horizontal conductivities in this model.

Table C3.2.2 Fixed Aquifer Constants

Hydrogeological Unit		Horizontal Hydraulic Conductivity : Kxx, Kyy (m/s)	Specific Yield: Sy (-)	Specific Storage Coefficient: Ss (1/m)	Note
Zone*	Name				
1	Ocean	1.0×10^{-1}	0.5	1.0×10^{-5}	For setting boundary condition
2	Marine Deposit 1	1.0×10^{-5}	0.25	1.0×10^{-5}	
3	Marine Deposit 2	1.0×10^{-3}	0.25	1.0×10^{-5}	
4	Aquifer 1	5.0×10^{-5}	0.3	1.0×10^{-5}	Relatively low hydraulic conductivity
5	Aquifer 2	5.0×10^{-4}	0.3	1.0×10^{-5}	Moderate hydraulic conductivity
6	Aquifer 3	1.0×10^{-3}	0.3	1.0×10^{-5}	High hydraulic conductivity
7	Fractured Bedrock 2	1.0×10^{-5}	0.25	1.0×10^{-5}	Largely varying hydraulic conductivity
8	Fractured Bedrock 3	1.0×10^{-4}	0.3	1.0×10^{-5}	
9	Fractured Bedrock 1	1.0×10^{-6}	0.2	1.0×10^{-5}	
10	Aquiclude	1.0×10^{-8}	0.15	1.0×10^{-5}	Clay layer
11	Low Permeable Rock 2	1.0×10^{-7}	0.15	1.0×10^{-5}	Groundwater distribute locally
12	Low Permeable Rock 1	1.0×10^{-7}	0.15	1.0×10^{-5}	Poor groundwater
13	Limestone	1.0×10^{-7}	0.15	1.0×10^{-5}	Groundwater flow is limited

*: For zone number and the location, please refer to Figure C3.1.1

Source: JICA Project Team 2

Since observation period and frequency of measurement are different among wells, it was decided to use the average observed water level for the calibration. In addition, observation wells are concentrated in the area from midstream to downstream of the Brantas River Basin where groundwater development are progressing. The quantitative calibration for remaining areas such as coastal area or upstream area is difficult, in the current situation, it is only confirmed whether groundwater flow and water balance are reasonable or not base on the experience.

(2) Calibration result

Cross-plot of observed vs. calculated average hydraulic heads in 20 years is shown Figure C3.2.2. Hydraulic heads are approximately recreated because almost all plots are positioned near the dashed line of calculation heads equal to observation heads. It means that model can represent the groundwater environment in the Brantas River basin well.

The Root Mean Square Error (RMS) of a model prediction with respect to the estimated variable is a frequently used measure of the difference between values predicted by a model and the values actually observed from the environment that is being modeled. The RMS of a model prediction with respect to the estimated variable X_{model} is defined as the square root of the mean squared error:

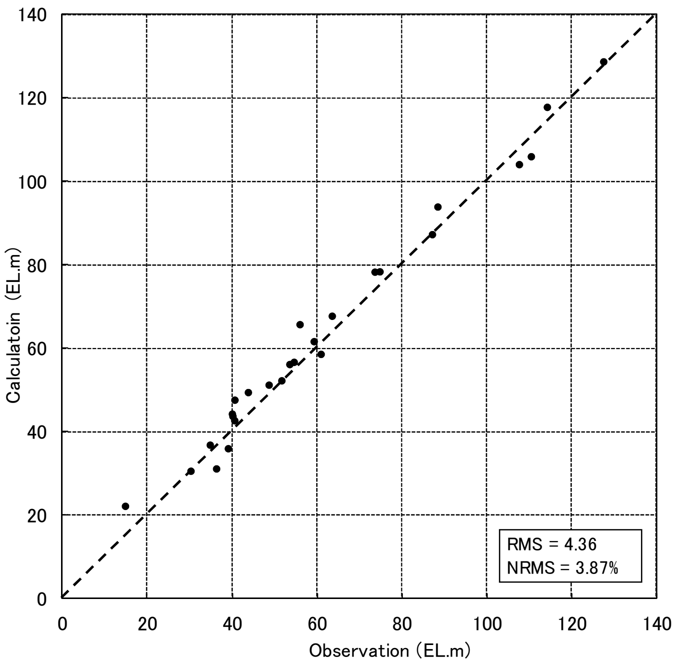
$$RMS = \sqrt{\frac{\sum_{i=1}^{n}\left(X_{obs,i} - X_{model,i}\right)^2}{n}}$$

where n is total number of the wells using calibration (n = 26), X_{obs} is observed values, and X_{model} is modeled values at time/place i.

Normalized root-mean-square error (NRMS) is often used on the process of model calibration as comparison index between observation data and calculated head with different units:

$$NRMS = \frac{RMS}{X_{obs,max} - X_{obs,min}}$$

NRMS, expressed as a percentage, is the representative parameter of the model and must be less than 10% for an adequate calibration.



No.	Well Name	Observation (m)	Calclation (m)
1	E178	40.05	43.88
2	ESDM-18	127.39	128.82
3	ESDM-8	30.17	30.76
4	EXJB176	59.19	61.80
5	OB-079	40.48	42.86
6	SDMJ464	55.86	65.88
7	SDNJ-151	40.53	47.79
8	SKJB297	60.83	58.76
9	SOJB076	54.49	56.85
10	SOJB9731	34.71	37.01
11	SONJ-019	53.46	56.32
12	SONJ-084	39.92	44.45
13	SONJ017	48.58	51.39
14	TW 161	74.69	78.53
15	TW-05	38.97	36.16
16	TW-109	88.34	94.06
17	TW-110	107.53	104.21
18	TW-157	114.12	117.93
19	TW-23	14.74	22.36
20	TW-49	36.20	31.32
21	TW-49 Jrambre	73.52	78.45
22	TW025	87.05	87.44
23	TW073	43.69	49.61
24	TW103	110.34	106.10
25	TW215	63.45	67.89
26	TWNJ-137	51.57	52.43

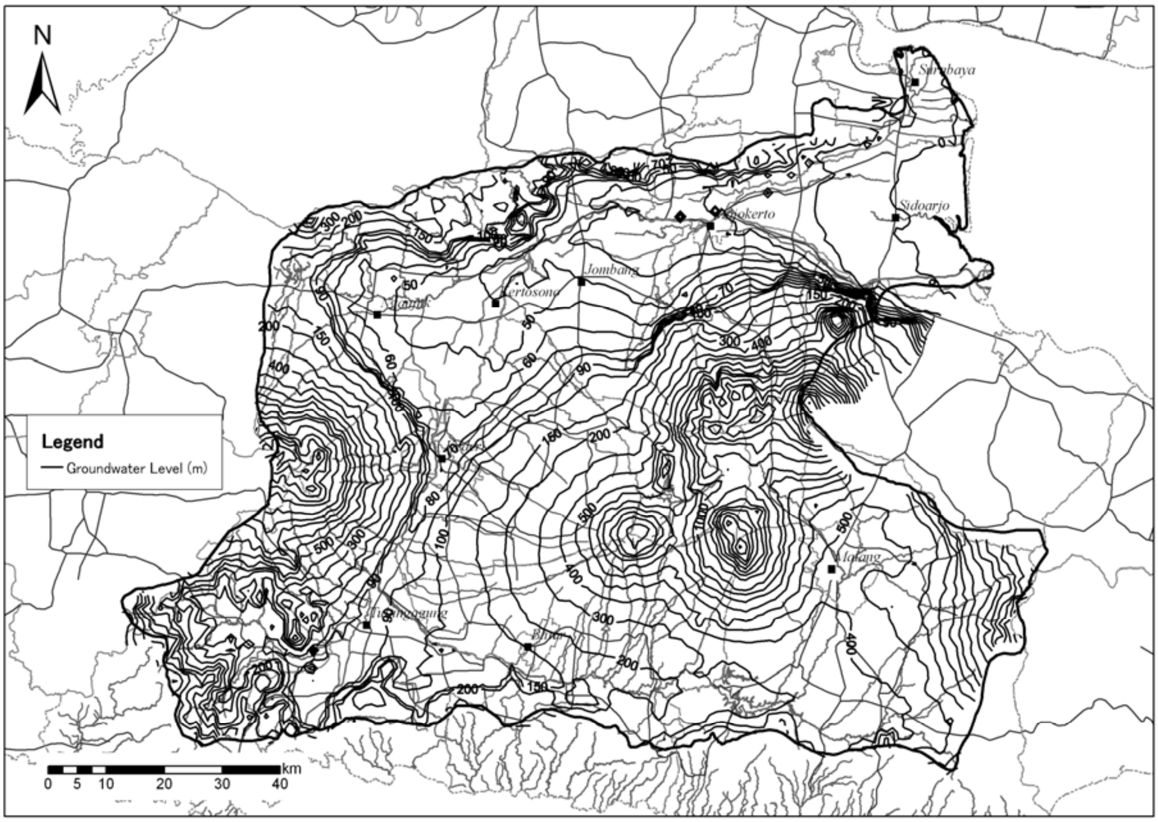
Source: JICA Project Team 2

Figure C3.2.2 Scatter Plot of Observed vs. Calculated Average Hydraulic Heads

(3) Groundwater Level and Groundwater Flow Direction

Groundwater level (shallow groundwater hydraulic heads) contour map of final day of simulation is shown in Figure C3.2.3.

The shape of groundwater level contours is quite similar to topographic contours. Shallow groundwater flows in the direction orthogonal to the contours, almost the same direction as surface water. That is, Groundwater in mountain range goes down along the slope to valley plain including the plains of the Brantas River, flow down along the river in plains to the ocean.



Source: JICA Project Team 2

Figure C3.2.3 Groundwater Level Contour at Final Month of Calculation

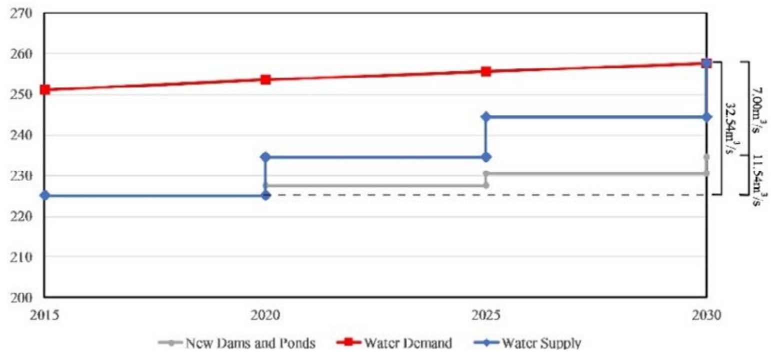
CHAPTER C4 GROUNDWATER POTENTIAL EVALUATION IN BRANTAS RIVER BASIN

C4.1 Groundwater Development Plan and Presidential Decree

C4.1.1 Groundwater Development Plan up to 2030

Groundwater development plan from 2015 to 2030 shown in Review POLA 2015 (Draft) is in total 21m^3/s (7m^3/s every 5 years) as shown in Figure C4.1.1. With respect to the basis of this value, as a result of document survey and interview survey, the process of calculation was clarified as follows:

1)	Difference between water demand and water supply plan up to 2030	(9.59 + 9.85 + 13.09) = 32.54m^3/s
2)	Additional water supply plan of new dams and pond constructions (1.43m^3/s every 5 years)	(2.59 + 2.85 + 4.09) = 11.54m^3/s
3)	Difference between water demand and planned water supply	(32.54 – 11.54) = 21.00m^3/s
4)	Groundwater development plan (potential) every 5 years	21.00 / 3 = 7.00m^3/s



Source: POLA(2006) and JICA Project Team 2

Figure C4.1.1 Relationship between Water Supply and Demand in Brantas River Basin

However, the location of the development should be selected carefully, it is considered that the groundwater development of 21m^3/s (662.26 million m^3/y) up to 2030 is possible based on the existing groundwater potential values found in Review POLA 2015 (Draft) and report of ESDM (2005 and 2010). The groundwater potential values shown in POLA and report of ESDM are as follows:

1) Charging groundwater in Brantas River Basin in POLA (2006):
   Total = 4,084.84 million m^3/y.
2) Groundwater Potential in Brantas River Basin in report of ESDM (2005 and 2010):
   Unconfined (shallow) groundwater = 3,674 million m^3/y.
   Confined (deep) groundwater = 175 million m^3/y.
   Total = 3,674 + 175 = 3,849 million m^3/y.
3) Ratio of planed groundwater development to total groundwater potential:
   662.26 / 4,084.84 = 16% (POLA(2006))
   662.26 / 3,849 = 17% (ESDM)

The method of estimation for the value of charging groundwater in the Brantas basin found in POLA (2006) and concerning groundwater potential in the Brantas basin by ESDM are not shown in POLA (2006) nor reports by ESDM. In interview survey, the groundwater basins are established by Presidential Decree No. 26 of 2011, and it is clarified that the groundwater potentials shown in POLA (2006) and ESDM reports are based on the result of Project carried out by Badan Geologi which is organization under ESDM.

The detail of groundwater potential estimated by ESDM is explained in Section C4.2.1.

C4.1.2 Presidential Decree No. 26 of 2011

According to Presidential Decree No. 26 of 2011, four hundred and twenty-one (421) groundwater basins across Indonesia were established as follows. However, groundwater potential for groundwater basins which were defined in the presidential decree is not mentioned.

DECISION:

DEFINITION: PRESIDENTIAL DECREE CONCERNING THE ESTABLISHMENT OF GROUNDWATER BASIN.

FIRST: Establish groundwater basins that include:
a. Groundwater basin in the district / city (included in the district / city);
b. Districts / cities Groundwater basin (spreading to two or more districts / cities);
c. Provincial ground water basins; and
d. Groundwater basins cross country;
to register and coordinate groundwater basin as listed in Annex I and maps of groundwater basin as listed in Annex II, which are an integral part of this decree.

SECOND: Determination of groundwater basins as defined in the First dictum can be revisited by physical changes in the groundwater basin in question and / or found new data in accordance with the provisions of the legislation in the field of groundwater.

(Presidential Decree No. 26 of 2011)

C4.2 Groundwater Potential under the Present Conditions

C4.2.1 Groundwater Potential in Previous Project

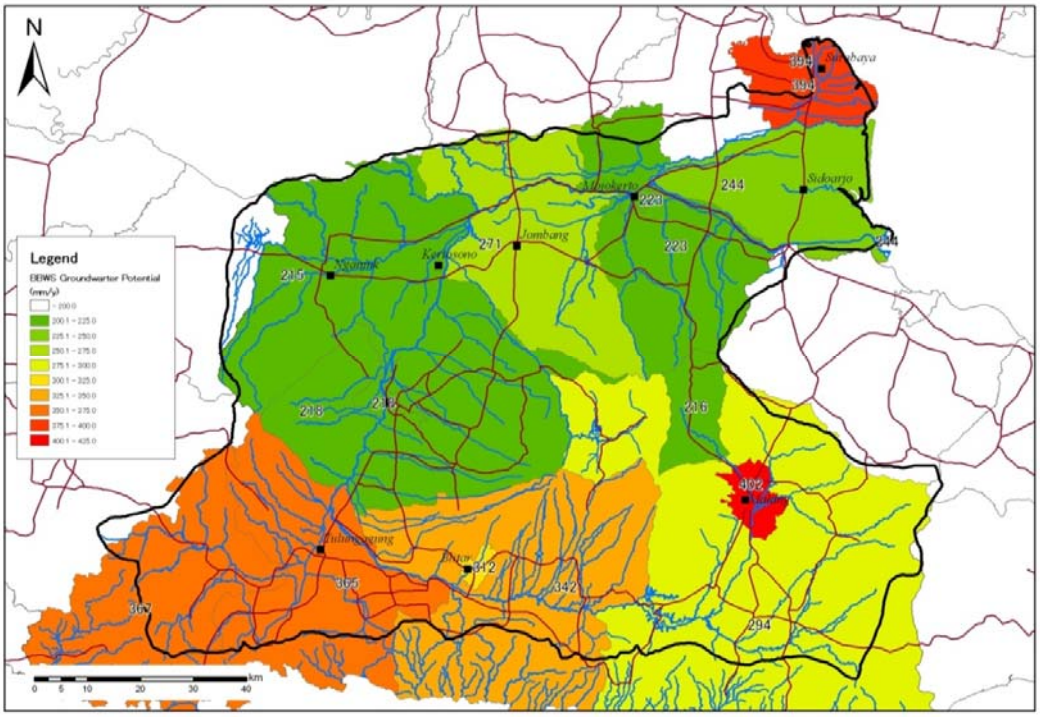
In 2005, Ministry of Energy and Mineral Resources (ESDM) has been created and published groundwater potential and its map of each groundwater basin. Groundwater potential in POLA, RENCANA, and presentation materials of other government agencies is all based on this groundwater potential map. Groundwater potential of the Brantas River basin is 3,849 million m^3/y (385mm/y). In POLA or RENCANA, useful groundwater potential value by regency/city which has been aggregated on the basis of the groundwater potential map is reported, however the aggregation method is unknown.

On the other hand, BBWS Brantas has also published groundwater potential by regency/city as shown in Table C4.2.1 and Figure C4.2.1. Total existing groundwater potential in the Brantas River basin is 4,038.84 million m^3/y (288.9 mm/y) and highest groundwater potential regency/city in height is Malang City 43.98 million m^3/y (401.9 mm/y). The record of groundwater use in Malang City aggregated by Environmental Section of Malang City from 2006 to 2008 shows 232.45 million m^3/y (2,124.4mm/y). This value is about 5 times of the existing groundwater potential estimate by BBWS Brantas, indicating the groundwater is still overuse condition, and dried up well has already been revealed.

Table C4.2.1 Existing Groundwater Potential Evaluation by Regency/City

No.	Regency / City	Area (km^2)	Groundwater Potential	
			(10^6 m^3/y)	(mm/y)
1	Malang Regency	3,440.09	1,010.75	293.8
2	Malang City	109.42	43.98	401.9
3	Batu City	211.87	45.76	216.0
4	Blitar Regency	1,753.54	598.38	341.2
5	Blitar City	33.45	10.43	311.9
6	Tulungagung Regency	1,152.51	420.27	364.7
7	Trenggalek Regency	1,244.60	457.12	367.3
8	Kediri City / Regency	1,587.63	345.39	217.6
9	Nganjuk Regency	1,292.29	278.08	215.2
10	Jombang Regency	1,121.17	304.14	271.3
11	Mojokerto City / Regency	994.10	222.01	223.3
12	Sidoarjo Regency	709.13	173.23	244.3
13	Surabaya City	327.85	129.30	394.4
Total		13,977.66	4,038.84	288.9

Source: BBWS Brantas and JICA Project Team 2



Source: JICA Project Team 2

Figure C4.2.1 Existing Groundwater Potential Evaluation in Brantas River Basin in Height

C4.2.2 Groundwater Potential in This Project

Groundwater potential under the present condition evaluated for regency/city is shown in Table C4.2.2 and remaining groundwater potential in height is shown in Figure C4.2.2. Groundwater demand of bold character regencies and cities is higher than their average recharge between 1991 and 2010. It means that these regencies/cities are not able to provide groundwater demand from their own groundwater recharge.

Furthermore, Gresik Regency indicates minus value for remaining groundwater potential (C) - (A), and it means that the groundwater is already over use condition. Gresik Regency has area facing the coast, and when groundwater is excessively pumped in the area, the possibility of saltwater intrusion and land subsidence is increased.

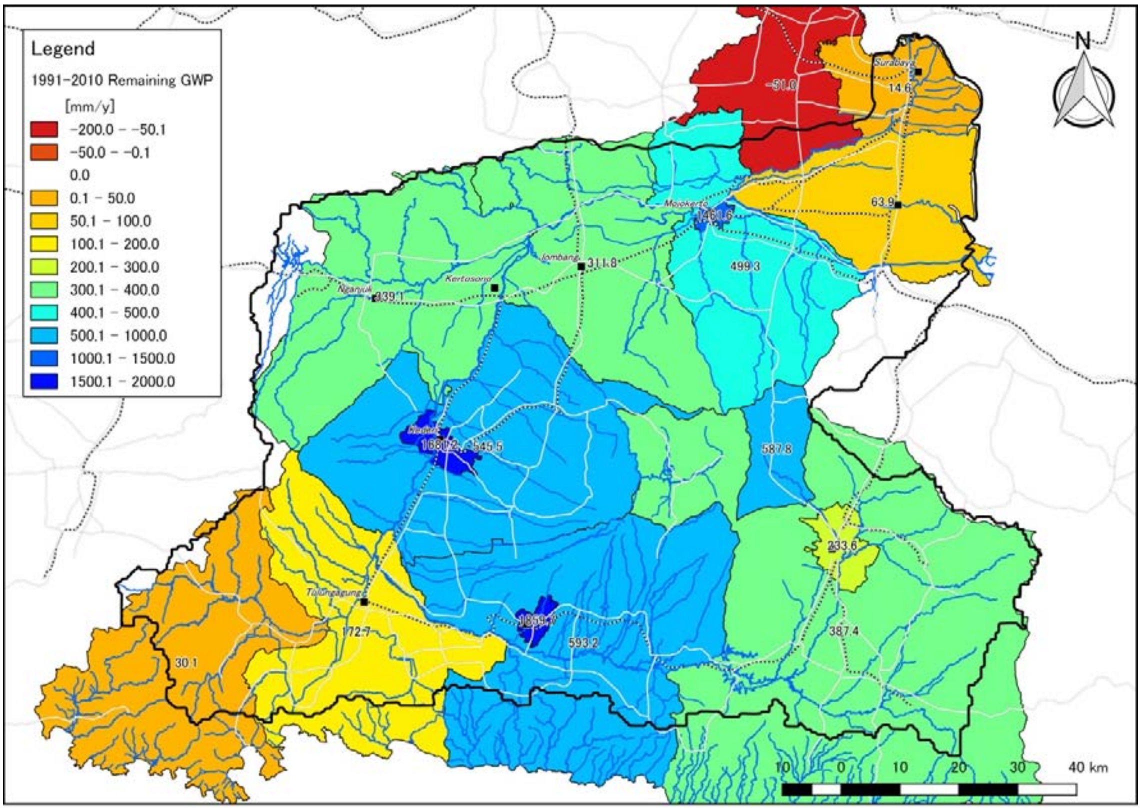
Sidoarjo Regency, Surabaya City and Mojokerto City are under the critical condition about groundwater potential because supply of groundwater should rely on inflow from aquifer in surrounded area or infiltration through riverbed.

Table C4.2.2 Evaluation of Present Groundwater Potential by Regency/City in Brantas River Basin

No.	Regency / City	Model Area*1 (km²)	(A) Groundwater Demand		(B) Recharge (1991-2010)		(B) - (A)		(C) Total Potential (1991-2010)		(C) - (A) Remaining Potential (1991-2010)	
			($10^6m^3/y$)	(mm/y)*1	($10^6m^3/y$)	(mm/y)*1	($10^6m^3/y$)	(mm/y)*1	($10^6m^3/y$)	(mm/y)*1	($10^6m^3/y$)	(mm/y)*1
1	Batu City	211.8	17.89	84.5	274.49	1296.3	256.60	1211.8	142.36	672.3	124.47	587.8
2	Malang Regency	2216.5	201.63	91.0	1727.40	779.3	1525.77	688.4	1060.40	478.4	858.77	387.4
3	Malang City	109.4	58.50	534.6	74.91	684.6	16.41	150.0	84.06	768.2	25.56	233.6
4	Kediri Regency	1521.0	57.20	37.6	821.27	540.0	764.06	502.3	886.89	583.1	829.69	545.5
5	Blitar Regency	1281.3	38.17	29.8	951.21	742.4	913.04	712.6	798.18	623.0	760.01	593.2
6	**Sidoarjo Regency**	690.4	40.46	58.6	33.85	49.0	**-6.61**	**-9.6**	84.59	122.5	44.13	63.9
7	Mojokerto Regency	899.4	31.01	34.5	420.70	467.8	389.69	433.3	480.02	533.7	449.01	499.3
8	Jombang Regency	1102.8	39.45	35.8	350.57	317.9	311.12	282.1	383.26	347.5	343.82	311.8
9	Kediri City	66.6	20.66	310.1	22.89	343.5	2.22	33.3	132.69	1991.3	112.02	1681.2
10	**Mojokerto City**	20.3	11.81	582.9	5.20	256.5	**-6.61**	**-326.4**	41.43	2044.5	29.62	1461.6
11	**Surabaya City**	237.5	34.85	146.7	0.27	1.1	**-34.58**	**-145.6**	38.32	161.3	3.47	14.6
12	Trenggalek Regency	632.3	26.45	41.8	256.88	406.2	230.42	364.4	45.48	71.9	19.03	30.1
13	Blitar City	33.4	8.71	260.3	23.90	714.5	15.19	454.2	70.90	2120.0	62.20	1859.7
14	Tulungagung Regency	951.9	26.73	28.1	405.65	426.1	378.92	398.0	191.13	200.8	164.40	172.7
15	Nganjuk Regency	1282.8	23.31	18.2	473.09	368.8	449.78	350.6	458.34	357.3	435.03	339.1
16	**Gresik Regency**	105.6	11.26	106.6	0.38	3.6	**-10.88**	**-103.0**	5.88	55.6	**-5.39**	**-51.0**
	Total	11363.1	648.08	57.0	5842.63	514.2	5194.54	457.1	4903.94	431.6	4255.85	374.5

*1: Caliculated using Model Area (km²)

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure C4.2.2 Distribution of Present Remaining Groundwater Potential in Height

C4.3 Groundwater Potential under the Near Future Condition in 2030

C4.3.1 Analytical Condition for 2030

Groundwater potential under the near future condition (2030) is evaluated using calibrated present groundwater model with the same analytical condition such as recharge, hydraulic constants, boundary conditions, and initial condition except for constant head boundary (sea water level) and groundwater demand (Table C4.3.1).

Table C4.3.1 Analytical Condition for Evaluation of Near Future Groundwater Potential

Item	Condition	Note
Code	MODFLOW2005 (Visual MODFLOW 2009.1)	
Base Model	Calibrated (Present) Model	Same value of hydraulic constants is used as the calibrated model
Boundary Condition	Constant Head Boundary (Sea Water Level)	0.05m: prediction based on sea level rising (5mm/y)
	Pumping Rate: Near Future Demand Value	Value is set based on present groundwater potential
Calculation	Transient Simulation	Same value of Initial condition is used as calibrated model
Duration	2011 – 2030 (20 years)	
Time Steps	1 month	

Source: JICA Project Team 2

C4.3.2 Groundwater Demand in 2030

BBWS Brantas studied water demand in the Brantas River basin and set the planned groundwater development volume by 2030. Taking into consideration of current groundwater usage, areas are divided into two: the area where additional groundwater can be developed and the area where it is better to avoid additional groundwater development. In this project, additional groundwater development potential is evaluated based on the result of present groundwater flow simulation, and groundwater demand for domestic/non-domestic and industrial water in 2030 is assumed. Groundwater demand assigned for the model to simulate near future (2030) is shown in Table C4.3.2 and Figure C4.3.1.

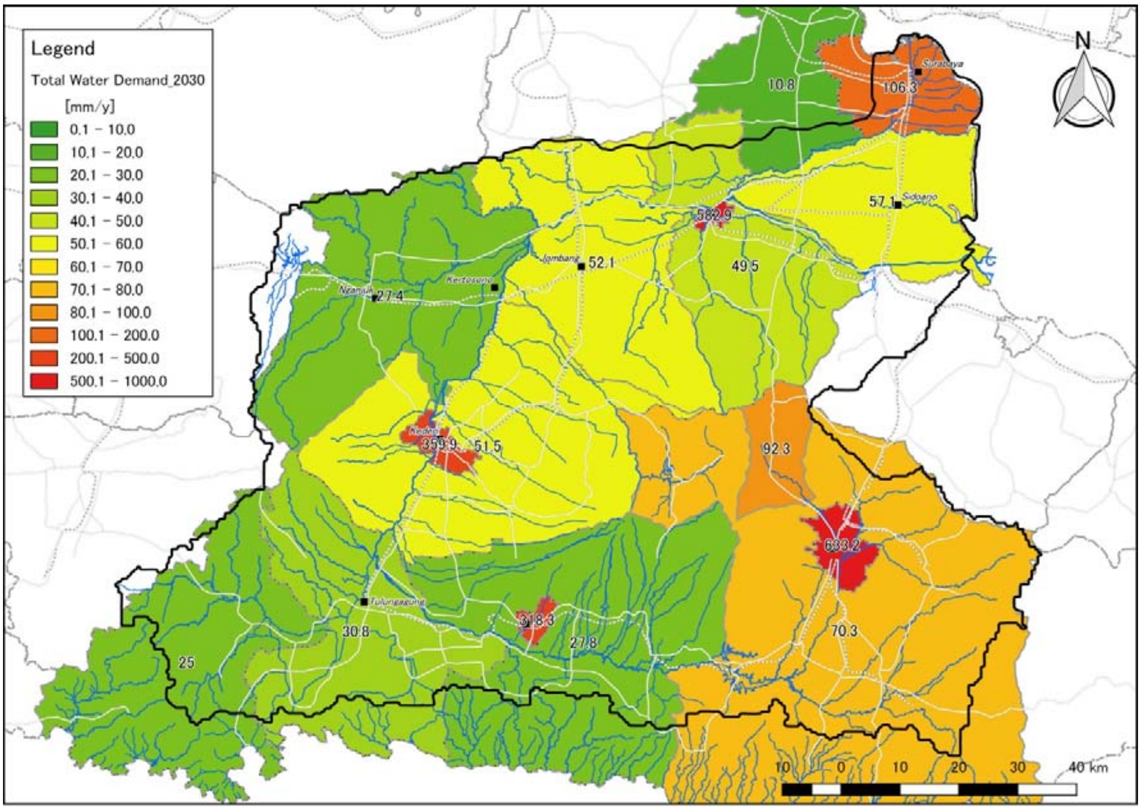
The model is used to assess the difference of groundwater potential change between near future (2030) and present status (2010) simply and to verify the sensitivity of calibrated groundwater model for groundwater demand change.

Table C4.3.2 Groundwater Demand of Regency/City in Brantas River Basin in 2030

No.	Regency / City	Area (km^2)	Groundwater Demand in 2030				
			Domestic / Non-Domestic	Industrial	Agricultural	Total	
			(10^6 m^3/y)			(10^6 m^3/y)	(mm/y)
1	Batu City	211.9	9.83	9.73	0.00	19.6	92.3
2	Malang Regency	3,440.1	100.74	141.02	0.00	241.8	70.3
3	Malang City	109.4	62.89	6.40	0.00	69.29	633.2
4	Kediri Regency	1,521.0	50.98	16.09	11.26	78.33	51.5
5	Blitar Regency	1,753.5	41.76	7.07	0.00	48.83	27.8
6	Sidoarjo Regency	709.1	40.14	0.32	0.00	40.46	57.1
7	Mojokerto Regency	973.8	46.88	1.34	0.00	48.22	49.5
8	Jombang Regency	1,121.2	43.99	4.04	10.35	58.37	57.5
9	Kediri City	66.6	13.14	10.85	0.00	23.98	359.9
10	Mojokerto City	20.3	2.35	9.46	0.00	11.81	582.9

No.	Regency / City	Area (km^2)	Groundwater Demand in 2030				
			Domestic / Non-Domestic	Industrial	Agricultural	Total	
			(10^6 m^3/y)			(10^6 m^3/y)	(mm/y)
11	Surabaya City	327.8	34.85	0.00	0.00	34.85	106.3
12	Trenggalek Regency	1,244.6	25.83	5.32	0.00	31.15	25.0
13	Blitar City	33.4	5.80	4.84	0.00	10.65	318.3
14	Tulungagung Regency	1,152.5	34.47	1.05	0.00	35.51	30.8
15	Nganjuk Regency	1,292.3	33.19	0.30	1.95	35.44	27.4
16	Gresik Regency	1,041.6	11.26	0.00	0.00	11.26	10.8
Total		15,019.2	558.11	217.81	23.56	799.5	53.2

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure C4.3.1 Distribution of Groundwater Demand in Height (2030)

C4.3.3 Groundwater Potential in 2030

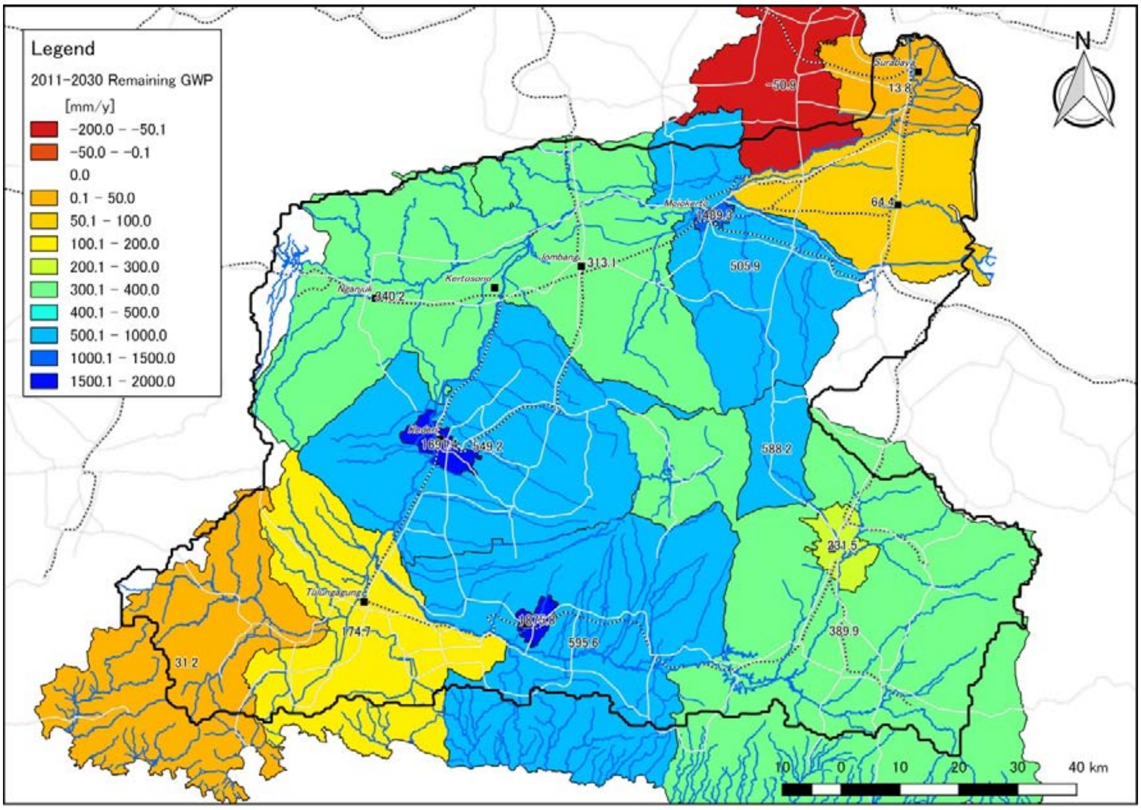
Groundwater potential under the near future (2030) condition evaluated for regency/city is shown in Table C4.3.3 and remaining groundwater potential in height is shown in Figure C4.3.2. Groundwater demand of bold character regencies and cities is higher than their average recharge between 2011 and 2030. It means that these regencies/cities are not able to provide groundwater demand from their own groundwater recharge.re These regencies/cities are not able to provide groundwater demand from their own groundwater recharge. Kediri City has changed to the area under the critical condition about groundwater potential where it is better to avoid further development from possible groundwater development area.

Table C4.3.3 Evaluation of 2030 Groundwater Potential by Regency/City in Brantas River Basin

No.	Regency / City	Model Area[*1] (km^2)	(A) Groundwater Demand		(B) Recharge (2011-2030)		(B) - (A)		(C) Total Potential (2011-2030)		(C) - (A) Remaining Potential (2011-2030)	
			($10^6m^3/y$)	(mm/y)[*1]	($10^6m^3/y$)	(mm/y)[*1]	($10^6m^3/y$)	(mm/y)[*1]	($10^6m^3/y$)	(mm/y)[*1]	($10^6m^3/y$)	(mm/y)[*1]
1	Batu City	211.8	19.56	92.4	274.49	1296.3	254.93	1203.9	142.44	672.7	122.89	580.3
2	Malang Regency	2216.5	241.76	109.1	1727.40	779.3	1485.64	670.3	1065.78	480.8	824.03	371.8
3	Malang City	109.4	69.29	633.2	74.91	684.6	5.62	51.4	83.82	766.1	14.53	132.8
4	Kediri Regency	1521.0	78.33	51.5	821.27	540.0	742.93	488.5	892.54	586.8	814.20	535.3
5	Blitar Regency	1281.3	48.83	38.1	951.21	742.4	902.38	704.3	801.24	625.3	752.40	587.2
6	**Sidoarjo Regency**	690.4	40.46	58.6	33.85	49.0	**-6.61**	**-9.6**	84.94	123.0	44.49	64.4
7	Mojokerto Regency	899.4	48.22	53.6	420.70	467.8	372.48	414.2	486.00	540.4	437.78	486.8
8	Jombang Regency	1102.8	58.37	52.9	350.57	317.9	292.19	265.0	384.71	348.9	326.34	295.9
9	**Kediri City**	66.6	23.98	359.9	22.89	343.5	**-1.10**	**-16.5**	133.37	2001.5	109.38	1641.6
10	**Mojokerto City**	20.3	11.81	582.9	5.20	256.5	**-6.61**	**-326.4**	41.99	2072.2	30.18	1489.3
11	**Surabaya City**	237.5	34.85	146.7	0.27	1.1	**-34.58**	**-145.6**	38.12	160.5	3.27	13.8
12	Trenggalek Regency	632.3	31.15	49.3	256.88	406.2	225.73	357.0	46.20	73.1	15.05	23.8
13	Blitar City	33.4	10.65	318.3	23.90	714.5	13.25	396.2	71.44	2136.1	60.80	1817.8
14	Tulungagung Regency	951.9	35.51	37.3	405.65	426.1	370.14	388.8	193.05	202.8	157.54	165.5
15	Nganjuk Regency	1282.8	35.44	27.6	473.09	368.8	437.64	341.2	459.73	358.4	424.29	330.8
16	**Gresik Regency**	105.6	11.26	106.6	0.38	3.6	**-10.88**	**-103.0**	5.89	55.7	**-5.38**	**-50.9**
Total		11363.1	799.48	70.4	5842.63	514.2	5043.15	443.8	4931.28	434.0	4131.80	363.6

*1: Caliculated using Model Area (km^2)

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure C4.3.2 Distribution of Evaluated Remaining Groundwater Potential in Height (2030)

C4.4 Groundwater Potential under the Future Conditions in 2050

C4.4.1 Analytical Condition for 2050

Groundwater potential under the future condition is evaluated using calibrated groundwater model with the same analytical condition such as hydraulic constants, boundary conditions, and initial condition except for constant head boundary (sea water level), recharges and groundwater demand, which is shown in Table C4.4.1. Groundwater demand in 2050 is used the same value of groundwater demand for near future (2030) calculation, which was estimated from surface water demand analysis based on the evaluation of present groundwater potential. Groundwater demand was used in this simulation to assess the difference between future and present status simply and to verify the sensitivity of calibrated groundwater model for climatic change impact in future.

Table C4.4.1 Analysis Condition for Evaluation of Future Groundwater Potential

Item	Condition	Note
Code	MODFLOW2005 (Visual MODFLOW 2009.1)	
Base Model	Calibrated (Present) Model	Same value of hydraulic constants is used as the calibrated model
Boundary Condition	Constant Head Boundary (Sea Water Level)	0.15m: prediction based on sea level rising (5mm/y)
	Groundwater Recharge: Provided data (3 Scenarios)	Groundwater recharge rate and the distribution is changed by climatic change impact
	Pumping Rate: Near Future Demand Value	Value is set based on present groundwater potential
Calculation	Transient Simulation	Same value of Initial condition is used as calibrated model
Duration	2046 – 2065 (20 years)	
Time Steps	1 month	

Source: JICA Project Team 2

C4.4.2 Future Groundwater Recharge

Average groundwater recharge is provided for three scenarios as shown in Table C4.4.2: Low Scenario, Medium Scenario, and High Scenario. Recharge distribution of these three scenarios are slightly different for each other. Model calculation has been conducted for three cases of recharge affected by climatic change impact.

Table C4.4.2 Average Groundwater Recharge Provided for Three Scenarios

No.	Regency / City	Model Area*1 (km^2)	Present Groundwater Recharge (1991-2010)		Future Groundwater Recharge (2046 - 2065)					
					High Scenario		Middle Scenario		Low Scenario	
			(Mm^3/y)	(mm/y)*1	(Mm^3/y)	(mm/y)*1	(Mm^3/y)	(mm/y)*1	(Mm^3/y)	(mm/y)*1
1	Batu City	211.8	274.49	1296.3	244.37	1154.1	251.98	1190.0	277.93	1312.5
2	Malang Regency	2216.5	1727.40	779.3	1217.43	549.2	1346.16	607.3	1480.21	667.8
3	Malang City	109.4	74.91	684.6	53.98	493.3	61.36	560.8	66.10	604.1
4	Kediri Regency	1521.0	821.27	540.0	569.43	374.4	538.95	354.3	698.21	459.0
5	Blitar Regency	1281.3	951.21	742.4	543.36	424.1	708.02	552.6	731.18	570.7
6	Sidoarjo Regency	690.4	33.85	49.0	29.68	43.0	25.57	37.0	38.61	55.9
7	Mojokerto Regency	899.4	420.70	467.8	310.47	345.2	274.09	304.8	393.47	437.5
8	Jombang Regency	1102.8	350.57	317.9	255.31	231.5	225.36	204.4	330.43	299.6
9	Kediri City	66.6	22.89	343.5	16.14	242.2	14.64	219.7	20.73	311.0
10	Mojokerto City	20.3	5.20	256.5	3.30	162.7	2.71	133.6	5.08	250.7
11	Surabaya City	237.5	0.27	1.1	4.27	18.0	3.89	16.4	4.22	17.8
12	Trenggalek Regency	632.3	256.88	406.2	126.36	199.8	133.57	211.2	180.30	285.1
13	Blitar City	33.4	23.90	714.5	9.00	269.2	15.28	456.8	16.86	504.0
14	Tulungagung Regenc	951.9	405.65	426.1	253.57	266.4	257.54	270.5	334.67	351.6
15	Nganjuk Regency	1282.8	473.09	368.8	342.40	266.9	312.90	243.9	440.64	343.5
16	Gresik Regency	105.6	0.38	3.6	1.84	17.4	1.91	18.1	3.12	29.5
	Total	11363.1	5842.63	514.2	3980.90	350.3	4173.92	367.3	5021.76	441.9

*1: Caliculated using Model Area (km^2)

Source: JICA Project Team 2

C4.4.3 Groundwater Potential in 2050

Groundwater potential under the future condition is evaluated using calibrated groundwater model with the same analytical condition such as hydraulic constants, boundary conditions, and initial condition except for constant head boundary (sea water level), recharges and groundwater demand. Groundwater demand in 2050 is used the same value of groundwater demand for near future (2030) calculation, which was estimated from surface water demand analysis based on the evaluation of present groundwater potential. Groundwater demand was used in this simulation to assess the difference between future and present status simply and to verify the sensitivity of calibrated groundwater model for climatic change impact in future.

The comparison of future groundwater potential and groundwater demand among three cases, and the estimations of future groundwater potential and remaining development potential for three cases are summarized in Table C4.4.3 and Table C4.4.4, respectively. The evaluation of Medium Scenario, which is most typical case in three cases, shows that remaining groundwater development potential of bold (red) five regencies/cities except for Gresik City in Table C4.4.3 are apparently sufficient for groundwater development from Table C4.4.4. However, in fact groundwater recharges are not enough and those five regencies/cities have to expect other groundwater resource such as inflow from surrounded area via aquifer as groundwater or infiltration through riverbed.

Table C4.4.3 Future Groundwater Recharge and Groundwater Demand by Regency/City in Brantas River Basin

No.	Regency / City	Model Area*1 (km^2)	(A) Groundwater Demand (2050 = 2030)		High Scenario (2046-2065)				Middle Scenario (2046-2065)				Low Scenario (2046-2065)			
					(B1) Recharge		(B1) - (A)		(B2) Recharge		(B2) - (A)		(B3) Recharge		(B3) - (A)	
			($10^6m^3/y$)	(mm/y)*1	($10^6m^3/y$)	(mm/y)*1	($10^6m^3/y$)	(mm/y)*1	($10^6m^3/y$)	(mm/y)*1	($10^6m^3/y$)	(mm/y)*1	($10^6m^3/y$)	(mm/y)*1	($10^6m^3/y$)	(mm/y)*1
1	Batu City	211.8	19.56	92.36	244.37	1154.1	224.82	1061.7	251.98	1190.0	232.42	1097.6	277.93	1312.52	258.37	1220.2
2	Malang Regency	2216.5	241.76	109.07	1217.43	549.2	975.67	440.2	1346.16	607.3	1104.40	498.3	1480.21	667.81	1238.46	558.7
3	**Malang City**	109.4	69.29	633.23	53.98	493.3	**-15.31**	**-139.9**	61.36	560.8	**-7.93**	**-72.4**	66.10	604.10	**-3.19**	**-29.1**
4	Kediri Regency	1521.0	78.33	51.50	569.43	374.4	491.09	322.9	538.95	354.3	460.62	302.8	698.21	459.05	619.88	407.5
5	Blitar Regency	1281.3	48.83	38.11	543.36	424.1	494.52	386.0	708.02	552.6	659.19	514.5	731.18	570.67	682.35	532.6
6	**Sidoarjo Regency**	690.4	40.46	58.60	29.68	43.0	**-10.78**	**-15.6**	25.57	37.0	**-14.88**	**-21.6**	38.61	55.92	**-1.85**	**-2.7**
7	Mojokerto Regency	899.4	48.22	53.62	310.47	345.2	262.25	291.6	274.09	304.8	225.87	251.1	393.47	437.50	345.25	383.9
8	Jombang Regency	1102.8	58.37	52.93	255.31	231.5	196.94	178.6	225.36	204.4	166.98	151.4	330.43	299.64	272.06	246.7
9	**Kediri City**	66.6	23.98	359.94	16.14	242.2	**-7.85**	**-117.8**	14.64	219.7	**-9.35**	**-140.3**	20.73	311.04	**-3.26**	**-48.9**
10	**Mojokerto City**	20.3	11.81	582.90	3.30	162.7	**-8.52**	**-420.2**	2.71	133.6	**-9.11**	**-449.3**	5.08	250.72	**-6.73**	**-332.2**
11	**Surabaya City**	237.5	34.85	146.71	4.27	18.0	**-30.58**	**-128.7**	3.89	16.4	**-30.96**	**-130.3**	4.22	17.78	**-30.63**	**-128.9**
12	Trenggalek Regency	632.3	31.15	49.26	126.36	199.8	95.21	150.6	133.57	211.2	102.42	162.0	180.30	285.14	149.15	235.9
13	**Blitar City**	33.4	10.65	318.29	9.00	269.2	**-1.64**	**-49.1**	15.28	456.8	4.63	138.5	16.86	503.98	6.21	185.7
14	Tulungagung Regency	951.9	35.51	37.30	253.57	266.4	218.06	229.1	257.54	270.5	222.03	233.2	334.67	351.57	299.16	314.3
15	Nganjuk Regency	1282.8	35.44	27.63	342.40	266.9	306.96	239.3	312.90	243.9	277.45	216.3	440.64	343.50	405.20	315.9
16	**Gresik Regency**	105.6	11.26	106.65	1.84	17.4	**-9.42**	**-89.2**	1.91	18.1	**-9.36**	**-88.6**	3.12	29.50	**-8.15**	**-77.2**
	Total	11363.1	799.48	70.36	3980.90	350.3	3181.43	280.0	4173.92	367.3	3374.44	297.0	5021.76	441.94	4222.29	371.6

*1: Caliculated using Model Area (km^2)

Source: JICA Project Team 2

Table C4.4.4 Evaluation of Future Groundwater Potential by Regency/City in Brantas River Basin

No.	Regency / City	Model Area*1 (km²)	(A) Groundwater Demand (2050 = 2030)		High Scenario (2046-2065) (C1) Total Potential		Remaining Potential (C1) - (A)		Middle Scenario (2046-2065) (C2) Total Potential		Remaining Potential (C2) - (A)		Low Scenario (2046-2065) (C3) Total Potential		Remaining Potential (C3) - (A)	
			(10^6m^3/y)	(mm/y)*1	(10^6m^3/y)	(mm/y)*1	(10^6m^3/y)	(mm/y)*1	(10^6m^3/y)	(mm/y)*1	(10^6m^3/y)	(mm/y)*1	(10^6m^3/y)	(mm/y)*1	(10^6m^3/y)	(mm/y)*1
1	Batu City	211.8	19.56	92.36	145.89	689.0	126.33	596.6	162.75	768.6	143.19	676.2	154.89	731.47	135.33	639.1
2	Malang Regency	2216.5	241.76	109.07	1057.29	477.0	815.53	367.9	1309.67	590.9	1067.91	481.8	1191.74	537.66	949.98	428.6
3	Malang City	109.4	69.29	633.23	86.56	791.1	17.27	157.9	96.29	880.0	27.00	246.8	89.99	822.41	20.70	189.2
4	Kediri Regency	1521.0	78.33	51.50	799.58	525.7	721.25	474.2	848.29	557.7	769.95	506.2	888.35	584.06	810.02	532.6
5	Blitar Regency	1281.3	48.83	38.11	660.38	515.4	611.54	477.3	844.03	658.7	795.20	620.6	745.88	582.14	697.05	544.0
6	Sidoarjo Regency	690.4	40.46	58.60	88.44	128.1	47.98	69.5	93.72	135.7	53.26	77.1	105.76	153.19	65.31	94.6
7	Mojokerto Regency	899.4	48.22	53.62	433.30	481.8	385.08	428.2	460.74	512.3	412.52	458.7	487.39	541.93	439.17	488.3
8	Jombang Regency	1102.8	58.37	52.93	303.63	275.3	245.26	222.4	324.47	294.2	266.10	241.3	381.98	346.39	323.61	293.5
9	Kediri City	66.6	23.98	359.94	130.83	1963.5	106.85	1603.5	131.95	1980.2	107.96	1620.2	134.40	2016.98	110.42	1657.0
10	Mojokerto City	20.3	11.81	582.90	40.29	1988.2	28.48	1405.3	40.54	2000.5	28.73	1417.6	41.77	2061.31	29.96	1478.4
11	Surabaya City	237.5	34.85	146.71	40.32	169.8	5.48	23.1	41.18	173.4	6.33	26.7	42.40	178.51	7.55	31.8
12	Trenggalek Regency	632.3	31.15	49.26	43.17	68.3	12.02	19.0	81.36	128.7	50.21	79.4	57.39	90.76	26.24	41.5
13	Blitar City	33.4	10.65	318.29	65.19	1949.1	54.54	1630.8	68.70	2054.1	58.05	1735.8	66.94	2001.58	56.30	1683.3
14	Tulungagung Regency	951.9	35.51	37.30	224.88	236.2	189.37	198.9	301.06	316.3	265.55	279.0	233.84	245.65	198.33	208.3
15	Nganjuk Regency	1282.8	35.44	27.63	409.44	319.2	374.00	291.5	430.30	335.4	394.86	307.8	472.43	368.28	436.99	340.6
16	**Gresik Regency**	105.6	11.26	106.65	7.58	71.8	**-3.68**	**-34.9**	7.98	75.6	**-3.28**	**-31.1**	9.64	91.30	**-1.62**	**-15.3**
Total		11363.1	799.48	70.36	4536.77	399.3	3737.30	328.9	5243.03	461.4	4443.55	391.1	5104.81	449.24	4305.33	378.9

*1: Calculated using Model Area (km²)

Source: JICA Project Team 2

Although groundwater recharge of Medium Scenario is smaller than that of Low Scenario, the total potential and remaining potential of Medium Scenario is larger than those of Low Scenario. As mentioned above, since groundwater potential of the Brantas River Basin is adopted minimum annual inflow/outflow value in 20 calculated years, variation of inflow/outflow, especially variation of groundwater recharge, affects the value. Smaller variation of groundwater recharge of Medium Scenario in 20 years resulted in this inversion phenomena of groundwater potential.

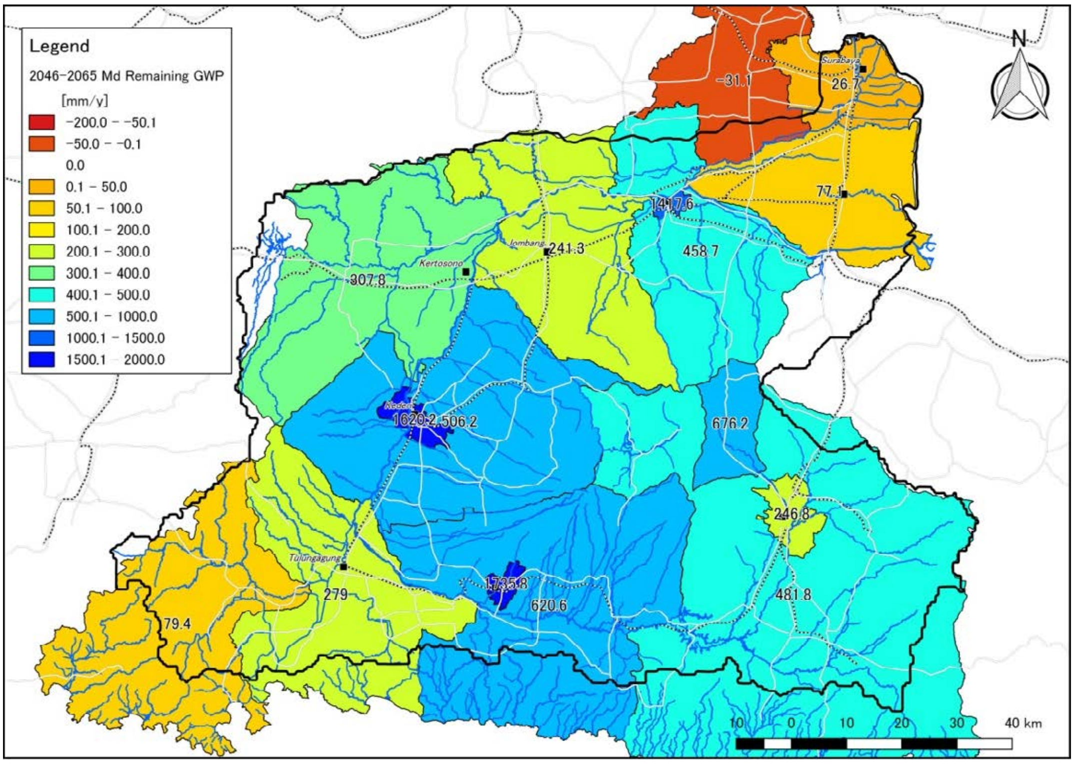
Detail evaluation of Medium scenario, which is typical scenario under the climate change, with component of groundwater flow from simulation is shown in Table C4.4.5. The remaining groundwater potential 1 (C) - (A) of all regencies/cities except for Gresik Regency shows positive value as shown in Figure C4.4.1. However, if groundwater inflow from surrounded regencies/cities and water infiltration through river bed degrease, the potential may reduce and it cannot be denied the occurrence of problem in the use of groundwater.

Table C4.4.5 Detail Evaluation with Component of Groundwater Flow (Medium Scenario)

No.	Regency / City	Model Area*1 (km²)	(A) Groundwater Demand (2050 = 2030)		(C) Total Potential (2046-2065Md)		(C) - (A) Remaining Potential 1		(D) Groundwater Inflow from Other District/City		(C) - (A) - (D) Remaining Potential 2		(E) Groundwater Inflow from River (2046-2065Md)		(C) - (A) - (D) - (E) Remaining Potential 3	
			(Mm^3/y)	(mm/y)*1	(Mm^3/y)	(mm/y)*1	(Mm^3/y)	(mm/y)*1	(Mm^3/y)	(mm/y)*1	(Mm^3/y)	(mm/y)*1	(Mm^3/y)	(mm/y)*1	(Mm^3/y)	(mm/y)*1
1	Batu City	211.8	19.56	92.36	162.75	768.6	143.19	676.2	1.33	6.3	141.86	669.9	0.63	3.0	141.23	667.0
2	Malang Regency	2216.5	241.76	109.07	1309.67	590.9	1067.91	481.8	56.08	25.3	1011.83	456.5	99.26	44.8	912.57	411.7
3	Malang City	109.4	69.29	633.23	96.29	880.0	27.00	246.8	35.21	321.8	**-8.21**	**-75.0**	5.16	47.2	**-13.37**	**-122.2**
4	Kediri Regency	1521.0	78.33	51.50	848.29	557.7	769.95	506.2	126.68	83.3	643.27	422.9	234.40	154.1	408.88	268.8
5	Blitar Regency	1281.3	48.83	38.11	844.03	658.7	795.20	620.6	84.56	66.0	710.64	554.6	145.37	113.5	565.26	441.2
6	**Sidoarjo Regency**	690.4	40.46	58.60	93.72	135.7	53.26	77.1	29.66	43.0	23.60	34.2	29.49	42.7	**-5.89**	**-8.5**
7	Mojokerto Regency	899.4	48.22	53.62	460.74	512.3	412.52	458.7	27.07	30.1	385.45	428.6	183.76	204.3	201.69	224.3
8	Jombang Regency	1102.8	58.37	52.93	324.47	294.2	266.10	241.3	58.42	53.0	207.68	188.3	26.18	23.7	181.50	164.6
9	Kediri City	66.6	23.98	359.94	131.95	1980.2	107.96	1620.2	104.06	1561.6	3.91	58.6	10.53	158.1	**-6.63**	**-99.5**
10	Mojokerto City	20.3	11.81	582.90	40.54	2000.5	28.73	1417.6	35.64	1758.8	**-6.91**	**-341.2**	1.04	51.4	**-7.96**	**-392.6**
11	**Surabaya City**	237.5	34.85	146.71	41.18	173.4	6.33	26.7	1.63	6.9	4.70	19.8	36.08	151.9	**-31.37**	**-132.1**
12	Trenggalek Regency	632.3	31.15	49.26	81.36	128.7	50.21	79.4	3.03	4.8	47.18	74.6	20.62	32.6	26.56	42.0
13	Blitar City	33.4	10.65	318.29	68.70	2054.1	58.05	1735.8	53.18	1590.1	4.87	145.7	3.44	102.8	1.44	43.0
14	Tulungagung Regency	951.9	35.51	37.30	301.06	316.3	265.55	279.0	26.78	28.1	238.77	250.8	28.40	29.8	210.36	221.0
15	Nganjuk Regency	1282.8	35.44	27.63	430.30	335.4	394.86	307.8	101.70	79.3	293.16	228.5	41.22	32.1	251.94	196.4
16	**Gresik Regency**	105.6	11.26	106.65	7.98	75.6	**-3.28**	**-31.1**	1.73	16.3	**-5.01**	**-47.4**	3.92	37.1	**-8.93**	**-84.5**
Total		11363.1	799.48	70.36	5243.03	461.4	4443.55	391.1	746.78	65.7	3696.78	325.3	869.50	76.5	2827.28	248.8

*1: Calculated using Model Area (km²)

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure C4.4.1 Distribution of Evaluated Future Groundwater Potential in Height (Medium Scenario)

C4.5 Evaluation and Additional Groundwater Development Potential for Each Scenarios

C4.5.1 Evaluation Method

Remaining groundwater potential can be calculated using the output of water balance from simulation which can be developed. However, additional groundwater development can be considered based on region-specific constraints and should be needed to investigate carefully before development. Examples of region-specific constraints are as follows: hydrogeological distribution, to ensure river discharge for maintenance, protection of springs as water source, to keep water level in specific well, setting of appropriate pumping rate not to generate land subsidence, groundwater demand as supplier for other citied / regencies, etc. Thus, additional groundwater potential can calculate using the following formula:

(Additional Groundwater Development Potential) =
(Hydrogeological Coefficient) x (Total Groundwater Potential)
- Groundwater Demand
- ∑ (Additional Groundwater Demand under the Constraints)

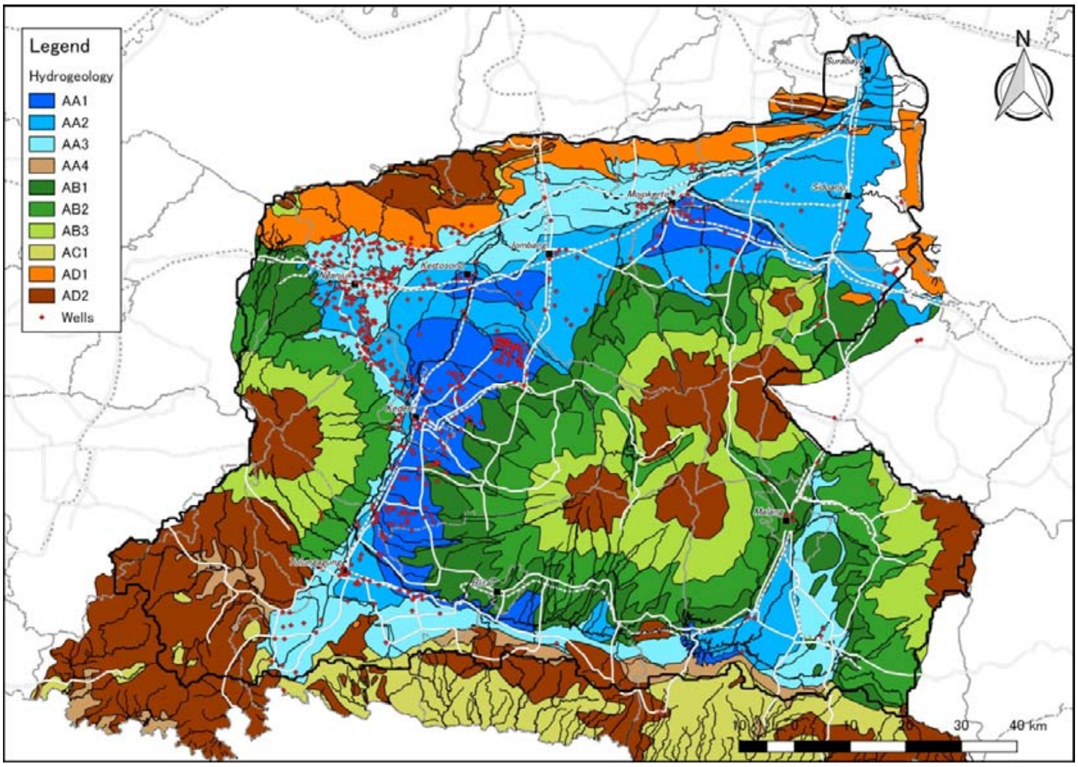
For more realistic evaluation, hydrogeological distribution, which is one of the main constraints expressed by aquifer coefficient, was taken into consideration in this Project.

Hydrogeological map of Brantas River Basin with wells distribution and hydrogeological zones is shown in Figure C4.5.1. Groundwater flow model is developed based on this hydrogeological map. The areas occupied by this hydrogeological division for each regency / city are gathered, given scores considering the aquifer capacity against the hydrogeological unit, and quantified the capacity of the aquifer for each regency / city. The ratio of each hydrogeological classification when the total area of each regency / city is 100% is shown in Table C4.5.1.

Given the capacity as aquifer potential for each hydrogeological classification, a multiplier which was defined and introduced in this Project, is shown in Table C4.5.2. This multiplier means that if AA 1, which has the highest capacity as an aquifer, occupies the entire regency or city, it is said that the total amount of remaining groundwater potential can be developed. On the other hand, if AD2 or TT occupies the entire area of the regency or city, development possibility will be zero. Evaluation of aquifer potential based on the hydrogeological classification is shown in Table C4.5.3. The coefficient for evaluation in regencies /cities (C) can be obtained by multiplying hydrological classification ratio (shown as (A) in Table C4.5.1) and multiplier, and summing each value for hydrogeological unit (shown as (B) in Table C4.5.2).

Kediri City whose coefficient of hydrogeological distribution is 0.85, followed by Mojokerto City (0.84), has widest developable area on the hydrogeological basis. Most of the city is dominated by AA1 which has high aquifer potential. On the other hand, Trenggalek Regency and Batu City are mostly dominated by low permeability hydrogeological unit and are not suitable for ground water development. Remaining groundwater development potential was modified by this coefficient.

Possibility of additional groundwater development is evaluated using standard shown in the Table C4.5.4. Threshold 100mm/year for "Modified Remaining Groundwater Potential – Additional Groundwater Demand as Water Supplier for Other Cities / Regencies" is temporary value including other constraints.



Source: ESDM(1984) and JICA Project Team 2

Figure C4.5.1 Hydrogeological Map of Brantas River Basin with wells distribution (Re-posting)

Table C4.5.1 Ratio of Hydrogeological Classification in Regency / City

No	Regency / City	Model Area (km2)	(A) Hydrogeological Classification Ratio											
			AA1	AA2	AA3	AA4	AB1	AB2	AB3	AC1	AD1	AD2	TT	Total
1	Batu City	211.8	0%	0%	0%	0%	1%	12%	31%	0%	0%	56%	0%	100%
2	Malang Regency	2,216.5	1%	6%	8%	3%	8%	19%	17%	20%	0%	20%	0%	100%
3	Malang City	109.4	0%	3%	20%	0%	69%	9%	0%	0%	0%	0%	0%	100%
4	Kediri Regency	1,521.0	35%	10%	4%	0%	0%	29%	17%	0%	0%	6%	0%	100%
5	Blitar Regency	1,281.3	7%	2%	4%	3%	19%	14%	13%	17%	0%	22%	0%	100%
6	Sidoarjo Regency	690.4	0%	68%	3%	0%	0%	0%	0%	0%	11%	0%	18%	100%
7	Mojokerto Regency	899.4	16%	23%	11%	0%	11%	12%	14%	0%	7%	8%	0%	100%
8	Jombang Regency	1,102.8	4%	27%	26%	0%	8%	8%	5%	2%	10%	10%	0%	100%
9	Kediri City	66.6	52%	21%	17%	0%	0%	10%	0%	0%	0%	0%	0%	100%
10	Mojokerto City	20.3	50%	19%	31%	0%	0%	0%	0%	0%	0%	0%	0%	100%
11	Surabaya City	237.5	0%	55%	0%	2%	0%	0%	0%	0%	12%	10%	21%	100%
12	Trenggalek Regency	632.3	0%	0%	1%	11%	0%	0%	2%	3%	0%	82%	0%	100%
13	Blitar City	33.4	1%	0%	0%	0%	86%	13%	0%	0%	0%	0%	0%	100%
14	Tulungagung Regency	951.9	4%	8%	30%	1%	0%	7%	9%	18%	0%	23%	0%	100%
15	Nganjuk Regency	1,282.8	7%	16%	23%	0%	8%	7%	7%	1%	18%	13%	0%	100%
16	Gresik Regency	105.6	0%	9%	14%	5%	0%	0%	0%	0%	66%	5%	0%	100%

Source: JICA Project Team 2

Table C4.5.2 Multiplier of Aquifer Potential for Hydrogeological Classification

Hydrological Classification	(B) Multiplier	Aquifer Feature
AA1	1.0	Extensive and highly productive aquifers
AA2	0.8	Extensive and productive aquifers
AA3	0.6	Extensive, moderately productive aquifers
AA4	0.4	Locally, moderately, productive aquifers
AB1	0.8	Extensive and highly productive aquifers
AB2	0.6	Extensive, moderately productive aquifers
AB3	0.4	Locally productive aquifers
AC1	0.6	Highly to moderate productive aquifers
AD1	0.2	Poor productive aquifers of local importance
AD2	0.0	Region without exploitable groundwater
TT	0.0	Coastal zone

Source: JICA Project Team 2

Table C4.5.3 Evaluation of Aquifer Potential based on Hydrogeological Classification

No	Regency / City	Model Area (km^2)	Aquifer Coefficient: [(A) x (B)]											
			AA1 (1.0)	AA2 (0.8)	AA3 (0.6)	AA4 (0.4)	AB1 (0.8)	AB2 (0.6)	AB3 (0.4)	AC1 (0.6)	AD1 (0.2)	AD2 (0.0)	TT (0.0)	(C) Total ∑[(A) x (B)]
1	Batu City	211.8	0.00	0.00	0.00	0.00	0.01	0.07	0.13	0.00	0.00	0.00	0.00	0.20
2	Malang Regency	2,216.5	0.01	0.05	0.05	0.01	0.06	0.11	0.07	0.12	0.00	0.00	0.00	0.47
3	Malang City	109.4	0.00	0.02	0.12	0.00	0.55	0.05	0.00	0.00	0.00	0.00	0.00	0.74
4	Kediri Regency	1,521.0	0.35	0.08	0.02	0.00	0.00	0.17	0.07	0.00	0.00	0.00	0.00	0.69
5	Blitar Regency	1,281.3	0.07	0.01	0.02	0.01	0.15	0.08	0.05	0.10	0.00	0.00	0.00	0.50
6	Sidoarjo Regency	690.4	0.00	0.55	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.59
7	Mojokerto Regency	899.4	0.16	0.18	0.06	0.00	0.09	0.07	0.05	0.00	0.01	0.00	0.00	0.63
8	Jombang Regency	1,102.8	0.04	0.22	0.16	0.00	0.06	0.05	0.02	0.01	0.02	0.00	0.00	0.58
9	Kediri City	66.6	0.52	0.17	0.10	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.85
10	Mojokerto City	20.3	0.50	0.15	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.84
11	Surabaya City	237.5	0.00	0.44	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.47
12	Trenggalek Regency	632.3	0.00	0.00	0.01	0.05	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.08
13	Blitar City	33.4	0.01	0.00	0.00	0.00	0.68	0.08	0.00	0.00	0.00	0.00	0.00	0.78
14	Tulungagung Regency	951.9	0.04	0.07	0.18	0.00	0.00	0.04	0.04	0.11	0.00	0.00	0.00	0.48
15	Nganjuk Regency	1,282.8	0.07	0.13	0.14	0.00	0.06	0.04	0.03	0.00	0.04	0.00	0.00	0.51
16	Gresik Regency	105.6	0.00	0.07	0.09	0.02	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.31

Source: JICA Project Team 2

Table C4.5.4 Evaluation Standard for Additional Groundwater Development Potential

Symbol	Additional Groundwater Development	Average Recharge – Groundwater Demand	Modified Remaining Groundwater Potential* – Additional Groundwater Demand as Water Supplier for Other Cities / Regencies
A	Possible	Plus	More than 100mm/y
B	Partially possible	Plus	Groundwater supplier to other area or less than 100mm/y
C	Impossible	Minus	Minus

*: (Hydrogeological Coefficient) x (Original Remaining Groundwater Potential)
Source: JICA Project Team 2

C4.5.2 Result of Evaluation

(1) Present Condition

Groundwater potential under the present condition with present water demand evaluated for regency/city is shown in Table C4.5.5. Groundwater demand of red colored regencies / cities is higher than their average recharge between 1991 and 2010 or modified remaining groundwater potential has negative value. It means that these regencies/cities are not recommended to develop additional groundwater.

To know groundwater potential under the present condition with water demand in 2050, another calculation has been conducted. Groundwater potential evaluated for regency/city is shown in Table C4.5.6. In addition to 5 regencies / cities, Malang city will be impossible level for developing additional groundwater.

Table C4.5.5 Groundwater Potential under the Present Condition with Present Water Demand

No	Regency / City	Model Area [km^2]	(C) Aquifer Coefficient	(D) Recharge (Rch)	(E) Total Groundwater Potential	(F) Groundwater Demand (GD)	(G) Additional GD as Donor	Rch - GD (D)-(F)	Modified Remaining GWP (C)x(E)-(F)-(G)		Evaluation
			[mm/y]	[mm/y]	[mm/y]	[mm/y]	[mm/y]	[mm/y]	[mm/y]	[10^{6}m^3/y]	
1	Batu City	211.8	0.20	1,296.26	672.3	84.5		1,211.8	51.1	10.81	B
2	Malang Regency	2216.5	0.47	779.33	478.4	91.0		688.4	133.7	296.34	A
3	Malang City	109.4	0.74	684.59	768.2	534.6		150.0	36.1	3.95	B
4	Kediri Regency	1521.0	0.69	539.95	583.1	37.6		502.3	364.7	554.65	B
5	Blitar Regency	1281.3	0.50	742.39	623.0	29.8		712.6	282.8	362.36	A
6	Sidoarjo Regency	690.4	0.59	49.03	122.5	58.6		-9.6	-	-	C
7	Mojokerto Regency	899.4	0.63	467.77	533.7	34.5	7.4	433.3	295.3	265.62	B
8	Jombang Regency	1102.8	0.58	317.90	347.5	35.8		282.1	164.8	181.79	A
9	Kediri City	66.6	0.85	343.45	1,991.3	310.1		33.3	1,382.7	92.14	A
10	Mojokerto City	20.3	0.84	256.53	2,044.5	582.9		-326.4	-	-	C
11	Surabaya City	237.5	0.47	1.12	161.3	146.7		-145.6	-	-	C
12	Trenggalek Regency	632.3	0.08	406.25	71.9	41.8		364.4	-36.1	-22.81	C
13	Blitar City	33.4	0.78	714.48	2,120.0	260.3		454.2	1,384.3	46.30	A
14	Tulungagung Regency	951.9	0.48	426.13	200.8	28.1		398.0	68.0	64.76	B
15	Nganjuk Regency	1282.8	0.51	368.79	357.3	18.2		350.6	164.6	211.11	A
16	Gresik Regency	105.6	0.31	3.64	55.6	106.6		-103.0	-	-	C

Source: JICA Project Team 2

Table C4.5.6 Groundwater Potential under the Present Condition with Future Water Demand

No	Regency / City	Model Area [km²]	(C) Aquifer Coefficient	(D) Recharge (Rch)	(E) Total Groundwater Potential	(F) Groundwater Demand (GD)	(G) Additional GD as Donor	Rch - GD (D)-(F)	Modified Remaining GWP (C)x(E)-(F)-(G)		Evaluation
			[mm/y]	[mm/y]	[mm/y]	[mm/y]	[mm/y]	[mm/y]	[mm/y]	[$10^6 m^3/y$]	
1	Batu City	211.8	0.20	1,296.26	672.7	92.4		1,203.9	43.3	9.16	B
2	Malang Regency	2216.5	0.47	779.33	480.8	109.1		670.3	116.7	258.74	A
3	Malang City	109.4	0.74	684.59	766.1	633.2		51.4	-64.1	-7.02	C
4	Kediri Regency	1521.0	0.69	539.95	586.8	51.5	0.7	488.5	352.6	536.32	B
5	Blitar Regency	1281.3	0.50	742.39	625.3	38.1		704.3	275.7	353.23	A
6	Sidoarjo Regency	690.4	0.59	49.03	123.0	58.6		-9.6	-	-	C
7	Mojokerto Regency	899.4	0.63	467.77	540.4	53.6	7.4	414.2	280.4	252.19	B
8	Jombang Regency	1102.8	0.58	317.90	348.9	52.9		265.0	148.4	163.70	A
9	Kediri City	66.6	0.85	343.45	2,001.5	359.9		-16.5	-	-	C
10	Mojokerto City	20.3	0.84	256.53	2,072.2	582.9		-326.4	-	-	C
11	Surabaya City	237.5	0.47	1.12	160.5	146.7		-145.6	-	-	C
12	Trenggalek Regency	632.3	0.08	406.25	73.1	49.3		357.0	-43.4	-	C
13	Blitar City	33.4	0.78	714.48	2,136.1	318.3		396.2	1,338.8	44.78	A
14	Tulungagung Regency	951.9	0.48	426.13	202.8	37.3		388.8	59.8	56.89	B
15	Nganjuk Regency	1282.8	0.51	368.79	358.4	27.6		341.2	155.7	199.69	A
16	Gresik Regency	105.6	0.31	3.64	55.7	106.6		-103.0	-	-	C

Source: JICA Project Team 2

(2) Future Condition for Each 3 Scenarios

Three scenarios of groundwater potential in 2050 are estimated under climate change condition. Three scenarios under climate change condition were selected by Team 1. Three scenarios are Medium scenario, low scenario and high scenario. High scenario is the most severe hydrological situation during dry season in three scenarios. Medium scenario is median scenario from 9 GCMs (Global Climate Models). And low scenario is a moderate scenario in three scenarios.

Remaining groundwater potential can be read as groundwater potential which can be developed. Detail evaluation of additional groundwater development considering hydrogeological condition is shown in Table C4.5.7.

Table C4.5.7 Detail Evaluation of Additional Groundwater Development for Future 3 Scenarios

Medium Scenario

No	Regency / City	Model Area [km^2]	(C) Hydro-geological Coefficient	(D) Recharge (Rch) [mm/y]	(E) Total Groundwater Potential [mm/y]	(F) Groundwater Demand (GD) [mm/y]	(G) Additional GD as Supplier [mm/y]	Rch - GD (D)-(F) [mm/y]	Modified Remaining GWP - Additional Demand (C)x(E)-(F)-(G) [mm/y]	[10^{6}m^3/y]	Evaluation
1	Batu City	211.8	0.20	1,189.97	768.6	92.4		1,097.6	62.6	13.26	B
2	Malang Regency	2,216.5	0.47	607.33	590.9	109.1	3.6	498.3	164.8	365.35	B
3	Malang City	109.4	0.74	560.79	880.0	633.2		-72.4	-	-	C
4	Kediri Regency	1,521.0	0.69	354.34	557.7	51.5	6.1	302.8	327.1	497.54	B
5	Blitar Regency	1,281.3	0.50	552.59	658.7	38.1		514.5	292.4	374.70	A
6	Sidoarjo Regency	690.4	0.59	37.04	135.7	58.6		-21.6	-	-	C
7	Mojokerto Regency	899.4	0.63	304.76	512.3	53.6	10.1	251.1	259.9	233.74	B
8	Jombang Regency	1,102.8	0.58	204.36	294.2	52.9		151.4	116.9	128.92	A
9	Kediri City	66.6	0.85	219.67	1,980.2	359.9		-140.3	-	-	C
10	Mojokerto City	20.3	0.84	133.58	2,000.5	582.9		-449.3	-	-	C
11	Surabaya City	237.5	0.47	16.37	173.4	146.7		-130.3	-	-	C
12	Trenggalek Regency	632.3	0.08	211.24	128.7	49.3		162.0	-39.0	-24.64	C
13	Blitar City	33.4	0.78	456.84	2,054.1	318.3		138.5	1,275.2	42.65	A
14	Tulungagung Regency	951.9	0.48	270.54	316.3	37.3		233.2	114.1	108.59	A
15	Nganjuk Regency	1,282.8	0.51	243.92	335.4	27.6		216.3	143.9	184.64	A
16	Gresik Regency	105.6	0.31	18.07	75.6	106.6		-88.6	-	-	C

High Scenario

No	Regency / City	Model Area [km^2]	(C) Hydro-geological Coefficient	(D) Recharge (Rch) [mm/y]	(E) Total Groundwater Potential [mm/y]	(F) Groundwater Demand (GD) [mm/y]	(G) Additional GD as Supplier [mm/y]	Rch - GD (D)-(F) [mm/y]	Modified Remaining GWP - Additional Demand (C)x(E)-(F)-(G) [mm/y]	[10^{6}m^3/y]	Evaluation
1	Batu City	211.8	0.20	1,154.05	689.0	92.4		1,061.7	46.5	9.86	B
2	Malang Regency	2,216.5	0.47	549.25	477.0	109.1	6.9	440.2	108.0	239.44	B
3	Malang City	109.4	0.74	493.33	791.1	633.2		-139.9	-	-	C
4	Kediri Regency	1,521.0	0.69	354.34	525.7	51.5	6.1	302.8	305.0	463.94	B
5	Blitar Regency	1,281.3	0.50	424.07	515.4	38.1	1.3	386.0	219.2	280.90	B
6	Sidoarjo Regency	690.4	0.59	37.04	128.1	58.6		-21.6	-	-	C
7	Mojokerto Regency	899.4	0.63	304.76	481.8	53.6	10.1	251.1	240.6	216.40	B
8	Jombang Regency	1,102.8	0.58	204.36	275.3	52.9		151.4	106.0	116.89	A
9	Kediri City	66.6	0.85	219.67	1,963.5	359.9		-140.3	-	-	C
10	Mojokerto City	20.3	0.84	133.58	1,988.2	582.9		-449.3	-	-	C
11	Surabaya City	237.5	0.47	16.37	169.8	146.7		-130.3	-	-	C
12	Trenggalek Regency	632.3	0.08	199.84	68.3	49.3		150.6	-43.8	-27.69	C
13	Blitar City	33.4	0.78	269.16	1,949.1	318.3		-49.1	-	-	C
14	Tulungagung Regency	951.9	0.48	266.37	236.2	37.3		229.1	75.8	72.13	B
15	Nganjuk Regency	1,282.8	0.51	243.92	319.2	27.6		216.3	135.6	173.97	A
16	Gresik Regency	105.6	0.31	17.42	71.8	106.6		-89.2	-	-	C

Law Scenario

No	Regency / City	Model Area [km^2]	(C) Hydro-geological Coefficient	(D) Recharge (Rch) [mm/y]	(E) Total Groundwater Potential [mm/y]	(F) Groundwater Demand (GD) [mm/y]	(G) Additional GD as Supplier [mm/y]	Rch - GD (D)-(F) [mm/y]	Modified Remaining GWP - Additional Demand (C)x(E)-(F)-(G) [mm/y]	[10^{6}m^3/y]	Evaluation
1	Batu City	211.8	0.20	1,312.52	731.5	92.4		1,220.2	55.1	11.67	B
2	Malang Regency	2,216.5	0.47	667.81	537.7	109.1	1.4	558.7	142.0	314.70	B
3	Malang City	109.4	0.74	604.10	822.4	633.2		-29.1	-	-	C
4	Kediri Regency	1,521.0	0.69	459.05	584.1	51.5	2.1	407.5	349.3	531.27	B
5	Blitar Regency	1,281.3	0.50	570.67	582.1	38.1		532.6	254.0	325.45	A
6	Sidoarjo Regency	690.4	0.59	55.92	153.2	58.6		-2.7	-	-	C
7	Mojokerto Regency	899.4	0.63	437.50	541.9	53.6	7.5	383.9	281.3	252.95	B
8	Jombang Regency	1,102.8	0.58	299.64	346.4	52.9		246.7	147.0	162.12	A
9	Kediri City	66.6	0.85	311.04	2,017.0	359.9		-48.9	-	-	C
10	Mojokerto City	20.3	0.84	250.72	2,061.3	582.9		-332.2	-	-	C
11	Surabaya City	237.5	0.47	17.78	178.5	146.7		-128.9	-	-	C
12	Trenggalek Regency	632.3	0.08	285.14	90.8	49.3		235.9	-42.0	-26.56	C
13	Blitar City	33.4	0.78	503.98	2,001.6	318.3		185.7	1,234.4	41.29	A
14	Tulungagung Regency	951.9	0.48	351.57	245.6	37.3		314.3	80.3	76.42	B
15	Nganjuk Regency	1,282.8	0.51	343.50	368.3	27.6		315.9	160.7	206.18	A
16	Gresik Regency	105.6	0.31	29.50	91.3	106.6		-77.2	-	-	C

Source: JICA Project Team 2

Final evaluation and additional groundwater development potential for each 3 scenarios compering with present condition are summarized in Table C4.5.8. Although average groundwater recharge of Medium scenario is smaller than that of Low scenario, the additional groundwater development potential of Medium scenario in some regencies / cities is larger than those of Low scenario. The same tendency can be confirmed between High scenario and Medium scenario. Thus, the scenario analysis includes the uncertainty that the High scenario is not necessarily the minimum groundwater potential evaluation.

Low scenario shows the same evaluation result as Medium scenario in Table C4.5.8, which is the most typical scenario. On the other hands, High scenario shows different evaluation result for Blitar regency and Blitar city. The reason why the evaluation of Blitar regency and Blitar city have changed is that groundwater demand of Blitar city will exceed recharge in High scenario, resulting in Blitar regency being responsible for the shortage of the demand as groundwater outflow via aquifer.

Table C4.5.8 Final Evaluation and Additional Groundwater Development Potential for Each 3 Scenarios Compering with Present Condition

No.	Regency / City	Model Area (km^2)	Hydro-geological Coefficient	Evaluation					Additional Groundwater Development Potential (10^6 m^3/y)				
				Present Climate; Present Demand	Present Climate; 2050 Demand	Medium; 2050 Demand	High; 2050 Demand	Low; 2050 Demand	Present Climate; Present Demand	Present Climate; 2050 Demand	Medium; 2050 Demand	High; 2050 Demand	Low; 2050 Demand
1	Batu City	212	0.20	B	B	B	B	B	10.81	9.16	13.26	9.86	11.67
2	Malang Regency	2,217	0.47	A	A	B	B	B	296.34	258.74	365.35	239.44	314.70
3	Malang City	109	0.74	B	C	C	C	C	3.95	-	–	–	–
4	Kediri Regency	1,521	0.69	A	B	B	B	B	554.65	536.32	497.54	463.94	531.27
5	Blitar Regency	1,281	0.50	A	A	A	B	A	362.36	353.23	374.70	280.90	325.45
6	Sidoarjo Regency	690	0.59	C	C	C	C	C	-	-	–	–	–
7	Mojokerto Regency	899	0.63	B	B	B	B	B	265.62	252.19	233.74	216.40	252.95
8	Jombang Regency	1,103	0.58	A	A	A	A	A	181.79	163.70	128.92	116.89	162.12
9	Kediri City	67	0.85	A	C	C	C	C	92.14	-	–	–	–
10	Mojokerto City	20	0.84	C	C	C	C	C	-	-	–	–	–
11	Surabaya City	238	0.47	C	C	C	C	C	-	-	–	–	–
12	Trenggalek Regency	632	0.08	C	C	C	C	C	-	-	–	–	–
13	Blitar City	33	0.78	A	A	A	C	A	46.30	44.78	42.65	–	41.29
14	Tulungagung Regency	952	0.48	B	B	A	B	B	64.76	56.89	108.59	72.13	76.42
15	Nganjuk Regency	1,283	0.51	A	A	A	A	A	211.11	199.69	184.64	173.97	206.18
16	Gresik Regency	106	0.31	C	C	C	C	C	-	-	–	–	–
	Total	11,363							2089.83	1874.70	1949.39	1573.54	1922.06

Source: JICA Project Team 2

Based on the evaluation result, points to be noted in groundwater development under the future climate for each regency / city in this Project are shown in Table C4.5.9.

Conclusion and remarks of this groundwater simulation Project is as follows:

- Malang City, Sidoarjo Regency, Kediri City, Mojokerto City, Surabaya City, Trenggalek Regency and Gresik Regency are difficult to develop additional groundwater resource under the climate change environment because of a large amount of groundwater demand and the region-specific constraints.
- Batu City, Malang Regency, Kediri Regency and Mojokerto Regency are able to develop some additional groundwater resource under the region-specific constraints.
- Blitar Regency, Jombang Regency, Blitar City, Tulungagung Regency, and Nganjuk Regency have enough potential to be able to develop additional groundwater resource under the region-specific constraints.
- It is strongly recommended to conduct sufficient investigation and analysis before additional groundwater development in order to manage groundwater resource in the Brantas River Basin properly and integrally and make effective use of valuable groundwater resource.

Groundwater model has been calibrated only under the 26 calibration targets and hydrogeological information has been very much limited. Therefore, evaluation of groundwater potential using this model is including a lot of uncertainty. To improve the accuracy of calculation, it is important to collect further information of hydrogeology and groundwater data including continuous groundwater level observation.

Table C4.5.9 Points to be Noted in Groundwater Development

No.	Regency / City	Note
1	Batu City	Brantas River headwaters area. Groundwater development area is limited to the plains in valleys.
2	Malang Regency	Supply the groundwater to Malang City through aquifer and river runoff. Groundwater development area is limited to the plains in valley.
3	Malang City	Depend on the groundwater flow from the Malang Regency.
4	Kediri Regency	Supply the groundwater for Kediri City through aquifer and river runoff. Productive aquifer is distributed. A number of wells already exist. There are many springs in the mountainous region.
5	Blitar Regency	Groundwater demand is small.
6	Sidoarjo Regency	Groundwater development along coastal areas is a possibility that the salt water intrusion occurs.
7	Mojokerto Regency	Supply the groundwater for Mojokerto City through groundwater flow and river runoff.
8	Jombang Regency	Productive aquifer is distributed. A number of well already exist.
9	Kediri City	Depend on the groundwater flow from the Kediri Regency.
10	Mojokerto City	Depend on the groundwater inflow from the Mojokerto Regency.
11	Surabaya City	Small amount of groundwater recharge and low probability of groundwater inflow from surrounding municipalities. Risk for saltwater intrusion is relatively high.
12	Trenggalek Regency	Low groundwater potential due to volcanic rock distribution area. Possible development area is limited to the plain in valley.
13	Blitar City	Large amounts of groundwater inflow from Blitar Regency.
14	Tulungagung Regency	Aquifer is developed and a lot of wells exist.
15	Nganjuk Regency	Productive aquifer is distributed. A number of well already exist.
16	Gresik Regency	Small amount of groundwater recharge and small extraction of groundwater inflow from surrounding municipalities.

Source: JICA Project Team 2

C4.6 Groundwater Potential under the Additional Groundwater Demand

C4.6.1 Additional Groundwater Demand

It was confirmed using groundwater flow model whether the additional water demand shown in Table C4.6.1 can be covered by groundwater as alternative water source of surface water with a high possibility of shortage in the future. Medium Scenario was used for examining this additional groundwater demand but cities / regencies whose evaluation C for the Medium Scenario in Table C4.5.8 was excluded in this study. The total additional water demand is 1.23 m^3/s, which is 25.83 m^3/s when added with the water demand in 2050.

Since additional water demand is difficult to cover with existing wells, it is supposed that new wells will be set up at suitable location. Therefore, groundwater simulation was carried out by adding appropriate new wells at appropriate positions in consideration hydrogeological structure in model as well.

Table C4.6.1 Additional Groundwater Demand as Alternative Water Source for Surface Water

City / Regency	2050 Water Demand							Revised 2050 Water Demand				
	Domestic and Industrial Water Demand					Irrigation Water Demand	Total	Additional Domestic and Industrial		Domestic and Industrial Total	Total (Domestic + Industrial + Irrigation)	
	PDAM		Non-PDAM		Domestic and Industrial Total							
	Domestic + Non-Domestic	Industrial	Domestic + Non-Domestic	Industrial								
	m3/s								10^6 m^3/y	m^3/s		10^6 m^3/y
1.Batu C.	0.15	0.32	0.15	0.00	0.62	0.00	0.62	0.18	5.68	0.80	0.80	25.23
2.Malang R.	1.06	3.93	1.48	1.20	7.67	0.00	7.67	0.48	15.14	8.15	8.15	257.02
3.Malang C.	1.69	0.21	0.30	0.00	2.20	0.00	2.20	0.00	0.00	2.20	2.20	69.38
4.Kediri R.	0.01	0.23	1.50	0.38	2.12	0.36	2.48	0.06	1.89	2.18	2.54	80.10
5.Blitar R.	0.13	0.27	1.15	0.00	1.55	0.00	1.55	0.01	0.32	1.56	1.56	49.20
6.Sidoarjo R.	0.00	0.00	1.27	0.01	1.28	0.00	1.28	0.00	0.00	1.28	1.28	40.37
7.Mojokerto R.	0.18	0.06	1.29	0.00	1.53	0.00	1.53	0.00	0.00	1.53	1.53	48.25
8.Jombang R.	0.30	0.00	1.04	0.18	1.52	0.33	1.85	0.00	0.00	1.52	1.85	58.34
9.Kediri C.	0.17	0.37	0.22	0.00	0.76	0.00	0.76	0.00	0.00	0.76	0.76	23.97
10.Mojokerto C.	0.00	0.00	0.07	0.30	0.37	0.00	0.37	0.00	0.00	0.37	0.37	11.67
11.Surabaya C.	0.00	0.00	1.11	0.00	1.11	0.00	1.11	0.00	0.00	1.11	1.11	35.00
12.Trenggalek R.	0.07	0.20	0.72	0.00	0.99	0.00	0.99	0.00	0.00	0.99	0.99	31.22
13.Blitar C.	0.08	0.18	0.08	0.00	0.34	0.00	0.34	0.49	15.45	0.83	0.83	26.17
14.Tulungagung R.	0.04	0.03	1.05	0.00	1.12	0.00	1.12	0.01	0.32	1.13	1.13	35.64
15.Nganjuk R.	0.00	0.00	1.06	0.00	1.06	0.06	1.12	0.00	0.00	1.06	1.12	35.32
16. Gresik R.	0.00	0.00	0.36	0.00	0.36	0.00	0.36	0.00	0.00	0.36	0.36	11.35
Total	3.88	5.80	12.85	2.07	24.60	0.75	25.35	1.23	38.79	25.83	26.58	838.23

Source: JICA Project Team 2

C4.6.2 Evaluation and Groundwater Potential under the Additional Groundwater Demand

Groundwater potential evaluation under the additional groundwater demand is shown in Table C4.6.2. Additional groundwater demand was able to be covered by all the municipalities except Blitar. In Blitar, the future total groundwater demand, which includes additional groundwater demand was exceeded groundwater recharge. To avoid this, it is decided to withdraw the amount of groundwater demand exceeding the recharge from the wells in Blitar Regency in the model. The results with this modification are shown in Table C4.6.3.

Evaluation of groundwater potential under the additional groundwater demand is shown in Table C4.6.4. Groundwater potential is calculated in the balance of groundwater flow field and it is also affected by the position of the wells incorporating additional groundwater demand. Therefore, the changes in the groundwater potential are recognized throughout the basin by additional groundwater demand assigned in the model. Although the additional groundwater demand was $1.23 m^3/s$ ($38.79 \times 10^6 m^3/y$), the decreases in groundwater potential under the additional demand are exceed the value: $69.82 \times 10^6 m^3/y$ and $74.19 \times 10^6 m^3/y$. The main reason is that by considering the additional groundwater demand, the groundwater demand in Blitar City exceeded the groundwater recharge under the future condition in 2050, and it became level C which it is better to avoid further groundwater development.

Table C4.6.2 Groundwater Potential under the Additional Groundwater Demand

No	Regency / City	Model Area [km^2]	(C) Hydro-geological Coefficient	(D) Recharge (Rch)	(E) Total Groundwater Potential	(F) Groundwater Demand (GD)	(G) Additional GD as Supplier	Rch - GD (D)-(F)	Modified Remaining GWP (C)x(E)-(F)-(G)		Evaluation
				[mm/y]	[mm/y]	[mm/y]	[mm/y]	[mm/y]	[mm/y]	[10^{6}m^3/y]	
1	Batu City	211.8	0.20	1,189.97	792.4	119.2		1,070.8	40.6	8.60	B
2	Malang Regency	2216.5	0.47	607.33	592.0	115.9	3.6	491.4	158.5	351.35	B
3	Malang City	109.4	0.74	560.79	876.9	633.2		-72.4	-	-	C
4	Kediri Regency	1521.0	0.69	354.34	558.6	52.8	6.1	301.5	326.4	496.50	B
5	Blitar Regency	1281.3	0.50	552.59	656.8	38.4	8.4	514.2	282.8	362.31	B
6	Sidoarjo Regency	690.4	0.59	37.04	135.9	58.6		-21.6	-	-	C
7	Mojokerto Regency	899.4	0.63	304.76	520.9	53.6	10.1	251.1	265.3	238.62	B
8	Jombang Regency	1102.8	0.58	204.36	294.5	53.0		151.4	117.0	129.03	A
9	Kediri City	66.6	0.85	219.67	1,979.7	359.9		-140.3	-	-	C
10	Mojokerto City	20.3	0.84	133.58	2,001.1	582.9		-449.3	-	-	C
11	Surabaya City	237.5	0.47	16.37	173.4	146.7		-130.3	-	-	C
12	Trenggalek Regency	632.3	0.08	211.24	129.3	49.3		162.0	-38.9	-24.61	C
13	Blitar City	33.4	0.78	456.84	2,248.5	780.3		-323.5	-	-	C
14	Tulungagung Regency	951.9	0.48	270.54	316.5	37.6		232.9	113.9	108.39	A
15	Nganjuk Regency	1282.8	0.51	243.92	335.6	27.6		216.3	144.0	184.77	A
16	Gresik Regency	105.6	0.31	18.07	75.6	106.6		-88.6	-	-	C

Source: JICA Project Team 2

Table C4.6.3 Groundwater Potential under the Modified Additional Groundwater Demand

No	Regency / City	Model Area [km^2]	(C) Hydro-geological Coefficient	(D) Recharge (Rch)	(E) Total Groundwater Potential	(F) Groundwater Demand (GD)	(G) Additional GD as Supplier	Rch - GD (D)-(F)	Modified Remaining GWP (C)x(E)-(F)-(G)		Evaluation
				[mm/y]	[mm/y]	[mm/y]	[mm/y]	[mm/y]	[mm/y]	[10^{6}m^3/y]	
1	Batu City	211.8	0.20	1,189.97	795.5	119.2		1,070.8	41.2	8.73	B
2	Malang Regency	2216.5	0.47	607.33	591.7	115.9	3.6	491.4	158.4	351.09	B
3	Malang City	109.4	0.74	560.79	877.0	633.2		-72.4	-	-	C
4	Kediri Regency	1521.0	0.69	354.34	557.7	52.8	6.1	301.5	325.8	495.54	B
5	Blitar Regency	1281.3	0.50	552.59	660.8	46.8		505.8	284.8	364.89	A
6	Sidoarjo Regency	690.4	0.59	37.04	135.7	58.6		-21.6	-	-	C
7	Mojokerto Regency	899.4	0.63	304.76	511.8	53.6	10.1	251.1	259.5	233.43	B
8	Jombang Regency	1102.8	0.58	204.36	294.0	53.0		151.4	116.7	128.72	A
9	Kediri City	66.6	0.85	219.67	1,980.2	359.9		-140.3	-	-	C
10	Mojokerto City	20.3	0.84	133.58	2,000.4	582.9		-449.3	-	-	C
11	Surabaya City	237.5	0.47	16.37	173.4	146.7		-130.3	-	-	C
12	Trenggalek Regency	632.3	0.08	211.24	128.7	49.3		162.0	-39.0	-24.64	C
13	Blitar City	33.4	0.78	456.84	2,105.1	456.8		0.0	-	-	C
14	Tulungagung Regency	951.9	0.48	270.54	316.0	37.6		232.9	113.6	108.17	A
15	Nganjuk Regency	1282.8	0.51	243.92	335.3	27.6		216.3	143.9	184.63	A
16	Gresik Regency	105.6	0.31	18.07	75.6	106.6		-88.6	-	-	C

Source: JICA Project Team 2

Table C4.6.4 Groundwater Development Potential Evaluation for Additional Groundwater Demand

No.	Regency / City	Model Area (km^2)	Hydro-geological Coefficient	Evaluation			Additional Groundwater Development Potential (10^6 m^3/y)		
				Medium; 2050 Demand	Medium; 2050 Demand+ Additional Demand	Medium; Revised 2050 Demand+ Revised Additional Demand	Medium; 2050 Demand	Medium; 2050 Demand+ Additional Demand	Medium; Revised 2050 Demand+ Revised Additional Demand
1	Batu City	212	0.20	B	B	B	13.26	8.60	8.73
2	Malang Regency	2,217	0.47	B	B	B	365.35	351.35	351.09
3	Malang City	109	0.74	C	C	C	–	–	–
4	Kediri Regency	1,521	0.69	B	B	B	497.54	496.50	495.54
5	Blitar Regency	1,281	0.50	A	B	A	374.70	362.31	364.89
6	Sidoarjo Regency	690	0.59	C	C	C	–	–	–
7	Mojokerto Regency	899	0.63	B	B	B	233.74	238.62	233.43
8	Jombang Regency	1,103	0.58	A	A	A	128.92	129.03	128.72
9	Kediri City	67	0.85	C	C	C	–	–	–
10	Mojokerto City	20	0.84	C	C	C	–	–	–
11	Surabaya City	238	0.47	C	C	C	–	–	–
12	Trenggalek Regency	632	0.08	C	C	C	–	–	–
13	Blitar City	33	0.78	A	C	C	42.65	-	-
14	Tulungagung Regency	952	0.48	A	A	A	108.59	108.39	108.17
15	Nganjuk Regency	1,283	0.51	A	A	A	184.64	184.77	184.63
16	Gresik Regency	106	0.31	C	C	C	–	–	–
Total		11,363					1,949.39	1,879.57	1,875.20

Source: JICA Project Team 2

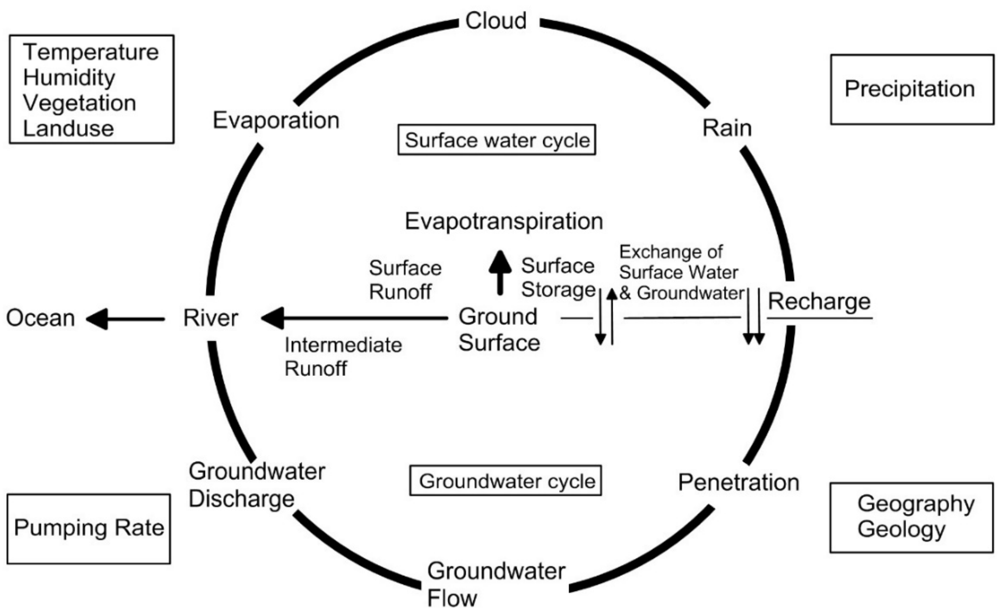
CHAPTER C5 GROUNDWATER MANAGEMENT FOR DROUGHT IN BRANTAS RIVER BASIN

C5.1 Sustainable Groundwater Cycle

A conceptual diagram of water cycle and its regulatory factors is shown in Figure C5.1.1. Groundwater is one of the components constituting the water cycle of the earth. Groundwater flowing through a recharge area - flow area - discharge area path forms a regional water circulatory system from shallow unconfined groundwater to deep confined groundwater. Adaptation measures for groundwater resources under the future climate change are nothing but the measures to keep this groundwater cycle sound and sustainable.

Although the individual components are constantly changing in the groundwater cycle, it can be considered that the dynamic equilibrium state of the cycle is maintained. When some changes occur in the components, the cycle shifts to the new dynamic equilibrium state by the natural regulating function. However, if the change exceeds the capacity of the function, e.g. sudden and significant changes like climate change, the dynamic equilibrium state of the cycle may collapse, and the groundwater resources may eventually fall into critical situation.

A sustainable water cycle is a state of water cycle in which the function of water for human activities and environmental preservation are properly maintained, and it includes not only the physical aspect but also the chemical / ecological and cultural aspects of the water cycle.



Source: Round-table conference on future groundwater use (2007); retouched

Figure C5.1.1 Conceptual Diagram of Water Cycle and its Regulatory Factors

The process of restoration in groundwater resources from the viewpoint of the water cycle is shown in Table C5.1.1. First, the causes of groundwater problems such as well drying-up, land subsidence, salt water intrusion, disappearance of spring water, decrease in spring water volume, and groundwater pollution need to be removed and the use of groundwater shall be optimized. Next, groundwater cycle improvement, that is, strengthening the function of the groundwater cycle, improvement of groundwater quality, and conservation of ecosystems shall be implemented. Finally, the groundwater cycle is to be maintained through sustainable conservation activities on a local basis.

Table C5.1.1 Process for Restoration in Groundwater Resource

Step	Objective	Measures for Restoration
1	Resolution of groundwater problems	Prohibition of excessive pumping extraction (Optimization of groundwater use)
2	Improvement of groundwater circulation	Enhancement of groundwater cycle system (Recharge area - Flow area - Discharge area), Water quality improvement / ecosystem conservation
3	Conservation of groundwater circulation	Sustainable conservation activities on a local basis (residents, municipalities, etc.)

Source: JICA Project Team 2

In the Brantas River basin, there might be a high possibility that the groundwater problems mentioned above are progressing quietly along with economic development especially in urban areas. However, the actual conditions of these groundwater problems are not grasped accurately now. If the influence of the future climate change is added to the present conditions, it is obvious that the situation will become worse. The important things to do are to start implementing measures for groundwater resources as soon as possible.

C5.2 Impacts of Climate Change on Groundwater Resources

Impacts on groundwater resources due to climate change in the Brantas River basin can be divided largely into direct and indirect items.

i. Direct items

- Impacts on groundwater recharge caused by the change of amount, duration and intensity of precipitation (aspect of groundwater quantity)
- Reduction of groundwater recharge due to increase in evapotranspiration accompanying temperature rise (aspect of groundwater quantity)
- Saltwater intrusion into coastal areas and rivers, and changes in groundwater flow system caused by sea level rise (aspect of groundwater quantity and quality)

ii. Indirect items

- Impacts on groundwater recharge due to the change of covering conditions of the soil: natural vegetation and growing crops (aspect of groundwater quantity)
- Increase in dependency on groundwater due to instability of surface water resources (aspect of groundwater quantity)
- Groundwater pollution in alluvial areas caused by frequent flooding (aspect of groundwater quality)

Since the impact of drought on groundwater resources is particularly concerned in the Brantas River basin, adaptation measures of groundwater resources against droughts are described here. In groundwater resources, the components most directly and indirectly affected by droughts are groundwater recharge and pumping rates. The amount of groundwater recharge may reduce due to decrease of precipitation and increase of evapotranspiration caused by temperature rise.

To know the degree of influence by climate change on groundwater recharge, the data of present situation and future situation (Medium case) in watersheds provided by Team 1 for each of 16 municipalities are compiled and compared in Table C5.2.1. Ratios (%) of future groundwater recharge to current groundwater recharge drastically decreases as going downstream (lower altitude) under the future climate conditions, the measures for recharge in the Medium stream and downstream areas are required to maintain a sustainable groundwater cycle.

Table C5.2.1 Ratios of Future Groundwater Recharge to Current Groundwater Recharge

Area in Brantas River Basin	Ratio of Groundwater Recharge (Future in Medium case/ Present)
Most upstream (Batu Regency)	92%
Medium stream (Blitar Regency etc.)	70 to 80 %
Downstream (Mojokerto City etc.)	50 to 60 %

Source: JICA Project Team 2

C5.3 Measures for Groundwater Resources

Adaptation measures for groundwater resources are largely divided into structural and non-structural measures. The structural measures are to improve the storage capacity in an aquifer using structures or to strengthen a groundwater extraction capacity from pumping wells. Meanwhile, the non-structural measures are aiming at sustainable use of groundwater by grasping actual usage of groundwater, establishing appropriate rules of conservation and management methods through laws and regulations, and complying with them.

Actual measures considered for the Brantas River basin are shown in Table C5.3.1. However, most realistic facilities are injection wells among proposed facilities under the present situation to improve effectively.

Table C5.3.1 Actual Measures Considered for Brantas River Basin

Type of Measure	Method	Purpose and Example
Structural	Improvement of aquifer storage capacity	To strengthen a recharge capacity and promote recharging, artificial recharging into aquifers is effective; such as **injection wells, rainwater storage and infiltration facilities, and promotion of underground penetration from paddy fields, reservoirs and check dams.** The location should be decided based on the groundwater potential study and additional detailed groundwater survey.
	Strengthening groundwater extraction capacity:	To acquire an alternative water source to unstable surface water under the future climate change, **new well construction** as additional groundwater development which should be proposed based on a groundwater potential study. The location of the well should be decided as the result of additional detailed groundwater survey.
Non-structural	Survey on actual condition of groundwater use	To understand the current situation of groundwater problems and identify areas which require restriction of pumping and groundwater development regulation.
	Resolution of groundwater problems	To control pumping rates and groundwater development regulations which are carried out based on the survey results of actual usage
	Conservation of groundwater cycle	To establish laws and regulations concerning groundwater conservation and sustainable management system

Source: JICA Project Team 2

C5.4 Approximate Well Construction Cost for Additional Groundwater Demand

C5.4.1 Basic Specifications and Unit Prices

Approximate construction cost of the new well was examined for the additional groundwater demand. The basic specifications and unit prices set in the study are as shown in Table C5.4.1 and Table C5.4.2. Basic specifications and unit prices differ between mountainous areas and plains. Any specifications and unit prices are applied considering groundwater development area of each municipality.

Since basically groundwater is taken from rock formation in mountainous area, the specifications are set as follows: maximum supposed discharge is 1,000m^3/day, depth of borehole is 200m, and diameter of casing is 150mm. On the other hand, basically groundwater is pumped from sedimentary aquifer in the plains, and the capacity of aquifer should be high. Therefore, the specifications are set as follows: maximum supposed discharge is 2,000m^3/day, depth of borehole is 150m, and diameter of casing is 200mm.

Preliminary survey such as electrical sounding is usually conducted before drilling. The drilling cost per meter is different between mountainous areas and plains, and unit price of drilling in mountainous regions is more expensive than unit price of drilling in plains. After drilling, pump is installed after test pumping and water quality analysis, but the price of pump depends on pumping capacity. The estimated installation cost per well finally became the same for mountainous regions and plains in this study.

Table C5.4.1 Basic Specifications for Drilling Borehole

Zone	Maximum Supposed Discharge	Depth of Borehole	Diameter of Casing
	m^3/day	m	mm
Mountain	1000	200	150
Plain	2000	100	200

Source: JICA Project Team 2

Table C5.4.2 Unit Prices and Total Cost for Well Construction Works

(Unit: Million Rp.)

Zone	Preliminary Survey	Cost of Drilling		Test Pumping etc.	Pump Installation	Total Cost
	/ well	/ m	/ well	/ well	/ well	/ well
Mountain	36	1.8	360	120	36	552
Plain	36	3.0	300	120	96	552

Source: JICA Project Team 2

C5.4.2 Approximate Well Construction Cost

Based on the specifications, unit prices and additional groundwater demand for each municipality, installation cost of new wells was estimated. Table C5.4.3 shows approximate well construction costs for initially supposed additional groundwater demand, and Table C5.4.4 shows approximate well construction cost when allocating groundwater demand exceeding groundwater recharge in Blitar city to Blitar regency. The latter is more expensive because it requires another one new well for additional groundwater demand in Blitar city and Blitar regency. In order to cover additional groundwater demand with drilling new wells and installation of pumps, it was estimated that roughly 60 billion

Indonesian rupiah as budget would be necessary.

Table C5.4.3 Approximate Well Construction Costs for Initially Supposed Additional Groundwater Demand

City / Regency	Additional Water Demand		Zone	Specification				Cost (10^6 Rp.)						
				Maximum Supposed Discharge	No. of BH	Depth of BH	Diameter of Casing	Preliminary Survey	Cost of Drilling		Test Pumping etc.	Pump Installation	Total Cost	
	m^3/s	m^3/day		m^3/day	-	m	mm	/ well	/ m	/ well	/ well	/ well	/ well	Total
1. Batu C.	0.18	15,552	Mountain	1000	16	200	150	36	1.8	360	120	36	552	8,832
2. Malang R.	0.48	41,472	Mountain	1000	42	200	150	36	1.8	360	120	36	552	23,184
3. Malang C.	0.00	0	Mountain	-	-	-	-	-	-	-	-	-	-	-
4. Kediri R.	0.06	5,184	Plain	2000	3	100	200	36	3.0	300	120	96	552	1,656
5. Blitar R.	0.01	864	Mountain	1000	1	200	150	36	1.8	360	120	36	552	552
6. Sidoarjo R.	0.00	0	Plain	-	-	-	-	-	-	-	-	-	-	-
7. Mojokerto R.	0.00	0	Plain	-	-	-	-	-	-	-	-	-	-	-
8. Jombang R.	0.00	0	Plain	-	-	-	-	-	-	-	-	-	-	-
9. Kediri C.	0.00	0	Plain	-	-	-	-	-	-	-	-	-	-	-
10. Mojokerto C.	0.00	0	Plain	-	-	-	-	-	-	-	-	-	-	-
11. Surabaya C.	0.00	0	Plain	-	-	-	-	-	-	-	-	-	-	-
12. Trenggalek R.	0.00	0	Mountain	-	-	-	-	-	-	-	-	-	-	-
13. Blitar C.	0.49	42,336	Mountain	1000	42	200	150	36	1.8	360	120	36	552	23,184
14. Tulungagung R.	0.01	864	Mountain	1000	1	200	150	36	1.8	360	120	36	552	552
15. Nganjuk R.	0.00	0	Plain	-	-	-	-	-	-	-	-	-	-	-
16. Gresik R.	0.00	0	Plain	-	-	-	-	-	-	-	-	-	-	-
Total	**1.23**	**106,272**												**57,960**

Source: JICA Project Team 2

Table C5.4.4 Approximate Well Construction Cost When Allocating Groundwater Demand Exceeding Groundwater Recharge in Blitar City to Blitar Regency

City / Regency	Additional Water Demand		Zone	Specification				Cost (10^6 Rp.)						
				Maximum Supposed Discharge	No. of BH	Depth of BH	Diameter of Casing	Preliminary Survey	Cost of Drilling		Test Pumping etc.	Pump Installation	Total Cost	
	m^3/s	m^3/day		m^3/day	-	m	mm	/ well	/ m	/ well	/ well	/ well	/ well	Total
1. Batu C.	0.18	15,552	Mountain	1000	16	200	150	36	1.8	360	120	36	552	8,832
2. Malang R.	0.48	41,472	Mountain	1000	42	200	150	36	1.8	360	120	36	552	23,184
3. Malang C.	0.00	0	Mountain	-	-	-	-	-	-	-	-	-	-	-
4. Kediri R.	0.06	5,184	Plain	2000	3	100	200	36	3.0	300	120	96	552	1,656
5. Blitar R.	0.35	30,505	Mountain	1000	31	200	150	36	1.8	360	120	36	552	17,112
6. Sidoarjo R.	0.00	0	Plain	-	-	-	-	-	-	-	-	-	-	-
7. Mojokerto R.	0.00	0	Plain	-	-	-	-	-	-	-	-	-	-	-
8. Jombang R.	0.00	0	Plain	-	-	-	-	-	-	-	-	-	-	-
9. Kediri C.	0.00	0	Plain	-	-	-	-	-	-	-	-	-	-	-
10. Mojokerto C.	0.00	0	Plain	-	-	-	-	-	-	-	-	-	-	-
11. Surabaya C.	0.00	0	Plain	-	-	-	-	-	-	-	-	-	-	-
12. Trenggalek R.	0.00	0	Mountain	-	-	-	-	-	-	-	-	-	-	-
13. Blitar C.	0.15	12,695	Mountain	1000	13	200	150	36	1.8	360	120	36	552	7,176
14. Tulungagung R.	0.01	864	Mountain	1000	1	200	150	36	1.8	360	120	36	552	552
15. Nganjuk R.	0.00	0	Plain	-	-	-	-	-	-	-	-	-	-	-
16. Gresik R.	0.00	0	Plain	-	-	-	-	-	-	-	-	-	-	-
Total	**1.23**	**106,272**												**58,512**

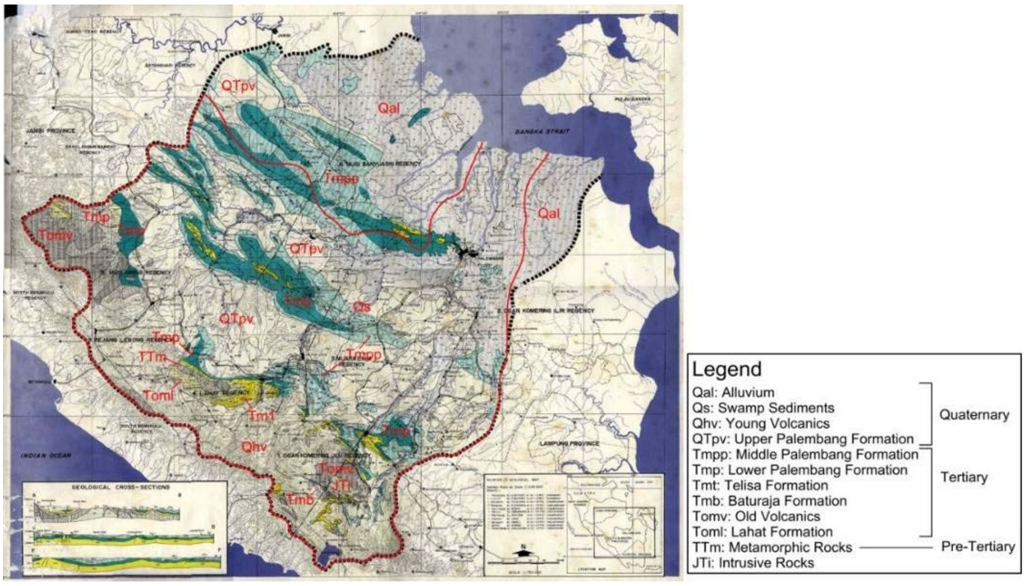
Source: JICA Project Team 2

PART 2 MUSI RIVER BASIN

CHAPTER C6 GROUNDWATER CONDITION IN MUSI RIVER BASIN

C6.1 Geology

A geological map of the Musi River basin is shown in Figure C6.1.1. The oldest geological formations of which distribution has been identified in the Musi River basin are pre-tertiary clastic limestone and plutonic rocks, which outcrop only in small portions of the mountains. These formations are covered by tertiary sediments and volcanic rocks with a thickness of up to about 6,000m. The tertiary formations, Lahat Formation (Toml), Old Volcanic (Tomv), Telisa Formation (Tmt), Baturaja Limestone (Tmb) and Lower-Medium Palembang Formation (Tmp-Tmpp) are lying in this order. Quaternary volcanic rocks, sediment layers consisting of tephras, marsh sediment layer, and alluvium are distributed on the top layer. The quaternary layers are composed of Upper Palembang Formation (QTpv), Young Volcanics (Qhv), Swamp Sediments (Qs), and Alluvial (Qal). As mentioned above, the pre-tertiary and tertiary formations outcrop in several belts with northwest-southeast strike, between which spaces are filled by the quaternary layers. In estimating groundwater potential of the Musi River basin, it is assumed that these quaternary layers are functioning as productive aquifers.



Source: Musi River Basin Study, PU, 1989

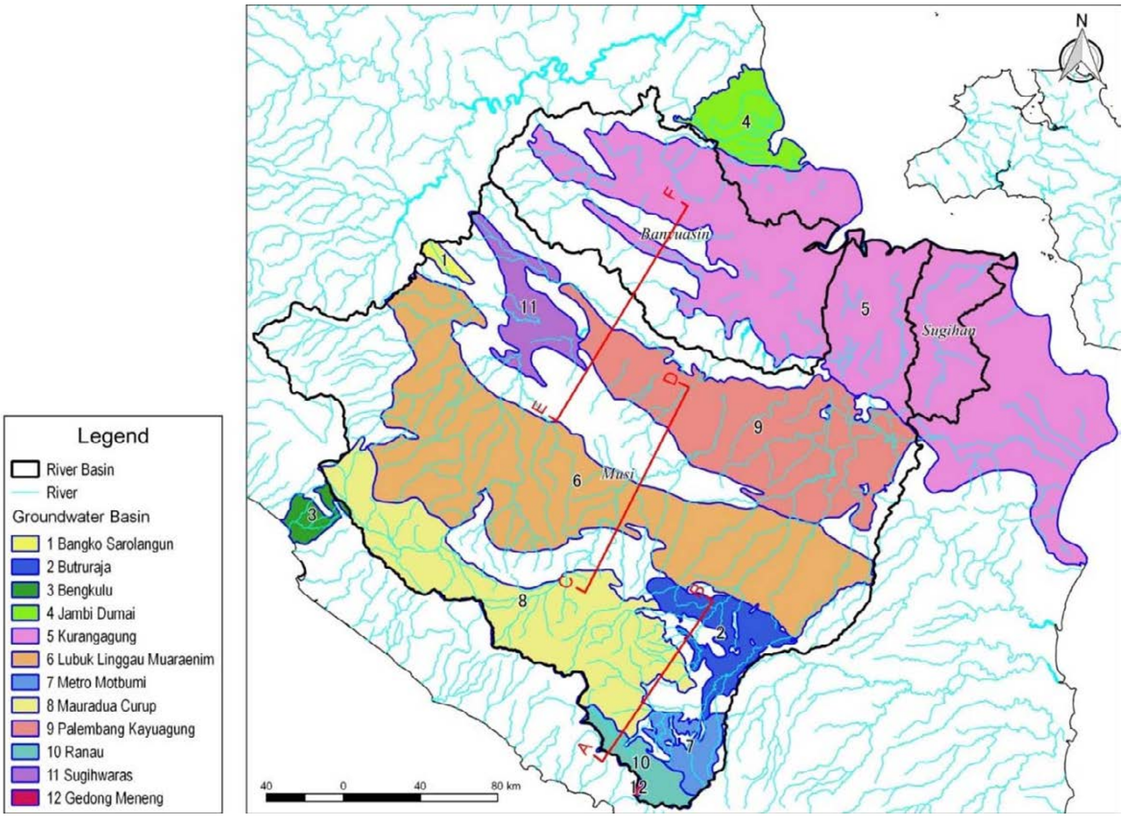
Figure C6.1.1 Geological Map in Musi River Basin

C6.2 Groundwater Basin and Hydrogeology

Rough estimation of the groundwater development potential of the Musi River basin was made by the Ministry of Energy and Mineral Resources (ESDM) under the study report of "Groundwater in Indonesia and its management, 2005". Some springs identified in the mountainous zone and alluvial plains are located along the rivers. Therefore, a certain degree of groundwater development potential is expected from groundwater in fractured rocks and shallow groundwater in alluvial deposit. However, the development potential of groundwater in Piedmont zone, Central Plains, and inland wetlands is limited only to shallow groundwater which exists in Quaternary deposits, because of difficulty of development and water quality risk. It should be noted that groundwater development potential of coastal plains including the provincial capital, Palembang is low due to the possibilities of saltwater intrusion and land subsidence.

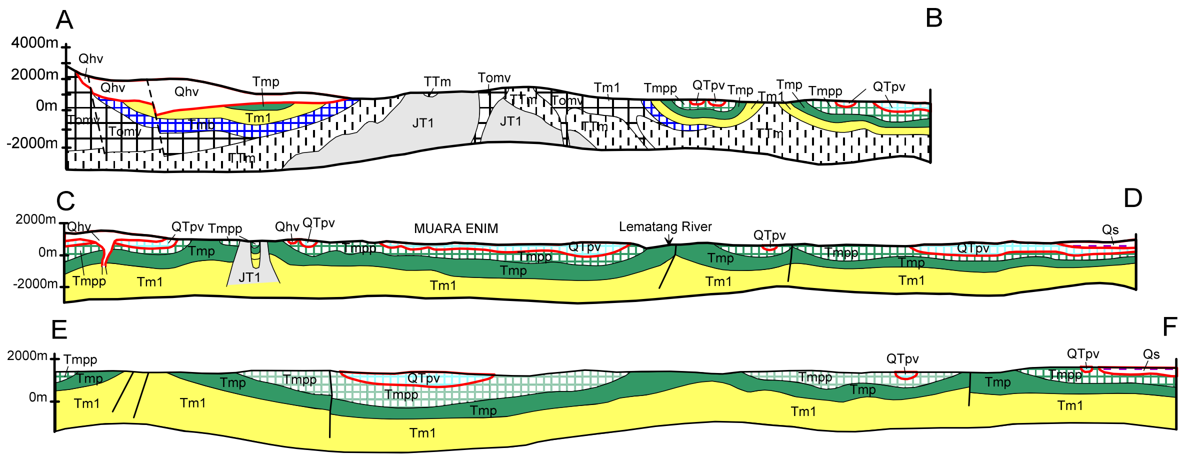
Based on the results of Team 1, it is evaluated how the present regional groundwater potential may change in the future for 12 groundwater basins shown in Figure C6.2.1 related to the Musi River basin. Some basins are only part of the whole basin may be included in the Musi River basin.

The groundwater basin was established by the Indonesian government in accordance with Presidential Decree No. 26 of 2011 as mentioned in CHAPTER C1. The relationship between the geology in cross section and the groundwater basin is shown in Figure C6.2.2 for reference. The portion surrounded by red line is groundwater basin defined by the Presidential Decree. Quaternary sediments are defined as aquifers, and it can be seen that they are divided mechanically.



Source: JICA Project Team 2

Figure C6.2.1 Groundwater Basin in Musi River Basin



Source: JICA Project Team 2

Figure C6.2.2 Definition of Groundwater Basin in Geological Section

Table C6.2.1 Total Groundwater Potential for Each Groundwater Basin

No.	Basin Name	Area (km²)	Q1+Q2*1 (M m³/y)	Q1+Q2*1 (%)	Ranking	(Q1+Q2)/Area (mm/y)
1	Bangko Sarolangun	6,072	4,221	5.8	5	695
2	Butruraja	2,404	1,151	1.6	10	479
3	Bengkulu	4,888	3,836	5.3	6	785
4	Jambi Dumai	69,776	20,401	28.0	1	292
5	Kurangagung	22,860	12,977	17.8	2	568
6	Lubuk Linggau Muaraenim	15,400	6,062	8.3	3	394
7	Metro Motbumi	21,640	12,331	16.9	8	570
8	Mauradua Curup	8,521	4,389	6.0	4	515
9	Palembang Kayuagung	8,652	3,759	5.2	7	434
10	Ranau	1,501	934	1.3	12	622
11	Sugihwaras	1,794	1,549	2.1	9	863
12	Gedong Meneng	1,412	1,185	1.6	11	839
Total 1(1,2,5,6,7,8,9,10,11)		88,844	47,373	65.1	-	533
Total 2(1-12)		164,920	72,795	100.0	-	441

*1: Q1 is shallow aquifer and Q2 is deep aquifer

Source：JICA Project Team 2

C6.3 Coastal Peatland Areas

It is known that the risk of wild fires increases as peatland becomes dry. It is estimated how the groundwater level in coastal peatland areas change under climate change, taking into consideration sea level rise.

The Project was implemented using the groundwater flow model MODFLOW in consideration of sea level rise with groundwater recharge (groundwater potential) evaluated in reginal groundwater potential Project. The analysis area is lowest Musi River basin and the tidal area where the tropical peatland extends.

C6.4 Groundwater Level Observation

C6.4.1 Construction of Observation Wells

Since there were no groundwater level data for the Musi River basin, three observation wells were constructed near the existing water level stations of the Musi River (Mambang), Lematang River (Sungai Rotan) and Komering River (Tanjung Raja). Immediately after the completion of the well construction, groundwater level monitoring was commenced. Table C6.4.1 shows information on the three observation wells which were constructed under the Project. The location of the three wells is also presented in Figure C6.4.1.

i) Musi-1 Observation Well (Mambang)

Musi-1 is located in the Medium of the Musi River Basin, about 120m far from the Musi River. The aquifer is unconfined. The groundwater level shows good response to rainfall events, but it has no seasonal change (around EL 27m).

ii) Musi-2 Observation Well (Sungai Rotan)

Musi-2 is located at the lower part of the Musi River Basin, about 1,200m far from the Lematang River. The observed ground water level is above the aquifer; therefore, the aquifer is confined. The groundwater level shows gentle changes without response to the rainfall. It may fluctuate mainly vary according to the river water level.

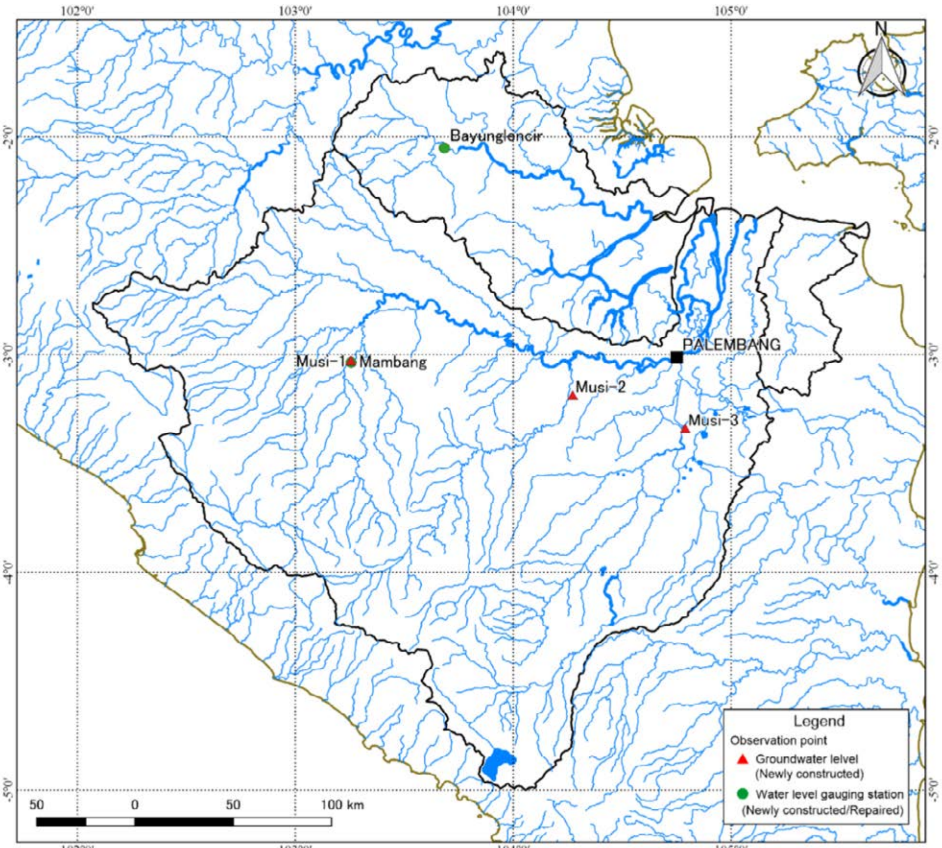
iii) Musi-3 Observation Well (Tanjung Raja)

Musi-3 is located at the lower part of the Musi River Basin, about 400m far from the Komering River. Since the observed water levels are above the aquifer, the aquifer is confined. The fluctuation of the groundwater level is concordant with that of Musi-2. The groundwater level may vary according to the river water level.

Table C6.4.1 Information on Observation Wells in Musi River Basin

Well Name	District	Village	Coordinate (WGS84)	Elevation (m msl)*	Depth (GL-m)	Casing (mm)	Screen Depth (GL-m)	Drilling Period
Musi-1 (Mambang)	Musi Rawas	Mambang	S 03 02'02.8" E 103 15' 17.7"	31.164	40.0	100	6–12, 32–38	29-30 Aug. 2013
Musi-2 (Sungai Rotan)	Muara Enim	Sukarami	S 03 11'36.9" E 104 16'20.6"	9.209	46.0	100	18-21, 31-34, 36-42	6-10 Sep. 2013
Musi-3 (Tanjung Raja)	Ogan Ilir	Sungai Pinang	S 03 20'46.5" E 104 47'20.3"	7.097	49.0	100	12-18, 30-33, 43-46	17-19 Sep. 2013

* at the top of concrete base of each well
Source: JICA Project Team 2

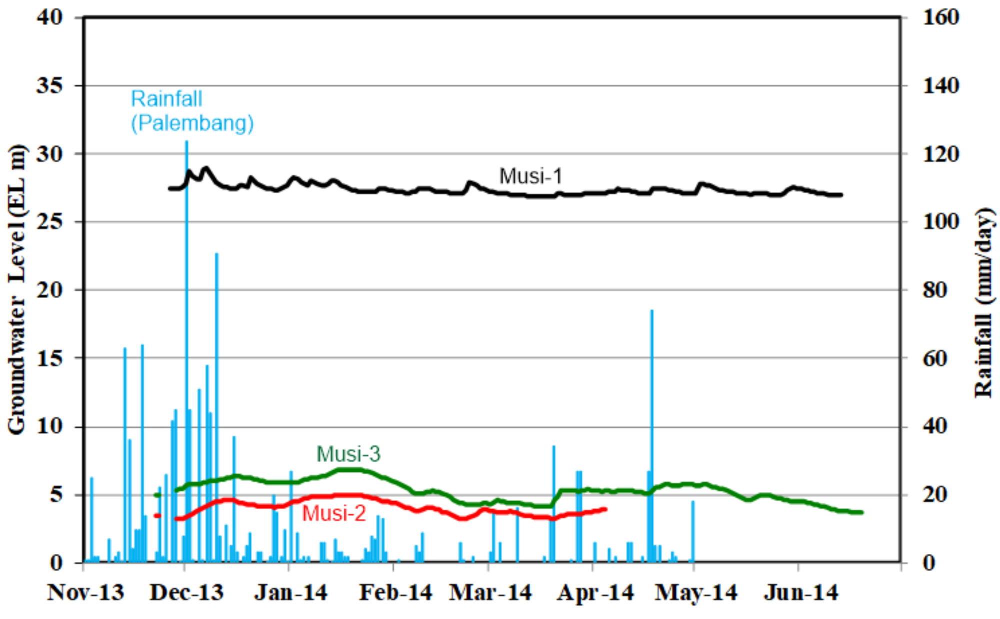


Source: JICA Study Team 2

Figure C6.4.1 Location of Newly Constructed Observation Wells with Gauging Station

C6.4.2 Observation Result

Hourly groundwater level monitoring has been carried out since November 2013 by an automatic piezometric data logger for the above three observation wells. Figure C6.4.2 shows result of the groundwater level monitoring from November 2013 to June 2014.



Source: JICA Study Team 2

Figure C6.4.2 Groundwater Level Data in Observation Wells

C6.5 Groundwater Use

Table C6.5.1 shows groundwater use in Musi River basin based on existing data, which is already introduced Progress Report 1 in this project. The ratio of groundwater use to total water use in Musi River basin is only about 2%. Even if economic growth in Indonesia after 2003 is taken into consideration, it is estimated to be 10% or less.

Table C6.5.1 Total Water Use and Groundwater Use

Utilization	A: Water Use (x 1000m^3/y)	B: Groundwater Use (x 1000m^3/y)	B: Groundwater Use (%)	B/A (%)
Domestic	101,000	8,168	7.2	8.1
Industrial	377,000	66,892	58.6	17.7
Mining	115,000	30,617	26.8	26.6
Irrigation	2,760,000	92	0.1	0.0
Swamp Area	1,961,000	-	-	-
Aquaculture	514,000	265	0.2	0.1
Tourism	150	-	-	-
Livestock	17,400	8,045	7.1	46.2
Hydropower	0	0	0.0	0.0
Total	5,845,550	114,079	100.0	2.0

Source: The Study on Comprehensive Water Management of Musi River Basin in the Republic of Indonesia (2003), JICA

Possible reasons are as follows:

i) The current water demand should be met with surface water.

ii) In Palembang, the largest city of Musi River basin, groundwater has high concentration of Iron ion and it is not suitable for use.

However, when considering the future increase in water demand and the change in water resources balance under climate change, it is necessary to estimate present groundwater potential and its changes in future the change.

CHAPTER C7 CHANGES IN REGIONAL GROUNDWATER POTENTIAL IN MUSI RIVER BASIN

C7.1 Effective Rainfall

It is difficult to consider the impact of temperature rise and land use change when using only rainfall data to estimate future groundwater potential changes which are affected by climate change. Therefore, it is proposed to evaluate groundwater potential using effective rainfall which is considered to be proportional to groundwater recharge.

Historical Rainfall (R), actual evapotranspiration (ET), and effective rainfall (R-ET) for each groundwater basin provided by Team 1 as the data under the present condition (15 years from 1985/9/1 to 2000/8/31)) is shown in Table C7.1.1. Since "4. Jambi Dumai" was not included in the analysis and examination area by Team 1, the result of "5. Karangagung" was used, which is assumed to be almost the same hydrological environment.

Table C7.1.1 Effective Rainfall in Present Climate Condition

No.	Groundwater Basin	Area (km^2)	Rain (R) (mm/y)	Evapo-transpiration (ET) (mm/y)	R-ET (Historical) (mm/y)	(million m^3/y)
1	Bangko Sarolangun	231	2,431	1,061	1,370	317
2	Butruraja	1,838	2,674	1,111	1,563	2,873
3	Bengkulu	18	2,762	1,039	1,723	32
4	Jambi Dumai*	7	2,728	1,150	1,578	10
5	Kurangagung	14,655	2,728	1,150	1,578	23,127
6	Lubuk Linggau Muaraenim	14,937	2,777	1,074	1,703	25,439
7	Metro Motbumi	994	2,675	1,079	1,596	1,587
8	Mauradua Curup	7,847	2,789	1,080	1,710	13,415
9	Palembang Kayuagung	8,592	2,604	1,091	1,513	12,999
10	Ranau	997	2,687	1,034	1,653	1,648
11	Sugihwaras	1,853	2,529	1,026	1,503	2,785
12	Gedong Meneng	29	2,687	1,034	1,653	47
Total (Average)		51,997	(2,719)	(1,098)	(1,621)	84,279

* : Substitution of "Karangagung" data because of no available data from Team 1

Source: JICA Project Team 2

C7.2 Present Groundwater Potential

Groundwater basins shown in Figure C6.2.2 is located to the Musi River basin, but some basins are only part of the whole basin may be included in the Musi River basin. The study of groundwater potential by Badan Geologi had being carried out before the Presidential Decree was issued. This published groundwater potential of each groundwater basin by Badan Geologi related to Musi River basin is shown in Table C7.2.1 and groundwater potential in Musi River basin was calculated using this value. Total amount of present groundwater potential was estimated to be 25,841million m^3/y.

Table C7.2.1 Present Groundwater Potential by Groundwater Basin

No.	Groundwater Basin	Area (km²)	Groundwater Potential		Musi River Basin Area (km²)	Groundwater Potential (million m³/y)
			(million m³/y)	(mm/y)		
1	Bangko Sarolangun	6,072	4,221	695	231	161
2	Butruraja	2,404	1,151	479	1,838	880
3	Bengkulu	4,888	3,836	785	18	14
4	Jambi Dumai	69,776	20,401	292	7	2
5	Kurangagung	22,860	12,977	568	14,655	8,319
6	Lubuk Linggau Muaraenim	15,400	6,062	394	14,937	5,880
7	Metro Motbumi	21,640	12,331	570	994	567
8	Mauradua Curup	8,521	4,389	515	7,847	4,042
9	Palembang Kayuagung	8,652	3,759	434	8,592	3,733
10	Ranau	1,501	934	622	997	620
11	Sugihwaras	1,794	1,549	863	1,853	1,600
12	Gedong Meneng	1,412	1,185	839	29	24
Total (Average)		164,920	72,795	(441)	51,997	25,841

Source: JCA Project Team 2

C7.3 Estimation Method of Future Groundwater Potential

The following method was used to estimate the groundwater potential:

i) Calculate the ratio (%) of present groundwater potential to present effective rainfall.

ii) In the case of forecasting, the effective rainfall of each scenario is multiplied by above ratio (%) to estimate the amount of groundwater potential.

Ratio of present groundwater potential to present effective rainfall is shown in Table C7.3.1.

Table C7.3.1 Ratio of Present Groundwater Potential to Present Effective Rainfall

No.	Groundwater Basin	Musi Area (km²)	A: R-ET (Historical) (mm/y)	B: Present Potential (mm/y)	Ratio (B / A) (%)
1	Bangko Sarolangun	231	1,370	695	51
2	Butruraja	1,838	1,563	479	31
3	Bengkulu	18	1,723	785	46
4	Jambi Dumai*	7	1,578	292	19
5	Kurangagung	14,655	1,578	568	36
6	Lubuk Linggau Muaraenim	14,937	1,703	394	23
7	Metro Motbumi	994	1,596	570	36
8	Mauradua Curup	7,847	1,710	515	30
9	Palembang Kayuagung	8,592	1,513	434	29
10	Ranau	997	1,653	622	38
11	Sugihwaras	1,853	1,503	863	57
12	Gedong Meneng	29	1,653	839	51
Total (Average)		51,997	(1,638)	(441)	(27)

* : Substitution of "Karangagung" data because of no available data from Team 1

Source: JICA Project Team 2

C7.4 Changes in Groundwater Potential Under Climate Change

C7.4.1 Selection of Climate Change Scenarios

Climate change scenarios were selected by the following procedure using effective rainfall:

i) The 15-year average value of effective rainfall for each of the 28 GCM scenarios in the below table provided by Team 1 is calculated and summarized for each groundwater basin.

Table C7.4.1 28 Climate Change Scenarios

Case	Climate (Scenario)	Land Use	Calculation Period
1	Historical (1GCM)	Present	1985/9/1~2000/8/31 (15 years)
2	Past (9GCMs)	Present	1985/9/1~2000/8/31 (15 years)
3	Future (9GCMs)	Present	2050/9/1~2065/8/31 (15 years)
4	Future (9GCMs)	Future	2050/9/1~2065/8/31 (15 years)

ii) The ratio of the past effective rainfall (Case 2) to the future effective climate (Case 3 and Case 4) is calculated, and it arranges in order of negative impact on groundwater potential. Negative impact means decrease in groundwater potential.

iii) Among the nine climate change scenarios (9 GCMs), the third GCM is extracted as future High scenario, the fifth GCM is extracted as future Medium scenario, and the seventh GCM is extracted as future Low scenario respectively, and

iv) Changes in groundwater potential is calculated and evaluated for the extracted three future scenarios.

The results are shown in Table C7.4.2. Finally, three scenarios were adopted: GFDL_2_1 as High scenario, MIUB_ECHO as Medium scenario, and GFDL_2_0 as Low scenario.

Table C7.4.2 Result of Selection of Climate Change Scenarios

GCM	Case2		Case3		Case4		Case3/Case2		Case4/Case2	
	R-ET (million m^3/y)	Rank	R-ET (million m^3/y)	Rank	R-ET (million m^3/y)	Rank	R-ET (-)	Rank	R-ET (-)	Rank
CCCMA_CGCM	54,493	4	60,578	7	61,561	8	1.112	8	1.130	8
CSIRO_MK35	58,596	7	43,213	1	44,241	1	0.737	1	0.755	1
GFDL_2_0	54,644	5	60,634	8	61,519	7	1.110	7	1.126	7
GFDL_2_1	57,258	7	52,835	3	53,612	3	0.923	3	0.936	3
GISS_AOM	52,525	1	59,240	6	59,871	6	1.128	6	1.140	6
INGV	53,564	2	53,342	4	54,267	4	0.996	4	1.013	4
MIUB_ECHO	54,767	6	57,240	5	58,101	5	1.045	5	1.061	5
MPI_ECHAM5	60,282	9	64,144	9	65,060	9	1.064	9	1.079	9
MRI_CGCM232A	54,096	3	49,622	2	50,349	2	0.917	2	0.931	2

Source: JICA Project Team 2

C7.4.2 Forecast of Groundwater Potential Change

Table C7.4.3 shows the amount of change in effective rainfall from present to future for each scenario. Then, the amount of change in groundwater potential was calculated multiplying the amount of change in effective rainfall in future by the conversion ratio (%) in Table C7.3.1.

The result shown in Table C7.4.4 indicates that the future groundwater potential will decrease 4,417 million m^3/y in the High scenario, 3,120 million m^3/y in the Medium scenario and 1,306 million m^3/y in the Low scenario in the entire basin. This is about 17% in High scenario, about 12% in the Medium scenario, and about 5% in the Low scenario with respect to the present total groundwater potential of 25,841 million m^3/y.

Table C7.4.3 Effective Rainfall in Future and Change from Present

No.	Groundwater Basin	Historical (mm/y)	Future(mm/y)			Change (mm/y)		
			High	Medium	Low	High	Medium	Low
1	Bangko Sarolangun	1,370	1,332	1,548	1,657	-38	179	287
2	Butruraja	1,563	1,645	1,544	1,599	82	-19	36
3	Bengkulu	1,723	1,204	1,706	1,752	-519	-17	29
4	Jambi Dumai*	1,578	1,141	1,136	1,294	-437	-443	-284
5	Kurangagung	1,578	1,141	1,136	1,294	-437	-443	-284
6	Lubuk Linggau Muaraenim	1,703	1,461	1,592	1,687	-242	-111	-16
7	Metro Motbumi	1,596	1,838	1,624	1,710	242	28	114
8	Mauradua Curup	1,710	1,416	1,625	1,684	-294	-84	-26
9	Palembang Kayuagung	1,513	1,269	1,400	1,511	-244	-113	-2
10	Ranau	1,653	1,906	1,677	1,736	253	24	83
11	Sugihwaras	1,503	1,314	1,545	1,678	-189	42	175
12	Gedong Meneng	1,653	1,907	1,678	1,737	253	25	83
Average		1,621	1,426	1,546	1,636	-195	-75	16

* : Substitution of "Karangagung" data because of no available data from Team 1

Source: JICA Project Team 2

Table C7.4.4 Groundwater Potential in Future and Change from Present

No.	Groundwater Basin Name	Historical Potential (million m^3/y)	Future Potential (million m^3/y)			Change (million m^3/y)		
			High	Medium	Low	High	Medium	Low
1	Bangko Sarolangun	161	156	182	195	-4	21	34
2	Butruraja	880	926	870	900	46	-10	20
3	Bengkulu	14	10	14	15	-4	-0	0
4	Jambi Dumai*	2	1	1	2	-1	-1	-0
5	Kurangagung	8,319	6,014	5,986	6,823	-2,305	-2,333	-1,496
6	Lubuk Linggau Muaraenim	5,880	5,043	5,496	5,824	-837	-384	-56
7	Metro Motbumi	567	653	577	607	86	10	41
8	Mauradua Curup	4,042	3,347	3,843	3,981	-694	-199	-61
9	Palembang Kayuagung	3,733	3,132	3,454	3,727	-601	-279	-6
10	Ranau	620	715	629	652	95	9	31
11	Sugihwaras	1,600	1,399	1,645	1,786	-201	45	186
12	Gedong Meneng	24	28	24	25	4	0	1
Total		25,841	21,425	22,721	24,536	-4,417	-3,120	-1,306

*: Substitution of "Karangagung" data because of no available data from Team 1

Source: JICA Project Team 2

C7.4.3 Estimation of Groundwater Potential Change from Groundwater Level Data

Ground water level data in depth is also provided by Team 1 together with meteorological data. However, this data is output in the process of surface water analysis and not calibrated, and its use is limited as reference. Table C7.4.5 shows that the future average groundwater level is lower than the present average groundwater level in all three scenarios.

It was estimated from groundwater level data that about 17% decrease for the present total groundwater potential may occur in Medium scenario. However, the effective porosity of aquifer used by Team 1 for calculation is around 0.5, which may be too large for general value of the effective porosity in aquifer.

Table C7.4.5 Groundwater Potential Change Estimated Groundwater Level Data

No.	Basin Name	Historical Depth (GL-m)	Future Depth (GL-m)			Depth Change (m)		
			High	Medium	Low	High	Medium	Low
1	Bangko Sarolangun	1.563	1.599	1.562	1.559	-0.035	0.001	0.005
2	Butruraja	1.083	1.166	1.161	1.156	-0.083	-0.078	-0.074
3	Bengkulu	2.082	2.202	2.083	2.073	-0.120	0.000	0.009
4	Jambi Dumai	0.426	0.524	0.437	0.441	-0.098	-0.011	-0.016
5	Kurangagung	0.426	0.524	0.437	0.441	-0.098	-0.011	-0.016
6	Lubuk Linggau Muaraenim	1.319	1.517	1.494	1.480	-0.198	-0.174	-0.161
7	Metro Motbumi	2.028	2.054	2.095	2.086	-0.026	-0.068	-0.058
8	Mauradua Curup	1.727	1.829	1.810	1.796	-0.102	-0.083	-0.069
9	Palembang Kayuagung	0.793	0.891	0.846	0.849	-0.098	-0.054	-0.056
10	Ranau	2.156	2.175	2.218	2.208	-0.018	-0.062	-0.052
11	Sugihwaras	0.925	1.188	1.110	1.101	-0.263	-0.185	-0.175
12	Gedong Meneng	2.543	2.537	2.587	2.577	0.005	-0.044	-0.034
Average		1.901	2.135	2.057	2.048	-0.234	-0.156	-0.147

*: Substitution of "Karangagung" data because of no available data from Team 1

Source: JICA Project Team 2

CHAPTER C8 CHANGED IN GROUNDWATER ENVIRONMENT IN COASTAL PEATLAND AREAS

C8.1 Analysis Condition

Three-dimensional groundwater flow model MODFLOW was used to evaluate the groundwater environment change in coastal peatland area.

The analysis conditions are shown in Table C8.1.1. Tide data used for analysis has many missing periods. Since it is necessary to use continuous data for analysis, it is selected to use the same data from 2000/9/1 to 2005/8/31 (5 years) repeatedly 3 times for 15 years forecast. In addition, 1985/9/1 to 2000/8/31 (15 years) of the same period as regional groundwater potential analysis is used to evaluate for present groundwater condition. There is no hydrogeological information, aquifer constant, and groundwater observation data as calibration target. The meteorological data from Team 1 to estimate groundwater recharge is provided only for the Musi River basin. Therefore, this data was applied for Banyuasin River basin and Sugihan River basin. Sea level rise is assumed to be 0.25m in future forecast.

The analysis area is shown in Figure C8.1.1, and birds-eye view of analysis model is shown in Figure C8.1.2.

Table C8.1.1 Analysis Condition

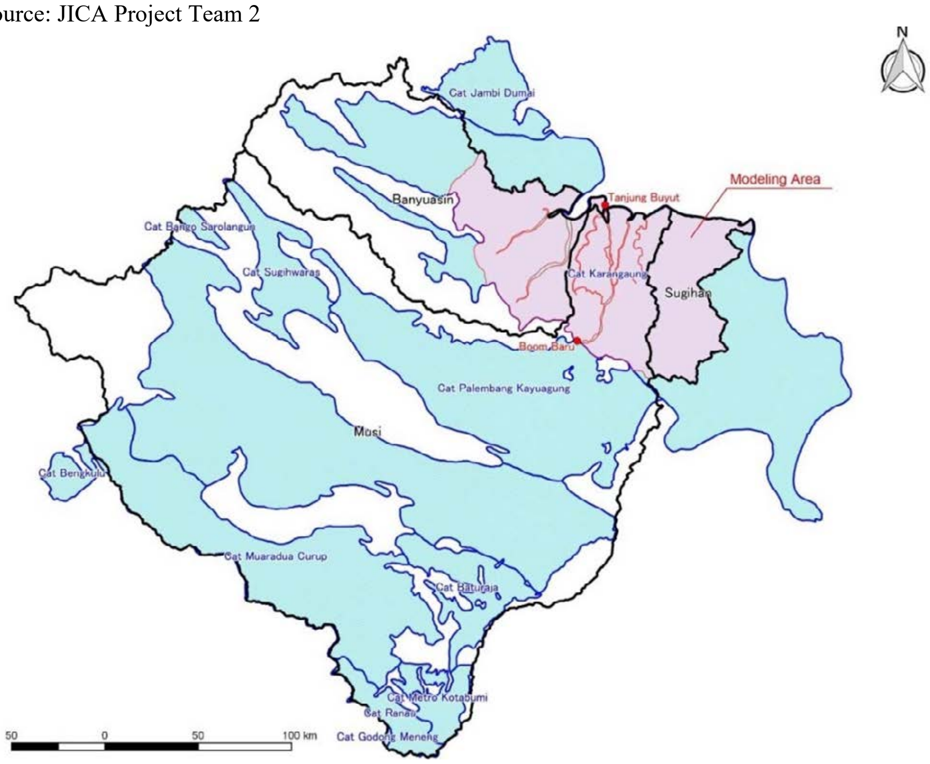
Item		Condition	Remarks
Analysis code		MODFLOW2005	One of the codes used worldwide
Analysis area		Coastal area of Kurangagung groundwater basin	See Figure C8.1.1 and Figure C8.1.2
		-200m (model bottom)	
Grid size		1 km×1km	Same as Brantas model
Analysis period	Present	1985/9/1～2000/8/31（15years）	Adopt this period according to the change evaluation of regional groundwater potential
	Future	2050/9/1～2066/8/31（15years）	Consider sea level rise (+0.25 m)
Time step		1 month	Same as Brantas model
Hydrogeological structure		Estimated from reginal geological map	Whole area is assumed to be peatland. DEMNAS data is processed and incorporated for ground surface of the model. 3 hydrogeological layers are assumed: shallow (unconfined) aquifer, transition zone, and deep (confined) aquifer
Aquifer constant		General value	The same value used in peatland groundwater analysis in Kalimantan is set (see Table C8.1.2)
Calibration target		No data	
Boundary condition	Ocean	Tanjung Buyut tidal data	The same data from 2000/9/1 to 2005/8/31 (5 years) repeatedly 3 times for 15 years forecast
	Upstream of the river	Boom Baru water level data	The same data from 2000/9/1 to 2005/8/31 (5 years) repeatedly 3 times for 15 years forecast
Groundwater recharge		Estimated value of Kurangagung groundwater basin	Groundwater potential is assumed as groundwater recharge

Source: JICA Project Team 2

Table C8.1.2 Aquifer Constant for the Model

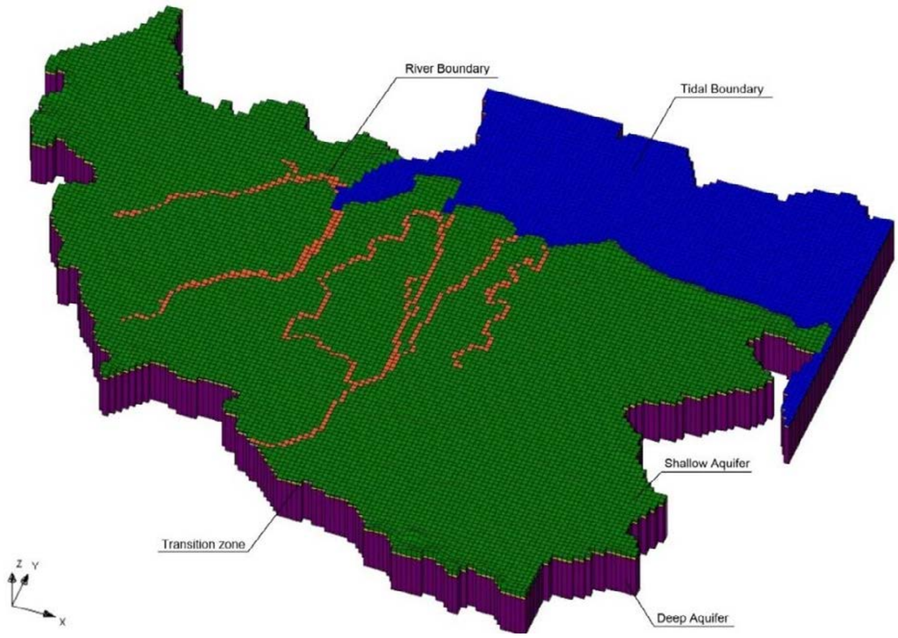
Layer	Aquifer	Kx , Ky (m/s)	Ky (m/s)	Ss (1/m)	Sy (-)
1	Shallow (unconfined)	5.0 x 10-4	5.0 x 10-5	1.0 x 10-5	0.2
2	Transition zone	1.0 x 10-4	1.0 x 10-5	1.0 x 10-5	0.2
3	Deep (confined)	5.0 x 10-5	5.0 x 10-6	1.0 x 10-5	0.2

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure C8.1.1 Groundwater Basin, Analysis Area and Location of Observation Station

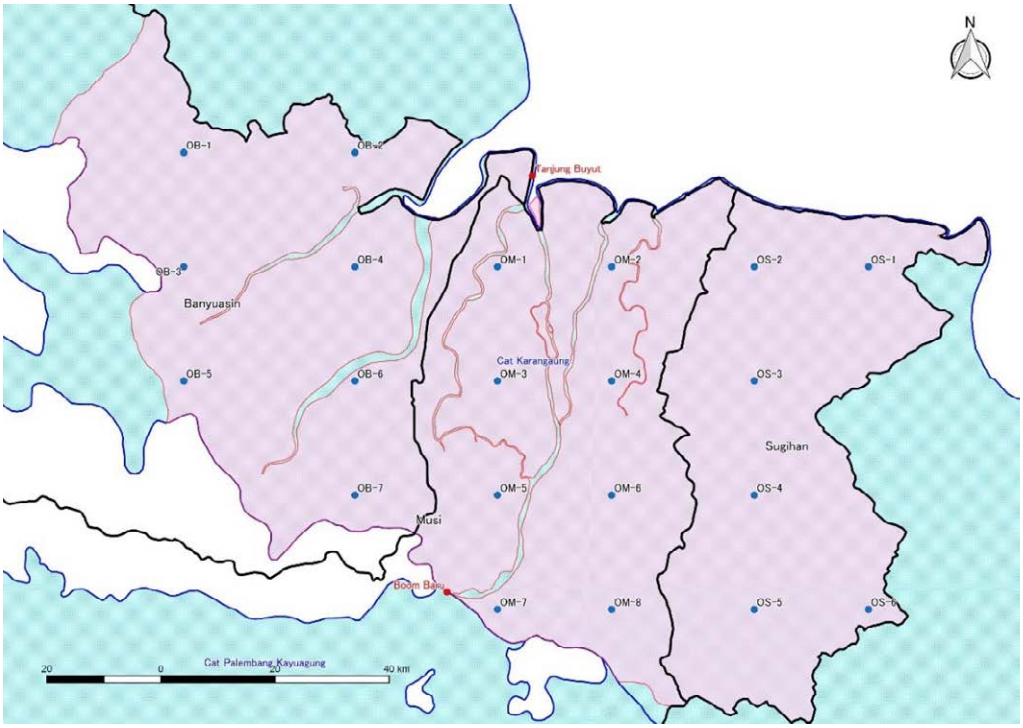


Source: JICA Project Team 2

Figure C8.1.2 Birds-eye View of Groundwater Model

C8.2 Changes in Groundwater Level

Virtual monitoring wells were set in the model for each river basin (Figure C8.2.1) to acquire output of groundwater level. Table C8.2.1 shows average groundwater depth in 15 years at each virtual monitoring well and comparisons of present and future climate. All future groundwater levels will be lower than the present despite sea level rise.



Source: JICA Project Team 2

Figure C8.2.1 Location of Virtual Monitoring Wells in Model

Table C8.2.1 Average Groundwater Depth in 15 Years and Change from the Present

No.	River Basin	Virtual Monitoring Wells	Present (m)	Future (m)			Water Level Change (m)		
				High	Medium	Low	High	Medium	Low
1	Musi	OM1-OM8	0.31	0.42	0.42	0.39	-0.11	-0.11	-0.08
2	Banyuasin	OB1-OB7	0.48	0.65	0.66	0.61	-0.16	-0.18	-0.13
3	Sugihan	OS1-OS6	1.39	1.63	1.64	1.58	-0.24	-0.25	-0.19
Average			0.68	0.84	0.85	0.80	-0.17	-0.17	-0.13

Source: JICA Project Team 2

C8.3 Evaluation of the Result

The risk of wild fires in tropical peatland is generally increased when the groundwater level drops below 0.4m from ground surface (for example, Henk Wösten et al., 2010). Therefore, it means that the risk of wild fire in coastal peatland area will increase in the future caused by the lowering of groundwater level. Although the sea level is expected to be 0.25 m higher than the present level, it is considered that the decrease in groundwater recharge more than the sea level rise resulted in the possibility of lowering the groundwater level in coastal peatland area. On the other hand, sea level rise also means increasing the risk of saltwater intrusion.

Supporting Report D

SPATIAL PLAN AND LAND USE

Abbreviations

	Indonesia	English
Bappeda	Badan Perencanaan Pembangunan Daerah	Regional Planning and Development Body
BAPPENAS	Badan Perencanaan Pembangunan Nasional	National Planning Agency
BBWS	Balai Besar Wilayah Sengai	Large River Basin Organization
BPS	Badan Pusat Statiks	Central Bureau of Statistics
DGAIF	Direktorat Jenderal Prasarana & Sarana Pertanian	Directorate General of Agricultural Infrastructure and Facilities
DGWR	Direktorat Jenderal Sumber Daya Air	Directorate General of Water Resources
GOI	Pemerintah Indonesia	Government of Indonesia
JICA	-	Japan International Cooperation Agency
KP	Kriteria Perencanaan	Planning Criteria
LP2B	Lahan Pertanian Pangan Berkelanjutan	Sustainable food production base
MBSL	Musi-Sugihan-Banyuasin-Lemaure	Musi-Banyuasin-Sugihan-Lemau
MH	Musim Hujan	Rainy season
MK	Musim Kemarau	Dry season
MOA	Kementarian Pertanian	Ministry of Agriculture
MPWH	Kementerian Pekerjaan Umum Dan Perumahan Rakyat	Ministry of Public Works and Housing
O&M	-	Operation & Maintenance
OKU	Ogan Komering Ulu (Kabupaten)	Ogan Komering Ulu (Regency)-
OKI	Ogan Komering Ilir (Kabupaten)	Ogan Komering Ilir (Regency)
PALI	Penukal Arab Lematang Ilir (Kabupaten)	Penukal Arab Lematang Ilir (Regency)
POLA	Rencana Strategis Manajemen Sumber Daya Air	Water Resources Management Strategic Plan
PP	Peraturan Pemerintah-	Presidential Decree
PUPR	Pekerjaan Umum dan Permahan Rakyat	Public Works and Public Housing
RENCANA	Rencana Penerapan Manajemen Sumber Daya Air	Water Resources Management Implementation Plan
RPJMD	Rencana Pembangunan Jangka Menegah Daerah	Medium Term Development Plan of Region
RDTR	Rencana Detil Tata Ruang	Detailed Spatial Plan
RTkRHL DAS		Forest and Land Rehabilitation Engineering Plan
RTRW	Rencana Tata Ruang Wilayah	Spatial Plan
SNI	Standar Nasional Indonesia	Indonesian National Standard
SRI	-	System of Rice Intensification
TOT		Training of Trainers
UU	Undang-Undang	Law
WUA	-	Water Users Association

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 D: SPATIAL PLAN AND LAND USE

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PART 1 GENERAL

CHAPTER D1 OVERVIEW OF SPATIAL PLAN IN INDONESIA

D1.1 Legal Background and Institutional Transition

D1.1.1 Legal Background of Spatial Plan

Since the independence. two regulations introduced in 1948 and 1949 by the Dutch Traditional Government were continuously enforced by the Government of Indonesia (GOI) for controlling urban development, especially in Island of Java. The basis of this formal spatial planning in Indonesia was European urban environmental regulations such as building lines and zoning.

To cope with increased complexity of urbanization and demand for purely Indonesian planning law, legal actions for spatial plan taken by GOI since 1990s are summarized in Table D1.1.1.

Table D1.1.1 Legal Actions for Spatial Plan by GOI since 1990s

Date	No.	Title	Key Point
13 Oct. 1992	UU No.24/1992	Spatial Plan	• To build up the first legal basis for spatial planning in Indonesia. • To back up centralized system of spatial planning by GOI. • To become outdated before implementation to full extent due to a major pollical change in Indonesia resulting from 1997-1998 Asian financial crisis
26 Apr. 2007	UU No.26/2007	Spatial Management	• To conform with newly introduced laws and regulations related to decentralized policy and rapid progressing urbanization, • To emphasize planning role of decentralized authorities through strengthening bargaining power of local authorities to push forward their goals in spatial planning.
10 Mar. 2008	PP No.26/2008	National Spatial Plan	• To guide effective and efficient planning processes for achieving stated objectives of the spatial plan. • To demarcate general spatial plan and to establish framework of detailed spatial plan • To give governors and central government the right to override land use decisions made by local authorities of regency/city when conflicts of land use planning between central government and local authorities occur in very special manner.
20 Dec. 2011	PM No.20/PRT/M/2011	Guidance for Development of Detailed Spatial Plan	• To provide local authorities and planners with a technical direction towards spatial planning including components of Detailed Special Plan, delineation of planning areas, components of zoning and stakeholders' involvement.

Source: JICA Project Team 2

D1.1.2 Institutional Transition of Spatial Planning

The organization responsible for drafting the plan in the Law No.26/2007 was the National Spatial Planning Coordination Board, which was chaired by the Coordinating Minister for the Economy. The board's offices were set up in the National Planning Agency (BAPPENAS) and headed by BAPPENAS's director. The Directorate General of Spatial Planning of the Ministry of Public Works was charged with handling the practical implementation of the board' plan.

In 2015, Ministry of Agrarian Affairs and Spatial Planning/National Land Agency was established by merging the Directorate General of Spatial Planning of the Ministry of Public Works into former National Land Agency whose role was administration of land registration. To cope with the increased authority of local governments as a result of decentralization, the new ministry should act as a sole organization responsible for administrative works related to spatial planning. Its function covers coordination of interests among local governments upon enhancement of local panning capacity, development of plans, etc. including policy matters transferred from BAPPENAS. At the local government level, implementation/ monitoring works of spatial plans are dealt by various agencies concerned such as Public Works and Housing Department (Dinas PUPR) and Regional Planning and Development Body (Bappeda).

D1.2 Outline of Latest Law and Government Regulation on Spatial Plan

D1.2.1 Spatial Management

The structure of Law No.26/2007 regarding Spatial Management is shown in Table D1.2.1.

Table D1.2.1 Outline of Law No.26/2007 regarding Spatial Management

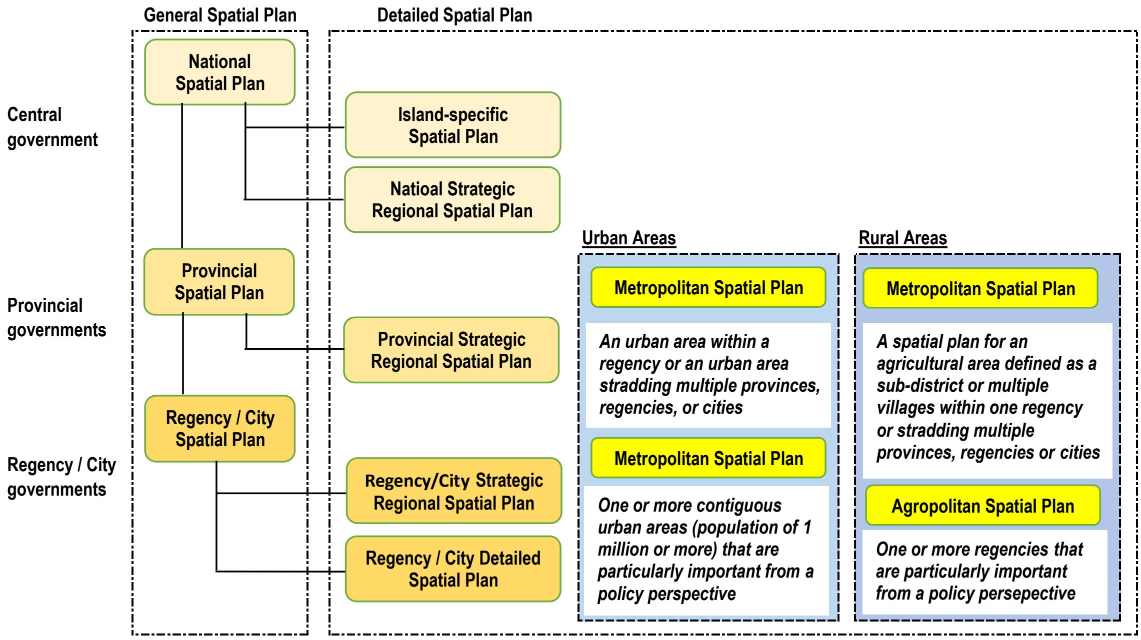
Chapter		Section		Sub-section		Article
I	General Provision					1
II	Principles and Goals					2 & 3
III	Spatial Planning Classification					4 to 6
IV	Obligation and Authority	One	Obligation			7
		Two	Government Authority			8 & 9
		Three	The Authority of Provincial Government			10
		Four	The Authority of Regency/ Municipal Government			11
V	Regulation and Establishment of Spatial Planning					12 & 13
VI	Execution of Spatial Management	One	Arrangement of Spatial Plan	1	General	14 to 18
				2	National Spatial Planning	19 to 21
				3	Provincial Spatial Planning	22 to 24
				4	Regency Spatial Planning	25 to 27
				5	Municipal Spatial Planning	28 to 31
		Two	Spatial Utilization	1	General	32 & 33
				2	Spatial Utilization	34
		Three	Control over Spatial Utilization			35 to 40
		Four	Urban Spatial Management	1	General	41
				2	Urban Spatial Planning	42 to 44
				3	Urban Spatial Utilization	45
				4	Control over Urban Spatial Utilization	46
				5	Cooperation on Urban Spatial Management	47
		Five	Rural Spatial Management	1	General	48
				2	Rural Spatial Plan	49 to 51
				3	Rural Spatial Utilization	62
				4	Control over Rural Spatial	53

Chapter		Section	Sub-section		Article
				Utilization	
			5	Cooperation of rural Spatial management	54
VII	Supervision on Spatial Planning				55 to 59
VIII	Right, Liability, and Role of the Society				60 to 66
IX	Dispute Settlement				67
X	Investigation				68
XI	Criminal Provisions				69 to 75
XII	Transitional Provisions				76 & 77
XIII	Closing Provisions				78 to 50

Source: Law No.26/2007 concerning Spatial Management

D1.2.2 Framework of Spatial Planning

In the abovementioned 2007 Law, the planning role of decentralization emphasizes and the formal process is conducted to produce two categories of planning documents such as general spatial plan and detailed spatial plan as illustrated in Figure D1.2.1



Source: JICA Project Team 2

Figure D1.2.1 Spatial Planning Framework in Indonesia

D1.2.3 Guideline of Detailed Spatial Planning

Aiming to provide local governments and planners with a formal direction towards the formulation of spatial plan, the Ministerial Ordinance No.20/PRT/M/2011 concerning guidance for development of Detailed Spatial Plan (RDTR) was enacted for following up the Law No.26/2007 and Presidential Decree No.26/2008 concerning National Spatial Plan. Focal points are summarized as follows:

- Spatial planning process;
- Spatial structural plan;
- Priority areas for development;
- Spatial use framework;
- Spatial pattern plan regulation;
- Spatial pattern planning (Zoning); and

- Stakeholders involvement.

In developing RDTR, the following stakeholders should be involved:

- Individual or group of people;
- Community organizations in urban or local level;
- Local government and its branches related to a planning area; and
- Private sector either local or those who may have interests to a invest in planning area.

Spatial pattern consists of two main categories, “Protection Zone” and “Utilization Zone”, and the both zones are further sub-categorized as listed up in Table D1.2.2.

Table D1.2.2 Category of Spatial Pattern

Protection Zone	Utilization Zone
A Protection Zone	B Utilization Zone
A1 Nature Reserve Zone	B1 Production Forest Zone
A2 Nature Conservation Zone	B2 Community Forest Zone
1) National park	B3 Agriculture Zone
2) Forest park	1) Wetland paddy field
3) Tourism park	2) Dryland upland crop field / Home garden
A3 Subordinate Protected zone	B4 Estate (Permanent) Crop Zone
1) Protected forest	B5 Fishery Zone
2) Watershed	B6 Residential and Industrial Zone
Swamp / Lake / Reservoir	Miscellaneous

Source: JICA Project Team 2

PART 2 BRANTAS RIVER BASIN

CHAPTER D2 SPATIAL PLAN OF BRANTAS RIVER BASIN

D2.1 Spatial Plan of East Java Province

D2.1.1 Spatial Plan for 2031 in East Java Province

BAPPEDA of East Java Province prepared provincial spatial plan (Rencana Tata Ruang Wilayah, hereinafter called "RTRW") in line with the national spatial plan. The purpose of the East Java RTRW 2011-2031 is determined based on the vision and mission of East Java regional medium-term development plan (Rencana Pembangnan Jangka Menengah Provinsi, hereinafter called "RPJMP") 2005-2025. In the spatial vision, agriculture sector is expected to become one of the main development drivers in East Java Province in the form of agribusiness packages focusing on food production and relevant agribusiness development activities in rural areas called as Agro-politan region. The East Java RTRW reveals the target area-wise distribution of spatial zones in East Java Province for 2031 as shown in Table D2.1.1.

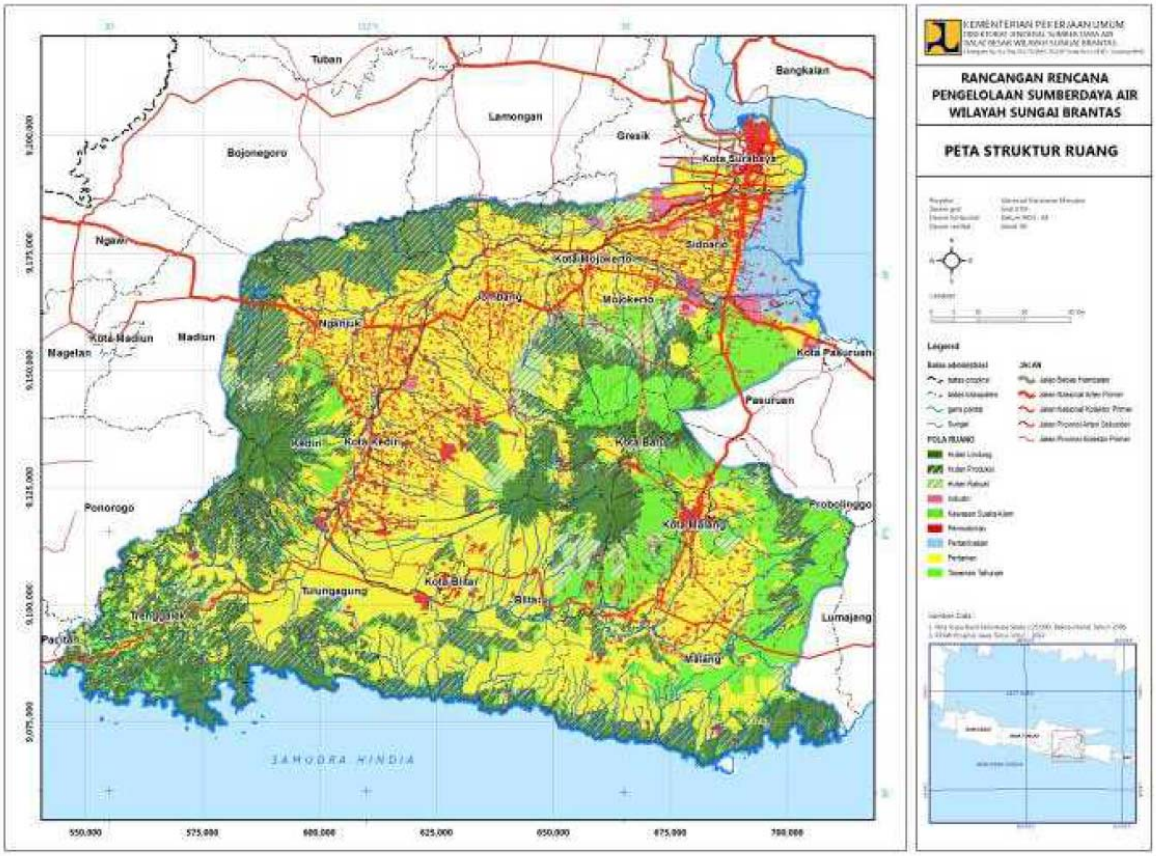
Table D2.1.1 Target Area-wise Distribution of Spatial Zones in East Java Province for 2031

Zone Category			Area (ha)	Percentage
A.	Protection Zone			
A1	Nature Reserve Zone		28,967	0.61
A2	Nature Conservation Zone			
	1)	National park	176,696	3.70
	2)	Forest park	27,868	0.58
	3)	Tourism park	298	0.01
A3	Subordinate Protected zone			
	1)	Protected forest	314,720	6.58
	2)	Watershed	27,534	0.58
B.	Utilization Zone			
B1	Production Forest Zone		782,772	16.38
B2	Community Forest Zone		404,191	8.46
B3	Agriculture Zone			
	1)	Wetland paddy field	957,239	20.02
	2)	Dryland upland crop field / Home garden	849,033	17.76
B4	Estate (Permanent) Crop Zone		398,036	8.33
B5	Fish Pond Zone		60,928	1.27
B6	Residential and Industrial Zone		735,701	15.39
Swamp / Lake / Reservoir			10,447	0.22
Miscellaneous			5,445	0.11
Province Total			4,779,875	

Source: RTRW Jawa Tmur 2011-2031

D2.1.2 Spatial Plan 2031 for Brantas River Basin

In Review POLA, BBWS Brantas prepared a distribution map based on the East Java RTRW depicting protection and utilization zones in the Brantas River basin as illustrated in Figure D2.1.1. Also, area-wise distribution of each zone category was calculated for nine Regencies and six Cities covering the Brantas River basin as shown in Table D2.1.2. In the Brantas River basin, there exist four development regions of Malang, Blitar, Kediri and Germaketosusilaplus as illustrated in Figure D2.1.2.



Source: BBWS Brantas

Figure D2.1.1 Protection and Utilization Zones in Brantas River Basin

Table D2.1.1 Area-wise Distribution of Spatial Zones by Regency/ City in Brantas River Basin (1/2)

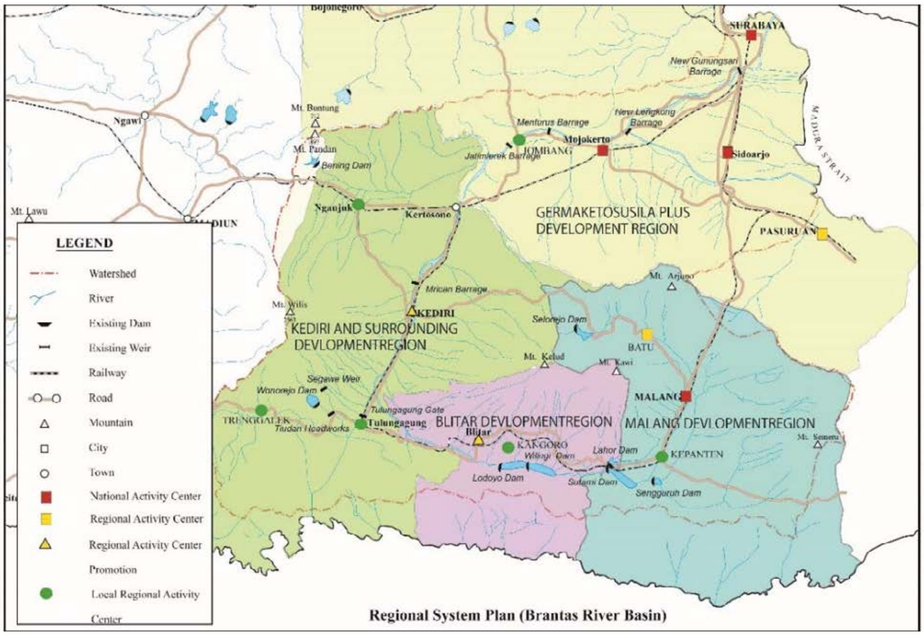
Zone Category	Regency							
	Malang (ha)	Blitar (ha)	Tulung. (ha)	Trengg. (ha)	Kediri (ha)	Nganjuk (ha)	Jombang (ha)	Mojoker. (ha)
A. Protection Zone								
A.1 Nature Reserve	877.0	0.0	0.0	0.0	19.0	0.0	0.0	0.0
A.2. Nature Conservation								
A.2.1 National park	19,005.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A.2.2 Forest park	5,494.1	0.0	0.0	0.0	0.0	0.0	3,767.0	0.0
A.2.3 Tourism park	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A.3 Subordinate Protected								
A.3.1 Protected forest	48,519.7	11,945.8	35,572.4	28,175.0	19,636.3	12,597.8	1,761.5	12,494.6
A.3.2 Watershed	28,895.3	29,792.3	12,334.4	10,828.9	8,766.6	5,677.2	97.7	6,692.9
B. Utilization Zone								
B.1 Production Forest*	19,062.6	2,312.5	13,562.5	31,187.5	1,562.4	37,336.1	17,108.3	9,125.0
B.2 Agriculture								
B.2.1 Wetland paddy field	56,519.7	45,236.6	14,600.0	16,500.0	48,361.5	31,460.8	44,279.0	30,000.0
B.2.2 Dryland upland field	40,763.2	19,747.8	14,452.8	9,817.0	21,836.2	14,590.6	18,398.5	4,495.5
B.3 Estate Crop	86,419.9	24,084.4	7,572.9	4,955.6	6,228.8	4,325.5	8,642.0	6,379.8
B.4 Fish Pond	60.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B.5 Residential / Industrial								
B.5.1 Residential	25,870.0	23,632.0	18,758.0	13,562.0	30,288.0	15,811.0	20,257.0	12,862.3
B.5.2 Industrial	2,766.0	1,128.6	1,800.3	2,070.5	1,906.2	634.0	1,639.0	2,391.3
Swamp / Lake / Reservoir	1,541.0	0.0	257.0	0.0	0.0	0.0	0.0	0.0
Miscellaneous	5,789.8	5,000.0	3,879.5	0.0	0.0	0.0	0.0	0.0
Regency / City Total	341,583.4	162,880.0	122,789.8	117,046.5	138,605.0	122,433.0	115,950.0	84,441.4

Note: *; Including community forest
Source: BBWS Brantas

Table D2.1.1 Area-wise Distribution of Spatial Zones by Regency/ City in Brantas River Basin (2/2)

Zone Category	Regency	City						Brantas R. Basin
	Sidoarjo	Batu	Malang	Blitar	Kediri	Mojoker.	Surabaya	
	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)
A. Protection Zone								
A.1 Nature Reserve	0.0	0.0	0.0	0.0	0.0	0.0	0.0	896.0
A.2. Nature Conservation								
A.2.1 National park	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19,005.1
A.2.2 Forest park	0.0	2,868.3	0.0	0.0	0.0	0.0	0.0	12,129.4
A.2.3 Tourism park	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A.3 Subordinate Protected								
A.3.1 Protected forest	0.0	2,301.0	0.0	0.0	0.0	0.0	0.0	172,954.1
A.3.2 Watershed	0.0	0.0	286.8	0.0	0.0	0.0	0.0	103,372.1
B. Utilization Zone								
B.1 Production Forest*	0.0	2,196.5	0.0	0.0	250.6	0.0	0.0	133,704.0
B.2 Agriculture								
B.2.1 Wetland paddy field	20,221.0	3,525.4	2,162.0	515.3	1,683.9	277.3	293.0	315,635.5
B.2.2 Dryland upland field	19,629.5	0.0	1,198.0	535.7	1,269.6	76.0	1,685.4	168,495.8
B.3 Estate Crop	0.0	3,443.8	1,800.7	0.0	243.9	0.0	0.0	154,097.3
B.4 Fish Pond	14,661.1	0.0	0.0	0.0	0.0	0.0	1,037.5	15,758.6
B.5 Residential / Industrial								
B.5.1 Residential	12,866.0	1,588.7	4,278.1	1,330.0	2,214.0	990.0	26,189.0	210,496.1
B.5.2 Industrial	4,088.4	54.7	1,280.1	199.9	261.6	303.2	3,260.1	23,783.9
Swamp / Lake / Reservoir	13.0	0.0	0.0	0.0	0.0	0.0	276.0	2,087.0
Miscellaneous	0.0	4,301.6	0.0	676.8	416.4	0.0	0.0	20,064.1
Regency / City Total	71,479.0	20,280.0	11,005.7	3,257.7	6,340/0	1,646.5	32,741.0	1,352,479.0

Note: *; Including community forest
Source: BBWS Brantas



Source: Rencana Tata Ruang Wilayah Provinsi Jawa Timur 2011-2031

Figure D2.1.2 Zoning of Development Region in Brantas River Basin

D2.2 Sustainable Preservation of Agricultural Land

D2.2.1 Sustainable Food Agricultural Land

The agriculture sector in Indonesia still considerably contributes to the national economy though absorption of a large workforce and the national food security through sustainable food supply to the people. However, the most fundamental problem of the agricultural sector is the reduction of productive farm land year by year due to a marked conversion to other purposes throughout the country. To cope with such serious situation, the Government and the Parliament enforced Law No.41/2009 concerning Sustainable Food Agricultural Land (Lahan Pertanian Pangan Berkelanjutan, hereinafter called "LP2B"). This law is expected to be able to restrain the conversion rate of paddy fields, especially technical irrigation areas and thereby to sustain the national food security.

The mandate of the law has been entrusted to local governments in formulating their spatial plans such as RTRW and RDTR. In BAPPENAS's evaluation report on the implementation of LP2B (Evaluasi Implementasi Kebijakan LP2B, 2015), it is pointed that the local governments have carried out only two aspects such as planning and determination of LP2B, and in some cases reserved land has not been placed in RDTR.

D2.2.2 Planning and Determination LP2B in Brantas River Basin

In the East Java RTRW, the area of LP2B for wetland and dryland in each Regency/ City is presented. The total LP2B area determined in the East Java Province is 802,357.9 ha for wetland and 215,191.8 ha for dryland, accounting for 83.8% of the wetland paddy field zone and 25.3 % of the dryland upland crop field/ home garden zone, respectively.

Table D2.2.1 shows wetland area-wise comparison of LP2B, RTRW, design area of registered surface irrigation schemes and existing irrigated area. As shown in this Table, there exist reversal cases on regency/ city basis between the LP2B and RTRW areas as well as between the RTRW and surface water irrigation scheme design areas. The LP2B areas of 15 Regencies and Cities covering the Brantas River basin account for 30.8% of wetland and 20.2% of dryland in the East Java Province.

Table D2.2.1 Area-wise Comparison of Defined Components in Brantas River Basin

Regency (R) / City (C)	Wetland Paddy Field Area				Dryland Upland Field Area		
	LP2B	RTRW	Design	Actual	LP2B	RTRW	Actual
	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)
Batu C.	1,757	3,525	2,435	474	0	0	3,323
Malang R.	33,110	56,520	47,282	34,641	12,778	40,763	96,544
Malang C.	0	2,162	2,150	865	0	1,198	1,608
Blitar R.	27,599	45,237	31,773	27,843	805	19,748	44,924
Blitar C.	677	515	1,384	1,097	677	536	35
Tulungagung R.	20,000	14,600	25,717	23,454	6,000	14,453	33,985
Trenggalek R.	8,639	16,500	11,602	11,049	4,146	9,817	25,440
Kediri R.	40,865	48,361	48,574	37,866	1,426	21,836	25,579
Kediri C.	500	1,684	2,328	1,005	0	1,270	551
Nganjuk R.	34,777	31,461	39,923	37,212	16,854	14,591	16,976
Jombang R.	39,876	44,279	48,029	37,235	800	18,399	10,487
Mojokerto R.	27,535	30,000	30,889	26,777	0	4,496	8,703
Mojokerto C.	104	277	633	511	0	76	125
Sidoarjo R.	12,206	20,221	21,884	17,517	0	19,629	85
Surabaya C.	0	293	0	0	0	1,685	1,622
Total	247,645	315,635	314,603	257,546	43,486	168,496	269,987

Source: JICA Project Team 2

D2.2.3 Selection of Surface Water Irrigation Schemes within LP2B Area

For projecting the future land use condition in the Brantas River basin, it should be considered to put the top priority over sustaining technically full-functioned surface water irrigation schemes with a larger size of command area. In this regard, the target wetland paddy field area of LP2B for 2031 should be maintained up to 2050 aiming to play as the main supplier of staple food to Indonesian people. Also, it is indispensable that all the target surface water irrigation schemes should be fully functionable as originally designed.

In selecting surface water irrigation schemes on the design area basis in each Regency/ City within the LP2B area,

the following steps are set up:

- Step-1 to select all the registered schemes managed by BBWS Brantas and other schemes diverting irrigation water from the main stream of the Brantas River;
- Step-2 to select all the registered schemes managed by the East Java Provincial Government;
- Step-3 to select four new schemes listed up in POLA and Review RENCANA;
- Step-4 to select the registered schemes managed by local governments of Regency/ City within the remaining LP2B areas after selecting schemes in Step-1 to Step-3;
- In principle, the minimum size of scheme in Step-4 is 100 ha. If the remaining LP2B is available, the minimum size is to lower accordingly; and
- When the accumulated total area of schemes exceeds over the limit of LP2B area in any step, skip the next step,

Table D2.2.2 shows the list of registered surface water irrigation schemes with design irrigation area selected within the LP2B area in each Regency/ City. Table D2.2.3 gives the summary of selection.

Table D2.2.2 List of Irrigation Schemes Selected within LP2B Area in Brantas River Basin

Regency & City / Step	Scheme Number Main (nos.)	Scheme Number Sub (nos.)	Scheme Area *LP2B* / Design (ha)	Scheme Name & Adjusted Design Area to LP2B
Batu City		*LP2B area 1,757 ha, while existing schemes in Step-2 and Step-4 (Design area over 40 ha) total 1,876 ha*		
Step-2			328	*D.I. Kalilanang (214 ha), D.I. Ngukir (114 ha)*
Step-4			1,548	D.I. Prambatan (492 ha), D.I. Gedang Klutuk (196 ha), D.I. Sarem (139 ha), D.I. Sbr. Beji I (110 ha), D.I. Sbr. Kalisusuh (110 ha), D.I. Sbr. Jrangjero (102 ha), D.I. Sbr. Jeding (91 ha), D.I. Sbr. Selayur (63 ha), D.I. Sbr.Gemulo (57 ha), D.I. Torong Sisir (51 ha), D.I. Sbr. Ngukir Meranak II (49 ha), D.I. Sbr. Trong Dadap I (48 ha), D.I. Sbr. Sumberan (40 ha)
Malang Regency		*LP2B area 33,110 ha, while existing and new schemes in Step-1, Step-2, Step-3 and Step-4 (Design area over 100 ha) total 33,495 ha*		
Step-1			8,771	D.I. IS Kedung Kandang (4,573 ha), D.I. Molek (3,883 ha), *D.I.Siman (315 ha)*
Step-2			3,215	D.I. Kadalpang (1,106 ha), D.I. Pakis (723 ha), D.I. Kali Metro (482 ha), D.I. Kalilanang (243 ha, D.I. Ngukir (168 ha), D.I. Bodo (97 ha), D.I. Urung-Urung (58 ha), D.I. Losawi (37 ha), D.I. Sembur Turus (19 ha), D.I. Sumber Tekik (15 ha), D.I. Sembur Turus (15 ha), *D.I. Turi (54 ha), D.I.Bakaran (53 ha), D.I. Sedudut (41 ha), D.I. Peniwen (28 ha), D.I. Sengkaling Kanan (21 ha), D.I. Sengkaling Kiri (18 ha), D.I. Podokaton (15 ha)*, *D.I. Kajar II A (10 ha)*, *D.I. Kebalon (10 ha), D.I. Trimo Semut (2 ha),*
Step-3			2,449	D.I. Jaruma I & II (2,449 ha)
Step-4			19,060	D.I. Sonosan (801 ha), D.I. Tumpang (614 ha), D.I. Gajahlonggong (478 ha), D.I. Sumberwuni (421 ha), D.I. Pidek (414 ha), D.I. Golek I (411 ha), D.I. Karanganyar (404 ha), D.I. Sumber Bureng I (367 ha),D.I. Sumber Bureng III (355 ha), D.I. Jarman II (349 ha), D.I. Ngawonggo (327 ha), D.I. Kramat (321 ha), D.I. Dukuh (294 ha), D.I. Mogal (291 ha), D.I. Plandi (265 ha), D.I. Segaran (260 ha), D.I. Kali Lumbangsan (252 ha), D.I. Jarman I (251 ha), D.I. Pasir (239 ha), D.I. Kali Manjing (234 ha), D.I. Gedok (234 ha), D.I. Ngajum (231 ha), D.I. Sumber Jambe (231 ha), D.I. Paron (225 ha), D.I. Karangjambe (224 ha), D.I. Mendalanwangl (220 ha), D.I. Sember Pantal (219 ha), D.I. Belung (219 ha), D.I. Mangunrejo (207 ha), D.I. Bulung I (202 ha), D.I. Pamolan (200 ha), D.I. Sumberawan I (200 ha), D.I. Akir (194 ha), D.I. Kedungbanteng (194 ha), D.I. Sumber Umbuhan (190 ha), D.I. Klampok III (183 ha), D.I. Tawangrejoni (179 ha), D.I. Sekaran (178 ha), D.I. Urek-Urek (178 ha), D.I. Dawuhan (177 ha), D.I. Sepanjang (177 ha), D.I. Peniwen (173

Regency & City / Step	Scheme Number Main (nos.)	Sub (nos.)	Scheme Area *LP2B* / Design (ha)	Scheme Name & Adjusted Design Area to LP2B
				ha), D.I. Talok (176 ha), D.I. Sumber Bureng II (172 ha), D.I. Wadung (172 ha), D.I. Rembun (166 ha), D.I. Pucangsongo (163 ha), D.I. Sumber Bening (157 ha), D.I. Pringo (157 ha), D.I. Bambang (152 ha), D.I. Kasembon (147 ha), D.I. Sumber Kedungkandang (143 ha), D.I. Wajak II (143 ha), D.I. Wajak I (139 ha), D.I. Sukoraharjo III (139 ha), D.I. Sumber Kasri (138 ha), D.I. Putat (136 ha), D.I. Luring (136 ha), D.I. Ubaran (135 ha), D.I. Tun (135 ha), D.I. Sumber Puring (133 ha), D.I. Jeru (131 ha), D.I. Donomulyo III (129 ha). D.I. Aran-Aran (129 ha), D.I. Pateguhan (128 ha), D.I. Purworejo I (128 ha), D.I. Sumber Buntu (127 ha), D.I. Melikan (126 ha), D.I. Singgahan (126 ha), D.I. Mulyosari (125 ha), D.I. Candol (122 ha), D.I. Sumber Buntung (120 ha), D.I. Pandanrejo I (117 ha), D.I. Pagelaran (114 ha), D.I. Ngambrek (113 ha), D.I. Arjosari (113 ha), D.I. Sumber Pakel (113 ha), D.I. Gejed (112 ha), D.I. Ngadirejo (111 ha), D.I. Sumber Kajaran (111 ha), D.I. Kenongo (110 ha), D.I. Mojosari (109 ha), D.I. Sumber Lebak (109 ha), D.I. Sumber Pandanrejo (109 ha), D.I. Sumber Genlong II (107 ha), D.I. Sumber Wedus (106 ha), D.I. Bangelan (105 ha), D.I. Paras (105 ha), D.I. Gombong II (105 ha), D.I. Talangsuko (104 ha), D.I. Toyomarto II (102 ha), D.I. Donomulyo II (100 ha), D.I. Kromengan (100 ha), D.I. Purworejo II (100 ha), D.I. Sumber Gedangan (100 ha), D.I. Sumber Sari (100 ha), D.I. Sumber Sih (100 ha)
Malang City		*LP2B area 0 ha, while existing schemes in Step-1 and Step-2 total 1,874 ha*		
Step-1			587	*D.I. IS Kedung Kandang <587 ha>*
Step-2			1,287	D.I. Sengkaling Kiri (439 ha), D.I. Sengkaling Kanan (172 ha), D.I. Kebalon (97 ha), D.I. Bakalan (95 ha), D.I. Turi (65 ha), D.I. Podokaton (55 ha), D.I. Trimo Semut (44 ha), D.I. Sedudut (41 ha), D.I. Peniwen (37 ha), D.I. Kajar II A (10 ha), *D.I. Kadalpang (106 ha), D.I. Bodo (59 ha), D.I. Kali Metro (45 ha)), D.I. Sembur Turus (13 ha), D.I. Pakis (3 ha), D.I. Urung-Urung (3 ha), D.I. Losawi (2 ha), D.I. Sumber Tekik (1 ha),*
Blitar Regency		*LP2B area 27,599 ha, while existing schemes in Step-1, Step-2 and Step-4 (Design area over 25 ha) total 27,634 ha*		
Step-1			1,637	*D.I. Lodoyo (1,637 ha)*
Step-2			2,163	D.I. Derman (1,763 ha), D.I. Kaliboto (157 ha), D.I. Jatinom (51 ha), D.I. Rembang (33 ha), *D.I. Jaten Termas (34 ha)*, *D.I. Sukorame (33 ha)*, *D.I. Sawahan (18 ha)*, *D.I. Sumber Tulung (14 ha), D.I. Plosotengah (13 ha), D.I. Sumber Berjo (13 ha), D.I. Ngrebo (10 ha), D.I. Jempor (2 ha)*, *D.I. Tambakrejo (2 ha),*
Step-4			23,834	D.I. Menjanrigankalung II (744 ha), D.I. Mangunari II (715 ha), D.I. Slemanan (583 ha), D.I. Bening (577 ha), D.I. Gadungan (516 ha), D.I. Kedung Cabak (387 ha), D.I. Popoh (370 ha), D.I. Bajang A (322 ha), D.I. Pupus (298 ha), D.I. Kalimanis I (268 ha),), D.I. Gajah (250 ha), D.I. Jumbleng II C (246 ha), D.I. Suru Kn (232 ha), D.I. Bakung (230 ha), D.I. Kesamben (219 ha), D.I. Tejo (218 ha), D.I. Karangrejo (217 ha), D.I. Sbr. Luweng (211 ha), D.I. Kaweron (195 ha), D.I. Semanding & II (195 ha), D.I. Laharan I & II (194 ha), D.I. Boro I (192 ha), D.I. Selopuro (192 ha), D.I. Putat (190 ha), D.I. Sukosan I & II (188 ha), D.I. Ngrendang I to III (185 ha), D.I. Jamewangi (184 ha), D.I. Tiaji (172 ha), D.I. Jarangan (171 ha), D.I. Purworejo, A & B (157 ha), D.I. Besuki (155 ha), D.I. Dadaplangu (155 ha), D.I. Ngasem, I & II (155 ha), D.I. Tawing II (151 ha), D.I. Bendosewu (151 ha), D.I. Sumbersari I (148 ha D.I. Doko (147 ha), D.I. Brintik (145 ha), D.I. Dawungtepas Kn/Kr (144 ha), D.I. Gading (144 ha), D.I. Krenceng I to V (144 ha), D.I. Kunir (143 ha). D.I. Sbr. Petung (137 ha), D.I. Bence Suren (133 ha), D.I. Garum (133 ha), D.I. Sbr. Blonyo (131 ha), D.I. Beridorejo I & II (131 ha), D.I. Olak-Alen (130 ha), D.I. Gogolatar (129 ha), D.I. Ampelgading I & II (129 ha), D.I. Banjarsari I to III (127 ha), D.I. Tapak I to IV (126 ha), D.I. Pucungsari I to III (124 ha), D.I. Maguan A to D (124 ha), D.I. Sumberjo (123 ha), D.I. Resapombo I & III (121 ha), D.I. Sbr. Suwito (119 ha), D.I. Karanggondang, I & II (118 ha), D.I. Ngadirejo I & II (117 ha),D.I. Temenggungan (116 ha), D.I. Cepoko (116 ha), D.I. Klampok I & II (112 ha), D.I. Kluwih Bajang II to V (110 ha), D.I. Kuningan (109 ha), D.I. Tawangsari I & II (107 ha), D.I. Rembang II & III (106 ha), D.I. S. Jambe (105 ha), D.I. Karangbendo, I & II (105 ha), D.I. Mangkurejo (103 ha), D.I. Kd. Puring I & II (101 ha), D.I. Babadan (100 ha), D.I. Jumbleng II B & II D (101 ha), D.I. Jumbleng I A, II & II A (100 ha), D.I. Jambon (100 ha), D.I. Tawang, I & II (100 ha), D.I. Potro I & II (99 ha), D.I. Kemloko I (99 ha), D.I. Kemloko II (99 ha), D.I. Sumber II & IV (97 ha), D.I. Petangi (97 ha), D.I. Krakat I to III (97 ha), D.I. Salam (96 ha), D.I. Kajar A to C (94 ha), D.I. Kerjen I to III (94 ha), D.I. Sumberaguno, I & IV (93 ha), D.I. Nyunyur I & II (91 ha), D.I. Glondong I to IV (90 ha), D.I. Bendo & I to IV (90 ha), D.I. Bacem I to III (89 ha), D.I. Sbr. Maron (89 ha), D.I. Sbr. Gempolan (89 ha), D.I. Pupus Kiri (89 ha), D.I. Sbr. Gempolan (89 ha), D.I. Cangkring (88 ha), D.I. Krenceng (86 ha), D.I. Kupu & I (86 ha), D.I. Karangsono I (85 ha), D.I. Sawahan (85 ha), D.I. Sumber Jaran (84 ha), D.I. Jajar (82 ha), D.I. Mukmin (82 ha), D.I. Sbr. Kr. Sono II & III (80 ha), D.I. Pengkol (80 ha), D.I. Sbr. Kerjen (79 ha),

Regency & City / Step	Scheme Number Main (nos.)	Scheme Number Sub (nos.)	Scheme Area *LP2B* / Design (ha)	Scheme Name & Adjusted Design Area to LP2B
				D.I. Wonorejo (78 ha), D.I. Tingal (74 ha), D.I. Sumber Jambedawa (74 ha), D.I. Bendelonje (72 ha), D.I. Bulusari (72 ha), D.I. Sbr. Tanjung (72 ha), D.I. Barek Kn/Kr (71 ha), D.I. Sbr. Onje (70 ha), D.I. Sbr. Dandang (69 ha), D.I. Centong (67 ha), D.I. Dam Satrio (65 ha), D.I. Jatikeplak (65 ha), D.I. Jumbleng II E (65 ha), D.I. Kajaran (65 ha), D.I. Baos (63 ha), D.I. Sambong (62 ha), D.I. Coban '62 ha), D.I. Jirak Kerep (60 ha), D.I. Judel (60 ha), D.I. Manukan (60 ha), D.I. Jagoan (59 ha), D.I. Sawentar A (58 ha), D.I. Banyu Urip (57 ha), D.I. Dermosari (57 ha), D.I. Kebonduren (57 ha), D.I. Ngaglik (56 ha), D.I. Banjarjo (55 ha), D.I. Dawuhan (55 ha), D.I. Sbr. Tambakboyo (55 ha), D.I. Papungan (54 ha), D.I. Bendosri (53 ha), D.I. Purwoasri III (53 ha), D.I. Ngambak (52 ha), D.I. Butun (51 ha), D.I. Dayu (51 ha), D. I. Jimbe (51 ha), D.I. Tawangbrak (51 ha), D.I. Suwaru (51 ha), D.I. Sbr. Banyu Urip (51 ha), D.I. Satreyan (51 ha), D.I. Bangsri (50 ha), D.I. Dam Banggle (50 ha), D.I. Jatitengah (50 ha), D.I. Kotes Mlalo (50 ha), D.I. Sbr. Aren (50 ha), D.I. Rondokuning (50 ha), D.I. Kotes Mlalo (50 ha), D.I. Tawing I (50 ha), D.I. Sukorejo (50 ha), D.I. Jondolo (48 ha), D.I. Sbr. Ngaringan (48 ha), D.I. Sumber Ploso (48 ha), D.I. Ngampel (47 ha), D.I. Patilaler (47 ha), D.I. Togogan I (47 ha), D.I. Sbr. Sumberingin (46 ha), D.I. Umbul mawar (46 ha), D.I. Combong (45 ha), D.I. Ngrawan (45 ha), D.I. Sesek (45 ha), D.I. Kebon Agung (44 ha), D.I. Sbr. Kotes (43 ha), D.I. Temas (43 ha), D.I. Slumbung III (43 ha), D.I. Sawentar I (43 ha), D.I. Ba;ong (43 ha), D.I. Nambaan (42 ha), D.I. Nglegok (42 ha), D.I. Pehpulo (42 ha), D.I. Jambepawon (41 ha), D.I. Pancir (41 ha), D.I. Sbr. Jetis (41 ha), D.I. Sendung (41 ha), D.I. Precel I (41 ha), D.T. Bajang II (40 ha), D.I. Boro II (40 ha), D.I. Karangtanjung (40 ha), D.I. Purworejo C Kn/Kr (40 ha), D.I. Sbr. Tangkil (40 ha), D.I. Serang II (40 ha), D.I. Jenang (39 ha), D.I. Karanganom (39 ha), D.I. Sbr. Ronggo (38 ha), D.I. Sumber Ulo (38 ha), D.I. Kumbo Kamo (38 ha), D.I. Bodo (37 ha), D.I. Sbr. Glodog I (37 ha), D.I. Sbr. Klampok I (37 ha), D.I. Sumbersari (37 ha), D.I. Jeruk (36 ha), D.I. Klepon (36 ha), D.I. Kuwut (36 ha), D.I. Sbr. Pojok Kidul (36 ha), D.I. Sumber Agung I (36 ha), D.I. Bebekan I (36 ha), D.I. Kruwuk II (36 ha), D.I. Penataran (36 ha), D.I. Belah (35 ha), D.I. Luweng (35 ha), D.I. Subontro I (35 ha), D.I. Sumber Mundu (35 ha), D.I. Wonosari (35 ha), D.I. Rejosari (35 ha), D.I. Gatel 34 ha), D.I. Jaten (34 ha), D.I. Karanggayam (34 ha), D.I. Sembon (34 ha), D.I. Bence II (34 ha), D.I. Kandangan (33 ha), D.I. Sumber Glodog (33 ha), D.I. Sumber Sanan (33 ha), D.I. Talun I (33 ha), D.I. Ngasem II (33 ha), D.I. Sempol II (33 ha), D.I. Sanandayu (32 ha), D.I. Sumber Kendi (32 ha), D.I. Sumber Kuntulan (32 ha), D.I. Sumber Urip I (32 ha), D.I. Dam Pakel (31 ha), D.I. Dulroji (31 ha), D.I. Lodeng (31 ha), D.I. Sukosewu (31 ha), D.I. Sbr. Asri (31 ha), D.I. Bintang IA (31 ha), D.I. Birowo (30 ha), D.I. Beru (30 ha), D.I. Kotes Tumpang (30 ha), D.I. Sbr. Bongkang (30 ha), D.I. Serut (30 ha), D.I. Sumber Bacin (30 ha), D.I. Kembangan I (30 ha), D.I. Duren A (30 ha), D.I. Ngoran II (30 ha), D.I. Barakan IV (30 ha), D.I. Gembong (29 ha), D.I. Kedawung II (29 ha), D.I. Kotes II (29 ha), D.I. Sumberingin (29 ha), D.I. Banjarmlau (28 ha), D.I. Bmn IV (28 ha), D.I. Mojo (28 ha), D.I. Pojek I (28 ha), D.I. S. Urung-urung (28 ha), D.I. Sbr. Ponggok (28 ha), D.I. Banjar Sari (27 ha), D.I. Celeng I (27 ha), D.I. Dam Ngrembat (27 ha), D.I. Glondong I (27 ha), D.I. Ilyas (27 ha), D.I. Loding, II (27 ha), D.I. Mojorejo I (27 ha), D.I. Ngrobyong (27 ha), D.I. Cupon II (26 ha), D.I. Delajat III (26 ha), D.I. Kamulan I (26 ha), D. I. Timang (26 ha), D.I. Wonokraman (26 ha), D.I. Bulu I (25 ha), D.I. Celeng II (25 ha), D.I. Doyo (25 ha), D.I. Jeblok (25 ha), D.i. Palem (25 ha), D.I. Pokah (25 ha), D.I. Sbr. Gayam (25 ha), D.I. Sbr. Pojok Lor (25 ha), D.I. Tumpang (25 ha), D.I. Sumber Dandang (25 ha)
Blitar City		*LP2B area 677 ha, while existing schemes in Step-2 and Step-4 (Design area over 50 ha) total 778 ha*		
Step-2			333	D.I. Sawahan (64 ha), D.I. Jempor (52 ha), D.I. Ngrebo (52 ha), D.I. Plosotengah (38 ha), D.I. Sukorame (36 ha), D.I. Sumber Berjo (32 ha), D.I. Sumber Tulung (24 ha), D.I. Tambakrejo (21 ha), *D.I. Rembang (9 ha)*, *D.I. Jatinom (5 ha)*,
Step-4			445	D.I. Sumber Jaran (84 ha), D.I. Tanjungsari (75 ha), D.I. Sbr. Lumbu (74 ha), D.I. Bd. Bangsongan (56 ha), D. I. Bd. Pangkol (55 ha), D.I. Ploso Tengah (51 ha), D.I. Karangsari (50 ha)
Tulungagung Reg.		*LP2B area 20,000 ha, while existing schemes in Step-1, Step-2 and Step-4 (Design area over 100 ha) total 21,211 ha*		
Step-1			10,580	D.I. Lodoyo (10,580 ha)
Step-2			4,915	D.I. Widoro (1,535 ha), D.I. Sbr. Gayam (1,461 ha), D.I. Gelang (1,378 ha), D.I. Paingan (533 ha), *D.I. Kaliboto (8 ha)*
Step-4			5,716	D.I. Pehoyot (761 ha), D.I. Kedung Wilud (486 ha), D.I. Garon (473 ha), D.I. Keboiren (344 ha), D.I. Blader (286 ha), D.I. Bendogilir (256 ha), D.I. Dadapan (238 ha), D.I. Dlimo (223 ha), D.I. Selotinatah (212) ha, D.I. Karangtalun (207 ha), D.I. Turi (169 ha), D.I. Ampelgading (169 ha), D.I. Subi II (168 ha), D.I. Kd. BantaL I (165 ha), D.I. Kd. Bebek (155 ha), D.I. Ngledok II (150 ha), D.I.

Regency & City / Step	Scheme Number		Scheme Area	Scheme Name & Adjusted Design Area to LP2B
	Main (nos.)	Sub (nos.)	*LP2B* / Design (ha)	
				Sawo (146 ha), D.I. Kluwih (142 ha), D.I. Peksi (137 ha), D.I. Ngelo I (135 ha), D.I. Lemamah Duwur I (128 ha), D.I. Cari (124 ha), D.I. Sbr. Bedalem (117 ha), D.I. Jirak (110 ha), D.I. Kedung Pucan II (108 ha), D.I. Cluwok (107 ha),
Trenggalek Regency	*LP2B area 8,639 ha, while existing and new schemes in Step-2 Step-3 and Step-4 (Design area over 40 ha) total 8,764 ha*			
Step-2			1,894	*D.I. Widoro (1,411 ha), D.I. Sbr. Gayam (465 ha), D.I. Paingan (18 ha)*
Step-3			1,185	D.I. Ngasinan (1,185 ha)
Step-4			5,685	D.I. Bagong (854 ha), D.I. Nglongah (477 ha), D.I. Ngepeh (345 ha), D.I. Jabung (335 ha), D.I. Prambon (318 ha), D.I. Suruh (250 ha), D.I. Kedung Kenteng (211 ha), D.I. Bugelan (178 ha), D.I. Jurug Plantir (168 ha), D.I. Pucung I to V (116 ha), D.I. Dalang Turu (104 ha), D.I. Ponggok (101 ha), D.I. Klumit I & II (95 ha), D.I. Kipik (94 ha), D.I. Jelok I & II (93 ha), D.I. Maron (92 ha), D.I. Balang (83 ha), D.I. Tawing (83 ha), D.I. Singgahan (82 ha), D.I. Kedung Gori Kana & Kiri (80 ha), D.I. Kedung Banteng (79 ha), D.I. Gembes (78 ha), D.I. Kali Mati Kanan & Kiri (75 ha), D.I. Tumpak Kendit (74 ha), D.I. Kedung Moro (73 ha), D.I. Ngasem (70 ha), D.I. Bangunsari (69 ha), D.I. Pakuran (69 ha), D.I. Waru Kn (66 ha), D.I. Cangkring (60 ha), D.I. Bubk (58 ha), D.I. Darungan (55 ha), D.I. Kedung Kotak (55 ha), D.I. Dowo I & II (55 ha), D.I. Tumpak Ajaran I & II (53 ha), D.I. Waringin (52 ha), D.I. Kedung Bendo (51 ha), D.I. Ngaliran I & II (48 ha), D.I. Songo (47 ha), D.I. Winong (46 ha), D. I. Manggis (45 ha), D.I. Banyunget I & II (44 ha), D.I. Pringapus (42 ha), D.I. Watulimas (41 ha), D,I, Pager Ukir I & II (41 ha), D.I. Semarangan (40 ha), D.I. Sukun I & II (40 ha)
Kediri Regency	*LP2B area 40,865 ha, while existing schemes in Step-1, Step-2 and Step-4 (Design area over 100 ha) total 41,136 ha*			
Step-1			9,179	D.I. Mrican Kiri <375 ha>, D.I. Mrican Kanan (3,952 ha), *D.I. Siman (4,852 ha)*
Step-2			4,183	D.I. Ketandan (1,637 ha), D.I. Pohblembem (1,086 ha), D.I. Jaten Termas (427 ha), D.I. Ngablak (209 ha), D.I. Kembangan (196 ha), D.I. Klitik Bendokrosok (186 ha), D.I. Klitih Kresek (75 ha), D.I. Bujei (74 ha), D.I. Ngaglik (63 ha), D.I. Pesantren (49 ha), *D.I. Gunting (171 ha)*, *D.I. Betis/Ngreco (10 ha)*
Step-4			27,774	D.I. Ampomangiran IV (530 ha), D.I. Kendal (512 ha), D.I. Ampomangiran VI (460 ha), D.I. Selodono II (429 ha), D.I. Badas (428 ha), D.I. Sidorawuh (394 ha), D.I. Galuhan (387 ha), D.I. Kromasan (387 ha), D.I. Ringinrejo (369 ha), D.I. Grogol (365 ha), D.I. Kamal (352 ha), D.I. Dungus (346 ha), D.I. Bangkok (307 ha), D.I. Petung (304 ha), D.I. Krandang (295 ha), D.I. Bolowono (291 ha), D.I. Ngino (281 ha), D.I. Tambakrejo (280 ha), D.I. Kaliboto (275 ha), D.I. Ampomangiran III (240 ha), D.I. Toyoaning (231 ha), D.I. Jantok (230 ha), D.I. Keling (222 ha), D.I. Bago (208 ha), D.I. Juranggeni (208 ha), D.I. Tarokan I (199 ha), D.I. Depok (197 ha), D.I. Mondokan (190 ha), D.I. Babaan (189 ha), D.I. Nglumpang (189 ha), D.I. Cema (186 ha), D.I. Sbr. Golek (178 ha), D.I. Tawangsari (178 ha), D.I. Karanganyar (174 ha), D.I. Genukrejo (173 ha), D.I. Lahargedok (172 ha), D.I. Bolo III (166 ha), D.I Nyawangan (165 ha), D.i. Tegalsari (165 ha), D.I. Suru (163 ha), D.I. Tulungrejo II (160 ha), D.I. Sambirejo (156 ha), D.I. Nepan V (154 ha), D.I. Blaru (153 ha), D.I. Tulungrejo I (153 ha), D.I. Paron (152 ha), D.I. Jurang Panjang (151 ha), D.I. Krebet (150 ha), D.I. Wonosari (149 ha), D.I. Sukomoro (148 ha), D.I. Bungkul (144 ha), D.I. Muneringan (144 ha), D.I. Singopadu (143 ha), D.I. Sbr. Sukorambil (142 ha), D.I. Sbr. Buntung (140 ha), D.I. Sbr. Slumbung (139 ha), D.I. Ampomangiran V (137 ha), D.I. Kandangan (137 ha), D.I. Banaran (137 ha), D.I. Kunjang IV (132 ha), D.I. Wangkal Kerep II Kiri (132 ha), D.I. Dempok (131 ha), D.I. Sbr. Dlopo (131 ha), D.I. Bulupasar (130 ha), D.I. Ngletih (130 ha), D.I. Nambaan (128 ha), D.I. Guwo (127 ha), D.I. Balong Jambe (127 ha), D.I. Sbr. Sendang (125 ha), D.I. Ngawen (125 ha), D.I. Sbr. Mabah Kinjong (125 ha), D.I. Ampomangiran VII (123 ha), D.I. Joho (121 ha), D.I. Pojok (120 ha), D.I. Winong (120 ha), D.I. Sentul (119 ha), D.I. Sekoto (117 ha), D.I. Tugurejo (117 ha), D.I. Recosolo (114 ha), D.I. Sbr. Pawon (112 ha), D.I. Sbr. Kalirong (111 ah), D.I. Glatik 110 ha), D.I. Sumber Agung I (105 ha), D.I. Sobo (104 ha), D.I. Gading (104 ha), D.I. Nglangu III (104 ha), D.I. Sbr. Dendeng (103 ha), D.I. Sbr. Pule (102 ha), D.I. Kedung Pawon (102 ha), D.I. Krekah (102 ha), D.I. Tempurusari (102 ha), D.I. Bioro (101 ha), D.I. Sbr. Genuk (100 ha), D.I. Bumirejo (100 ha), D.I. Dedehan II (100 ha), D.I. Payak I (100 ha),
Kediri City	*LP2B area 500 ha, while existing schemes in Step-2 total 620 ha*			
Step-2			620	D.I. Gunting (198 ha), D.I. Batis/Ngreco (28 ha), *D.I. Klitik Bendokrosok (146 ha)*, *D.I. Kembangan (85 ha)*, *D.I. Bujel (39 ha), D.I. Ngablak (36 ha)*, *D.I. Ngaglik (35 ha), D.I. Klitih Kresek (33 ha), D.I. Pasantren (20 ha)*
Nganjuk Regency	*LP2B area 34,777 ha, while existing and new schemes in Step-1, Step-2, Step-3 and Step-4 (Design area over 100 ha) total 35,989 ha*			
Step-1			21,106	D.I. Mrican Kiri (12,354 ha), D.I. Waduk Bening (8,752 ha)

Regency & City / Step	Scheme Number		Scheme Area	Scheme Name & Adjusted Design Area to LP2B
	Main (nos.)	Sub (nos.)	*LP2B* / Design (ha)	
Step-2			3,866	D.I. Kedung Gent (1,470 ha), D.I. Bulakmojo (1,211 ha), D.I. Ngrambe (1.185 ha)
Step-3			700	D.I. Kedung Soko (700 ha)
Step-4			10,317	D.I. Mlilir (795 ha), D.I. Ketandan (757 ha), D.I. Dam Banaran (687 ha), D.I. Tretes (599 ha), D.I. Kapas (483 ha), D.I. Kedung Sengon (439 ha), D.I. Macanan (369 ha), D.I. Joso (364 ha), D.I. Tiripan (363 ha), D.I. Sbr. Agung (322 ha), D.I. Maguan (311 ha), D.I. Bedrek (298 ha), D.I, Tunglur (266 ha), D.I. Kalianjok (266 ha), D.I. Logawe (259 ha), D.I. Besuk (248 ha), D.I. Kramat (233 ha), D.I. Jetis (227 ha), D.I. Girirejo (213 ha), D.I. Kedung Kudi (183 ha), D.I. Sbr. Argomulyo (178 ha), D.I. Sumber Sono (162 ha), D.I. Gilis I (160 ha), D.I. Balongrejo (159 ha), D.I. Klali (158 ha), D.I. Sumber Kepuh (135 ha), D.I. Gilis I (135 ha), D.I. Perning (133 ha), D.I. Puh Salak (131 ha), D.I. Mencaro (130 ha), D.I. Pengkol (126 ha), D.I. Watulanang I (122 ha), D.I. Ngomben (122 ha), D.I. Sbr. Ngambak II (120 ha), D.I. Bodo (116 ha), D.I. Tirip (114 ha), D.I. Selopuro I (113 ha), D.I. Klonggean II (111 ha), D.I. Dokerso (109 ha), D.I. Sumber Kemin (104 ha)
Jomban Regency	*LP2B area 39,876 ha, while existing and new schemes in Step-1, Step-2, Step-3 and Step-4 (Design area over 100 ha) total 43,525 ha*			
Step-1			34,956	D.I. Jatimlerek (1,812 ha), D.I. Siman (17,893 ha), D.I. Mrican Kanan (13,660 ha), *D.I. Menturus (409 ha)*
Step-2			1,607	D.I. Slumbung (1,182 ha), D.I. Kejagan (211 ha), D.I. Kawaden (46 ha), D.I. Tawangsan (34 ha), *D.I. Memung (117 ha), D.I.Badas (17 ha),*
Step-3			800	D.I. Bareng (800 ha)
Step-4			6,162	D.I. W. Grojogan (781 ha), D.I. Tawangsari (520 ha), D.I. Penanggalan (418 ha), D.I. Pandean (385 ha), D.I. Johowinong (385 ha), D.I. Kabuh I (362 ha), D.I. Banjarejo (341 ha), D.I. Karangan IV (335 ha), D. I. Kulak I (305 ha), D.I. K. Bancang (280 ha), D.I. Mojowarno (229 ha), D.I. Kromon III (210 ha), D.I. Segitik (209 ha), D.I. Klak III (196 ha), D.I. Marmoyo VII (186 ha), D.I. Sembung (185 ha), D.I. Katemas II (182 ha), D.I. Made I (181 ha), D.I. Katemas I (180 ha), D.I. Bunder II (175 ha), D.I. Kabuh II (167 ha), D.I. Made II (166 ha), D.I. Bunder I (159 ha), D.I. Karangan IV (156 ha), D.I. Watu Mayung II (155 ha), D.I. W. Sumbergondang (150 ha), D.I. Balongsono (141 ha), D.I. Kedungsuruh (139 ha), D.I. Mundusewu (134 ha), D.I. Banjarejo (132 ha), D.I. Gedangan (126 ha), D.I. Mangir II (117 ha), D.I. Ngares I (117 ha), D.I. Memung I (110 ha), D.I. Memung II (110 ha), D.I. Wonoayu (105 ha), D.I. Kalibening (100 ha),
Mojokerto Regency	*LP2B area 27,535 ha, while existing schemes in Step-1, Step-2 and Step-4 (Design area over 30 ha) total 27,710 ha*			
Step-1			8,241	D.I. Menturus (3,223 ha), D.I. Padi Pomahan (4,256 ha), D.I. Jati Kulon (586 ha), *Delta Brantas (176 ha)*
Step-2			4,889	D.I. Candi Limo (1,911 ha), D.I Kromong II (1,055 ha), D.I. Penewon (780 ha), D.I. Merunun (544 ha), D.I. Subantoro (416 ha), *D.I. Kejagan (77 ha)*, *D.I. Sinoma (55 ha), Tawangsari (28 ha), D.I. Kawadern (23 ha)*
Step-4			14,580	D.I. Pehngaron (977 ha), D.I. Lebak Sumengko (915 ha), D.I. Pudaksan (831 ha), D.i. Wonokusumo (790 ha), D..I. Janjing (495 ha), D.I. Bacem (314 ha), D.I. Sbr. Candi Tikus (312 ha), D.I. Sekargadung (311 ha), D.I. Bendel (267 ha), D.I. Tekuk (246 ha), D.I. Ketidul (214 ha), D.I. Sumberkembar (198 ha), D.I. Kedungkutil (191 ha), D.I. Kedung Gempol (188 ha), D.I. Jatisari (187 ha), D.I. Gero II (181 ha), D.i. Unengan (175 ha), D.I. Or-Oro Jipang (159 ha), D.I. Gebangmalang (151 ha), D.I. Dlimo (149 ha), D.i. Sumbersari II (144 ha), D.i. Singopadu (142 ha), D.I. Mojolegi (140 ha), D.I. Curahmojo (139 ha), D.I. Selomalang (137 ha), D.I. Tempuran (137 ha), D.I. Lungdi (127 ha), D.I. Balonmasin II (121 ha), D.I. Sbr. Kepiting (121 ha), D.I. Kemiri Bawan (120 ha), D.I. Sidomulyo (113 ha), D.I. Mojojejer (111 ha), D.I. Tebuk (111 ha), D.I. Kedung Peluk (101 ha), D.I. Baraan (98 ha), D.I. Jolopeto (98 ha), D.I. Kemiri Alas (98 ha), D.I. Dosermo (97 ha), D.I. Kandangan (97 ha), D.I. Kebondalem (96 ha), D.I. Ngrayung I to III (94 ha), D.I. Tampingrejo (93 ha), D.I. Wonokoyo (92 ha), D.I. Sampang (90 ha), D. I. Bendorejo (89 ha), D.I. Sumberejo I & II (86 ha), D.I. Sbr. Sambikuning (82 ha), D.I. Clangap (80 ha), D.I. ketok (78 ha), D.I. Pendowo (78 ha), D.I. Ngungkung (76 ha), D.i. Sbr. Wungu (76 ha), D.I. Mojosongo Bawah (70 ha), D.I. Pulosari (70 ha), D.I. Teras (70 ha), D.I. Sbr. Punggul (69 ha), D.I. Patung (68 ha), D.I. Urung-Urung I & II (68 ha), D.I. Sumber Soko II (67 ha), D.I. Mojosarirejo I (67 ha), D.I. Sbr. Sidorejo (66 ha), D.I. Jeblokan (65 ha), D.I. Padusan 64 ha), D.I. Balong Kenongo (63 ha), D.I. Cepogo (62 ha), D.I. Gero I (61 ha), D.I. Karangasem I & II (60 ha), D.i. Waru Binatur (60 ha), D.I. Bajangan (57 ha), D.I. Talok (57 ha), D.I. Genengan (57 ha), D.I. Sbr. Kr. Tengah (57 ha), D.I. Sumbersan I & III (57 ha), D.I. Kupusari (56 ha), D.I. Sbr. Borang I & II (56 ha), D.I. Sbr. Getik II & III (56 ha), D.I. Randubango (55 ha), D.I. Baureno (54 ha), D.I. Kembangan (54 ha), D.I. Mantung (53 ha), D.I. Sbr. Petung (53 ha), D.I.

Regency & City / Step	Scheme Number		Scheme Area	Scheme Name & Adjusted Design Area to LP2B
	Main (nos.)	Sub (nos.)	*LP2B* / Design (ha)	
				Karangploso (52 ha), D.I. Trino (51 ha), D.I. Punggin (50 ha), D.I. Sbr. Coban I & II (50 ha), D.I. Kaliurip (49 ha), D.I. Sbr. Sindu (49 ha), D.I. Tumpangsari (49 ha), D.I. Karangsari (47 ha), D.I. Sembung (47 ha), D.i. Sumber Soko I (47 ha), D.I. Sudimoro (46 ha), D.I. Pikatan II (46 ha), D.I. Sbr. Baruk II (46 ha), D.I. Kanigoro (45 ha), D.I. Kuwangen (45 ha), D.I. Mojokembang I (45 ha), D.I. Bendungan (43 ha), D.I. Bringin (43 ha), D.I. Dukuh (43 ha), D.I. Jiyu (43 ha), D.I. Lebak II (43 ha), D.I. Sbr. Gelang (43 ha), D.I. Lebak (42 ha),D.I. Tinggar I (42 ha), D.I. Pekukuhan (41 ha), D.I. Sbr. Panji (41 ha), D.I. Jambu (40 ha), D.I. Trawas (40 ha), D.I. Mrasih (39 ha), D.I. Kesiman (38 ha), D.I. Salen (36 ha), D.I. Sbr. Karangri I (36 ha), D.I. Tun (36 ha), D.I. Sbr. Curah Landak (35 ha), D.I. Sukoanyar (35 ha), D.I. Sbr. Panjer II (35 ha), D.I. Gelonggongan (34 ha), D.I. Sukorejo (34 ha), D.I. Pekuwon (33 ha), D.I. Purwojati (33 ha), D.I. Sbr. Bendo Waru (33 ha), D.I. Sbr. Jedong (33 ha), D.I. Sbr. Renteng (33 ha), D.I. Jamirahari (32 ha), D.I. Ketapan (32 ha), D.I. Kuripan (32 ha), D.I. Mojogeneng (32 ha), D.I. Sukoanyar (32 ha), D.I. Kembang (31 ha), D.I. Kepuh Gunung (31 ha), D.I. Sbr. Semodo (31 ha), D.I. Sumberpandan (31 ha), D.I. Balongmasin I (30 ha), D.I. Mojoroto (30 ha), D.i. NGembeh (30 ha), D.i. Randegan (30 ha)
Mojokerto City	*LP2B area 104 ha, while existing schemes in Step-1 and Step-2 total 633 ha*			
Step-1			105	*D.I. Padi Pomahan (53 ha), D.I. Jati Kulon (52 ha)*
Step-2			528	D.I. Sinoman (238 ha), *D.I. Penewon (191 ha)*, *D.I. Subantoro (99 ha)*
Sidoarjo Regency	*LP2B area 12,206 ha, while existing scheme in Step-1 totals 17,766 ha*			
Step-1			17,766	D.I. Delta Brantas (17,766 ha)

Note: Scheme name and area written in Italic shows spread portion from the neighboring Regency or City.
Source: JICA Project Team 2

Table D2.2.3 Summary of Irrigation Scheme Selection in Brantas River Basin

Regency (R) / City (C)	LP2B Area (ha)	Number and Area through Step-wise Selection of Surface water Irrigation Schemes								
		Total	Step-1		Step-2		Step-3		Step-4	
		(ha)	(nos.)	(ha)	(nos.)	(ha)	(nos.)	(ha)	(nos.)	(ha)
Batu C.	1,757	1,876	0	0	1 (1)	328	0	0	13	1,548
Malang R.	33,110	33,495	2 (1)	8,771	11 (10)	3,215	1	2,449	97	19,060
Malang C.	0	1,874	(1)	587	10 (8)	1,287	0	0	0	0
Blitar R.	27,599	27,634	(1)	1,637	4 (9)	2,163	0	0	271	23,834
Blitar C.	677	778	0	0	8 (2)	333	0	0	7	445
Tulungagung R.	20,000	21,211	1 (0)	10,580	4 (1)	4,915	0	0	26	5,716
Trenggalek R.	8,639	8,764	0	0	(2)	1,894	1	1,185	47	5,685
Kediri R.	40,865	41,136	2 (1)	9,179	10 (2)	4,183	0	0	96	27,774
Kediri C.	500	620	0	0	2 (7)	620	0	0	0	0
Nganjuk R.	34,777	35,989	2 (0)	21,106	3 (0)	3,866	1	700	40	10,317
Jombang R.	39,876	43,525	3 (1)	34,956	4 (2)	1,607	1	800	37	6,162
Mojokerto R.	27,535	27,710	3 (1)	8,241	5 (4)	4,889	0	0	138	14,580
Mojokerto C.	104	633	(2)	105	1 (2)	528	0	0	0	0
Sidoarjo R.	12,206	17,766	1 (0)	17,766	0 (0)	0	0	0	0	0
Total	247,140	263,011	14 (8)	112,928	63 (50)	29,828	4	5,134	2.059	115,121

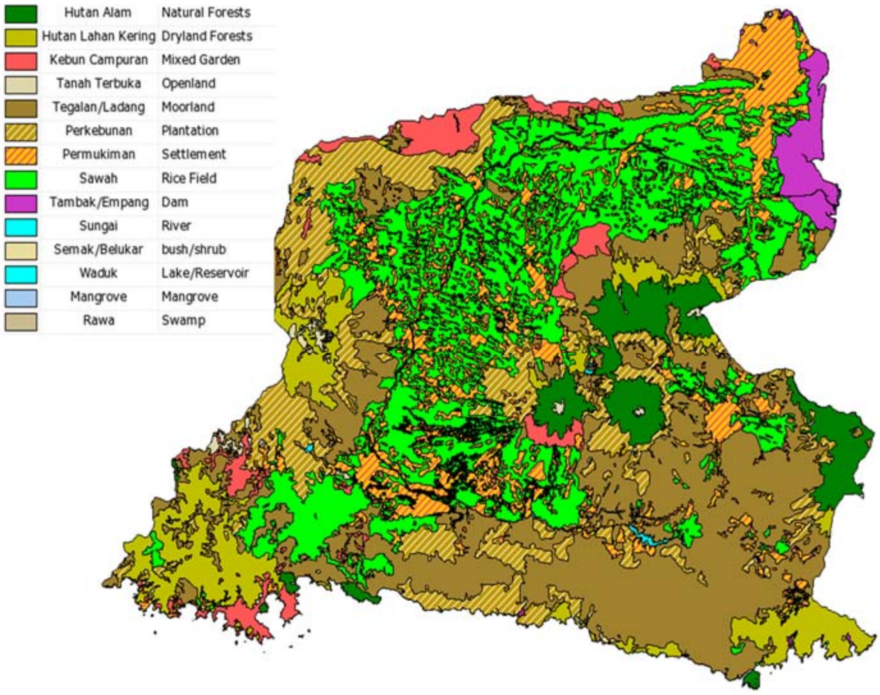
Note: Figure in parenthesis shows number of schemes spread from the neighboring Regency or City.
Source: JICA Project Team 2

As shown in Tables D2.2.2 and D2.2.3, the minimum size of selected surface water irrigation schemes within the upper limit of LP2B varies Regency by Regency. The size is 200 ha for Nganjuk Regency, 100 ha for Malang, Tulungagung, Kediri and Jombang Regencies, 40 ha for Treggalek Regency, 30 ha for Mojokerto Regency and 25 ha for Blitar Regency. Such situation reveals he difference of decision making strategies about the LP2B policy among local governments.

CHAPTER D3 LAND USE IN BRANTAS RIVER BASIN

D3.1 Present Land Use in Brantas River Basin

Present land use map in the Brantas River basin was prepared by referring to satellite image as depicted in Figure D3.1.1.



Source: JICA Project Team 1

Figure D3.1.1 Present Land Use Map in Brantas River Basin (Satellite Image)

Land use condition is compared between data as of 1994 and 2005 (BBWS Brantas) and satellite image as of 2012 is shown in Table D3.1.1. The land use map indicates that about 65% of land in the Brantas River basin is utilized for agricultural purpose and many farmers are engaging in food crop cultivation works.

Table D3.1.1 Present Land Use in Brantas River Basin

Classification	Land Use in 1994		Land Use in 2005		Land use in 2012*	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Natural Forest	117,600	8.35	109,730	7.79	71,675	6.00
Dry Land Forest					55,650	4.66
Bush/Shrub	69,040	4.90	64,550	4.58	675	0.06
Mangrove/ Swamp	2,430	0.17	2,690	0.19	50	0.01
Paddy Field	413,610	29.36	397,320	28.20	337,925	28.30
Upland Crop Field	327,010	23.21	322,880	22.92	273,875	22.93
Plantation (Estate crop field)					157,995	13.23
Mixed Garden	247,400	17.56	272,890	19.37	40,030	3.35
Grassland/ Fallow Land	17,360	1.23	19,300	1.37	6,700	0.56
Settlement (Residential Area)	179,750	12.76	181,550	12.89	225,050	18.85
Fishpond/ Pond	23,580	1.68	24,710	1.75	22,525	1.89
Lake/ Reservoir	11,010	0.78	13,170	0.94	1,825	0.15
River					175	0.01
Total	1,408,790	100.00	1,408,790	100.00	1,194,150	100.00

Note: Land use data in 2012 not including Surabaya River Basin area
Source: BBWS Brantas and JICA Project Team 1

D3.2 Future Land Use Plan in Brantas River Basin

In predicting the future land use in the Brantas River basin for 2050, the followings are referred to as basic data and making assumptions:

- Wet paddy field is to decrease annually by 0.4% until 2031 considering the planned area of land resources management zone set up in the Spatial Plan of East Java (RTRW Jawa Timur 2011-2031) as well as target area of the irrigated and the rain-fed paddy field by regency/ city in East Java Province for preserving sustainable food production base (LP2B) according to the instruction of the Ministry of Agriculture relevant to RTRW;
- Other categories of agricultural land use such as dry upland, and permanent estate crop planting area are not to change in their coverage;
- Residential and industrial areas are to increase by 1.5% up to 2031 and 0.8% afterward,
- Natural and man-made forest coverage rate is to be maintained at the same level for watershed conservation purpose, and
- Water surface areas (fish pond, farm pond, river, reservoir, inland swamp and tidal swamp) are to be kept at the present level.

The projected land use condition in the Brantas River basin for 2031 and 2050 is tabulated in Table D3.2.1.

Table D3.2.1 Projected Land Use in Brantas River Basin for 2031 and 2050

Land Use Category	2010 (ha)	Annual change	2031 (ha)	Annual change	2050 (ha)
Natural Forest	71,675	0.0%	71,675	0.0%	71,675
Dry Land Forest	55,650	0.0%	55,650	0.0%	55,650
Bush/Shrub	675	0.0%	675	0.0%	675
Mangrove	50	0.0%	50	0.0%	50
Plantation (Perennial crop field)	157,995	0.0%	157,995	0.0%	157,995
Paddy Field	337,925	-0.40%	309,600	0.0%	309,600
Upland Crop Field	273,875	0.0%	273,875	0.0%	273,875
Fallow Land	6,700	0.0%	6,700	-3.1%	2,530
Mixed Garden	40,030	0.17%	41,465	0.0%	41,465
Residential/ Industrial Area	225,050	0.57%	251,940	0.08%	256,110
Fishpond/Pond	22,525	0.0%	22,525	0.0%	22,525
Lake/Reservoir	1,825	0.0%	1,825	0.0%	1,825
River	175	0.0%	175	0.0%	175
Total	1,194,150		1,194,150		1,194,150

Source: JICA Project Team 2

PART 3 MUSI RIVER BASIN

CHAPTER D4 SPATIAL PLAN OF MUSI RIVER BASIN

D4.1 Spatial Plan of South Sumatra Province

D4.1.1 Spatial Plan for 2036 in South Sumatra Province

BAPPEDA of South Sumatra Province prepared provincial spatial plan (Provincial Rule No.11/2016 concerning Rencana Tata Ruang Wilayah Provinsi Sumatera Selatan Tahun 2016-2036, hereinafter called "RTRW"). In line with the Ministerial Ordinance No.20/PRT/M/2011 concerning guidance for development of Detailed Spatial Plan (RDTR), BAPPEDA revised its draft plan. The purpose of the South Sumatra RTRW 2016-2036 is determined based on the vision and mission of South Sumatra regional medium-term development plan (Rencana Pembangnan Jangka Menengah Provinsi Sumatera Selatan, hereinafter called "RPJMP") 2005-2025.

D4.1.2 Spatial Structural Plan of RTRW South Sumatra 2016-2036

The objective, policies and strategies of RTRW spatial structural plan cover urban system and transportation, energy. telecommunication, water resources and other network systems. In case of the water resources network system, the structural plan is generally described compared with other systems and targets river, dam/ reservoir, irrigation and surface water as shown in Table D4.1.1.

Table D4.1.1 Spatial Structural Plan on Water Resources Network System in South Sumatra

Target Item	Strategy	Target River/ Area
River	Development and/ or management of rivers for the water resources network system is prioritized for large river networks in the Province, intending the fulfillment of raw, industrial and irrigation water.	Musi, Banyuasin, Batang Harileko, Ogan, Enim, Kelingi, Kikim, Komering, Lematang, Lintang Kana, Mesuji, Semangus, Sugihan, Rawas, Rupit
Dam/ reservoir	Development and/ or construction of dams/ reservoirs for water resources network systems is directed to ecological functions, ecosystems, conservation of water resources and flood control as well as to supply to strategic areas such as agricultural cultivation areas, flagship, mining areas and activity center cities.	Regencies: OKU Timur, Lahat, Muara Enim, Musi Rawas, Empat Lawang, Banyuasin, OKU and OKU Selatan Cities: Palembang, Pagar Alam, Lubuk Linggau
Irrigation	Development and/ or construction of irrigation including technical irrigation, swamp/ tidal irrigation and non-technical irrigation for the water resources network system is directed at areas with potential for food crop production.	
Surface water	Surface water development is directed at rivers, lakes, swamps and sea waters in the Province.	

Source: No.11/2016 concerning RTRW South Sumatra 2016-2036

In the spatial structural plan, water resources infrastructure system development is directed as follows:

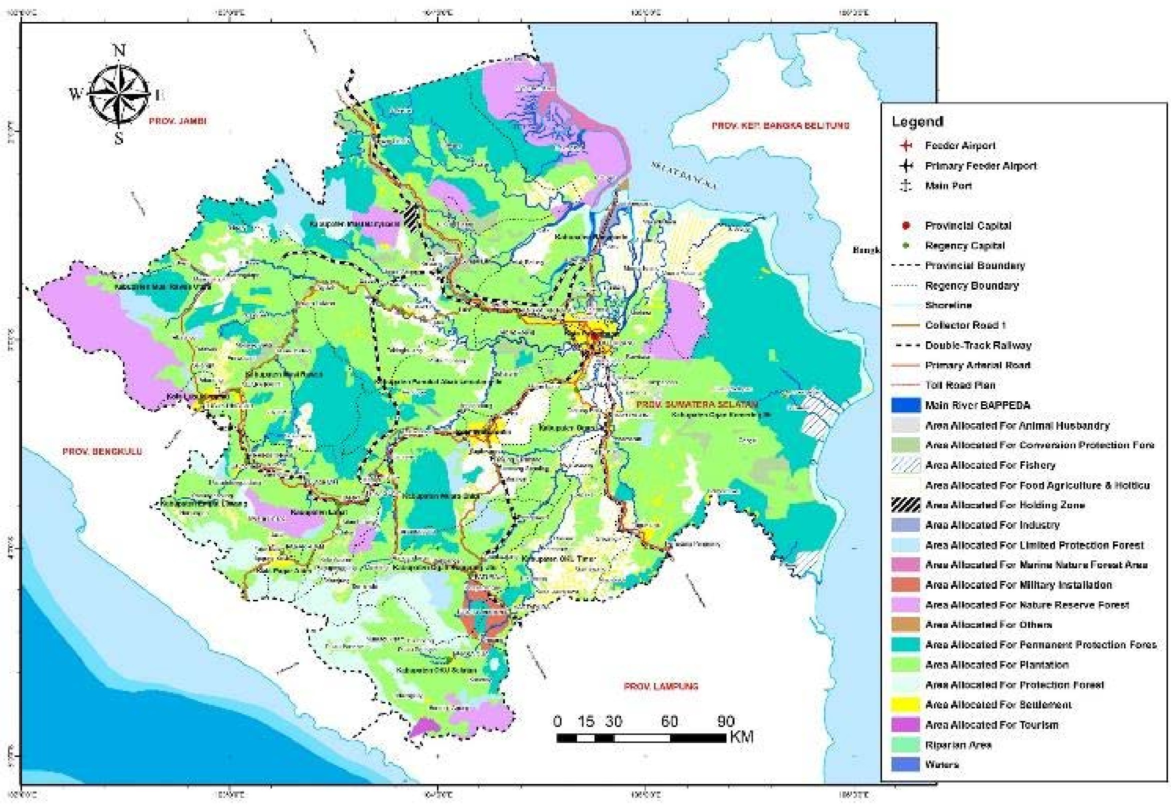
- To increase the availability of raw water in accordance with its purpose which can be utilized by various business sectors and activities for the entire region through the construction of reservoirs in areas that are hydrologically, geologically topographically and ecologically possible;

- To use water resources for supporting the national policy program to protect the Sustainable Food Agricultural Land (LP2B) for functionable purpose; and
- To secure the central plain area with groundwater potential in a major river basin.

In order to secure the above strategies on water resources infrastructure system development, zoning is needed through a formal zoning process (spatial pattern plan) synergizing with laws and regulations in each sector of area conservation such as securing buffer zones, preservation and security of water resources, prevention of erosion, and prevention of water pollution.

D4.1.3 Spatial Pattern Plan of RTRW South Sumatra 2016-2036

In RTRW South Sumatra 2016-2036, it is stressed that around 7.2 million-ha land or 83% of the whole land area in South Sumatra Province is suitable for agricultural use and thereby agriculture sector is expected to become one of the main development drivers in the province. The South Sumatra RTRW reveals the area-wise distribution of spatial pattern (zone) in South Sumatra Province for 2036 as shown in Figure D4.1.1 and Table D4.1.2. The breakdown of area-wise distribution of spatial zones by Regency/ City is presented in Table D4.1.3.



Source: BBWS Sumatera VIII

Figure D4.1.1 Protection and Utilization Zoning Map of Musi River Basin

Table D4.1.2 Area-wise Distribution of Spatial Pattern in South Sumatra Province for 2036

Zone Category		Area (ha)	Percentage
A.	Protection Zone		
A1	Nature Reserve Zone	711,828	7.14
A2	Nature Conservation Zone	40,961	0.41
A3	Subordinate Protected Zone		
	1) Protected forest	538,126	5.39
	2) Watershed	100,937	1.01
B.	Utilization Zone		
B1	Production Forest Zone	1,810,023	18.15
B2	Community Forest Zone	214,679	2.15
B3	Convertible Production Forest	600,323	6.02
B4	Agriculture Zone		
	1) Wetland paddy field	784,004	7.86
	2) Dryland upland crop field / Home garden	541,159	5.43
B5	Estate (Permanent) Crop Zone	3,185,446	31.93
B6	Fish Pond/ Livestock Zone	57,473	0.58
B7	Residential and Industrial Zone	157,744	1.58
B8	Mining	1,231,361	12.35
Province Total		9,974,064	100.00

Source: BBWS Sumatera VIII

Table D4.1.3 Area-wise Distribution of Spatial Patterns by Regency/ City in Musi River Basin (1/2)

Zone Category	City				Regency		
	Palemb. (ha)	Prabum. (ha)	P. Alam (ha)	L. Lingg. (ha)	OKI (ha)	Og. Ilir (ha)	OKU T. (ha)
A. Protection Zone							
A.1 Nature Reserve	50	0	0	9,052	4,828	0	0
A.2. Nature Conservation	0	0	0	0	0	0	0
A.3 Subordinate Protected	0	0	0	0	0	0	0
A.3.1 Protected forest	0	0	23,076	567	105,140	0	0
A.3.2 Watershed	0	0	0	0	0	8,730	0
A.3 Subordinate Protected							
A.3.1 Protected forest	0	0	0	0	0	0	0
A.3.2 Watershed	2,686	0	0	0	1,189	0	4,160
B. Utilization Zone							
B.1 Production Forest	0	0	0	0	645,100	0	13,000
B.2 Community Forest	0	0	0	1,029	9,886	0	0
B.3 Convertible Forest	0	0	0	0	329,239	15,638	0
B.4 Agriculture							
B.4.1 Wetland paddy field	2,355	0	0	0	150,863	88,612	173,585
B.4.2 Dryland upland crop field	0	1,150	0	1,705	109,680	14,334	43,009
B.5 Estate (Plantation) Crop	10,731	32,200	21,804	22,648	282,413	129,006	90,658
B.6 Fish Pond/ Livestock	0	0	0	0	42,594	0	0
B.7 Residential	21,581	6,512	13,036	6,979	9,597	10,289	11,192
B.8 Mining	0	15,063	0	0	0	0	42,729
Regency/ City Total	37,403	54,925	57,916	41,980	1,690,529	266,609	378,333

Note: Palemb. = Palembang; Prabum. = Pramubli; P. Alam = Pagar Alam; L. Lingg. = Lubuk Linggau;
Og. Ilir = Ogan Ilir; OKU T. = OKU Timur
Source: BBWS Sumatera VIII

Table D4.1.3 Area-wise Distribution of Spatial Patterns by Regency/ City in Musi River Basin (2/2)

Zone Category	Regency						
	OKU (ha)	OKU S. (ha)	M Enim (ha)	Lahat (ha)	Rawas (ha)	M. Ban. (ha)	Banyu. (ha)
A. Protection Zone							
A.1 Nature Reserve	0	50,950	9,440	52,829	242,200	83,350	259,129
A.2. Nature Conservation	0	0	0	0	0	13,872	27,089
A.3 Subordinate Protected	0	0	0	0	0	0	0
A.3.1 Protected forest	0	0	71,700	0	0	0	0
A.3.2 Watershed	0	0	0	0	0	0	0
A.3 Subordinate Protected							
A.3.1 Protected forest	48,140	102,881	0	118,024	1,275	10,207	58,616
A.3.2 Watershed	3,498	1,680	5,568	2,718	6,840	12,563	51,288
B. Utilization Zone							
B.1 Production Forest	30,267	22,415	189,115	41,747	301,458	497,921	69,000
B.2 Community Forest	33,300	12,631	30,105	11,881	26,480	90,396	0
B.3 Convertible Forest	0	0	0	0	89,878	68,370	160,351
B.4 Agriculture							
B.4.1 Wetland paddy field	0	0	13,714	14,603	58,813	111,977	381,608
B.4.2 Dryland upland crop field	44,105	95,788	170,910	54,199	109,402	143,062	51,823
B.5 Estate (Plantation) Crop	127,081	238,892	352,830	58,999	368,805	411,694	166,866
B.6 Fish Pond/ Livestock	0	3,041	0	0	0	0	0
B.7 Residential	5,369	12,005	15,412	8,250	8,306	4,288	24,930
B.8 Mining	76,686	0	257,446	27,388	194,454	602,533	15,063
Regency/ City Total	368,446	540,283	1,116,240	390,638	1,407,911	2,050,233	1,265,763

Note: OKU S. = OKU Selatan; M Enim= Muara Enim including Empat Lawang Regency; Lahat including PALI Regency; Rawas = Musi Rawas including Musi Rawas Utara Regency; M. Ban. = Musi Banyuasin; Banyu. = Banyuasin

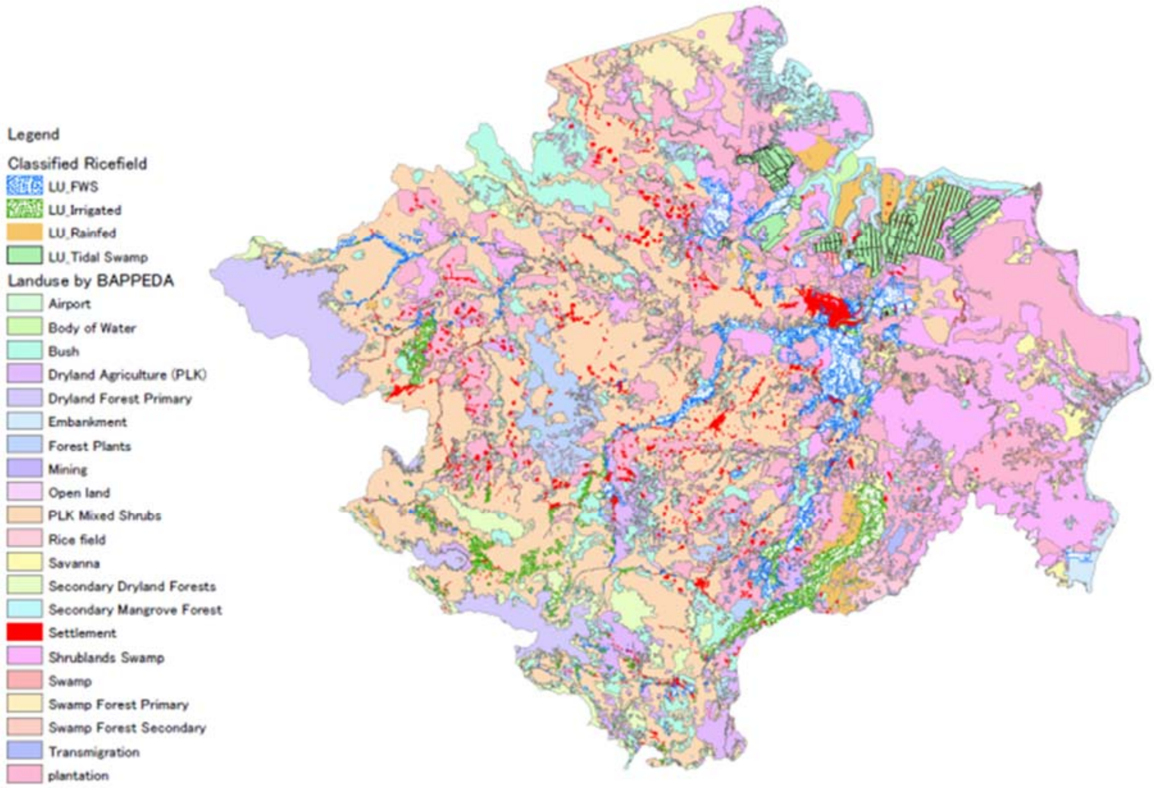
Source: BBWS Sumatera VIII

CHAPTER D5 LAND USE IN MUSI RIVER BASIN

D5.1 Present Land Use in Musi River Basin

D5.1.1 Present Condition of Land use

The JICA Project Teams 1 and 2 jointly elaborated the present land use map, based on the land use map 2010 prepared by Bappeda of South Sumatra Province, by adding categories of paddy areas such as fresh water swamp, irrigated, rainfed and tidal swamp, as shown in Figure D5.1.1.



Source: JICA Project Teams 1 and 2

Figure D5.1.1 Present Land Use Map in Musi River Basin

Statistical data on extent of major land use categories in South Sumatra Province as of 2015 are officially fixed by Central Bureau of Statistics, Ministry of Agriculture and South Sumatra Bureau of Statistics as shown in Table D5.1.1. Total forest area is broken down as shown in Table D5.1.2.

Table D5.1.1 Major Land Use Category Area by City/ Regency in South Sumatra for 2015

Regency (R) / City (C)	Wetland Crop Area (ha)	Dryland Crop Area (ha)	Shifting Cultivation Area (ha)	Estate Crop Area (ha)	Temporarily Fallow Area (ha)	Total Forest Area (ha)
Palembang C.	6,189	1,839	653	522	3,164	50
Prabumulih C.	700	3,745	960	11,197	864	2,138
Pagar Alam C.	3,440	2,045	438	12,546	874	52,188
Lubuk Linggau C.	1,894	2,165	2,116	11,620	548	8,777
OKI R.	185,998	86,021	34,442	270,742	104,785	872,210
Ogan Ilir R.	67,627	15,384	3,605	42,682	25,060	100
OKU Timur R.	85,620	27,279	7,681	103,359	5,399	19,486

Regency (R) / City (C)	Wetland Crop Area (ha)	Dryland Crop Area (ha)	Shifting Cultivation Area (ha)	Estate Crop Area (ha)	Temporarily Fallow Area (ha)	Total Forest Area (ha)
OKU R.	8,872	26,945	17,076	117,509	29,787	228,872
OKU Selatan R.	18,040	35,631	21,556	82,562	22,074	339,230
Muara Enim R.	27,017	30,676	23,449	224,329	34,425	346,115
PALI R.	6,579	11,204	4,714	55,476	6,720	23,887
Lahat R.	17,525	20,538	4,507	151,408	56,111	186,134
Empat Lawang R.	14,091	9,942	13,867	69,355	3,517	81,993
Musi Rawas R.	30,451	29,785	14,916	232,516	46,777	333,955
Musi Rawas Utara R.	7,131	21,018	13,775	125,468	64,546	356,450
Musi Banyuasin R.	66,810	29,739	29,524	395,099	95,264	689,264
Banyuasin R.	226,518	23,287	9,823	248,287	30,525	545,769
	774,502	377,243	203,102	2,154,677	530,440	4,086,618

Source: Statistik Indonesia 2017, Statistik Perkebunan Indonesia 2015-2017, Sumatera Selatan Dalam Angka 2017

Table D5.1.2 Breakdown of Total Forest Area in South Sumatra for 2015

Regency (R) / City (C)	Protection Forest (ha)	Nature Reserve Forest (ha)	Limited Protection Forest (ha)	Permanent Production Forest (ha)	Convertible Production Forest (ha)	Total Forest Area (ha)
Palembang C.	0	50	0	0	0	0
Prabumulih C.	0	0	1,069	0	1,069	2,138
Pagar Alam C.	26,094	0	0	0	26,094	26,094
Lubuk Linggau C.	1,216	4,153	1,096	0	2,312	3,408
OKI R.	96,506	15,291	10,035	643,838	106,540	760,413
Ogan Ilir R.	0	0	0	100	0	100
OKU Timur R.	5	0	0	19,476	5	19,481
OKU R.	68,309	0	18,647	54,959	86,957	160,563
OKU Selatan R.	127,967	44,988	10,232	17,845	138,199	166,276
Muara Enim R.	61,943	8,863	25,498	162,370	87,441	275,309
PALI R.	0	0	0	23,887	0	23,887
Lahat R.	48,312	52,261	4,351	28,547	52,663	85,561
Empat Lawang R.	884	3,759	4,555	3,269	69,526	77,350
Musi Rawas R.	64,971	75,352	7,386	177,976	8,270	193,632
Musi Rawas Utara R.	189	172,779	36,753	109,786	36,942	183,481
Musi Banyuasin R.	16,301	67,552	94,282	400,546	110,583	605,411
Banyuasin R.	64,630	345,577	0	70,932	64,630	135,562
	577,327	790,625	213,904	1,713,531	791,231	4,086,618

Source: Sumatera Selatan Dalam Angka 2017

D5.1.2 Prevailing Conflict in Land Use

In South Sumatra, natural resource development activities cause conflicts in land use among interests. Table D5.1.3 shows the land use conflict condition as of 2006 by Regency/ City. Since then, the conflict areas are considered to have more increased.

Table D5.1.3 Land Use Conflicts among Interests in South Sumatra as of 2006

Regency (R) / City (C)	Conflict Area between		
	Forest & Estate Crop	Forest & Mining	Estate Crop & Mining
Palembang C.	0	0	0
Prabumulih C.	147	0	1,000
Pagar Alam C.	145	0	0
Lubuk Linggau C.	732	0	0
OKI R.	7,028	0	0
Ogan Ilir R.	295	0	0
OKU Timur R.	0	877	2,005
OKU R.	2,459	2,604	2,458

Regency (R) / City (C)	Conflict Area between		
	Forest & Estate Crop	Forest & Mining	Estate Crop & Mining
OKU Selatan R.	1,437	2,298	0
Muara Enim R.	9,750	12,409	12,458
Lahat R.	5,206	145	2,025
Musi Rawas R.	4,299	1,525	1,657
Musi Banyuasin R.	11,094	15,948	22,744
Banyuasin R.	1,636	446	562
Total	44,228	36,252	44,909

Source: BBWS Sumatera VIII

D5.2 Future Land Use in Musi River Basin

D5.2.1 Focal Points for Prediction of Future Land Use

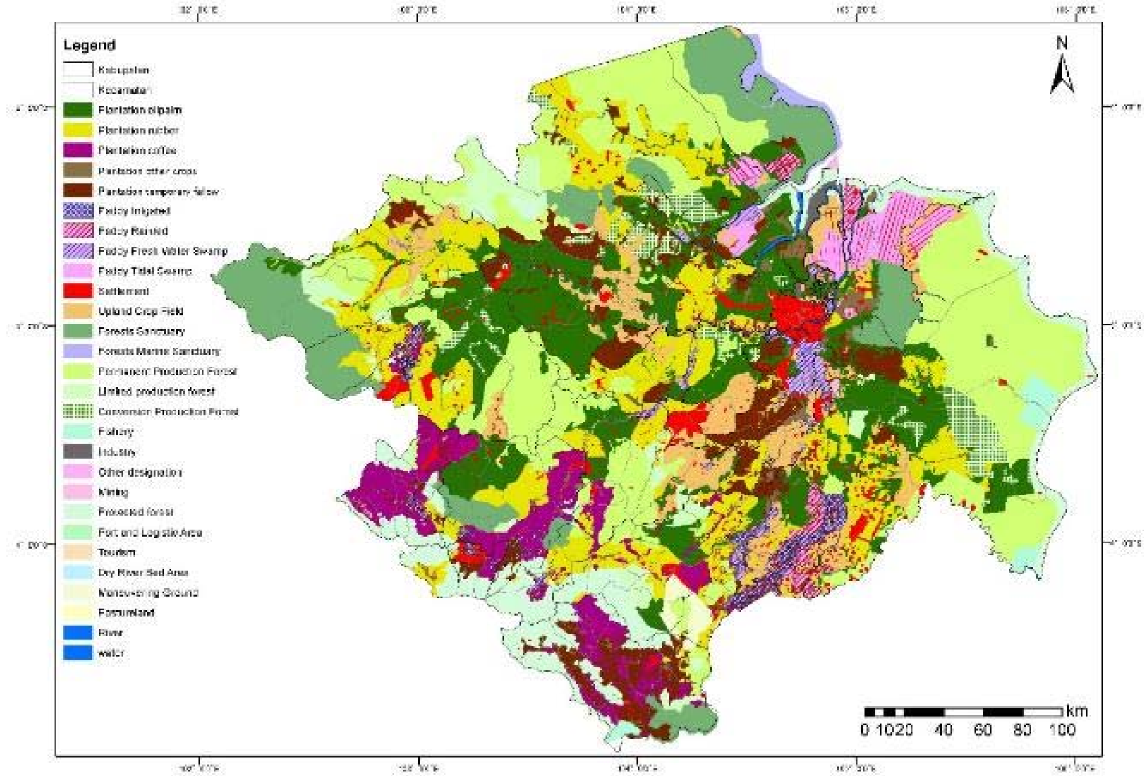
In predicting the future land use in the Musi River basin for the year of 2050, the basic concept is to refer to POLA 2014 and RENCANA 2017 of the MSBL River basin as well as the Spatial Plan of South Sumatra Province (RTRW Sumatera Selatan). The planning target year made in these references is 2031 by POLA/RENCANA and 2036 by RTRW.

For the purpose of providing input data required for undertaking run-off analysis by JICA Project Team-1, the future land use condition in 2050 is set up as follows:

- Protection zone comprising protection forest areas, nature reserve forest areas and limited protection forest areas, demarcated in RTRW South Sumatra covering 13.95% of the province, is to be fully maintained;
- As for the existing wetland paddy field areas consisting of surface water irrigation scheme areas, tidal swamp drainage scheme areas as well as rainfed paddy field areas in dry land zone will be fully maintained from the viewpoint of food security in South Sumatra Province;
- Estate crop growing areas will be expanded up to 3.19 million ha or the maximum area of plantation zone set up in RTRW up to 2050, considering that estate crops are contributing to one of the main financial income sources of South Sumatra Province. To meet land resource requirement for the expansion of about one million ha for developing new estate crop areas, the existing temporally unused land areas, shifting cultivation areas, and convertible production forest areas as well as a part of permanent production forest areas will be converted in order; and
- The whole area of Palembang and Prabmulih Cities will be fully utilized for residential, industrial and public purposes in 2050. In other Regencies and Cities, residential areas will be extended due to population increase so that dry farm land area will partly be converted to residential area as required.

D5.2.2 Predicted Future Land Use Area

Taking the above assumptions into account, the future land use condition in the Musi River basin for 2050 is predicted as shown in Figure D5.2.1 and Table D5.2.1. In addition, the breakdowns of forest areas and permanent tree crop areas are tabulated in Tables D5.2.2.and D5.2.3, respectively.



Source: JICA Project Team 2

Figure D5.2.1　　Land Use Condition of Musi River Basin in 2050

Table D5.2.1　　Major Land Use Category Area by City/ Regency in South Sumatra for 2050

Regency (R) / City (C)	Wetland Crop Area (ha)	Dryland Crop Area (ha)	Shifting Cultivation Area (ha)	Estate Crop Area (ha)	Temporarily Fallow Area (ha)	Total Forest Area (ha)
Palembang C.	0	0	0	0	0	0
Prabumulih C.	0	0	0	0	0	0
Pagar Alam C.	3,440	1,600	0	15,460	0	50,580
Lubuk Linggau C.	1,894	1,690	0	15,970	0	7,090
OKI R.	185,998	68,810	0	486,150	0	796,020
Ogan Ilir R.	67,627	12,300	0	55,070	16,240	100
OKU Timur R.	85,620	21,820	1,400	109,630	5,390	19,490
OKU R.	8,872	21,550	0	192,850	0	200,390
OKU Selatan R.	18,040	28,500	0	114,200	0	339,160
Muara Enim R.	27,017	24,540	0	328,950	0	299,360
PALI R.	6,579	8,960	0	82,240	0	8,550
Lahat R.	17,525	16,430	0	261,680	0	136,480
Empat Lawang R.	14,091	7,950	0	112,340	0	56,380
Musi Rawas R.	30,451	23,820	0	322,770	0	305,390
Musi Rawas Utara R.	7,131	16,810	0	178,860	24,870	356,410
Musi Banyuasin R.	66,810	23,790	0	555,790	0	653,300
Banyuasin R.	226,518	18,630	0	357,040	0	477,320
South Sumatra Total	774,503	297,200	1,400	3,189,000	46,500	3,708,200

Source: JICA Project Team 2

Table D5.2.2 Breakdown of Total Forest Area in South Sumatra for 2050

Regency (R) / City (C)	Protection Forest (ha)	Nature Reserve Forest (ha)	Limited Protection Forest (ha)	Permanent Production Forest (ha)	Convertible Production Forest (ha)	Total Forest Area (ha)
Palembang C.	0	50	0	0	0	50
Prabumulih C.	0	0	1,069	0	1,060	2,130
Pagar Alam C.	26,094	0	0	0	24,490	50,580
Lubuk Linggau C.	1,216	4,153	1,096	0	620	7,090
OKI R.	96,506	15,291	10,035	643,840	30,350	796,020
Ogan Ilir R.	0	0	0	100	0	100
OKU Timur R.	5	0	0	19,480	0	19,490
OKU R.	68,309	0	18,647	54,960	58,470	200,390
OKU Selatan R.	127,967	44,988	10,232	17,840	138,130	339,160
Muara Enim R.	61,943	8,863	25,498	162,370	40,690	299,360
PALI R.	0	0	0	8,550	0	8,550
Lahat R.	48,312	52,261	4,351	28,550	3,010	136,480
Empat Lawang R.	884	3,759	4,555	3,270	43,920	56,380
Musi Rawas R.	64,971	75,352	7,386	157,680	0	305,390
Musi Rawas Utara R.	189	172,779	36,753	109,780	36,910	356,410
Musi Banyuasin R.	16,301	67,552	94,282	400,520	74,650	653,300
Banyuasin R.	64,630	345,577	0	67,160	0	477,320
	577,327	790,625	213,904	1,674,100	452,300	3,708,200

Source: JICA Project Team 2

Table D5.2.3 Future Permanent Tree Crop Planting Area in South Sumatra for 2050

Regency (R) / City (C)	Rubber (ha)	Coconut (ha)	Oil Palm (ha)	Coffee (ha)	Others (ha)	Total (ha)	Change (ha)
Palembang C.	0	0	0	0	0	0	▲ 522
Prabumulih C.	0	0	0	0	0	0	▲ 11,197
Pagar Alam C.	1,180	40	0	12,440	1,800	15,460	2,914
Lubuk Linggau C.	12,210	220	0	2,910	630	15,970	4,350
OKI R.	198,390	3,320	265,040	2,030	17,370	486,150	215,408
OKU Timur R.	28,350	3,360	14,560	0	8,800	55,070	12,388
Ogan Ilir R.	49,580	480	45,690	3,910	9,970	109,630	6,271
OKU R.	99370	1,120	51,630	33,320	7,410	192,850	75,341
OKU Selatan R.	5,840	1,180	60	96,360	10,760	114,200	31,638
Muara Enim R.	136,350	1,260	123,050	31,810	36,480	328,950	104,621
PALI R.	58,430	330	11,400	0	12,080	82,240	26,764
Lahat R.	55,080	550	77,930	95,080	33,040	261,680	110,272
Empat Lawang R.	5,440	750	0	85,700	20,450	112,340	42,985
Musi Rawas R.	132,960	1,550	172,800	4,450	11,010	322,770	90,254
Musi Rawas Utara R.	138,390	390	30,500	230	9,350	178,860	53,392
Musi Banyuasin R.	193,720	4,950	337,490	0	19,630	555,790	160,691
Banyuasin R.	91,510	47,300	201,050	4,160	13,020	357,040	108,753
South Sumatra	1,206,800	66,800	1,331,200	372,400	211,800	3,189,000	1,034,323

Source: JICA Project Team 2

Supporting Report E

AGRICULTURE AND IRRIGATION

Abbreviations and Glossaries

	Indonesia	English
Bappeda	Badan Perencanaan Pembangunan Daerah	Regional Planning and Development Body
BAPPENAS	Badan Perencanaan Pembangunan Nasional	National Planning Agency
BBWS	Balai Besar Wilayah Sengai	Large River Basin Organization
BPS	Badan Pusat Statiks	Central Bureau of Statistics
DGAIF	Direktorat Jenderal Prasarana & Sarana Pertanian	Directorate General of Agricultural Infrastructure and Facilities
DGWR	Direktorat Jenderal Sumber Daya Air	Directorate General of Water Resources
GOI	Pemerintah Indonesia	Government of Indonesia
JICA	-	Japan International Cooperation Agency
KIP		Komering Irrigation Project
KP	Kriteria Perencanaan	Planning Criteria
LP2B	Lahan Pertanian Pangan Berkelanjutan	Sustainable food production base
MBSL	Musi-Sugihan-Banyuasin-Lemaure	Musi-Banyuasin-Sugihan-Lemau
MH	Musim Hujan	Rainy season
MK	Musim Kemarau	Dry season
MOA	Kementarian Pertanian	Ministry of Agriculture
MPWH	Kementerian Pekerjaan Umum Dan Perumahan Rakyat	Ministry of Public Works and Housing
O&M	-	Operation & Maintenance
OKU	Ogan Komering Ulu (Kabupaten)	Ogan Komering Ulu (Regency)-
OKI	Ogan Komering Ilir (Kabupaten)	Ogan Komering Ilir (Regency)
PALI	Penukal Arab Lematang Ilir (Kabupaten)	Penukal Arab Lematang Ilir (Regency)
PIRIMP		Participatory Irrigation Rehabilitation and Management Project
POLA	Rencana Strategis Manajemen Sumber Daya Air	Water Resources Management Strategic Plan
PP	Peraturan Pemerintah-	Presidential Decree
PUPR	Pekerjaan Umum dan Permahan Rakyat	Public Works and Public Housing
RENCANA	Rencana Penerapan Manajemen Sumber Daya Air	Water Resources Management Implementation Plan
RPJMD	Rencana Pembangunan Jangka Menegah Daerah	Medium Term Development Plan of Region
RDTR	Rencana Detil Tata Ruang	Detailed Spatial Plan
RTkRHL DAS		Forest and Land Rehabilitation Engineering Plan
RTRW	Rencana Tata Ruang Wilayah	Spatial Plan
SNI	Standar Nasional Indonesia	Indonesian National Standard
SRI	-	System of Rice Intensification
TOT		Training of Trainers
UU	Undang-Undang	Law
WUA	-	Water Users Association

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 E: AGRICULTURE AND IRRIGATION

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PART 1 GENERAL

CHAPTER E1 OVERVIEW OF CLIMATE CHANGE IMPACTS ON AGRICULTURE IN INDONESIA

E1.1 Global Climate Change Impacts on Agriculture in Indonesia

E1.1.1 Features on Impact of Climate Change on Agriculture Sector

Agriculture in Indonesia is a contributor to global climate change and vis-à-vis receiver of the impact of global climate change. The agricultural sector releases Greenhouse Gas (GHG) emissions into the atmosphere in significant quantities, while the sector is increasingly affected to considerable extent by the incidence of floods and droughts caused by climate change.

Features on GHG emissions and impacts of climate changes related to agricultural activities in Indonesia are summarized in Table E1.1.1.

Table E1.1.1 Features on GHG Emissions and Impacts of Agriculture Sector in Indonesia

Item	Description
GHG Emissions from agriculture sector releasing CO_2, CH_4, N_2O	
Current situation on emission in Indonesia (2013)	- Total emission: 2,163 million tons Carbo Dioxide equivalent ($MtCO_2e$) and discharging 4.47% of the whole world's emission - Composition by sector: 63.5% from land use change and forestry, 22.6% from energy, 7.4% from agriculture, 3.0% from waste and 1.5% from industrial processes
Source activity	- Burning of plant residues, Soil organic matter, Organic matter decomposition, Ruminant digestive fermentation, Livestock manure, Wetland
Highest sources	- Fertilizer use, Rice fields, Livestock and waste, Burning the remains of agriculture
Emission discharged from agriculture sector	- 2005: around 141 million tons $MtCO_2e$ - 2013: around 160 million tons $MtCO_2e$
Past trend of emission level	- Increasing caused by upward trends of number of months with extreme rainfalls
Future emission trend	- Continuing to increase caused by food demand increase by Indonesian people
Impacts of climate changes on agricultural sector	
Downward trend of annual rainfall	- Decrease in inflow into reservoirs and natural river flow triggering to tighten irrigation water resources
Change in precipitation pattern	- Significant amount of rainfall during shortened duration reducing the potential for a period of paddy growing season
Floods and droughts	- Alternative occurrence affected by El-Nino and La-Nina causing crop harvest failure by droughts and floods
Mean annual temperature increase	- Triggering increase in transpiration causing lower crop productivity, increased water consumption by crop, early ripening time, lower quality of harvested crops, and encouraged development of plant pests
Sea-level rise	- Damage to agricultural infrastructure along Java Sea coastal areas - Damage to crop growth caused by increased salinity level
Future trend	- No or less efforts against climate changes at national level causing considerable reduction of strategic crop production

Source: Country Report Indonesia presented in Workshop on Climate Change and its Impact on Agriculture, Seoul, 2011

E1.1.2 Mitigation and Adaptation Approaches to Global Climate Changes in Agricultural Sector

In the agricultural sector of Indonesia, the following approaches can be considered as applicable from technical point of view:

- Mitigation approach consisting of breeding of new crop varieties, application of farming technology and increase in carbon sequestration; and

- Adaptation approach comprising improvement of farming practices, use of resistant crop varieties, rain harvesting and water saving irrigation system

In Table E1.1.2, mitigation and adaptation measures in the agricultural sector are itemized.

Table E1.1.2 Mitigation and Adaptation Measures against Climate Change in Indonesia

Item	Description
Mitigation Measures for GHG Emissions discharge	
Reduction of carbon emissions	- Breeding of low-emission rice varieties with specific features of pest tolerance and plant disease resistance - Use of ZA (Ammonium Sulfate) fertilizers, enabling to reduce methane gas emission
Application of farming technology	- Non-tillage cultivation method enabling to reduce methane gas emission up to about half level compared with perfect tillage - Intermittent irrigation system enabling to reduce GHG emissions up to about half level compared with flooded cultivation method
Increase in carbon sequestration	- Promotion of organic farming systems - Development of green energy
Adaptation Measures for Climate Change	
Improvement of farming practices	- Optimization of planting time - Adjustment of cropping pattern
Use of resistant crop variety	- Growing rice, maize, soybean and groundnut tolerant to drought, flooding and salinity
Rain harvesting	- Construction of small-scale reservoir (Embung), long storage and farm pond
Water saving irrigation system	- Introduction of capillary irrigation, drop irrigation, rotating irrigation and intermittent irrigation systems

Source: Country Report Indonesia presented in Workshop on Climate Change and its Impact on Agriculture, Seoul, 2011

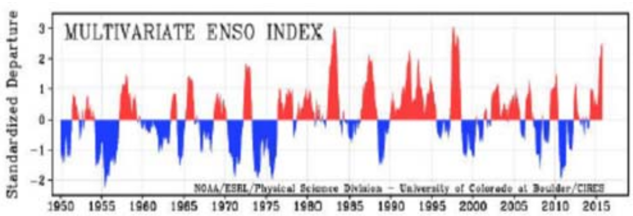
E1.2 Global Climate Change Impacts on Food Crop Production in Indonesia

E1.2.1 Occurrence of El-Nino and La-Nino Events

Variation in rainfall as a common element of many natural disasters is influenced by global, regional and/or local factors in the following manner:

- Global climate factors include El-Nino and La-Nino with the dipole mode;
- Regional factors include monsoon circulation, the Madden-Julian oscillation and fluctuations in the surface temperature of the seas of Indonesia; and
- Local factors include elevation, island position, the circulation of land and sea breezes and land cover.

In Indonesia, the occurrence of extreme climate events associated with El-Nino and La-Nino with the dipole mode. As shown in Figure E1.2.1, El-Nino (red part) year normally triggers drought, while La-Nino (blue part) year brings higher rainfall causing floods.



Source: ADB Country Water Assessment Report, Indonesia

Figure E1.2.l Variation of El-Nino-Southern Oscillation Index, 1950-2014

During the period from 2003 to 2008, the total accumulation of rice cultivation areas affected by floods were 1.8 million ha equivalent to 15% of total area of 12 million ha under rice cultivation in 2009. On the other hand, 2.0 million ha or 17% were affected by droughts and hence combined affected areas equaled 32% of the total cultivation areas. Java was most affected island followed by Sumatra and Sulawesi islands

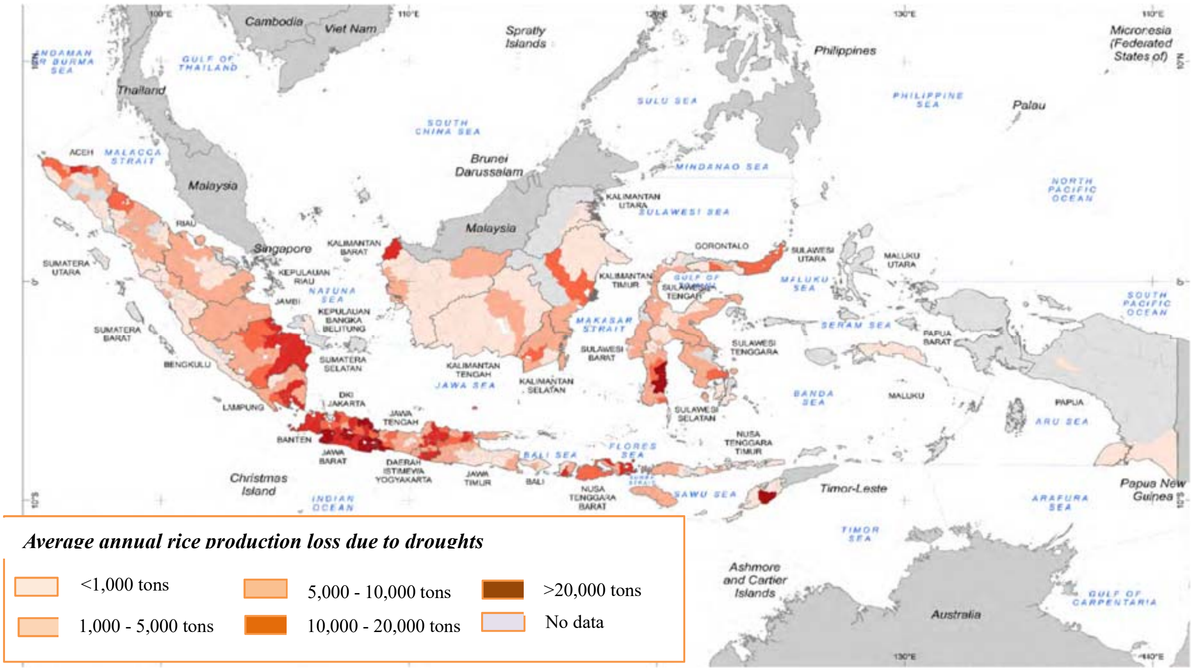
E1.2.2 Drought and Flood Impacts on Rice and Maize Production

In the report of "Food Security and Vulnerability Atlas of Indonesia 2015" prepared by the Ministry of Agriculture in collaboration with the World Food Program, a damaged area is defined as an area where crop production has declined resulting from natural disasters such as floods, droughts and/or pest infestation. Table E1.2.1 shows the proportion of the rice and maize areas damaged by these natural hazards in each province between 2011 and 2013. As global climate condition for this period was normal as shown in Figure E1.2.1, damage rate of paddy and maize areas caused by the natural hazards was relatively low at less than 1% throughout Indonesia. Average rice production losses during the period from 1990 to 2013 are shown in Figure E1.2.2 for floods and Figure E1.2.3 for droughts.

Table E1.2.1 Proportion of Paddy and Maize Areas Damaged by Climate Hazards

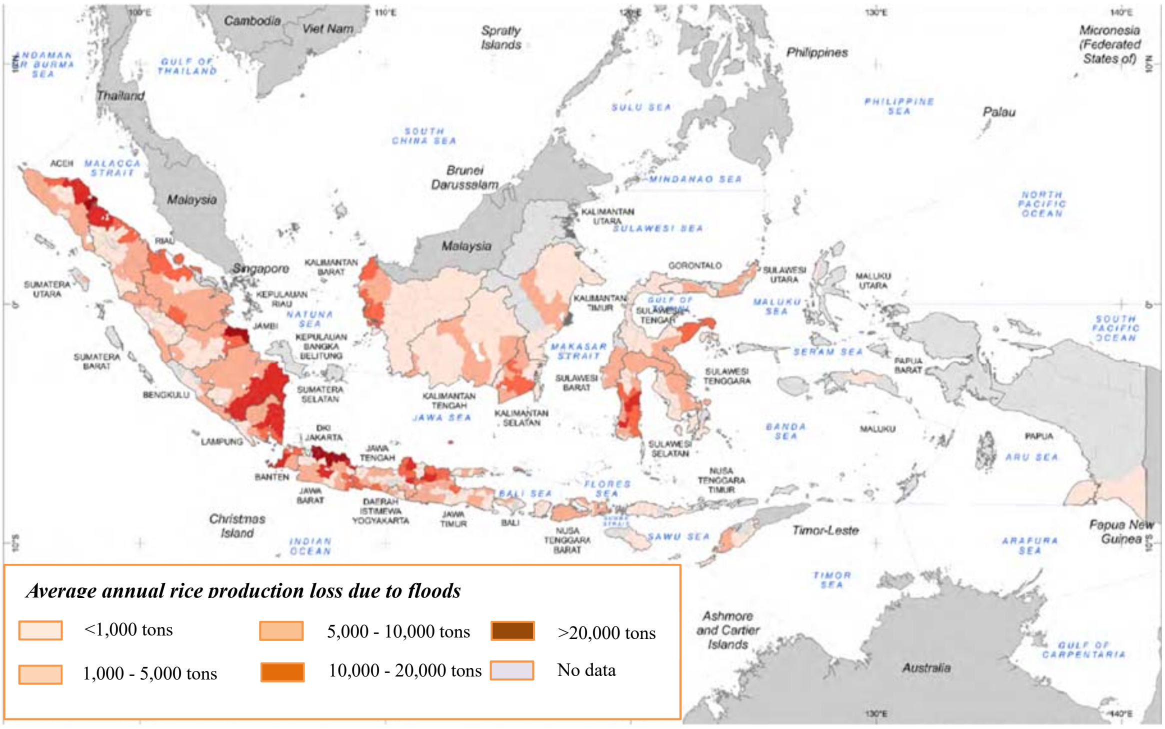
Province	Paddy Damaged Area (%)				Maize Damaged Area (%)			
	2010	2011	2012	2013	2010	2011	2012	2013
Sumatra								
1. Ache	0.65	1.83	2.93	2,63	0.09	0.10	0.54	0.37
2. Sumatera Utara	0.16	9.11	0.23	0.53	1.55	0.56	0.43	0.04
3. Sumatera Barat	0.20	0.31	0.14	0.11	0.71	2.45	0.11	0.19
4. Riau	0.11	2.16	0.58	1.01	0.15	1.10	0.05	0.16
5. Jambi	3.08	1.04	1.27	1.71	31.45	0.81	0.63	0.66
6. Sumatera Selatan	1.53	0.34	0.17	0.23	0.15	0.01	0.31	0.08
7. Bengkulu	-	0.10	0.03	0.08	0.01	1.46	-	-
8. Lampung	2.15	1.42	1.45	0.81	0.24	0.08	0.17	0.01
9. Kepulauan Bangka Belitung	-	-	-	-	-	-	-	-
10. Kepulauan Riau	-	-	-	-	-	-	-	-
Java								
11. DKI Jakarta	0.75	-	-	-	-	-	-	-
12. Jawa Barat	0.44	0.84	0.22	0.26	-	0.01	0.00	-
13. Jawa Tengah	0.63	0.70	0.78	0.79	0.48	0.06	0.03	0.02
14. DI Yogyakarta	1.07	1.84	0.76	-	0.21	0.01	-	-
15. Jawa Timur	.0.47	2.04	0.36	0.81	0.38	0.13	0.02	0.18
16. Banten	0.14	0.57	3.58	2.30	-	-	-	-
Bali & Nusa Tenggara								
17. Bali	-	0.12	0,12	0.00	-	-	-	-
18. Nusa Tenggara Barat	2.10	0.25	0.62	0.47	8.93	-	0.48	0.11
19. Nusa Tenggara Timur	2.24	0.38	0.10	0.28	2.32	0.02	0.03	0.63
Kalimantan								
20. Kalimantan Barat	0.03	0.21	0.26	0.08	-	0.00	-	-
21. Kalimantan Tengah	1.98	0.15	0.96	0.26	1.21	-	0.27	0.09
22. Kalimantan Selatan	1.05	0.24	0.34	0.00	0.01	0.02	0.01	-
23. Kalimantan Timur	0.42	0.45	0.44	0.48	0.13	-	-	^
Sulawesi								
24. Sulawesi Utara	0.17	0.02	0.01	0.05	-	-	-	0/00
25. Sulawesi Tengah	0.15	0.05	0.18	0.04	0.18	0.00	-	0.01
26. Sulawesi Selatan	2.22	1.86	0.97	1.87	0.83	0.71	0.37	1.30
27. Sulawesi Tenggara	0.47	1.37	1.38	0.78	0.02	-	0.01	1.05
28. Gorontalo	10.95	0.68	0.35	0.02	1.81	0.58	0.03	0.03
29. Sulawesi Barat	0.23	0.76	0.67	0.01	0.03	-	-	^
Maluku & Papua								
30. Maluku	2.55	-	0.47	.0.12	0.46	-	0.03	-
31. Maluku Utara	-	0.17	0.20	0.08	-	-	-	0.02
32. Papua Barat	-	0.04	-	0.03	-	-	-	-
33. Papua	0.03	0.86	0.01	0.67	-	-	-	-
Indonesia	*0.88*	*9.93*	*0.67*	*0.50*	*0.96*	*0.23*	*0.11*	*0.15*

Source: Ministry of Agriculture



Source: Food Security and Vulnerability Atlas of Indonesia 2015, Ministry of Agriculture

Figure E1.2.2 Average Rice Production Loss due to Droughts in Indonesia from 1990 to 2013



Source: Food Security and Vulnerability Atlas of Indonesia 2015, Ministry of Agriculture

Figure E1.2.3 Average Rice Production Loss due to Floods in Indonesia from 1990 to 2013

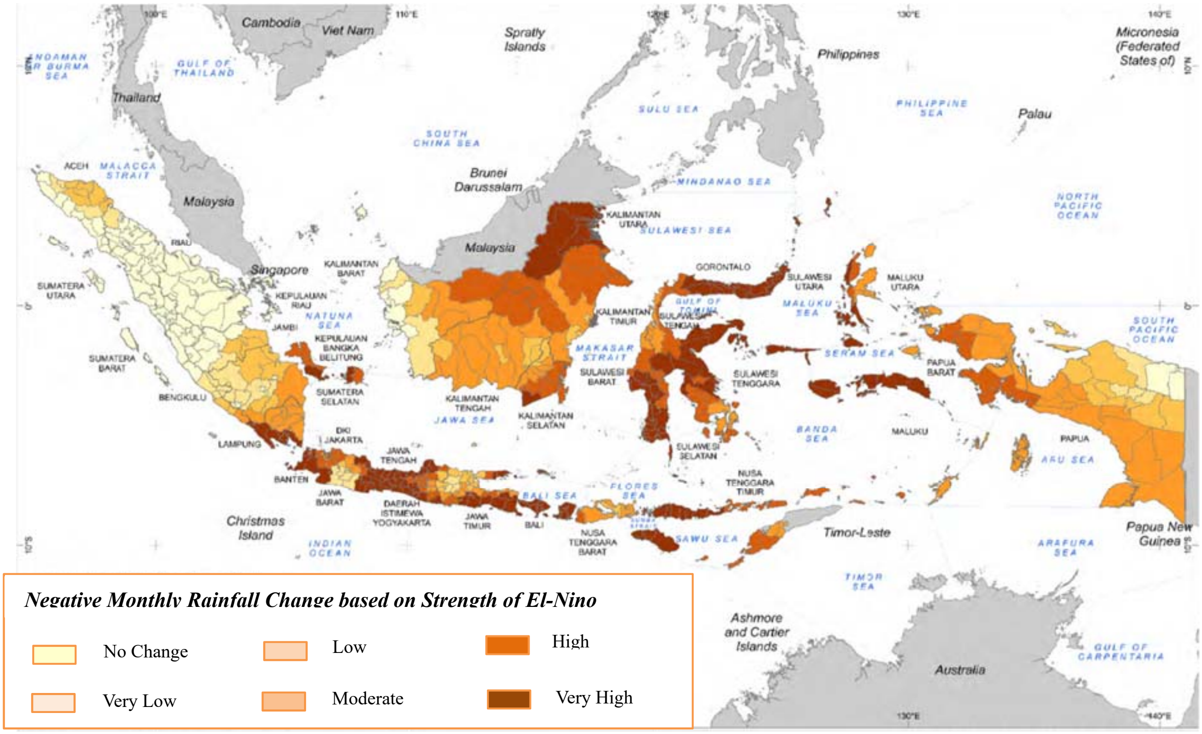
In Figures E1.2.2 and E1.2.3, areas in dark red experienced heavy losses averaging more than 20,000 tons per year during 24-year period from 1990 to 2013. Most of the affected areas are distributed in West Java Province for the both drought and flood cases. In addition, droughts caused significant rice production losses in Central Java, West Nusa Tenggara and South

Sulawesi Provinces, while floods damaged heavily rice production in Aceh, North Sumatra, Jambi, South Sumatra, Lampung and South Sulawesi Provinces.

E1.2.3 Future Trend of Global Climate Change

It is kwon that a 1°C change in sea surface temperature will result in the negative change in monthly rainfall through strengthening El-Nino and La-Nino events. Unless water reservoirs and irrigation systems are improved in the future, rainfall variation will still affect crop growing condition adversely and hence reduce crop yield level.

Figure E1.2.4 shows distribution of areas according to the average decrease in monthly rainfall associated with a rise in the sea surface temperature. Areas in dark red have the largest negative changes in rainfall.



Source: Food Security and Vulnerability Atlas of Indonesia 2015, Ministry of Agriculture

Figure E1.2.4 Negative Monthly Rainfall Change by Strengthening of El-Nino Event

CHAPTER E2 IRRIGATION SECTOR IN INDONESIA

E2.1 Functional Situation of Existing Surface Water Irrigation Schemes in Indonesia

E2.1.1 Regally Registered Schemes

In Indonesia, there exist 56,291 schemes registered in the Ministerial Ordinance No. 14/PRT/M/2015 on "Criteria and Status of Irrigation Schemes". These schemes consist of 48,028 surface water irrigation schemes, 5,659 groundwater irrigation schemes, 45 pump and polder irrigation schemes, 2,227 swamp drainage schemes and 332 fish pond water supply schemes. The Ordinance stipulates jurisdiction of these schemes based on scheme size and location as follows:

- DGWR through its regional river basin management offices (BBWS or BWS) is responsible for operation and management (O&M) of schemes having over 3,000-ha design area or spreading over two countries or provinces;
- Provincial governments take care of schemes having design area from 1,000 ha to 3,000 ha or spreading over two regencies and/ or cities; and
- Local (Regency and City) governments control schemes with design area of under 1,000 ha.

Table E2.1.1 shows distribution of registered schemes by region and management body.

Table E2.1.1 Distribution of Registered Schemes by Management Body in Indonesia

Region & Management Body	Surface water		Groundwater		Pump / Polder		Swamp drainage		Fish pond	
	(nos.)	(ha)	(nos.)	(ha)	(nos.)	(ha)	(nos.)	(ha)	(nos.)	(ha)
Sumatra	*9,851*	*1,875,326*	*313*	*6,848*	*0*	*0*	*603*	*759,045*	*30*	*19,644*
BBWS/ BWS	68	574,832	0	0	0	0	53	396,785	1	7,000
Province	251	311,703	0	0	0	0	118	226,471	6	7,335
Regency/ City	9,332	988,791	313	6,848	0	0	432	135,789	23	5,309
Java	*28,123*	*3,001,332*	*2,637*	*74,432*	*39*	*7,503*	*21*	*1,556*	*163*	*50,301*
BBWS/ BWS	93	1,117,361	0	0	0	0	0	0	1	3,322
Province	443	388,632	0	0	2	2,305	0	0	12	15,458
Regency/ City	27,587	1,495,339	2,637	74,432	37	5,198			150	31,521
Bali & N. Tenggara	*3,276*	*686,935*	*1,674*	*17,909*	*0*	*0*	*0*	*0*	*0*	*0*
BBWS/ BWS	51	220,152	0	0	0	0	0	0	0	0
Province	91	127,704	0	0	0	0	0	0	0	0
Regency/ City	3,134	339,079	1,674	17,909	0	0	0	0	0	0
Kalimantan	*1,796*	*323,056*	*0*	*0*	*1*	*5,987*	*1,399*	*821,383*	*19*	*9,334*
BBWS/ BWS	9	40,058	0	0	1	5,987	53	396,779	0	0
Province	28	29,993	0	0	0	0	108	167,607	2	2,636
Regency/ City	1,759	253,005	0	0	0	0	1,238	256,997	17	6,698
Sulawesi	*4,711*	*1,081,267*	*934*	*14,010*	*0*	*0*	*41*	*43,702*	*120*	*110,469*
BBWS/ BWS	47	364,639	0	0	0	0	4	18,149	5	15,600
Province	110	168,227	0	0	0	0	10	20,764	49	77,958
Regency/ City	4,554	548,401	934	14,010	0	0	27	4,789	66	16,911
Maluku & Papua	*271*	*179,253*	*101*	*402*	*5*	*30,740*	*163*	*17,597*	*0*	*0*
BBWS/ BWS	15	59,479	0	0	0	0	0	0	0	0
Province	61	79,274	0	0	0	0	5	8,460	0	0
Regency/ City	195	40,500	101	402	5	30,740	158	9,137	0	0
INDONESIA	*48,028*	*7,145,168*	*5,639*	*113,601*	*45*	*44,230*	*2,227*	*1,643,283*	*332*	*189,747*
BBWS/ BWS	283	2,376,521	0	0	6	36,727	110	703,362	7	25,922
Province	984	1,105,474	0	0	2	2,305	241	423,302	69	103,386
Regency/ City	46,761	3,663,173	5,639	113,601	37	5,198	1,876	516,619	256	60,439

Source: DGWR

E2.1.2 Functional Condition of Surface Water Irrigation Schemes

In 2014, DGWR carried out nation-wide inventory survey on questionnaire format filling-up basis aiming to confirm functional condition of the whole surface water irrigation schemes through scoring method of damage level. In the survey, the following four damage levels were established:

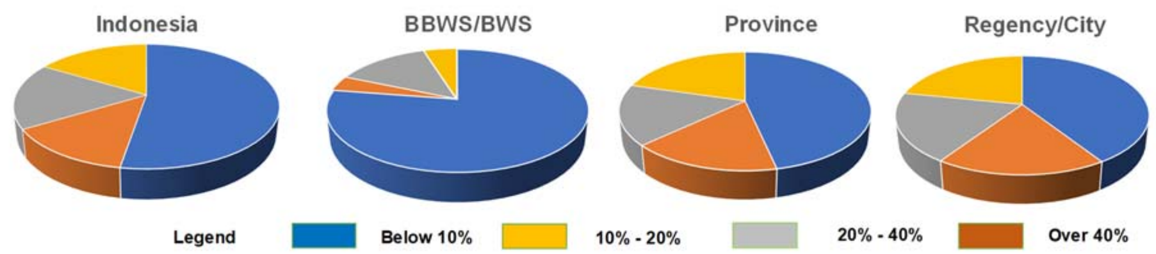
- Well maintained with damage level below 10%;
- Slightly damaged with damage level of 10% to 20%;
- Moderately damaged with damage level of 20% to 40%; and
- Heavily damaged with damage level over 40%.

The summarized result of inventory survey by DGWR is shown in Table E2.1.2 and Figure E2.1.1.

Table E2.1.2 Functional Condition of Surface Water irrigation Schemes in Indonesia

Management Body	Damage Level								Total Area
	Under 10%		10% - 20%		20% - 40%		Over 40%		
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)
BBWS / BWS	1,840,874	77.46	94,114	3.96	326,178	13.73	115,355	4.85	2,376,521
Province	515,092	46.59	181,820	16.45	182,576	16.52	225,987	20.44	1,105,474
Regency / City	1,500,209	40.95	673,340	18.38	691,196	18.87	798,427	21.80	3,663,174
Indonesia	3,656,175	51.17	949,274	13.29	1,199,950	16.79	1,139,769	15.95	7,145,168

Source: DGWR



Source: DGWR

Figure F2.1.1 Functional Condition of Surface Water irrigation Schemes in Indonesia

E2.2 Irrigation Water Requirement Estimate Methodology in Indonesia

E2.2.1 Comparison of Irrigation Water Requirement Calculation Methodologies

In POLA, Indonesian National Standard (SNI 19-6728.1-2002) is applied to calculate irrigation water demand. Unit irrigation water consumption is ubiformly set up at 1.0 l/s/ha for all irrigation schemes. In calculating annual irrigation water diversion requirement by this SNI formula, two factors such as irrigation command area and cropping intensity are used. Accordingly, no climatic factors is taken into considration.

Aiming to quantify effects of the climate change on irrigation water demand in line with the Project scope, therefore, the formula of “Irrigation Planning Standard, Design Criteria for Irrigation Networks (KP-1)” of DGWR is taken up. In this formula, irrigation water demand is calculated based on several factors including two climate factors such as rainfall and evapotranspiration.

The both formulas are compared in Table E2.2.1.

Table E2.2.1 Comparison of Irrigation Water Requirement Calculation Methodologies

SNI Formula	KP-1 Formula
IWR = A x CI x a Where, IWR: Irrigation water requirement A: irrigation command area CPI: cropping intensity (%) a: unit water requirement (l/s/ha)	*KAI = (Etc + IR + WLR + P- Re)/IE ×A* Where KAI: Supplemental irrigation water requirement Etc: consumptive water needs (mm/day IR: irrigation water needs at paddy field level (mm/day) WLR: water needs to replace the water layer (mm/day) P: percolation (mm/day) Re: effective rainfall (mm/day) IE: irrigation efficiency (%) A: irrigation area (ha)

Source: JICA Project Team 2

E2.2.2 Input Climate Data

Input climate data into KP-1 formula are prepared in the following manner:

- Observed daily precipitation and evapotranspiration data with observation period of minimum 20 years;
- Daily effective rainfall data are made by reducing daily precipitation over 80 mm to 80 mm and below 5 mm to 0 mm; and
- If reliable observed evapotranspiration data are not available, estimated evapotranspiration data are used by using the Thornthwaite formula.

E2.3 On-farm Level Adaptation Measures against Drought

E2.3.1 Overview

From practical viewpoint, the following can be considered as on-farm level non-structural and structural adaptation measures against drought in Indonesia:

- Rotation system of irrigation water distribution within a command area of each surface water irrigation scheme;
- Optimization of cropping calendar;
- Improvement of on-farm level irrigation efficiency; and
- Promotion of System Rice Intensification (SRI) method.

Aiming to encourage paddy farmers for practicing these adaptation measures in their paddy field, it is prerequisite to establish cooperation and collaboration working system among the related organizations as well as the persons concerned from central to local government levels for providing paddy farmers with effective and sustainable supports.

E2.3.2 Rotation System of Irrigation Water Distribution

An expected impact of this adaptation measure on irrigation water management is to level peak of on-farm level irrigation water use and thereby to reduce water use quantity at peak time.

In any irrigation scheme command area, shorter duration of irrigation water distribution causes to make peak water supply requirement more. Aiming to reduce the peak water requirement, the command area is divided into three blocks and the irrigation water distribution starts from upstream block to downstream block with 10-day interval. Through adapting such rotation system, the total duration of practicing land preparation and stage-wise crop management works will be able to make longer according to water distribution period in three rotation blocks.

E2.3.3 Optimization of Cropping Calendar

An expected impact of this adaptation measure on irrigation water management is to save water use during the wet season land preparation work period that normally falls on the lowest flow period of irrigation water source rivers.

In optimizing cropping calendar, a focal point is put over the frequency of occurrence to fully meet water requirement for land preparation works with daily effective rainfalls (5.0 mm - 80.0 mm) for the lower to lowest flow period of irrigation water source rivers. In practical, the period of three months from the beginning of October to the end of December for Sumatra region and the beginning of November to the end of January for Java region is divided into every 10-day section. Then, it is examined whether average 10-day effective rainfall can meet land preparation water needs throughout the rainfall data available period with minimum 10 years.

E2.3.4 Improvement of Irrigation Efficiency

An expected impact of this adaptation measure on irrigation water management is to save water loss at water conveyance time through tertiary canals and/ or plot-to-plot water distribution by reduction of leakage water.

In the DGWR design criteria, the irrigation efficiency is defined based on water conveyance loss of irrigation canal. As the design target, the loss is set at 10% for main canal and 15% for the secondary and tertiary canals and thereby the irrigation efficiency is calculated at 65% (= 0.9 x 0.85 x 0.85). It is commonly understood that the current level of conveyance loss of tertiary canal system is still around 30% and thereby reduction of leakage water from the existing irrigation canal systems is one of effective adaptation measures against drought from viewpoint of water saving. As the high level of conveyance loss is caused by deteriorated or not yet facilitated condition of tertiary canal system, it is essential to implement tertiary canal system improvement works such as replacement to pre-cast concrete block lining canal.

The following approach is prerequisite for improvement of tertiary canal system:

- To identify target schemes with design irrigation command area of over 100 ha;
- To undertake inventory survey in participatory manner for the purpose of confirming farmers' needs and generating their consensus;
- To promote participatory design work of tertiary canal network layout using precast concrete block for minimizing unusable paddy field on contribution basis; and
- To collaborate with local agencies concerned for realizing public financial assistance to participatory implementation of tertiary canal improvement works.

E2.3.5 Promotion of System Rice Intensification (SRI)

In relation to improve the efficiency of irrigation water use through promoting SRI method, the main concern of GOI is to make SRI more popular in intensive rice cultivation areas. Core practices of SRI are:

- To supply quality seed and fertilizers;
- To extend line planting method of young-aged seedlings;
- To carry out through leveling works of paddy field; and
- To conduct intermittent and shallow depth irrigation practices.

The Ministry of Agriculture has encouraged Provincial governments to establish and operate demonstration plots for disseminating SRI method to rice farmers focusing on demonstration of line planting and qualified farm inputs.

Although the effectiveness of SRI method on irrigation water saving has yet commonly quantified on area-wise basis in any irrigation scheme, the Bogor Agricultural University in Indonesia reported its experimental result indicating that irrigation water consumption for dry season could be reduced by 3.35% by applying SRI method.

It is indispensable to conduct step-wise introduction works for promoting sophisticated SRI method as follows:

- First steps are extension of farming practices such as introduction of line planting method and utilization of qualified seed and fertilizers. For this purpose, capacity building of agricultural extension workers needs to be done followed by generating awareness of farmers about merits of SRI, selecting key farmers, and providing them with training of trainers (TOT) programs by extension workers at the existing SRI demonstration plots; and
- Second steps are introduction of on-farm level physical works and promotion of scheme level works. Such modernization works of irrigation facilities aim to introduce intermittent and shallow depth irrigation practices as well as leveling of paddy field. However, a lot of pre-arrangement works are required for building a consensus among various stakeholders. In this regard, the second step activities need to be promoted in long-term manner.

PART 2 BRANTAS RIVER BASIN

CHAPTER E3 AGRICUTURE IN BRANTAS RIVER BASIN

E3.1 Current Production of Food and Estate Crops in Brantas River Basin

E3.1.1 Food Crop Bowl in Indonesia

Agricultural sector has considerably contributed to regional economy in East Java Province. Especially, achievements of rice cultivation are firstly ranked in Indonesia, sharing 15.2% (2.15 million ha) of the annual harvested area and 17.5% (13.15 million ton) of annual paddy production for 2015. Also, the Brantas River basin has played fundamental part in food crop production in East Java as shown in Table E3.1.1.

Table E3.1.1 Contribution of Brantas River Basin as Food Crop Supply Source

Food Crop	East Java Province				Brantas River basin			
	Harvested Area (ha)	Share in Country (%)	Crop Production (ton)	Share in Country (%)	Harvested Area (ha)	Share in Province (%)	Crop Production (ton)	Share in Province (%)
Paddy	2,152,070	15.25	13,154,957	17.48	515,129	23.94	3,243,367	24.66
Maize	1,213,654	32.05	6,116,313	31.19	299,023	24.64	2,020,939	33.04
Soybean	208,067	33.89	344,998	35.82	37,058	17.81	62,182	18.02
Groundnut	139,544	30.73	191,579	31.66	14,824	10.62	22,727	11.86
Cassava	146,787	15.46	3,161,573	14.51	39,027	26.59	1,190,782	37.66

Source: Statistics Indonesia 2016

Due to urbanization activities implemented elsewhere throughout the Brantas River basin, however, wetland paddy field as the rice production base recently shows decreasing tendency in the respective Regencies and Cities as shown in Table E3.1.2.

Table E3.1.2 Decreasing Tendency of Rice Production Base in Brantas River Basin

Regency (R) / City (C)	Wetland Paddy Field Area in 2010			Wetland Paddy Field Area in 2015			Change in Total (ha)
	Irrigated (ha)	Rainfed (ha)	Total (ha)	Irrigated (ha)	Rainfed (ha)	Total (ha)	
Batu C.	2,107	0	2,107	474	0	474	▲ 1,633
Malang C.	1,070	0	1,070	34,641	2,183	36,824	▲ 205
Malang R.	40,433	3,422	43,855	865	0	865	▲ 7,031
Blitar C.	1,141	0	1,141	27,843	3,151	30,994	▲ 44
Blitar R.	29,845	1,203	31,048	1,097	0	1,097	▲ 54
Tulungagung R.	22,742	2,626	25,368	23,454	2,410	25,864	496
Trenggalek R.	10,695	1,087	11,782	11,049	890	11,939	157
Kediri C.	1,288	50	1,338	37,866	335	38,201	▲ 333
Kediri D.	38,980	435	39,415	1,005	0	1,005	▲ 1,214
Nganjuk R.	38,230	3,629	41,859	37,212	4,269	41,481	▲ 378
Jombang R.	36,999	5,666	42,665	37,235	4,742	41,977	▲ 688
Mojokerto C.	586	15	601	26,777	4,676	31,453	▲ 90
Mojokerto R.	25,996	3,694	29,690	511	0	511	1,763
Sidoarjo R.	22,671	30	22,701	17,517	0	17,517	▲ 5,184
Surabaya C.	386	1,368	1,754	0	1,353	1,353	▲ 401
Total	273,169	23,225	296,394	257,546	24,009	281,555	▲ 14,839

Source: Dalam Angka, BPS Jawa Timur

E3.1.2 Current Rice Production in Brantas River Basin

As shown in Table E3.1.3, annual harvested areas, yield and production of wetland paddy in the Brantas River basin have been fluctuated by effects of climate changes caused by the El-

Nino event in addition to the above urbanization effect. During the period from 2008 to 2015, the rice cultivation in the downstream area of the Brantas River in 2011 was affected to the maximum level by drought triggered by the El-Nino events.

Table E3.1.3 Rice Production Trend in Brantas River Basin

Regency (R) / City (C)	2008			2010			2011			2015		
	H.A. (ha)	Y. t/ha	P.P. (ton)	H.A. (ha)	Y. t/ha	P.P. (ton)	H.A. (ha)	Y. t/ha	P.P. (ton)	H.A. (ha)	Y. t/ha	P.P. (ton)
Batu C.	1,006	6.73	6,766	1,298	5.42	7,037	1,018	5.07	5,164	691	6.43	4,442
Malang C.	2,096	4.74	9,936	2,008	5.52	11,087	2,029	5.66	11,494	1,977	7.26	14,347
Malang R.	56,431	6.94	391,742	58,148	6.53	379,586	60,968	6.87	418,768	63,047	7.13	449,497
Blitar C.	1,568	6.54	10,257	2,125	5.85	12,429	2,336	3.63	8,474	1,850	6.44	11,905
Blitar R.	40,962	6.01	246,273	49,647	6.12	303,913	54,362	5.73	311,552	51,020	6.34	323,325
Tulungagung R.	38,545	6.39	246,167	44,029	5.95	262,133	43,587	5.71	248,684	45,003	6.21	279,554
Trenggalek R.	20,786	5.94	123,382	26,760	5.51	147,522	22,462	5.78	129,766	24,648	6.61	163,043
Kediri C.	1,358	6.89	9,356	2,113	6.56	13,862	2,558	5.84	14,949	1,901	5.49	10,439
Kediri R.	53,086	5.70	302,356	54,879	5.70	312,740	53,273	5.62	299,241	55,625	5.97	332,085
Nganjuk R.	68,619	6.17	423,138	73,922	5.52	407,895	70,698	5.44	384,548	83,188	6.20	516,077
Jombang R.	65,856	6.17	406,412	72,137	6.41	462,342	70,430	5.37	378,112	73,796	6.06	447,345
Mojokerto C.	932	4.80	4,474	970	4.93	4,785	970	4.83	4,683	965	5.59	5,398
Mojokerto R.	45,624	6.26	285,565	49,024	6.31	309,137	45,933	5.95	273,360	53,205	5.94	315,827
Sidoarjo R.	29,103	6.04	175,867	1,298	6.01	187,963	28,779	5.49	157,883	30,266	7.91	239,400
Surabaya C.	1,457	5.49	7,993	2,008	5.48	12,367	2,425	4.88	11,839	1,758	6.35	11,160
	427,429	6.20	2,649,684	470,589	6.02	2,834,798	461,828	5.76	2,658,517	488,940	6.39	3,123,844

Note: H.A.; Annual harvested area (ha), Y.; Unit dry paddy yield (ton/ha), P.P.; Annual paddy production (ton)
Source: Dalam Angka, BPS Jawa Timur

E3.1.3 Other Food Crops in Brantas River Basin

Under the condition of dense population in rural areas, farmers in the Brantas River basin have utilized slope areas of hill and mountatain sides as dryland crop field to the maximum extent for growing maize, dryland paddy, cassava and soybean as shown in Table E3.1.4.

Table E3.1.4 Other Food Crop Production in Brantas River Basin for 2015

Regency (R) / City (C)	Dryland Paddy		Maize		Cassava		Soybean	
	H. Area (ha)	Product (ton)	H. Area (ha)	Product (ton)	H. Area (ha)	Product (ton)	H. Area (ha)	Product (ton)
Batu C.	16	72	226	1,055	51	1,104	0	0
Malang C.	0	4	151	640	91	1,995	0	0
Malang R.	4,601	20,786	45,251	287,175	9,614	360,322	293	220
Blitar C.	0	0	1,844	8,874	0	0	0	0
Blitar R.	5,333	29,180	55,187	360,357	4,513	126,057	11,465	16,535
Tulungagung R.	4,758	20,120	46,642	324,452	7,043	145,182	3,850	6,857
Trenggalek R.	5,151	22,441	14,138	90,076	12,384	298,195	5,178	10,124
Kediri C.	2	7	1,012	5,577	32	827	27	21
Kediri R.	457	2,012	51,480	362,501	4,667	143,431	1,238	1,689
Nganjuk R.	4,540	17,244	30,292	241,546	4,019	88,629	10,105	19,458
Jombang R.	591	3,310	29,412	211,164	635	10,148	487	324
Mojokerto C.	0	0	6	36	0	0	31	47
Mojokerto R.	740	4,347	23,091	125,882	880	14,732	3,270	4,782
Sidoarjo R.	0	0	116	687	0	0	1,114	2,125
Surabaya C.	0	0	175	917	8	160	0	0
Total	26,189	119,523	299,023	2,020,939	43,937	1,190,782	37,058	62,182

Source: Dalam Angka 2016, BPS Jawa Timur

E3.1.4 Estate Crops in Brantas River Basin

Major estate crops grown in the Brantas River basin are coconut, sugarcane, coffee, eocoa and clove matching natural environmental circumstance. Table E3.1.5 shows current palanted area and production of these major estate crops.

Table E3.1.5 Estate Crop Production in Brantas River Basin for 2015

Regency (R) / City (C)	Coconut		Sugarcane		Coffee		Cocoa		Clove	
	P. A. (ha)	C. P. (ton)	P. A. (ha)	C. P. (ton)	P. A. (ha)	C. P. (ton)	P. A. (ha)	C. P. (ton)	P. A. (ha)	C. P. (ton)
Batu C.	0	0	125	632	130	12	0	0	0	0
Malang C.	359	259	619	4,625	8	0	0	0	0	0
Malang R.	13,866	17,485	40,369	277,489	14,147	9,382	2,555	1,803	3,385	1,301
Blitar C.	25	32	0	0	0	0	0	0	0	0
Blitar R.	19,593	23,681	5,906	36,630	2,279	1,343	4,476	2,222	2,513	546
Tulungagung R.	18,984	18,075	5,417	29,802	437	165	1,650	929	1,457	709
Trenggalek R.	14,238	16,375	568	3,545	469	273	4,170	2,680	5,322	961
Kediri C.	2,926	954	1,003	5,960	0	0	0	0	0	0
Kediri R.	9,293	8,611	23,805	163,921	933	619	2,164	469	1,693	334
Nganjuk R.	3,338	808	3,499	24,232	327	107	2,711	1,190	2,263	610
Jombang R.	1,505	656	10,916	55,062	1,338	933	1,454	323	2,335	923
Mojokerto C.	79	71	164	1,048	0	0	0	0	0	0
Mojokerto R.	773	560	8,062	51,814	172	39	0	0	159	35
Sidoarjo R.	2,309	1,079	5,184	28,858	0	0	0	0	0	0
Surabaya C.	0	0	0	9	0	9	0	0	0	0
Total	87,288	88,646	105,637	683,627	20,240	12,882	19,180	9,616	19,127	5,419

Note: P.A.; Plantedd area, C.P.; Annual crop production
Source: Dalam Angka 2016, BPS Jawa Timur

E3.2 Future Rice Cultivation in Brantas River Basin

E3.2.1 Future Rice Harvesting Area in Brantas River Basin

The future rice harvesting area in the Brantas River basin is predicted by applying the results of water balance study as shown in Table E3.2.1.

Table E3.2.1 Prediction of Future Rice Harvesting Areas in Brantas River Basin

Regency (R) / City (C)	Irrigated Area by Regulated Flow				Irrigated Area by Natural Flow				
	Irrigated Area (ha)	CPI (%)	Harvested Area (ha)		Irrigated Area (ha)	CPI (%)		Harvested Area (ha)	
			MH	MK		MH	MK	MH	MK
Batu C.	0	0.0	0	0	1,252	73.5	56.4	920	706
Malang R.	11,220	200.0	11,220	11,220	24,339	73.5	56.4	17,889	13,727
Malang C.	587	200.0	587	587	0	0.0	0.0	0	0
Blitar R.	1,637	200.0	1,637	1,637	25,962	73.5	56.4	19,082	14,643
Blitar C.	0	0.0	0	0	677	73.5	56.4	498	382
Tulungagung R.	10,580	200.0	10,580	10,580	9,420	73.5	56.4	6,924	5,313
Trenggalek R.	1,185	200.0	1,185	1,185	8,639	73.5	56.4	6,350	4,872
Kediri R.	9,179	200.0	9,179	9,179	31,686	73.5	56.4	23,289	17,871
Kediri C.	0	0.0	0	0	500	73.5	56.4	368	282
Nganjuk R.	21,806	200.0	21,806	21,806	13,671	73.5	56.4	10,048	7,710
Jombang R.	34,574	200.0	34,574	34,574	7,914	73.5	56.4	5,817	4,463
Mojokerto R.	8,065	200.0	8,065	8,065	19,931	73.5	56.4	14,649	11,241
Mojokerto C.	105	200.0	105	105	0	0.0	0.0	0	0
Sidoarjo R.	12,206	200.0	12,206	12,206	0	0.0	0.0	0	0
Surabaya C.	0	0.0	0	0	0	0.0	0.0	0	0
Total	111,144		111,144	111,144	143,991			105,833	81,211

Source: JICA Project Team 2

E3.2.2 Future Rice Production in Brantas River Basin

The future rice production in the Brantas River basin is predicted in the following manner:

- New high-yielding rice varieties tolerant to droughts, floods and pest infestation will be grown;
- On-farm level crop management technologies from nursery to harvesting stages will be practiced; and
- Average unit yield level of paddy will be increased to 6.5 ton/ha for the wet season and 7.0 ton/ha for the dry season in regulated flow irrigation areas as well as 6.0 ton/ha for the wet season and 6.5 ton/ha for the dry season in natural flow irrigation areas.

Based on the above assumptions, the future annual rice production in the Brantas River basin is predicted at million tons in total and the breakdown by Regency/ City is shown in Table E3.2.2.

Table E3.2.2 Prediction of Future Rice Production in Brantas River Basin

Regency (R) / City (C)	Irrigated Area by Regulated Flow						Irrigated Area by Natural Flow					
	Wet Season Paddy			Dry Season Paddy			Wet Season Paddy			Dry Season Paddy		
	A*.	Y*.	P*.	A.	Y.	P.	A.	Y.	P.	A.	Y.	P.
Batu C.	0	6.5	0	0	7.0	0	0	6.0	0	706	6.5	4,590
Malang R.	11,220	6.5	72,930	11,220	7.0	78540	5,498	6.0	32,987	13,727	6.5	89,227
Malang C.	587	6.5	3,816	587	7.0	4109	288	6.0	1,726	0	6.5	0
Blitar R.	1,637	6.5	10,641	1,637	7.0	11459	802	6.0	4,813	14,643	6.5	95,177
Blitar C.	0	6.5	0	0	7.0	0	0	6.0	0	382	6.5	2,482
Tulungagung R.	10,580	6.5	68,770	10,580	7.0	74060	5,184	6.0	31,105	5,313	6.5	34,534
Trenggalek R.	1,185	6.5	7,703	1,185	7.0	8295	581	6.0	3,484	4,872	6.5	31,671
Kediri R.	9,179	6.5	59,664	9,179	7.0	64253	4,498	6.0	26,986	17,871	6.5	116,161
Kediri C.	0	6.5	0	0	7.0	0	0	6.0	0	282	6.5	1,833
Nganjuk R.	21,806	6.5	141,739	21,806	7.0	152642	10,685	6.0	64,110	7,710	6.5	50,118
Jombang R.	34,574	6.5	224,731	34,574	7.0	242018	16,941	6.0	101,648	4,463	6.5	29,013
Mojokerto R.	8,065	6.5	52,423	8,065	7.0	56455	3,952	6.0	23,711	11,241	6.5	73,067
Mojokerto C.	105	6.5	683	105	7.0	735	51	6.0	309	0	6.5	0
Sidoarjo R.	12,206	6.5	79,339	12,206	7.0	85442	5,981	6.0	35,886	0	6.5	0
Surabaya C.	0	6.5	0	0	7.0	0	0	6.0	0	0	6.5	0
Total	111,144		722,436	111,144		778,008	54,461		326,763	81,211		527,871

Note: A.; Harvested area (ha), Y.; Paddy yield (ton/ha), P. Paddy production (tons)
Source: JICA Project Team 2

CHAPTER E4 IRRIGATION IN BRANTAS RIVER BASIN

E4.1 Surface Water Irrigation Area in Brantas River Basin

E4.1.1 Existing Surface Water Irrigation Schemes in Brantas River Basin

In the Ministerial Ordinance No.14/2015 concerning criteria and status of irrigation, 3,698 surface water irrigation schemes are listed up with irrigation command design areas in 15 Regencies/ Cities covering the Brantas River basin. These schemes are also categorized in three groups based on management authority criteria of the ordinance as shown in Table E4.1.1. The main stream of the Brantas River is functioning as irrigation water source river for seven existing surface water irrigation schemes, while tributaries are water source rivers of all other schemes including five BBWS Brantas managed schemes as listed up in Table E4.1.2.

Table E4.1.1 Existing Surface Water Irrigation Areas in Brantas River basin

Regency (R) / City (C)	BBWS Brantas		Province*		Regency / City**				Total	
	Over 10,000 ha		10,000 – 1,000 ha		1,000 - 100 ha		Below 100 ha			
	(nos.)	(ha)	(nos.)	(ha)	(nos.)	(ha)	(nos.)	(ha)	(nos.)	(ha)
Batu C.	0	0	(2)	328	6	1,139	36	968	42 (2)	2,435
Malang R.	2 (1)	8,771	11 (9)	3,165	99	19,033	618	16,313	730 (10)	47,282
Malang C.	(1)	587	9 (9)	1,287	0	0	10	276	19 (10)	2,150
Blitar R.	(1)	1,637	4 (9)	2,123	53	11,553	621	16,460	678 (10)	31,773
Blitar C.	0	0	8 (2)	333	0	0	36	1,051	44 (2)	1,384
Tulungagung R.	1	10,580	3 (2)	4,915	27	5,825	141	4,397	172 (2)	25,717
Trenggalek R.	0	0	1 (2)	1,894	11	3,342	512	6,366	524 (2)	11,602
Kediri R.	(3)	9,179	11 (2)	4,611	97	17,763	538	17,021	646 (5)	48,574
Kediri C.	0	0	2 (7)	620	3	363	39	1,345	44 (7)	2,328
Nganjuk R.	2	21,106	3	3,866	41	11,106	169	3,845	215 (0)	39,923
Jombang R.	2 (1)	31,962	5 (2)	3,419	38	9,145	158	3,503	203 (3)	48,029
Mojokerto R.	2 (1)	7,655	6 (4)	5,477	35	9,173	330	8,584	373 (5)	30,889
Mojokerto C.	(1)	53	1 (4)	580	0	0	0	0	1 (5)	633
Sidoarjo R.	1	17,766	0	0	12	3,827	6	291	19 (0)	21,884
Surabaya C.	0	0	0	0	0	0	0	0	0 (0)	0
Total	8	109,296	54	32,618	422	92,269	3,214	80,420	3,698	314,603

Note: *; Dinas PU Sumber Daya Air Jawa Timur, **; PU Local Government
Source: DGWR

Table E4.1.2 List of BBWS Brantas Managed Irrigation Schemes by Water Source River

Brantas Main Stream as Water Source River				Brantas Tributaries as Water Source River			
Scheme	Design Area (ha)		Location	BBWS Brantas Scheme	Design Area (ha)		Location
D.I. Lodoyo	12,217	1,637	Blitar R.	D.I. Kedung Kandang	5,160	4,573	Malang R.
		10,580	Tulungagung R.			587	Malang C.
D.I. Mrican Kanan	17,612	3,952	Kediri R.	D.I. Molek	3,883		Malang R.
		13,660	Jombang R.	D.I. Waduk Bening	8,752		Nganjuk R.
D.I. Mrican Kiri	12,729	375	Kediri R.	D.I. Siman	23,060	315	Malang R.
		12,354	Nganjuk R.			4,852	Kediri R.
D.I. Jatimlerek		1,812	Jombang R.			17,893	Jombang R.
D.I. Mentrus	3,632	409	Jombang R.	D.I. Padi Pomahan	4,309	4,256	Mojokerto R.
		3,223	Mojokerto R.			53	Mojokerto C.
D.I. Jati Kulon	638	586	Mojokerto R.				
		52	Mojokerto C.				
D.I. Delta Brantas	17,942	176	Mojokerto R.				
		17,766	Sidoarjo R.				
Total	64,770				45,164		

Source: DGWR

E4.1.2 Future Surface Water Irrigation Scheme Area

Future surface water irrigation areas in the Brantas River basin are to be predicted in conjunction with the projection of land use in 2050 as described in Chapter 5.2.2. Further assumptions are made as follows:

- All the existing schems are seperated into two groups based on irrigation water sources. The first group consists of schemes depending irrigation water sources on regulated flow supplied from the existing and palnned dam reservoirs, while the second group consists of schems diverting natural river flow from intake facilities;
- Along with the LP2B policy, irrigation schemes of the first group should be maintained to full extent of the respective desing areas including four new schemes with the total desin area of 5,134 ha along tributaries of the Brantas River. On the other hand, 5,736 ha out of Dlta Brantas irrigation scheme area will be converted to residential areas due to its location adjacent to Surabaya City and thereby the future design irrigation area will reduce to 12,206 ha; and
- Irrigation schemes of the second group locating in urban areas will be converted for meeting residential and industrial land resources requiremewnts to considerable extent, while maintained schemes will be utilized to full extent of the desingn irrigation areas.

Based on the above assumptions, the future surface water irrigation areas are predicrted by Regenct/ City as shown in Table E4.1.3.

Table E4.1.3 Prediction of Future Irrigation Areas in Brantas River Basin

Regency (R.) / City (C.)	Present Condition for 2010 (ha)			Future Condition for 2050 (ha)		
	Irrigation Total Area	Irrigation Water Source		Irrigation Total Area	Irrigation Water Source	
		Regulated	Natural flow		Regulated	Natural flow
Batu C.	2,435	0	2,435	1,252	0	1,252
Malang R.	47,282	8,771	38,511	35,559	11,220	24,339
Malang C.	2,150	587	1,563	587	587	0
Blitar R.	31,773	1,637	30,136	27,599	1,637	25,962
Blitar C.	1,384	0	1,384	677	0	677
Tulungagung R.	25,717	10,580	15,137	20,000	10,580	9,420
Trenggalek R.	11,602	0	11,602	9,824	1,185	8,639
Kediri R.	48,574	9,179	39,395	40.865	9,179	31,686
Kediri C.	2,328	0	2,328	500	0	500
Nganjuk R.	39,923	21,106	18,817	35,477	21,806	13,671
Jombang R.	48,029	33,774	14,255	42,488	34,574	7,914
Mojokerto R.	30,889	8,241	22,648	27,996	8,065	19,931
Mojokerto C.	633	105	528	105	105	0
Sidoarjo R.	21,884	17,766	4,118	12,206	12,206	0
Surabaya C.	0	0	0	0	0	0
Total	314,603	111,746	202,857	255,135	111,144	143,991

Source: JICA Project Team 2

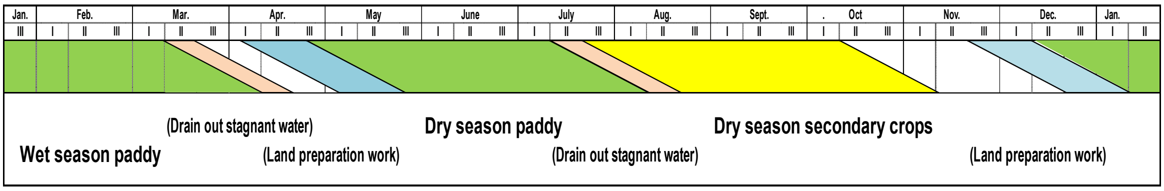
E4.2 Irrigation Water Demand in Brantas River Basin

E4.2.1 Unit Irrigation Water Requirement under Observed Climate Condition

In order to quantify the effect of different climate change models on irrigation water demand, unit irrigation water requirement is calculated by substituting evapotranspiration and effective rainfall data of future low, medium, high risk scenario patterns as well as present rainfall pattern in the KP-1 formula as described in Chapter E2.2.1. In the Brantas

River basin case, focal points are as follow:

- Effective rainfall indicates daily rainfall between 5.0 mm and 80.0 mm;
- The calculation works are carried out on the 10-day period basis by using 10-day average evapotranspiration and effective rainfall data;
- The calculation period is 20 years from 1991 to 2010 for the present pattern and 2046 to 2065 for the future scenario patterns;
- A sole cropping calendar as shown in Figure E4.2.1 with the lowest peak irrigation water requirement selected through comparative examination works is applied to all irrigation schemes for the both present and future climate conditions; and
- The calculation results are shown as the average unit irrigation water requirement of 10-day period for each crop growing period of wet season paddy (MH), dry season paddy (MK-1) and dry season secondary crop (MK-2).



Source: JICA Project Team 2

Figure E4.2.1 Cropping Calendar for Irrigation Schemes in Brantas River Basin

Table E4.2.1 shows the calculation results of scenario-based unit irrigation water requirement for the respective surface water irrigation schemes managed by BBWS Brantas including three medium-scale schemes using the main stream flow of the Brantas River. The calculation results on Regency/ City basis are shown in Table E4.2.2.

Table E4.2.1 Seasonal Average of Unit Irrigation Water Requirement by Major Scheme

Surface Water Irrigation Scheme	10-day Average Unit Irrigation Water Requirement by Crop Season (l/s/ha)											
	Present Rainfall (1995 – 2010)			Low Scenario (2046 – 2065)			Medium Scenario (2046 – 2065)			High Scenario (2046 – 2065)		
	MH	MK-1	MK-2	MH	MK-1	MK-2	MH	MK-1	MK-2	MH	MK-1	MK-2
BBWS Brantas Managed Irrigation Schemes withdrawing water from tributaries of Brantas River												
Kedung Kandang	0.40	0.88	0.29	0.52	1.00	0.50	0.45	1.07	0.48	0.57	1.16	0.48
Molek	0.27	0.81	0.26	0.31	0.84	0.40	0.45	1.04	0.47	0.41	1.02	0.41
Siman	0.55	0.96	0.32	0.56	1.05	0.56	0.58	1.17	0.57	0.61	1.24	0.55
Waduk Bening	0.34	0.87	0.24	0.42	0.96	0.54	0.51	1.13	0.52	0.48	1.17	0.52
Padi Pomahan	0.50	0.98	0.33	0.53	1.05	0.56	0.56	1.18	0.58	0.59	1.24	0.55
Jaruma I & II	0.49	0.86	0.24	0.53	1.00	0.51	0.47	1.06	0.47	0.59	1.16	0.49
Ngasinan	0.61	0.96	0.29	0.70	1.08	0.53	0.64	1.14	0.51	0.71	1.24	0.53
Kedung Soko	0.36	0.86	0.24	0.44	0.97	0.54	0.47	1.10	0.53	0.49	1.18	0.52
Bareng	0.46	0.93	0.32	0.49	1.00	0.53	0.51	1.13	0.52	0.63	1.20	0.51
BBWS Brantas Managed Irrigation Schemes withdrawing water from main stream of Brantas River												
Lodoyo (Lodagung)	0.48	0.94	0.37	0.56	1.02	0.52	0.49	1.12	0.53	0.55	1.21	0.51
Mrican Kanan	0.53	0.98	0.37	0.54	1.04	0.54	0.58	1.18	0.57	0.60	1.24	0.55
Mrican Kiri	0.44	0.98	0.39	0.47	1.00	0.55	0.49	1.14	0.56	0.52	1.21	0.53
Jatimlerek	0.49	0.92	0.33	0.53	1.03	0.56	0.56	1.16	0.57	0.58	1.23	0.54
Mentrus	0.53	0.97	0.34	0.56	1.05	0.56	0.58	1.18	0.58	0.61	1.24	0.55
Jatikulon	0.53	0.91	0.36	0.54	1.05	0.56	0.57	1.18	0.58	0.59	1.24	0.55
Brantas Delta	0.33	0.94	0.25	0.42	1.02	0.53	0.47	1.14	0.53	0.48	1.18	0.49

Source: JICA Project Team 2

Table E4.2.2 Seasonal Average of Unit Irrigation Water Requirement by Regency/ City

Regency (R) / City (C)	10-day Average Unit Irrigation Water Requirement for Crop Season (l/s/ha)											
	Present Rainfall (1995 – 2010)			Low Scenario (2046 – 2065)			Medium Scenario (2046 – 2065)			High Scenario (2046 – 2065)		
	MH	MK-1	MK-2	MH	MK-1	MK-2	MH	MK-1	MK-2	MH	MK-1	MK-2
Batu C.	0.19	0.80	0.28	0.27	0.78	0.35	0.29	0.82	0.33	0.44	0.84	0.32
Malang R.	0.32	0.81	0.30	0.39	0.79	0.22	0.38	0.84	0.32	0.45	0.96	0.30
Malang C.	0.32	0.81	0.30	0.39	0.92	0.23	0.38	0.84	0.32	0.58	0.96	0.30
Blitar R.	0.36	0.83	0.27	0.39	0.80	0.17	0.39	0.81	0.27	0.48	0.91	0.25
Blitar C.	0.36	0.83	0.27	0.45	0.84	0.25	0.44	0.96	0.44	0.49	1.07	0.42
Tulungagung R.	0.42	0.76	0.37	0.43	0.85	0.31	0.44	0.84	0.25	0.44	0.95	0.23
Trenggalek R.	0.54	0.92	0.29	0.52	0.87	0.27	0.52	0.92	0.23	0.46	1.02	0.24
Kediri R.	0.38	0.87	0.28	0.36	0.75	0.24	0.43	0.85	0.29	0.36	0.97	0.26
Kediri C.	0.26	0.78	0.28	0.24	0.74	0.31	0.34	0.79	0.24	0.36	0.87	0.47
Nganjuk R.	0.30	0.77	0.25	0.32	0.75	0.24	0.35	0.74	0.23	0.39	0.91	0.20
Jombang R.	0.43	0.91	0.36	0.38	0.92	0.38	0.39	0.82	0.34	0.49	1.06	0.35
Mojokerto R.	0.39	0.91	0.31	0.38	0.87	0.32	0.40	1.06	0.36	0.44	1.10	0.39
Mojokerto C.	0.43	0.91	0.34	0.38	0.89	0.21	0.42	0.84	0.24	0.47	1.02	0.32
Sidoarjo R.	0.26	0.90	0.23	0.34	0.95	0.38	0.42	0.87	0.24	0.37	0.95	0.29

Source: JICA Project Team 2

E4.2.2 Unit Irrigation Water Requirement for Planning Purpose

In planning rehabilitation, renovation and extension of the existing irrigation schemes as well as new development of irrigation scheme, it is ideal to apply rainfall data on 5-year probable drought year instead of the average rainfall data of a certain period aiming at optimization of design capacity of relevant irrigation facilities. In this regard, Table E4.2.3 presents unit irrigation water requirement on the 5-year probable year basis.

Table E4.2.3 Unit Irrigation Water Requirement for Planning Purposes

Surface Water Irrigation Scheme	10-day Average Unit Irrigation Water Requirement by Crop Season (l/s/ha)											
	Present Rainfall (1995 – 2010)			Low Scenario (2046 – 2065)			Medium Scenario (2046 – 2065)			High Scenario (2046 – 2065)		
	MH	MK-1	MK-2	MH	MK-1	MK-2	MH	MK-1	MK-2	MH	MK-1	MK-2
BBWS Brantas Managed Irrigation Schemes withdrawing water from tributaries of Brantas River												
Kedung Kandang	0.68	1.12	0.42	0.85	1.35	0.60	0.97	1.40	0.62	1.14	1.41	0.60
Molek	0.43	1.09	0.40	0.54	1.29	0.59	0.97	1.39	0.61	0.96	1.38	0.60
Siman	0.86	1.19	0.44	0.86	1.39	0.64	1.05	1.44	0.66	1.06	1.45	0.65
Waduk Bening	0.53	1.10	0.33	0.74	1.35	0.63	1.00	1.40	0.61	0.90	1.44	0.64
Padi Pomahan	0.74	1.20	0.44	0.84	1.40	0.64	1.04	1.44	0.67	1.04	1.45	0.65
Jaruma I & II	0.71	1.10	0.34	0.88	1.36	0.60	1.00	1.40	0.61	1.15	1.42	0.61
Ngasinan	0.93	1.15	0.41	0.95	1.39	0.61	1.08	1.41	0.61	1.20	1.42	0.61
Kedung Soko	0.51	1.09	0.34	0.76	1.36	0.63	0.99	1.42	0.64	0.93	1.44	0.64
Bareng	0.74	1.09	0.34	0.82	1.36	0.61	1.04	1.43	0.61	1.03	1.44	0.64
BBWS Brantas Managed Irrigation Schemes withdrawing water from main stream of Brantas River												
Lodoyo (Lodagung)	0.76	1.17	0.51	0.91	1.39	0.62	1.02	1.43	0.66	1.19	1.43	0.62
Mrican Kanan	0.80	1.22	0.47	0.84	1.37	0.61	1.05	1.44	0.66	1.06	1.45	0.65
Mrican Kiri	0.78	1.21	0.48	0.81	1.38	0.64	1.00	1.43	0.66	0.97	1.45	0.65
Jatimlerek	0.73	1.16	0.43	0.84	1.39	0.64	1.04	1.44	0.66	1.03	1.45	0.65
Mentrus	0.82	1.21	0.46	0.86	1.40	0.64	1.05	1.44	0.66	1.06	1.45	0.65
Jatikulon	0.74	1.20	0.22	0.84	1.40	0.64	1.04	1.44	0.66	1.06	1.45	0.66
Brantas Delta	0.49	1.13	0.33	0.68	1.35	0.62	0.96	1.41	0.64	0.88	1.43	0.63

Source: JICA Project Team 2

From the above data, it is suggested that the design capacity of fundamental irrigation facilities needs to be increased by 35% to 45% compared with the standard design capacity stipulated in the SNI formula in order to cope with the respective future climate change scenarios.

E4.2.3 Irrigation Water Diversion Requirement

Irrigation water demand is defined as supplemental requirement for meeting insufficient irrigation water needs which cannot be fulfilled by effective rainfall. In surface water irrigation scheme areas, such supplemental irrigation water needs to be diverted from water source rivers.

In predicting irrigation water diversion requirements by referring to the future rice harvesting areas in the Brantas River basin as predicted in Table E2.2.1, the following points are considered:

- Cropping intensity of the existing and future irrigation schemes with water sources of regulated flow is 250% (100% each for paddy in the both wet and dry seasons and 50% for dry season secondary crop) under the present and future climate conditions; and
- Cropping intensity in irrigation schemes depending water sources on natural river flow is assumed to be 73.5% for the wet season paddy, 45.6% for the dry season paddy and 4.9% for the dry season secondary crop at present level, while the future cropping intensity increases to 55.4% only for the dry season paddy and remains at the same level for the wet season paddy as well as the dry season secondary crop.

Taking the above assumptions into account, the irrigation water demand is predicted for the 20-year period of the respective climate scenarios. The calculation results as shown in Table E4.2.4 indicate the average of 10-day irrigation water diversion requirements during each crop season in case of irrigation scheme areas with regulated water sources, while the results as shown in Table E4.2.5 reveal the average same as above in case of irrigation scheme areas depending irrigation water sources on natural river flow.

Table E4.2.4 Average Irrigation Water Demand for Regulated Flow-based Irrigation Schemes

Surface Water Irrigation Scheme	Scheme Area (ha)	Present Rainfall Pattern (m^3/s) 1991 - 2010			Scheme Area (ha)	Low Scenario Pattern (m^3/s) 2046 - 2965		
		MH	MK-1	MK-2		MH	MK-1	MK-2
BBWS Brantas Managed Irrigation Schemes withdrawing water from tributaries of Brantas River								
Kedung Kandang	5,160	2.0	4.5	0.7	5,160	2.7	5.2	1.3
Molek	3,883	1.1	3.1	0.5	3,883	1.2	3.2	0.8
Siman	23,060	12.7	22.0	3.7	23,060	12.9	24.2	6.5
Waduk Bening	8,752	3.0	7.6	1.0	8,752	3.7	8.4	2.4
Padi Pomahan	4,309	2.1	4.2	0.7	4,309	2.3	4.5	1.2
Jaruma I & II	2,449	1.2	2.1	0.3	2,449	1.3	2.4	0.6
Ngasinan	1,185	0.7	1.1	0.2	1,185	0.8	1.3	0.3
Kedung Soko	700	0.2	0.6	0.1	700	0.3	0.7	0.2
Bareng	800	0.4	0.7	0.1	800	0.4	0.8	0.2
BBWS Brantas Managed Irrigation Schemes withdrawing water from main stream of Brantas River								
Lodoyo (Lodagung)	12,217	5.8	11.5	2.2	12,217	6.8	12.5	3.2
Mrican Kanan	17,612	9.3	17.3	3.2	17,612	9.6	18.2	4.7
Mrican Kiri	12,729	5.6	12.5	2.5	12,729	6.0	12.8	3.5
Jatimlerek	1,812	0.9	1.7	0.3	1,812	1.0	1.9	0.5
Mentrus	3,632	1.9	3.5	0.6	3,632	2.0	3.8	1.0
Jatikulon	638	0.3	0.6	0.1	638	0.3	0.7	0.2
Brantas Delta	17,765	5.9	16.8	2.2	12,206	5.1	12.4	3.2

Surface Water Irrigation Scheme	Scheme Area (ha)	Medium Rainfall Pattern (m^3/s) 2046 - 2965			Scheme Area (ha)	High Scenario Pattern (m^3/s) 2046 - 2965		
		MH	MK-1	MK-2		MH	MK-1	MK-2
BBWS Brantas Managed Irrigation Schemes withdrawing water from tributaries of Brantas River								
Kedung Kandang	5,160	2.3	5.5	1.2	5,160	3.0	6.0	1.3
Molek	3,883	1.8	4.1	0.9	3,883	1.6	3.9	0.8
Siman	23,060	13.4	27.0	6.6	23,060	14.0	28.5	6.3
Waduk Bening	8,752	4.5	9.9	2.3	8,752	4.2	10.3	2.3
Padi Pomahan	4,309	2.4	5.1	1.2	4,309	2.5	5.3	1.2
Jaruma I & II	2,449	1.1	2.6	0.6	2,449	1.4	2.9	0.6
Ngasinan	1,185	0.8	1.3	0.3	1,185	0.8	1.5	0.3
Kedung Soko	700	0.3	0.8	0.2	700	0.3	0.8	0.2
Bareng	800	0.4	0.9	0.2	800	0.5	1.0	0.2
BBWS Brantas Managed Irrigation Schemes withdrawing water from main stream of Brantas River								
Lodoyo (Lodagung)	12,217	6.0	13.6	3.2	12,217	6.8	14.8	3.1
Mrican Kanan	17,612	10.2	20.8	5.1	17,612	10.6	21.8	4.8
Mrican Kiri	12,729	6.2	14.4	3.6	12,729	6.6	15.3	3.4
Jatimlerek	1,812	1.0	2.1	0.5	1,812	1.1	2.2	0.5
Mentrus	3,632	2.1	4.3	1.0	3,632	2.2	4.5	1.0
Jatikulon	638	0.4	0.8	0.2	638	0.4	0.8	0.2
Brantas Delta	12,206	5.7	13.9	3.2	12,206	5.9	14.4	3.0

Source: JICA Project Team 2

Table E4.2.5 Average Irrigation Water Demand for Natural Flow-based Irrigation Schemes

Regency (R) / City (C)	Scheme Area (ha)	Present Rainfall Pattern (m^3/s) 1991 - 2010			Scheme Area (ha)	Low Scenario Pattern (m^3/s) 2046 - 2965		
		MH	MK-1	MK-2		MH	MK-1	MK-2
Batu C.	2,435	0.3	0.9	0.03	1,252	0.2	0.5	0.02
Malang R.	38,511	9.2	14.2	0.55	24,339	6.1	9.3	0.23
Malang C.	1,563	0.4	0.6	0.02	0	0.0	0.0	0.00
Blitar R.	30,136	7.9	11.3	0.40	25,962	7.4	11.5	0.22
Blitar C.	1,384	0.4	0.5	0.02	677	0.1	0.3	0.01
Tulungagung R.	15,137	4.6	5.3	0.27	9,420	3.0	4.4	0.14
Trenggalek R.	11,602	4.6	4.9	0.16	8,639	3.3	3.5	0.10
Kediri R.	39,395	10.9	15.5	0.50	31,686	8.2	13.2	0.37
Kediri C.	2,328	0.4	0.8	0.03	500	0.1	0.2	0.01
Nganjuk R.	18,817	4.2	6.6	0.22	13,671	3.0	5.4	0.15
Jombang R.	14,255	4.5	5.9	0.25	7,914	1.5	2.7	0.10
Mojokerto R.	22,648	6.5	9.4	0.34	19,931	5.4	9.4	0.31
Mojokerto C.	528	0.2	0.2	0.01	0	0.0	0.0	0.00
Sidoarjo R.	4,118	0.8	1.7	0.04	0	0.0	0.0	0.00
Regency (R) / City (C)	**Scheme Area (ha)**	**Medium Rainfall Pattern (m^3/s) 2046 - 2965**			**Scheme Area (ha)**	**High Scenario Pattern (m^3/s) 2046 - 2965**		
		MH	**MK-1**	**MK-2**		**MH**	**MK-1**	**MK-2**
Batu C.	1,252	0.3	0.6	0.02	1,252	0.4	0.6	0.02
Malang R.	24,339	6.0	9.9	0.33	24,339	7.0	11.3	0.31
Malang C.	0	0.0	0.0	0.00	0	0.0	0.0	0.00
Blitar R.	25,962	7.4	11.7	0.34	25,962	9.2	13.1	0.32
Blitar C.	677	0.2	0.4	0.01	677	0.2	0.4	0.01
Tulungagung R.	9,420	3.0	4.4	0.12	9,420	3.0	5.0	0.11
Trenggalek R.	8,639	2.8	3.8	0.08	8,639	2.5	4.2	0.09
Kediri R.	31,686	10.0	14.9	0.45	31,686	8.4	17.0	0.40
Kediri C.	500	0.1	0.2	0.01	500	0.1	0.2	0.01
Nganjuk R.	13,671	3.3	5.3	0.15	13,671	3.8	6.5	0.13
Jombang R.	7,914	1.5	2.4	0.09	7,914	1.9	3.1	0.09
Mojokerto R.	19,931	5.7	11.4	0.34	19,931	6.3	11.9	0.37
Mojokerto C.	0	0.0	0.0	0.00	0	0.0	0.0	0.00
Sidoarjo R.	0	0.0	0.0	0.00	0	0.0	0.0	0.00

Source: JICA Project Team

PART 3 MUSI RIVER BASIN

CHAPTER E5 AGRICUTURE IN MUSI RIVER BASIN

E5.1 Present Situation of Major Crop Production in Musi River Basin

E5.1.1 Present Condition of Food Crop Cultivation in Musi River Basin

In South Sumatra, it is featured that almost half of wetland paddy cultivation areas are distributed in tidal and inland swamp areas and rice plants are mostly grown under rainfed condition with limited share (15.2%) of irrigated paddy field. Table E5.1.1 gives feature of rice cultivation prevailing in the Musi River basin.

Table E5.1.1 Features of Rice Cultivation in Musi River Basin

Item	Irrigated field	Rain-fed field	Tidal swamp field	Inland swamp area
Plot location	Paddy field plot is made in a fixed place.			No paddy field plot is made, and planted area is shifted according to water level change in inland swamp.
Plot type	Water level of paddy field plot can be controlled by man-made ditches dividing paddy filed.			No shape of paddy field plot.
Water source	Natural flow of water source river and/ or regulated flow discharged from reservoir	Rain water	Rain water and/ or pumped up fresh water from drainage canal	Stagnant fresh water in inland swamp
Share of area	13.7%	13.2%	29.9%	43.2%
Cropping period	Land preparation & transplanting times are fixed for both wet and dry season crops.	Land preparation & transplanting times of wet season crop are linked with starting of rainy season.		Seedlings grown in nurseries made in other dry land areas are transplanted in dry season
Public service (Facility)	Legal status as irrigation scheme is given and O&M responsible agency is decided based on related Government regulation.	No legal status is given, but, if paddy field has a certain scale, the area has a possibility of being taken up as the candidate area for new irrigation development.	Legal status as swamp drainage scheme is given and responsible agency for O&M is decided based on related Government regulation.	Out of public services
Public service (Extension)	Cultivation of high yielding rice varieties are encouraged to farmers for triple cropping with paddy for two seasons and dry season secondary crop, double cropping of paddy, and/ or two cropping of paddy and secondary crop.	Growing of high yielding variety of rice for wet season is recommended.	Long stem and salt tolerant rice variety is advised.	Long stem variety is advised.

Source: JICA Project Team 2

E5.1.2 Current Rice Cultivation Areas in South Sumatra

As a result of implementing large scale surface water irrigation and swamp drainage schemes during the period of South Sumatra RPJMD 2010 - 2014, functioned wetland paddy field areas increased by around 163,000 ha or 4.4% per annum for six years between 2010 and 2015 as shown in Table E5.1.2. In irrigated paddy field areas, farmers are encouraged to practice double cropping of wetland rice, but many of them are facing high risks due to unstable condition of natural flow in irrigation water source rivers. Further, some of them are reluctant to carry out dry season rice cultivation due to the existence of partly deteriorated irrigation system.

Table E5.1.2 Current Wetland Paddy Field Areas in South Sumatra

Regency (R) / City (C)	Wetland Paddy Field in 2010 Irrigated (ha)	Wetland Paddy Field in 2010 Rainfed (ha)	Wetland Paddy Field in 2010 Total (ha)	Wetland Paddy Field in 2015 Irrigated (ha)	Wetland Paddy Field in 2015 Rainfed (ha)	Wetland Paddy Field in 2015 Total (ha)	Change in Total (ha)
Palembang C.	0	6,728	6,728	0	6,189	6,189	▲ 539
Prabumulih C.	0	473	473	0	700	700	227
Pagar Alam C.	3,500	0	3,500	3,440	0	3,440	▲ 60
Lubuk Linggau C.	1,624	270	1,894	1,637	257	1,894	0
OKI R.	650	120,812	121,462	650	185,348	185,998	64,536
Ogan Ilir R.	0	50,865	50,865	0	67,627	67,627	16,762
OKU Timur R.	35,669	43,230	78,899	43,506	42,114	85,620	6,721
OKU R.	2,492	1,876	4,368	3,244	5,628	8,872	4,504
OKU Selatan R.	12,737	2,241	14,978	16,099	1,941	18,040	3,062
Muara Enim R.	5,842	22,547	28,389	6,395	20,622	27,017	▲ 1,372
PALI R.	0	0	0	0	6,579	6,579	6,579
Lahat R.	15,166	1,623	16,789	15,845	1,680	17,525	736
Empat Lawang R.	11,215	795	12,010	13,105	986	14,091	2,081
Musi Rawas R.	13,002	14,808	27,810	13,421	17,030	30,451	2,641
Musi Rawas Utara R.	0	0	0	415	6,716	7,131	7,131
Musi Banyuasin R.	140	54,310	54,450	0	66,810	66,810	12,360
Banyuasin R.	0	188,771	188,771	0	226,518	226,518	37,747
South Sumatra Total	102,037	509,349	611,386	117,757	656,745	774,502	163,116

Source: Sumatera Selatan Dalam Angka

E5.1.3 Current Rice Production in South Sumatra

Table E5.1.3 shows the past trend of rice production by Regency/ City in South Sumatra in terms of annual harvested area, cropping intensity, yield and dry paddy production in 2010 and 2015.

Table E5.1.3 Current Wetland Paddy Production in South Sumatra

Regency (R) / City (C)	2010 Harvested Area (ha)	2010 Cropping Intensity (%)	2010 Unit Yield (ton/ha)	2010 Annual Product. (ton)	2015 Harvested Area (ha)	2015 Cropping Intensity (%)	2015 Unit Yield (ton/ha)	2015 Annual Product. (ton)
Palembang C.	6,336	94.2	3.91	24,773	5,814	93.9	4.46	25,912
Prabumulih C.	468	101.1	2.97	1,390	511	73.0	2.88	1,472
Pagar Alam C.	6,167	56.8	5.19	31,817	8,694	252.7	4.95	43,040
Lubuk Linggau C.	4,340	43.6	5.52	23,961	5,482	289.4	4.60	25,208
OKI R.	115,143	94.8	6.20	715,767	132,641	71.3	4.62	612,706
Ogan Ilir R.	47,067	92.5	4.14	195,038	45,253	66.9	3.83	173,244
OKU Timur R.	138,730	175.8	6.01	833,400	141,729	165.5	6.08	861,235
OKU R.	6,988	160.0	5.65	125,814	7,196	81.1	4.83	34,744
OKU Selatan R.	24,195	161.5	5.20	16,099	39,602	219.5	5.00	197,973
Muara Enim R.	9,874	34.8	5.98	59,027	26,138	96.7	4.51	117,997
PALI R.	0	0	0	0	5,629	85.6	3.65	20,551
Lahat R.	27,775	165.4	4.96	137,857	30,207	172.4	4.98	150,312
Empat Lawang R.	23,731	197.6	4.24	100,619	28,883	205.0	4.28	123,746
Musi Rawas R.	46,180	166.1	5.24	241,844	42,706	140.2	5.84	249,603
M. Rawas Utara R.	0	0	0	0	2,950	41.4	3.97	11,700
Musi Banyuasin R.	51,994	95.5	5.18	269,144	45,197	67.7	4.98	225,249
Banyuasin R.	185,525	98.3	4.26	790,495	253,034	111.7	4.87	1,231,803
South Sumatra	694,513	113.6	5.14	3,567,045	821,666	106.1	5.00	4,106,495

Source: BPS Sumatera Selatan

E5.1.4 Current Estate Crop Planting Areas in South Sumatra

Strategic crops in South Sumatra Province are perennial tree crops such as rubber, coconut, oil palm and coffee. The current planted area of these four estate crops in South Sumatra Province are shown in Table E5.1.4. Majority of rubber growers are smallholders followed by government and private estates, while oil palm is grown by private estates to a large extent over smallholders and government estates. On the other hand, coconut and coffee are planted by smallholders only.

Ministry of Agriculture through Directorate General of Estate Crops established a guideline of data management on estate crop commodities aiming at synchronization and validation of estate crop statistical data prepared at regency level as primary data. In the guideline, estate crop planting areas are classified based on crop status such as immature, mature and damaged as well as growers' status such as government estate, private estate, foreign investor's estate and smallholder. This guideline has been applied to data throughout the country from 2015. In case of South Sumatra, therefore, there exist discrepancies of data with a wide range between Statistics for 2015 issued by BPS South Sumatra and Ministry of Agriculture. The total planted area data of the four major estate crops for 2015 in South Sumatra Statistics are 1,260,821 ha for rubber, 68,078 ha for coconut, 400,188 ha for oil palm and 249,510 ha for coffee. So, there remain discrepancies of statistical data on rubber and oil palm planting areas between BPS South Sumatra and Ministry of Agriculture.

Table E5.1.4 Current Estate Crop Planted Areas in South Sumatra

Regency (R) / City (C)	2010 based on BPS South Sumatra				2015 based on Ministry of Agriculture			
	Rubber (ha)	Coconut (ha)	Oil Palm (ha)	Coffee (ha)	Rubber (ha)	Coconut (ha)	Oil Palm (ha)	Coffee (ha)
Palembang C.	0	0	0	0	364	31	127	0
Prabumulih C.	18,626	118	970	8	10,267	76	854	0
Pagar Alam C.	1,544	39	0	8,323	936	39	0	8,384
Lubuk Linggau C.	13,874	221	104	1,463	9,631	221	235	1,463
OKI R.	164,005	4,846	131,936	1,218	108,584	3,323	157,620	996
Ogan Ilir R.	35,628	486	8,690	0	21,939	484	10,529	0
OKU Timur R.	75,024	3,357	31,079	2,316	47,330	3,359	34,669	2,318
OKU R.	73,779	1,581	43,746	25,799	49,207	1,119	44,616	21,964
OKU Selatan R.	4,025	1,779	101	70,779	3,461	1,179	389	70,799
Muara Enim R.	227,340	1,588	105,729	23,495	102,600	1,258	95,759	23,450
PALI R.	0	0	0	0	46,269	332	8,875	0
Lahat R.	31,678	625	47,049	51,299	38,621	554	55,167	51,837
Empat Lawang R.	4,579	748	1,572	61,979	2,713	748	345	61,978
Musi Rawas R.	330,879	2,441	124,687	4,000	97,378	1,936	129,597	3,477
M. Rawas Utara R.	0	0	0	0	102,654	507	22,041	207
Musi Banyuasin R.	171,154	3,342	213,515	315	133,283	4,951	256,835	6
Banyuasin R.	108,769	48,776	114,638	5,136	63,512	47,285	134,424	2,632
South Sumatra	1,260,904	69,947	823,816	256,130	838,749	67,402	952,082	249,511

Source: Dalam Angka Sumatra Selatan 2011 and Statistik Perkebunan Indonesia 2015-2017

E5.1.5 Current Estate Crop Production in South Sumatra

The past trend of current production of four major estate crops in South Sumatra Province is shown in Table E5.1.5. Estate crop production data from 2015 have been synchronized and validated in accordance with the said guideline. Therefore, a rather wide range of discrepancy in production date for 2015 between South Sumatra Statistics and Ministry of Agriculture Statistics is found. As of 2015, BPS data indicate 74,396-ton more for rubber, 58,231-ton less for coconut, 1,223,927-ton less for oil palm and the same for coffee.

Table E5.1.5 Current Estate Crop Production in South Sumatra

Regency (R) / City (C)	2010 based on BPS South Sumatra				2015 based on Ministry of Agriculture			
	Rubber (ton)	Coconut (ton)	Oil Palm (ton)	Coffee (ton)	Rubber (ton)	Coconut (ton)	Oil Palm (ton)	Coffee (ton)
Palembang C.	0	0	0	0	496	15	211	0
Prabumulih C.	14,824	109	3,245	0	9,684	36	2,703	0
Pagar Alam C.	646	46	0	11,375	231	3	0	3,770
Lubuk Linggau C.	9,502	29	77	679	2,052	149	96	277
OKI R.	185,991	4,479	812,874	691	156,558	2,903	540,328	636
Ogan Ilir R.	37,959	266	147,403	0	18,119	264	32,361	0
OKU Timur R.	60,263	1,259	10,854	1,250	31,024	3,245	102,954	2,151
OKU R.	67,035	497	211,341	30,851	53,402	194	148,752	15,992
OKU Selatan R.	853	357	66,089	32,949	4,296	1,218	136	33,491
Muara Enim R.	238,297	1,437	1,225,643	25,125	145,037	1,144	282,491	25,147
PALI R.	0	0	0	0	66,643	301	7,785	0
Lahat R.	14,372	370	551,700	21,161	39,875	320	187,322	21,175
Empat Lawang R.	4,127	535	110,533	33,625	1,383	628	135	5,251
Musi Rawas R.	245,385	1,826	1,186,293	2,181	114,433	1,933	428,686	1,889
M. Rawas Utara R.	0	0	0	0	110,223	360	55,212	182
Musi Banyuasin R.	114,066	2,186	1,429,028	122	105,659	5,002	751,200	3
Banyuasin R.	486,733	47,893	814,132	2,250	84,847	44,269	281,567	388
South Sumatra	1,480,053	61,289	6,569,212	162,259	943,962	61,984	2,821,939	110,352

Source: Dalam Angka Sumatra Selatan 2011 and Statistik Perkebunan Indonesia 2015-2017

E5.2 Future Situation of Major Crop Production in Musi River Basin

E5.2.1 Future Rice Cultivation Area in Musi River Basin

Along with the future population increase in South Sumatra, it is indispensable for keeping the existing rice production base for food security purpose. To deal with such situation, wetland paddy field will be improved in terms of area expansion as well as productivity increase through new irrigation development activities coupled with rehabilitation works of the existing irrigation schemes to make surface water irrigation schemes function fully the respective design areas as shown in Table E5.2.1.

Table E5.2.1 Prediction of Future Wetland Paddy Field Area in South Sumatra

Regency (R) / City (C)	Existing Wetland Paddy Field Area				Future Wetland Paddy Field Area			
	Irrigated (ha)	Drainage (ha)	Rainfed (ha)	Total (ha)	Irrigated (ha)	Drainage (ha)	Rainfed (ha)	Total (ha)
Palembang C.	0	341	5,848	6,189	0	0	0	0
Prabumulih C.	0	0	700	700	0	0	0	0
Pagar Alam C.	3,440	0	0	3,440	13,054	0	0	13,054
Lubuk Linggau C.	1,637	0	257	1,894	2,851	0	0	2,851
OKI R.	650	45,480	139,868	185,998	13,500	54,480	118,018	185,998
Ogan Ilir R.	0	43,232	24,395	67,627	0	46,232	21,395	67,627
OKU Timur R.	43,506	8,250	33,864	85,620	59,680	8,250	17,690	85,620
OKU R.	3,244	0	5,628	8,872	3,824	0	5,048	8,872
OKU Selatan	16,099	0	1,941	18,040	9,980	0	1,944	11,924
Muara Enim	6,395	3,957	16,665	27,017	33,212	3,957	0	37,169
PALI	0	0	6,579	6,579	0	0	6,579	6,579
Lahat	15,845	0	1,680	17,525	23,791	0	0	23,791
Empat Lawang	13,105	0	986	14,091	16,358	0	0	16,358
Musi Rawas	13,421	0	17,030	30,451	41,337	0	0	41,337
Musi Rawas Utara	415	0	6,716	7,131	3,640	6,000	0	9,640
Musi Banyuasin R.	0	58,518	8,292	66,810	0	61,518	5,292	66,810
Banyuasin R.	0	166,263	60,255	226,518	0	166,263	60,255	226,518
Sub-total	117,757	326,041	339,704	774,502	221,227	346,700	236,221	804,148

Source: JICA Project Team 2

E5.2.2 Future Rice Production in Musi River Basin

Considering decreasing availability of natural flow in irrigation water source rivers due to degrading watersheds caused by over-logging and land clearing activities in the existing forest areas, it is assumed that the dry season crop growing rate of irrigated paddy field areas is 100% for paddy and 50% for secondary crop for only BBWS Sumatra VIII managed surface water irrigation scheme areas. In South Sumatra Province managed scheme areas, the said rate is assumed at 40% for rice and 10% for secondary crop, while the rate of Regency/ City managed schemes is assumed to be 20% for rice and 5% for secondary crop. Based on such assumptions, future annual harvested area, target yield and annual production of wetland paddy by Regency/ City in 2050 is predicted for surface and swamp irrigation scheme areas as well as the remaining rainfed paddy field distributed in dry land areas, tidal swamp areas and inland swamp areas as shown in Table E5.2.2.

Table E5.2.2 Future Wetland Paddy Production by Regency/ City in South Sumatra

Regency (R) / City (C)	Surface Water Irrigated Area			Swamp Drainage Area			Rainfed Area			Total Product (ton)
	H-Area (ha)	Yield (t/ha)	Product (ton)	H-Area (ha)	Yield (t/ha)	Product (ton)	H-Area (ha)	Yield (t/ha)	Product (ton)	
Palembang C.	0	0.00	0	0	0.00	0	0	0.00	0	0
Prabumulih C.	0	0.00	0	0	0.00	0	0	0.00	0	0
Pagar Alam C.	24,005	5.00	120,025	0	0.00	0	0	0.00	0	120,025
Lubuk Linggau C.	4,479	5.50	24,635	0	0.00	0	0	0.00	0	24,635
OKI R.	27,000	6.00	162,000	53,461	2.50	133,653	118,018	2.00	236,036	531,689
Ogan Ilir R.	0	5.50	0	31,528	2.50	78,820	21,395	2.00	42,790	121,610
OKU Timur R.	7,668	5.50	42,174	7,550	2.50	18,875	17,690	2.00	35,380	96,429
OKU R.	4,589	5.50	25,240	0	0.00	0	5,048	2.00	10,096	35,336
OKU Selatan R.	121,156	6.50	787,514	0	0.00	0	1,944	3.00	5,832	793,346
Muara Enim R.	41,631	4.00	166,524	1,200	3.00	3,600	0	3.00	0	170,124
PALI R.	0	4.50	0	0	0.00	0	6,579	2.00	13,158	13,158
Lahat R.	38,038	4.00	152,152	0	0.00	0	0	3.00	0	152,152
Empat Lawang R.	27,325	4.50	122,963	0	0.00	0	0	3.00	0	122,963
Musi Rawas R.	75,416	5.00	377,080	6,000	2.50	15,000	0	2.00	0	392,080
M. Rawas Utara R.	6,768	3.00	20,304	0	0.00	0	0	2.00	0	20,304
Musi Banyuasin R.	0	5.50	0	43,706	2.50	109,265	5,292	2.00	10,584	119,849
Banyuasin R.	0	5.00	0	164,197	2.50	410,493	60,255	2.00	120,510	531,003
South Sumatra	378,075		2,000,611	307,642		769,706	236,221		474,386	3,244,703

Source: JICA Project Team 2

E5.2.3 Future Condition of Estate Crop Planting Areas in Musi River Basin

In the South Sumatra RTRW 2036, estate crop planting zone area is set up at 3.19 million ha. Considering the current land use conflicts among production forests, estate crops and mining sites, however, the progress of estate crop area development activities will become slow and hence the total estate crop planting areas in the future is assumed to achieve the maximum limit of estate crop planting zone set up in RTRW by 2050. Table E5.2.3 shows the predicted estate crop planting areas in South Sumatra for 2050 with changes in the total planting areas of four major estate crops by Regency/ City between 2015 and 2050..

Table E5.2.3 Predicted Estate Crop Planting Areas in South Sumatra for 2050

Regency (R) / City (C)	Rubber (ha)	Coconut (ha)	Oil Palm (ha)	Coffee (ha)	Others (ha)	Total (ha)	Change* (ha)
Palembang C.	0	0	0	0	0	0	▲ 522
Prabumulih C.	0	0	0	0	0	0	▲ 11,197
Pagar Alam C.	1,180	40	0	12,440	1,800	15,460	4,301
Lubuk Linggau C.	12,210	220	0	2,910	630	15,970	3,790

Regency (R) / City (C)	Rubber (ha)	Coconut (ha)	Oil Palm (ha)	Coffee (ha)	Others (ha)	Total (ha)	Change* (ha)
OKI R.	198,390	3,320	265,040	2,030	17,370	486,150	198,257
OKU Timur R.	28,350	3,360	14,560	0	8,800	55,070	13,318
Ogan Ilir R.	49,580	480	45,690	3,910	9,970	109,630	11,984
OKU R.	99,370	1,120	51,630	33,320	7,410	192,850	68,534
OKU Selatan R.	5,840	1,180	60	96,360	10,760	114,200	27,612
Muara Enim R.	136,350	1,260	123,050	31,810	36,480	328,950	69,403
PALI R.	58,430	330	11,400	0	12,080	82,240	14,684
Lahat R.	55,080	550	77,930	95,080	33,040	261,680	82,461
Empat Lawang R.	5,440	750	0	85,700	20,450	112,340	26,106
Musi Rawas R.	132,960	1,550	172,800	4,450	11,010	322,770	79,372
Musi Rawas Utara R.	138,390	390	30,500	230	9,350	178,860	44,101
Musi Banyuasin R.	193,720	4,950	337,490	0	19,630	555,790	141,085
Banyuasin R.	91,510	47,300	201,050	4,160	13,020	357,040	96,167
South Sumatra	1,206,800	66,800	1,331,200	372,400	211,800	3,189,000	869,456

Note: Change*; Change in the total area of four major estate crops between 2015 and 2050
Source: JICA Project Team 2

E5.2.4 Future Condition of Estate Crop Production in Musi River Basin

The present productivity level of major estate crops in each Regency/ City of South Sumatra is assumed to be maintain in 2050 taking tree crop management situation such as re-planting, immature stage and old stage into account. Table E5.2.4 shows the future estate crop production predicted based on the average productivity in South Sumatra for 2050.

Table E5.2.4 Predicted Estate Crop Production in South Sumatra for 2050

Regency (R) / City (C)	Rubber		Coconut		Oil Palm		Coffee	
	Product (ton)	Increase (ton)	Product (ton)	Increase (ton)	Product (ton)	Increase (ton)	Product (ton)	Increase (ton)
Palembang C.	0	▲ 496	0	▲ 15	0	▲ 211	0	0
Prabumulih C.	0	▲ 9,684	0	▲ 36	0	▲ 2,703	0	0
Pagar Alam C.	291	60	3	0	0	0	5,594	1,824
Lubuk Linggau C.	2,601	549	148	▲ 1	0	▲ 96	551	274
OKI R.	286,042	129,484	2,900	▲ 3	908,568	368,240	1,296	660
OKU Timur R.	23,414	5,295	1,833	1,569	44,750	12,389	0	0
Ogan Ilir R.	32,499	1,475	464	▲ 2,781	135,682	32,728	3,628	1,477
OKU R.	107,842	54,440	194	0	172,137	23,385	24,260	8,268
OKU Selatan R.	7,249	2,953	1,219	1	21	▲ 115	45,582	12,091
Muara Enim R.	192,747	47,710	1,146	2	363,000	80,509	34,112	8,965
PALI R.	84,159	17,516	299	▲ 2	10,000	2,215	0	0
Lahat R.	56,868	16,993	318	▲ 2	264,615	77,293	38,839	17,664
Empat Lawang R.	2,773	1,390	630	2	0	▲ 135	7,261	2,010
Musi Rawas R.	156,247	41,814	1,548	▲ 385	571,595	142,909	2,418	529
M. Rawas Utara R.	148,594	38,371	277	▲ 83	76,402	21,190	202	20
Musi Banyuasin R.	153,570	47,911	5,001	▲ 1	987,103	235,903	0	-3
Banyuasin R.	122,250	37,403	44,274	5	421,123	139,556	613	225
South Sumatra	1,377,145	433,183	60,253	-1,731	3,954,995	1,133,056	164,357	54,005

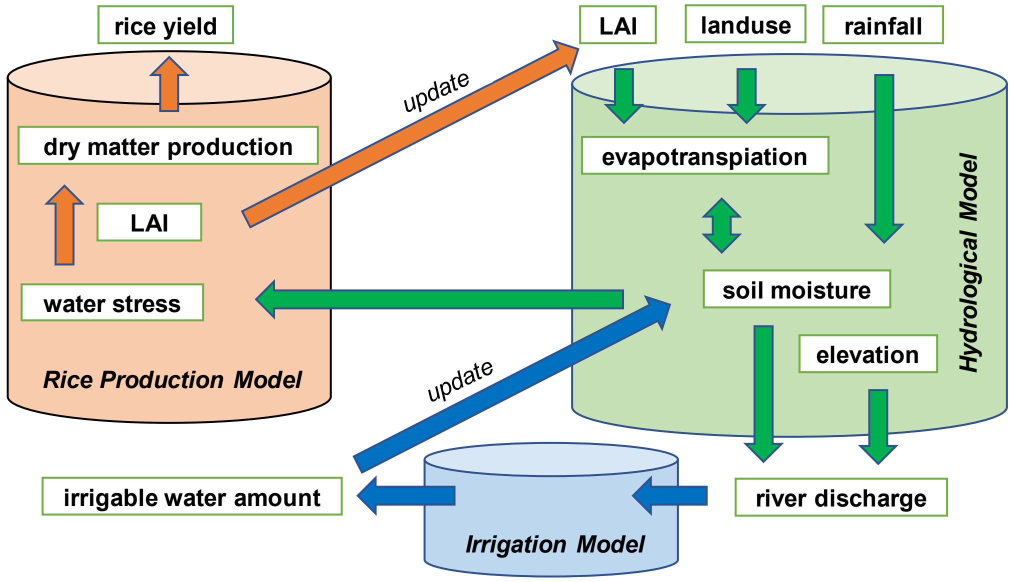
Source: JICA Project Team 2

E5.3 Survey for Crop Modeling Data Collection

E5.3.1 Simulation Model for Rice-Weather Relation

Aiming to evaluate impacts of the future climate change on rice yield in quantitative manner, a simulation model which calls Simulation Model for Rice-Weather Relation (SIMRIW)-rainfed has been developed by the JICA Project Team 1, based on the Water and Energy Budget-based Distributed Hydrological Model (WEB-DHM). The model is composed of WEB-DHM, SIMRIW-rainfed, Paddy model, Coupling system and Irrigation model.

Figure E5.3.1 shows linkage between hydrologic, irrigation and crop models.



Source: JICA Project Team 2

Figure E5.3.1 Linkage between Hydrological, Irrigation and Rice Production Models

E5.3.2 Survey Items and Method

Aiming to collect on-farm level observation data for putting into the above crop model, items of field survey and laboratory analysis items were selected as shown in Table E5.3.1, considering wet paddy field types in South Sumatra Province. Implementation of on-farm level data collection and laboratory works were contracted out to Sri Wijaya University.

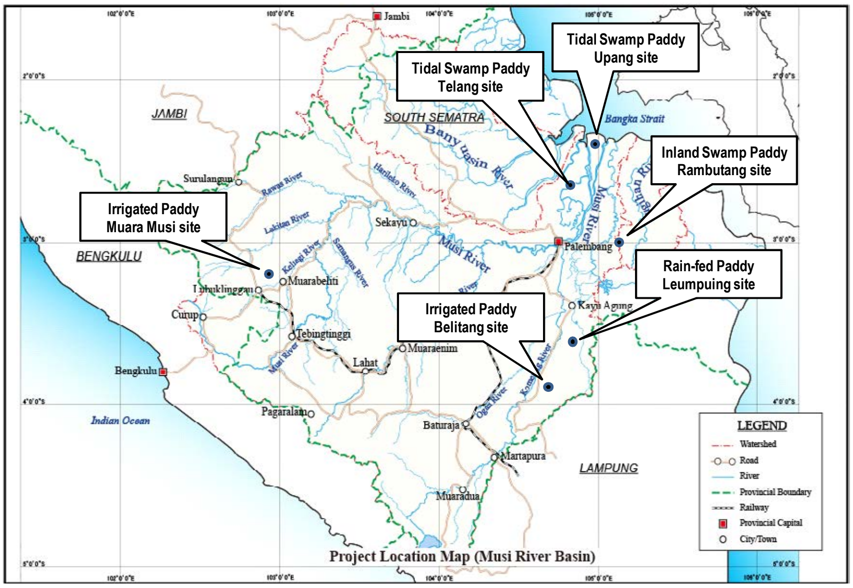
Table E5.3.1 Survey Items and Methods

Survey Method	Survey Item		
Field observation & interview	Cultivation practices	Work period	Land preparation, puddling, transplanting (nursery, planting), direct sowing, prevention & harvesting
		Work method	Manual, animal power (own-breeding, contract) & farm machine (own, contract)
	Farm input	Seed	Variety, sowing amount & supply source (purchase, own-stock)
		Fertilizer	Type of chemical fertilizers, application time, amount (material, weight, nitrogen content, phosphate content, potassium content) & organic fertilizer (compost, manure)
		Agro-chemical	Kind of pest and disease, agrochemicals used (type, amount) & spraying time and frequency
	Paddy field condition		Surface water depth for rainy season & surface water drain condition
	Irrigation	Period	Supplemental irrigation for rainy season & full irrigation for dry season
		Method	Plot-to-plot irrigation, direct intake from on-farm level canal & Irrigation water depth
Laboratory analysis	Soil sample	Physical	Soil moisture content, percolation rate, pF & soil texture
		Chemical	Total carbon content (T-C), total nitrogen content (T-N) & C/N ratio
	Plant sample	Sampling time	2-week after transplanting, 6-week transplanting, heading & maturity (grain, straw)
		Physical	Dried matter weight, leaf area & yield
		Chemical	Total nitrogen content

Source: JICA Project Team 2

E5.3.3 Survey Area

Field observation and sampling places were set up at two sites each in paddy field of irrigation scheme and tidal swamp reclamation schemes as well as one site each in rain-fed paddy and inland freshwater swamp areas. In the respective sites, 25 sample farm households were selected for gathering information on their paddy cultivation practices through face-to-face interview survey to individual sample farmers by enumerators of Sri Wijaya University. Plant samples were collected at the abovementioned four sampling times from the field observation sites in the rain-fed paddy area during the rainy season, the inland freshwater swamp area during the dry season, and the irrigation schemes and tidal swamp reclamation schemes during the both seasons. Dried soil and plant samples were used for physical and chemical analysis in the laboratory of Sri Wijaya University. The location of field observation sites is illustrated in Figure E5.3.2.



Source: JICA Project Team 2

Figure E5.3.2 Location of Survey Areas

E5.3.4 Survey Results

Out of field observation and laboratory analysis results, focal points are summarized in the form of average data as shown in Table E5.3.2.

Table E5.3.2 Focal Points of Survey Results

Item		Unit	Field Condition of Observation Site					
			Irrigated		Rain-fed	Tidal swamp		Inland
Field observation site			Belitang	Muara Musi	Leumpuing	Telang	Upang	Rambutan
Average data of interview results on rainy season field observation								
Yield	Dry paddy	(ton ha-1)	4.08	3.89	3.96	5.01	2.94	-
Fertilizer	Urea	(kg ha-1)	50	112	56	111	75	-
Applied	TSP	(kg ha-1)	41	77	58	92	69	-
Amount	NPK	(kg ha-1)	61	108	53	76	82	-
Average data of interview results on dry season field observation								
Yield	Dry paddy	(ton ha-1)	4.28	4.58	-	-	-	2.72
Fertilizer	Urea	(kg ha-1)	75	114	-	-	-	92
Applied	TSP	(kg ha-1)	46	88	-	-	-	66
Amount	NPK	(kg ha-1)	71	105	-	-	-	137

Item		Unit	Field Condition of Observation Site					
			Irrigated		Rain-fed	Tidal swamp		Inland
Laboratory analysis data on soil samples								
Texture	Sand	(g g-1)	0.318	0.579	0.403	0.443	0.195	-
	Silt	(g g-1)	0.414	0.301	0.379	0.447	0.403	-
	Clay	(g g-1)	0.268	0.120	0.218	0.110	0.402	-
Element	T-N	(mg g-1)	15.204	15.316	47.448	10.262	45.954	-
	T-C	(mg g-1)	1.096	2.596	1.552	1.000	2.400	-
	C/N ratio		13.9	5.9	30.6	10.3	19.1-	-
Laboratory analysis data on rainy season plant samples								
Dry matter weight	2-weel	(g m-2)	10.4	22.8	15.0	2.2	3.2	-
	6-week	(g m-2)	63.4	45.2	92.0	30.0	36.3	-
	Heading	(g m-2)	303.0	659.0	361.0	349.0	437.0	-
	Grain	(g m-2)	302.0	670.0	375.0	470.0	281.0	-
	Straw	(g m-2)	582.0	754.0	685.0	652.0	389.0	-
T-N content	2-weel	(g g-1)	0.011	0.014	0.016	0.012	-	-
	6-week	(g g-1)	0.012	0.019	0.021	0.013	-	-
	Heading	(g g-1)	0.026	0.013	0.032	0.011	0.048	-
	Grain	(g g-1)	0.090	0.017	0.017	0.012	0.037	-
	Straw	(g g-1)	0.024	0.025	0.025	0.009	0.051	-
Laboratory analysis data on dry season plant samples								
Dry matter weight	2-weel	(g m-2)	-	-	-	-	-	-
	6-week	(g m-2)	-	-	-	-	-	-
	Heading	(g m-2)	-	-	-	-	-	-
	Grain	(g m-2)	-	-	-	-	-	-
	Straw	(g m-2)	-	-	-	-	-	-
T-N content	2-weel	(g g-1)	0.012	-	-	-	-	-
	6-week	(g g-1)	0.022	-	-	-	-	-
	Heading	(g g-1)	0.027	-	-	-	-	-
	Grain	(g g-1)	0.047	-	-	-	-	-
	Straw	(g g-1)	0.026	-	-	-	-	-

Source: JICA Project Team 2

E5.3.5 Findings

To practice the model for estimating rice yield precisely under the present climate, it is required to set up initial condition as follows:

- In the hydrological model, input data required are solar radiation, day length, and temperature, to be observed, and soil moisture, to be measured;
- In the rice production model, input date required are information on farm management aspects at field level in terms of rice variety, transplanting date as well as fertilizer application rates and date. Also, laboratory analysis works are needed for grasping dry matter and Nitrogen content of rice plant samples to be taken during crop growing period;
- In this model, leaf area index (LAI) should be calculated; and
- In the irrigation model, input data are river discharge to be obtained from the hydrological model.

For simulating the impact of future climate changes on rice yield, it is indispensable to clarify an eco-system of paddy field. In case of the Musi River basin, the eco-system is classified into irrigated, rainfed, tidal swamp and inland fresh water swamp. As not only natural features but also farmers' paddy cultivation practices are different among these eco-systems so that it is needed to make adjustment of the effect of water stress on crop yield. For this purpose, the technological coefficient that is theoretically simulated crop yield against the observed yield is set up. For example, the coefficient set up for each ecosystem of MBSL river basin is 1.065 for irrigated, 1.183 for rainfed, 1.130 for tidal swamp and 0.821 for inland fresh water swamp.

As the eastern part of Sumatra island including the MBSL Basin is directly affected by drought condition caused by the El Nino Southern Oscillation Signal, it is desirable to establish fixed observation sites of paddy filed in each ecosystem for collecting field data at least five years as reliable basic inputs to the rice production model. From such point of view, it has been decided under the present study to examine the sufficiency of supplemental irrigation water diversion requirement in the irrigation ecosystem and thereby to estimate the impacts of future climate change focusing on the area basis instead of the crop yield basis.

CHAPTER E6 IRRIGATION IN MUSI RIVER BASIN

E6.1 Present Condition of Irrigation and Drainage Schemes in South Sumatra

E6.1.1 Registered Surface Water Irrigation and Swamp Drainage Schemes

In South Sumatra Province, there exist 899 registered schemes consisting of 731 surface water irrigation schemes and 168 swamp irrigation schemes, which are listed up in the attached table of the Ministerial Ordinance No.14/PRT/M/2015 on "Criteria and Status of Irrigation Schemes", as shown in Table E6.1.1. The schemes under the management authority of BBWS Sumatra VIII are listed up in Table E6.1.2.

Table E6.1.1 Number and Area of Registered Irrigation and Swamp Drainage Schemes

Regency (R) / City (C)	BBWS S8		Province*		Regency/ City**				Total	
	Over 3,000 ha		3,000 – 1,000 ha		1,000 – 100 ha		Below 100 ha			
	(nos.)	(ha)	(nos.)	(ha)	(nos.)	(ha)	(nos.)	(ha)	(nos.)	(ha)
Surface Water Irrigation Scheme										
Pagar Alam C.	1	3,050	0	0	7	891	92	5,025	99	5,016
L. Linggau C.	(1)	1,322	0	0	5	1,529	0	0	5 (1)	2,851
OKI R.	(1)	9,500	0	0	0	0	0	0	(1)	9,500
OKU Timur R.	1	47,988	3	4,920	1	650	0	0	5	53,558
OKU R.	0	0	0	0	16	2.844	18	980	34	3,824
OKU Selatan R.	0	0	3	4,801	20	4,007	21	1.172	44	9,980
Muara Enim R.	0	0	5	8,885	82	17,855	159	6.472	246	33,212
Lahat R.	0	0	8	10,423	31	6,059	183	7,289	222	24,671
E. Lawang R.	3	9,244	1	1,500	16	5,464	2	150	22	16,358
Musi Rawas R.	2	18,341	4	6,033	21	6,153	22	650	49	31,177
Sub-total	7	89,445	28	41,541	199	45,452	497	21,738	731	198,176
Lampung Province	(1)	5,048	0	0	0	0	0	0	0	0
Total	7	94,493	28	41,541	199	45,452	497	21,738	731	198,176
Tidal and Inland Swamp Irrigation Scheme										
Palembang C.	0	0	0	0	1	288	1	53	2	341
OKI R.	3	30,335	8	14,126	3	1,019	0	0	14	45,480
Ogan Ilir R.	2	13,536	7	14,992	46	14,425	4	279	59	43,232
OKU Timur R.	0	0	4	7,550	1	700	0	0	5	8,250
Muara Enim R.	0	0	1	1,200	4	2,757	0	0	5	3,957
M. Banyuasin R.	3	29,065	7	11,641	55	17,722	1	90	66	58,518
Banyuasin R.	14	164,197	0	0	3	2,066	0	0	17	166,263
Total	22	237,133	27	49,509	113	38,977	6	422	168	326,041

Note: *; Dinas PU Pengairan dan Bina Marga Sumatera Selatan, **; PU Local Government
Source: DGWR

Table E6.1.2 Registered Irrigation and Swamp Drainage Schemes under BBWS Sumatra VIII

Scheme	(ha)	Location	Scheme	(ha)	Location
Surface Water Irrigation Scheme			Swamp Drainage Scheme		
1. Komering Selatan/ Way Komering	62,536		5. Delta Upang	5,896	Banyuasin R.
	(9,500)	OKI R.	6. Gasing Puntian	4,830	Banyuasin R.
	(47,988)	OKU Timur R.	7. Karang Agung Hilir	9,777	Banyuasin R.
	(5,048)	Lampung Province	8. Karang Agung I	6,300	Banyuasin R.
2. Kelingi Tugu Mulyo	10,163		9. Katang Agung Tengah	4,001	Banyuasin R.
	(8,841)	Musi Rawas R.	10. Kumbang Padang	4,268	Banyuasin R.
	(1,322)	Lubuk Linggau C.	11. Padang Sugihan	10,200	Banyuasin R.
3. Air Keruh	3,152	Empat Lawang R.	12. Pulau Rimau	23,184	Banyuasin R.
4. Lintang Kanan	3,054	Empat Lawang R.	13. Telang I	18,676	Banyuasin R.
5. Lintang Kiri	3,038	Empat Lawang R.	14. Telang II	9,660	Banyuasin R.
6. Air Lakitan	9,500	Musi Rawas	15. Air Tenggulang	6,156	M. Banyuasin R.
7. Muara Riben	3,050	Pagar Alam C.	16. Karang Agung Hulu	6,350	M. Banyuasin R
Irrigation Scheme Total	94,493		17. Karang Agung II	17,000	M. Banyuasin R
(South Sumatra Total)	(89,445)		18. Lubuk Tnjung Seteko	3,876	Ogan Ilir R.

Scheme	(ha)	Location	Scheme	(ha)	Location
Swamp Drainage Scheme			19. Ogan Keramasan I + II	9,660	Ogan Ilir R.
1. Air Saleh	17,011	Banyuasin R.	20. M. Gajah Mati I	5,950	OKI R.
2. Air Senda	4,711	Banyuasin R.	21. Sugihan Kanan i	20,885	OKI R.
3. Delta Air Sugihan Kiri	34,690	Banyuasin R.	22. Sungai Lumpur	3,500	OKI R.
4. Delta Cinta Manis	5,554	Banyuasin R.	Drainage Scheme Total	237,133	

Source: DGWR

E6.1.2 Recent Development of Surface Water Irrigation Schemes

In the Musi River basin, large scale civil works in surface water irrigation schemes with JICA's financial assistance have been recently completed for rehabilitation of Air Lakitan irrigation scheme under Participatory Irrigation Rehabilitation and Management Project (PIRIMP) in 2016 and extension of Komering irrigation scheme under Komering Irrigation Project (KIP) Stage II Phase 2 in 2017. After completion, the actual irrigation command areas of the both Projects are fixed as follows:

- Air Lakitan irrigation scheme is commanding 6,920 ha among the design area of 9,500 ha, while the balance of 2,580 ha is recognized as no irrigation potential area; and
- Komering irrigation scheme is commanding 59,167 ha including diverted area of 5,048 ha to Lampung Province as the actual irrigation command area accumulated through implementation of Stage I to Stage II Phase 2. Further financing by JICA for implementing Komering Irrigation Development Stage III has been officially decided covering new extension area of 8,500 ha.

E6.1.3 Specific Features of Surface Water Irrigation Scheme in Musi River Basin

In the Musi River basin, there exists no dam/ reservoir for irrigation water supply purpose at moment. As a result, all of 731 surface water irrigation schemes depend their irrigation water sources on natural river flow of water source rivers and streams throughout the basin. Table E6.1.3 shows a sample case which is the actual monthly diversion record of irrigation water from the Komering River through the Perjaya Barrage to the command area of KIP.

Table E6.1.3 Monthly Water Diversion Record at Perjaya Barrage by KIP

(Unit: m^3/s)

Month	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
January	-	27.99	28.58	24.94	40.49	26.46	35.27	35.85	9.86	21.06	37.44	28.40
February	-	20.82	25.33	30.03	30.18	42.69	34.31	37.48	17.94	29.39	24.79	28.06
March	-	13.85	34.55	30.24	33.59	39.62	37.52	30.14	14.67	9.26	25.79	22.19
April	31.34	35.95	40.70	31.50	37.27	39.61	37.09	35.67	23.27	8.38	34.39	19.07
May	34.66	39.93	40.31	44.01	40.67	36.63	41.39	38.88	29.94	25.62	33.88	39.25
June	40.78	47.32	39.29	42.39	42.13	24.38	43.09	44.85	19.90	42.50	35.55	40.44
July	32.58	45.30	31.04	39.00	17.79	40.80	37.67	41.30	16.74	21.15	33.07	33.90
August	27.97	25.61	29.33	33.12	24.22	21.91	37.30	35.35	27.81	29.05	21.05	-
September	28.80	26.49	32.36	34.63	10.99	31.09	15.07	11.43	26.75	27.27	2.44	-
October	30.35	44.81	31.45	29.46	18.82	33.07	32.68	37.35	41.84	26.87	6.75	-
November	33.96	23.84	24.34	34.78	19.46	35.67	47.00	19.79	12.03	39.32	13.27	-
December	33.27	20.92	31.19	40.20	35.81	38.36	21.43	14.53	15.47	35.36	24.94	-

Source: Komering Irrigation Operation and Management Office

Under the on-going RPJMD (2015 - 2019), Komering II (Tiga Dihaji) dam construction plan was adopted by GOI's own budget, and detailed design works have been completed at present. This is the first case of dam/ reservoir construction for irrigation water supply purpose in South

Sumatra Province. Its beneficial area is Komering irrigation command area aiming to secure sustainable irrigation water resource coping with the implementation of KIP Stage III.

E6.2 Future Surface Water Irrigation and Swamp Drainage Areas in Musi River Basin

E6.2.1 Proposed Development Area in BBWS Sumatra VIII RENCANA 2017

In BBWS Sumatra VIII RENCANA 2017, the future development plan of new surface water irrigation and swamp drainage schemes for the next 20-year period is proposed with implementation schedule on five-year term basis as shown in Table E6.2.1.

Table E6.2.1 Proposed Development Plan in BBWS Sumatra VIII RENCANA 2017

Name of Scheme	Regency (R) / City (C)	2016-20	2021-25	2026-30	2031-35	T0tal
Surface Water Irrigation Scheme						
Komering Selatan	OKU Timur R. & OKI R.	0	5,000	5,000	3,500	13,500
Lematang	Pagar Alam C.	2,000	0	0	0	2,000
Air Rawas	Musi Rawas R.	0	2,000	3,000	4,000	9,000
Kembahang	Musi Rawas Utara R.	0	0	0	3,000	3,000
Muara Beliti	Musi Rawas R.	0	0	0	3,000	3,000
Air Gegas	Musi Rawas R.	0	2,000	0	0	2,000
Merap	Pagar Alam C.	0	0	0	5,000	5,000
Donku Kanan / Kiri	Lahat R.	0	0	0	10,000	10,000
Komering Tulang Bawang	Lampung Province	0	0	0	10,000	10,000
Surface Irrigation Scheme Area Total						
Swamp Drainage Scheme						
Batangharileko	Musi Banyuasin R.	3,000	0	0	0	3,000
Lebak Jejawi	OKI R.	0	2,000	2,000	2,000	6,000
Lebak Pangkalan Lampam	Musi Rawas Utara R.	0	2,000	2,000	2,000	6,000
Lebung Hitam	OKI R.	0	1,000	2,000	0	3,000
Burai	Ogan Ilir R.	0	1,000	2,000	0	3,000
Swamp Drainage Scheme Area Total						

Source: BBWS Sumatera Selatan VIII RENCANA 2017

Among the proposed surface water irrigation schemes as listed up in Table E6.2.1, Komering Selatan scheme has been partly developed under JICA financed KIP Stage II Phase 2 covering 5,000 ha, and the remaining part of 8,500 ha will be developed by 2025 under JICA financed KIP Stage III. In case of Lematang surface water irrigation scheme, the proposed area has been partly developed until now, and hence the remaining development area is 1,000 ha.

E6.2.2 Prediction of Future Surface Water Irrigation Area

Focal points in predicting the future surface water irrigation area in the Musi River basin are as follows:

- Considering the current distribution of paddy field as shown in Table E5.1.2, the existing rainfed paddy field areas of 39,491 ha will be newly upgraded to new six surface water irrigation schemes;
- The existing small-scale surface irrigation schemes under the provincial and local governments' management covering 19,000 ha will be integrated into three new surface water irrigation schemes; and
- The already developed and scheduled command areas of surface water irrigation schemes under JICA financing are considered.

Based on the above condition, the future design areas of surface water irrigation schemes are predicted as shown in Table E6.2.2.

Table E6.2.2 Prediction of Future Surface Water Irrigation Areas

Regency (R) and City (C) with Surface Water Irrigation Schemes	Present Irrigation Area			Conversion		Future Irrigation Area		
	BBWS-S8	Local Gov.*	Total	Rain-fed	Local Gov.*	BBWS-S8	Local Gov.*	Total
	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)
Pagar Alam C.	3,050	10,004	13,054	0	7,000	10,050	3,004	13,054
Lubuk Linggau C.	1,322	1,529	2,851	0	0	1,322	1,529	2,851
OKI R.	5,000	0	5,000	8,500	0	13,500	0	13,500
OKU Timur R.	49,119	5,570	54,689	4,991	0	54,110	5,570	59,680
OKU R.	0	3,824	3,824	0	0	0	3,824	3,824
OKU Selatan	0	9,980	9,980	0	0	0	9,980	9,980
Muara Enim	0	33,212	33,212	0	0	0	33,212	33,212
Lahat	0	23,791	23,791	0	10,000	10,000	13,791	23,791
Empat Lawang	9,244	7,114	16,358	0	0	9,244	7,114	16,358
Musi Rawas	15,761	12,576	28,337	13,000	2,000	30,761	10,576	41,337
Musi Rawas Utara	0	640	640	3,000	0	3,000	640	3,640
Sub-total	83,496	110,240	191,736	29,491	19,000	131,987	89,240	221,227
Lampung	5,048	0	5,048	10,000	0	15,048	0	15,048
Sub-total	5,048	0	5,048	10,000	0	15,048	0	15,048
Total	88,544	108,240	196,786	39,491	19,000	147,035	89,240	236,275

Note; *; South Sumatra Provincial and Regency/ City Governments
Source: JICA Project Team 2

E6.3 Estimate of Irrigation Water Requirement for Selection of Representative GCMs

E6.3.1 Purpose

Aiming to assess impacts of the future climate change on irrigation water demand in surface water irrigation scheme command areas in the Musi River basin, selection of representative climate change models is to be carried out prior to the impact assessment. In this regard, water balance examination method is applied to the selection of three representative GCMs among nine GCMs. For preparing input data concerning irrigation water diversion requirement, therefore, the following cases have been set up. Then, unit irrigation water requirement of each case has been estimated for the respective nine GCMs by referring to GCM rainfall data of nine areas where surface water irrigation schemes are located;

- Case 1: Historical climate observation data and irrigated area of existing schemes;
- Case 2: Past climate model data and irrigation area of existing schemes;
- Case 3: Future climate model data and irrigation area of existing schemes; and
- Case 4: Future climate model data and irrigation area of future schemes.

Thus, 324 outputs of unit irrigation water requirement in total (4 cases x 9 GCMs x 9 sub-basin rainfall data) have been made and thereafter used for calculating irrigation water diversion requirements of surface water irrigation schemes.

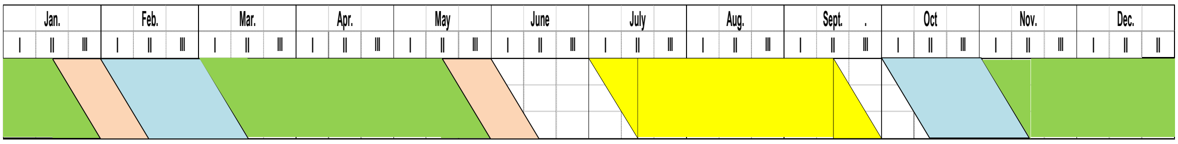
E6.3.2 Irrigation Water Demand Calculation Methodology and Input Data

Irrigation water demand is calculated by applying the formula of KP-1 described in Chapter E2.2. Input data on average effective rainfall and evapotranspiration for 10-day period are made by referring to historical rainfall observation data for the period of 15 years from 1985/86 wet season to 2000 dry season as well as future predicted basin rainfall data of nine GCMs from 2050/51 wet season to 2065 dry season.

E6.3.3 Cropping Calendar

For calculating irrigation water needs for crop cultivation on irrigated paddy field, it is required to set up a cropping calendar for each cropping season of paddy and secondary crops. Also, it is prerequisite to use the sole cropping calendar in clarifying the impact of climate change on irrigation water needs in the Musi River basin aiming to simplify a comparative examination procedure for alternative climate change cases. To cope with such pre-condition, the sole cropping calendar is set up by basically referring to RENCANA 2017 as well as data on planting and harvesting times of paddy and secondary crops on monthly basis collected from Food Crops and Horticulture Office of South Sumatra Province.

With some modifications based on the above data, the cropping calendar 15-day land preparation period before transplanting seedlings of the both wet and dry season paddy and 10-day water supply cutting period before harvesting time of the both seasons, the sole cropping calendar is set up as illustrated in Figure E6.3.1.



Note: Blue-colored part; Land preparation period, Green-colored part; Rice growing period under irrigated condition, Pink-colored part; Rice growing period under dried-up condition, Yellow-colored period; Secondary crop growing period under irrigated condition
Source: JICA Project Team 2

Figure E6.3.1 Cropping Calendar for Surface Water Irrigation Schemes in Musi River Basin

E6.3.4 Unit Irrigation Water Requirement

For quantifying the effect of different climate change models on irrigation water demand, unit irrigation water requirement is calculated by substituting evapotranspiration and rainfall data of nine GCMs for the areas where surface irrigation schemes exist. The calculation works are carried out on the 10-day period basis for 15 years as mentioned before. The calculation results are shown in Table E6.3.1 for Case 1, Table E6.3.2 for Case 2 and Table E6.3.3 for Case 3 and Case 4.

Table E6.3.1 Area-wise Seasonal Average of Unit Irrigation Water Requirement for Case 1

Crop Season / Crop		Area-wise Average of Unit Irrigation Water Requirement by Crop Season (l/s/ha)								
		OKI & OKU-T	OKU	OKU Selatan	Muara Enim	Lahat	Pagar Alam	Musi Rawas	Empat Lawang	Lubuk Linggau
All GCM cases in common										
MH	Paddy	0.78	0.73	0.76	0.94	0.71	0.73	0.89	0.59	0.76
MK-1	Paddy	0.80	0.82	0.85	0.82	0.85	0.81	0.97	0.76	0.92
MK-2	Secondary	0.58	0.57	0.58	0.55	0.58	0.51	0.49	0.45	0.50

Source: JICA Project Team 2

Table E6.3.2 Area-wise Seasonal Average of Unit Irrigation Water Requirement for Case 2

Crop Season / Crop		Area-wise Average of Unit Irrigation Water Requirement by Crop Season (l/s/ha)								
		OKI & OKU-T	OKU	OKU Selatan	Muara Enim	Lahat	Pagar Alam	Musi Rawas	Empat Lawang	Lubuk Linggau
GCM-1										
MH	Paddy	0.95	0.95	0.99	0.96	1.00	0.94	0.46	0.59	0.89
MK-1	Paddy	0.60	0.58	0.54	0.54	0.47	0.53	0.99	0.53	0.62
MK-2	Secondary	0.75	0.67	0.58	0.68	0.59	0.80	0.43	0.51	0.70
GCM 2										

Crop Season / Crop		Area-wise Average of Unit Irrigation Water Requirement by Crop Season (l/s/ha)								
		OKI & OKU-T	OKU	OKU Selatan	Muara Enim	Lahat	Pagar Alam	Musi Rawas	Empat Lawang	Lubuk Linggau
MH	Paddy	0.92	0.93	0.93	0.94	0.94	0.88	0.62	0.63	0.85
MK-1	Paddy	0.83	0.59	0.59	0.57	0.57	0.45	0.70	0.53	0.52
MK-2	Secondary	0.59	0.43	0.43	0.43	0.44	0.37	0.40	0.36	0.45
GCM 3										
MH	Paddy	0.83	0.78	0.78	0.67	0.68	0.73	0.63	0.59	0.64
MK-1	Paddy	1.13	1.13	1.07	0.90	0.86	0.82	0.78	0.93	0.82
MK-2	Secondary	0.59	0.59	0.53	0.40	0.38	0.46	0.36	0.34	0.48
GCM 4										
MH	Paddy	0.69	0.66	0.80	0.62	0.67	0.61	0.62	0.58	0.81
MK-1	Paddy	0.75	0.64	0.67	0.74	0.81	0.74	0.75	0.73	0.97
MK-2	Secondary	0.61	0.55	0.60	0.50	0.49	0.42	0.45	0.43	0.53
GCM 5										
MH	Paddy	0.63	0.66	0.66	0.78	0.82	0.70	0.76	0.71	0.93
MK-1	Paddy	0.58	0.64	0.64	0.69	0.71	0.61	0.69	0.59	0.88
MK-2	Secondary	0.78	0.60	0.61	0.65	0.67	0.58	0.63	0.60	0.77
GCM 6										
MH	Paddy	0.70	0.63	0.60	0.62	0.70	0.67	0.64	0.62	0.81
MK-1	Paddy	0.92	0.91	0.90	0.84	0.85	0.84	0.76	0.81	0.96
MK-2	Secondary	0.57	0.47	0.45	0.45	0.47	0.41	0.28	0.42	0.53
GCM 7										
MH	Paddy	0.93	0.92	0.92	0.94	0.95	0.95	0.64	0.62	0.88
MK-1	Paddy	0.80	0.74	0.74	0.78	0.80	0.78	0.80	0.79	0.78
MK-2	Secondary	0.55	0.50	0.50	0.50	0.50	0.47	0.37	0.39	0.50
GCM 8										
MH	Paddy	0.71	0.68	0.68	0.56	0.53	0.53	1.04	0.68	0.71
MK-1	Paddy	0.79	0.68	0.68	0.48	0.45	0.47	1.11	0.47	0.72
MK-2	Secondary	0.47	0.30	0.30	0.25	0.24	0.21	0.47	0.31	0.36
GCM 9										
MH	Paddy	0.71	0.80	0.74	0.72	0.71	0.71	0.65	0.60	0.80
MK-1	Paddy	0.81	0.95	0.90	0.81	0.81	0.88	0.75	0.66	0.95
MK-2	Secondary	0.47	0.50	0.43	0.40	0.40	0.39	0.37	0.33	0.50

Source: JICA Project Team 2

Table E6.3.3 Area-wise Seasonal Average of Unit Irrigation Water Requirement for Cases 3 & 4

Crop Season / Crop		Area-wise Average of Unit Irrigation Water Requirement by Crop Season (l/s/ha)								
		OKI & OKU-T	OKU	OKU Selatan	Muara Enim	Lahat	Pagar Alam	Musi Rawas	Empat Lawang	Lubuk Linggau
GCM-1										
MH	Paddy	0.92	0.99	0.99	1.00	1.00	0.98	1.01	0.58	0.82
MK-1	Paddy	0.51	0.54	0.54	0.48	0.47	0.49	0.47	0.55	0.57
MK-2	Secondary	0.56	0.58	0.58	0.59	0.59	0.58	0.59	0.41	0.48
GCM 2										
MH	Paddy	1.16	1.16	1.23	1.23	1.23	1.18	0.77	0.87	1.10
MK-1	Paddy	0.85	0.85	0.60	0.58	0.58	0.43	0.97	0.70	0.52
MK-2	Secondary	0.30	0.30	0.27	0.27	0.27	0.25	0.23	0.25	0.26
GCM 3										
MH	Paddy	0.79	0.84	0.84	0.70	0.73	0.72	0.68	0.62	0.64
MK-1	Paddy	1.06	1.10	1.10	0.83	0.80	0.80	0.68	0.83	0.65
MK-2	Secondary	0.41	0.44	0.36	0.38	0.40	0.42	0.39	0.29	0.38
GCM 4										
MH	Paddy	0.79	0.80	0.80	1.30	0.83	0.76	0.83	0.72	0.87
MK-1	Paddy	0.70	0.67	0.67	1.36	0.96	0.88	0.88	0.86	1.01
MK-2	Secondary	0.59	0.60	0.60	0.18	0.45	0.40	0.42	0.40	0.46
GCM 5										
MH	Paddy	0.76	0.70	0.70	0.86	0.64	0.76	0.82	0.60	0.60
MK-1	Paddy	0.69	0.68	0.68	0.77	0.65	0.64	0.74	0.54	0.54

Crop Season / Crop		Area-wise Average of Unit Irrigation Water Requirement by Crop Season (l/s/ha)								
		OKI & OKU-T	OKU	OKU Selatan	Muara Enim	Lahat	Pagar Alam	Musi Rawas	Empat Lawang	Lubuk Linggau
MK-2	Secondary	0.63	0.62	0.62	0.66	0.38	0.61	0.65	0.63	0.63
GCM 6										
MH	Paddy	0.82	0.96	0.97	0.79	0.76	0.77	0.68	0.72	0.83
MK-1	Paddy	0.81	0.88	0.88	0.80	0.88	0.80	0.76	0.76	0.88
MK-2	Secondary	0.55	0.54	0.54	0.52	0.40	0.46	0.29	0.48	0.49
GCM 7										
MH	Paddy	0.92	0.97	0.97	0.99	1.00	0.97	0.75	0.78	0.76
MK-1	Paddy	0.95	0.95	0.95	0.98	0.98	0.96	0.79	0.89	0.69
MK-2	Secondary	0.48	0.49	0.49	0.50	0.50	0.48	0.35	0.38	0.44
GCM 8										
MH	Paddy	0.86	0.79	0.79	0.67	0.67	0.67	1.02	0.77	0.76
MK-1	Paddy	0.88	0.73	0.73	0.49	0.49	0.51	1.08	0.75	0.69
MK-2	Secondary	0.46	0.45	0.45	0.42	0.42	0.40	0.46	0.41	0.44
GCM 9										
MH	Paddy	0.85	0.98	0.98	0.93	0.92	0.95	0.86	0.81	0.93
MK-1	Paddy	0.82	0.98	0.99	0.93	0.92	0.98	0.85	0.75	0.96
MK-2	Secondary	0.46	0.51	0.51	0.49	0.49	0.49	0.46	0.44	0.49

Source: JICA Project Team 2

E6.3.5 Irrigation Water Diversion Requirement

Irrigation water diversion requiremnt is predicted based on the above-mentioned unit irrigationan water requirement, cropping clemder and design area of each surface water irrigation scheme. Also, cropping intensity is set up at 300% for making more clearly diferenciate features on rainfall patterns throughout the year among the respective GCMs. The calculation results on the 10-day period basis indicate the area-wise average of irrigation water diversion requirement for supplemetal irrigation water supply purpose during each crop season as shown in Table E6.3.4 for Case 1, Table E6.3.5 for Case 2, Table E6.3.6 for Case 3 and Table E6.3.7 for Case 4.

Table E6.3.4 Area-wise Average of Irrigation Water Diversion Requirement for Case 1

Crop Season / Crop		Area-wise Average of Irrigation Water Diversion Requirement by Crop Season (m^3/s)								
		OKI & OKU-T	OKU	OKU Selatan	Muara Enim	Lahat	Pagar Alam	Musi Rawas	Empat Lawang	Lubuk Linggau
All GCM cases in common										
MH	Paddy	53.6	2.8	7.6	22.9	16.7	9.4	28.1	1.7	12.3
MK-1	Paddy	54.4	3.1	8.5	27.3	20.2	10.6	30.5	2.2	15.1
MK-2	Secondary	38.8	2.2	5.8	18.3	13.8	6.7	15.4	1.3	8.2

Source: JICA Project Team 2

Table E6.3.5 Area-wise Average of Irrigation Water Diversion Requirement for Case 2

Crop Season / Crop		Area-wise Average of Irrigation Water Diversion Requirement by Crop Season (m^3/s)								
		OKI & OKU-T	OKU	OKU Selatan	Muara Enim	Lahat	Pagar Alam	Musi Rawas	Empat Lawang	Lubuk Linggau
GCM 1										
MH	Paddy	62.6	3.5	9.7	31.0	23.7	11.9	14.4	1.6	14.3
MK-1	Paddy	41.0	2.2	5.4	17.8	11.3	7.0	31.7	1.5	10.3
MK-2	Secondary	50.1	2.5	5.9	22.1	14.1	8.6	13.3	1.4	11.2
GCM 2										
MH	Paddy	63.4	3.6	9.5	31.7	22.8	11.7	19.7	1.8	14.3
MK-1	Paddy	57.8	2.3	6.1	19.8	14.1	6.2	22.2	1.5	8.7
MK-2	Secondary	38.9	1.5	4.0	13.5	9.7	4.5	12.5	1.0	6.9
GCM 3										
MH	Paddy	56.3	3.0	7.8	22.1	16.0	9.5	19.6	1.7	10.4

Crop Season / Crop		Area-wise Average of Irrigation Water Diversion Requirement by Crop Season (m^3/s)								
		OKI & OKU-T	OKU	OKU Selatan	Muara Enim	Lahat	Pagar Alam	Musi Rawas	Empat Lawang	Lubuk Linggau
MK-1	Paddy	77.1	4.1	10.8	30.1	20.8	10.8	24.9	2.7	13.6
MK-2	Secondary	39.2	2.0	5.2	13.3	9.1	6.0	11.3	1.0	8.0
GCM 4										
MH	Paddy	49.3	2.6	7.7	21.3	16.6	8.3	20.4	1.7	13.0
MK-1	Paddy	51.3	2.5	6.8	25.0	19.5	9.9	24.2	2.1	15.8
MK-2	Secondary	42.7	2.2	5.9	11.7	12.0	5.6	14.7	1.3	8.8
GCM 5										
MH	Paddy	43.2	2.5	6.6	26.0	19.5	9.2	23.5	2.0	15.3
MK-1	Paddy	39.8	2.5	6.5	23.1	17.0	8.0	22.1	1.7	14.6
MK-2	Secondary	53.3	2.3	6.0	21.8	16.1	7.7	19.7	1.7	12.7
GCM 6										
MH	Paddy	46.1	2.2	5.6	20.0	16.3	8.5	20.3	1.7	13.0
MK-1	Paddy	62.5	3.5	9.0	27.9	20.2	11.0	24.2	2.3	15.8
MK-2	Secondary	39.5	1.8	4.5	15.2	11.3	5.4	8.7	1.2	8.8
GCM 7										
MH	Paddy	63.2	3.5	9.2	31.1	22.7	12.4	19.9	1.8	14.2
MK-1	Paddy	55.3	2.9	7.5	26.4	19.2	10.3	25.7	2.3	13.0
MK-2	Secondary	36.4	1.9	4.8	16.1	11.6	5.9	11.6	1.1	8.1
GCM 8										
MH	Paddy	47.1	2.6	6.9	19.1	13.1	7.1	32.9	2.0	11.8
MK-1	Paddy	53.0	2.7	7.0	16.5	11.0	6.3	35.6	2.2	12.1
MK-2	Secondary	30.6	1.1	2.8	7.8	5.5	2.5	13.7	0.8	5.5
GCM 9										
MH	Paddy	47.1	3.0	7.2	23.3	16.5	9.1	20.0	1.7	12.8
MK-1	Paddy	54.3	3.6	8.9	26.7	19.2	11.3	7.6	1.9	15.3
MK-2	Secondary	32.9	2.0	4.4	13.8	9.8	5.3	11.9	1.0	8.4

Source: JICA Project Team 2

Table E6.3.6 Area-wise Average of Irrigation Water Diversion Requirement for Case 3

Crop Season / Crop		Area-wise Average of Irrigation Water Diversion Requirement by Crop Season (m^3/s)								
		OKI & OKU-T	OKU	OKU Selatan	Muara Enim	Lahat	Pagar Alam	Musi Rawas	Empat Lawang	Lubuk Linggau
GCM 1										
MH	Paddy	62.4	3.7	9.7	32.9	23.7	12.6	31.6	1.7	13.2
MK-1	Paddy	34.9	2.1	5.4	16.1	11.3	6.4	14.9	1.6	9.5
MK-2	Secondary	39.2	2.3	5.9	19.7	14.1	7.7	18.8	1.2	8.2
GCM 2										
MH	Paddy	79.9	4.5	12.3	41.0	29.4	15.5	24.9	2.5	18.3
MK-1	Paddy	58.4	3.3	6.0	19.3	13.8	5.6	30.2	2.0	8.4
MK-2	Secondary	45.0	2.5	6.0	20.0	14.4	7.3	16.1	1.6	9.6
GCM 3										
MH	Paddy	56.1	3.4	8.8	24.0	17.4	9.8	21.2	1.8	10.5
MK-1	Paddy	71.9	4.2	10.9	27.1	18.7	10.4	21.3	2.3	10.5
MK-2	Secondary	26.4	1.6	3.4	12.2	9.2	5.2	12.0	0.8	6.1
GCM 4										
MH	Paddy	52.6	3.0	7.7	42.9	19.6	9.9	26.2	2.0	14.1
MK-1	Paddy	48.8	2.6	6.8	45.2	23.0	11.6	28.1	2.5	16.6
MK-2	Secondary	39.3	2.2	5.9	3.3	10.9	5.3	13.6	1.2	7.6
GCM 5										
MH	Paddy	41.9	2.6	6.8	28.2	15.2	9.7	25.7	2.6	9.7
MK-1	Paddy	38.5	2.6	6.9	26.1	15.3	8.4	23.9	2.4	8.9
MK-2	Secondary	42.2	2.3	6.1	21.7	8.9	7.9	20.2	1.9	10.1
GCM 6										
MH	Paddy	55.0	3.7	9.7	26.0	18.0	9.9	20.9	2.0	13.4
MK-1	Paddy	55.9	3.4	8.9	26.7	21.2	10.4	24.3	2.2	14.4

Crop Season / Crop		Area-wise Average of Irrigation Water Diversion Requirement by Crop Season (m^3/s)								
		OKI & OKU-T	OKU	OKU Selatan	Muara Enim	Lahat	Pagar Alam	Musi Rawas	Empat Lawang	Lubuk Linggau
MK-2	Secondary	36.8	2.0	5.2	17.0	9.7	5.9	9.7	1.3	7.9
GCM 7										
MH	Paddy	62.9	3.7	9.8	33.2	24.0	12.8	22.9	2.2	11.7
MK-1	Paddy	64.0	3.6	9.4	32.1	23.2	12.5	25.3	2.5	11.2
MK-2	Secondary	32.3	1.8	4.8	16.1	11.6	6.1	10.8	1.1	6.9
GCM 8										
MH	Paddy	56.6	2.8	7.4	20.6	14.7	8.0	31.3	2.1	11.7
MK-1	Paddy	60.1	2.8	7.3	16.0	11.5	6.6	34.0	2.1	11.2
MK-2	Secondary	33.1	1.8	4.8	14.9	10.7	5.6	15.5	1.2	7.7
GCM 9										
MH	Paddy	58.4	3.7	9.8	31.0	22.1	12.4	27.2	2.3	15.3
MK-1	Paddy	56.9	3.8	10.1	31.5	22.3	13.2	27.4	2.2	16.0
MK-2	Secondary	30.3	1.9	10.1	15.6	11.1	6.2	13.9	1.2	7.7

Source: JICA Project Team 2

Table E6.3.7 Area-wise Average of Irrigation Water Diversion Requirement for Case 4

Crop Season / Crop		Area-wise Average of Irrigation Water Diversion Requirement by Crop Season (m^3/s)								
		OKI & OKU-T	OKU	OKU Selatan	Muara Enim	Lahat	Pagar Alam	Musi Rawas	Empat Lawang	Lubuk Linggau
GCM-1										
MH	Paddy	83.3	3.7	9.7	32.9	23.7	12.6	39.6	1.7	13.2
MK-1	Paddy	46.6	2.1	5.4	16.1	11.3	6.4	18.7	1.6	9.5
MK-2	Secondary	52.3	2.3	5.9	19.7	14.1	7.7	23.6	1.2	8.2
GCM 2										
MH	Paddy	106.8	4.5	12.3	41.0	29.4	15.5	31.3	2.5	18.3
MK-1	Paddy	78.0	3.3	6.0	19.3	13.8	5.6	37.9	2.0	8.4
MK-2	Secondary	60.1	2.5	6.0	20.0	14.4	7.3	20.2	1.6	9.6
GCM 3										
MH	Paddy	74.9	3.4	8.8	24.0	17.4	40.2	26.6	1.8	10.5
MK-1	Paddy	96.0	4.2	10.9	27.1	18.7	44.5	26.7	2.3	10.5
MK-2	Secondary	35.2	1.6	3.4	12.2	9.2	17.4	15.1	0.8	6.1
GCM 4										
MH	Paddy	70.2	3.0	7.7	42.9	19.6	9.9	32.8	2.0	14.1
MK-1	Paddy	65.2	2.6	6.8	45.2	23.0	11.6	35.2	2.5	16.6
MK-2	Secondary	52.5	2.2	5.9	3.3	10.9	5.3	17.0	1.2	7.6
GCM 5										
MH	Paddy	55.5	2.6	6.8	28.2	15.2	9.7	32.2	2.6	9.7
MK-1	Paddy	50.9	2.6	6.9	26.1	15.3	8.4	30.0	2.4	8.9
MK-2	Secondary	56.3	2.3	6.1	21.7	8.9	7.9	25.4	1.9	10.1
GCM 6										
MH	Paddy	73.5	3.7	9.7	26.0	18.0	9.9	26.2	2.0	13.4
MK-1	Paddy	74.7	3.4	8.9	26.7	21.2	10.4	30.5	2.2	14.4
MK-2	Secondary	49.2	2.0	5.2	17.0	9.7	5.9	12.2	1.3	7.9
GCM 7										
MH	Paddy	84.0	3.7	9.8	33.2	24.0	12.8	28.8	2.2	11.7
MK-1	Paddy	85.5	3.6	9.4	32.1	23.2	12.5	31.8	2.5	11.2
MK-2	Secondary	43.2	1.8	4.8	16.1	11.6	6.1	13.5	1.1	6.9
GCM 8										
MH	Paddy	75.6	2.8	7.4	20.6	14.7	8.0	39.3	2.1	9.2
MK-1	Paddy	80.2	2.8	7.3	16.0	11.5	6.6	42.7	2.1	8.3
MK-2	Secondary	39.5	1.6	4.3	13.2	9.4	4.9	17.4	1.1	3.5
GCM 9										
MH	Paddy	78.0	3.7	9.8	31.0	22.1	12.4	34.1	2.3	15.3
MK-1	Paddy	76.0	3.8	10.1	31.5	22.3	13.2	34.3	2.2	16.0
MK-2	Secondary	40.4	1.9	4.9	15.6	11.1	6.2	17.4	1.2	7.7

Source: JICA Project Team 2

E6.4 Irrigation Water Demand with Adaptation Measures against Droughts

E6.4.1 Adaptation Measures for Irrigation Water Demand Management against Drought

Among possible on-farm level adaptation measures against drought as described in Chapter E4.3, SRI method is to be partiarily promoted by adopting line transplanting method aiming to make rice plant growing condition on paddy field better than prevailing dense planting method and thereby to improve rice plant productivity. This line planting method has been demonstrated in implementing KIP Sage II Phase 2. In this stage of SRI method promotion, however, on-farm level crop management activity is not directly related to on-farm level irrigation water saving method.

Accordingly, the other three adaptation measures such as rotation system of irrigation water distribution, optimization of cropping calendar and improvement of irrigation efficiency are to be adopted in calculating irrigation water requiremnt under the future climate condition of three selected GCM cases.

In Table E6.4.1, the difference of irrigation water demand estimate procedures between without and with adaptation measures are itemized. Futher, focal points in optimzing croping calender as well as setting up cropping intensity in the Musi River basin are to be detailedly mentioned in E6.4.2 and E6.4.3.

Table E6.4.1 Comparison of Irrigation Water Demand Estimate Procedures

Item		Selection of Representative GCMs without Adaptation Measures	Selected GCMs with Adaptation Measures
1.	Objective	To clarify the difference of irrigation water demand calculation procedures between POLA and JICA Study in selecting typical GCMs	To assess impacts of the future climate condition under three selected typical GCMs on irrigation water demand after practicing adaptation measures of irrigation water management against droughts and thereby to provide necessary data for estimating cost and benefit of climate change adaptation measures
2.	Calculation formula of irrigation water demand	POLA: Indonesian National Standard (SNI 19-6728-1-2002) JICA Study: DGWR's Irrigation Planning Standard, Design Criteria for Irrigation Networks (KP-1)	KP-1
3.	Unit water requirement	POLA: Fixed rate of 1.0 l/s/ha JICA Study: Varied rates related to crop consumptive use data	Varied rates related to crop consumptive use data
4.	Parameter related to climate	None	Precipitation and evapotranspiration
5.	Irrigation efficiency	60%	60% for observed climate and 65% for future climate
6.	Irrigation water distribution system	Not considered	Rotation system on the block basis with 10-day interval for commencement date
7.	Cropping calendar	Fixed farm operation schedule with no relation to rainfall patterns	Optimized cropping calendar with the least water requirement for land preparation work of wet season
	Wet season paddy	October 1 to February 15	Base type: Nov. 1 to Mar.31 L3 type: Dec. 1 to Apr.30
	Dry season paddy	February 1 to June 15	Base type: Dec. 1 to Apr. 30 L3 type: Jan.1 to May 31
	Dry season secodary crop	June 16 to September 30	Base type: June 21 to Sept.30 L3 type: July 21 to Oct. 31
8.	Work period of each farming	15 days	30 days

Item		Selection of Representative GCMs without Adaptation Measures	Selected GCMs with Adaptation Measures
9.	Cropping intensity	300% (100% each for wet season paddy, dry season paddy and dry season secondary crop each)	250% for BBWS-S8 managed schemes, 150% (100%-40%-10&) for province managed schemes and 125% (100%-20%-5%) for local government

Source: JICA Project Team 2

E6.4.2 Optimization of Cropping Calendar

Based on the description in Chapter E4.3, the frequency of occurrence to fully meet water requirement for land preparation works with effective rainfalls. Under the observed climate situation in 1/5 probability drought year, the optimum land preparation period of wet season is examined for seven cases starting from October 1 to December 1 with 10-day interval and 30-day land preparation work period each.

As a result, the following two types of land preparation period for the wet season are selected:

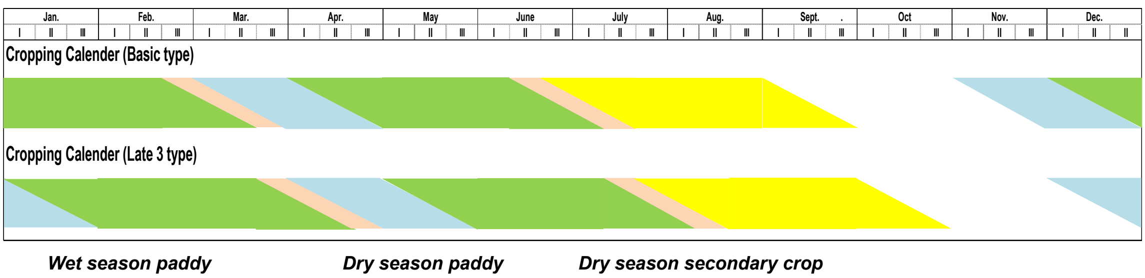
- Basic type of land preparation works for the wet season paddy cultivation starting from November 1; and
- L3 type starting from December 1.

To establish an optimum cropping calendar for these two types, the following conditions are set up:

- Crop growth period including 20-day nursery period is 110 days for wet season paddy, 100 days for dry season paddy and 70 days for dry season secondary crop;
- Rotation system of irrigation water distribution is introduced; and
- Complete dried-up period of irrigation canal system is fixed at 30 days once a year.

Thus, the following two types of cropping calendar as illustrated in Figure E6.4.1 are established:

- Basic type with crop cultivation works for wet season paddy starting from November 1 and ending March 31, dry season paddy starting from March 1 and ending July 20 and dry season secondary crop starting from June 21 to September 30; and
- L3 type with crop cultivation works for wet season paddy from December 1 to April 30, dry season paddy from April 1 to August 20 and dry season secondary crop from July 21 to October 31.



Note: Blue-colored part; Land preparation period, Green-colored part; Rice growing period under irrigated condition, Pink-colored part; Rice growing period under dried-up condition, Yellow-colored part; Secondary crop growing period under irrigated condition

Source: JICA Project Team 2

Figure E6.4.1 Optimized Cropping Calendar in Musi River Basin

The above two types of cropping calendar are to be applied to surface water irrigation scheme areas as follow:

- Basic type for schemes located in Musi Rawas and Musi Rawas Utara Regencies; and
- L3 type for schemes located in OKU, OKI, Muara Enim, Lahat, OKU Selatan, OKU Timur and Empat Lawang Regencies as well as Pagar Alam and Lubuk Linggau Cities.

E6.4.3 Setting-up of Cropping Intensity

Comparing the fixed statistical data as shown in Table E3.1.2 coupled with the design area of each registered surface irrigation scheme as shown in Table E6.1.1, it can be justified that the actual irrigated areas are functional parts of the existing surface water irrigation schemes, while the non-irrigated areas consist of rainfed paddy field areas including not functioned part of the existing surface water irrigation schemes as well as paddy growing areas in tidal and inland swamp irrigation schemes. Further, the cropping intensity as shown in Table E3.1.3 indicates actual utilization of wetland paddy field by farmers for rice cultivation purpose.

Considering these data, it is assumed that the future cropping intensity of wetland paddy field in surface water irrigation scheme areas will be as shown in Table E6.4.2, while the cropping intensity in rainfed paddy field areas will be 100% during the wet season only.

Table E6.4.2 Future Cropping Intensity in Surface Water Irrigation Scheme Areas

Authority / Size / Cropping Intensity			Wet Season		Dry Season 1		Dry Season 2	
BBWS-S8	Over 3,000 ha	250%	Rice	100%	Rice	100%	Secondary crop	50%
Province	3,000 – 1,000 ha	150%	Rice	100%	Rice	40%	Secondary crop	10%
Regency / City	Below 1,000 ha	125%	Rice	100%	Rice	20%	Secondary crop	5%

Source: JICA Project Team 2

E6.4.4 Unit Irrigation Water Requirement with Adaptation Measures against Drought

For quantifying the effect of different climate change models on irrigation water demand, unit irrigation water requirement is calculated by substituting evapotranspiration and rainfall data of three typical GCMs in the areas where surface irrigation schemes exist. The calculation works are carried out on the 10-day period basis for 15 years as mentioned before. Table E6.4.3 shows the calculation results of unit irrigation water requirement for the observed climate condition with 60% and 65% irrigation efficiency cases as well as the future climate condition under low risk scenario (GCM 3), medium risk scenario (GCM 8) and high risk scenarion (GCM 6).

Table E6.4.3 Area-wise Average of Unit Irrigation Water Requirement with Adaptation Measures

Case / Season / Crop		Area-wise Average of Unit Irrigation Water Requirement by Crop Season (l/s/ha)								
		OKI & OKU-T	OKU	OKU Selatan	Muara Enim	Lahat	Pagar Alam	Musi Rawas	Empat Lawang	Lubuk Linggau
Cropping Calendar		L3	L3	L3	L3	L3	L3	Basic	L3	L3
Observed Climate Condition (Irrigation efficiency: 60%)										
MH	paddy	0.53	0.51	0.55	0.43	0.45	0.55	0.33	0.43	0.43
MK-1	paddy	0.96	0.93	0.95	0.96	1.00	0.88	0.82	0.79	0.79
MK-2	secondary	0.29	0.28	0.29	0.24	0.26	0.24	0.25	0.20	0.20
Observed Climate Condition (Irrigation efficiency: 65%)										
MH	paddy	0.49	0.47	0.51	0.40	0.42	0.51	0.30	0.40	0.40
MK-1	paddy	0.89	0.85	0.88	0.89	0.92	0.81	0.76	0.73	0.73
MK-2	secondary	0.27	0.26	0.27	0.23	0.24	0.22	0.23	0.18	0.18
Future Climate Condition with Low Risk <GCM-3> (Irrigation efficiency: 65%)										

Case / Season / Crop		Area-wise Average of Unit Irrigation Water Requirement by Crop Season (l/s/ha)								
		OKI & OKU-T	OKU	OKU Selatan	Muara Enim	Lahat	Pagar Alam	Musi Rawas	Empat Lawang	Lubuk Linggau
MH	paddy	0.48	0.48	0.48	0.38	0.40	0.29	0.47	0.45	0.33
MK-1	paddy	1.07	1.11	1.11	0.89	0.87	0.89	0.53	0.81	0.77
MK-2	secondary	0.22	0.27	0.27	0.18	0.18	0.22	0.25	0.14	0.16
Future Climate Condition with Medium Risk <GCM-8> (Irrigation efficiency: 65%)										
MH	paddy	0.48	0.32	0.32	0.22	0.21	0.21	0.80	0.41	0.32
MK-1	paddy	0.80	0.71	0.71	0.61	0.60	0.53	0.79	0.72	0.74
MK-2	secondary	0.31	0.31	0.32	0.29	0.29	0.29	0.29	0.25	0.30
Future Climate Condition with High Risk <GCM-6> (Irrigation efficiency: 65%)										
MH	paddy	0.42	0.43	0.43	0.49	0.57	0.58	0.58	0.53	0.67
MK-1	paddy	0.86	0.82	0.82	0.82	0.84	0.76	0.56	0.75	0.84
MK-2	secondary	0.34	0.40	0.40	0.29	0.28	0.26	0.18	0.26	0.26

Source: JICA Project Team 2

E6.4.5 Irrigation Water Diversion Requirement with Adaptation Measures against Drought

Irrigation water diversion requiremnt with adapatation measures against drought is predicted based on the above-mentioned unit irrigationan water requirement and cropping clemder as well as design area of each surface water irrigation scheme as shown in Table E6.2.2. The calculation results of irrigation water diversion requirement with adapatation measures against drought are shown in Table E6.4.4 for the cases of observed climate condition with 60% and 65% irrigation efficiency as well as the future climate conditions under low risk scenario (GCM 3), medium risk scenario (GCM 8) and high risk scenarion (GCM 6).

Figures in Table E6.4.4 indicate the average of supplemental water demand for every 10-day period during each crop season. In other words, such average quantity of water will be diverted from source rivers evry 10-day period during each crop season.

Table E6.4.4 Area-wise Average of Irrigation Water Diversion Demand with Adaptation Measures

Crop Season / Crop		Area-wise Average of Irrigation Water Diversion Requirement by Crop Season (m^3/s)								
		OKI & OKU-T	OKU	OKU Selatan	Muara Enim	Lahat	Pagar Alam	Musi Rawas	Empat Lawang	Lubuk Linggau
Observed Climate Condition (Irrigation efficiency 60%)										
MH	Paddy	35.9	1.9	5.5	14.3	10.8	1.7	18.9	1.2	9.0
MK-1	Paddy	62.2	0.7	2.8	8.1	6.8	2.7	15.4	1.3	11.1
MK-2	Secondary	9.9	0.1	0.2	0.5	0.5	0.4	2.7	0.2	1.2
Observed Climate Condition (Irrigation efficiency 65%)										
MH	Paddy	33.1	1.8	5.1	13.2	9.9	1.5	17.5	1.1	8.3
MK-1	Paddy	57.4	0.7	2.6	7.5	6.3	2.5	14.2	1.2	10.2
MK-2	Secondary	9.1	0.1	0.2	0.5	0.4	0.4	2.5	0.1	1.1
Future Climate Condition under Low Risk Scenario (GCM 3)										
MH	Paddy	48.6	2.2	5.7	14.8	10.5	4.8	21.1	1.5	6.3
MK-1	Paddy	90.4	0.9	3.3	7.5	12.4	9.9	21.3	1.3	8.5
MK-2	Secondary	9.3	0.1	0.2	0.4	1.1	1.2	4.9	0.1	0.8
Future Climate Condition under Medium Risk Scenario (GCM 8)										
MH	Paddy	42.6	1.2	3.1	7.3	4.5	2.7	36.1	1.2	5.1
MK-1	Paddy	67.5	0.5	2.1	5.1	8.5	5.9	31.7	1.2	8.1
MK-2	Secondary	13.0	0.1	0.2	0.6	1.7	1.5	5.7	0.2	1.5
Future Climate Condition under High Risk Scenario (GCM 6)										
MH	Paddy	36.5	1.6	4.2	16.1	12.9	7.5	1.5	10.9	7.5
MK-1	Paddy	72.6	0.6	2.4	6.9	11.9	8.4	22.7	1.2	8.4
MK-2	Secondary	14.4	0.1	0.3	0.6	1.7	1.4	3.6	0.2	1.4

Source: JICA Project Team 2

E6.5 Swamp Drainage Scheme

E6.5.1 Prevailing Rice Farming Practicies in Swamp Drainage Scheme Areas

At present, BBWS-S8 has constructed waterways for large-scaled tidal swamp drainage scheme areas which is being used as transmigration areas. The surface level of paddy fields in these areas are lower than the high tide level. The irrigation method of the tidal swamp areas is very much dependent on the tidal fluctuation. Generally during the high tide river water is drawn to and stored in the tertiary canals, from where the stored water is further pumped up to the paddy fields. During the low tide, the water in the paddy field is drained to the canals and then to the river.

E6.5.2 On-farm Level Supplemental Irrigation Water Requiremnt in Tidal Swamp Area

Aiming to conduct a preliminary water balance analysis for the lowest areas of the Musi River basin, Banyuasin River basin and Sugihan River basin, the following assumptions are made for estimating on-farm level freshwater consumption volume:

- Single cropping of rice with 90-day growing variety for the wet season is the basic condition, which is commonly practiced by imigrant farmers;
- Land preparation work starts after accumulated precipitation at the beginning of wet season is over 20 mm and then contimues until on-farm water depth becomes 250 mm;
- After transplanting rice seedlings, pumping-up of water from drainage canal is done by farmers themselves upon their own decision and expense aiming to maintain water depth at the level of 250 mm to protect sea water risinfg from deep soil layer;
- Accordingly, rice cultivation period changes year by year reflecting rainfall condition in the initial stage of wet season; and
- Main gates of drainage system is controlled by BBWS Sumatra VIII, while on-farm level drainage facilities are managed by farmers.

Based on the above assumptions, the on-farm level water balance under rainfed rice growing condition has been assessed for the respective drainage scheme groups along Banyuasin, Musi and Sugihan Rivers under selected three GCM climate condition. An example of calculation results of on-farm level supplemental water demand by pumping up from drainage canals in tidal swamp drainage scheme areas is as shown in Table E6.5.1.

Table E6.5.1 Example of On-farm Level Supplemental Water Demand in Tidal Swamp Areas

Year	Past Climate Model (m^3/s)			Year	Future Climate Model (m^3/s)					
	Existing Scheme Area				Existing Scheme Area			Future Scheme Area		
	Low	Medium	High		Low	Medium	High	Low	Medium	High
	GCM 3	GCM 8	GCM 6		GCM 3	GCM 8	GCM 6	GCM 3	GCM 8	GCM 6
1985/86	264.5	61.0	447.0	2050/51	437.6	127.9	138.7	473.0	138.2	149.9
1986/87	620.7	448.5	174.1	2051/52	245.9	39.1	174.4	265.9	42.2	188.5
1987/88	620.7	96.5	118.7	2052/53	78.5	31.6	138.8	84.8	34.2	160.9
1988/89	254.8	99.8	30.3	2053/54	252.0	32.3	179.7	272.4	34.9	194.3
1989/90	173.1	72.5	287.4	2054/55	395.7	210.6	289.2	427.7	227.7	312.6
1990/91	196.7	395.3	177.8	2055/56	78.5	113.9	145.0	84.8	123.1	156.8
1991/92	310.5	203.2	186.9	2056/57	190.0	0	131.1	205.4	0	141.7
1992/93	334.4	276.6	105.2	2057/58	198.3	134.3	101.9	214.3	145.2	110.1
1993/94	245.4	174.1	220.2	2058/59	124.9	166.3	281.7	135.0	179.8	304.5
1994/95	300.1	239.7	246.5	2059/60	101.5	53.8	165.2	109.7	58.1	178.6
1995/96	187.8	83.0	192.0	2060/61	279.3	279.0	389.0	301.9	301.7	420.5
1996/97	671.3	291.0	311.6	2061/62	148.1	372.7	245.4	160.1	402.9	265.3
1997/98	205.5	128.4	332.4	2062/63	535.9	122.4	389.0	579.3	132.3	420.5
1998/99	203.8	255.8	292.2	2063/64	619.6	229.4	254.8	669.9	248.0	275.4
1999/00	302.2	209.9	170.9	2064/65	160.9	361.0	152.3	173.9	390.3	164.6

Source: JICA Project Team 2

Supporting Report F

WATER SUPPLY AND SEWERAGE

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 F : WATER SUPPLY AND SEWERAGE

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PART 1 BRANTAS RIVER BASIN

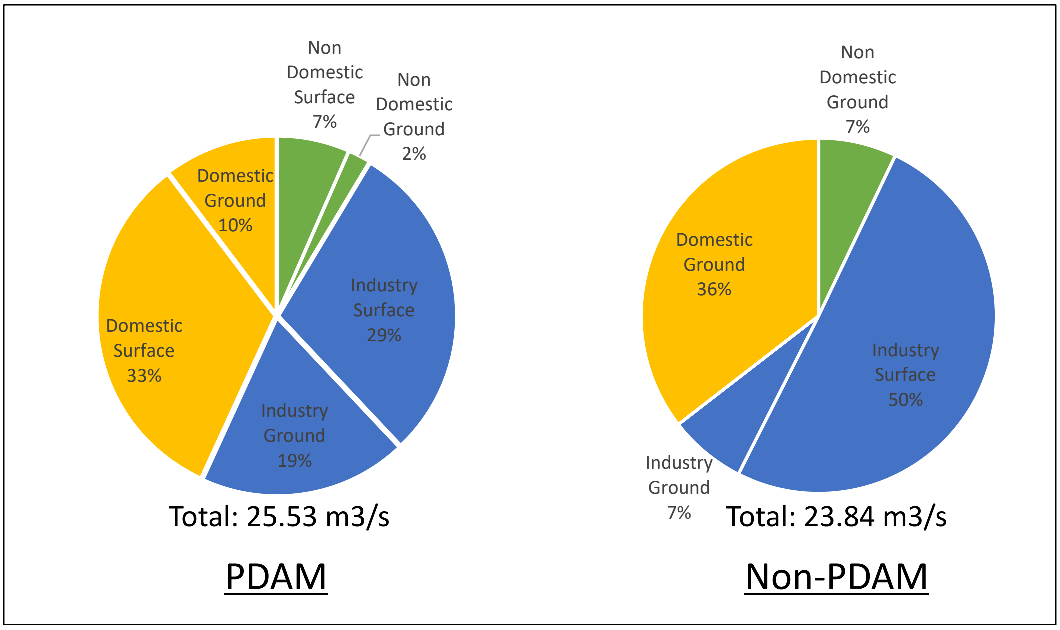
CHAPTER F1 WATER DEMAND PROJECTION IN 2050

F1.1 Municipal and Industrial Water Demand

In this section, municipal and industrial water demand projection in 2050 is explained.

F1.1.1 Current Water Supply Situation

Figure F1.1.1 shows water allocation in 2010 which demarcate supplier, purpose of water usage and water source in the Brantas River basin. Water supply for irrigation and fish pond is not considered in this section.



Source: JICA Project Team 2

Figure F1.1.1 Water Supply Sources to Each User in 2010

(1) PDAM and Non-PDAM

PDAMs are supplying water to several fields of residence, commercial, public area and industrial zones. Those customers are receiving water supply service from PDAM based on the contract. While, Non-PDAM means the area where PDAM does not supply water. Therefore, coverage ratio as mentioned in Section F1.1.2 means the total PDAM's customers ratio in each city and regency.

1) Purposes of water usage

In PDAM and Non-PDAM area, purposes of water usages are classified into (a) domestic water, (b) non-domestic water, and (c) industrial water as summarized below:

(a) Domestic water : Water consumption for bath, kitchen and restroom in residential area

(b) Non-domestic water : Commercial water consumption in shopping malls and public areas such as schools and government offices, etc.

(c) Industrial water : Water consumption of industrial estates, private factories etc.

2) Source of water

The water source consists of surface water and groundwater in the Brantas River basin. In the domestic and non-domestic water categorized in Non-PDAM, only groundwater is used. Table F1.1.1 shows the water demand (domestic, non-domestic and industrial water) in 2010.

Table F1.1.1 Actual Water Demand in 2010

Unit: m³/s

No	City/Regency	Surface Water			Groundwater		
		Domestic +Non-domestic	Industry	Total	Domestic +Non-domestic	Industry	Total
1.	Batu City	0.00	0.00	**0.00**	0.27	0.29	**0.56**
2.	Malang Regency	0.10	0.66	**0.76**	2.12	4.28	**6.40**
3.	Malang City	0.00	0.19	**0.19**	1.68	0.18	**1.86**
4.	Kediri Regency	0.07	1.33	**1.40**	1.04	0.42	**1.46**
5.	Blitar Regency	0.00	0.00	**0.00**	1.00	0.21	**1.21**
6.	Sidoarjo Regency	1.14	7.30	**8.44**	1.27	0.01	**1.28**
7.	Mojokerto Regency	0.00	0.14	**0.14**	0.95	0.04	**0.99**
8.	Jombang Regency	0.00	0.24	**0.24**	0.81	0.11	**0.92**
9.	Kediri City	0.00	0.00	**0.00**	0.33	0.32	**0.65**
10.	Kota Mojokerto City	0.08	0.33	**0.41**	0.07	0.30	**0.37**
11.	Surabaya City	7.66	7.16	**14.82**	1.11	0.00	**1.11**
12.	Trenggalek Regency	0.00	0.00	**0.00**	0.67	0.17	**0.84**
13.	Blitar City	0.00	0.00	**0.00**	0.13	0.14	**0.27**
14.	Tulungagung Regency	0.15	0.12	**0.27**	0.82	0.03	**0.85**
15.	Nganjuk Regency	0.13	0.18	**0.31**	0.68	0.00	**0.68**
16.	Gresik Regency	0.74	1.84	**2.58**	0.36	0.00	**0.36**
	Total (including NRW)	**10.07**	**19.49**	**29.56**	**13.31**	**6.50**	**19.81**
		49.37					

Source: JICA Project Team 2

(2) Existing Water Supply Treatment Plant

Existing water supply treatment plant in the Brantas River basin is listed as shown in Table F1.1.2 which was collected from PDAM in each city and regency.

F1.1.2 Methodology

(1) Methodology of Review POLA 2015 (Draft)

POLA is updated every five years generally. Therefore, Review POLA 2015 (Draft) is being updated based on POLA which was prepared in 2010. Demand forecast for domestic water is calculated in accordance with Indonesian National Standard (Standar National Indonesia; hereinafter called "SNI"). The formula in SNI is simplified to calculate water demand by multiplying unit water consumption with population. Unit water consumption is set at 120 l/capita/day for urban residents and 60 l/capita/day for rural residents. Ratio of the population for urban and rural in each city and regency seems to be 50% and 50%. However, no clear description regarding several factors for demand forecast such as unit water consumption, coverage ratio and Non-Revenue Water (NRW) as mentioned in Section F1.1.2 could be found in Review POLA 2015 (Draft). Furthermore, demand for non-domestic water might not be calculated in Review POLA 2015 (Draft) although Team 2 estimated at 20% of domestic water. As for industrial water in Review POLA 2015 (Draft), basis for the estimation came from forty six (46) industries, on the other hand, Team 2 collected the basic data for actual surface water consumption of one hundred and forty seven (147) industries in 2010 from PJT 1 and actual groundwater consumption of thirty six (36) industries in 2010 from ESDM.

Table F1.1.2 Existing Water Supply Treatment Plant in Brantas River Basin

No.	City / Regency	Name	Nos of WTP System	Capacity (ltr/sec)	No.	City / Regency	Name	Nos of WTP System	Capacity (ltr/sec)
1	Batu City	Oro-oro Ombo	1	22.0	6	Sidoarjo Regency	Kedunguling	1	150.0
		Punten I	1	45.0			Porong	1	45.0
		Punten II	1	31.0			Siwalan Panji	1	175.0
		Punten III	1	9.0			Krian	1	230.0
		Punten IV	1	14.0			Hanarida Tirta Birawa	1	500.0
		Songgokerto I	1	6.0			Taman Tirta Sidoarjo	1	250.0
		Songgokerto II	1	3.0			Umbulan	1	150.0
2	Malang Regency	Bendo Ijo	1	23.0			Taping Pondok Candra KMS	1	40.0
		Ubalan	1	100.2	7	Mojokerto Regency	Pacet	5	75.0
		Metro	1	7.6			Trowulan	1	10.0
		Umbulan	1	9.1			Mojosari	2	25.0
		Umbuldandang	1	4.4			Dawarblandong	2	5.0
		Bedji	1	5.1			Kemlagi	1	4.5
		Ngembul	1	36.3			Bangsal	1	2.5
		Kasri	1	5.4			Puri	1	2.5
		Pelus	1	14.2			Ngoro	1	2.5
		Kali Lesti	1	33.6			Jetis	1	10.0
		Durmo (P)	1	10.8	8	Jombang Regency	Jombang	7	146.0
		Durmo (G)	1	2.4			Ploso	3	29.0
		Beling	1	6.4			Kabuh	3	17.0
		Sendang Biru	1	22.9			Mojoagung	2	8.0
		Harjo Kuncaran	1	7.2			Bareng	3	12.0
3	Malang City	Binangun Pipa Lama	1	87.5			Diwek	1	10.0
		Binangun Pipa Baru	1	146.3	9	Kediri City	N/A	N/A	N/A
		Karangan	1	30.6	10	Mojokerto City	Wates	1	100.0
		Sumbersari	1	16.1	11	Surabaya City	Ngagel I	1	1800.0
		Wendit I	1	342.4			Ngagel II	1	1000.0
		Wendit II	1	317.8			Ngagel III	1	1750.0
		Wendit III	1	183.6			Karangpilang I	1	1450.0
		Banyuning	1	81.2			Karangpilang II	1	2500.0
		Badut I	1	9.6			Karangpilang III	1	2000.0
		Badut II	1	14.1	12	Trenggalek Regency	N/A	N/A	N/A
		Sumbersari I	1	2.1	13	Blitar City	N/A	N/A	N/A
		Istana Dieng	1	11.8	14	Tulungagung Regency	Jatiwekas I	1	100.0
		TPA Supit Urang I	1	4.7			Jatiwekas II	1	50.0
		Supit Urang II	1	10.0			Agrowilis	1	20.0
4	Kediri Regency	Kepung	1	20.0			Nglorok	1	20.0
		Puncu	1	10.0			Pokek	1	20.0
		Semen	1	7.5			Gambiran	1	20.0
		Grogol/Banyakan	1	7.5	15	Nganjuk Regency	Nganjuk	5	85.0
		Ngancar	1	-			Kertosono	2	25.0
		Wates	1	5.0			Berbek	2	30.0
5	Blitar Regency	Balerejo	1	50.0			Sawahan	1	15.0
		Slumbung	1	5.0			Ngetos	2	10.0
		Kesamben	1	50.0			Lengkong	2	12.5
		Talun	1	5.0			Jatikalen	1	5.0
		Gandusari	1	10.0			Loceret	2	20.0
		Garum	1	35.0			Bajulan	1	2.5
		Kanigoro	1	5.0			Wilangan	2	22.5
		Nglegok	1	3.5			Bagor	1	2.5
		Doko	1	15.0			Gondang	1	5.0
		Srengat	1	5.0			Rejoso	1	5.0
		Jambangan 2	1	15.0			Tanjung Anom	1	7.5
		Kedungsuru	1	7.5			Baron	-	-
		Maron	1	2.5			Prambon	1	2.5
		Jambangan 1	1	2.5	16	Gresik Regency	GKB III	1	30.0
		Jambangan	1	25.0			Legundi	1	550.0
		Semen	1	15.0			Perumnas	1	100.0
		Sambigede	1	7.5			Segoromadu	1	30.0
		Ngadri	1	10.0			Gadung	1	5.0
		Ngembul	1	20.0			PT Dewata	1	200.0
		Selopuro	1	10.0			PT Drupadi	1	400.0

Note N/A: Data is not available
Source: PDAMs in city and regency

In this Project, it is necessary to consider the mitigation measures to lack of water after evaluation of the influence by the climate change. Upon consideration of the adaptation and/or the mitigation measures such as reduction of NRW, it is better to apply for the above factors to calculate demand forecast. Therefore, it is evaluated that demand forecast of Team 2 can be more realistic.

The comparison between Review POLA 2015 (Draft) and estimation results of Team 2 is shown in Table F1.1.3. Although target year for the Project is set at the year of 2050, Table F1.1.3 shows the projection as at 2030 for this comparison purpose.

Table F1.1.3 Comparison with Review POLA 2015 (Draft)

Contents	Review POLA 2015 (Draft)	JICA Project
Population of the Brantas River basin in 2030	18,931,132	17,725,416
Demand Forecast in 2030		
- Domestic	25.14 m^3/s	27.68 m^3/s
- Non-domestic	N/A	5.54 m^3/s
- Industrial	18.68 m^3/s	28.61 m^3/s

Source: Review POLA 2015 (Draft) and Team 2

(2) Methodology in the Project

1) Water Supply Demand in 2010

Basis for the demand forecast is set at the condition in 2010 as a current water supply demand in the Brantas River basin as shown in Table F1.1.4.

Table F1.1.4 Basic Condition for Demand Forecast – Demand in 2010

Organization		PDAM		Non-PDAM	
Water Source*1		Surface	Ground	Surface	Ground
Purpose to Use	Domestic	- Population (Census Data), - Unit Water Consumption*2, - Coverage*3, - NRW*3		N/A	- Lpcd =(Lpcd(PDAM)+30*5)/2 - Area which is not supplied by PDAM. (100%-PDAM area) - NRW=0%
	Non-Domestic*4	20% of Domestic		N/A	20% of Domestic
	Industrial	Total Water Resource*3 – (Domestic + Non-Domestic).		12m^3/s in the Brantas basin*6.	1.68m^3/s in the Brantas basin. Actual Data from ESDM

Note: *1: Ratio of Surface/Ground is referred to the actual consumption in 2010 (ref: Direktori Perpamsi 2010).

*2: Calculated from actual supplied water volume (sell volume) and no. of user (ref: Direktori Perpamsi 2010).

*3: All numbers are referred from Direktori Perpamsi 2010. Coverage is calculated at population ratio which is supplied by PDAM.

*4: Water for public facility is calculated by 10-15% of domestic water demand according to the criteria of Directorate General of Human Settlement, Ministry of Public Work 1996. 20% of domestic water is estimated taking into consideration commercial use about 5-10%.

*5: 30 litter is unit consumption for residents in agricultural area which is estimated in Study on Formulation of Spatial Planning for GERBANGKERTOSUSILA (GKS) Zone in East Java Province in Indonesia.

*6: 12 m^3/s is calculated from the list of industrial water consumption in the Brantas River basin which was provided by PJT1.

Source: JICA Project Team 2

2) Factors for Future Water Supply Demand

Projection of water supply demand until 2050 is prepared based on the demand in 2010 taking into consideration the increasing target factors as summarized in Table F1.1.5. Details are shown below.

Table F1.1.5 Increasing Ratio for Demand Forecast until 2050

Organization		PDAM		Non-PDAM	
Water Source		Surface	Ground	Surface	Ground
Purpose to Use	Domestic	1)Pop. growth, 2)Future lpcd[*1], 3)Coverage[*2], 4)NRW[*3]	Increase until available ground water potential by 2030 and fixed the maximum demand from 2030 to 2050.	N/A	Increase until available ground water potential by 2030 and fixed the maximum demand from 2030 to 2050.
	Non-Domestic	20% of Domestic	Fixed as 2010	N/A	Fixed as 2010
	Industrial	Based on development (population) growth ratio	Fixed as 2010	Based on development (population) growth ratio	Fixed as 2010

Note: *1: Per capita in 2050; 200 lpcd for Surabaya, 150 lpcd, 120 lpcd for others (Ref. Criteria of Cipta Karya)
*2: 1% increase in average to meet total coverage ratio of 70% in the Brantas River basin in 2050
*3: By 2050 gradually reduce NRW to 20%-25% depend on the current NRW in 2010
Source: JICA Project Team 2

3) Umbulan Spring Water

According to Surabaya PDAM, in order to meet the water supply demand in Surabaya city there is an expansion plan for the treatment capacity of Karang Pilang IV which takes the water from Surabaya River. However, the expansion plan is suspended due to the plan to receive the water from Umbulan spring located in Pasuruan regency. In the case Umbulan spring water project can be implemented, Surabaya city will be able to receive 1,000 l/s by 2020 although the Umbulan spring water project is also not proceeding as schedule.

F1.1.3 Assumption of Water Demand Projection

(1) Future unit water consumption

According to the criteria issued by Cipta Karya, unit water consumption is defined based on the scale of the city which expresses as the number of populations as shown in Table F1.1.6. Unit water consumptions for each city and regency are defined 120 or 150 litter per capita per day (lpcd). As for the Surabaya city, it is necessary to pay special attention since it is the second largest city in Indonesia. Unit water consumption of Surabaya city is applied for 180 lpcd until 2025 which is used by PDAM Surabaya for their forecast. After 2025, unit water consumption is defined by Team 2 to increase gradually to 200 lpcd until 2050. Unit water consumption for the demand forecast until 2050 is shown in Table F1.1.7.

Table F1.1.6 Standard Unit Water Consumption in Indonesia

Descriptions	Categorization of City by Number of Population (in person)				
	> 1 mill.	500 thous.-1 mill.	100 thous.- 500 thous.	20 thous.-100 thous.	< 20 thous.
	Metropolitan city	Big city	Medium city	Small city	Rural
Domestic water consumption (lt./pers./d)	>150	120-150	90-120	80-120	60-80

Source: Criteria of Directorate General of Human Settlement, Ministry of Public Work 1996

Table F1.1.7 Unit Water Consumption for Demand Forecast

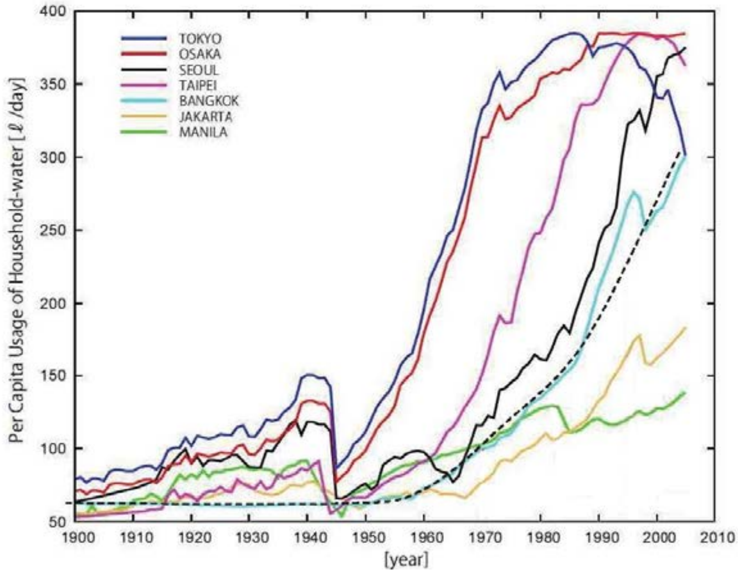
Unit: litter/capita/day

City / Regency	2010*	2015	2020	2030	2033	2040	2050
1.Batu City	116	117	117	118	118	119	120
2.Malang Regency	69	75	82	95	98	107	120
3.Malang City	113	118	122	132	134	141	150
4.Kediri Regency	73	79	85	97	100	108	120
5.Blitar Regency	92	95	99	106	108	113	120
6.Sidoarjo Regency	101	107	113	126	129	138	150
7.Mojokerto Regency	94	101	108	122	126	136	150
8.Jombang Regency	57	65	73	89	93	104	120
9.Kediri City	105	107	109	113	114	116	120
10.Mojokerto City	86	90	95	103	106	112	120
11.Surabaya City	180	180	180	187	189	193	200
12.Trenggalek Regency	105	107	109	113	114	116	120
13.Blitar City	74	86	86	97	100	109	120
14.Tulungagung Regency	97	100	103	109	110	114	120
15.Nganjuk Regency	75	81	86	98	101	109	120
16. Gresik Regency	64	71	78	92	96	106	120

Note *: Calculated from actual supplied water volume (sell) and no. of user (ref: Direktori Perpamsi 2010)

Source: JICA Project Team 2

As a past trend of unit water consumption at large scale city around eastern side of Asia, increasing trend are shown in Figure F1.1.2. There is a possibility for unit water consumption to increase drastically at cities in the Brantas River basin, however, it is set as not so high considering introduction of water management such as water saving campaigns, recycling water usage and so on. Referring to unit water consumptions in Bangkok and Jakarta, it believes that applied 200 liters for Surabaya, and 120 and 150 litters for other cities in 2050 are reasonable volume of unit water consumption.

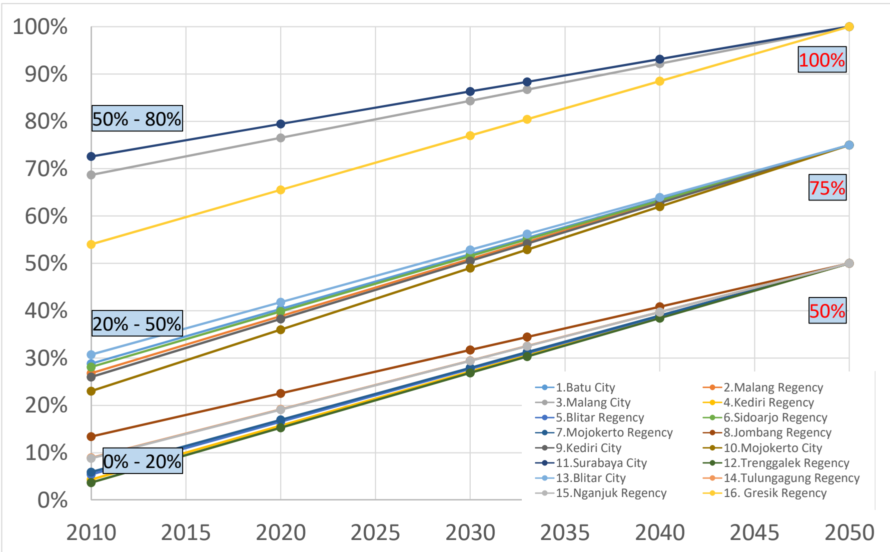


Source: Research Institute for Human and Nature, Japan

Figure F1.1.2 Unit Water Consumption in Asia

(2) Coverage ratio

Future coverage ratio is decided to have three (3) target categories of 100%, 75%, and 50% taking into consideration the current coverage ratio of each city or regency as shown in Figure F1.1.3. Each coverage ratio in city or regency will be gradually increased to each target level until 2050.

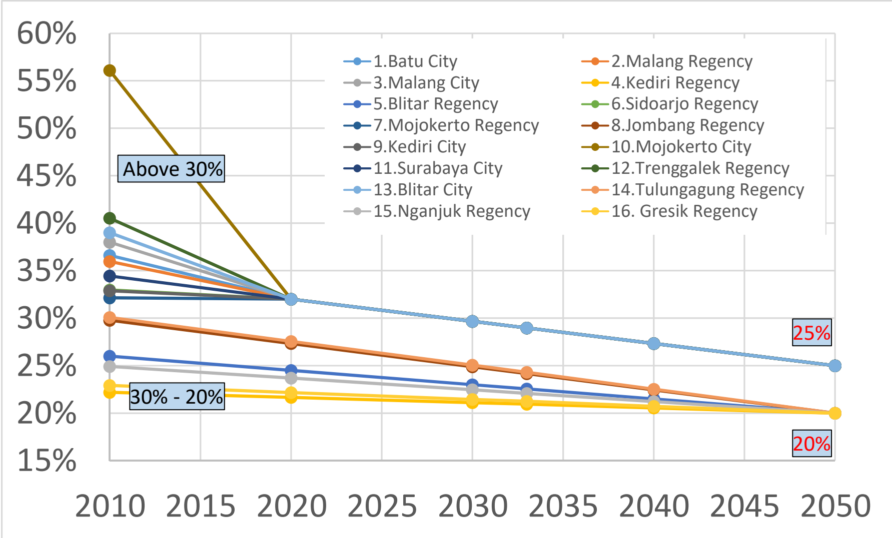


Source: JICA Project Team 2

Figure F1.1.3 Coverage Ratio until 2050

(3) Non-Revenue Water (NRW) ratio

Reduction of non-revenue water (NRW) has two target grades of 25% and 20% depend on the current NRW ratio of each city or regency in 2010. It is generally known that the NRW ratio can be reduced easily until 30% by means of the systematic way of replacing pipes based on the leakage survey, and control and monitoring water consumption volume by water meter. However, it will take cost and time to be lower ratio than 30%. The highest NRW ratio of 56.1% in Mojokerto city was recorded in 2010.



Source: JICA Project Team 2

Figure F1.1.4 NRW until 2050

(4) Groundwater

Groundwater volume is set at stable. In case law or regulation for restriction of groundwater usage is issued by government in order to mitigate bad water quality and ground subsidence, extraction volume shall be reduced. In case PDAM supplies treated water from the surface water source which means coverage ratio is increased, groundwater usage will be decreased. On the other hand, although ground water potential used for irrigation is estimated at the capacity of 21 m^3/s in Review POLA 2015 (Draft), BBWS Brantas is planning to gradually reduce the groundwater for irrigation purpose and the balance is to be used for the purpose of domestic, non-domestic and industry. Therefore, Team 2 assumed to use groundwater in which the potential groundwater is available. Groundwater volume is set at stable from 2030 to 2050 with the available maximum ground water in 2030.

F1.1.4 Projected Population

(1) Population Projection in Review POLA 2015 (Draft)

Population is simply projected in Review POLA 2015 (Draft) by the formula which can be calculated by the factors such as growth ratio and years with the basis of the population in 2010. This projection therefore does not reflect the long term population growth in East Java formulated by BPS and urbanization factor for each city and regency is not taken into consideration.

On the other hand, Team 2 estimated taking into consideration urbanization factor which BPS estimated the urbanization ratio in 2035 at 66.7%. From the view point to express the different growth ratio for urban and rural area in each city or regency, it can be evaluated that the method of Team 2 will be more realistic.

(2) Population Projection in the Project

There is no projected population data until 2050. BPS has projected to each province from 2010 to 2035. Projection of population growth until 2050 is prepared with the following basis;

- Growth ratio of projected population and urbanization factor in East Java Province until 2035 published by BPS, and

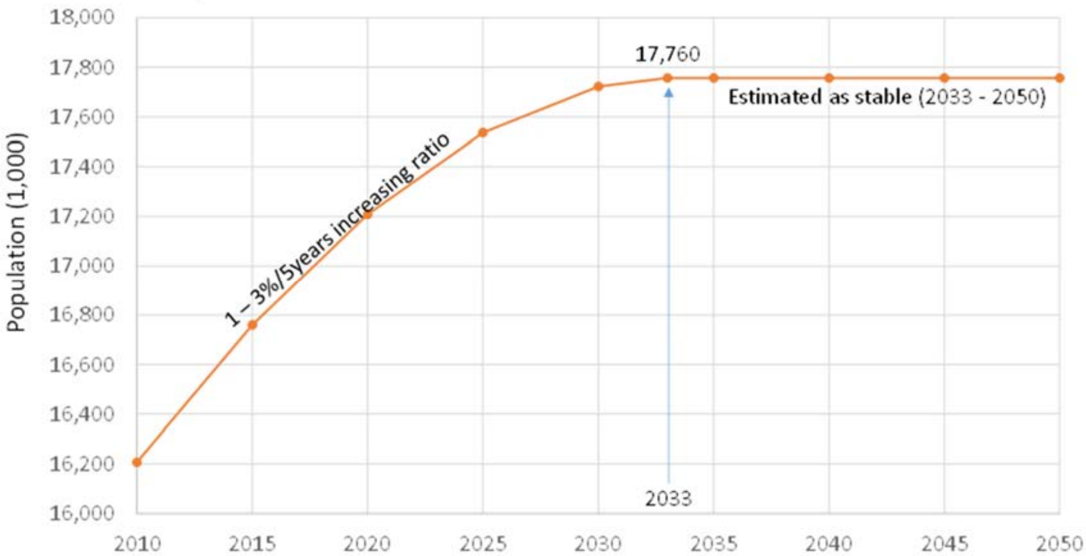
- Allocation ratio between urban and rural for each city and regency in 2010 referred to census data of Indonesia
- Population of East Java projected by BPS will be maximum in 2033 and gradually reduced until 2035. The population projected by BPS is estimated until 2035, therefore Team 2 assumed that the maximum population in 2033 will be stable until 2050 and the projected population is used for the demand forecast until 2050 since it will be safer side.

Table F1.1.8 Projection of Population until 2050

Unit: 1,000 People

No	City/Regency	2010	2015	2020	2030	2033	2050
1.	Batu City	190	200	203	211	211	211
2.	Malang Regency	2,446	2,554	2,586	2,651	2,652	2,652
3.	Malang City	820	851	879	913	917	917
4.	Kediri Regency	1,500	1,546	1,584	1,623	1,624	1,624
5.	Kab. Blitar Regency	1,117	1,145	1,177	1,204	1,203	1,203
6.	Sidoarjo Regency	1,941	2,117	2,075	2,152	2,160	2,160
7.	Mojokerto Regency	1,025	1,080	1,084	1,111	1,112	1,112
8.	Jombang Regency	1,202	1,250	1,276	1,313	1,315	1,315
9.	Kediri City	269	280	288	299	300	300
10.	Kota Mojokerto City	120	125	129	134	134	134
11.	Surabaya City	2,765	2,848	2,963	3,078	3,093	3,093
12.	Trenggalek Regency	674	689	709	723	723	723
13.	Blitar City	132	137	141	147	148	148
14.	Tulungagung Regency	990	1,021	1,046	1,072	1,072	1,072
15.	Nganjuk Regency	1,017	1,041	1,072	1,095	1,095	1,095
	Total	**16,210**	**16,890**	**17,211**	**17,725**	**17,760**	**17,760**

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure F1.1.5 Projected Population for Demand Forecast

F1.1.5 Water Demand Projection

Demand forecast until 2050 by means of the applying factors as described above is summarized in Table F1.1.9. Demand forecasts for each city and regency in 2010, 2015, 2030 and 2050 are shown from Tables F1.1.10 to F1.1.13. Figure F1.1.6 also shows the water demand in comparison with population growth and reduction of NRW graphically.

Table F1.1.9 Summary for Water Demand Projection until 2050

Unit: m^3/s

Year	2010		2015		2030		2050	
Purpose	Surface	Ground	Surface	Ground	Surface	Ground	Surface	Ground
Domestic	8.37	11.10	10.41	11.09	13.80	13.95	20.00	13.95
Non-Domestic	1.68	2.20	2.08	2.21	2.91	2.78	4.73	2.78
Industry	19.49	6.50	20.84	6.50	20.53	7.87	21.15	7.87
Total	29.54	19.80	33.33	19.80	37.24	24.60	45.88	24.60
	49.34		53.13		61.83		70.48	

Source: JICA Project Team 2

Table F1.1.10 Water Demand Projection for each City and Regency in 2010

Unit: m^3/s

City / Regency	Surface Water			Groundwater			Total		
	D+ND	IND	Total	D+ND	IND	Total	D+ND	IND	Total
1.Batu C.	0.00	0.00	**0.00**	0.27	0.29	**0.57**	**0.27**	**0.29**	**0.57**
2.Malang R.	0.10	0.66	**0.76**	2.12	4.28	**6.39**	**2.21**	**4.94**	**7.15**
3.Malang C.	0.00	0.19	**0.19**	1.68	0.18	**1.85**	**1.68**	**0.37**	**2.05**
4.Kediri R.	0.07	1.33	**1.41**	1.04	0.42	**1.46**	**1.11**	**1.76**	**2.87**
5.Blitar R.	0.00	0.00	**0.00**	1.00	0.21	**1.21**	**1.00**	**0.21**	**1.21**
6.Sidoarjo R.	1.14	7.30	**8.44**	1.27	0.01	**1.28**	**2.41**	**7.31**	**9.72**
7.Mojokerto R.	0.00	0.14	**0.14**	0.95	0.04	**0.98**	**0.95**	**0.18**	**1.12**
8.Jombang R.	0.00	0.24	**0.24**	0.81	0.11	**0.92**	**0.81**	**0.35**	**1.16**
9.Kediri C.	0.00	0.00	**0.00**	0.33	0.32	**0.66**	**0.33**	**0.32**	**0.66**
10.Mojokerto C.	0.08	0.33	**0.40**	0.07	0.30	**0.37**	**0.15**	**0.63**	**0.78**
11.Surabaya C.	7.66	7.16	**14.81**	1.11	0.00	**1.11**	**8.76**	**7.16**	**15.92**
12.Trenggalek R.	0.00	0.00	**0.00**	0.67	0.17	**0.84**	**0.67**	**0.17**	**0.84**
13.Blitar C.	0.00	0.00	**0.00**	0.13	0.14	**0.28**	**0.13**	**0.14**	**0.28**
14.Tulungagung R.	0.15	0.12	**0.27**	0.82	0.03	**0.85**	**0.97**	**0.15**	**1.12**
15.Nganjuk R.	0.13	0.18	**0.31**	0.68	0.00	**0.68**	**0.81**	**0.18**	**0.99**
16. Gresik R.	0.74	1.84	**2.57**	0.36	0.00	**0.36**	**1.09**	**1.84**	**2.93**

Note: D: Domestic, ND: Non-Domestic, IND: Industry

Source: JICA Project Team 2

Table F1.1.11 Water Demand Projection for each City and Regency in 2015

Unit: m^3/s

City / Regency	Surface Water			Groundwater			Total		
	D+ND	IND	Total	D+ND	IND	Total	D+ND	IND	Total
1.Batu C.	0.05	0.02	**0.06**	0.27	0.29	**0.57**	**0.32**	**0.31**	**0.63**
2.Malang R.	0.45	0.88	**1.33**	2.12	4.28	**6.39**	**2.56**	**5.15**	**7.72**
3.Malang C.	0.17	0.20	**0.37**	1.68	0.18	**1.85**	**1.85**	**0.38**	**2.23**
4.Kediri R.	0.17	1.39	**1.56**	1.04	0.42	**1.46**	**1.21**	**1.81**	**3.02**
5.Blitar R.	0.13	0.01	**0.14**	1.00	0.21	**1.21**	**1.13**	**0.22**	**1.35**
6.Sidoarjo R.	1.61	7.96	**9.57**	1.27	0.01	**1.28**	**2.88**	**7.97**	**10.85**
7.Mojokerto R.	0.11	0.15	**0.26**	0.95	0.04	**0.98**	**1.05**	**0.19**	**1.24**
8.Jombang R.	0.03	0.25	**0.28**	0.81	0.11	**0.92**	**0.84**	**0.36**	**1.20**
9.Kediri C.	0.06	0.01	**0.08**	0.33	0.32	**0.66**	**0.40**	**0.34**	**0.73**
10.Mojokerto C.	0.09	0.36	**0.44**	0.07	0.30	**0.37**	**0.16**	**0.66**	**0.82**
11.Surabaya C.	8.08	7.37	**15.45**	1.11	0.00	**1.11**	**9.18**	**7.37**	**16.56**
12.Trenggalek R.	0.12	0.01	**0.13**	0.67	0.17	**0.84**	**0.79**	**0.18**	**0.97**
13.Blitar C.	0.03	0.01	**0.03**	0.13	0.14	**0.28**	**0.16**	**0.15**	**0.31**
14.Tulungagung R.	0.27	0.13	**0.40**	0.82	0.03	**0.85**	**1.09**	**0.15**	**1.25**
15.Nganjuk R.	0.19	0.19	**0.38**	0.68	0.00	**0.68**	**0.87**	**0.19**	**1.06**
16. Gresik R.	0.94	1.91	**2.85**	0.36	0.00	**0.36**	**1.30**	**1.91**	**3.21**

Note: D: Domestic, ND: Non-Domestic, IND: Industry

Source: JICA Project Team 2

Table F1.1.12 Water Demand Projection for each City and Regency in 2030

Unit: m^3/s

City / Regency	Surface Water			Groundwater			Total		
	D+ND	IND	Total	D+ND	IND	Total	D+ND	IND	Total
1.Batu C.	0.05	0.02	**0.06**	0.30	0.32	**0.62**	**0.35**	**0.34**	**0.68**
2.Malang R.	0.78	0.55	**1.33**	2.54	5.13	**7.67**	**3.32**	**5.68**	**8.99**
3.Malang C.	0.25	0.12	**0.37**	1.99	0.21	**2.20**	**2.24**	**0.33**	**2.57**
4.Kediri R.	0.53	1.03	**1.56**	1.51	0.61	**2.13**	**2.04**	**1.65**	**3.69**
5.Blitar R.	0.14	0.00	**0.14**	1.28	0.27	**1.55**	**1.41**	**0.28**	**1.69**
6.Sidoarjo R.	2.60	8.09	**10.69**	1.27	0.01	**1.28**	**3.88**	**8.10**	**11.97**
7.Mojokerto R.	0.21	0.05	**0.26**	1.47	0.06	**1.53**	**1.68**	**0.11**	**1.79**
8.Jombang R.	0.19	0.08	**0.28**	1.34	0.18	**1.52**	**1.53**	**0.27**	**1.80**
9.Kediri C.	0.06	0.02	**0.08**	0.39	0.37	**0.76**	**0.45**	**0.39**	**0.84**
10.Mojokerto C.	0.12	0.40	**0.52**	0.07	0.30	**0.37**	**0.20**	**0.70**	**0.90**
11.Surabaya C.	9.48	7.97	**17.45**	1.11	0.00	**1.11**	**10.59**	**7.97**	**18.56**
12.Trenggalek R.	0.14	0.01	**0.15**	0.79	0.20	**0.99**	**0.93**	**0.21**	**1.14**
13.Blitar C.	0.03	0.01	**0.03**	0.16	0.18	**0.34**	**0.19**	**0.18**	**0.37**
14.Tulungagung R.	0.32	0.08	**0.40**	1.09	0.03	**1.13**	**1.41**	**0.11**	**1.52**
15.Nganjuk R.	0.28	0.10	**0.38**	1.06	0.00	**1.06**	**1.34**	**0.10**	**1.44**
16. Gresik R.	1.53	2.01	**3.54**	0.36	0.00	**0.36**	**1.89**	**2.01**	**3.90**

Note: D: Domestic, ND: Non-Domestic, IND: Industry

Source: JICA Project Team 2

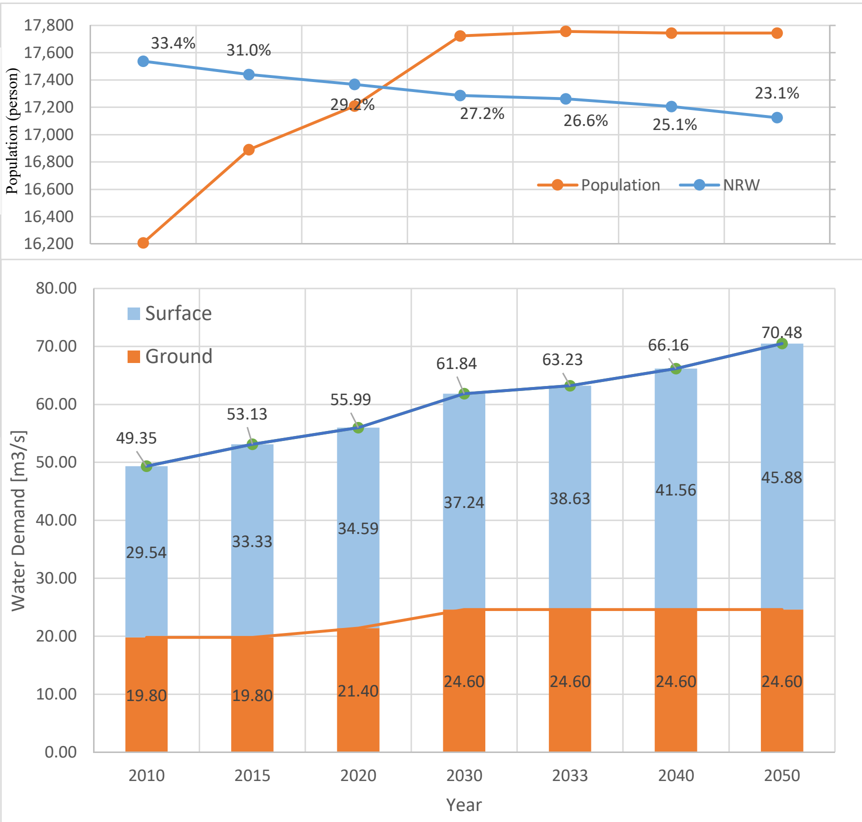
Table F1.1.13 Water Demand Projection for each City and Regency in 2050

Unit: m^3/s

City / Regency	Surface Water			Groundwater			Total		
	D+ND	IND	Total	D+ND	IND	Total	D+ND	IND	Total
1.Batu C.	0.09	0.02	**0.11**	0.30	0.32	**0.62**	**0.39**	**0.34**	**0.73**
2.Malang R.	2.06	0.74	**2.80**	2.54	5.13	**7.67**	**4.60**	**5.87**	**10.46**
3.Malang C.	0.60	0.16	**0.76**	1.99	0.21	**2.20**	**2.59**	**0.37**	**2.96**
4.Kediri R.	1.16	1.15	**2.31**	1.51	0.61	**2.13**	**2.68**	**1.76**	**4.44**
5.Blitar R.	0.55	0.01	**0.56**	1.28	0.27	**1.55**	**1.83**	**0.28**	**2.11**
6.Sidoarjo R.	3.91	8.12	**12.02**	1.27	0.01	**1.28**	**5.18**	**8.13**	**13.31**
7.Mojokerto R.	0.81	0.10	**0.90**	1.47	0.06	**1.53**	**2.28**	**0.15**	**2.43**
8.Jombang R.	0.75	0.16	**0.91**	1.34	0.18	**1.52**	**2.09**	**0.34**	**2.44**
9.Kediri C.	0.15	0.02	**0.18**	0.39	0.37	**0.76**	**0.54**	**0.40**	**0.94**
10.Mojokerto C.	0.18	0.40	**0.59**	0.07	0.30	**0.37**	**0.26**	**0.70**	**0.96**
11.Surabaya C.	10.35	8.00	**18.35**	1.11	0.00	**1.11**	**11.45**	**8.00**	**19.46**
12.Trenggalek R.	0.36	0.01	**0.38**	0.79	0.20	**0.99**	**1.15**	**0.21**	**1.36**
13.Blitar C.	0.10	0.01	**0.11**	0.16	0.18	**0.34**	**0.26**	**0.19**	**0.45**
14.Tulungagung R.	0.61	0.10	**0.71**	1.09	0.03	**1.13**	**1.71**	**0.13**	**1.84**
15.Nganjuk R.	0.71	0.13	**0.84**	1.06	0.00	**1.06**	**1.77**	**0.13**	**1.91**
16. Gresik R.	2.33	2.01	**4.34**	0.36	0.00	**0.36**	**2.69**	**2.01**	**4.70**

Note: D: Domestic, ND: Non-Domestic, IND: Industry

Source: JICA Project Team 2



Note: Average NRW of cities and regencies in Brantas River basin is shown.

Source: JICA Project Team 2

Figure F1.1.6 Water Supply Demand Forecast until 2050

CHAPTER F2 SEWERAGE

F2.1 Existing Wastewater Facilities

Sewerage systems in the Brantas River basin are not so fully provided yet. Wastewater from residents is once collected by septic tank and overflowed wastewater is discharged into the drainage channel nearby each house. The collected wastewater by septic tank is usually only for black water, while gray water is discharged directly into the channel. On the other hand, wastewater from industries is currently responsible for each operator of industries.

According to sewerage development plan of Surabaya city in 2010, there are several communal systems in residential areas which were built by Cipta Karya. Modular type of treatment plants is applied for the area since the capacity is not so large. Septage treatment plant with the capacity of 400 m^3/day which treat the collected sewage from septic tank is available in Keputih, Surabaya. However, receiving volume of sewage is just 100 m^3/day.

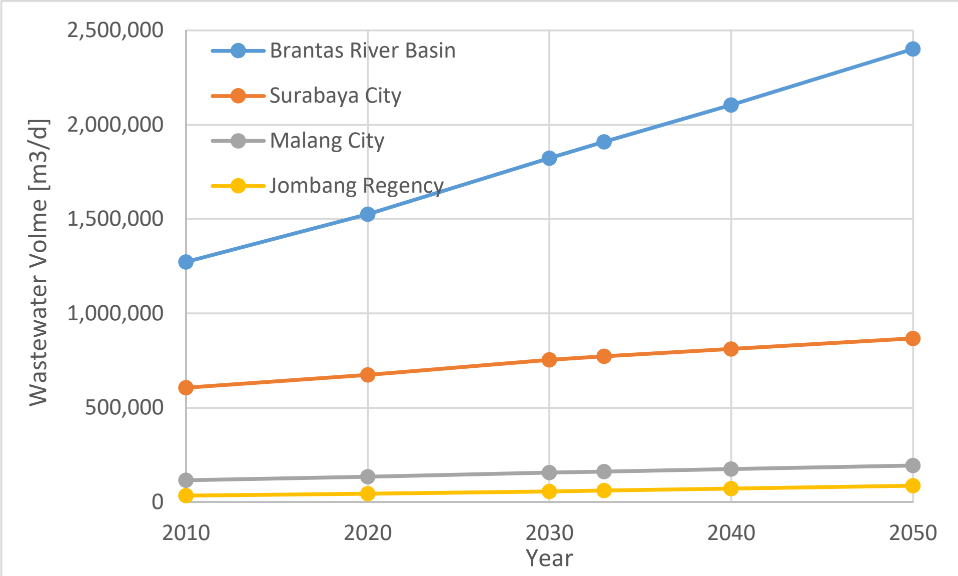
As for Malang city, eighty five (85) wastewater treatment plants are exist of which twenty one (21) plants have problems in terms of operation of the plant, physical problems at building, and claims from residents living around. Those plants are ~~all~~ small scale of communal treatment plants.

Wastewater system in Jombang regency covers only 2.3% in 2010 and effluent from residents are discharging directly to river, drain or pond without any treatment. Although it is known that wastewater treatment plant is urgently required, recent development makes difficult to find the available land for wastewater treatment plant.

As mentioned above, wastewater facilities in the Brantas River basin are still insufficient and due to lack of proper operation and maintenance of existing facilities these are not in good condition.

F2.2 Estimation of Future Sewerage Volume

Team 2 estimated preliminary the wastewater volume based on the water supply demand forecast until 2050 as shown in Figure F2.2.1. It was assumed that wastewater will be treated only for the water in urban area, and also wastewater from industrial area was not counted since operator of industries has to treat the wastewater before discharging into drain nearby. Estimated wastewater volume derived from 80% of water supply demand for domestic and non-domestic water in urban area. Water supply volume will be increased, accordingly wastewater volume will also be increased. However, existing sewerage system in the Brantas River basin seems to be insufficient. In terms of water quality, it will be required to avoid pollution of surface water which is used as water sources. Therefore, development for wastewater treatment plant and sewerage system shall be implemented in a phased manner especially for the urban area of dense city which pollution load might be higher than other area.



Source: JICA Project Team 2

Figure F2.2.1 Estimated Wastewater Volume until 2050

F2.3 Proposed Improvement for Wastewater Sector

(1) Updating for sewerage master plan and action plan

Sewerage development plan for 10 years and action plan for 5 years were prepared by Directorate General of Human Settlement (Direktorat Jenderal Cipta Karya, hereinafter called "Cipta Karya") in each city and regency. Generating wastewater volume will depend on the volume of water supply consumption. Therefore, it is important for Cipta Karya to make consensus with future water supply demand forecast for preparation of sewerage development plan and action plan. Indonesian Regional Water Utility Companies (Perusahaan Daerah Air Minum, hereinafter called "PDAM") are ~~is~~ preparing their business plan for future water supply demand of their coverage area mainly for urban area. The development plan and action plan shall be prepared in a quantitative form as much as possible.

(2) Water quality management for rivers

Water quality of main stream and tributaries in the Brantas River basin is being monitored by PJT1 periodically. Water quality which can discharge into river is regulated in effluent water quality standard as shown in Table F2.3.1. However, water quality seems to be worse with the urbanization of the cities. It is not sure that all polluters including resident, commercial and industrial water consumers follow the standard. It is expected that the regulation does not work properly since there is no penalty clause of regulation.

Table F2.3.1 Effluent Water Quality Standard in Indonesia

Effluent standard from Domestic

Parameter	Unit	Limit
pH	mg/L	6-9
BOD	mg/L	30
COD	mg/L	100
TSS	mg/L	30
Oil	mg/L	5
Ammonia	mg/L	10
Total Coliform	total/100mL	3000
Discharge	l/person/day	100

Source: No. 68/2016 Domestic Wastewater Standard, Ministry of Environment

Effluent Standard from Industry

Parameter	Unit	Limit
pH	mg/L	6-9
TSS	mg/L	150
BOD	mg/L	50
COD	mg/L	100
Sulfate	mg/L	1
NH_3-N	mg/L	20
Phenol	mg/L	1
Oil	mg/L	15
Ionic detergent	mg/L	10
Cd	mg/L	0.1
Cr^{6+}	mg/L	0.5
Cr	mg/L	1
Cu	mg/L	2
Pb	mg/L	1
Ni	mg/L	0.5
Zn	mg/L	10
Max waste water volume		0.8 l/s/ha

Source: No. 72/2013 Wastewater Standard for Industry and / or other business activities, East Java

PART 2 MUSI RIVER BASIN

CHAPTER F3 WATER DEMAND PROJECTION IN 2050

F3.1 Municipal and Industrial Water Demand

F3.1.1 Conditions

(1) Coverage of Municipal and Industrial Water Demand

Municipal and industrial water demand in this study covers the water demand of the human life and urban activities; activities in houses, offices, commercial facilities, governmental facilities, public facilities and industrial facilities. The section does not cover the water demands of the irrigation, fishery, forestry and maintenance of river.

(2) Areas and Boundaries of Study Area

Certain datum of the statistical records for the water - demand projection are adjusted to the following manner because of changing administrative boundaries with plural times in recent years.

The statistical information of water supply as the basis of the water - demand projection is basically compiled in accordance with the administrative area.

Furthermore, the structure of the cities/regencies in South Semetra province had been changed in plural times in recent years. The Lahat regency has been separated to Lahat and Empat Lawang regency from 2007. The Musi Rawas regency has been separated to Musi Rawas and Musi Rawas Ultra regency and the Muara Emin regency has also separated to Muara Emin and Panukul Abab Lematang Ilir regency from 2017. The categories of the regencies in statistical datum are different based on its year because of the change.

Above the situation, the information of the water supply utilized for the water - demand projection is distributed by the ratio prepared by the area of the river basin divided the administrative area in each city/regency. The areas of the river basins in each city/regency are presented in the Table F3.1.1.

Table F3.1.1 Areas of River Basins in each City/Regency

River Basin	City/Regency	Administrative area (km^2)	Area of river basin (km^2)	Remark
Musi	Banyuasin	12,361	443	Administrative area does not cover the river basin area.
	Empat Lawang	2,312	2,312	Separated from Lahat in 2007
	Lubuklinggau	365	365	
	PagarAram	633	633	
	Palembang	364	364	
	Prabumulih	458	458	
	Lahat	4,297	4,297	
	MuaraEmin	6,901	6,901	
	Musi Banyuasin	14,530	6,426	Administrative area does not cover the river basin area.
	Musi Rawas	6,331	6,331	
	Musi Rawas Ultra	5,837	5,387	Separated from Musi Rawas in 2017
	Ogan Ilir	2,411	2,411	
	Ogan Komering Ilir	17,086	2,326	Administrative area does not

				cover the river basin area.
	Ogan Komering Ulu	3,748	3,748	
	Ogan Komering Ulu Selatan	4,544	4,544	
	Ogan Komering Ulu Timur	3,397	3,397	
	Panukal Abab Lematan Ilir	1,845	1,845	Separated from Muara Emin in 2017
	Rejang Lebong	1,640	1,640	
	Kepahian	665	665	
	Sarolangun	6,184	100	Administrative area does not cover the river basin area.
	Batanghari	5,804	63	Administrative area does not cover the river basin area.
Banyuasin	Banyuasin	12,361	3,946	Administrative area does not cover the river basin area.
	Musi Banyasin	14,530	7,149	Administrative area does not cover the river basin area.
	Sarolangun	6,184	4	Administrative area does not cover the river basin area.
	Batanghari	5804	1076	Administrative area does not cover the river basin area.
	Mauro Jambi	5,326	1,136	Administrative area does not cover the river basin area.
Sugihan	Banyuasin	12,361	1,046	Administrative area does not cover the river basin area.
	Ogan Komering Ilir	17,086	2,332	Administrative area does not cover the river basin area.

Source: Census 2010 of Indonesia, Statistic Information of Province 2017 South Semetra, Jambi and Bengkulu and JICA Project Team 2

(2) Current Water Supply Situation

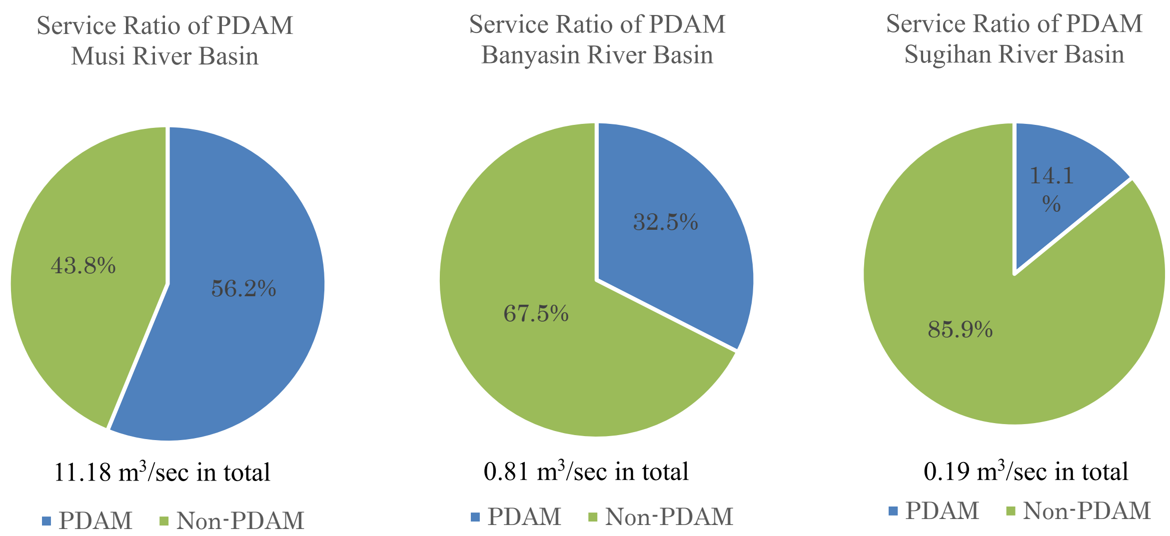
Generally, public water supply systems in Indonesia are managed by Indonesian Regional Water Utility Company (hereafter; PDAM) of each regency or Kota under the Ministry of Public Works.

1) PDAM and Non-PDAM

PDAMs are supplying water to several fields of residence, commercial, public area and industrial zones. Those customers are receiving water supply service from PDAM based on the contract. While, Non-PDAM means the area where PDAM does not supply water. Water users in the area take raw water directly from water sources such as surface water body or ground, but not taking the water from PDAM's water supply pipes, and use it for drinking, shower, kitchen or bottled water depending on their use application. Therefore, coverage ratio as mentioned in Section F3.1.2 means the total PDAM's customers ratio in each city and regency.

Figure F3.1.1 shows water allocation in 2015 which demarcate supplier in the Musi, Banyasin and Sugihan River basin. Water supply for irrigation, fish pond and flushing and maintenance of river is not considered in this section.

As of 2016, the coverage ratio of PDAM had been around/under 30% in regencies of the study area except Palembang city with 77% in 2015.



Source: JICA Project Team 2

Figure F3.1.1 Service Ratio of PDAM in Musi, Banyuasin and Sugihan River Basin in 2015

2) Purposes of water usage

In PDAM and Non-PDAM area, purposes of water usages are classified into a) domestic water, b) non-domestic water, and c) industrial water as summarized below:

a)	Domestic water	:	Water consumption of life activities; bath, kitchen, cleaning and restroom in residential area
b)	Non-domestic water	:	Water consumption for commercial, governmental and public activities; Shopping malls, restaurants, hotels, sports centers, theaters, governmental offices, police and fireguard posts, etc.
c)	Industrial water	:	Water consumption of industrial estates, private factories etc.

3) Source of water

The water source consists of surface water and groundwater in the Musi, Banyasin and Sugihan River basin based on the Statistical information of water (ref: Directori Perpamusi 2016). Although the statistical data of the water resources in Non-PDAM area has not been available subject to the results of the interviews with the related organizations by the JICA Project Team 2, the bottled water for the potable water and the raw water taken from surface water and/or collector of rainfall for cleaning are main resources in the area based on the staffs working in the area. Table F3.1.2, F3.1.3 and F3.1.4 shows the water demand (domestic, non-domestic and industrial water) in 2015.

Table F3.1.2 Water Demand of Musi River Basin in 2015

Province	City/Regency	Domestic Water (m^3/s)	Non-domestic Water (m^3/s)	Industry (m^3/s)	Total (m^3/s)
South Semetra	Banyasin	0.04	0.01	0.0005	0.0505
	Empat Lawang	0.22	0.05	0.0019	0.2719
	Lubbuklinggau	0.42	0.08	0.0014	0.5014
	PagarAlam	0.14	0.03	0.003	0.1730
	Palembang	4.08	0.82	0.0125	4.9125
	Prabumulih	0.10	0.02	0.0029	0.1229
	Lahat	0.37	0.07	0.0031	0.4431
	MuaraEmin	0.52	0.10	0.0010	0.621
	Musi Banyasin	0.21	0.04	0.0054	0.2554
	Musi Rawas	0.37	0.07	0.0008	0.4408
	Musi Rawas Ultra	0.17	0.03	0.0004	0.2004
	Ogan Ilir	0.47	0.09	0.0035	0.5635
	Ogan Komering Ilir	0.07	0.01	0.0011	0.0811
	Ogan Komering Ulu	0.49	0.10	0.0078	0.5978
	Ogan Komering Ulu Selatan	0.34	0.07	0.0002	0.4102
	Ogan Komering Ulu Timur	0.63	0.13	0.0002	0.7602
	Panukul Abab Lematang Ilir	0.15	0.03	0.0003	0.1803
Bengkulu	Rejang Rebong	0.03	0.06	0.0037	0.0937
	Kapahian	0.01	0.04	0.0012	0.0512
Jambi	Salorangun	0.004	0.0008	0.0001	0.0049
	Batanghari	0.002	0.0005	0[*1]	0.0025
Total		8.836	1.8513	0.0556	10.738

Note[*1] : Neglected due to two digits under the others

Source : JICA Project Team 2

Table F3.1.3 Water Demand of Banyasin River Basin in 2015

Province	City/Regency	Domestic Water (m^3/s)	Non-domestic Water (m^3/s)	Industry (m^3/s)	Total (m^3/s)
South Semetra	Banyasin	0.3228	0.0646	0.0041	0.3915
	Musi Banyasin	0.2335	0.0467	0.0060	0.2862
Jambi	Salorangun	0.0002	0[*1]	0[*1]	0.0002
	Batanghari	0.0424	0.0085	0.0004	0.0513
	Mauro Jambi	0.0735	0.0147	0.0006	0.0888
Total		0.6723	0.1345	0.0111	0.818

Note[*1] : Neglected due to two digits under the others

Source : JICA Project Team 2

Table F3.1.4 Water Demand of Sugihan River Basin in 2015

Province	City/Regency	Domestic Water (m^3/s)	Non-domestic Water (m^3/s)	Industry (m^3/s)	Total (m^3/s)
South Semetra	Banyasin	0.0856	0.0171	0.0011	0.1038
	Ogan Komering Ilir	0.0694	0.0139	0.0011	0.0844
Total		0.1550	0.0310	0.0022	0.188

Note[*1] : Neglected due to two digits under the others

Source : JICA Project Team 2

4) Existing Water Supply Treatment Plant (PDAM)

Existing water supply treatment plants in the Musi, Banyasin and Sugihan River basins are listed as shown in Table F3.1.5 which was collected from PDAM in each city and regency.

Table F3.1.5 Existing Water Supply Treatment Plants in Musi, Banyasin and Sugihan River Basins

No.	City/Regency	Name of WTP	Source	Capacity (liter/sec)	Status
1	Banyasin	Unit Pangkalan Balai1	Musi river	20	
		Unit Pangkalan Balai2	Musi river	60	
		Unit Sembawa	Musi river	30	
		Unit Betung	Musi river	20	
		Unit Talang Kelapa	Musi river	50	
		Unit Air Batu	Musi river	5	not in operation
		Sungai Pinang	Musi river	20	
		Unit Tanjung Kerang	Musi river	10	
		Unit Mariana	Musi river	15	
		Unit Sungai Rebo	Musi river	10	not in operation
		Unit Sri Mulyo	Musi river	5	
2	Empat Lawang	Cabang Tebing Tinggi	Seguring river	50	
		Unit Muara Pinang1	Air Lintang river	20	not in operation
		Unit Muara Pinang2	Spring	20	not in operation
		Unit Pendopo	Air Deras river	5	not in operation
		Unit Padang Tepong	Musi river	10	
		Unit Pasemah Air Keruh	Air Deras river	10	
		Unit Talang Padang	Selepah river	10	
3	Lubuklinggau	Unit Mata Air apur	Kelingi river	40	
		IPA1	Kelingi river	80	
		IPA2	Kelingi river	40	
		IPA3	Kelingi river	80	
		Unit Taba Lestari	Well	10	
		Unit Taba Rejo	Well	10	
		Unit Lubuk Kupang	Kelingi river	10	
		Unit Petanang	Musi river	20	
		Unit Simpang Periuk	N/A	10	
4	Pagar Alam	IPA Simpang Petani	Suban river	20	
		IPA Gunung Dempo	Spring	10	
		IPA Pagar Wangi	Spring	20	
		IPA Gunung Agung Lama	Spring	10	
		IPA Gunung Jare	Spring	10	
5	Palembang	Sakarame IPA1	Musi river	50	
		Sakarame IPA2	Musi river	10	
		Sakarame IPA3	Musi river	20	
		Sakarame IPA4	Musi river	50	
		Sebrang Ulu I	Ogan river	80	
		Unit 3 Ilir	Musi river	1,130	
		Unit Rambutan	Musi river	1,020	
		Unit Polygon	Musi river	30	
		Unit Borang	Musi river	190	
		Unit Ogan	Ogan river	600	
		Unit Karang Anyar	Musi river	600	
6	Prabumulih	Unit Prabumulih 1,2 and 3	Lematang river	60	
7	Lahat	Unit Lahat1 (Benteng)	Lematang river	20	
		Unit Lahat2 (Gunung Gajah)	Lematang river	30	
		Unit Lahat3 (Karang Baru)	Lematang river	50	
		Unit IKK Kota Agung	Spring	5	
		Unit IKK Bunga Mas	Kikim river	10	
		Unit IKK Jarai	Spring	10	
8	MuaraEmin	Talang Jawa	Lematang river	60	
		Pelita Sari	Enim river	50	
		Gunung Megang	Lengi river	10	
		Unit Ujan Mas	Lematang river	10	
		Tanjung Raman	Lematang river	5	
		Unit Beringin	Beringin river	10	
		Unit Gelumbang	Well	5	
		Unit Tebat Agung	Niru river	10	
		Unit Tanjung Enim	Enim river	40	

		Unit Karang Asam	Enim river	40	
		Unit Tanjung Agung	Enim river	10	
		Unit Bedegung	Bedegung	10	
		Unit Pulau Panggung	Spring	5	
		Unit Teluk Lubuk	Lematang river	60	
		Unit Air Hitam	Well	10	
		Unit Simpang Babat	Well	10	
		Unit Tempirai	Well	10	
		Unit Penukal Utara	Mesat river	30	
		Unit Arisan Musi	Musi river	20	
		Unit Benakat	Musi river	10	
		Unit Tanah Abang	Lematang river	10	
		Unit Sungai Rotan	Sukarami	60	
		Unit Benakat	Lematang river	10	
		Unit Sekayu	Musi river	75	
		Unit Kayuara	Musi river	35	
		Unit Lumpatan	Musi river	15	
		Unit Muara Teladan	Musi river	5	
		Unit Sakarami	Musi river	20	
		Unit Baliangu	Musi river	10	
		Unit Babat Toman	Musi river	17.5	
		Unit Mangunjaya	Musi river	5	
		Unit Cabang Ngulak	Musi river	20	
		Unit Air Balui	Musi river	5	
		Unit Keban I	Musi river	5	
		Unit Keban II	Musi river	20	
		Unit Pengage	Musi river	5	
		Unit Bayung Lencir	Lanan river	40	
		Unit Sungai Lilin	Dawas river	40	
		Cabang Keluang	Batang Hari Leko river	40	
		Cbang Tanah Abang	Batang Hari Leko river	10	
		Unit Pinggap-Pengaturan	Batang hari Leko river	5	
		Unit Cabang Lais	Musi river	10	
		Unit Teluk Kijing	Musi river	5	
		Unit Petaling	Musi river	10	
		Unit Tanjung Agung Barat	Musi river	10	
		Cabang Tebing Bulang	Tebing Bulang river	20	
		Unit Jirak	Tebing Bulang river	5	
		Unit Sinar Jaya	Musi river	5	
		Unit Cabang Bandar Agung	Tebing Bulang	10	
		Cabang Sido Rahayu	Batang Hari Leko river	5	
		Unit Air Putih Ulu	Batang Hari Leko river	5	
		Unit Bukit Indah	Batang Hari Leko river	5	
		Unit Warga Mulya	Batang Hari Leko river	5	
		Unit Talang Tinggi	Tungkal river	20	
		Unit Ulak Paceh Jaya	Musi river	30	
		Unit Peninggalan	Tungkal river	10	
10	Musi Rawas	Muara Beliti	Beliti	60	
		Jaya Loka	Well	5	
		Giri Yaso II	Well	5	
		Magang Sakti	Magang river	5	
		Muara Rupit	Rapit river	10	
		Tugu Mulyo I	Megang river	5	
		Tugu Mulyo II	Megang river	20	
		Muara Lakitan	Musi river	20	

		Binging Teluk	Rawas river	10	
		Muara Kelingi	Musi river	10	
		Suka Karya	Gregas river	N/A	not in operation
		Purwodadi	Musi river	N/A	not in operation
		Karang Dapo	Rawa river	10	
		Tarawas	Lakitan	20	
		Karang Jaya	Rupit river	20	
		Simpang Semambang	Musi river	10	
		Surulangun	Rawas river	20	
12	Ogan Ilir	Indralaya Utara	Ogan and Kelekar river	40	
		Tanjung Sejaro	Kelekar	5	
		Tanjung Raja	Ogan river	10	
		Unit Sungai Pinang 1 and 2	Ogan river	40	
		Meranjat	Well	10	
		Unit Tanjung Batu	Well	7.5	
		Unit Desa Sri Tanjung	Well	10	
		Payamaran	Well	7.5	
		Lubuk Keliat	Well	10	
		IKK Rantau Panjang	Ogan river	20	
		IKK Rantau Alai	Ogan river	10	
13	Ogan Komering Ilir	Unit Kayu Agung1	Well	10	
		Unit Kayu Agung2	Teloko lake	40	
		Unit Pedamaran	Komering river	5	not in operation
		Unit Serinanti	Komering river	10	
		Unit Pampangan	Well	5	
		Unit Pangarayan	Well	5	
		Unit Mesuji	Dalam river	5	
		Sirah Pulau Padang	Komering river	10	
		Tulung Selapan	Well	5	
		Tanjung Lubuk	Well	5	
		Lmpuing	Well	5	
		Jejawi	Komering	10	
14	Ogan Komering Ulu	Unit Parkotaan Baturaja	Ogan river	60	
		Unit Perkotaan Tanjung Baru	Ogan river	30	
		Unit Perkotaan Tanjung Agung	Ogan river	35	
		Unit Perkotaan Bakung	Ogan river	35	
		Unit IKK Penyandingan	Saka river	5	
		Unit IKK Tanjung Lengkayap	Lengkayap river	5	
		Unit IKK Lubuk Batang	Ogan river	5	
15	Ogan Koemring Ulu Selatan	Unit Muara Dua	Saka Selabung river	30	
		Unit Simpang	Tara river	5	
		Unit Banding Agung	Ranau Lake	30	
		Unit Sipatuhu	Way Hijau river	20	
		Unit Simpang Sender	Spring	10	
		Unit Pulau Beringin	Spring	5	
		Unit Kota Batu	Ranau lake	10	
		Muara Dua Kisam	Air Keni river	5	
		Blambangan Kec. Buay Runjung	Way Sulam river	5	
16	Ogan Koemring Ulu Timur	Pusat Martapura	Komering river	10	
		Unit Gumawang	Over Komering river	30	
		Unit Cempaka	Sungai Komering	10	
		Unit Nusa Bakti	Well	7.3	
21	Kepahian	N/A	N/A	N/A	N/A
22	Rejang Rebopng	N/A	N/A	N/A	N/A
31	Salorangun	N/A	N/A	N/A	N/A
32	Batanghari	N/A	N/A	N/A	N/A
33	Mauro Jambi	N/A	N/A	N/A	N/A

Source: Monitoring drinking water supply system 2012 (PDAM of each city/regency)

F3.1.2 Master Plan and Methodology

(1) Existing Master Plan for POLA 2014 and RENCANA 2017

1) Outline

The POLA 2014 is the latest and authorized master plan of the water - resource management for the Musi, Sugihan, Banyasin and Lemau river basin. The area of this study is one portion of the areas covered by the master plan. RENCANA 2017 explained also the future demand projection of domestic, industry and public, however it was clarified through the JICA Study that some areas which are located outside of the Musi, Banyasin and Sugihan River basins were included in the target area for the demand projection in RENCANA 2017, and that the population projection method in RENCANA 2017 was not necessarily conforming to the population data of BPS. Therefore, the demand projection in JICA Study was based on the available statistic data required for the demand projection as much as possible shown in the following sections. The categories to the flushing/maintenance river and plantation water demand are not covered in this section as mentioned in the item (1) of section F3.1.1.

2) Demand projection of water supply

The POLA 2014 presented the comprehensive projection about whole area mentioned in item (1) 1) of the section F3.1.2. Thus, the results of the projection do not present the breakdown of the result about the water supply and it will be comprehensively shown in the study of the water balance including the demand projection of the water supply.

3) Targets of the water - resource management

The POLA has the targets for each area including water supply. The JICA Project Team 2 has reviewed its achievement within the period of the master plan require the huge amount of the budget and manpower after comparing the targets with the present progress mentioned in the following sections. The targets of water supply for the area of the development plan and swamp areas will require another study in the area on the master plan of the water supply and its feasibility. The targets of water supply in POLA 2014 are presented in Table F3.1.6.

Table F3.1.6 Targets of Water Supply in POLA 2014

Item of Target		Figure of Target		
		Until 2017	Until 2022	Until 2032
Achievement of Water Supply Service (%) (Please see the item (1) of Section F3.1.2)	Household (Domestic use)	70	80	100
	Public (Non- Domestic use)	65	85	100
	Industry	65	85	100
	Irrigation	50	70	100
Maintaining the raw water for water supply (%)		50	75	100
Water Supply for the Development area of Tanjung Api-Api port, Jakabaring Sports City and Kota Terpadu Mandiri (%)		35	70	100
Potable Water Supply for Swamp Area (%)		35	70	100
Monitoring and Evaluation of Water Supply Services (%)	Household (Domestic use)	60	70	100
	Public (Non- Domestic use)	50	65	100
	Industry	40	70	100
Construction of Reservoirs to meet the Water Demand (m^3)		95 million	125 million	452 million

Source: POLA 2014

(2) Methodology of water projection for water supply in this study

1) Outline of the methodology for the water demand projection

Basis for the demand forecast is set at the condition in 2015 as a current water supply demand in the Musi, Banyasin and Sugihan River basin as shown in Table F3.1.7 and F3.1.8.

Table F3.1.7 Basic Condition for Demand Forecast until 2015

Organization		PDAM		Non-PDAM	
Water Source[*1]		Surface	Ground	Surface	Ground or Collecting Rain Water
Purpose to Use	Domestic	- Population (Census Data), - Unit Water Consumption[*2], - Coverage[*3], - NRW[*3]		- Lpcd =(Lpcd(PDAM)+30[*5])/2 - Area which is not supplied by PDAM. (100%-PDAM area) - NRW=0%	
	Non-Domestic[*4]	20% of Domestic		20% of Domestic	
	Industrial	26 l/capita/day based on the criteria of Cipta Karya 1998 Provincial statistical data of workers (Dalam Angka 2017)		26 l/capita/day based on the criteria of Cipta Karya 1998 Provincial statistical data of workers (Dalam Angka 2017)	

Note*1: Ratio of Surface/Ground is referred to the actual consumption (ref: DirektoriPerpamsi).

Note*2: Calculated from actual supplied water volume (sell volume) and no. of user (ref: DirektoriPerpamsi) until 2016.

Note*3: All numbers are referred from DirektoriPerpamsi. Coverage is calculated at population ratio which is supplied by PDAM.

Note*4: Water for public facility is calculated by 10-15% of domestic water demand according to the criteria of Directorate General of Human Settlement, Ministry of Public Work 1996. 20% of domestic water is estimated taking into consideration commercial use about 5-10%.

Note*5: 30 litter is average unit consumption for residents in agricultural area which is stipulated as the public tap in the criteria of Directorate General of Human Settlement, Ministry of Public Work 1996.

Source: JICA Project Team 2

Table F3.1.8 Basic Condition for Demand Forecast until 2050

Organization		PDAM		Non-PDAM	
Water Source		Surface	Ground	Surface	Ground
Purpose to Use	Domestic	1)Pop. growth, 2)Future lpcd[*1], 3)Coverage[*2], 4)NRW[*3]	Increase until available ground water potential by 2030 and fixed the maximum demand from 2030 to 2050.	Increase until maximum of rural area (80) by 2030 and fixed the maximum demand from 2030 to 2050.	
	Non-Domestic	20% of Domestic	Fixed as 2015	Fixed as 2015	
	Industrial	development (population) growth ratio for the data in 2015			

Note*1: Per capita in 2050; 200 lpcd for Surabaya, 150 lpcd, 120 lpcd for others (Ref. Criteria of CiptaKarya)

Note*2: Objectives will be set based on the status of each regency in 2016 with50%, 75% and 100%of 2050 in Musi river basin

Note*3: By 2050 gradually reduce NRW to 20%-25% depend on the current NRW in 2016

Source: JICA Project Team 2

F3.1.3 Assumption of Water Demand Projection

(1) Coverage Ratio of Water Supply Services

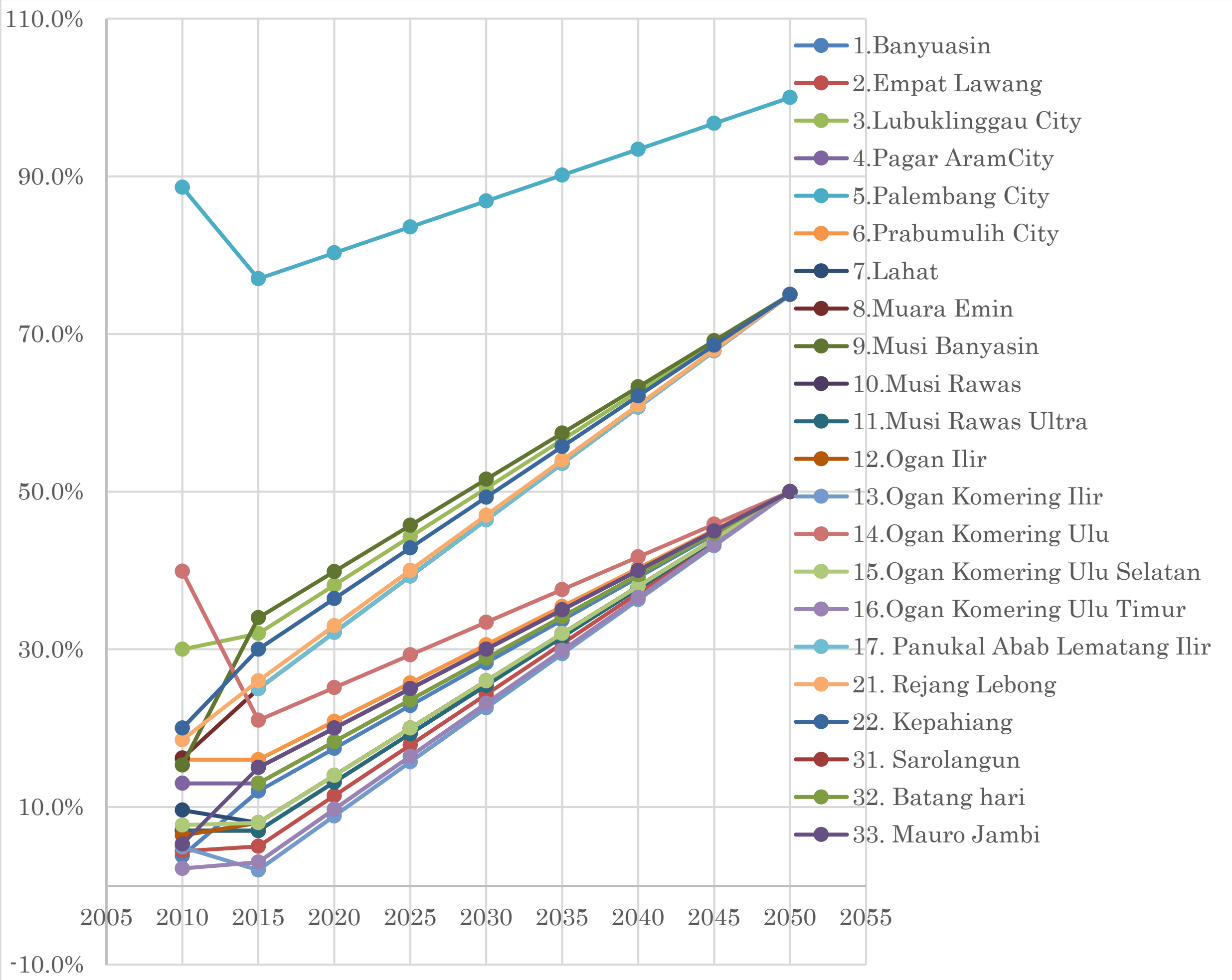
According to the existing record of coverage ratio, the JICA Project Team 2 set three (3) targets with 100%, 75%, and 50%, taking into consideration the current coverage ratio of each city or regency as presented in the Direktori Perpamusi 2010 and 2016.

The coverage ratio of each city or regency is shown in Table F3.1.9 and Figure F3.1.2. Each coverage ratio in city or regency will be gradually increased to each target level until 2050. Although the coverage ratio has been projected to achieve 100% until 2033 in POLA 2014, the JICA Project Team 2 has projected the coverage ratio to adjust it the three categories of 50, 75 and 100%, because coverage ratios are not high as shown in 2010 and 2015 of the Table F3.1.9.

Table F3.1.9 Coverage Ratio of Each City or Regency

Province	Regency/City	Coverage Ratio of Service by PDAM (%)								
		2010*1	2015*1	2020	2025	2030	2035	2040	2045	2050
South Sematra	1. Banyuasin	3.8	12	17.4	22.9	28.3	33.7	39.1	44.6	50
	2. Empat Lawang	4.4	5	11.4	17.9	24.3	30.7	37.1	43.6	50
	3. Lubuklinggau	30.0	32	38.1	44.3	50.4	56.6	62.7	68.9	75
	4. Pagar Aram	13.0	13	18.3	23.6	28.9	34.1	39.4	44.7	50
	5. Palembang	88.6	77	80.3	83.6	86.9	90.1	93.4	96.7	100
	6. Prabumulih	16.0	16	20.9	25.7	30.6	35.4	40.3	45.1	50
	7. Lahat	9.6	8	14.0	20.0	26.0	32.0	38.0	44.0	50
	8. Muara Emin	16.2	25	32.1	39.3	46.4	53.6	60.7	67.9	75
	9. Musi Banyasin	15.3	34	39.9	45.7	51.6	57.4	63.3	69.1	75
	10. Musi Rawas	7.0*2	7	13.1	19.3	25.4	31.6	37.7	43.9	50
	11. Musi Rawas Ultra	7.0*2	7	13.1	19.3	25.4	31.6	37.7	43.9	50
	12. Ogan Ilir	6.4	8	14.0	20.0	26.0	32.0	38.0	44.0	50
	13. Ogan Komering Ilir	4.9	2	8.9	15.7	22.6	29.4	36.3	43.1	50
	14. Ogan Komering Ulu	39.9	21	25.1	29.3	33.4	37.6	41.7	45.9	50
	15. Ogan Komering Ulu Selatan	7.7	8	14.0	20.0	26.0	32.0	38.0	44.0	50
	16. Ogan Komering Ulu Timur	2.2	3	9.7	16.4	23.1	29.9	36.6	43.3	50
	17. Panukal Abab Lematang Ilir	16.2	25	32.1	39.3	46.4	53.6	60.7	67.9	75
Bengkulu	21. Rejang Lebong	18.5	26	33.0	40.0	47.0	54.0	61.0	68.0	75
	22. Kepahiang	20.0	30	36.4	42.9	49.3	55.7	62.1	68.6	75
Jambi	31. Sarolangun	13.0	15	20.0	25.0	30.0	35.0	40.0	45.0	50
	32. Batang hari	8.6	13	18.3	23.6	28.9	34.1	39.4	44.7	50
	33. Mauro Jambi	5.3	15	20.0	25.0	30.0	35.0	40.0	45.0	50

Note*1: Datum in 2010 and 2015 based on the Directori Perupamusi 2010 and 2016
*2: Data of Musi Rawas and Musi Rawas Ultra in 2010 utilized the figure of 2015 due to the lack of data.
Source Directri Perupamsi and JICA Project Team 2



Source: JICA Project 2

Figure F3.1.2 Projection of Coverage Ratio by PDAM until 2050

(2) Unit Water Consumption

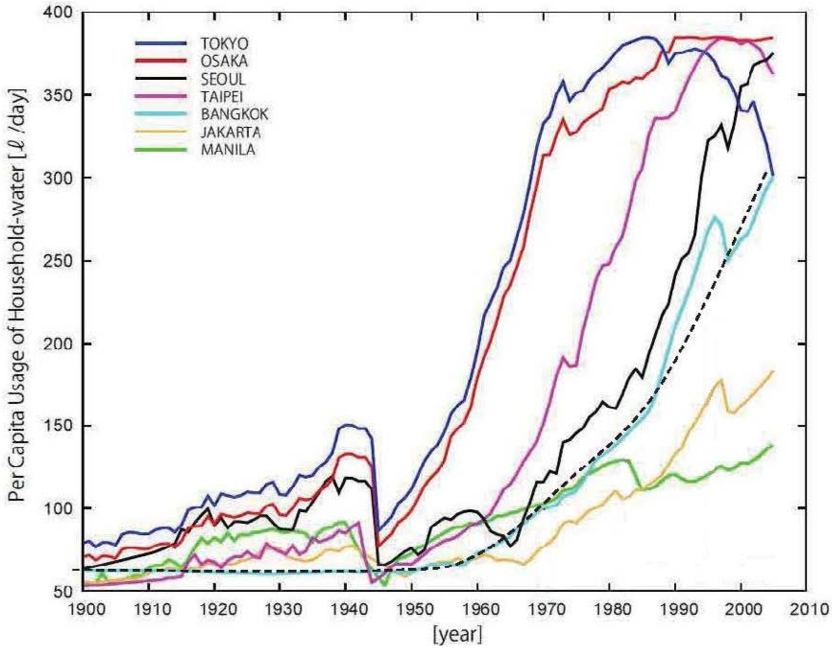
According to the criteria issued by Cipta Karya, unit water consumption is defined based on the scale of the city which expresses as the number of populations as shown in Table F3.1.6. Unit water consumptions for each city and regency are defined 120 or 150 litter per capita per day (lpcd). As for the Palembang city is necessary to pay special attention since it is the second city in Semetra Island. Unit water consumption of Palembang city is applied for 200 lpcd until 2025 which is used by PDAM Surabaya for their forecast. After 2025, unit water consumption is defined by Team 2 to increase gradually to 200 lpcd until 2050. Unit water consumption for the demand forecast until 2050 is shown in Table F3.1.10.

Table F3.1.10 Standard Unit Water Consumption in Indonesia

Descriptions	Categorization of City by Number of Population (in person)				
	> 1 mill.	500 thous.-1 mill.	100 thous.-500 thous.	20 thous.-100 thous.	< 20 thous.
	Metropolitan city	Big city	Medium city	Small city	Rural
Domestic water consumption (lt./pers./d)	>150	120-150	90-120	80-120	60-80

Source: Criteria of Directorate General of Human Settlement, Ministry of Public Work 1996

As a past trend of unit water consumption at large scale city around eastern side of Asia, increasing trend are shown in Figure F3.1.3. There is a possibility for unit water consumption to increase drastically at cities in the Musi, Banyasin and Sugihan River basin, however, it is set as not so high considering introduction of water management such as water saving campaigns, recycling water usage and so on. Referring to unit water consumptions in Bangkok and Jakarta, it believes that applied 200 liters for Surabaya, and 120 and 150 litters for other cities in 2050 are reasonable volume of unit water consumption.



Source: Research Institute for Human and Nature, Japan

Figure F3.1.3 Unit Water Consumption in Asia

(3) Non-Revenue Water (NRW) ratio

Reduction of non-revenue water (NRW) has two target grades of 30%, 25%, 20% and the current ratio under 20% depend on the current NRW ratio of each city or regency in 2015. It is generally known that the NRW ratio can be reduced easily until 30% by means of the systematic way of replacing pipes based on the leakage survey, and control and monitoring water consumption volume by water meter. In the river basins, certain coverage ratios of the water supply have been under 30% as of 2015. The development of the water supply services, especially the development of the pipeline network, is under the risk of increasing the NRW. The JICA Project Team 2 also considered.

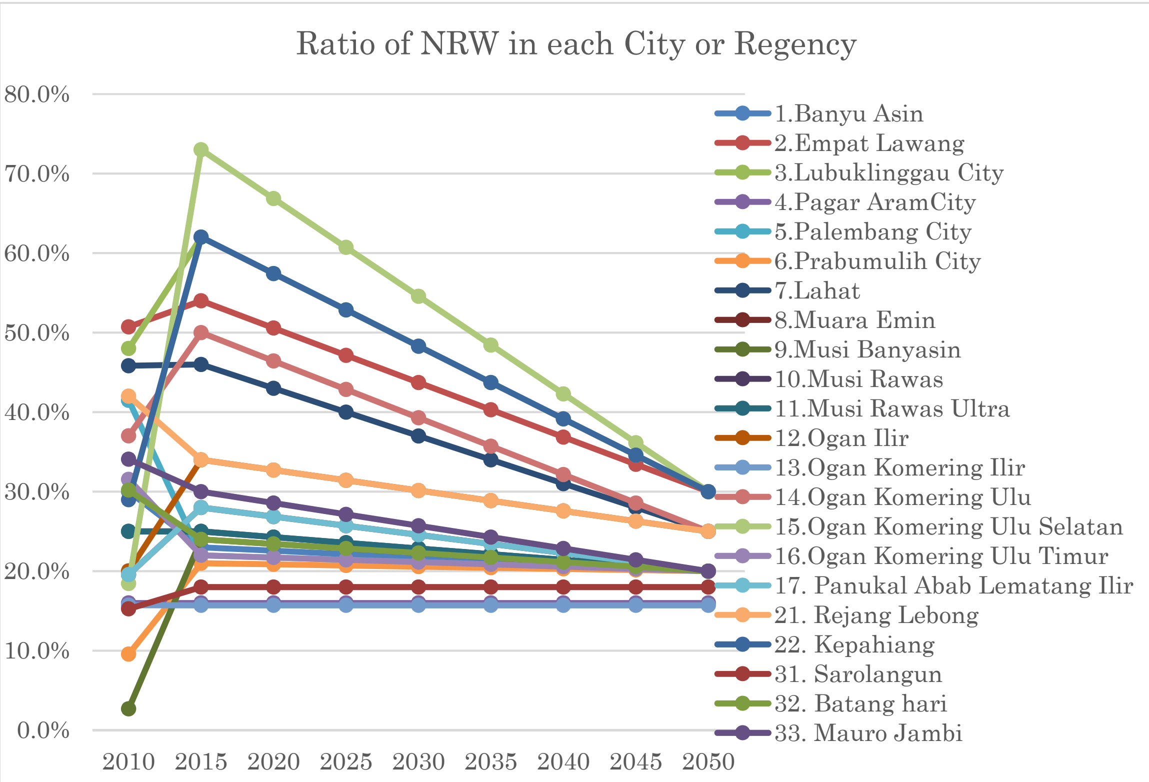
The NRW of each city or regency until 2050 is presented in Table F3.1.11 and Figure F3.1.4.

Table F3.1.11 NRW of Each City or Regency until 2050

Province	Regency/City	NRW (%)								
		2010	2015	2020	2025	2030	2035	2040	2045	2050
1. South Sematra	1. Banyu Asin	30.0	23.0	22.6	22.1	21.7	21.3	20.9	20.4	20
	2. Empat Lawang	50.7	54.0	50.6	47.1	43.7	40.3	36.9	33.4	30
	3. Lubuklinggau	48.0	62.0	57.4	52.9	48.3	43.7	39.1	34.6	30
	4. Pagar Aram City	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16
	5. Palembang City	41.5	22.0	21.7	21.4	21.1	20.9	20.6	20.3	20

Province	Regency/City	NRW (%)								
		2010	2015	2020	2025	2030	2035	2040	2045	2050
	6. Prabumulih City	9.6	21.0	20.9	20.7	20.6	20.4	20.3	20.1	20
	7. Lahat	45.8	46.0	43.0	40.0	37.0	34.0	31.0	28.0	25
	8. Muara Emin	19.6	28.0	26.9	25.7	24.6	23.4	22.3	21.1	20
	9. Musi Banyasin	2.7	24.0	23.4	22.9	22.3	21.7	21.1	20.6	20
	10. Musi Rawas	25.0	25.0	24.3	23.6	22.9	22.1	21.4	20.7	20
	11. Musi Rawas Ultra	25.0	25.0	24.3	23.6	22.9	22.1	21.4	20.7	20
	12. Ogan Ilir	20.0	34.0	32.7	31.4	30.1	28.9	27.6	26.3	25
	13. Ogan Komering Ilir	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	16
	14. Ogan Komering Ulu	37.0	50.0	46.4	42.9	39.3	35.7	32.1	28.6	25
	15. Ogan Komering Ulu Selatan	18.5	73.0	66.9	60.7	54.6	48.4	42.3	36.1	30
	16. Ogan Komering Ulu Timur	31.5	22.0	21.7	21.4	21.1	20.9	20.6	20.3	20
	17. Panukal Abab Lematang Ilir	19.6	28.0	26.9	25.7	24.6	23.4	22.3	21.1	20
2. Bengkulu	21. Rejang Lebong	42.0	34.0	32.7	31.4	30.1	28.9	27.6	26.3	25
	22. Kepahiang	29.0	62.0	57.4	52.9	48.3	43.7	39.1	34.6	30
3. Jambi	31. Sarolangun	15.3	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18
	32. Batang hari	30.2	24.0	23.4	22.9	22.3	21.7	21.1	20.6	20
	33. Mauro Jambi	34.1	30.0	28.6	27.1	25.7	24.3	22.9	21.4	20

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure F3.1.4 NRW until 2050

(4) Groundwater

Ground Water is projected by the ratio of water resource on the basis of the data mentioned in Direktori Perpamsi 2016 throughout the period of the projection (2010-2050). The utilized ratio of the surface water and ground water for the water-demand projection is presented in Table F3.1.12.

Table F3.1.12 Ratio of Surface and Ground Water

Regency/City	Water resource of Water Supply (liter/sec)				Ratio of Ground Water (%)
	River	Spring	Lake	Deep well	
1. Banyu Asin	370				0
2. Empat Lawang	100				0
3. Lubuklinggau	185				0
4. Pagar Aram	110				0
5. Palembang	3,763				0
6. Prabumulih City	250				0
7. Lahat	161				0
8. Muara Emin	828	20		20	0.023
9. Musi Banyasin	1,080		115		0
10. Musi Rawas	10		1	3	0.214
11. Musi Rawas Ultra	*1	*1	*1	*1	0.214
12. Ogan Ilir	230				0
13. Ogan Komering Ilir	N/A	N/A	N/A	N/A	0*2
14. Ogan Komering Ulu	234				0
15. Ogan Komering Ulu Selatan	228				0
16. Ogan Komering Ulu Timur	75			10	0.118
17. Panukal Abab Lematang Ilir	*1	*1	*1	*1	0.023
21. Rejang Lebong	56	86			0
22. Kepahiang	N/A	N/A	N/A	N/A	0*2
31. Sarolangun	213			20	0.086
32. Batang hari	165			5	0.029
33. Mauro Jambi	320	56	50		0

Note *1: The regencies mentioned in Clause F3.1.1 utilized the same ratio of the same regency before the separation.
*2: In case, the data for preparing the ratio is not available, the ratio is set zero considering the higher risk of the water shortage on the water balance of the river basins.
Source: Direktori Perpamsi 2017 and JICA Project Team 2

F3.1.4 Projected Population

(1) Population Projection in Review POLA 2014

Population is simply projected in Review POLA 2014 by the formula which can be calculated by the factors such as growth ratio and years with the basis of the population in 2012. This projection therefore does not reflect the long term population growth in South Semetra, Jambi and Bengkulu province formulated by BPS and urbanization factor for each city and regency is not taken into consideration.

On the other hand, Team 2 estimated taking into consideration urbanization factor which

BPS estimated the urbanization ratio of South Semetra, Jambi and Bengkulu province in 2035 at 40.1%, 38.2% and 35.6% in Census 2010 of Indonesia, respectively. From the view point to express the different growth ratio for urban and rural area in each city or regency, it can be evaluated that the method of Team 2 will be more realistic.

(2) Population Projection in the Project

There is no projected population data until 2050. BPS has projected to each province from 2010 to 2035. Projection of population growth until 2050 is prepared with the following basis;

1) Basis of the data for the projection; is Census 2010 of Indonesia by BPS and is complemented by the data of Provinsi Dalam Angka 2017 issued by the branch office of BPS in each province.
2) The projection of population is carried out for each city/regency. Until 2035, the population of the regency and city is calculated to utilize the grow ratio of each province based on Census 2010.
3) After 2035, the JICA Project Team 2 expands the growth ratios with the linear formula of the increment ratio about the growth ratio. In case, the growth ratio is projected under zero between 2035 and 2050, the growth ratio for the projection keeps with zero.
4) As the projection is for the water demand projection and is separately carried out in accordance with the urban/rural areas. The urban and rural population for each city/regency are projected by the data of urban/rural population of Census 2010 until 2035 and the expanded data by the urbanized ratio projected by JICA Project Team 2 in accordance with the same method of the growth ratio.
5) As explained in Section F3.1.1, all datum of the population are adjusted by the ratio with the area of the basin divided by the administrative area of each city/regency.

Table F3.1.13 Growth Ratio of Population and Urbanized Ratio for each Province

No	Province	Item	2010	2015	2020	2025	2030	2035	2040	2045	2050
1.	South Semetra	Population (1,000 persons)	7,481	8,052	8,568	9,000	9,345	9,611	9,783	9,848	9,848
		Yearly Growth Ratio (%)	-	1.4	1.15	0.89	0.67	0.49	0.27	0.04	0
		Urbanized Ratio (%)	35.9	36.7	37.6	38.4	39.3	40.1	40.8	41.1	41.1
2.	Jambi	Population (1,000 persons)	3,108	3,402	3,678	3,927	4,142	4,323	4,460	4,545	4,577
		Yearly Growth Ratio (%)	-	1.73	1.47	1.21	0.98	0.77	0.53	0.29	0.04
		Urbanized Ratio (%)	30.7	32.6	34.4	36.3	38.2	38.2	39.4	40.2	40.5
3.	Bengkulu	Population (1,000 persons)	1,722	1,875	2,020	2,126	2,264	2,361	2,435	2,486	2,510
		Yearly Growth Ratio (%)	-	1.63	1.41	1.17	0.95	0.76	0.54	0.32	0.11
		Urbanized Ratio (%)	31.0	32.8	34.6	36.4	38.3	35.6	36.7	37.5	37.9

Source: Census 2010 of Indonesia, Provisi Dalam Angka 2017 (Semetra Selatan, Jambi and Bengkulu) and JICA Project Team 2

Table F3.1.14 The Projected Population of Each Regency/City

Regency/City	Category of Population	Population (1,000 persons)								
		2010	2015	2020	2025	2030	2035	2040	2045	2050
1. Banyuasin	Urban	183	201	219	235	250	262	272	276	276
	Rural	569	605	635	658	674	683	687	689	689
	Total	752	806	854	893	924	945	959	965	965
2. Empat Lawang	Urban	16	17	19	20	21	22	23	23	23
	Rural	206	219	230	238	244	247	249	249	249
	Total	222	236	249	258	265	269	272	272	272
3. Lubuklinggau	Urban	160	176	192	206	219	230	238	242	242
	Rural	43	45	48	49	51	51	52	52	52
	Total	203	221	240	255	270	281	290	294	294
4. Pagar Aram	Urban	78	86	93	100	106	112	116	117	117
	Rural	49	52	54	56	58	58	59	59	59
	Total	127	138	147	156	164	170	175	176	176
5. Palembang	Urban	1,453	1,601	1,743	1,872	1,987	2,087	2,162	2,191	2,191
	Rural	15	16	16	17	17	18	18	18	18
	Total	1,468	1,617	1,759	1,889	2,004	2,105	2,180	2,209	2,209
6. Prabumulih	Urban	122	135	147	158	167	176	182	184	184
	Rural	41	44	46	48	49	49	50	50	50
	Total	163	179	193	206	216	225	232	234	234
7. Lahat	Urban	93	103	112	120	128	134	139	141	141
	Rural	277	295	309	320	328	333	335	335	335
	Total	370	398	421	440	456	467	474	476	476
8. Muara Emin	Urban	109	120	131	140	149	156	162	164	164
	Rural	444	471	495	513	525	533	536	537	537
	Total	553	591	626	653	674	689	698	701	701
9. Musi Banyasin	Urban	70	77	84	90	95	100	104	105	105
	Rural	493	524	550	570	584	592	595	596	596
	Total	563	601	634	660	679	692	699	701	701
10. Musi Rawas	Urban	12	13	15	16	17	17	18	18	18
	Rural	345	366	385	399	408	414	416	417	417
	Total	357	379	400	415	425	431	434	435	435
11. Musi Rawas Ultra	Urban	6	6	7	7	8	8	9	9	9
	Rural	164	174	183	190	194	197	198	198	198
	Total	170	180	190	197	202	205	207	207	207
12. Ogan Ilir	Urban	78	85	93	100	106	111	115	117	117
	Rural	304	323	339	352	360	365	367	368	368
	Total	382	408	432	452	466	476	482	485	485
13. Ogan Komering Ilir	Urban	64	71	77	83	88	92	96	97	97
	Rural	665	707	742	769	787	798	803	804	804
	Total	729	778	819	852	875	890	899	901	901
14. Ogan Komering Ulu	Urban	125	138	150	161	171	180	186	189	189
	Rural	200	212	223	231	236	240	241	242	242
	Total	325	350	373	392	407	420	427	431	431
15. Ogan Komering Ulu Selatan	Urban	27	29	32	34	36	38	39	40	40
	Rural	293	311	327	338	347	351	353	354	354
	Total	320	340	358	372	383	390	392	394	394
16. Ogan Komering Ulu Timur	Urban	56	61	67	72	76	80	83	84	84
	Rural	556	590	620	642	658	667	671	672	672
	Total	612	651	687	714	734	747	754	756	756
17. Panukal Abab Lematang Ilir	Urban	33	36	39	42	45	47	49	49	49
	Rural	133	142	149	154	158	160	161	161	161
	Total	166	178	188	196	203	207	210	210	210
21. Rejang Lebong	Urban	96	111	126	142	157	152	162	168	172
	Rural	151	160	168	174	178	194	196	198	199
	Total	247	271	294	316	335	346	358	366	370

22. Kepahiang	Urban	31	36	41	46	51	49	52	54	55
	Rural	94	100	105	108	111	121	122	123	124
	Total	125	136	146	154	162	170	174	177	179
31. Sarolangun	Urban	29	34	39	44	48	51	54	56	57
	Rural	217	232	244	253	259	271	274	276	276
	Total	246	266	383	297	307	322	328	332	333
32. Batang hari	Urban	41	48	54	61	61	71	76	78	80
	Rural	201	215	226	234	234	250	253	254	255
	Total	242	263	280	295	295	321	329	332	335
33. Mauro Jambi	Urban	17	20	23	26	26	30	32	33	33
	Rural	326	349	366	380	380	406	411	413	414
	Total	343	369	389	406	406	436	442	446	448

Source: Census 2010 of Indonesia, Provisi Dalam Angka 2017 (Semetra Selatan, Jambi and Bengkulu) and JICA Project Team 2

F3.1.5 Water Demand Projection

Demand forecast until 2050 by means of the applying factors as described above is summarized in Table F3.1.9. Demand forecasts for each city and regency in 2015, 2025, 2035 and 2050 are shown from Tables F3.1.15 to F3.1.17 for Musi, Banyasin and Sugihan river basin, respectively. Figure F3.1.18 to F3.1.23 present the water demand projection of each regency/city in 2015 and 2050 for Musi, Banyasin and Sugihan river basin. The difference of water demand projection between RENCANA 2017 and the Study is also shown in Figure F3.1.5. This difference in the projected water demand is mainly due to differences in the target areas and projection methods of target population applied for RENCANA 2017 and JICA Study, respectively.

Table F3.1.15 Summary for Water Demand Projection of Musi River Basin until 2050

Year	2015		2025		2035		2050	
Purpose	Surface	Ground	Surface	Ground	Surface	Ground	Surface	Ground
Domestic	9.071	0.205	12.895	0.292	15.152	0.371	18.158	0.480
Non-Domestic	1.816	0.041	2.581	0.058	3.033	0.074	3.634	0.096
Industry	0.048	0.000	0.054	0.000	0.058	0.000	0.059	0.000
Total	10.935	0.246	15.530	0.350	18.243	0.445	21.851	0.576
	11.181		15.880		18.688		22.427	

Source: JICA Project Team 2

Table F3.1.16 Summary for Water Demand Projection of Banyasin River Basin until 2050

Year	2015		2025		2035		2050	
Purpose	Surface	Ground	Surface	Ground	Surface	Ground	Surface	Ground
Domestic	0.671	0.001	0.968	0.002	1.276	0.002	1.732	0.003
Non-Domestic	0.134	0.000	0.194	0.000	0.255	0.000	0.346	0.001
Industry	0.011	0.000	0.012	0.000	0.013	0.000	0.014	0.000
Total	0.816	0.001	1.174	0.002	1.544	0.002	2.092	0.004
	0.817		1.176		1.546		2.096	

Source: JICA Project Team 2

Table F3.1.17 Summary for Water Demand Projection of Sugihan River Basin until 2050

Year	2015		2025		2035		2050	
Purpose	Surface	Ground	Surface	Ground	Surface	Ground	Surface	Ground
Domestic	0.155	0	0.220	0	0.289	0	0.392	0
Non-Domestic	0.031	0	0.044	0	0.058	0	0.078	0
Industry	0.002	0	0.002	0	0.003	0	0.003	0
Total	0.188	0	0.266	0	0.350	0	0.473	0
	0.188		0.266		0.350		0.473	

Source: JICA Project Team 2

Table F3.1.18 Water Demand Projection of Musi River Basin in 2015

City / Regency	Surface Water			Groundwater			Total		
	D+ND	IND	Total	D+ND	IND	Total	D+ND	IND	Total
1. Banyuasin	0.044	0.000	**0.044**	0.000	0.000	**0.000**	**0.044**	**0.000**	**0.044**
2. Empat Lawang	0.263	0.002	**0.265**	0.000	0.000	**0.000**	**0.263**	**0.002**	**0.265**
3. Lubuklinggau	0.498	0.001	**0.499**	0.000	0.000	**0.000**	**0.498**	**0.001**	**0.499**
4. Pagar Aram	0.173	0.000	**0.174**	0.000	0.000	**0.000**	**0.173**	**0.000**	**0.174**
5. Palembang	4.900	0.012	**4.913**	0.000	0.000	**0.000**	**4.900**	**0.012**	**4.913**
6. Prabumulih	0.118	0.003	**0.121**	0.000	0.000	**0.000**	**0.118**	**0.003**	**0.121**
7. Lahat	0.449	0.003	**0.453**	0.000	0.000	**0.000**	**0.449**	**0.003**	**0.453**
8. Muara Emin	0.606	0.001	**0.607**	0.014	0.000	**0.014**	**0.620**	**0.001**	**0.621**
9. Musi Banyasin	0.252	0.005	**0.257**	0.000	0.000	**0.000**	**0.252**	**0.005**	**0.257**
10.Musi Rawas	0.344	0.001	**0.345**	0.094	0.000	**0.094**	**0.438**	**0.001**	**0.439**
11.Musi Rawas Ultra	0.163	0.000	**0.163**	0.044	0.000	**0.044**	**0.207**	**0.000**	**0.208**
12.Ogan Ilir	0.569	0.003	**0.573**	0.000	0.000	**0.000**	**0.569**	**0.003**	**0.573**
13.Ogan Komering Ilir	0.083	0.001	**0.084**	0.000	0.000	**0.000**	**0.083**	**0.001**	**0.084**
14.Ogan Komering Ulu	0.589	0.008	**0.597**	0.000	0.000	**0.000**	**0.589**	**0.008**	**0.597**
15.Ogan Komering Ulu Selatan	0.407	0.000	**0.408**	0.000	0.000	**0.000**	**0.407**	**0.000**	**0.408**
16.Ogan Komering Ulu Timur	0.664	0.000	**0.664**	0.089	0.000	**0.089**	**0.753**	**0.000**	**0.753**
17.Panukal Abab Lematang Ilir	0.181	0.000	**0.181**	0.004	0.000	**0.004**	**0.185**	**0.000**	**0.186**
21.Rejang Rebong	0.335	0.004	**0.339**	0.000	0.000	**0.000**	**0.335**	**0.004**	**0.339**
22.Kepahian	0.241	0.001	**0.243**	0.000	0.000	**0.000**	**0.241**	**0.001**	**0.243**
31.Sarolangun	0.004	0.000	**0.004**	0.000	0.000	**0.000**	**0.005**	**0.000**	**0.005**
32.Batanghari	0.003	0.000	**0.003**	0.000	0.000	**0.000**	**0.003**	**0.000**	**0.003**
33.Mauro Jambi	0.000	0.000	**0.000**	0.000	0.000	**0.000**	**0.000**	**0.000**	**0.000**
Total	10.888	0.048	**10.935**	0.246	0.000	**0.246**	**11.134**	**0.048**	**11.182**

Note: D: Domestic, ND: Non-Domestic, IND: Industry
Source: JICA Project Team 2

Table F3.1.19 Water Demand Projection of Musi River Basin in 2050

City / Regency	Surface Water			Groundwater			Total		
	D+ND	IND	Total	D+ND	IND	Total	D+ND	IND	Total
1. Banyuasin	0.096	0.001	**0.097**	0.000	0.000	**0.000**	**0.096**	**0.001**	**0.097**
2. Empat Lawang	0.651	0.002	**0.653**	0.000	0.000	**0.000**	**0.651**	**0.002**	**0.653**
3. Lubuklinggau	0.754	0.002	**0.756**	0.000	0.000	**0.000**	**0.754**	**0.002**	**0.756**
4. Pagar Aram	0.396	0.000	**0.397**	0.000	0.000	**0.000**	**0.396**	**0.000**	**0.397**
5. Palembang	7.671	0.015	**7.686**	0.000	0.000	**0.000**	**7.671**	**0.015**	**7.686**
6. Prabumulih	0.488	0.004	**0.492**	0.000	0.000	**0.000**	**0.488**	**0.004**	**0.492**
7. Lahat	1.058	0.004	**1.062**	0.000	0.000	**0.000**	**1.058**	**0.004**	**1.062**
8. Muara Emin	1.783	0.001	**1.785**	0.042	0.000	**0.042**	**1.825**	**0.001**	**1.827**
9. Musi Banyasin	0.808	0.007	**0.815**	0.000	0.000	**0.000**	**0.808**	**0.007**	**0.815**
10.Musi Rawas	0.725	0.001	**0.726**	0.197	0.000	**0.198**	**0.922**	**0.001**	**0.923**
11.Musi Rawas Ultra	0.344	0.000	**0.344**	0.094	0.000	**0.094**	**0.438**	**0.000**	**0.438**
12.Ogan Ilir	1.335	0.004	**1.339**	0.000	0.000	**0.000**	**1.335**	**0.004**	**1.339**
13.Ogan Komering Ilir	0.243	0.001	**0.244**	0.000	0.000	**0.000**	**0.243**	**0.001**	**0.244**
14.Ogan Komering Ulu	1.069	0.010	**1.079**	0.000	0.000	**0.000**	**1.069**	**0.010**	**1.079**
15.Ogan Komering Ulu Selatan	0.938	0.000	**0.939**	0.000	0.000	**0.000**	**0.938**	**0.000**	**0.939**
16.Ogan Komering Ulu Timur	1.736	0.000	**1.737**	0.232	0.000	**0.232**	**1.969**	**0.000**	**1.969**
17.Panukal Abab Lematang Ilir	0.428	0.000	**0.429**	0.010	0.000	**0.010**	**0.439**	**0.000**	**0.439**
21.Rejang Rebong	0.823	0.005	**0.828**	0.000	0.000	**0.000**	**0.823**	**0.005**	**0.828**
22.Kepahian	0.426	0.002	**0.428**	0.000	0.000	**0.000**	**0.426**	**0.002**	**0.428**
31.Sarolangun	0.010	0.000	**0.010**	0.001	0.000	**0.001**	**0.011**	**0.000**	**0.011**
32.Batanghari	0.007	0.000	**0.007**	0.000	0.000	**0.000**	**0.008**	**0.000**	**0.008**
33.Mauro Jambi	0.000	0.000	**0.000**	0.000	0.000	**0.000**	**0.000**	**0.000**	**0.000**
Total	21.791	0.059	**21.850**	0.577	0.000	**0.577**	**22.368**	**0.060**	**22.427**

Note: D: Domestic, ND: Non-Domestic, IND: Industry
Source: JICA Project Team 2

Table F3.1.20 Water Demand Projection of Banyasin River Basin in 2015

City / Regency	Surface Water			Groundwater			Total		
	D+ND	IND	Total	D+ND	IND	Total	D+ND	IND	Total
1. Banyuasin	0.387	0.004	**0.391**	0.000	0.000	**0.000**	**0.387**	**0.004**	**0.391**
9. Musi Banyasin	0.280	0.006	**0.286**	0.000	0.000	**0.000**	**0.280**	**0.006**	**0.286**
31.Sarolangun	0.000	0.000	**0.000**	0.000	0.000	**0.000**	**0.000**	**0.000**	**0.000**
32.Batanghari	0.049	0.000	**0.050**	0.001	0.000	**0.001**	**0.051**	**0.000**	**0.051**
33.Mauro Jambi	0.088	0.001	**0.089**	0.000	0.000	**0.000**	**0.088**	**0.001**	**0.089**
Total	0.805	0.011	**0.816**	0.001	0.000	**0.002**	**0.807**	**0.011**	**0.818**

Note: D: Domestic, ND: Non-Domestic, IND: Industry
Source: JICA Project Team 2

Table F3.1.21 Water Demand Projection of Banyasin River Basin in 2050

City / Regency	Surface Water			Groundwater			Total		
	D+ND	IND	Total	D+ND	IND	Total	D+ND	IND	Total
1. Banyuasin	0.855	0.005	**0.860**	0.000	0.000	**0.000**	**0.855**	**0.005**	**0.860**
9. Musi Banyasin	0.899	0.007	**0.906**	0.000	0.000	**0.000**	**0.899**	**0.007**	**0.906**
31.Sarolangun	0.000	0.000	**0.000**	0.000	0.000	**0.000**	**0.000**	**0.000**	**0.000**
32.Batanghari	0.126	0.000	**0.126**	0.004	0.000	**0.004**	**0.129**	**0.000**	**0.130**
33.Mauro Jambi	0.199	0.001	**0.200**	0.000	0.000	**0.000**	**0.199**	**0.001**	**0.200**
Total	2.079	0.014	**2.092**	0.004	0.000	**0.004**	**2.083**	**0.014**	**2.096**

Note: D: Domestic, ND: Non-Domestic, IND: Industry
Source: JICA Project Team 2

Table F3.1.22 Water Demand Projection of Sugihan River Basin in 2015

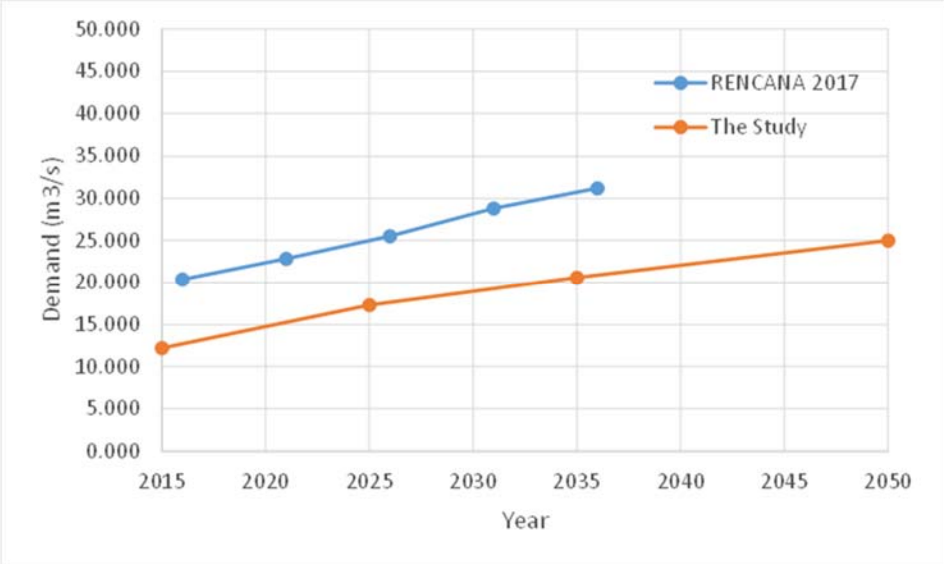
City / Regency	Surface Water			Groundwater			Total		
	D+ND	IND	Total	D+ND	IND	Total	D+ND	IND	Total
1. Banyuasin	0.103	0.001	**0.104**	0	0	**0**	**0.103**	**0.001**	**0.104**
13.Ogan Komering Ilir	0.083	0.001	**0.084**	0	0	**0**	**0.083**	**0.001**	**0.084**
Total	0.186	0.002	**0.188**	0	0	**0**	**0.186**	**0.002**	**0.188**

Note: D: Domestic, ND: Non-Domestic, IND: Industry
Source: JICA Project Team 2

Table F3.1.23 Water Demand Projection of Sugihan River Basin in 2050

City / Regency	Surface Water			Groundwater			Total		
	D+ND	IND	Total	D+ND	IND	Total	D+ND	IND	Total
1. Banyuasin	0.227	0.001	**0.228**	0	0	**0**	**0.227**	**0.001**	**0.228**
13.Ogan Komering Ilir	0.243	0.001	**0.245**	0	0	**0**	**0.243**	**0.001**	**0.245**
Total	0.470	0.003	**0.473**	0	0	**0**	**0.470**	**0.003**	**0.473**

Note: D: Domestic, ND: Non-Domestic, IND: Industry
Source: JICA Project Team 2



Source: JICA Project Team 2

Figure F3.1.5 Comparison for Water Demand Projection between RENCANA 2017 and The Study

As mentioned in the previous section (1) of F3.1.2 Existing Master Plan for POLA 2014 and RENCANA 2017, in JICA Study the areas of Cities/Regencies located inside the three river basins including Musi, Banyasin and Sugihan basins are considered, and the population projection is made based on the long term population data (2011 to 2035) of BPS. The demand projection in JICA Study is therefore considered more realistic, while demand projection of RENCANA 2017 based on simple average of short term population growth rates (2006 to 2010) is seemed overestimate.