Chapter5 Master Plan for Bekasi River Flood Control (Draft)

5.1 Overview

(Excerpts from Minutes)

- **The estimation of Budget Estimation Plan (RPB) is being prepared and the procurement phase will start at least July. The nominal budget is Rp. 4.6 trillion and input from the project team is going to be needed during these phases.**
- **The project team suggested to review the plan, design and implementation plan of Bekasi River improvement works.**

In response to the flood on January 2020 at Bekasi River basin, Minister Basuki of the Ministry of Public Works and Housing ordered the prompt implementation of the Bekasi River flood control project. Following the order, BBWS Ciliwung-Cisadane (herein after BBWS CiliCis) commenced a river improvement project based on the detailed design carried out in 2015 from the CBL estuary to confluence of Cikeas and Cileungsi Rivers in Bekasi River. Minister Basuki also instructed BBWS CiliCis to conduct value engineering prior to the commencement of the works, to consider reduction of construction costs. At the same time, he requested the JICA study team who has been proposing the implementation of the Jakarta Flood Control Master Plan to review the detailed design and the value engineering results.

In a meeting among Bappenas, DGWR and BWWS CiliCis of PUPR, Bappeda and DSDA of DKI Jakarta and JICA on June 16, 2020, the four (4) parties agreed to cooperate in the implementation of the Bekasi River Improvement Works and to review the planning and design.

In response to the above request, the JICA study team started the review of the detailed design and gave advice to the consultants for Value Engineering. In March 2020 the results of the review of the detailed design were organized, and then a meeting was held in June 2020 with BBWS CiliCis regarding the results of evaluation of Value Engineering and the review of the detailed design, taking into consideration the flood situation in January 2020. Then JICA study team presented a proposal for measures against the flood issues as follows:

a) Revision of the design flood discharge (including Project Scale) to match the flood runoff in January 2020.

b) Review of the design river profile
- Review of the design river profile of the upstream section of the Bekasi weir together with examination of countermeasures against sedimentation upstream of the weir.
- Review of the design river profile of the downstream section of the weir and resetting of the riverbed elevation at the confluence with the Cikarang-Bekasi-Laut Floodway (CBL) channel.

c) Review of the design river cross sections
- Re-design of high concrete retaining wall or change of levee type.

d) Lowering of the design high water level of the upstream section of Bekasi weir.

e) Extension of the river improvement stretch (up to Cikeas & Cileungsi River).

f) Additional consideration on flood regulation measures

In response to this proposal, BBWS CiliCis asked the JICA study team to prepare a comprehensive and long-term flood control vision including these proposals. The JICA study team proposed a plan aiming at improving the issues pointed out in the review of the 2015 detailed design and enhancing the safety level against floods by taking into account the actual situations of the flood in January 2020.

5.2 Overview of the Bekasi River and its Basin

5.2.1 Basic Information

(1) Overview of the Bekasi River Basin

The Cikeas and Cileungsi rivers, which are tributaries of the Bekai River and both of which headwater is Mt. Gunung Halimun with altitude of about 1,500 m, meet in the south of Bekasi City, creating the Bekasi River. The Bekasi River flows through Bekasi City, and then meets the CBL (Cikaran-Bekasi-Laut Floodway). The former Bekasi River downstream of the CBL channel has been abandoned, but a portion of it is being used as an agricultural canal.

The river channel in the upper and middle reaches is a valley formed by the scouring of the Bekasi River, and in the lower reaches, an alluvial plain is formed and natural levees are partially distributed in this section. Urban area of Bekasi city has been developing on the river terrace at an altitude of over 12.5 m, and the floodplain along the coast has been used for farmland (mainly paddy field).

The Bekasi weir, which was constructed in 1958, used to keep the water level of the Bekasi River raised by about 8 m in order to carry the water of the West Tarum Canal from east to west, causing frequent flood damage in the urban area of Bekasi city located at upstream of the weir. To address this, the West Tarum Canal across the Bekasi River was converted into a siphon to allow the Bekasi River gates to open in the event of flood (constructed by ADB). The office of PJT-II, which operates the weir, prepared a flood gates' SOP (Standard Operation Procedure) during flood, but the gates are operated so as to maintain the water level high even in the event of flood, and the SOP based on the arrival time of flood is not used properly. It is supposed that delays in gate operation during floods are one of the main causes of flood damage in the upper basin. To address this problem, the River Technical Center (Balai Teknik Sungai, BTS) proposed a simplified gate operation method against a 5 year-flood, but no measures were taken for a larger flood (For details, refer to "5.6.4 Improving the operation of the Bekasi Barrage flood gate.").

The outline of the Bekasi River is as follows.

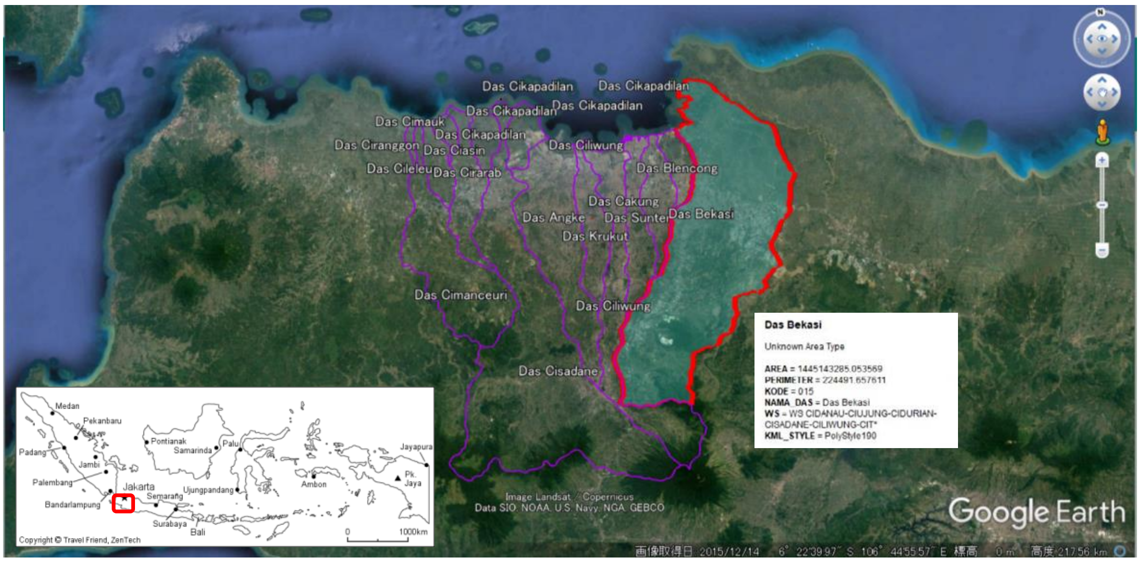


Figure 5-1 Location of Bekasi River

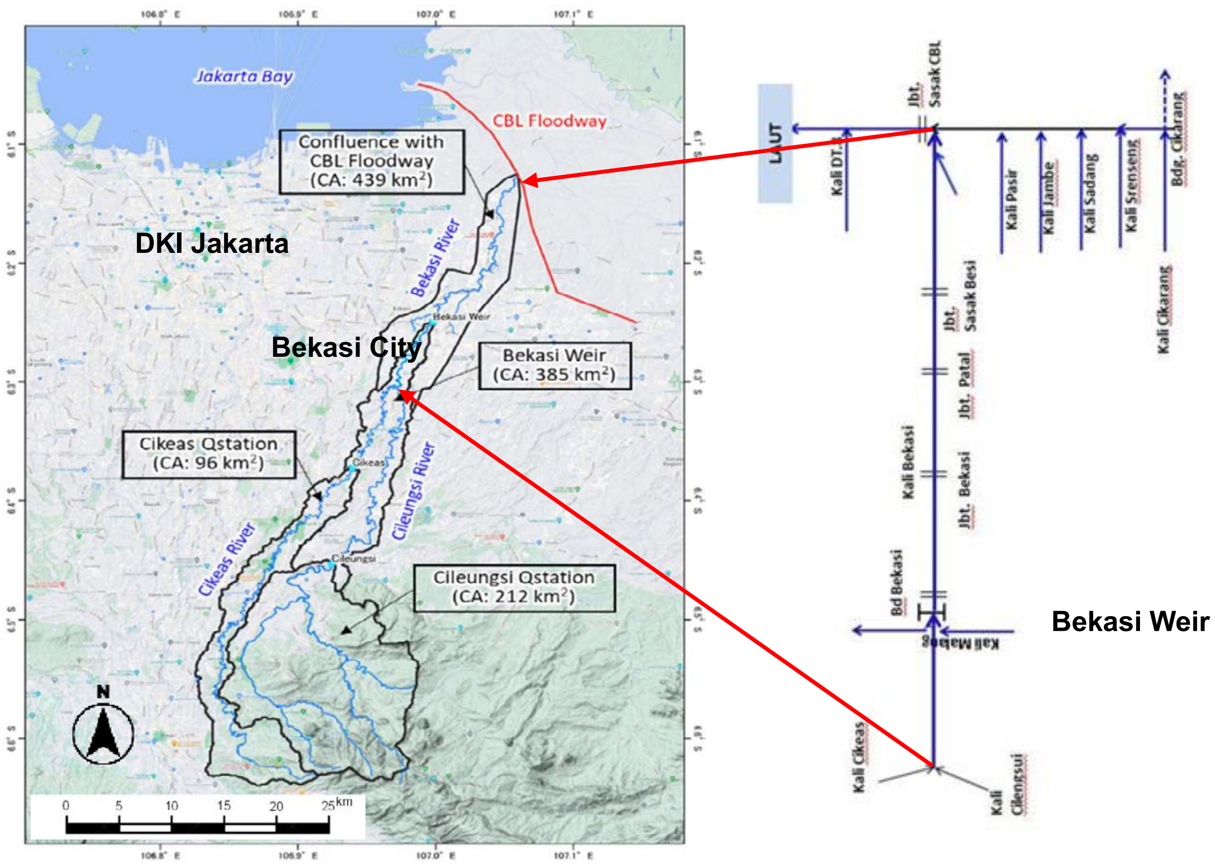


Figure 5-2 General Map of Bekasi River Basin

(i) Catchment Area

- Total Catchment Area of Bekasi River : 439.17 km^2
- Cileungsi River Basin : 265.04 km^2
- Cikeas River Basin : 111.76 km^2
- Downstream Section : 62.37 km^2

(ii) Length of River

- Total Length: 115.1 km
- Estuary-Confluence of CBL & Bekasi River: 14.3 km
- CBL Confluence - Bekasi Weir : 22.0 km
- Bekasi Seir – Confluence with Tributaries : 11.4 km
- Cileungsi River: 67.4 km

(iii) Annual rainfall (extracted from 1997 MP):

- Coastal Plain : 1,800 mm/year
- Hilly Area : 2,500 mm/year

- Mountainous Area : 3,500 mm/year

(iv) River Profile

- CBL: 1/3,750
- CBL - Bekasi Weir: 1/4,300
- Bekasi Weir － Confluence: Level
- Cikeas River: 1/740
- Cileungsi River: 1/510
-

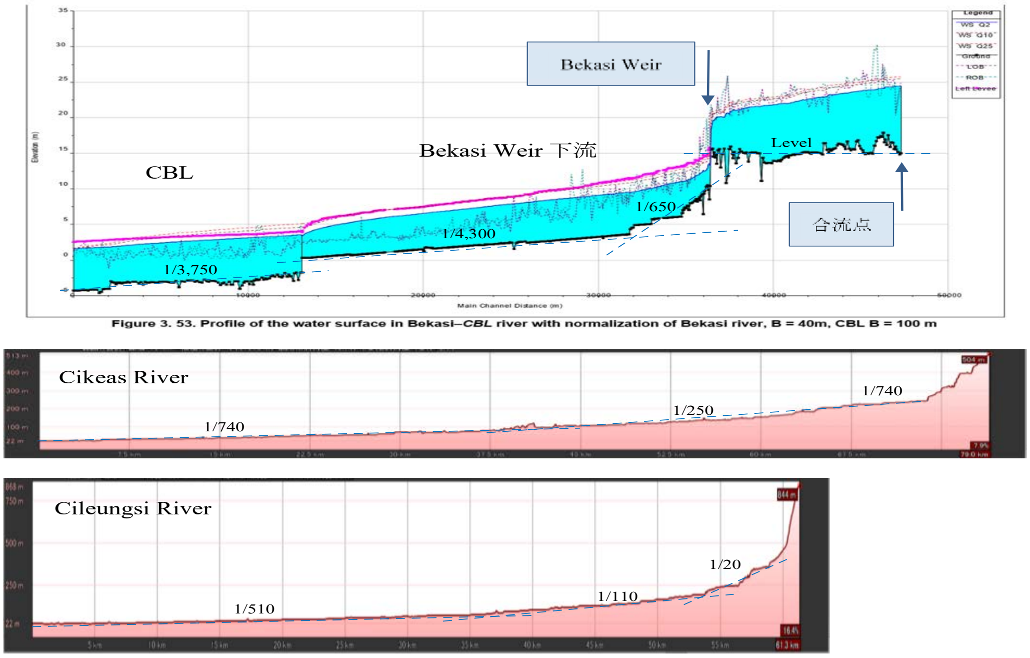


Figure 5-3 River Profile of Bekasi River

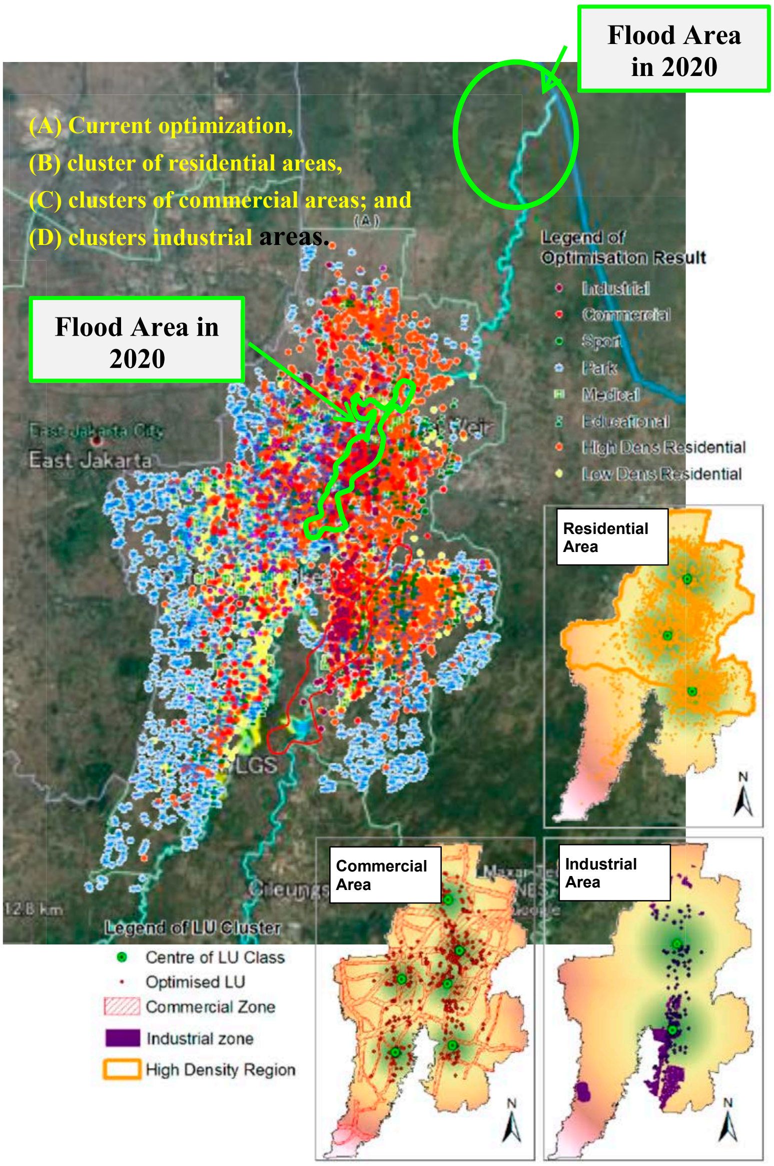
(2) Land Use and Inundation Area in the Basin

As shown in Figure 5-4, the administrative district in the Bekasi River basin is Bogor Regency in the upstream and the major flood inundation area at downstream from the confluence of the tributaries is mainly Bekasi City. Bekasi city is a city of 2.6 million people, and more than 10% of which are living in flood inundation area.

Bekasi City		2,663,011
Bekasi Regency	Babelan	297,645
Bogor Regency	Cileungsi	347,414
	Gunung Putri	453,696
	Jongol	119,432
	Klapanunggal	121,218

Figure 5-4 Administrative Boundaries and Population

The spatial plan of the centre of Bekasi city was established, dividing it into residential area, commercial area and industrial area (see Figure 5-5). As shown in the figure, the whole flood prone area has already developed, and the population density in the area is very high (population density 15,000/km^2). Flood occurs almost every year in this region, so the urgency of flood control projects is extremely high.



Source : Achieving a Sustainable Urban Form through Land Use Optimization: Insights from Bekasi City's Land-Use Plan (2010–2030), Rahmadya Trias Handayanto, Asian Institute of Technology, Sustainability 2017, 9

Figure 5-5 Current Status of Land Use (Bekasi City)

(3) Project Budget of BBWS CiliCis

As shown in Table 5-1, PUPR BBWS CiliCis has budgeted 15.6 billion yen (about 3 billion yen per year) for the Bekasi River basin from 2020 to 2024. BBWS CiliCis regards how to make effective use of this budget as a challenge, and also considers incorporating the plan proposed by the JICA study team in the budget.

Table 5-1 BBWS CiliCis 2020 -2024 Budget

No.	Programs/activities/outputs/packages/SUB-Packages	Ta. 2020	Ta. 2021	Ta. 2022	Ta. 2023	Ta. 2024	百万円
RENSTRA FLOOD CONTROL ACTIVITIES IN BANTEN PROVINCE YEAR 2020-2024							-
RENSTRA FLOOD CONTROL ACTIVITY IN WEST JAVA PROVINCE YEAR 2020-2024							35,703.7
1	Flood Control in Bekasi River, Cikeas, Cileungsi (continued)	100,000	10,000	50,000	50,000		1,555.6
2	Cikarang River Flood Control		50,000	50,000	50,000	50,000	1,481.5
3	Flood Control in Cilemah Abang River		50,000	50,000	50,000	50,000	1,481.5
4	Cipinang Gading River Flood Control		70,000				518.5
5	Cibening / Bojong Rangkong River Flood Control			190,000	110,000		2,222.2
6	Jatiluhur River Flood Control	180,000	120,000				2,222.2
7	Flood Control in Bekasi River, Cikeas, Cileungsi (continued)	100,000	10,000	50,000	50,000		1,555.6
8	Cikarang River Flood Control		50,000	50,000	50,000	50,000	1,481.5
9	Reinforcement of Bekasi River Cliffs	80,000					592.6
10	Reinforcement of Kali Cikarang Cliff		23,000				170.4
11	Normalization of CBL Flood Canal		430,000	400,000			6,148.1
12	Main Drainage Rehabilitation of Bekasi City	50,000	50,000	50,000	50,000	50,000	1,851.9
13	Polder / retention pond for the Bekasi River Cileungsi watershed		47,000				348.1
14	Polder / retention pond for the Bekasi River Cikeas watershed			120,000			888.9
15	Polder / retention pond of the Cikarang watershed				50,000	50,000	740.7
16	Construction of the Sabo Dam, Upstream of the Sukamahi Dam	30,000					222.2
17	Construction of the Sabo Dam, Upstream of the Ciawi Dam	40,000					296.3
18	Ciawi Dam Construction (continued)	200,000					1,481.5
19	Sukamahi Dam Construction (continued)	70,000					518.5
20	Narogong Dam Construction				700,000		5,185.2
21	Revitalization of Situ-Situ in Bogor Regency	40,000	40,000	40,000	20,000	20,000	1,185.2
22	Revitalizing of Situ-Situ in Depok City	40,000	40,000	40,000	20,000	20,000	1,185.2
23	Revitalizing of Situ-Situ in Bekasi City	40,000	40,000	40,000	20,000	20,000	1,185.2
24	Revitalizing of Situ-Situ in Bekasi District	40,000	40,000	40,000	20,000	20,000	1,185.2

Note)The budget for Bekasi River indicated in blue
Source: BBWS CiliCis

(4) Flow Capacity

Flow capacity of the Bekasi River was calculated in the 1997 MP and 2015 DD as follows. When the ongoing project is completed, the flow capacity will be improved to accommodate a 25-year flood discharge.

(i) Study at 1997 MP

- Bekasi 80~1,600 m^3/s
- CBL Floodway 100~950 m^3/s

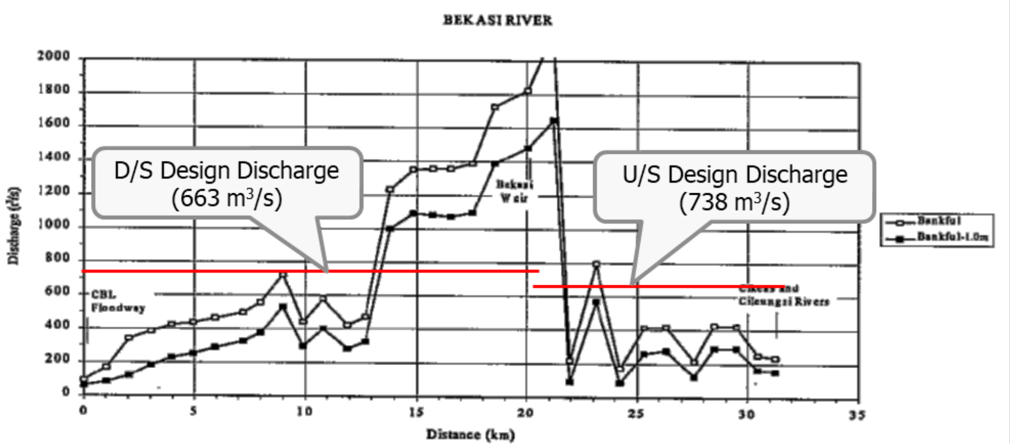


Figure 5-6 Flow Capacity along Bekasi River (1997 MP)

(ii) Estimation in 2015 DD

(A) Upstream of Bekasi Weir:

The flow capacity in this section is mostly Q 10 [*]1 (563.3 m^3/s) or more, but there are several portions of which capacity is less than Q2 (372.6 m^3/s) (Sta B 5, B 89, B 107, etc.).

(B) Downstream of Bekasi Weir

The 1 km section just downstream of the weir has flow capacity of Q 10 to Q 100, in the further downstream section there are continuously existing portions that cannot accommodate even Q2 (372.6 m^3/s).

In this report, the floods that occur almost every year along the downstream of weir are attributed to the discharge of the Bukasi weir.

(C) After implementation of the project

The entire river channel will be improved into a river with a flow capacity of 25-year flood discharge (662.9 m^3/s) (under construction contract).。

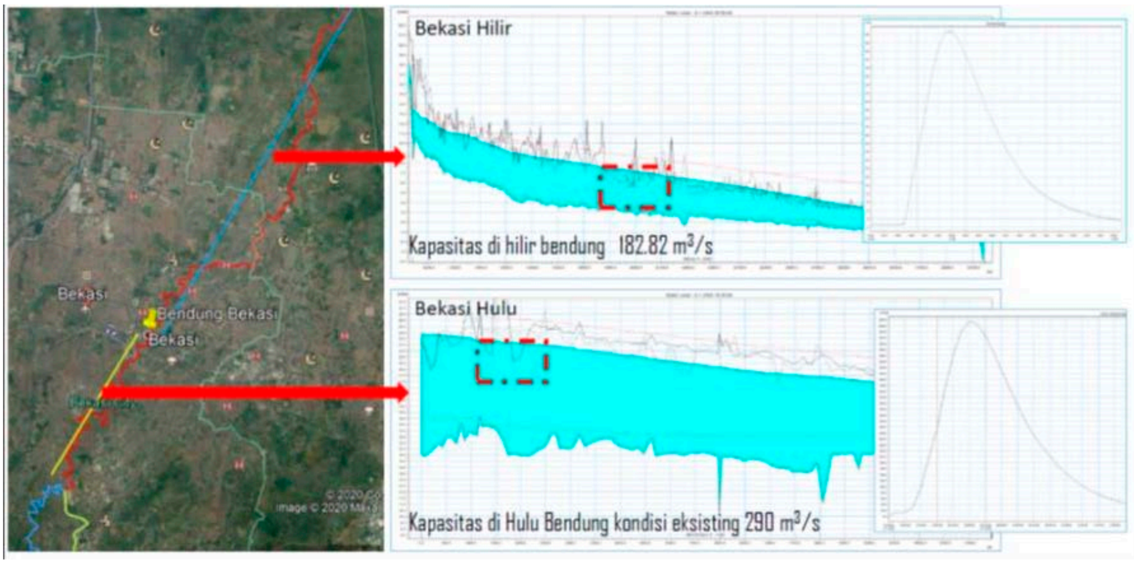
(iii) Estimation by the River Technical Center (BTS)

When the River Technology Department (Balai Teknik Sungai: BTS) of PUPR examined the SOP of the Bekasi Weir flood gate in 2020, it evaluated the flow capacity of the Bekasi River, although the evaluation did not cover the entire river channel but was limited locally.

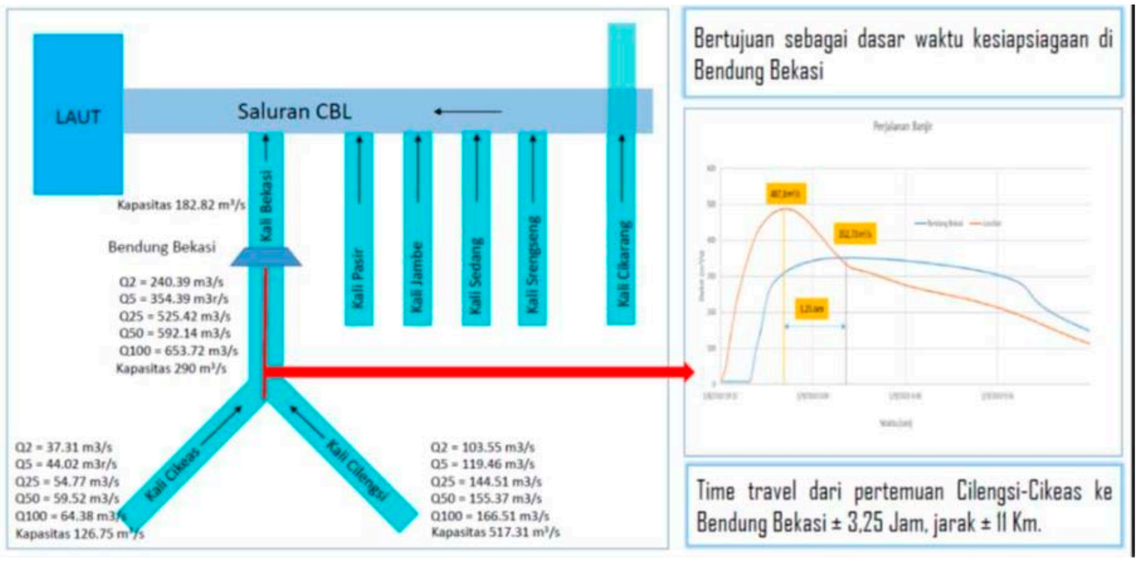
Results of the evaluation are as follows:

- Downstream of Bekasi Weir : 183 m^3/s
- Upstream of Bekasi Weir : 290 m^3/s
- Cikeas river : 128 m^3/s
- Cileungsi river : 517 m^3/s

[1] The n-year probability discharge is expressed as Qn.



Confirmation of overflow section



Examination of flow distribution

Figure 5-7 Evaluation Results of Bekasi River Flow Capability by BTS

(5) Flood Condition in Bekasi

The past inundation area in Bekasi City is shown in the Figure 5-8. It was found that the inundation has been occurred mainly in the urban area in the upstream of Bekasi Weir and near the confluence point of CBL channel in the downstream of the weir. The conditions of the January 2020 flood are described in the next chapter.

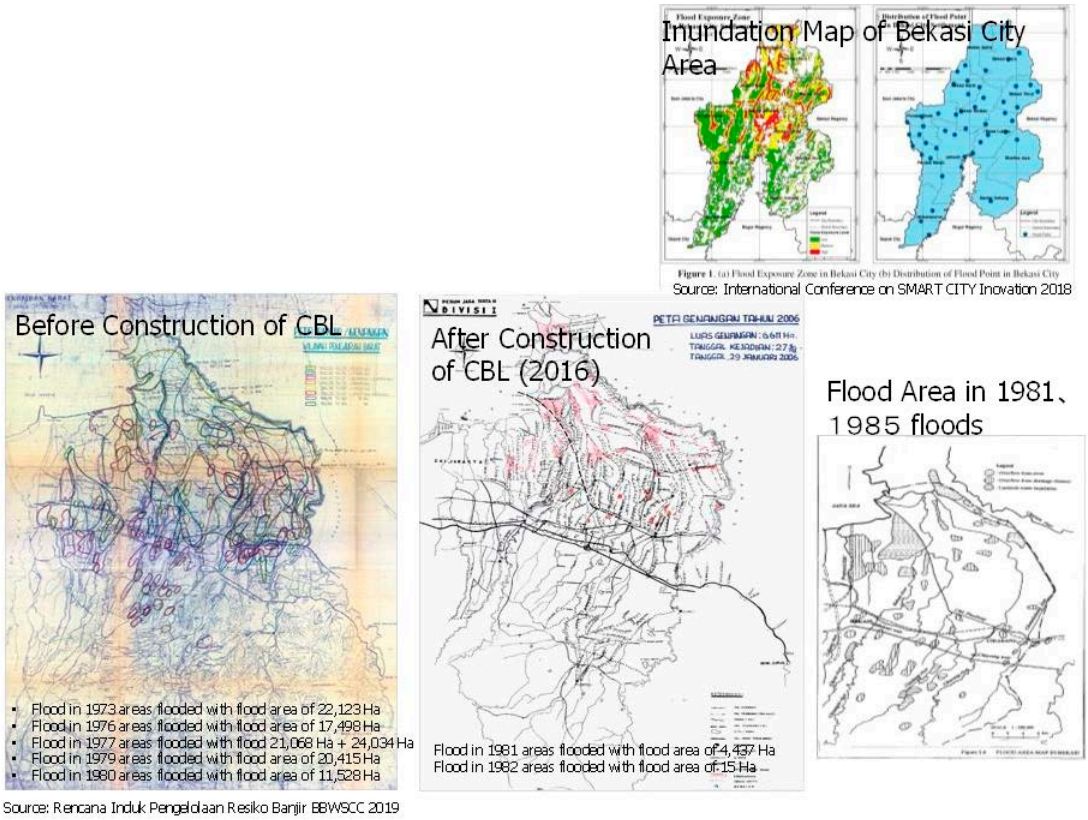


Figure 5-8 Past flooding in Bekasi

5.2.2 Previous Studies and Proposed Measures

For the Bekasi River, as shown below, a number of flood control projects have been planned, and some of them, including the construction of CBL and the partial implementation of retaining wall and embankments along the upstream of the weir, have been implemented.

In 2015, in view of the repeated flood damage, the detailed design of river improvement works for the entire river basin based on the current situations was carried out, and in 2020, Value Engineering on this design was carried out (see Chapter 2.5). The tendering for the procurement of contractors for the river improvement works was subsequently carried out and its construction work started in 2021.

Development Plan of Bekasi River Basin

1997: Master Plan of CBL and Lower Bekasi River

2008: Detail Desain Kali Bekasi Hulu (Detailed Design of Bekasi River Upstream)

2008: Perencanaan dan DD Pengendalian Banjir Kali CBL
CBL Floodway Flood Control Plan and Detailed Design)

2011: Detail Desain Pengendalian Banjir Kali Cikarang
(Detailed Design of Cikarang River Flood Control Project)

2012: SID Pengendalian Banjir di Kali Cikeas dan Cilengsi
SID for Flood Control Plan in Cikeas and Cilengsi Rivers [*]2

2014: Studi Restorasi dan Peningkatan Sungai Cikeas

[2] SID : Survey, Investigation and Design

(Study on Restoration and Improvement of the Cikeas River)

2015: Detail Desain Pengendalian Banjir Kali Bekasi Hilir
(River Normalization of Bekasi River Upstream (from Confluence of Cikeas and Cileungusi to CBL))

2020: Value Engineering by BBWS CiliCis (2020) & Check & VE Review by JICA Team

5.2.3 Damages Caused by 2020 flood and the 2021 flood

(1) January 2020 Flood

(i) Flood Discharge

The maximum discharge of 927 m^3/s was observed at the Bekasi Weir. This discharge exceeded, by nearly 200 m^3/s, the 50-year flood discharge of 737 m^3/s which was estimated in the 2015 detailed design.

The highest water level was observed at the Cileungsi water level gauging station at 9:00 of January 1, and at the Bekasi Weir, about 42 km downstream from the station, the maximum discharge was observed at 13:00 of January 1. Therefore, the travel time of flood was estimated to be about 4 hours, and the average flow velocity was estimated to be about 3 m/s.

(ii) Inundation Area in Flood January 2020

According to a survey conducted by Bekasi City as shown in Figure 5-9, the inundation area caused by the January 2020 flood was about 850 ha, and all the flood areas have been developed as residential areas or commercial areas. It is estimated that more than 115,000 people were affected by the flood.

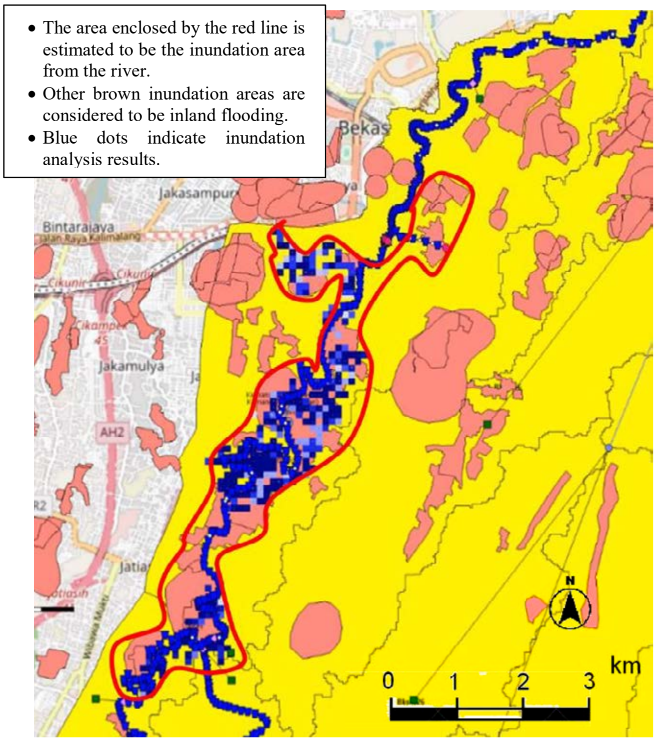


Figure 5-9 Inundation Area in January 2020

Flood damage has been reported at the following locations.

- Around the confluence of the Cikeas and Cileungsi rivers. In particular, along the Cileungsi river right bank upstream of the confluence and the right and left banks along the downstream of the confluence.
- A wide area upstream of the Bekasi Weir. Breaching of dike was also reported.
- The Kali Mati (Mati River) pumping station immediately below the Bekasi Weir. The cause is considered to be the failure of one pump and the delay of gate operation.

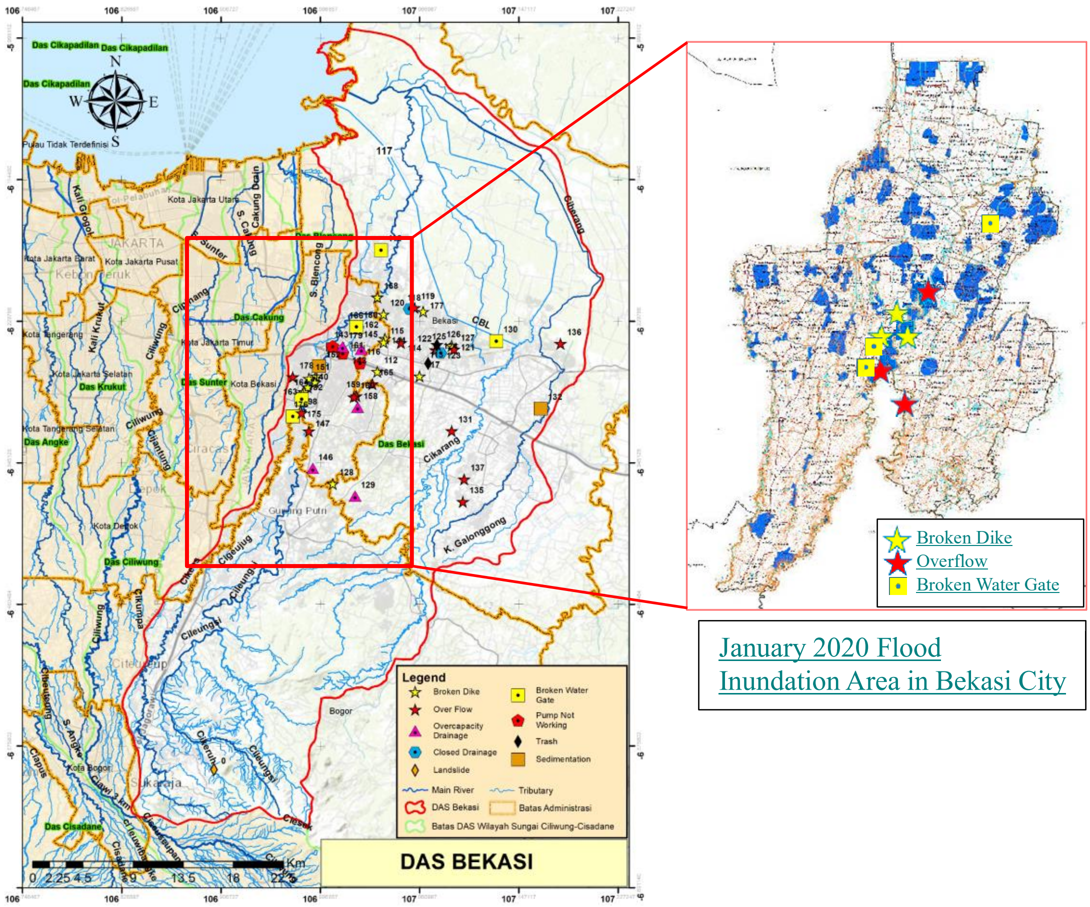


Figure 5-10 Damage in the Bekasi River Basin

(iii) Rainfall

On December 31, 2019, a daily rainfall of 316 mm/day was observed at the Sungai Cikeas Station in the basin. In addition, the daily rainfalls recorded at the rainfall stations in Jakarta and its surrounding area on the day are shown below. Heavy rain was recorded in the whole basin.

- Halim 377mm
- Cakung 300mm
- Paman Mini 335mm
- Jati Asih 259mm

According to the criteria for classifying the intensity of rainfall set up by the the Indonesian Meteorological Agency (BMKG), the rainfall in the day rated as “EXTREME”.

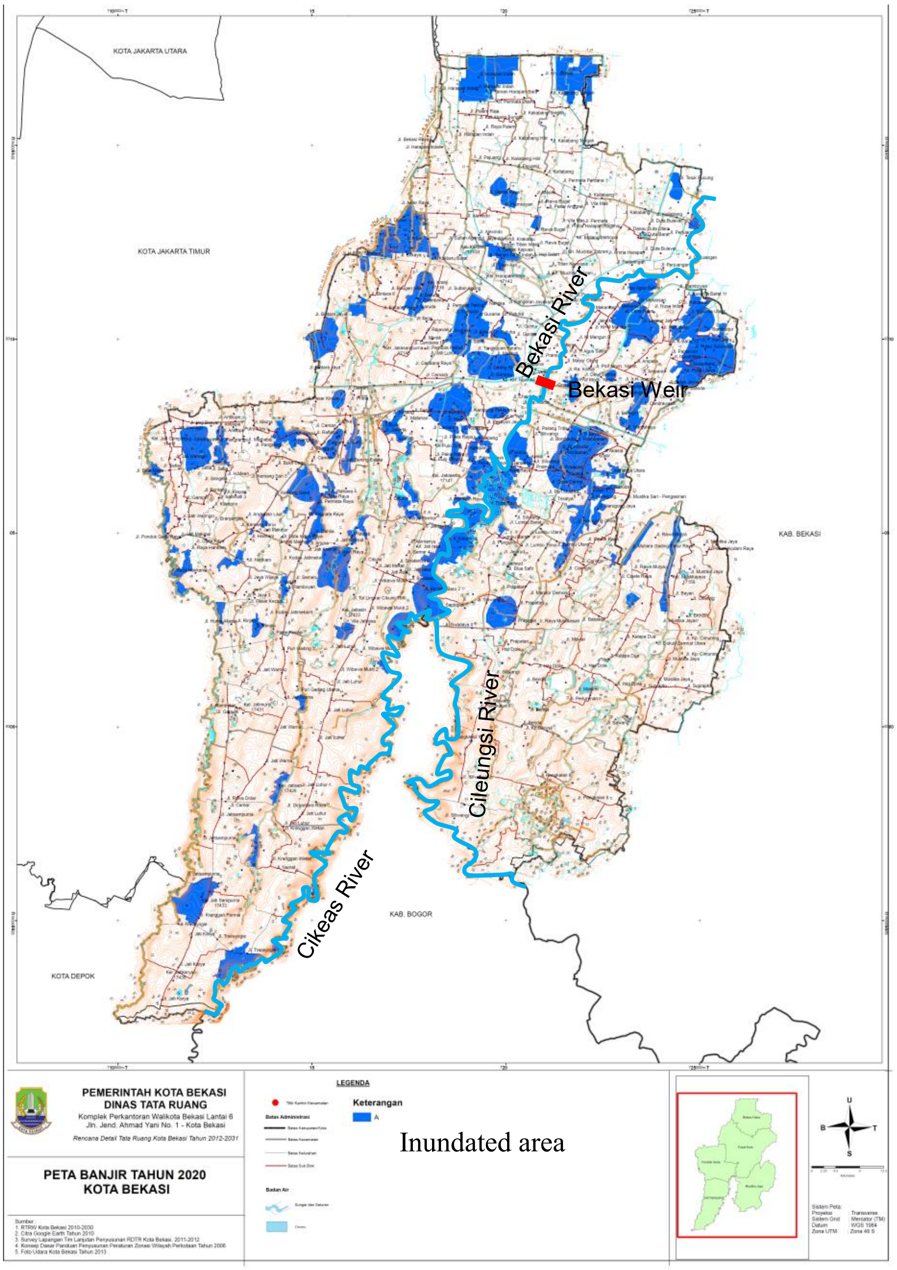
- 0.5-20 mm/day Light rain
- 20-50 mm/day Medium rain
- 50-100 mm/day Heavy rain
- 100-150 mm/day Very heavy rain
- 150 mm/day or more Extreme rain

The past records of Extreme Rain around Jakarta are as follows, and it can be seen that the rainfall of December 31, 2019 was one of the largest rainfalls ever.

1996	216 mm/day	2002	168 mm/day
2007	340 mm/day	2008	250 mm/day
2015	277 mm/day	2016	100-150 mm/day

(iv) Inundation Area

As shown in Figure 5-11, in the inundation area of Bekasi City, river flooding occurs between the confluence point of the Cikeas and Cileungsi Rivers and the Bekasi Weir.



Source: Supplied by Kota Bekasi

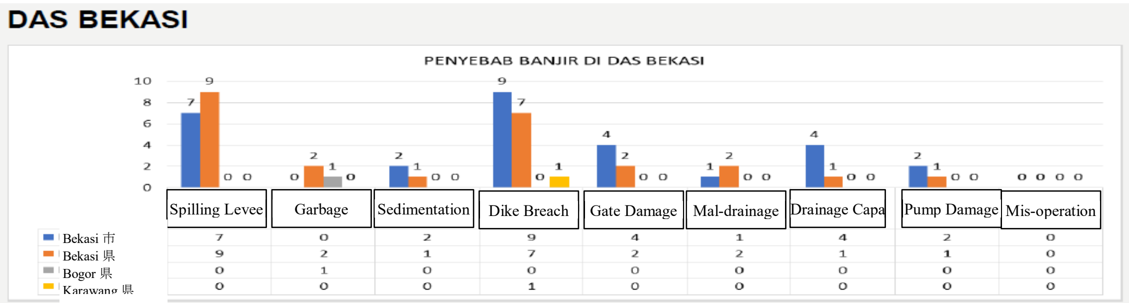
Figure 5-11 Flooded area in Bekasi

(v) Cause of Flood

Since a day after the flood, PUPR had conducted a flood damage survey and summarized the causes of the 2020 January Bekasi River flood as shown below.

As shown in Table 5-2, the main cause of the flood was spilling from the dike caused by the record discharge in the history and breaching of the dikes. In addition, several issues such as insufficient capacity in the drainage channels and a failure in the gate/pump function were also pointed out.

Table 5-2 Causes of Flooding



	Spilling Levee	Garbage	Sedimentation	Dike Breach	Gate Damage	Mal-drainage	Drainage Capa	Pump Damage	Mis-operation
Bekasi 市	7	0	2	9	4	1	4	2	0
Bekasi 県	9	2	1	7	2	2	1	1	0
Bogor 県	0	1	0	0	0	0	0	0	0
Karawang 県	0	0	0	1	0	0	0	0	0

Source :From the results of the PUPR flood damage survey

(2) February 2021 Flood

On February 2, 2021, a year after the 2020 flood, flood of the same magnitude occurred in the Bekasi River basin. The maximum discharge observed in Bekasi Weir was 826 m^3/s (927 m^3/s in the 2020 flood). The concrete retaining wall collapsed and caused massive flood damage again in the densely populated residential area of Bekasi city (the risk of concrete retaining wall was pointed out in Chapter 2.5 recommendations for detailed design). The flood water reached the second floors of the nearby houses.

After the flood, the Bekasi City authorities, the administrator, reinforced the collapsed retaining wall with sandbags, but in February 2022 a flood overflew the damaged wall, which collapsed even more.

Figure 5-12 Concrete Retaining Wall Collapse Site

5.3 Concepts of Draft Master Plan

5.3.1 Necessity and Urgency of Project

The Bekasi River has suffered flood damage several times in the past. In January 2020, a record flood suffered the Bekasi River Basin and caused enormous flood damage. In particular, the upstream section of Bekasi Weir (population density: 15,000/km^2), where residential areas and commercial facilities are densely extended, was inundated with an area of about 850 hectares, and more than 120,000 people suffered from flood damage. The inundation area downstream of the Bekasi Weir used to be mainly paddy fields, but the area has been developing rapidly. Furthermore, the same scale of flood occurred in February 2021, the following year, and similar damages were recorded. (See Damages Caused by 2020 flood and the 2021 flood)

Although the Bekasi River basin is under development, flood damage occurs almost every year, and the urgency of projects to reduce flood damage is extremely high.

5.3.2 Project Scale

When the project scale (improvement target) of a flood control master plan is determined, actual conditions of the damage by the past flood and economic effect of the plan, etc. as well as the importance of the river are comprehensively taken into consideration. In view of the fact that Bekasi city suffered from serious damage due to the flooding in January 2020, the scale of the project will be determined, taking this flood into consideration.

The maximum discharge of the January 2020 flood was 924 m /s at the Bekasi Weir site, which far exceeded the 100-year return period flood discharge (813 m^3/s) that was estimated in the 2015 detailed design. In this study, the rainfall and runoff analysis was carried out by adding recent rainfall data from 2015 to 2020. As a result, it was found that the magnitude of the January 2020 flood corresponded to a 43-year flood, and the design discharge (663 m ^{3}/s) of the ongoing river improvement project can cope with only a 10-year flood discharge.

Regarding the target safety level (project scale of flood control projects) of river projects in Indonesia, there are the following minister order and guidelines on the other hand. Judging from these criteria, it is administratively appropriate to apply the 50-year discharge.

(1) Order of the Minister of PUPR 28/PRT/M/2015

According to the minister order shown in Table 5-3, since there are provincial capital level cities in the Bekasi and Chisadane river basins, the project scale should correspond to the 50-year flood discharge. On the other hands, the Ciliwung River, which runs through Jakarta, the national capital, should be improved to cope with the 100-year flood.

Table 5-3 Minister Order of PUPR 28/PRT/M/2015

PENETAPAN GARIS SEMPADAN SUNGAI DAN GARIS SEMPADAN DANAU

LAMPIRAN I PERATURAN MENTERI NOMOR : 28/PRT/M/2015

The design discharge of river shall meet with the following regulations.

1) Kabupaten Capital area: Q10-Q20
2) Provincial capital area: Q20-Q50
3) Capital/metropolitan area: Q50-Q100

The scales of the river projects currently being implemented by BBWS CiliCis are as follows.

- Ciliwung River: 50-year flood discharge,
- Bekasi River: 25-year flood discharge (Temporary Rehabilitation). It will be raised to 50-year flood discharge in the future.
- Chisadane River: 50-year flood discharge. It will be raised to a 100-year flood discharge in the future.

(2) Guidelines for Flood Control Projects, 1996, DPU (currently PUPR)

The 2015 DD (for the downstream section of the Pasar Baru weir) applied the 50-year flood discharge in accordance with the flood control guidelines shown in Table 5-4.

Table 5-4 Recommended Plan Scale for Flood Control Project Guidelines

Channel System	Based on the type of flood control project and population	Return Period	
		Early Stage	Final Stage
River	Emergency Project	5	10
	New Project	10	25
	Updating Project		
	• For rural and/or urban areas with a population of less than 2 million people	25	50
	• For urban areas with a population of more than 2 million	25	100
Secondary Drainage System (DSA Area > 500 Ha)	Rural Area	2	5
	Urban with a population of less than 500 thousand	5	10
	Urban with population between 500 - 2 million	5	15
	Cities with a population of more than 2 million	10	25
Sistem Saluran Tertiary Drainage System (DPS Area < 10 Ha)	Rural and Urban Are	1	2

Source: Guidelines for Flood Control, DPU, Directorate General of Irrigation, 1996

Source: Pedoman Pengendalian Banjir, DPU, Direktorat Jendral Pengairan, 1996

(3) Planning Scale of NCICD (for reference)

The NCICD has set the planning scale of the project as follows, based on the Governor's Order No. 121/2012 of Jakarta Province and PUPR Ministerial Order 28/PRT/M/2015.

Drains and river levees:

- Q 10 (Small (Micro) Drainages)
- Q 25 (Sub-Macro)
- Q 100 (Large (Macro) Drainage/River Levees)

The coastal dikes including reclaimed land are supposed to be planned with the return period of 1,000 years, but 10,000 years has been applied considering the effect of land subsidence.

(4) Summary

As described above, the flood on January 2020 was evaluated to be a 43-year return period flood, and in order to cope with a flood of this scale at least, the project scale for the Bekasi river needs to be of 50-year return period. Since this value also meets the Indonesia's criteria (Minister Order PUPR 28/PRT/M/2015, 25-50year-flood for state capital), it is judged that the BBWS CiliCis's plan, which is upgrading the target safety level from 25 year-flood to 50 year flood, is reasonable. Therefore, the target safety level of the flood control master plan for the Bekasi River set at 50-year return period flood and the design high water will be updated to include the January 2020 flood.

5.3.3 Basic Concept for planning master plan is prepared based on the following concept:

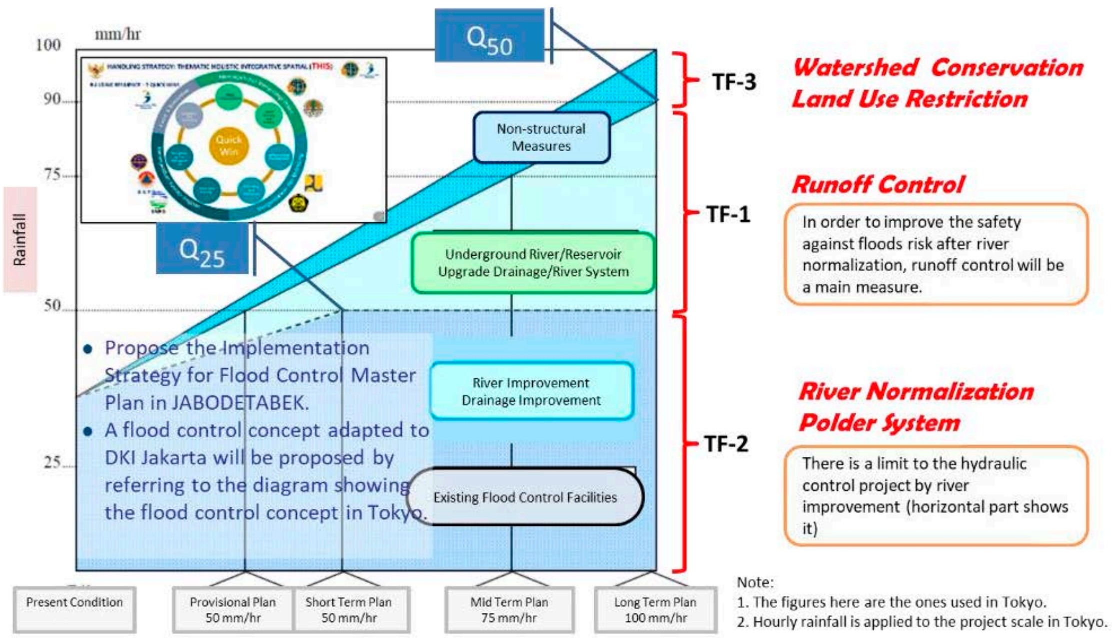
1) Increasing the river's flow capacity up to the maximum and possible extent by normalization of river channel by the ongoing project, and
2) Making up for the shortfall of river capacity by flood discharge regulation measures.

This is based on the same concept as the Tokyo Metropolitan Government's concept for implementation of flood control measures, and consists of the following three measures.

- Facilities to prevent flooding: River improvements, etc. (equivalent to Quick Win TF -2)
- Facilities for controlling runoff: Reservoir/dam, land use regulation, watershed conservation, etc. (equivalent to Quick Win TF -1)
- Facilities to mitigate flood damage: Flood forecast warning, operational improvement of facilities, etc. (equivalent to Quick Win TF -3)

These three measures are also in line with BAPPENAS '"Quick Win Initiative" for flood control, and their validity can be confirmed. In the review of JABODETABEK flood control plan, this idea will be reflected.

A conceptual diagram of the basic reform policy is shown in Figure 5-13. Table 5-5 summarizes the Quick Win concept of BAPPENAS and proposes specific measures.



Source: Tokyo Metropolitan Government's Basic Policy on Heavy Rainfall Measures (revised), 2014, Tokyo

Figure 5-13 Tokyo Metropolitan Flood Countermeasure Implementation Concept and Quick Win

When the ongoing river improvement project by BBWS CiliCis is completed, the river channel flow capacity is supposed to increase to the 25-year design discharge of (662.9 m^3/s). However, the review of the rainfall and runoff analysis that used the latest rainfall data including those of the January 2020 flood revealed that the 25-year discharge is actually as small as that of 10-year return period (See the next section). Therefore, even if the ongoing project is completed, further improvements will be required to ensure the target safety level of 50-year return period. Besides the river channel improvement, it is necessary to take measures to regulate flood discharge, such as dam/retarding pond[3] construction or applying a new SOP for flood control of the Bekasi Weir flood gates.

In addition to these measures, the examination of following matters will be also required.

- Study on flood control effect of Narogon dam planned by BBWS CiliCis.
- In the upstream section of Bekasi weir, aggradation of the river bed due to sedimentation is observed. It is required to flash the sedimentation and maintain stable river channel in order to improve the flow capacity and lower the water level during floods. As a countermeasure, the change of the Bekasi weir flood gate operation procedure to hasten the sediment flashing or the installation of sand trap facilities are considered.

It is also important to consider lowering the design high water level in order to reduce the flood damage potential and to facilitate the removal of inland water, because the flood water flows at a water level of nearly 8 m higher than the ground level in the current plan.

[3] In Japan, "Retarding Basin" (land that impounds flood water temporarily during flood. constructed adjacent to the river) and "Retention Pond" (pond that temporarily stores the local flood water before entering the river) are used separately. In Indonesia, both runoff control facilities are called as Kolam Ritensi (Retention Pond), so here, "Retention Pond" is used as runoff control space, for the understanding of the Indonesian side.

Table 5-5 BAPPENAS Proposed Quick Win Concepts and Proposed Countermeasures

COORDINATION & SYNCHRONIZATION

QW-7 : Regulation & Institutional

- Advise technical issues to the "JABOBEDTABEK Flood Risk Reduction Task Force" which is established by GOI.

RISK PREVENTION & REDUCTION

QW-1: Risk Reduction (Runoff Control)

Conforming to the concept of "Zero Delta Q Policy" to reduce the flood risk in urban area, propose runoff control facilities based on the Japanese experience in comprehensive flood management scheme.

The system can be meet with increasing of runoff due to the urbanization and climate change.

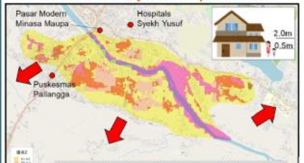
QW-2: Special Plan & Building Regulations

Flood Hazards Analysis in the study area and propose some counter measures such as high standard embankments, flood retention ponds harmonizing city development, etc.

IMPROVE PREPAREDNESS

QW-5 : Effective Flood Early Warning

- Evaluate the existing flood warning and evacuation systems.
- Recommend system improvement



Inundation Depth, Evacuation Sites

Evacuation Drill

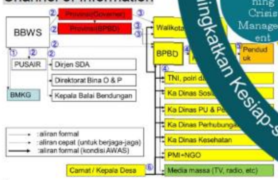
Evacuation Sign

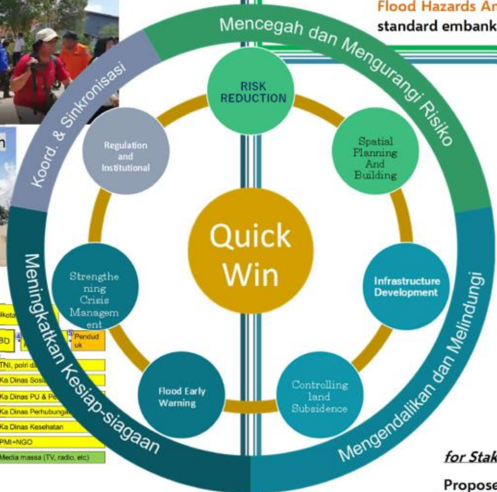
Recommendation from Governor

<<Kasus SIAGA>>
Tanggal: DD / MM / YYYY Jam……
Perihal : Pengumuman Peringatan Dini banjir Status;SIAGA

Deskripsi: Sungai Jeneberang di sekitar hulu Jembatan Sungguminasa dapat meluap dalam dua (2) jam kemudian. Daerah terdampak : (Perumahan Nusa Mapala dan sekitarnya).
Tindakan: Semua orang harus sudah diamankan ke lokasi evakuasi
Situs evakuasi: Madrasah Arifah
Tertanda: Gubernur/ Bupati/Walikota

Channel of Information

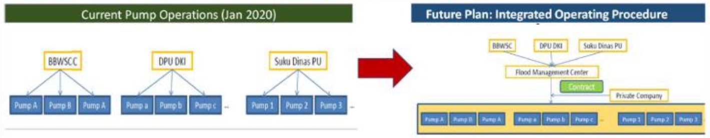




QW-6 : Strengthen Critical Management

Renew the cooperation framework for Central Government – Local Government

- Improvement and integration of Gates & Pumps operation systems



- Monitoring data (rainfall/water level) accumulation and processing system for effective utilization

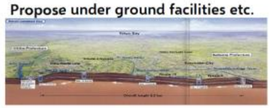
INFRASTRUCTURE DEVELOPMENT

QW-3 : Flood Controlling & Protection

1. Evaluation of Flood on January 2020
2. Propose Acceleration plan for Existing Flood Management Master Plan

for Staked Project

Propose under ground facilities etc.



for Low-readiness Plan & Design

- Propose river normalization plan for low-readiness rivers such as Bekasi River.
- Evaluation of utilization of existing SDEW (Situ, Danau, Embung, Waduk)
- Improvement of existing gate and pump systems considering complexed floods (inland and river floods)
- Enhancement of Operation & Maintenance for flood control facilities

QW-4 : Control Land Subsidence

(Ongoing under JICA TA)

5.4 Review of Design Discharge

(1) Necessity of Review of Design Discharge

On January 1, 2020, a large-scale flood occurred in Jakarta and surrounding areas. On February 20, 2021, the following year, a large-scale flood occurred again, although the damages was not as severe as that of the previous year.

In these floods, the Bekasi Weir located in the middle stream observed in the consecutive two years record discharges exceeding the 100-year flood of 813 m^3/s that was estimated in the 2015 Detailed Design (924 m^3/s on January 1, 2020 and 826 m^3/s on February 20, 2021). In view of this actual situation, it is necessary to review the probable flood discharge for planning. Since the January 2020 flood was the largest flood in the last 50 years, the January 2020 flood was selected as a representative flood, and the probable discharges at the Bekasi Weir site has been examined.

(2) Basic Flood Discharge Analysis

Basic flood discharge (unregulated peak discharge) was estimated by the examination flow shown in Figure 5-14.

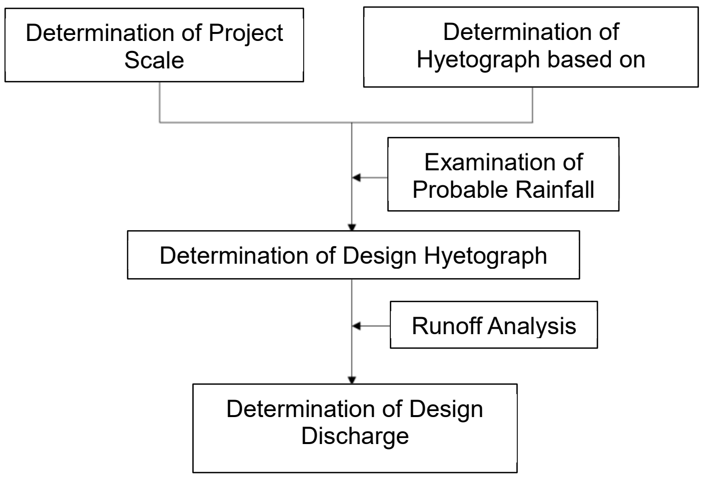


Figure 5-14 Flow Chart of Basic Flood Discharge Analysis

For more information on rainfall analysis, see Section 2.1. Further details of the runoff analysis are given in Aachment2.

(3) Results of Analysis

The runoff analysis was carried out using a hyetograph that was obtained by enlarging or reducing the hyetograph of the January 2020 flood (Daily rainfall 138.2 mm/day, 43-year rainfall) to the probable daily rainfall. The results are shown in Table 5-6 and Figure 5-15. As shown in the table, the basic flood discharge corresponding to 50-year flood at the Bekasi weir is 1,022 m^3/s.

In the 2015D/D of which design scale is 25-year flood, the upstream section of Bekasi Weir (Bekasi Weir to the confluence of Cileungsi and Cikeas rivers) will be improved to accommodate 663 m^3/s. However, the 25-year flood discharge revised in this study is 871 m^3/s. This means that the flow capacity after the ongoing river improvement work will be still short by about 200 m^3/s from the revised 25-year discharge.

Table 5-6 Comparison of probable discharges (Bekasi weir)

Return Period	Discharge in 1997M/P	Discharge In 2015D/D	Updated Discharge
1/25	-	663 m3/s	871 m3/s
1/50	590 m3/s	738 m3/s	1,022 m3/s
1/100	-	813 m3/s	1,185 m3/s
1/200	-	-	1,370 m3/s

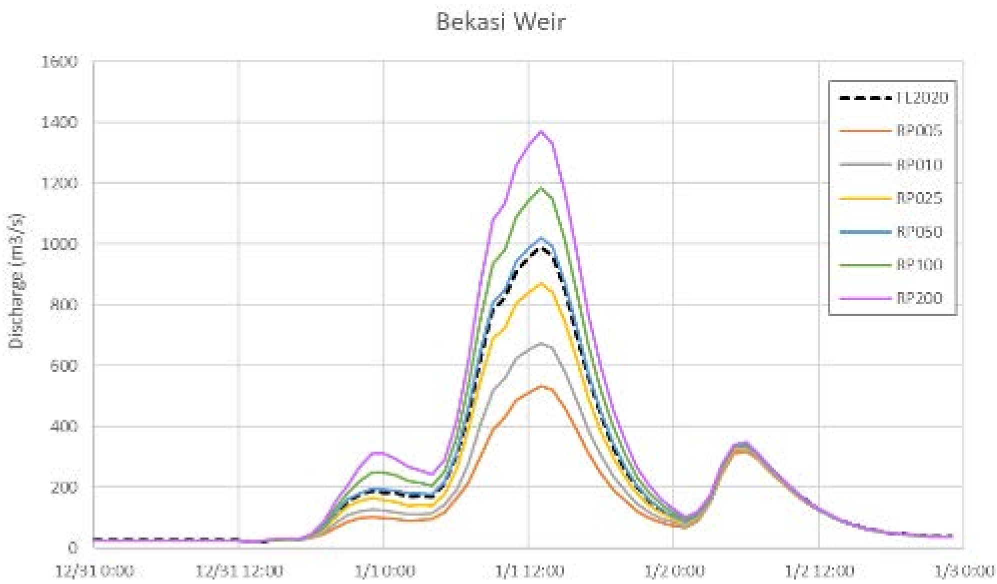


Figure 5-15 Hydrograph by Return Period (Bekasi Weir Site)

A flow distribution diagram of the Bekasi River is prepared based on these results as shown in Figure 5-16.

Flood Distribution: Bekasi River

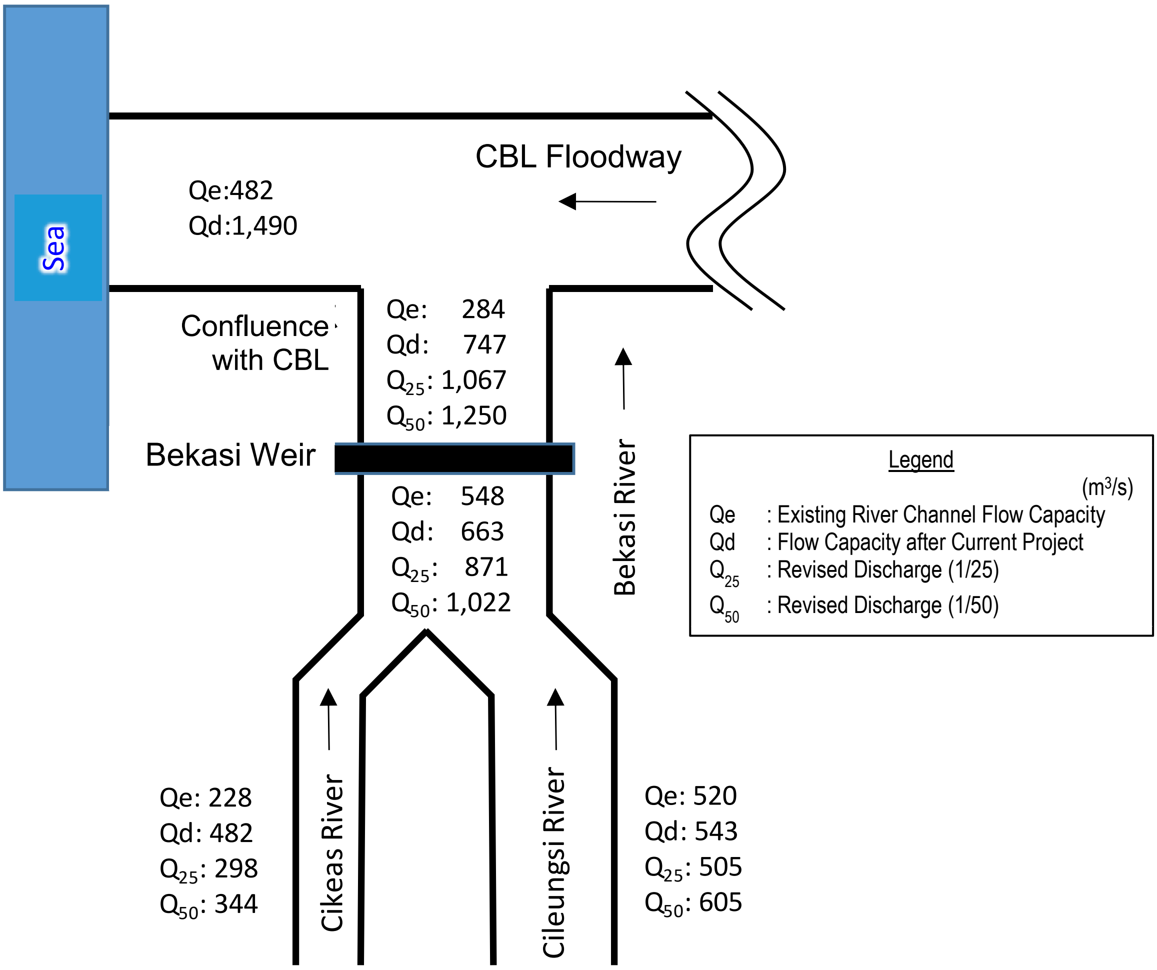


Figure 5-16 Flood Distribution of Bekasi River after Flow Revision

Under the ongoing river improvement project the river section from the Bekasi Weir to the confluence of the Cileungsi and Cikeas rivers is being improved at a design discharge of 663 m^3/s. If the 50-year flood discharge is applied as the target design scale, the flow capacity of the river improvement section will still be 359 m^3/s short to ensure the target safety level even after the completion of the project. Several countermeasures, therefore, shall be additionally provided.

5.5 Inundation Analysis

Balai Hidrologi dan Lingkungan Keairan (BHLK, Hydrological and Aquatic Environment Center) of PUPR has been conducting inundation analysis in the Ciliwung River basin including the East and West floodways using SOBEK, an inundation analysis software, and utilized it in the Jakarta Flood Early Warning System (JFEWS). A model of the Ciliwung River basin in the DKI Jakarta, where many drainage channels and rivers are interlaced, enables real-time inundation calculations, and PUPR has been continuously maintaining and improving the system since the system was installed. However, among the three major rivers (Bekasi, Ciliwung, and Cisadane) that flow through the metropolitan area, only the Ciliwung River is modeled, and the modeling of the whole area of JABODETABEK including the other two river basins had been left as a future issue. Under these situations the modeling of Bekasi and Chisadane Rivers was conducted in this study by using SOBEK in order to obtain basic information on flood inundation areas for preparing the master plan, and the analysis results are also expected to contribute to disaster prevention activities in Indonesia in the future (refer to Attachment 5-1 Runoff Analysis and Chapter 6: Countermeasures for Non-Structures).

Data necessary for the modeling and analysis of Bekasi and Cisadane Rivers were arranged and input, and verification calculation was carried out for the January 2020 flood. As a result, the water level hydrographs and inundation areas of the January 2020 flood were reproduced almost the same as the actual phenomenon. In the future, the model will be incorporated into the JFEWS and also modified to be applied for flood control project development, flood forecasting, and flood warning.

Using this model, flood inundation areas of the 50-year return period was estimated for the Bekasi River basin. The 50-year model hyetograph which was obtained by enlarging the actual hyetograph of the January 2020 flood to the 50-year return period daily rainfall was applied to the model as the external force. From the actual average daily rainfall in the Bekasi river basin (138.2 mm/day) and the 50-year return period (142.5 mm / day), the extension rate is 1.03 times. The inundation area map is shown in Figure 5-17, and the inundation area is shown in Table 5-7.

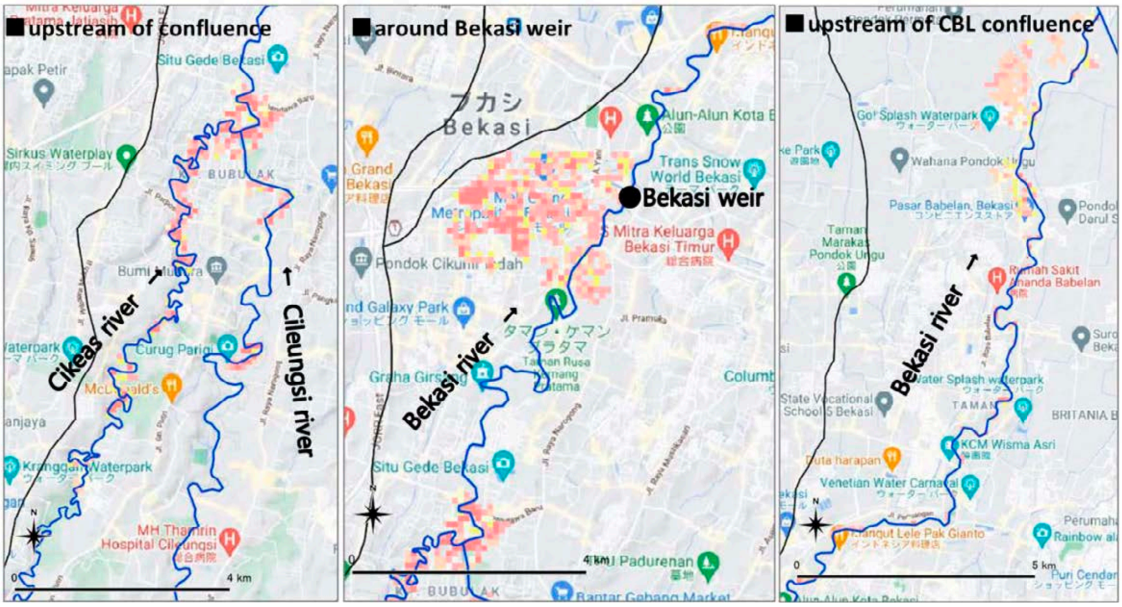


Figure 5-17 Flooded area map (50-year flood)

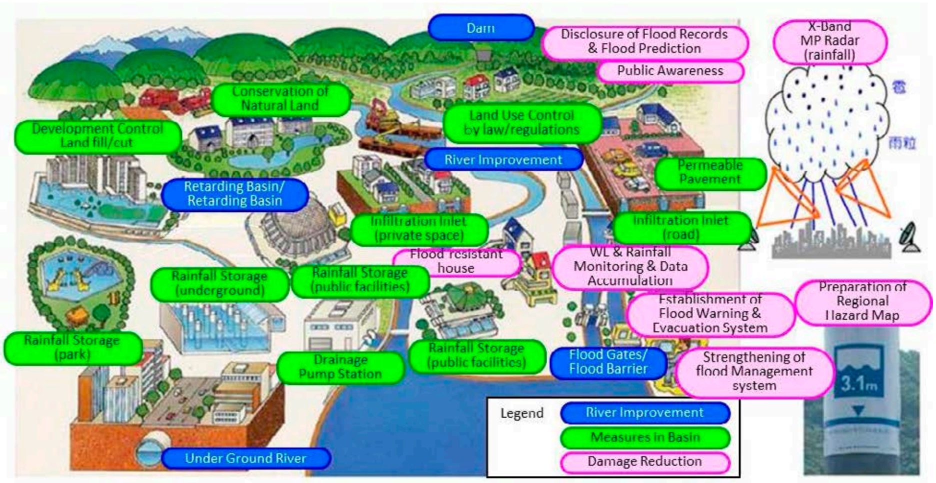
Table 5-7 Inundation area (50-year flood)

Inundation depth	Area(km^2)
- 0.2	0.50
0.2 - 0.5	1.03
0.5 - 2.0	2.46
2.0 - 5.0	2.87
5.0 - .	1.60
sum	8.46

5.6 Flood Control Measures

In planning of flood control measures, besides the ongoing river improvement project, flood control measures that can be implemented in the Bekasi River basin are listed, and a combination of these measures that can ensure the targeted safety level of flood control is selected. The outline of the flood control measures currently being taken by the Ministry of Land, Infrastructure, Transport and Tourism Japan (MLIT) is presented in Figure 5-18. Among them, following measures are examined in this study:

a) Improvement of ongoing river improvement projects
b) Retention Pond plan
c) Dam plan
d) Improvement of flood gates standard operation procedure (SOP) of Bekasi weir



Source:Ministry of Land, Infrastructure, Transport and Tourism website

Figure 5-18 Example of Flood Control Facilities

5.6.1 River Channel Improvement

In June 2020, the JICA study team proposed the following improvement points in the ongoing river project, based on the results of the 2015DD review (See Chapter 2.5 for details):

a) <u>Extension of Project Area</u> : Extension of the improvement area to the upstream of the confluence of Cikeas and Cileungsi rivers;
b) <u>Revision of Design Flood Discharge</u> : Rainfall analysis and runoff analysis including the January 2020 flood and examination of design high water level;
c) <u>Change of Longitudinal Profile</u> : a longitudinal riverbed profile so as to eliminate the effect of sedimentation by Bekasi weir;
d) <u>Smoothing of Channel Width</u> : smooth change from upstream to downstream and widening of meandering portion;
e) <u>Lowering of Design High Water Level (HWL) and Structural Design Review of Dike (retaining wall)</u> : efforts to lower flood water level and change to more resilient dike structure (avoiding concrete retaining walls); and
f) Shortcut at Meandering Portion

These issues were proposed to PUPR by the JICA study team in June 2020, and BBWS CiliCis has started to study and revise them partially (shape of embankment, extent of repair, etc.).

Shortcuts of meandering portions were proposed in the retention pond plan as described in the next section, and their effects are expected from the results of the inundation area survey and the inundation analysis (see Figure 5-19). In conclusion three shortcuts are proposed, namely two (2) shortcuts on the upstream section of the Bekasi weir and one (1) shortcut on the Cikeas River (see Figure 5-20 and Figure 5-21). The original river channels are to be used as retention ponds.

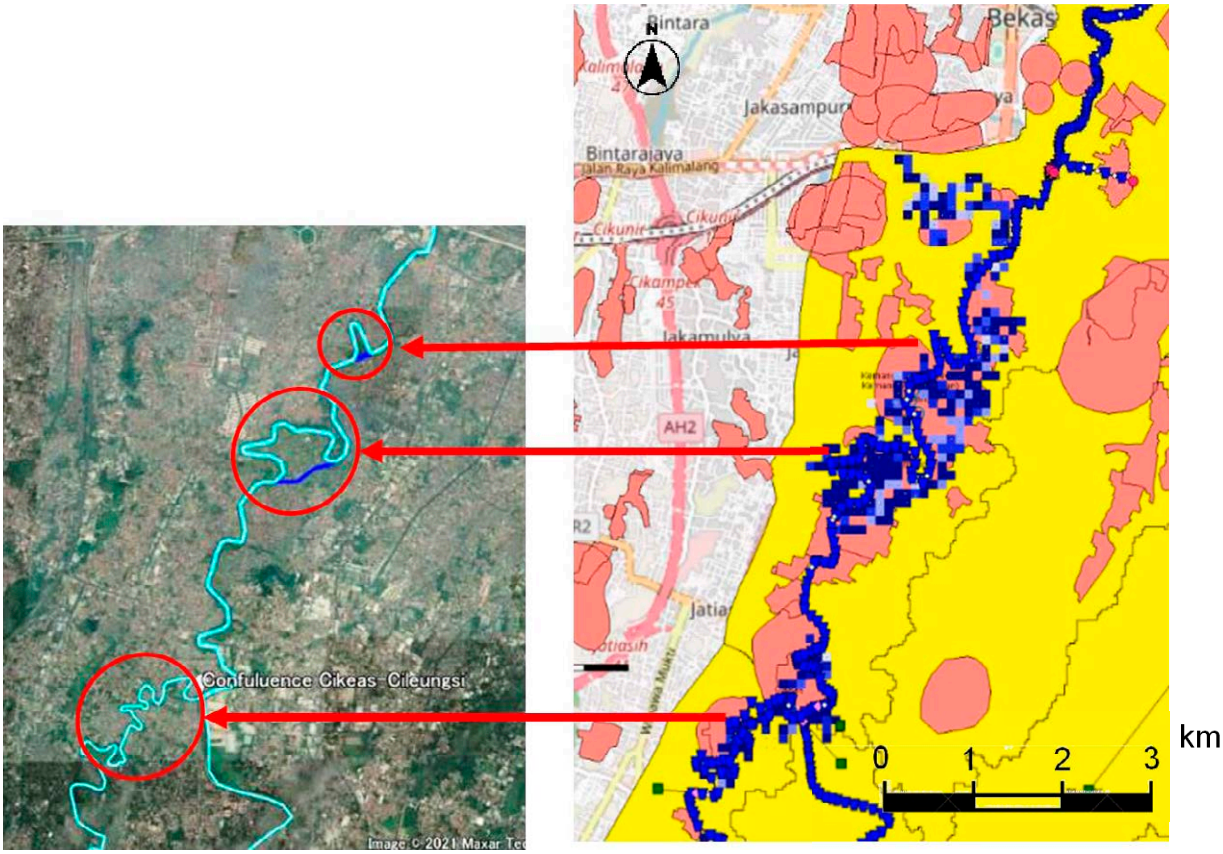


Figure 5-19 Relationship between Flood Area and River Meandering Portion

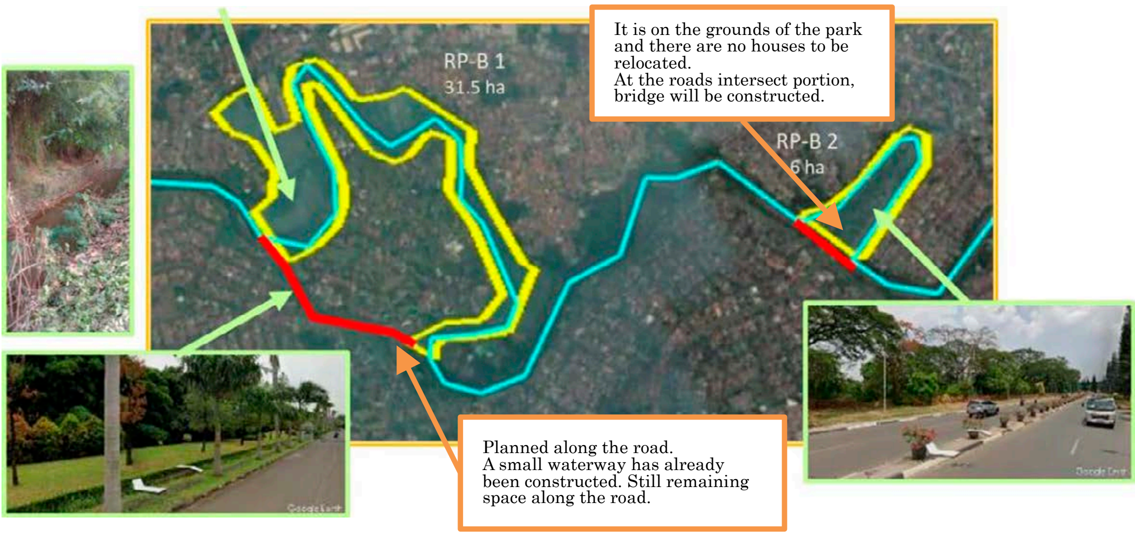


Figure 5-20 Shortcut Point for the Upstream Section of Bekasi Weir

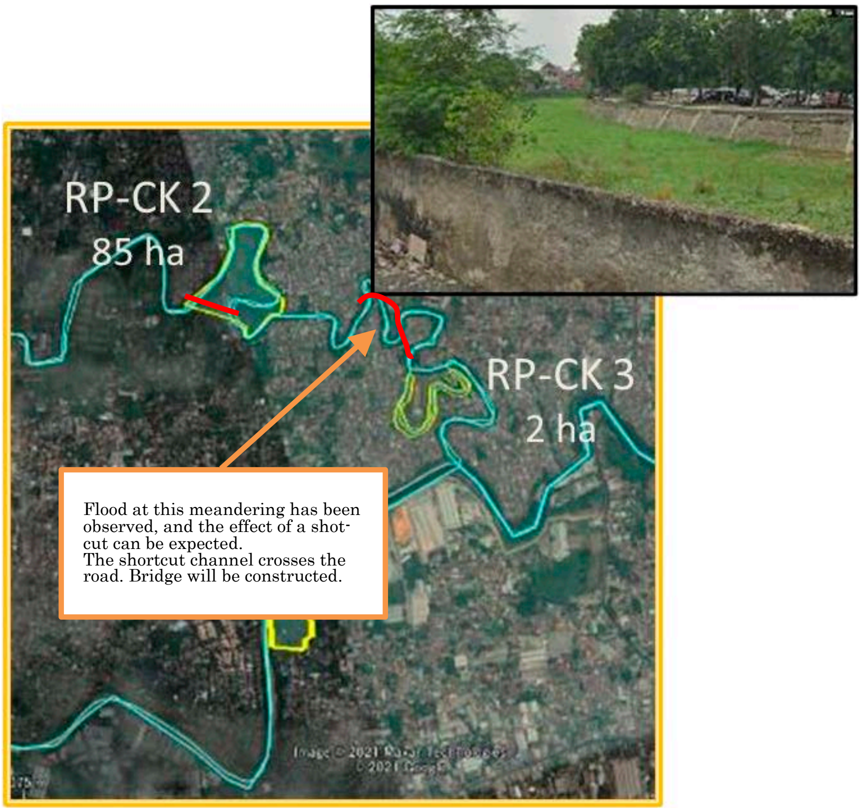


Figure 5-21 The Cikeas River Shortcut

5.6.2 Retention Pond Plan

It is judged that the measures for increasing the flow capacity of the river channel have almost reached to the limit when the ongoing river channel improvement project is completed. Therefore, in order to make up for the shortage of the flow capacity of the river channel, retention ponds are planned to regulate the flood discharge. The candidate sites for the retention ponds are spaces that are relatively easy to acquire such as agricultural land, idle land, and wasteland along the river channel.

From the field survey and interpretation of satellite photographs, a total of eight sites were nominated, namely three (3) sites along the Cikeas river, two (2) sites along the Cileungsi river, two (2) sites along the upstream section and one (1) along the downstream section of the Bekasi Weir (see Figure 5-22). Table 5-8, Figure 5-23 and Figure 5-24 show the location, features and current status of each retention pond site.

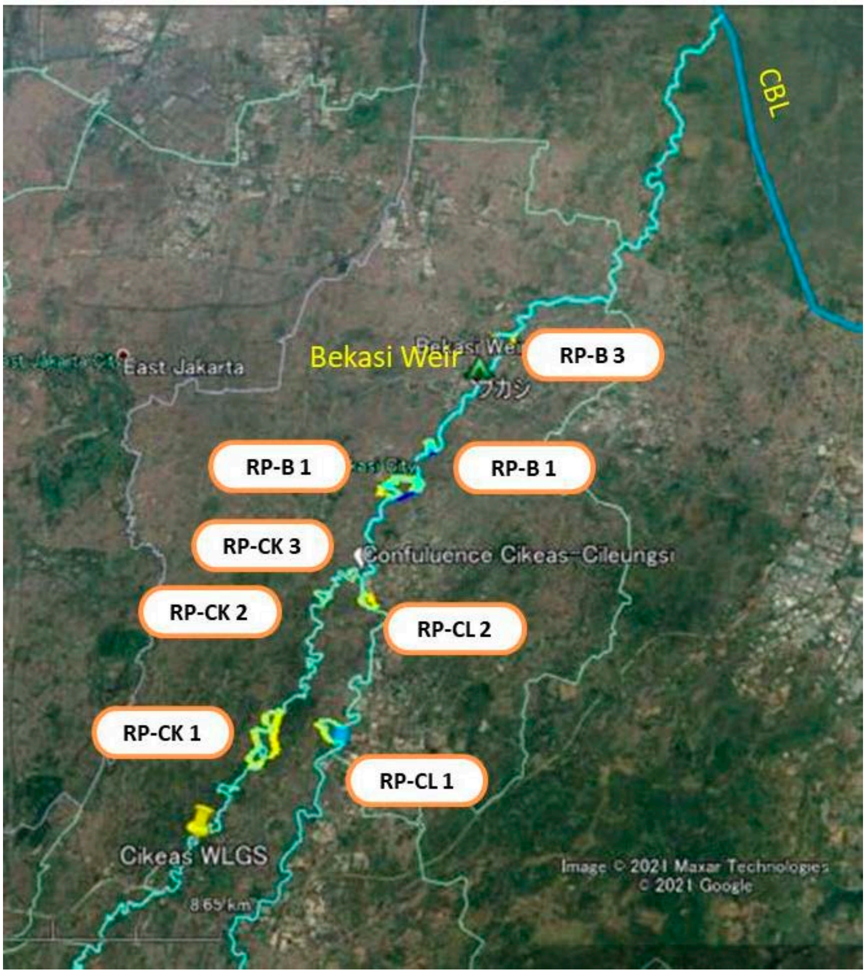


Figure 5-22 Proposed Site for Retarding Basins

Table 5-8 Feature of Proposed Retention Ponds (maximum development)

	A (m^2)	h (m)	V (m^3)	
RP-CL 1	250,000	5	1,000,000	Cileungsi
RP-CL 2	110,000	5	440,000	Cileungsi
RP-CK 1	610,000	5	2,440,000	Cikeas
RP-CK 2	85,000	5	340,000	Cikeas, Short cut
RP-CK 3	20,000	5	80,000	Cikeas, Short cut
RP-B 1	315,000	5	1,260,000	Upper Weir, Short cut
RP-B 2	63,000	5	252,000	Upper Weir, Short cut
RP-B 3	195,000	5	780,000	Lower weir downstream

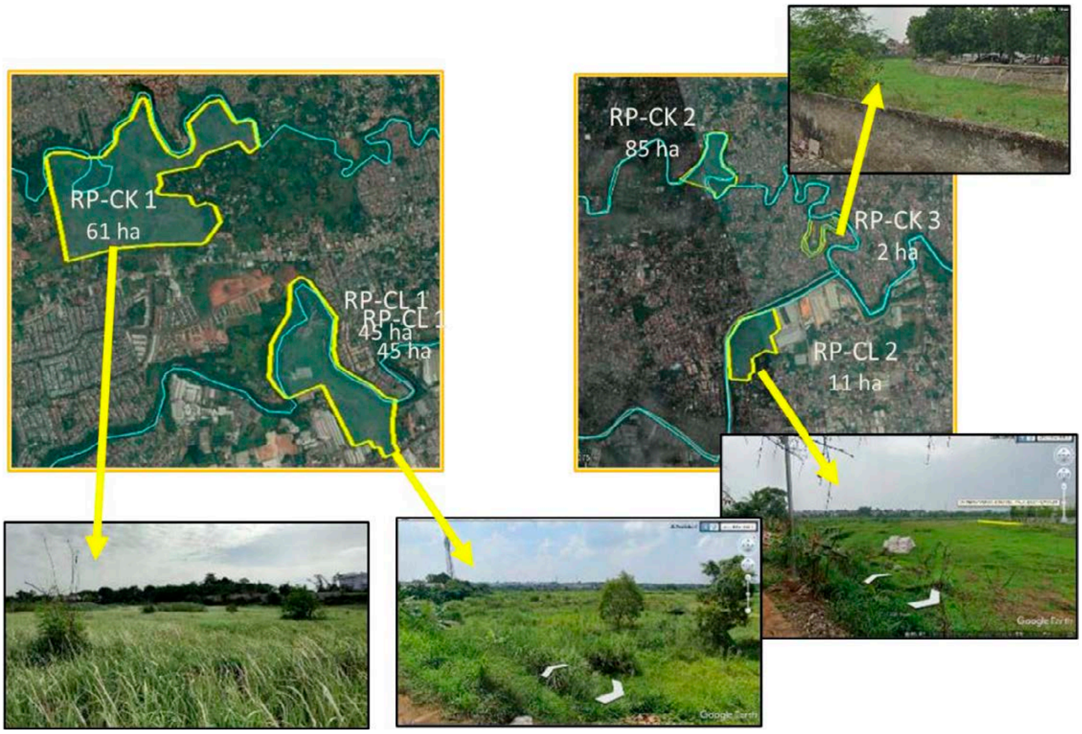


Figure 5-23 Proposed Sites for Retention Pond along the Cikeas/Cileungsi River (RP-B1, 2 & 3)

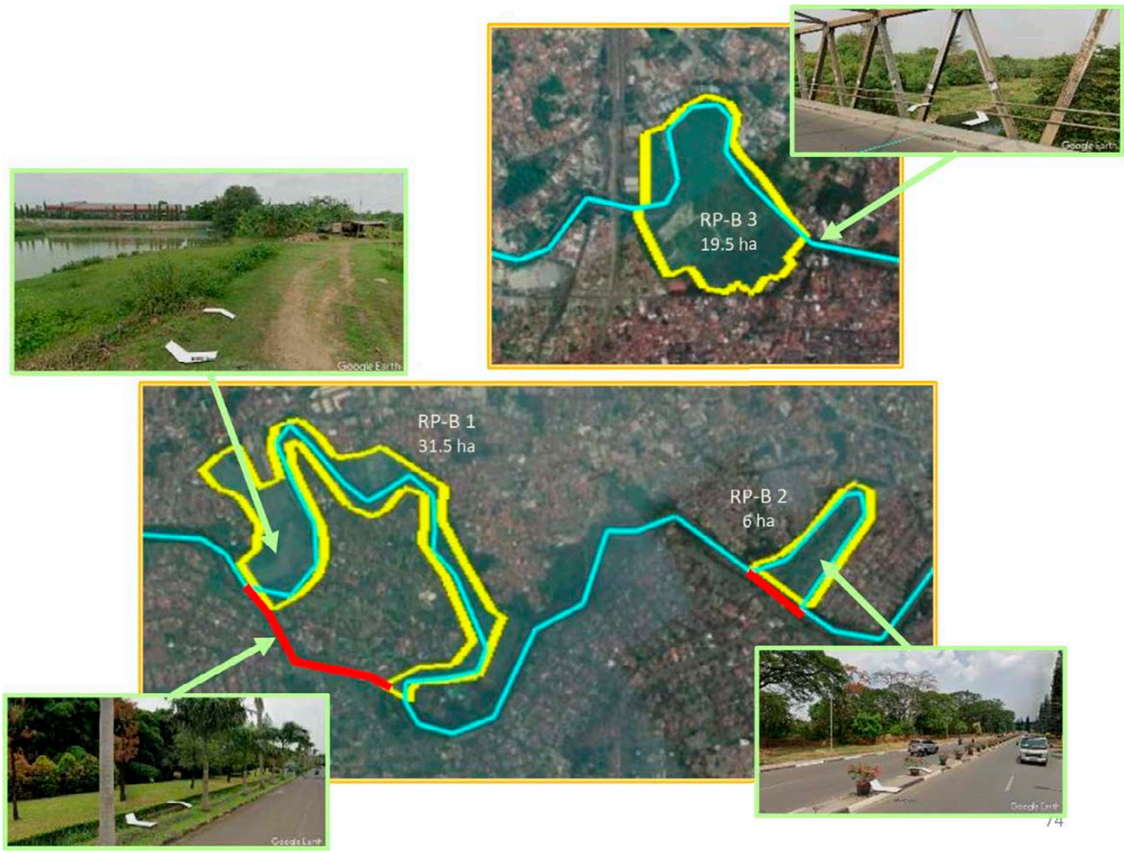


Figure 5-24 Proposed Sites for Retention Pond along Bekasi River (RP-B1, 2 & 3)

5.6.3 Dam

BBWS CiliCis had carefully studied potential dam sites in the basin and proposed the Narogong Dam on the upstream of the Cileungsi River. According to BBWA CiliCis, this site was the only one suitable site for dam construction with a wide catchment area in the Bekasi River basin.

The Narogong Dam aims to develop municipal water for Bekasi city and reduce flooding. The dam reservoir has a flood control function to regulate the 100-year flood discharge of 113 m^3/s to 81 m^3/s at the dam site (peak cut of 32 m^3/s). Due to its small catchment area of only 16.8 km^2 (6.4% of the Cileungsi River basin), however, this peak cut at the dam can hardly contribute to reduction of the flood discharge in the flood prone areas located in the downstream. To confirm the effect of flood mitigation by dam, runoff analysis with and without dam using 2020 flood was conducted. As a result, it is found that the Narogong Dam contributes to reduce the flood discharge about 12m^3/s at Bekasi weir site. This reduction, however, is only 1.2% of total discharge and it is negligible small. Therefore, the effect of flood control function of Narogong dam is not considered in this plan.

It can be said that the construction of retention ponds is essential to effectively regulate the flood discharge.

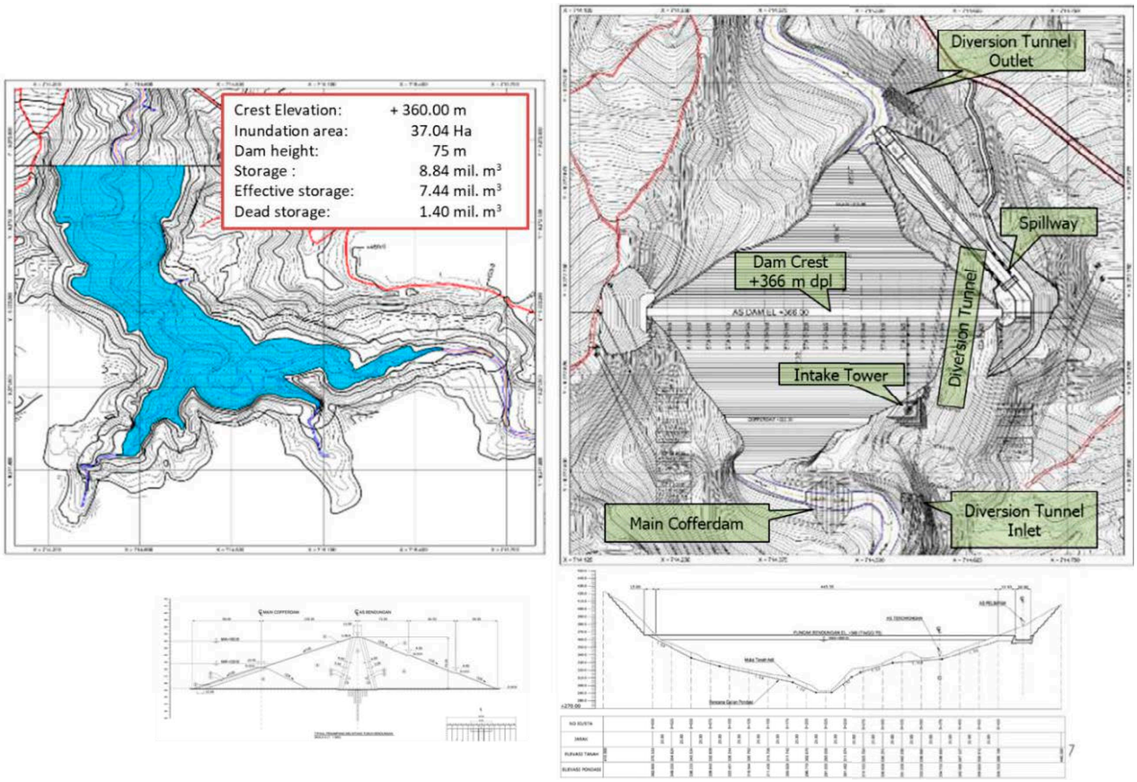


Figure 5-25 Design Features and Structural Details of Narogong Dam

Source : DED Lanjutan dan Model Test Waduk Narogong, BBWS CiliCis

5.6.4 Improvement of Operation of Bekasi Weir Flood Gate

(1) Current Gate Operation Procedure

In accordance with the request of BBWS CiliCis, the Balai Teknik Sungai, PUPR (BTS, River Technology Center) studied the operation procedure of the Bekasi weir flood gates during floods. The study aimed to simplify the gate operation procedure during small-scale floods (the objective flood is the 5-year discharge, 290 m^3/s), and it aimed to avoid gate operation errors rather than to reduce the release discharge during a flood. According to the proposed operation procedure, the water level is to be temporarily lowered by 1 m during a flood to secure a room for operation time, thus the transfer of municipal and irrigation water for of Bekasi City will be affected. Therefore, BTS proposed that a water intake pump of 5 m^3/s capacity be installed so as not to stop the water transfer to Bekasi City when the water level is drawn down.

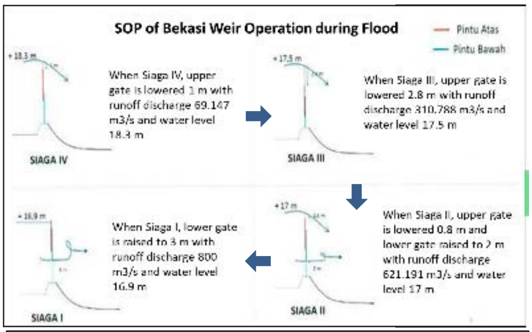
The effect of the sedimentation by the weir on the flood was also mentioned in the BTS study. It advocated the necessity of flushing sediment, but no concrete measures were presented in the study. (BTS informed that installation of sediment flushing gates had been proposed, but their specifications and structural details are still unknown.)

Existing SOP of Bekasi Weir based on upper stations

Status	STA. Gn Putri TMA	STA. Gn Putri Gate opening in Bekasi Weir (m) Upper gate	STA. Gn Putri Gate opening in Bekasi Weir (m) Lower gate	STA. Stasiun Villa Nusa Indah TMA	STA. Stasiun Villa Nusa Indah Gate opening in Bekasi Weir (m) Upper gate	STA. Stasiun Villa Nusa Indah Gate opening in Bekasi Weir (m) Lower gate	STA. Bendung Bekasi Gate opening in Bekasi Weir (m) Upper gate	STA. Bendung Bekasi Gate opening in Bekasi Weir (m) Lower gate
Normal	<0.2	0	-		-	-	-	-
Siaga IV	0,2 – 1,2	0 s.d. 1	-	<22	1	-	1	-
Siaga III	1,2 – 2,4	1 s.d. 2	-	22,2 - 23	2.8	-	2 s.d. 2,8	-
Siaga II	2,4 - 3,0	2 s.d. 2,8	-	23 – 23,5	0.8	2	0,8	2
Siaga I	>3,0	> 2,8	-	>23,5	-	>3	-	>3

Rekomendasi Perubahan SOP Banjir

Status	Gate opening in Bekasi Weir (m) Upper gate	Gate opening in Bekasi Weir (m) Lower gate	Notes
Siaga IV	1	-	Entering the peak of flood season, upper gate lowered 1 m
Siaga III	2 s.d. 2,8	-	Opening of Upper gate
Siaga II/I	-	3 s.d. >4	Opening of Lower gate



Proposed SOP for Bekasi Weir Flood Gates by BTS

Siaga I: Lowered upper gate 1m, WL+18.3m, Q=69m^3/s
Siaga II: Lowered upper gate 2.8m, WL+17.5m, Q=310m^3/s
Siaga III: Lowered upper gate 0.8m & Open lower gate 2m, WL+17m, Q=621m^3/s
Siaga IV: Lower gate 3m open, WL+16.9m, Q=800m^3/s

Figure 5-26 New Gate Operation Procedure Proposed by BTS

A detail structural design of the Bekasi weir gate is shown below.

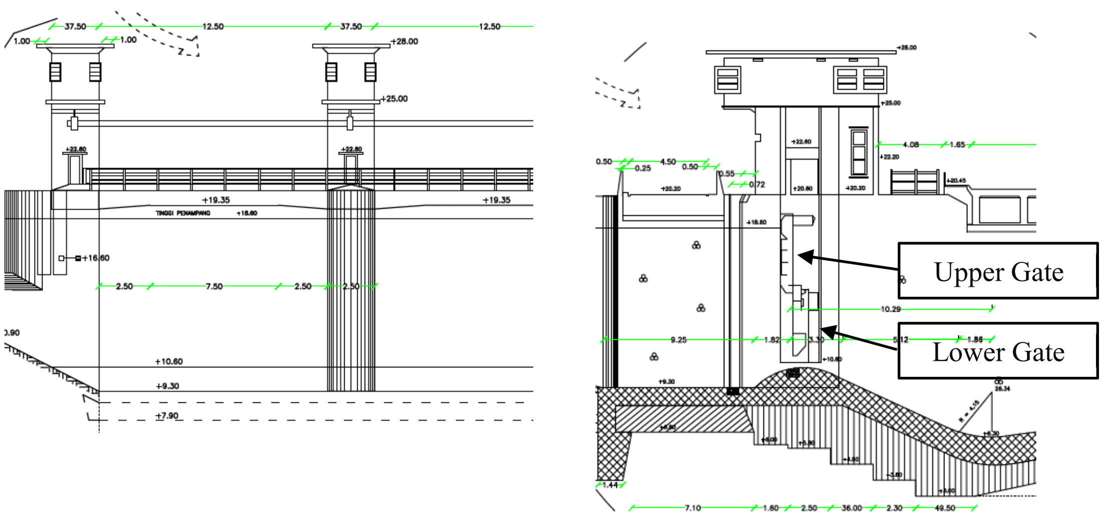


Figure 5-27 Detail of Bekasi Weir Flood Gate

(2) Proposal of Gate Operation Procedure during Large Scale Flood

The study team proposed a gate operation procedure that aims at reducing release discharge to the downstream during a large-scale flood like the 50-year flood.

This operation procedure is a pre-release method which is to release the impounded water before a flood comes to ensure a space in the river channel for storing the flood water based on the flood information in the upstream area. When a flood arrives at the weir, part of flood discharge exceeding the flow capacity in the downstream is stored in the river channel above the weir while the rest part is safely released to the downstream.

(3) Conditions for Gate Operation

The pre-release method shall be carried out under the following conditions.

a) At normal conditions, the current operation procedure is followed. Namely the water level s maintained at EL. 18.8 m by operating the upper gate. The pre-release is carried out by opening the lower gate to discharge sediment. As the water level is lowered, sedimentation in the upstream are efficiently carried down to the weir in an open channel flow condition, and is discharged to the downstream.

b) Considering the top elevation of the West Tarum siphon (EL. 12 m), the lowest upstream water level of the weir is set at EL. 13 m (see Figure 5-28).

c) The effects of discharging sediment and the stability of river structures (Dikes and bridges) after lowering of the river bed should be examined in detail in the future.

d) To continue the water transfer to Bekasi City even when the water level is drawn down, it is necessary to install a water pump of 5 m^3/s against 8m head (EL 12 to 20 m) on the left bank of the weir (This pump installation will be implemented in accordance with the BTS's proposal).

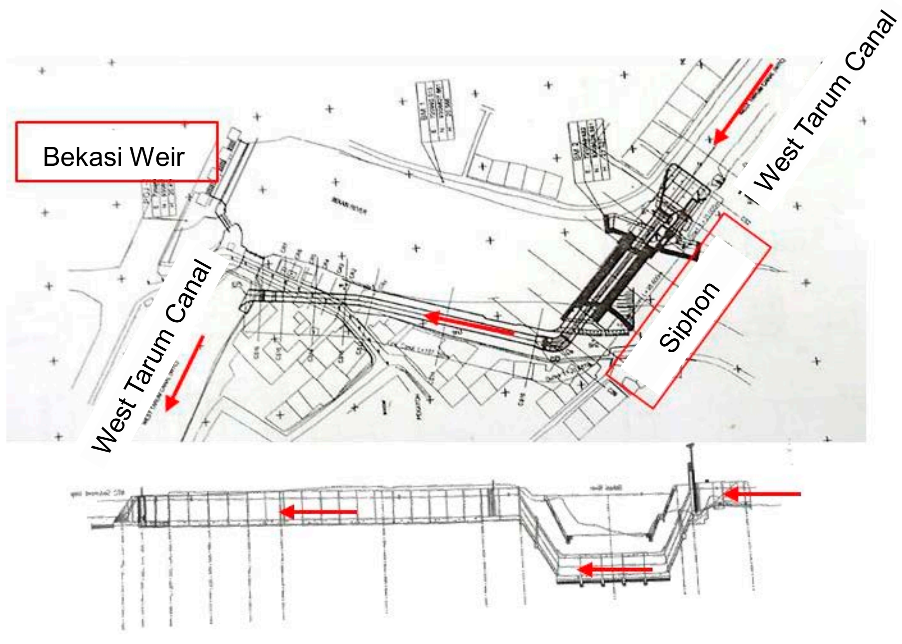


Figure 5-28 West Tarum Waterway and Siphon

(4) Standard Operation Procedure

The standard operation procedure of the gate was set as follows on the premise of development of a retention pond.

a) In the event of the January 2020 flood, the flood travel time from the Cileungsi WLGS to the Bekasi Weir was about 3 ~ 4 hours. Since the discharge at the Cileungsi WLGS was about 250 m^3/s 4 hours before the design discharge at the weir (663 m^3/s) reached the weir, the start time of pre-release (lowering water level at the Weir) is set when the discharge at Cileungsi WLGS exceeds 250 m^3/s.

b) Lowering the water level up to EL. 13 m in one hour (1 m/10 min). There is a margin of 2 ~ 3 hours before the design discharge reaches the weir (the lowered water level is maintained by continuing to release water until the design flood comes).

c) The maximum release discharge from the weir is set at 747 m^3/s which is the design discharge for downstream section of the weir.

d) The maximum limit of the upstream water level of the weir is set at the maximum water level of the weir (EL 18.8 m) and when the maximum limit is reached, IN = OUT operation is conducted. In this extraordinary flood case, the release discharge to the downstream section would exceed the design discharge.

(5) Effects and Issues of pre-release

It was found that the proposed gate operation procedure could reduce the peak discharge at the weir from 830 m^3/s (84% of the peak inflow of 990 m^3/s of the January 2020 flood at the Weir) to 740 m^3/s of the design discharge of the downstream section (see Table 5-9).

Table 5-9 Simulation Results of Pre-release (84% of 2020 flood, no Retention Pond)

Efect of Runoff Control Measures : Bekasi Weir Preliminary Release System : Flood on Jan 2020

Catchment Area			Prliminary lerease					Orifice Flow (Lower Gates)		Overflow (Upper Gates)		Design Discharge (2015DD)		
RP-B 2	382.0	km2	Target WL	EL.	13.0	m	at Bekasi Weir	C	0.80	C	1.8	Max Q from Bekasi Weir	750.0	m3/s
Bekasi Weir	385.0	km2	Cileungsi	More than	250.0 m3/s		9:00am	B	12.5 x 3			Max Q from Bekasi Weir	750.0	m3/s
Rate	101%		Cikeas	More than	300.0 m3/s		6:00am	=	37.50					
			Expected Discharge at Confuluence					Sill EL.	10.60	m		Qmax	745.5	m3/s
				More than	500.0 m3/s				13.00			Hmax EL.	18.8	m
Q25												Hmin EL.	13.0	m

Qmax
Q

	Discharge at WLGS			Inflow at Bekasi Weir					Gete Open (H)		Discharge from Weir			Volume from Weir		Volume	Volume at	Water
	Cileungsi	Cikeas	Total	Discharge (m3/s)				Volume	Lower	Upper	Lower	Upper	Total	Lower	Upper	Valance	US of Weir	Level
Time	(m3/s)	(m3/s)	(m3/s)	w/o RPs			Total	(m3)	(m)	(m)	(m3/s)	(m3/s)	(m3/s)	(m3)	(m3)	(m3)	(m3)	(EL.m)
																	882,000.0	18.8
2019/12/31 18:00	101.3	8.0	109.3	33.1			27.8	33,360.8	-	1.00	-	66.5	66.5	-	79,850.0	-46,489.2	835,510.8	18.7
2019/12/31 18:20	93.8	8.6	102.5	48.7			40.9	49,056.0	-	1.00	-	57.6	57.6	-	69,159.0	-20,103.0	815,407.8	18.7
2019/12/31 18:40	86.4	9.3	95.6	57.9			48.7	58,396.8	-	1.00	-	57.6	57.6	-	69,159.0	-10,762.2	804,645.6	18.7
2019/12/31 19:00	78.9	9.9	88.8	67.2			56.4	67,737.6	-	1.00	-	57.6	57.6	-	69,159.0	-1,421.4	803,224.1	18.7
2019/12/31 19:20	72.2	12.5	84.7	82.5			69.3	83,193.6	-	1.00	-	57.6	57.6	-	69,159.0	14,034.6	817,258.7	18.7
2019/12/31 19:40	65.5	15.0	80.6	97.9			82.2	98,649.6	-	1.00	-	57.6	57.6	-	69,159.0	29,490.6	846,749.3	18.7
2019/12/31 20:00	58.9	17.6	76.5	113.2			95.1	114,105.6	-	1.10	-	67.5	67.5	-	81,000.0	33,105.6	879,854.9	18.8
2019/12/31 20:20	53.6	19.1	72.7	127.2			106.8	128,217.6	-	1.20	-	88.7	88.7	-	106,477.3	21,740.3	901,595.3	18.8
2019/12/31 20:40	48.4	20.6	69.0	141.2			118.6	142,329.6	-	1.50	-	124.0	124.0	-	148,806.5	-6,476.9	895,118.4	18.8
2019/12/31 21:00	43.1	22.1	65.2	155.2			130.4	156,441.6	-	1.50	-	124.0	124.0	-	148,806.5	7,635.1	902,753.4	18.8
2019/12/31 21:20	38.5	21.1	59.7	162.3			136.4	163,632.0	-	1.70	-	149.6	149.6	-	179,538.8	-15,906.8	886,846.6	18.8
2019/12/31 21:40	34.0	20.2	54.1	169.5			142.4	170,822.4	-	1.70	-	149.6	149.6	-	179,538.8	-8,716.4	878,130.2	18.8
2019/12/31 22:00	29.4	19.2	48.6	176.6			148.3	178,012.8	-	1.90	-	176.8	176.8	-	212,136.5	-34,123.7	844,006.5	18.7
2019/12/31 22:20	27.4	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	-	1.80	-	149.6	149.6	-	179,538.8	1,901.2	845,907.6	18.7
2019/12/31 22:40	25.4	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	-	1.80	-	149.6	149.6	-	179,538.8	5,328.4	851,236.0	18.7
2019/12/31 23:00	23.4	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	-	1.80	-	149.6	149.6	-	179,538.8	8,755.6	859,991.6	18.8
2019/12/31 23:20	21.8	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	-	1.80	-	163.0	163.0	-	195,611.2	-8,560.0	851,431.5	18.7
2019/12/31 23:40	20.3	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	-	1.80	-	149.6	149.6	-	179,538.8	6,269.2	857,700.7	18.8
2020/01/01 0:00	18.7	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	-	1.80	-	163.0	163.0	-	195,611.2	-11,046.4	846,654.3	18.7
2020/01/01 0:20	20.9	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	-	1.70	-	136.6	136.6	-	163,932.5	19,725.1	866,379.4	18.8
2020/01/01 0:40	23.0	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	-	1.70	-	149.6	149.6	-	179,538.8	3,211.6	869,591.0	18.8
2020/01/01 1:00	25.1	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	-	1.70	-	149.6	149.6	[illegible]	[illegible]	[illegible]	[illegible]	18.8
2020/01/01 1:20	30.0	47.6	77.7	176.9			148.6	178,348.8	-	1.70	-	149.6	149.6	[illegible]	[illegible]	[illegible]	[illegible]	18.8
2020/01/01 1:40	35.0	57.5	92.4	173.5			145.7	174,854.4	-	1.60	-	136.6	136.6	[illegible]	[illegible]	[illegible]	[illegible]	18.8
2020/01/01 2:00	39.9	67.3	107.2	170.0			142.8	171,360.0	-	1.60	-	136.6	136.6	[illegible]	[illegible]	[illegible]	[illegible]	18.8
2020/01/01 2:20	69.4	88.4	157.8	170.6			143.3	171,998.4	-	1.60	-	136.6	136.6	[illegible]	[illegible]	[illegible]	[illegible]	18.8
2020/01/01 2:40	99.0	109.4	208.4	171.3			143.9	172,636.8	-	1.60	-	136.6	136.6	[illegible]	[illegible]	[illegible]	[illegible]	18.8
2020/01/01 3:00	128.5	130.5	259.0	171.9			144.4	173,275.2	-	1.70	-	149.6	149.6	-	179,538.8	6,263.6	899,561.4	18.8
2020/01/01 3:20	153.0	162.2	315.2	170.9			143.6	172,300.8	-	1.70	-	149.6	149.6	-	179,538.8	[illegible]	892,323.3	18.8
2020/01/01 3:40	177.5	193.9	371.4	170.0			142.8	171,326.4	-	1.70	-	149.6	149.6	-	179,538.8	[illegible]	884,110.9	18.8
2020/01/01 4:00	201.9	225.6	427.5	169.0			142.0	170,352.0	-	1.70	-	149.6	149.6	-	179,538.8	-9,186.8	874,924.1	18.8
2020/01/01 4:20	213.8	243.2	456.9	182.7			153.5	184,195.2	1.00	-	391.9	-	391.9	470,339.7	-	-286,144.5	[illegible]	18.0
2020/01/01 4:40	225.6	260.7	486.3	196.5			165.0	198,038.4	1.00	-	373.5	-	373.5	448,193.5	-	-250,155.1	[illegible]	16.7
2020/01/01 5:00	237.4	278.3	515.7	210.2			176.6	211,881.6	1.00	-	341.4	-	341.4	409,660.4	-	-197,778.8	140,845.7	14.9
2020/01/01 5:20	242.0	296.9	538.9	241.5			202.9	243,465.6	1.10	-	321.9	-	321.9	386,291.9	-	-142,826.3	-1,980.6	13.2
2020/01/01 5:40	246.6	315.5	562.1	272.9			229.2	275,049.6	1.00	-	234.0	-	234.0	280,758.5	-	-5,708.9	-7,689.4	13.1
2020/01/01 6:00	251.2	334.1	585.3	304.2			255.5	306,633.6	1.10	-	255.3	-	255.3	306,333.6	-	300.0	-7,389.4	13.1
2020/01/01 6:20	235.1	313.8	548.9	351.3			295.1	354,144.0	1.20	-	280.8	-	280.8	336,910.2	-	17,233.8	9,844.5	13.3
2020/01/01 6:40	218.9	293.6	512.5	398.5			334.7	401,654.4	1.40	-	343.0	-	343.0	411,641.8	-	-9,987.4	-143.0	13.2
2020/01/01 7:00	202.8	273.3	476.1	445.6			374.3	449,164.8	1.50	-	364.8	-	364.8	437,789.8	[illegible]	[illegible]	[illegible]	13.3
2020/01/01 7:20	206.8	243.7	450.5	507.4			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	510,757.9	[illegible]	[illegible]	[illegible]	13.4
2020/01/01 7:40	210.7	214.1	424.8	569.2			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	586,707.0	[illegible]	[illegible]	[illegible]	13.2
2020/01/01 8:00	214.7	184.5	399.2	631.0			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	639,761.0	[illegible]	[illegible]	[illegible]	13.1
2020/01/01 8:20	306.6	199.0	505.5	681.7			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	665,619.3	[illegible]	[illegible]	[illegible]	13.4
2020/01/01 8:40	398.4	213.4	611.9	732.3			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	765,408.4	-	-27,216.4	-10,448.8	13.0
2020/01/01 9:00	490.3	227.9	718.2	783.0			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	761,620.2	-	27,643.8	17,195.0	13.4
2020/01/01 9:20	466.0	218.4	684.4	796.2			668.8	802,536.0	2.50	-	668.6	-	668.6	802,268.1	-	267.9	17,462.9	13.4
2020/01/01 9:40	441.6	208.9	650.5	809.3			679.8	815,808.0	2.60	-	699.6	-	699.6	839,493.4	-	-23,685.4	-6,222.5	13.1
2020/01/01 10:00	417.3	199.4	616.7	822.5			690.9	829,080.0	2.60	-	673.5	-	673.5	808,196.8	-	20,883.2	14,660.7	13.4
2020/01/01 10:20	372.3	169.5	541.8	853.0			716.5	859,857.6	2.70	-	730.9	-	730.9	877,081.2	-	-17,223.6	-2,562.9	13.2
2020/01/01 10:40	327.3	139.5	466.9	883.6			742.2	890,635.2	2.80	-	744.1	-	744.1	892,976.5	-	-2,341.3	-4,904.2	13.1
2020/01/01 11:00	282.3	109.6	391.9	914.1			767.8	921,412.8	2.80	-	734.8	-	734.8	881,743.6	-	39,669.2	34,764.9	13.7
2020/01/01 11:20	247.0	89.2	336.2	927.8			779.4	935,256.0	2.60	-	724.7	-	724.7	869,664.4	-	65,591.6	100,356.5	14.5
2020/01/01 11:40	211.7	68.9	280.5	941.6			790.9	949,099.2	2.40	-	720.2	-	720.2	864,267.8	-	84,831.4	185,188.0	15.4
2020/01/01 12:00	176.3	48.5	224.8	955.3			[illegible]	962,942.4	2.30	-	745.5	-	745.5	894,619.4	-	68,323.0	253,510.9	16.0
2020/01/01 12:20	153.2	39.6	192.8	966.9			[illegible]	974,601.6	2.20	-	745.3	-	745.3	894,399.1	-	80,202.5	333,713.4	16.6
2020/01/01 12:40	130.1	30.8	160.8	978.4			821.9	986,260.8	2.10	-	740.9	-	740.9	889,131.2	-	97,129.6	430,843.0	17.3
2020/01/01 13:00	106.9	21.9	128.8	***990.0***			***831.6***	997,920.0	2.00	-	737.5	-	737.5	884,967.6	-	112,952.4	543,795.4	17.8
2020/01/01 13:20	93.8	18.9	112.7	979.9			823.1	987,772.8	1.90	-	720.8	-	720.8	864,936.9	-	122,835.9	666,631.4	18.3
2020/01/01 13:40	80.7	16.0	96.6	969.9			814.7	977,625.6	1.90	-	742.6	-	***742.6***	891,073.8	-	86,551.8	753,183.2	18.5
2020/01/01 14:00	67.5	13.0	80.5	959.8			806.2	967,478.4	1.80	-	709.6	-	709.6	851,463.1	-	116,015.3	869,198.5	18.8
2020/01/01 14:20	59.4	12.0	71.4	922.4			774.8	929,745.6	1.85	-	742.6	-	742.6	891,128.2	-	38,617.4	907,815.9	18.8
2020/01/01 14:40	51.3	11.1	62.4	884.9			743.3	892,012.8	1.85	-	742.6	-	742.6	891,128.2	-	884.6	908,700.6	18.8
2020/01/01 15:00	43.2	10.1	53.3	847.5			711.9	854,280.0	1.85	-	742.6	-	742.6	891,128.2	-	-36,848.2	871,852.4	18.8
2020/01/01 15:20	38.5	9.7	48.2	798.3			670.5	804,652.8	1.85	-	742.6	-	742.6	891,128.2	-	-86,475.4	785,377.0	18.6
2020/01/01 15:40	33.8	9.3	43.1	749.0			629.2	755,025.6	1.85	-	734.4	-	734.4	881,308.3	-	-126,282.7	659,094.4	18.3
2020/01/01 16:00	29.1	8.9	38.0	699.8			587.8	705,398.4	1.85	-	722.0	-	722.0	866,369.8	-	-160,971.4	498,123.0	17.6
2020/01/01 16:20	26.4	8.7	35.1	652.4			548.0	657,619.2	1.85	-	692.1	-	692.1	830,468.9	-	-172,849.7	325,273.3	16.6
2020/01/01 16:40	23.8	8.4	32.2	605.0			508.2	609,840.0	1.85	-	646.9	-	646.9	776,307.2	-	-166,467.2	158,806.1	15.1
2020/01/01 17:00	21.2	8.2	29.4	557.6			468.4	562,060.8	-	-	-	-	-	-	-	562,060.8	720,866.9	18.5
2020/01/01 17:20	20.0	8.2	28.2	516.6			433.9	520,732.8	-	3.00	-	299.5	299.5	-	359,360.8	161,372.0	882,239.0	18.8
2020/01/01 17:40	18.9	8.1	27.1	475.6			399.5	479,404.8	-	3.40	-	423.2	423.2	-	507,812.5	-28,407.7	853,831.2	18.8
2020/01/01 18:00	17.8	8.1	25.9	434.6			365.1	438,076.8	-	3.40	-	423.2	423.2	-	507,812.5	-69,735.7	784,095.5	18.6
2020/01/01 18:20	17.3	8.1	25.4	401.8			337.5	405,014.4	-	3.40	-	386.4	386.4	[illegible]	[illegible]	[illegible]	[illegible]	18.5
2020/01/01 18:40	16.9	8.0	24.9	369.0			310.0	371,952.0	-	3.40	-	368.4	368.4	[illegible]	[illegible]	[illegible]	[illegible]	18.3
2020/01/01 19:00	16.4	8.0	24.4	336.2			282.4	338,889.6	-	3.40	-	333.4	333.4	[illegible]	[illegible]	[illegible]	[illegible]	18.0
2020/01/01 19:20	16.0	8.0	24.0	310.1			260.5	312,614.4	-	3.40	-	283.0	283.0	[illegible]	[illegible]	[illegible]	[illegible]	17.9
2020/01/01 19:40	15.7	8.0	23.7	284.1			238.6	286,339.2	-	3.40	-	266.8	266.8	[illegible]	[illegible]	[illegible]	[illegible]	17.8
2020/01/01 20:00	15.4	8.0	23.4	258.0			216.7	260,064.0	-	2.40	-	111.8	111.8	[illegible]	[illegible]	[illegible]	[illegible]	18.3
2020/01/01 20:20	15.1	8.0	23.1	238.5			200.3	240,408.0	-	2.30	-	163.0	163.0	-	195,611.2	44,796.8	704,027.8	18.4
2020/01/01 20:40	14.8	8.0	22.8	219.0			184.0	220,752.0	-	2.20	-	163.0	163.0	-	195,611.2	25,140.8	729,168.6	18.5
2020/01/01 21:00	14.4	8.0	22.4	199.5			167.6	201,096.0	-	2.10	-	163.0	163.0	-	195,611.2	5,484.8	734,653.3	18.5
2020/01/01 21:20	14.2	8.0	22.2	184.6			155.1	186,076.8	-	1.90	-	136.6	136.6	-	163,932.5	22,144.3	756,797.7	18.5
2020/01/01 21:40	13.9	8.0	21.9	169.7			142.5	171,057.6	-	1.90	-	136.6	136.6	-	163,932.5	7,125.1	763,922.8	18.6
2020/01/01 22:00	13.7	8.0	21.7	154.8			130.0	156,038.4	-	1.70	-	124.0	124.0	-	148,806.5	7,231.9	771,154.7	18.6
2020/01/01 22:20	21.3	12.8	34.1	144.8			121.6	145,924.8	-	1.70	-	124.0	124.0	-	148,806.5	-2,881.7	768,273.0	18.6
2020/01/01 22:40	28.9	17.7	46.5	134.7			113.2	135,811.2	-	1.60	-	111.8	111.8	-	134,176.7	1,634.5	769,907.5	18.6
2020/01/01 23:00	36.5	22.5	59.0	124.7			104.7	125,697.6	-	1.40	-	88.7	88.7	-	106,477.3	19,220.3	789,127.8	18.6
2020/01/01 23:20	86.7	55.5	142.2	117.9			99.1	118,876.8	-	1.40	-	88.7	88.7	-	106,477.3	12,399.5	801,527.4	18.6
2020/01/01 23:40	137.0	88.4	225.4	111.2			93.4	112,056.0	-	1.40	-	88.7	88.7	-	106,477.3	5,578.7	807,106.1	18.7
2020/01/02 0:00	187.2	121.4	308.6	104.4			87.7	105,235.2	-	1.40	-	100.1	100.1	-	120,060.5	-14,825.3	792,280.8	18.6

When Cileungsi WLGS discharge of 250 m^3/s at (210 m^3/s at 84% in this case), pre-discharge started from the lower gate.

1 hour after the start of pre-release, maintain the water level at EL. 13 m

start of storage

Peak cut of 88 m^3/s is possible up to 743 m^3/s of discharge for a maximum inflow of 831 m^3/s

The upper water level of the weir maintains the design flood level.

5.7 Long-Term Flood Control Measures

As shown in Table 5-10, when all proposed measures which are consisting of the 8 retention ponds and the improvement of Bekasi weir flood gates operation procedure, are completed, the 50-year flood discharge (1,022 m^3/s at the Bekasi weir site) can be safely drained down in all sections only except for the area near the confluence with CBL. At the confluence with CBL, the 50-year discharge exceeds the design discharge of the ongoing river improvement project by about 10 m^3/s. Since the area around the CBL confluence point has not been urbanized yet, it is considered that extension of river improvement works (widening of river section) is possible.

Therefore, to achieve the target safety level against the 50-year flood, all the proposed measures shall be implemented together with the river channel improvement works at the downstream area (expansion of the river area by 1.5%).

Table 5-10 Discharge and Required Reservoir Volume with All Proposed Measures (50-year flood)

Maxim Development
Q 50 Flood

		RP-CL 1	RP-CL 2	CL End	RP-CK 1	RP-CK 2	RP-CK 3	CK End	Confuluence	RP-B 1	RP-B 2	Bekasi Weir	RP-B 3	CBL
Cut Volume	m3/s	490	470		171	182	182			690	685		625	
Reservoir Volume	m3	950,812	381,440		2,413,964	314,134	58,164			1,254,412	182,755		729,936	
Remaining Space	m3	49,188	58,560		26,036	25,866	21,836			5,588	69,245		50,064	
Lowest Water Level												13		
Peak Out Flow w/ Project	m3/s	490	470	485	171	182	182	182	667	690	685	***660***	625	***759***
Design Discharge (2015 DD)	m3/s			543				228	663	663	663	***663***	747	***747***
Peak Out Flow w/o Project	m3/s	708	742	757	366	398	401	401	996	1,003	1,011	1,022	1,035	1,250
Peak Cut Discharge	m3/s	218	272	272	195	216	219	219	329	313	326	362	410	491
											Max WL	18.8		
											Min WL	13.0		

Note) The calculation was carried out at 20 minute intervals from the upstream retarding basin, starting the flow cut at the point of time when the discharge exceeded the cut volume. Reservoir volume is the impounded flood water in the retention pond, and represents the scale of the reservoir.

5.8 Project Implementation Plan (Draft)

According to the results of the runoff analysis that used the latest data including those of the January 2020 flood, the design discharge Q25 (663 m^3/s for the upstream section and 747m^3/s for the downstream section of the weir) of the ongoing river improvement project is actually equivalent to the 10-year discharge.

The 25-year discharge that PUPR had set as the provisional improvement target is 871 m^3/s in the upstream section of the weir and 1,067 m^3/s in the downstream section of the weir respectively, and the 50-year discharge that the proposed master plan aims to cope with is 1,022 m^3/s in the upstream section and 1,250 m^3/s in the downstream section of the weir respectively.

The proposed master plan is based on the assumption that BBWS CiliCis will complete its ongoing river improvement project. However, the proposed improvement of the Bekasi weir operation and the retention ponds will be very effective by themselves whether the ongoing river improvement project has been completed or not. Therefore, it might be also possible to implement them it in parallel with the ongoing river improvement work which is behind the schedule.

The retarding basins as discharge regulation facilities are individually effective when constructed. As a guideline for future development, the individual effect of each proposed retention pond was evaluated. The results are shown in Table 5-11. The effects are shown in terms of the degree to which the peak discharge can be reduced when constructed alone and the discharge scale (return period) after the peak cut. Each retention pond is effective on its own, but the maximum effect is expected if the 8 (eight) retention ponds are operated integrated as a group.

Table 5-11 Individual effects of the proposed facility

	Inflow	Reduction	Qout with project	Effect of each Structure	Const Cost
	Qin (m3/s)	Qr (m3/s)	Qout (m3/s)	Return Period (1/n year)	C (10^9 Rp.)
RP-CL 1	591.1	201.1	390.0	23	293
RP-CL 2	619.7	129.7	490.0	31	183
RP-CK 1(100%)	317.5	177.5	140.0	26	505
RP-CK1(40%)	317.5	107.5	210.0	33	217
RP-CK1(20%)	317.5	87.5	230.0	36	171
RP-CK 2	345.2	65.2	280.0	39	156
RP-CK 3	347.9	27.9	320.0	45	67
RP-B 1	855.2	115.2	740.0	32	313
RP-B 2	861.9	41.9	820.0	43	92
Bekasi Weir	871.3	86.3	785.0	36	104
RP-B 3	861.9	61.9	800.0	40	263

Note) The effect of each reserve is shown by how much the scale of the flood can be reduced by constructing each reserve alone against the 50 year flood at the junction with the CBL. The scale is shown in return period.

On the other hand, since the construction works of the river improvement project with the current design discharge has already been started, it is considered to implement the master plan in stages as follows.

- Phase 1: The river improvement project being carried out by PUPR will complete the river capable of dealing with the 10-year flood. Since there is still room for improvement of the project, it will be reviewed and then implemented.
- Phase 2: Implement countermeasures for the 25-year flood discharge as PUPR initially aimed to cope with.
- Phase 3: Complete all the works to meet the target safety level of the 50-year flood.

The following three cases are considered as those for Phase 2. Regarding the large-scale retention pond along the Cikeas River, RP-CK1, its construction is proposed to be made in a few phases.

(1) Case 1: Discharge Regulation by Retention Ponds

- Retarding basins that are constructed by shortcutting meandering portion are given priority (RP-CK2, RP-CK3, RP-B1, RP-B2).
- Part of the RP-CK1 (20% development on the meandering portion) and the RP-CL2 will also be constructed in order to regulate river discharges within the existing flow capacities of the Cikeas and Cileungsi rivers.
- The pre-release system will be adopted for the Bekasi weir, and RP-B3 will be constructed to regulate the river discharge downstream of the weir.
- Although RP-B2 is unnecessary for this stage, the sharp bend at this point is considered to be one of the bottlenecks of the Bekasi River. Therefore, streamlining of the river alignment will be made by providing a shortcut channel.

Phase 2, Q25, Case 1														
		RP-CL 1	RP-CL 2	CL End	RP-CK 1	RP-CK 2	RP-CK 3	CK End	Confuluence	RP-B 1	RP-B 2	Bekasi Weir	RP-B 3	CBL
Cut Volume	m3/s	9,999	490		230	230	228			600	9,999		635	
Reservoir Volume	m3	-	418,216		494,228	294,306	60,403			1,118,720	-		-	
Remaining Space	m3	1,000,000	21,784		1,945,772	45,694	19,597			141,280	252,000		780,000	
Lowest Water Level												13		
Peak Out Flow w/ Project	m3/s	591	490	502	230	230	228	228	710	600	607	***622***	632	***744***
Design Discharge (2015 DD)	m3/s			543				228	663	663	663	***663***	747	***747***
Peak Out Flow w/o Project	m3/s	591	620	632	318	345	348	348	840	855	862	871	882	1,067
Peak Cut Discharge	m3/s	-	130	130	88	115	120	120	130	255	255	250	250	323
Peak Discharge without Project		505									Max WL	18.8		
					20%						Min WL	13.0		

Note) The cut volume 9,999 indicates a state where there is no retention pond.

(2) Case 2: Retention Ponds + river channel improvement

- Instead of the development of RP-CK1, the shortage of flow capacity in the Cikeas River will be made up by river channel improvement.
- Although RP-B2 is unnecessary, the sharp bend at this point is considered to be one of the bottlenecks. Therefore, streamlining of the river alignment will be made by providing a shortcut channel.
- The about 2.5 km section upstream of the confluence point of the Cikeas River where river improvement works were already over is difficult to widen because there are standing many private houses close together.

Phase 2, Q25, Case 2														
		RP-CL 1	RP-CL 2	CL End	RP-CK 1	RP-CK 2	RP-CK 3	CK End	Confuluence	RP-B 1	RP-B 2	Bekasi Weir	RP-B 3	CBL
Cut Volume	m3/s	9,999	490		9,999	275	270			590	9,999		9,999	
Reservoir Volume	m3	-	418,216		-	301,191	63,776			1,250,720	-		-	
Remaining Space	m3	1,000,000	21,784		2,440,000	38,809	16,224			9,280	252,000		780,000	
Lowest Water Level												13		
Peak Out Flow w/ Project	m3/s	591	490	502	318	275	270	270	710	590	597	***613***	624	***735***
Design Discharge (2015 DD)	m3/s			543				228	663	663	663	***663***	747	***747***
Peak Out Flow w/o Project	m3/s	591	620	632	318	345	348	348	840	855	862	871	882	1,067
Peak Cut Discharge	m3/s	-	130	130	-	70	78	78	130	265	265	258	258	332
Peak Discharge without Project		505									Max WL	18.8		
					0%						Min WL	13.0		

(3) Case 3: Flow control by a Retention Pond

- Part (40%) of RP-CK1 will be developed in advance in place of the shortcuts of RP-CK2 and RP-CK3 of the Cikeas River in Case 1.
- The pre-release system will be adopted for the Bekasi weir, and RP-B3 will be constructed to regulate the river discharge downstream of the weir.
- Although RP-B2 is unnecessary, the sharp bend at this point is considered to be one of the bottlenecks. Therefore, streamlining of the river alignment will be made by providing a shortcut channel.

Phase 2, Q25, Case 3														
		RP-CL 1	RP-CL 2	CL End	RP-CK 1	RP-CK 2	RP-CK 3	CK End	Confuluence	RP-B 1	RP-B 2	Bekasi Weir	RP-B 3	CBL
Cut Volume	m3/s	9,999	490		195	9,999	99,999			600	9,999		635	
Reservoir Volume	m3	-	418,216		1,003,989	-	-			1,118,720	-		-	
Remaining Space	m3	1,000,000	21,784		1,436,011	340,000	80,000			141,280	252,000		780,000	
Lowest Water Level												13		
Peak Out Flow w/ Project	m3/s	591	490	502	195	223	225	225	710	600	607	***622***	632	***744***
Design Discharge (2015 DD)	m3/s			543				228	663	663	663	***663***	747	***747***
Peak Out Flow w/o Project	m3/s	591	620	632	318	345	348	348	840	855	862	871	882	1,067
Peak Cut Discharge	m3/s	-	130	130	123	123	123	123	130	255	255	250	250	323
Peak Discharge without Project		505									Max WL	18.8		
					41%			2.8			Min WL	13.0		

5.9 Construction project cost

The estimated construction cost for each work is presented in Table 5-12.

To achieve the target safety level of 50-year flood, the total construction cost will be about 16.5 billion yen (About Rp.2 Trillion). Details are given in Attachment 3.

Table 5-12 Estimated Construction Cost of Countermeasure Projects

Unit: 1 million yen

	項目	25年洪水対応			50年洪水対応	Compensation Works	
		Case 1	Case 2	Case 3		Land	House
Project Scale		25-year			50-year	(m2)	(houses)
	Retention Pond						
	RP-CL1	-	-	-	2,441	260,000	32
	RP-CL2	1,529	1,529	1,529	1,529	112,000	4 & 1 Warehouse
	RP-CK1 (full)	-	-	-	4,205	615,000	0
	RP-CK1 (20%)	1,425	-	-	-	140,000	0
	RP-CK1 (40%)	-	-	1,810	-	210,000	0
	RP-CK2	1,297	1,297	-	1,297	96,000	1 Warehouse
	RP-CK3	562	562	-	562	20,250	0
	RP-B1	2,606	2,606	2,606	2,606	20,250	1 Sports Facility
	RP-B2	-	-	-	765	60,000	1 Bridge
	RP-B2 （only Short Cut channel）	306	306	306	-	15,000	0
	RP-B3	-	-	-	2,194	194,000	0
	Bekasi Weir	864	864	864	864		
	Telemetry/Monitering System	✓	✓	✓	✓		
	Pump Station for Water Supply	✓	✓	✓	✓		
	River Cannel Improvement （Cikeas river）		✓				
Construction Cost	Retention Pond	8,588	7,164	7,116	16,463		
	River Improvement （Cikeas river）		****				

5.10 Project Benefit

The damage that can be prevented by implementing the master plan is as follows.

Figure 5-29 shows the results of flood inundation analysis that was conducted by PusAir for the January 2020 flood, using river cross sections after the completion of the ongoing river improvement project. The area colored in blue is the inundation area (actual) of the January 2020 flood, and the area colored in yellow to red is the flood area (analysis result) after the river improvement project. Therefore, the part that remains blue can be regarded as the estimated effect of the river improvement project being carried out by BBWS-CiliCis. If the master plan that targets the 50-year flood is implemented, not only all these inundation areas but also those of the 50-year flood will be eliminated.

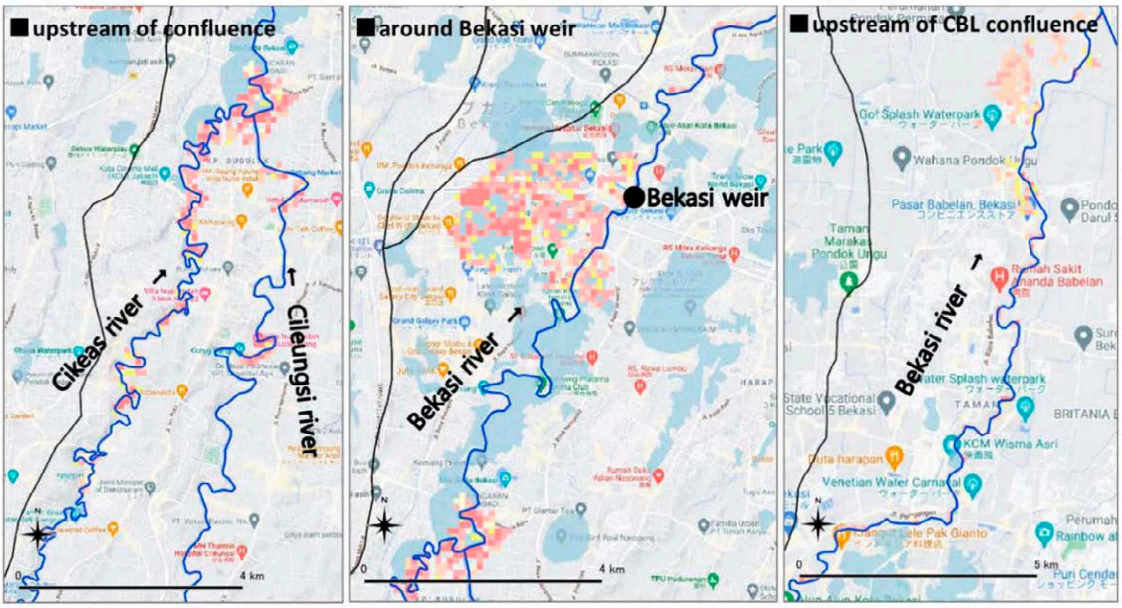


Figure 5-29 Flood inundation analysis results for January 2020 flood (after completion of ongoing river improvement project)

The estimated flood inundation area after the river improvement is 8.46 km^2 as shown in Table 5-13. The affected population is estimated from the population density of 11,907 people/km^2 in urban areas, and it is estimated that about 100,000 people and 24,000 households will be affected.

Table 5-13 Estimated inundation area and depth for January 2020 flood (after completion of ongoing river improvement project

Inundation depth	Area (km^2)
- 0.2	0.50
0.2 - 0.5	1.03
0.5 - 2.0	2.46
2.0 - 5.0	2.87
5.0 - .	1.60
Total	8.46

Flood damage amount of the above inundation area was roughly estimated as presented in Table 5-14. This table suggest that even if the ongoing river improvement project is completed, a single flood of the same scale as the flood in January 2020 would cause damage of approximately 26 billion yen (Rp 3.14 trillion). Therefore, early implementation of the master plan is desirable.

Table 5-14 Estimation of flood damage amount (in an event of a flood of the same scale as the January 2020 flood after the ongoing river improvement project)

1 million rupiahs

	amount of damage	Yen value (1 million yen)
I. direct damage		
(a) building damage	**1,885,004.9**	**15,708.4**
(b) property damage	**488,286.7**	**4,069.1**
(c) damage to infrastructure	**522,124.2**	**4,351.0**
Sub Total I.	**2,895,415.7**	**24,128.5**
II. indirect damage		
(a) Loss of revenue (commercial and industrial units)		
(i) Commercial Unit	**218,684.4**	**1,822.4**
(ii) Industrial Unit	**11,881.0**	**99.0**
(b) Decrease in revenue of water suppliers		
(i) Household	**1,847.0**	**15.4**
(ii) Non-household	**103.1**	**0.9**
(c) Decrease in revenue of electric power companies	**8,782.0**	**73.2**
Sub Total II.	**241,297.5**	**2,010.8**
Total	**3,136,713.3**	**26,139.3**

Note) See Chapter 4 for the method of calculating the amount of damage, basic unit price, etc.

5.11 Preliminary Environmental Impact Evaluation

A preliminary environmental impact assessment was conducted based on the JICA Environmental Checklist (River and Sabo) for the project implementation.

Since large-scale excavation work (about 6 million m^3 in total) will be carried out in the urban area in the Bekasi project, so it is important to pay attention to the traffic safety during construction, the conservation of the surrounding environment (such as dust and noise), and disposal of waste soil. It is also necessary to consider the impact to changes of groundwater in the surrounding retention ponds, due to excavation or impounding floods in retention ponds.

5.12 Recommendation

The works required for the implementation of the proposed flood control projects are summarized as follows.

(1) Changes to the current river improvement plan

As described in the Value Engineering Review conducted in June 2020,

- Detailed review of master plan, feasibility study and detailed design of proposed measures
- Improvement of flood runoff and inundation model using SOBEK (input of facility information and its operation method and improvement of reproducibility of flood and inundation)
- Three-dimensional hydraulic model test (moving bed) on sediment flushing through Bekasi Weir flood gate
- Study of effective SOP for sediment flushing
- Confirmation of effects of river bed subsidence on river structures and proposals of their countermeasures

(2) Other Issues

- Develop emergency response plans (contingency plan) for flooding:
- Study on flood early warning system and preparation of hazard maps
- Centralized management of rainfall and water level data and disclosure of information
- Improvement of accuracy of rating curves (water level - discharge curves) of water level gauging stations

Attachment 5-1 Flood runoff and inundation analysis

Flood runoff and inundation analysis was carried out in order to verify flood inundation characteristics and to calculate the design discharge.

1 Examination of design discharge (tentative)

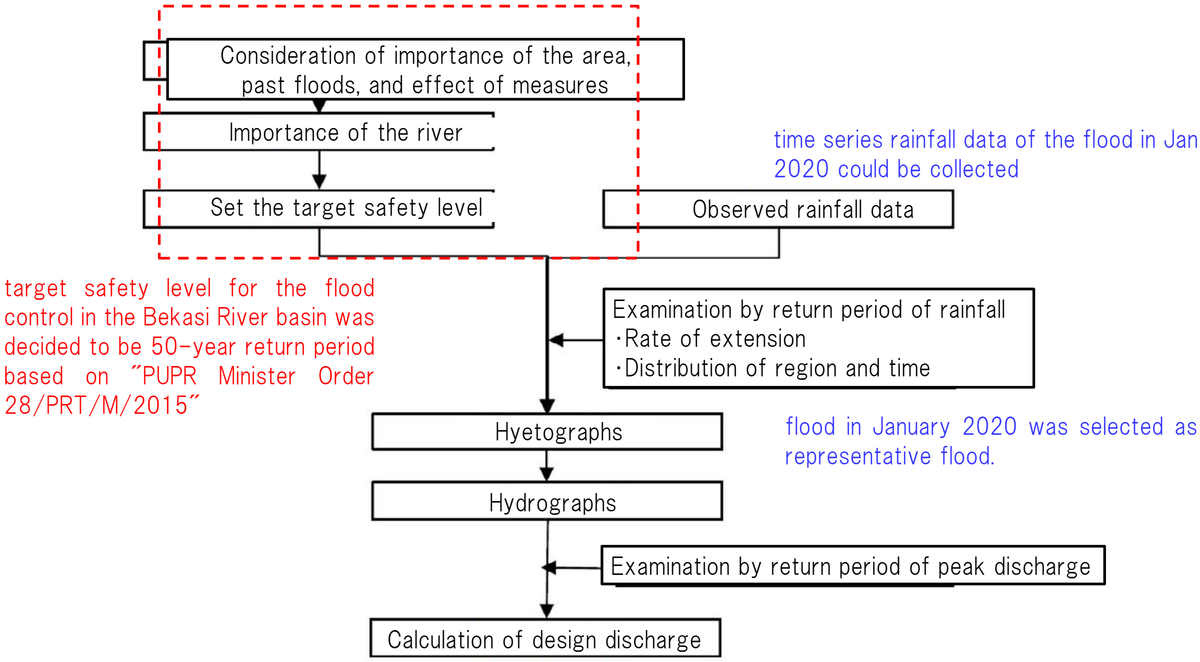
At the Bekasi weir, the design discharge of 100-year return period (813 m^3/s) that was set at downstream of the Bekasi weir under the D/D in 2015 was exceeded 2 times in 2020 and 2021. In order to improve flood control safety in the basin based on the recent flood occurrence, the design discharge was reviewed.

2 Policy of the examination

The study flow of examining the design discharge is shown in Figure 1. In the discussion with BBWS-CC and River and Coastal Department in PUPR on 28th June 2021, the target safety level for the flood control in the Bekasi River basin was decided to be 50-year return period, based on "PUPR Minister Order 28/PRT/M/2015".

The flood in January 2020 is the largest flood in the last 50 years and time series data of rainfall could be collected, and then the flood in January 2020 was selected as a representative flood.

The control point for flood control was determined to be Bekasi weir, which is located upstream of the urban area and is rich in accumulated observation data.

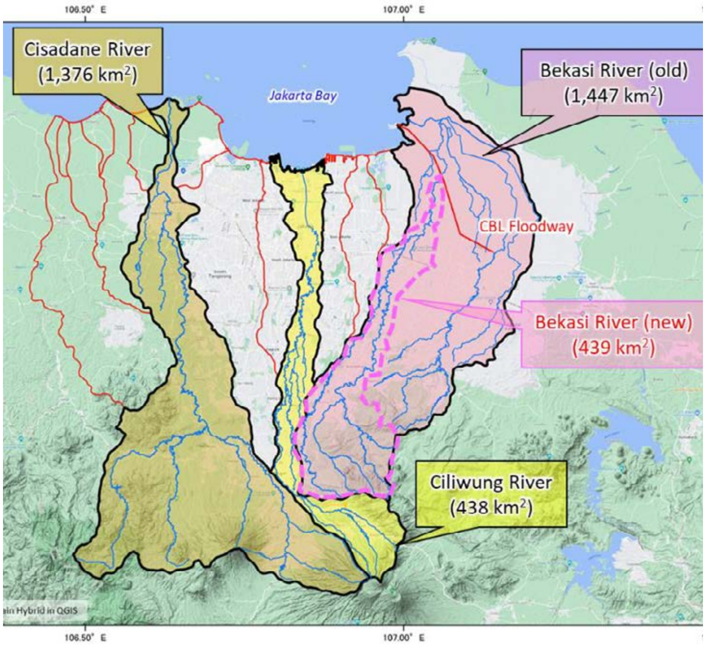


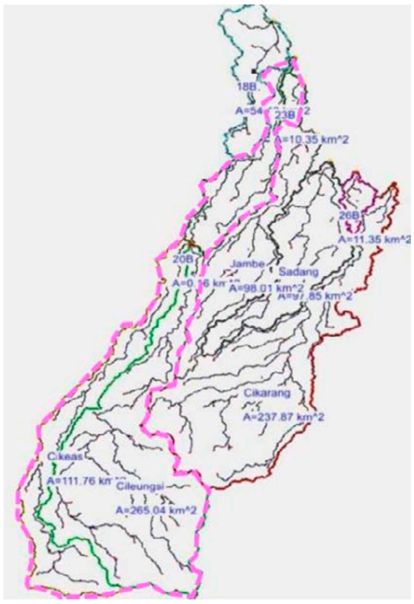
Source: JICA study team based on Technical Standards for River and Sabo, March 2018

Figure 1 Flow of examining design discharge

2.1 Target area

The target area of this study is the Bekasi River basin. The Bekasi River basin used to have a basin area of approx. 1,447 km^2 as shown in Figure 2, but due to the construction of the CBL Floodway (Cikarang-Bekasi-Laut Floodway) completed in 1985, the current area of the Bekasi River basin become less, approx. 439 km^2 at upstream of the CBL Floodway.





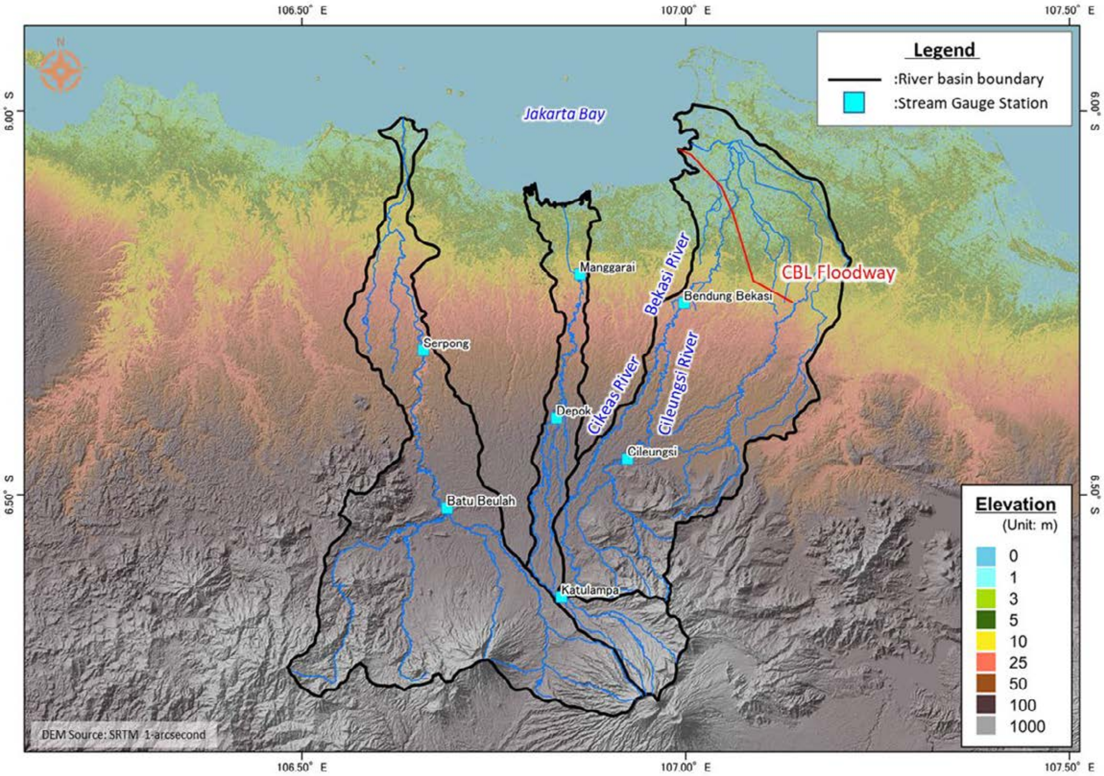
Sub basins

Source：JICA study team based on D/D in 2015

Figure 2 Target area（the Bekasi River basin）

2.2 Topographic characteristics

The elevation contour map is shown in Figure 3. The Bekasi River basin is mostly covered by the catchment areas of the two tributaries, the Cileungsi and Cikeas Rivers, and the stretch from the confluence of the two tributaries to the confluence with the CBL floodway is called the Bekasi River. The Cileungsi and Cikeas Rivers are relatively steep with average slope of over 1/1,000. From the confluence of the two tributaries to the Bekasi weir is almost flat, and from the Bekasi weir to the CBL confluence is very gentle with a slope of less than 1/4,000.

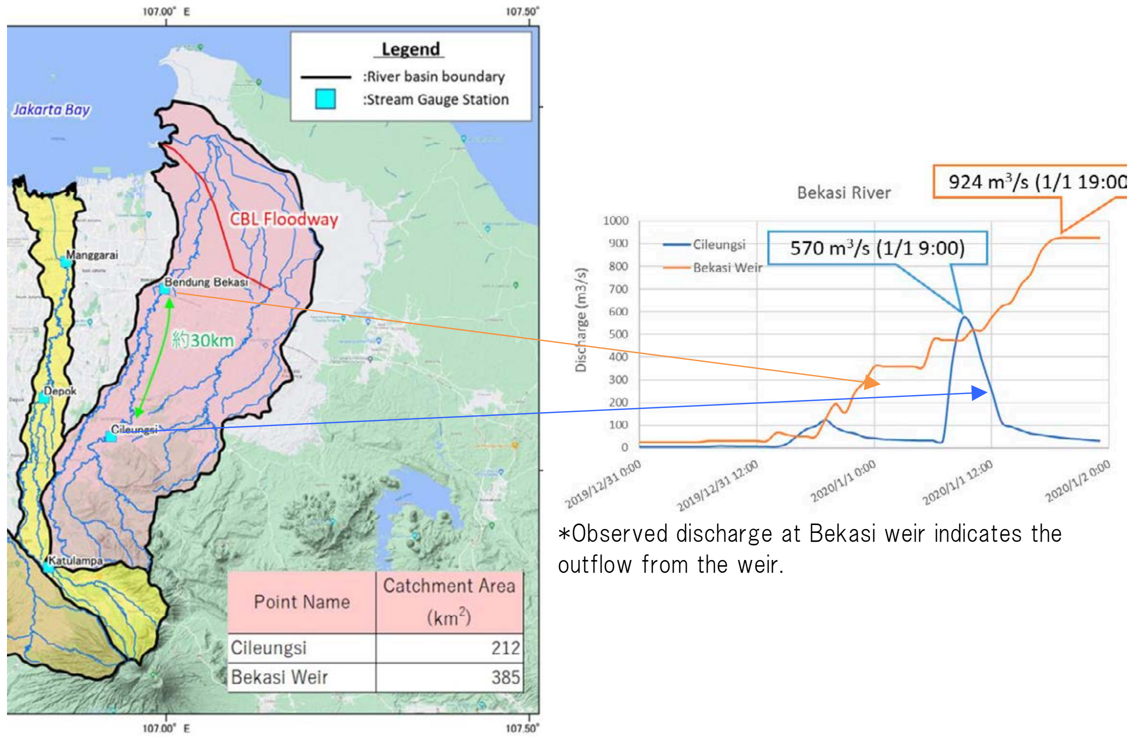


Source：JICA study team

Figure 3 Elevation contour map by SRTM

2.3 Overview of the flood in Jan 2020

The observed discharge data of the flood in January 2020 is shown in Figure 4. Since the catchment areas at the Gunung Putri (Cileungsi) station and at the Bekasi weir are about 212 km^2 and about 385 km^2. Respectively, the specific peak discharges were 2.69 $m^3/s/km^2$ at the Gunung Putri (Cileungsi) station and 2.40 $m^3/s/km^2$ at the Bekasi weir. They seem to be large scale outflow. It should be noted that the observed discharge at Bekasi weir indicates the outflow converted by water level and operation of the gate, and thus includes the effect of gate operation and different from the discharge of inflow to the weir.

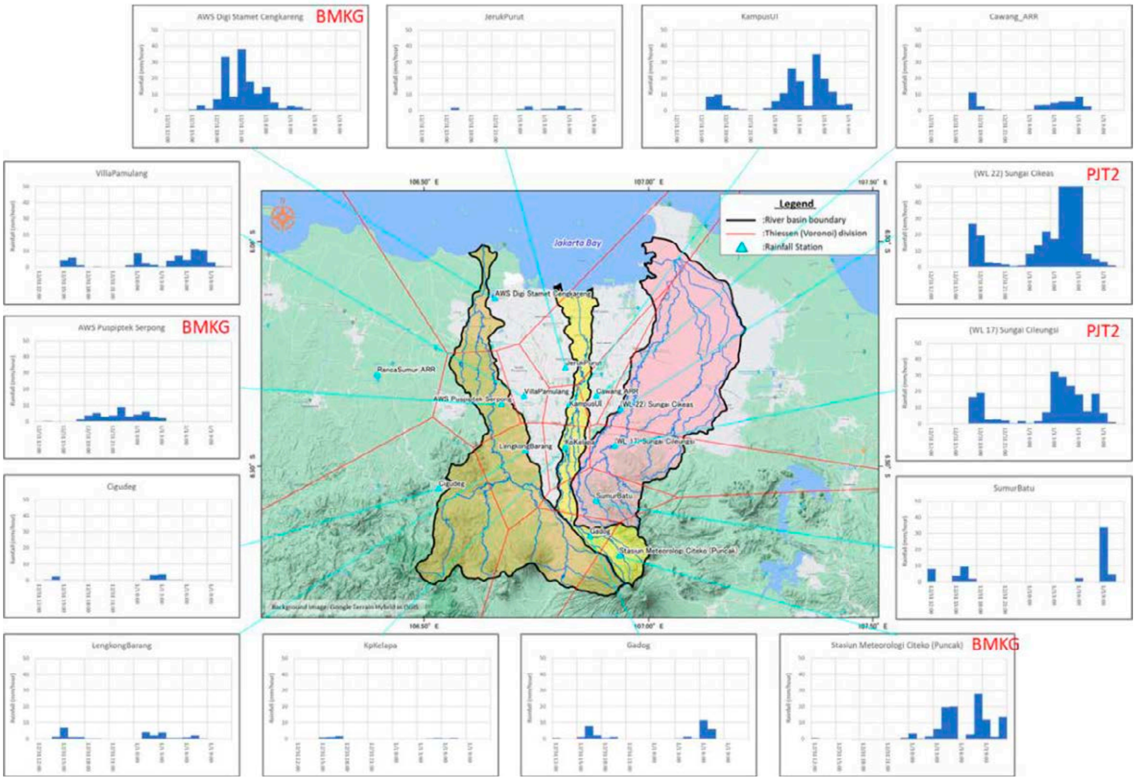


Source：JICA study team based on observed data by BBWS-CC

Figure 4 Observed discharge data (2019/12/31 0:00 - 2020/1/1 23:00)

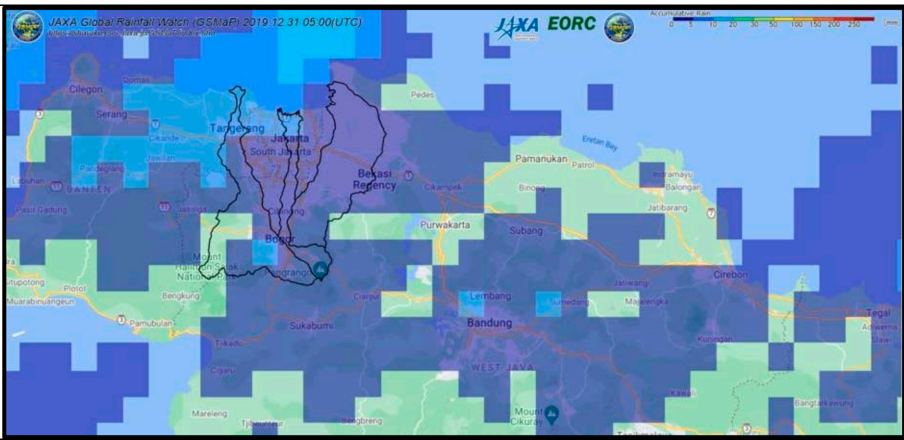
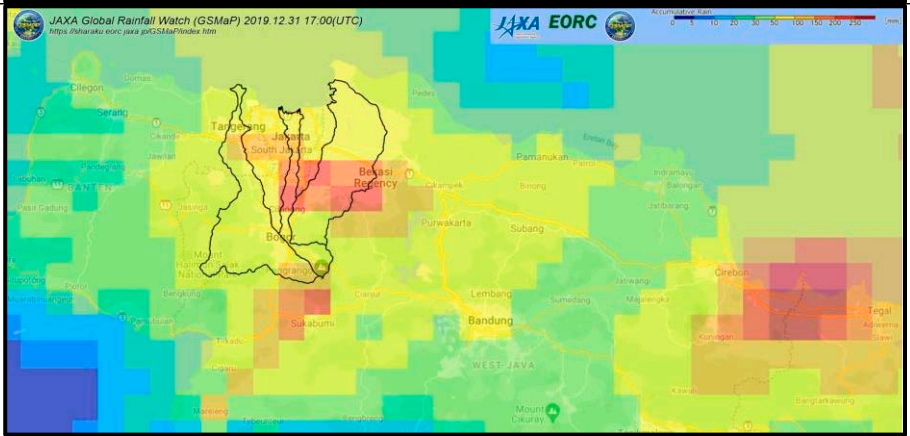
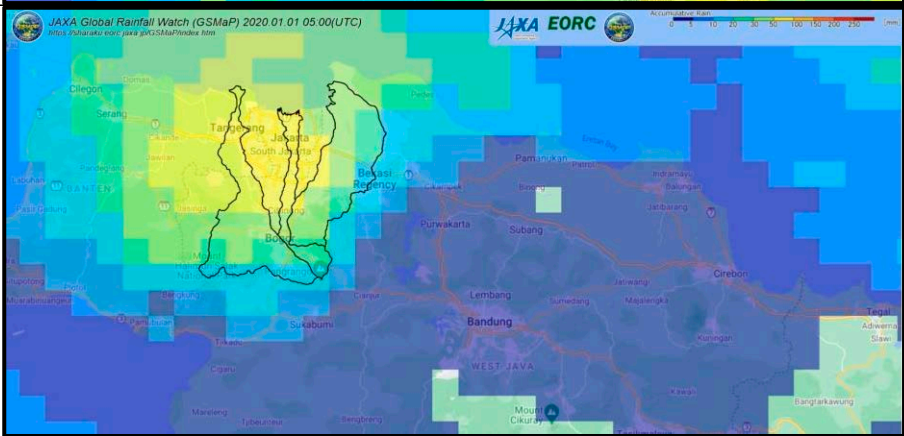
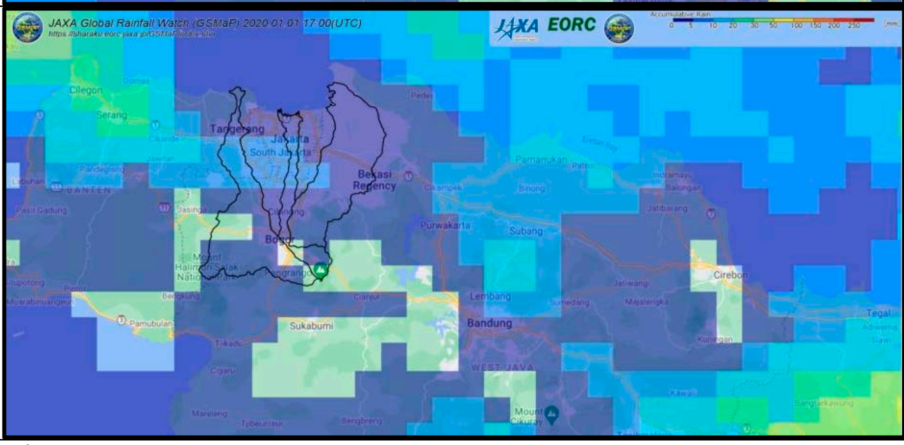
The observed rainfall of the flood in January 2020 is shown in Figure 5. In the Bekasi River basin, (WL 17) Sungai Cileungsi station and (WL 22) Sungai Cikeas station recorded especially heavy rainfall in the early morning of 1st January 2020. In particular, (WL 22) Sungai Cikeas station observed very heavy rainfall with a maximum of 77.5 mm/hour and 325.5 mm/day from 12:00 on 31st December to 12:00 on the following day. The verification of observation accuracy is needed.

The rainfall during the flood in January 2020 was confirmed by comparing with data of the Global Satellite Mapping of Precipitation (GSMaP) published by JAXA. As shown in Figure 6, rainfall areas exceeding 200 mm/12hour were seen in the Bekasi River basin and the Ciliwung River basin. Therefore, the observed rainfall at Cikeas station was judged not to be abnormal data.



* Red letters indicate data source. Other stations were provided by BBWS-CC.
**(WL 22) Observations with bars above the upper limit at the Sungai Cikeas station are, 60.5, 54.0, and 77.5 mm.
Source：JICA study team based on observed rainfall data

Figure 5 Observed rainfall data (2019/12/31 12:00 – 2020/1/1 11:00)

<table>
<tr><td>2019/12/31 1:00 – 2019/12/31 12:00</td><td></td></tr>
<tr><td>2019/12/31 13:00 – 2019/12/31 24:00</td><td></td></tr>
<tr><td>2020/1/1 1:00 – 2020/1/1 12:00</td><td></td></tr>
<tr><td>2020/1/1 13:00 – 2020/1/1 24:00</td><td></td></tr>
</table>

*WIB in Jakarta = UTC+7hr
*Black line shows the boundary of the Cisadane, Ciliwung and Bekasi River basin.
Source： GSMaP(https://sharaku.eorc.jaxa.jp/GSMaP/index_j.htm)

Figure 6 Rainfall amount for 12 hours by GSMaP (2019/12/31 1:00 – 2020/1/1 24:00)

3 Runoff analysis by HEC-HMS

3.1 Software and calculation conditions

The software used for runoff analysis was HEC-HMS (Hydrologic Engineering Center – Hydrologic Modeling System) developed by the U.S. Army Corps of Engineers, which was also used for runoff analysis in the Detailed Design of the lower Bekasi River in 2015.

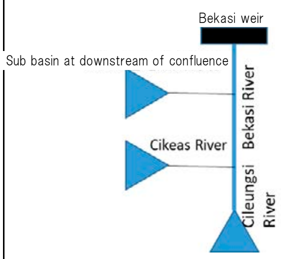
Summary of the software is shown in Table 1, calculation condition in Table 2, ratio of enlargement of hyetograph in Table 3 and extended basin average rainfall in Figure 7.

Table 1 Software of runoff analysis

Software name	HEC-HMS
Version	Version 4.3
Release	September 2018
Download link	https://www.hec.usace.army.mil/software/hec-hms/

Source： JICA study team

Table 2 Calculation condition of runoff analysis

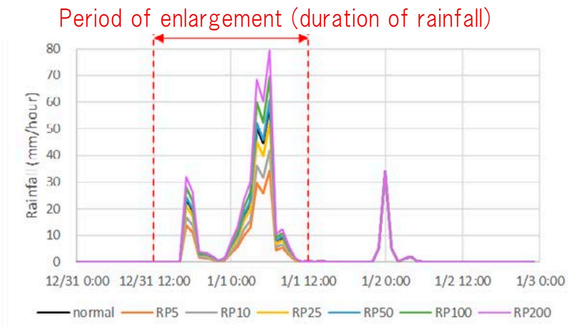
	Calculation condition
Design hyetograph	Flood in January 2020
Duration of rainfall	24 hours （12:00 on 31st December, 2019 ~ 12:00 on 1st January 2020）
Runoff analysis model	SCS Unit Hydrograph
Diagram of runoff analysis	 *▲ : sub basin
Calibration	Observed discharge data at Gunung Putri (Cileungsi) station and Bekasi weir

Source： JICA study team

Table 3 ratio of enlargement of hyetograph

Return period	Ratio of enlargement
1/5	0.58
1/10	0.71
1/25	0.89
1/50	1.03
1/100	1.18
1/200	1.35

Source： JICA study team



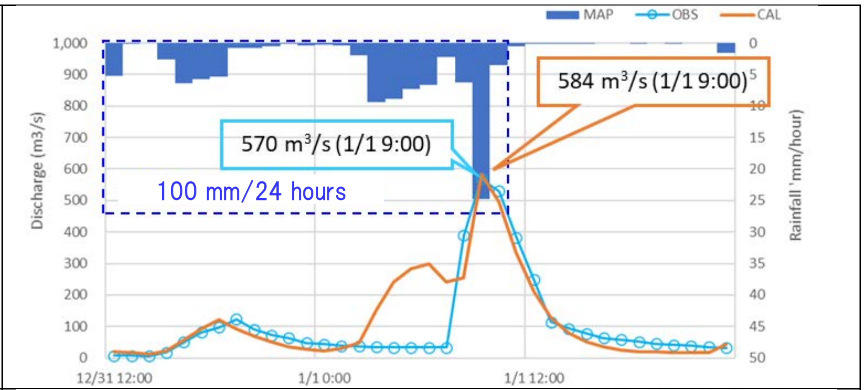
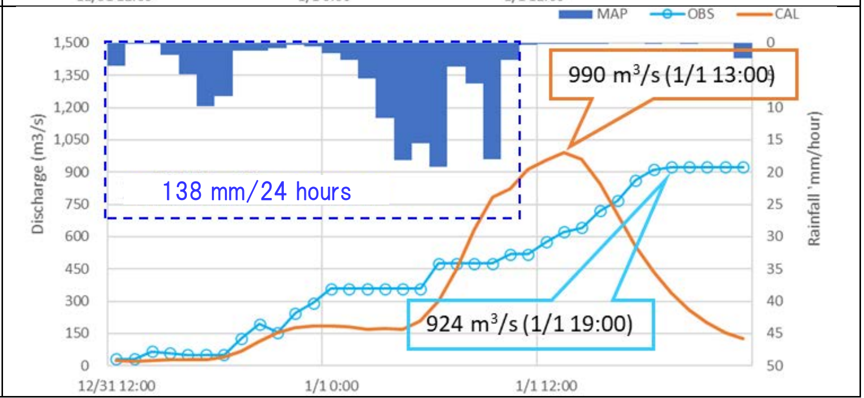
*normal: basin average rainfall in Jan 2020、RPXX: enlarged hyetograph
Source： JICA study team

Figure 7 Enlarged basin average rainfall (upstream of Bekasi weir)

3.2 Calibration of flood in Jan 2020

The results of the calibration for the flood in January 2020 at Gunung Putri (Cileungsi) station and Bekasi weir is shown in Figure 8.

- The peak discharge and timing of the hydrograph were well reproduced by the simulation model at Gunung Putri (Cileungsi) station.
- Regarding the result at Bekasi weir, the timing of the peak at Bekasi weir is generally appropriate since the peak at Gunung Putri (Cileungsi) station and the peak at Bekasi weir were evaluated to be about 3~4 hours apart in Chapter6. About the discharge at Bekasi weir, observed data shows the outflow discharge by the gate operation of the Bekasi weir. On the other hand, the calculated result shows the inflow discharge into the Bekasi weir. Therefore, although the hydrodynamic waveform is different, the amount of flow is almost same, and it is appropriate as a phenomenon at the weir. The total volume of calculated and observed hydrograph should generally match, parameter was adjusted so that the calculated peak discharge is higher than the observed peak flow.

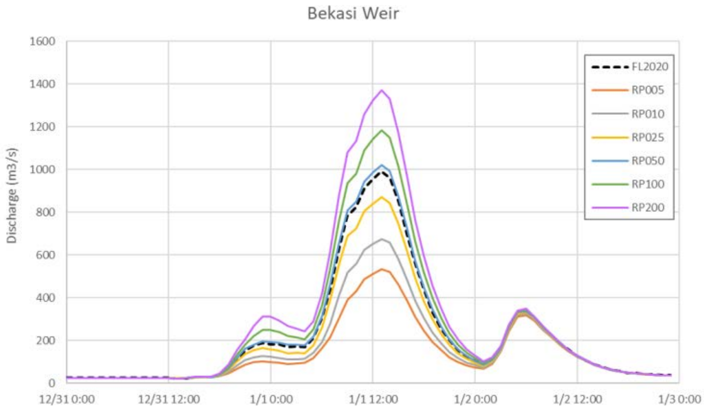
Gunung Putri (Cileungsi) station (catchment area : 212 km²)	
Bekasi weir (catchment area : 385 km²) *Observed discharge at Bekasi weir indicates the outflow converted by water level and operation of the gate.	

*Legend (MAP: basin average rainfall、OBS: observed discharge、CAL: calculation result)
Source : JICA study team

Figure 8 Result of Reproduction

3.3 Probable discharge calculation

Figure 9 shows the results of discharge calculation based on the runoff analysis model. Since the return period of the flood in January 2020 was evaluated as 43-year return period, the enlargement ratio of 50-year return period is 1.03. Therefore, the probable discharge with 50-year return period is slightly larger than the flood in January 2020. The peak discharge of the flood in January 2020 is 990 m^3/s, and the peak discharge of 50-year return period was calculated to be 1,022 m^3/s.



*FL2020：flood in 2020、 RPXXX：result of discharge with XXX-year return period
Source：JICA study team

Figure 9 Result of probable discharge calculation (Bekasi weir)

3.4 Result of examining design discharge

The estimated probable discharges at the Bekasi weir are compared with the design discharges of the previous studies as shown in Table 4.

Based on the D/D in 2015, the river channel improvement at upstream of Bekasi weir is now in progress. The flow capacity after completion of river channel improvement will be 663 m^3/s (25-year return period, D/D in 2015). Once the discharge of 1,022 m^3/s is set as an updated design discharge, additional improvement of about 360 m^3/s is required.

Table 4 Comparison of discharge at Bekasi weir

Return period	1977 M/P	2015 D/D	Probable Discharge (This study)
1/25	-	663 m^3/s	871 m^3/s
1/50	590 m^3/s	738 m^3/s	1,022 m^3/s
1/100	-	813 m^3/s	1,185 m^3/s
1/200	-	-	1,370 m^3/s

Source：JICA study team

4 [Reference] Runoff and inundation analysis by SOBEK

4.1 Software

Pusair, a hydrological research institute under PUPR, has developed and operating a flood runoff and inundation analysis model in the Ciliwung River basin. The runoff and inundation analysis is carried out, using the simulation model and the forecast rainfall by BMKG, and the forecast results including inundation area maps and water levels at main points are always opened on the website (Jakarta Flood Early Warning System; JFEWS[※]). This runoff and inundation analysis model, which uses SOBEK as an analysis software, was developed jointly by BMKG and Deltares.

By expanding the modelling area to include the Bekasi and Cisadane River basins, it is possible to enhance and improve the accuracy of the existing JFEWS. In addition, by utilizing the simulation model currently in operation, it is expected that the sharing of information with related organizations will be facilitated, and work efficiency will be improved. Development and analysis of the flood runoff and inundation analysis model were carried out under the subcontract with Pusair.

※ JFEWS Bulletin (https://buletin-jfews.pusair-pu.go.id/)

"SOBEK", which is a software developed by Deltares and widely used for hydrological analysis, was used for the development of the flood runoff and inundation analysis model including the Bekasi and Cisadane River basins.

The modules included in SOBEK are outlined below.

① SOBEK RR

The SOBEK RR (Rainfall-Runoff) module is used for runoff analysis. It can be used in combination with SOBEK -1 DFLOW.

② SOBEK1DFLOW

The SOBEK1D module is used for one-dimensional analysis in irrigation, drainage, rainwater systems, etc. It can be used to examine irrigation facilities, drainage, canal systems, dredging, flood control measures, urban drainage, and retention pond. It can be used in combination with other modules such as the SOBEK RR module.

③ SOBEK2DFLOW

The SOBEK2D module is used for two-dimensional analysis such as flood inundation. It is integrated with the 1DFLOW module, it can be used for analysis of river systems and inundation.

4.2 Calculation conditions

The calculation conditions for the flood runoff and inundation analysis are summarized as follows.

(1) Target area

The runoff analysis model covers the Cisadane, Ciliwung, and Bekasi River basins. Since the simulation model of the Ciliwung River basin has already been developed and operated, the Cisadane and the Bekasi River basins have been added to the existing model.

(2) DEM Data

The following DEM data were used to set the ground height of the floodplain. The resolution of the DEM to be used was set in consideration of the analysis accuracy and calculation time.

- DEMNAS： approx. 100 m mesh

- ASTER DEM : approx. 100 m mesh
- Lidar data : approx. 100 m mesh (for central Jakarta in the Ciliwung River basin)

(3) land use

Based on the land use map published by KLHK (Indonesian Ministry of Environment and Forestry) in 2011, the land use situation of flood plain was set.

(4) river cross sections

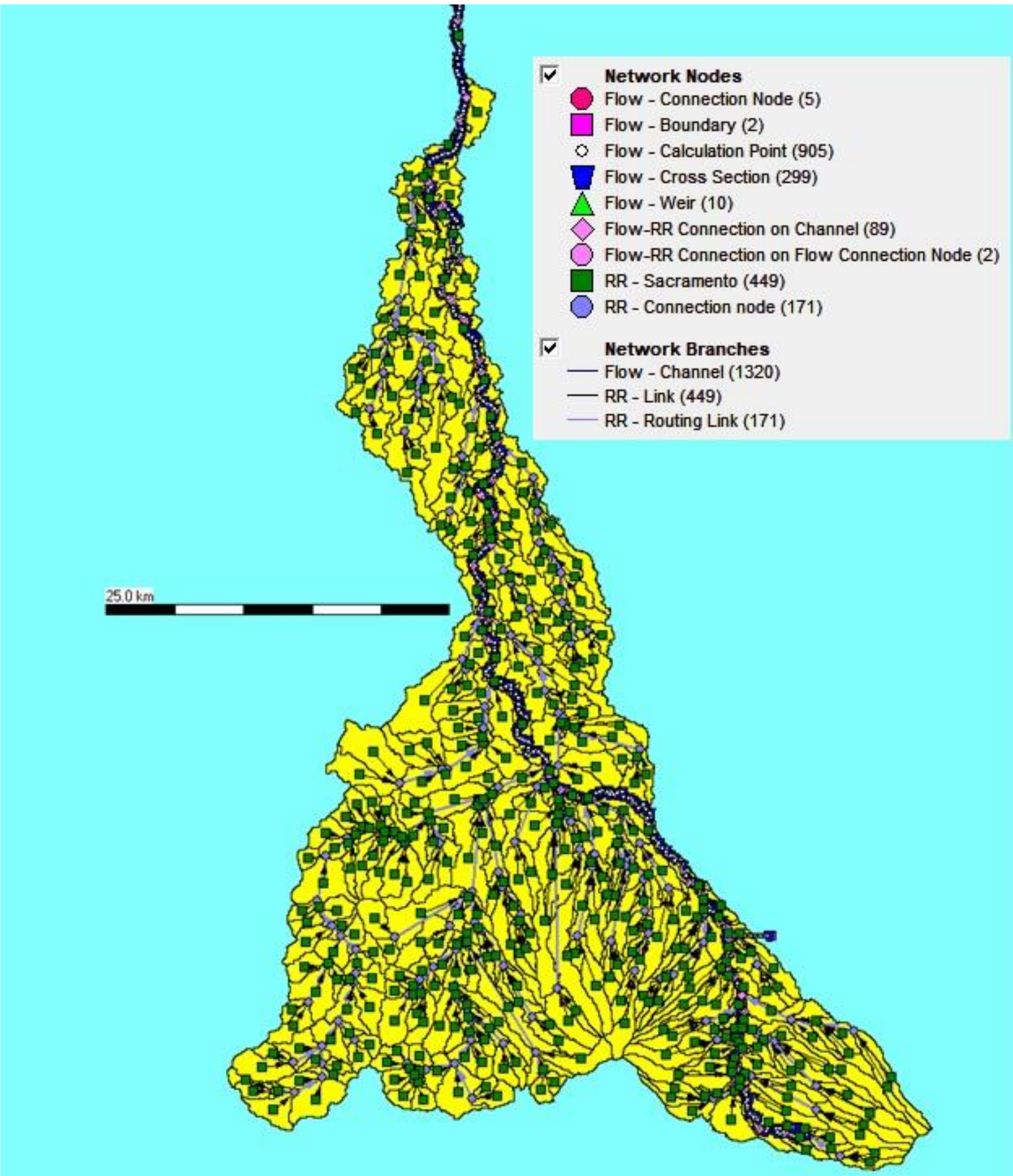
The latest river crossing survey results were collected from PUPR and BBWS-CC, and they were applied to the runoff and inundation analysis model.

(5) structures

Structures such as bridges, weirs, floodgates, drainage pump stations, etc. were set in the runoff and inundation analysis model.

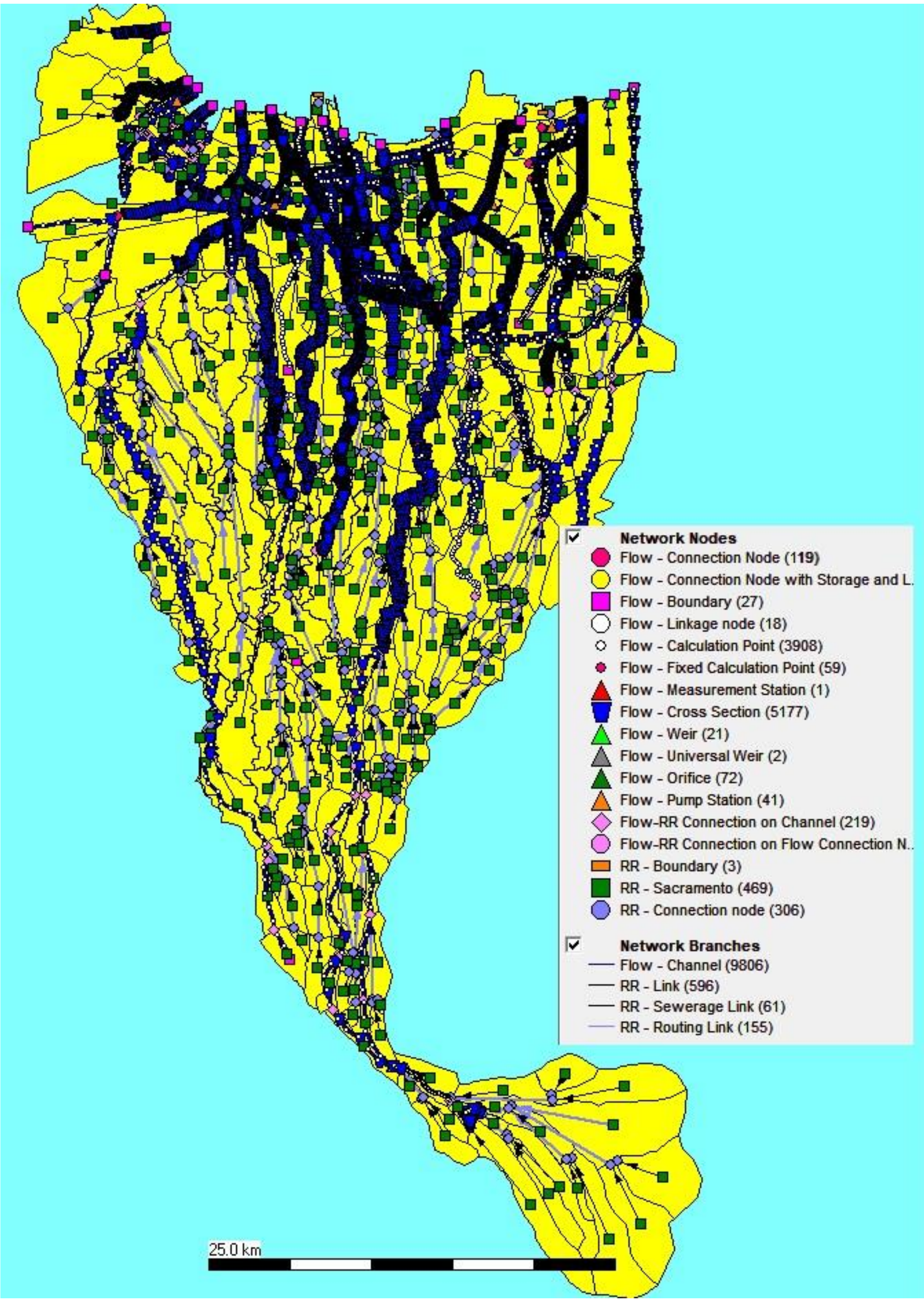
(6) rainfall data

Rainfall data for each case were set for each sub basin by the IDW method (inverse distance weighted method).



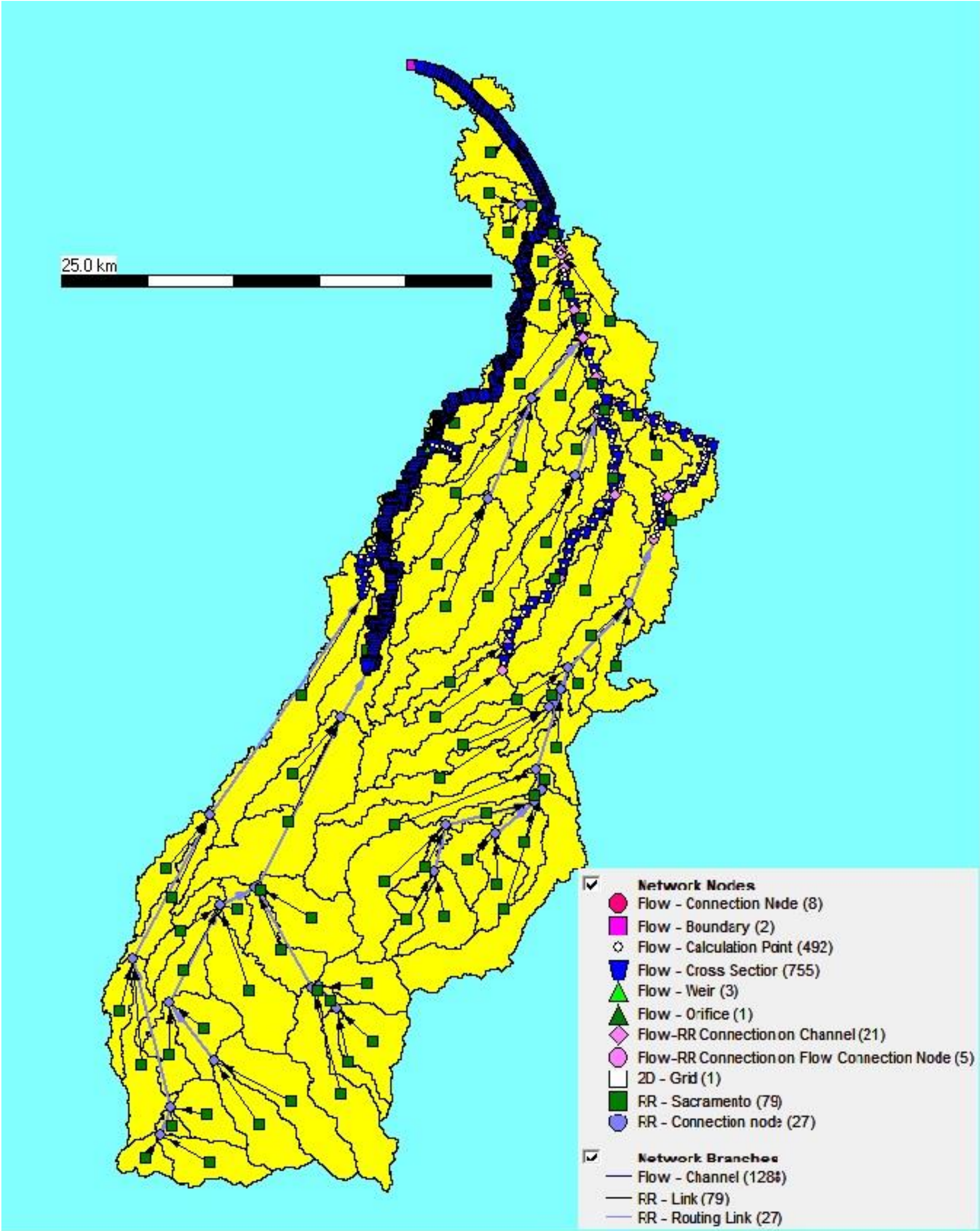
Source：JICA study team

Figure 10 Model Diagram (the Cisadane River Basin)



Source：JICA study team

Figure 11 Model Diagram (the Ciliwung River Basin)



Source：JICA study team

Figure 12 Model Diagram (the Bekasi River basin)

(7) Calculation Case

In each basin, runoff and inundation analysis was carried out for two cases, namely (1) reproduction of the flood in January 2020 for model calibration and (2) flood simulation of 50-year return period. Examples of the hyetographs of the case (2) are shown in Figure 13.

Regarding the case (2) for the Bekasi River basin, the hyetograph enlarged to the 50-year return period was set as design hyetograph (See 2.1.2 (4), 2.1.4 (3)).

In the Cisadane River basin, design hyetograph of 50-year return period was set by following the existing plan of D/D in 2015.

■the Bekasi River basin

Flood control point: Bekasi weir (It is located at upstream of populated urban area and contains hydrological data.)

Basin average daily rainfall of the flood in January 2020: 138.2 mm/day (the largest flood in the Bekasi River basin)

Basin average daily rainfall of 50-year return period: 142.5 mm/day

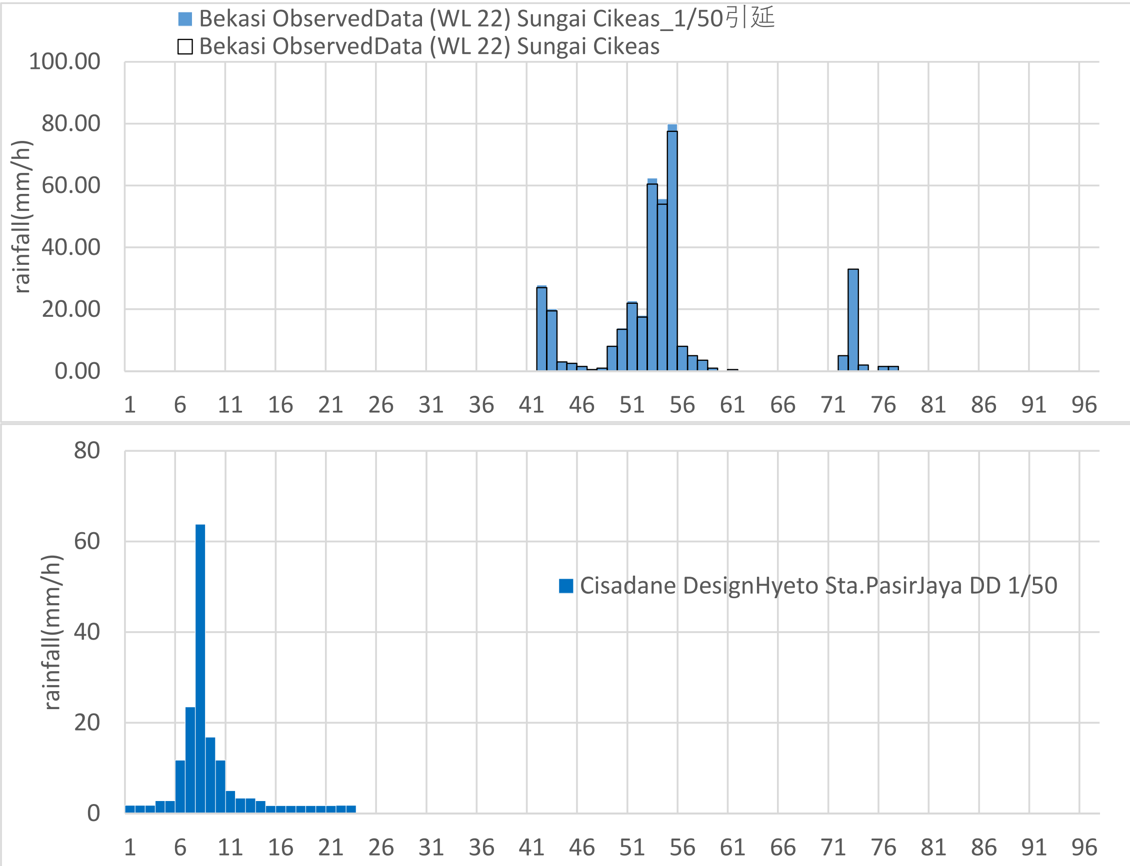
Ratio of enlargement: 1.03

The rainfall conditions in each case are shown in Table 5.

Table 5 Calculation Case

Case	Purpose	Target basin	Rainfall data	Remarks
① Reproduction of the flood in Jan. 2020 (Calibration)	・Verifying the accuracy of the simulation model ・Understanding of flood characteristics	・Bekasi ・Cisadane ・Ciliwung	・Observed rainfall data during flood in January 2020 (see 2.1.2 (4))	・Accuracy verification based on observed water level, discharge and inundated area (See 2.1.2 (4), 2.1.2 (2))
② Flood simulation of 50-year return period	・Calculation of the design discharge	・Bekasi ・Cisadane	Bekasi: hyetograph of the flood in January 2020 enlarged to 50-year return period Cisadane: designed hyetograph of D/D in 2015	

Source：JICA study team



Source：JICA study team

Figure 13 Example of hyetograph for case (2)

4.3 Reproduction of flood in January 2020 (model calibration)

The reproduction results were compared with the actually observed data during the flood in January 2020, and accuracy of the simulation model was confirmed.

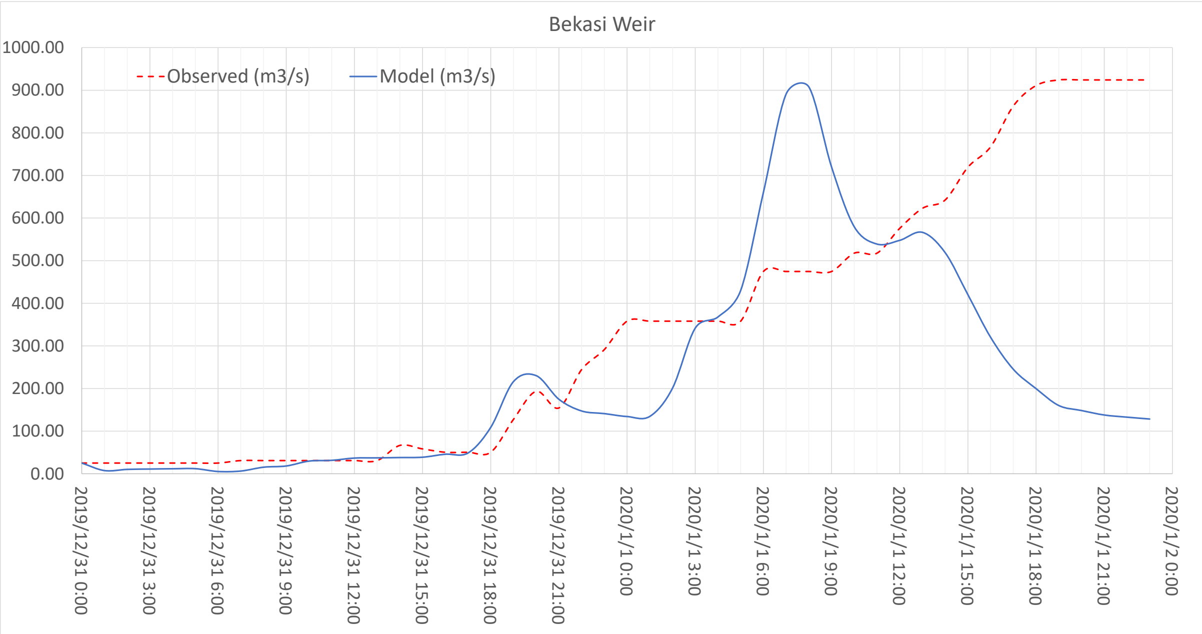
(1) The Bekasi River Basin

Simulated hydrographs and inundation maps of the Bekasi River Basin are shown in Figure 14 to Figure 18. From the following viewpoints, it was confirmed that the runoff and inundation analysis model well reproduced the observed phenomenon.

- Regarding the discharge at the Bekasi weir, observed data shows the outflow discharge by the gate operation of the Bekasi weir. On the other hand, the simulated result shows the inflow discharge into the Bekasi weir. Therefore, although their hydrodynamic waveforms are different, the amounts of flow are almost same, and the simulation result seems to be appropriate as a phenomenon at the weir.
- The water level at the Bekasi weir was well reproduced by the simulation model. The water level varies by the effect of gate operation.
- The peak discharge and peak time are well reproduced by the simulation model at Gunung Putri (Cileungsi) station.
- At Gunung Putri (Cikeas) station, there is a difference of about 14 hours between the peak of rainfall (1st January 2020, 6:00) and the peak of discharge (1st January 2020, 20:00). It seems that the actual discharge of rainfall could not be properly observed at Cikeas station because the time of the peak discharge was too late for the catchment

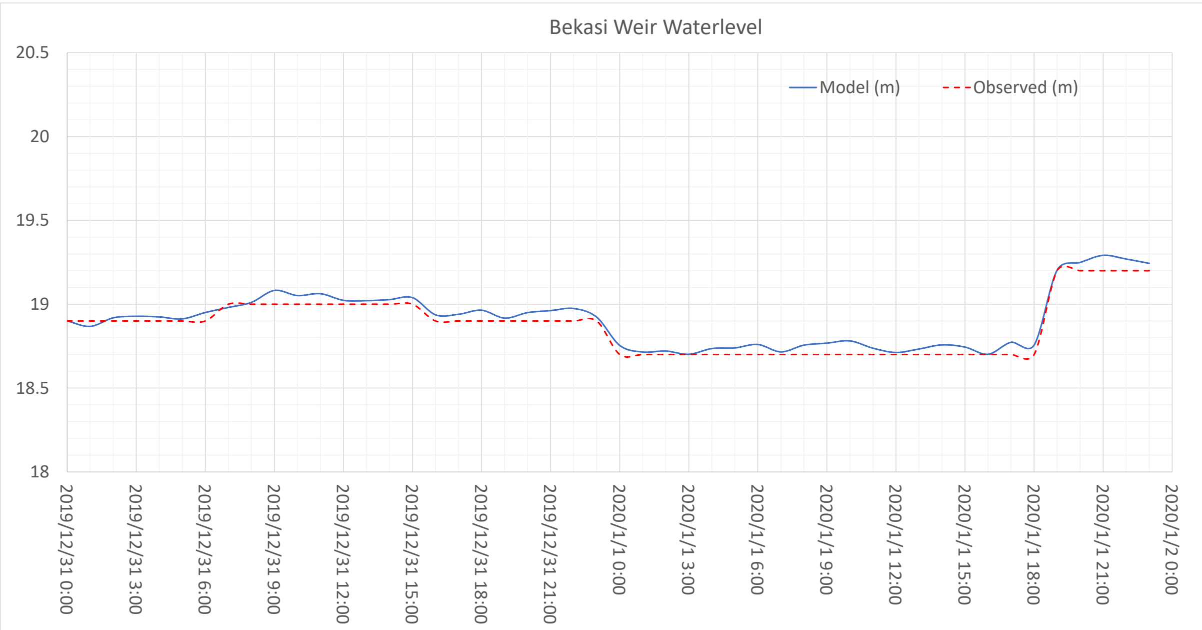
area of less than 100 km^2. In addition, the observed data at Cikeas station could not capture a distinct peak discharge, and the observed data is constant over 4 hours before and after the peak. It is guessed that the peak water level during the flood in January 2020 exceeded the observable water level at Cikeas station. Based on the above, hydrograph at Cikeas station cannot be used for calibration. (see Figure 19)

- The inundation area was well reproduced around the confluence of the Cikeas and Cileungsi rivers and the area between the confluence and the Bekasi weir.



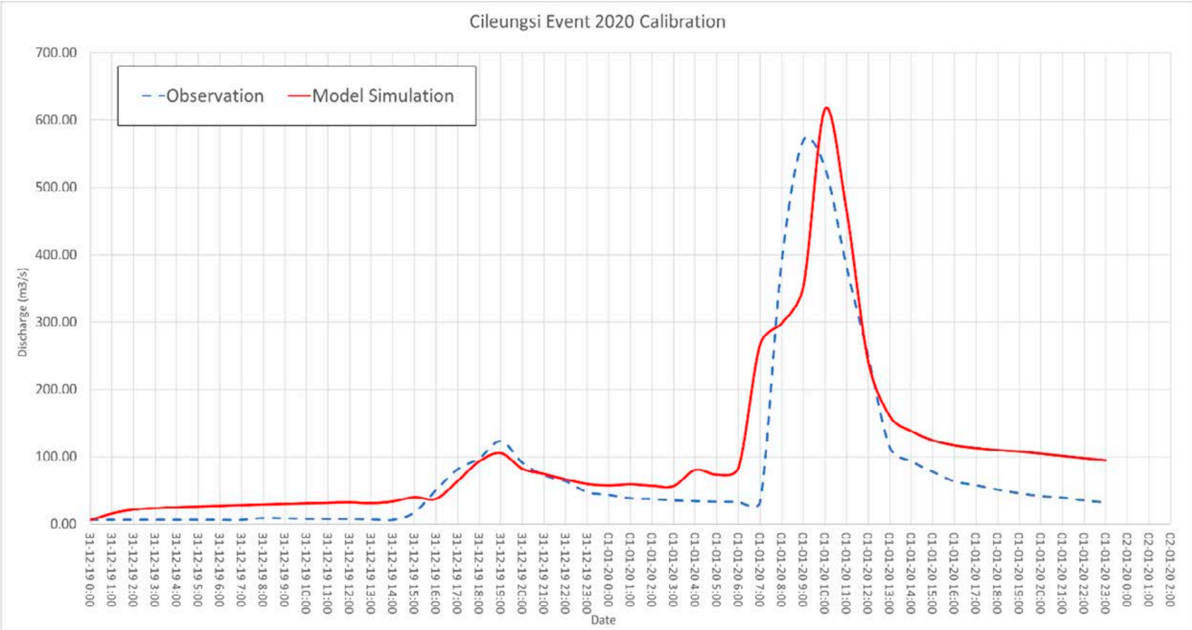
Source：JICA study team

Figure 14 Reproduction of discharge (Bekasi weir)



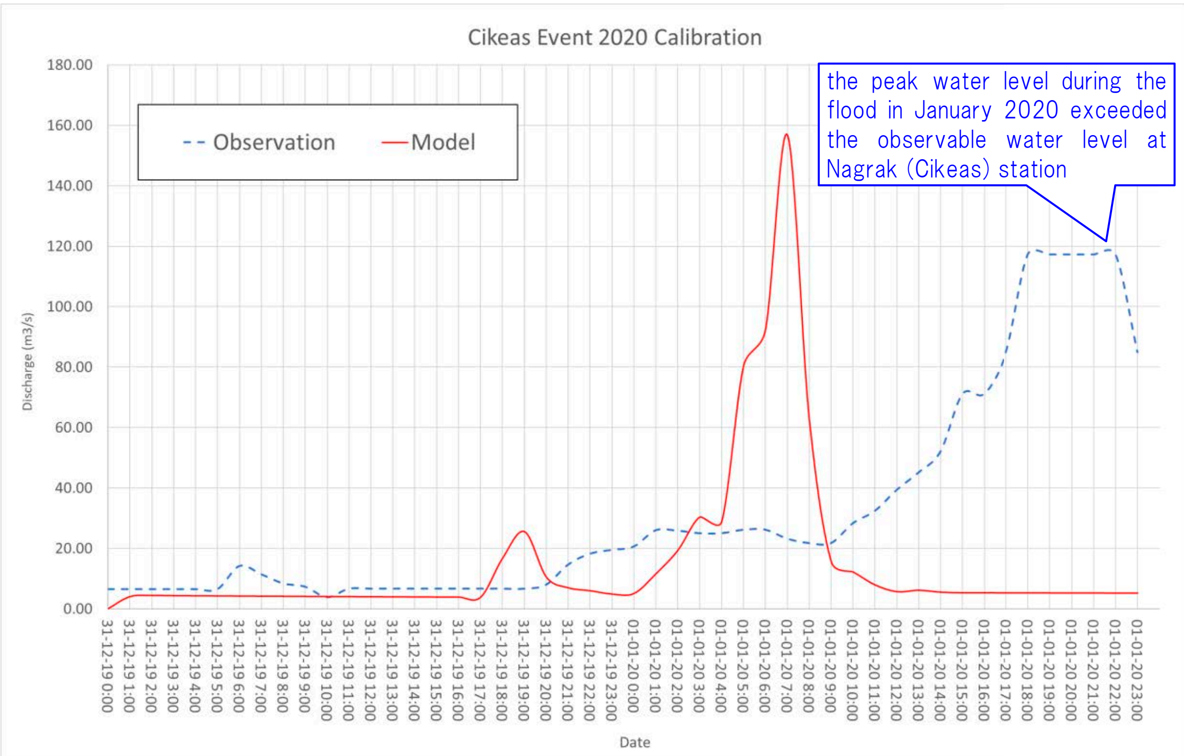
Source：JICA study team

Figure 15 Reproduction of water level (Bekasi weir)



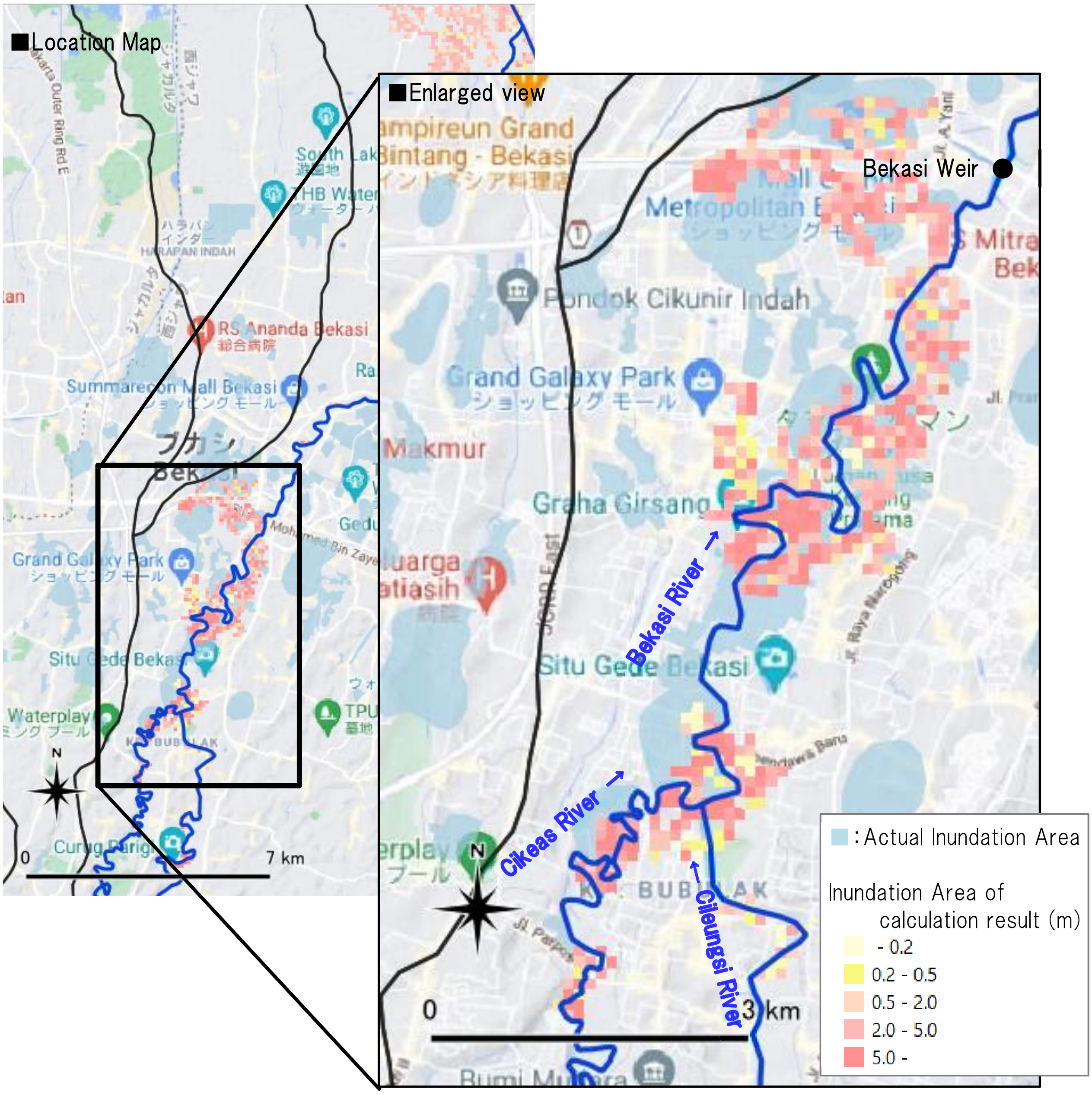
Source：JICA study team

Figure 16 Reproduction of discharge (Gunung Putri (Cileungsi) station)



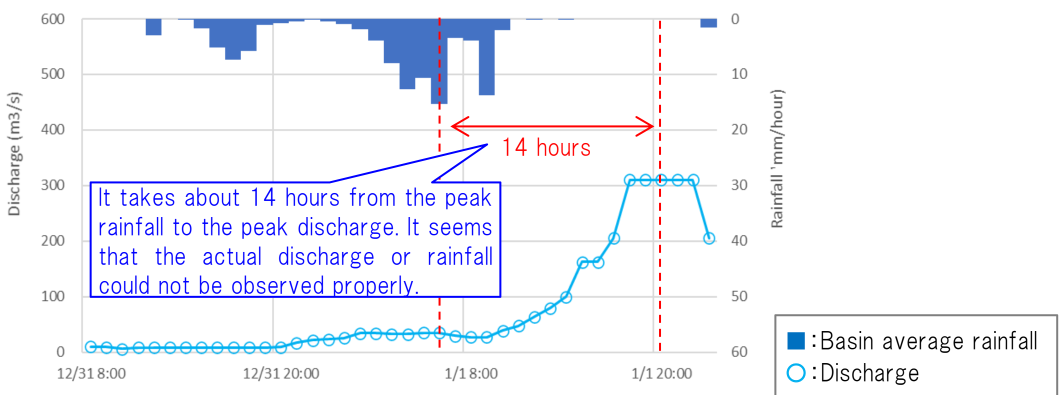
Source：JICA study team

Figure 17 Reproduction of discharge (Nagrak (Cikeas) station)



Source：JICA study team

Figure 18 Reproduction of inundation area (the Bekasi River basin)



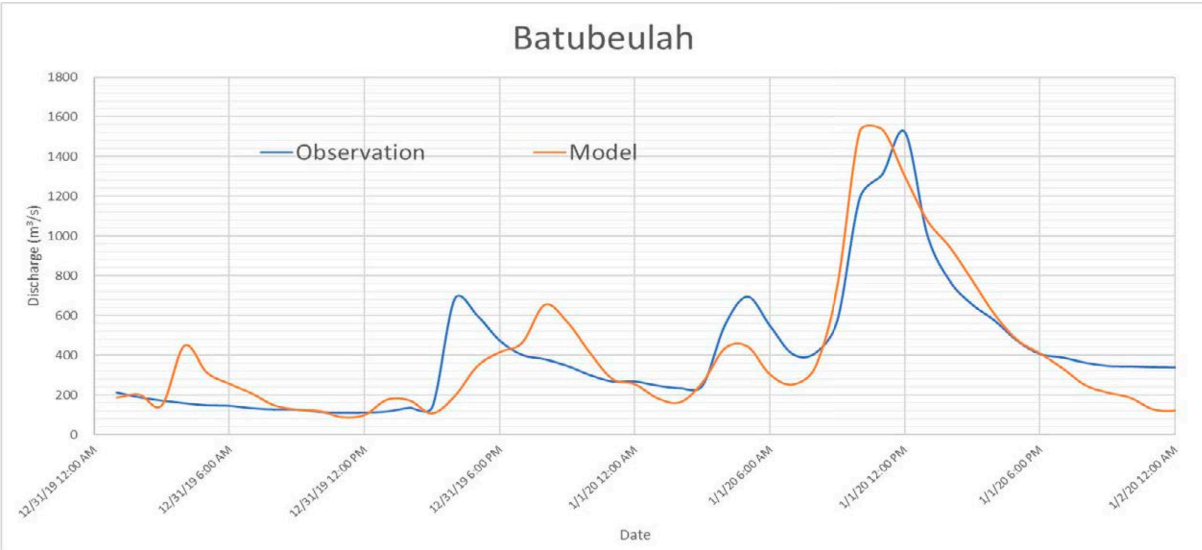
Source：JICA study team

Figure 19 Observed discharge and rainfall (Nagrak (Cikeas) station)

(2) The Cisadane River Basin

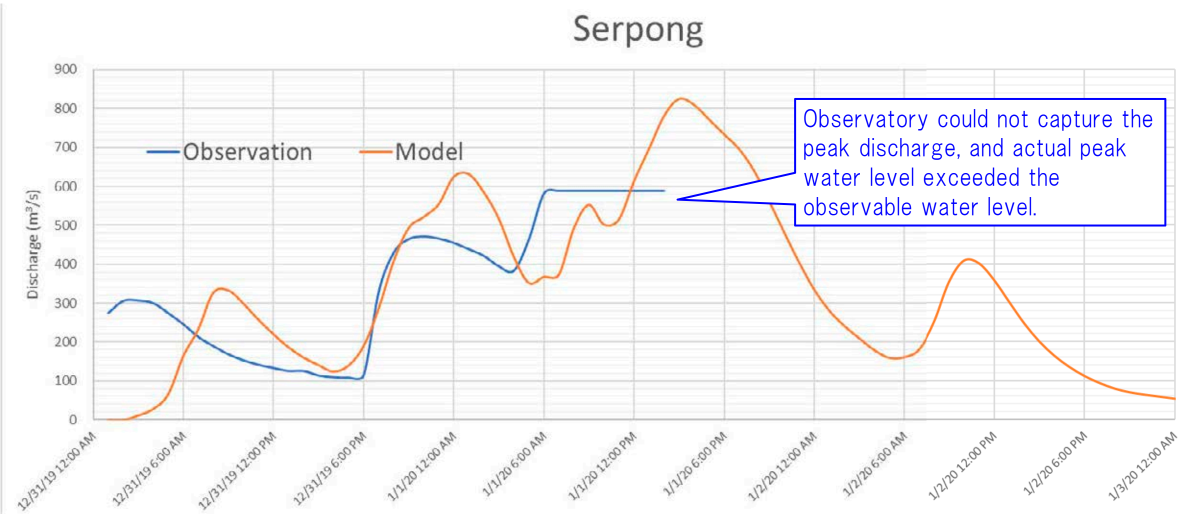
Hydrographs and inundation maps of the Cisadane River Basin are shown in Figure 20 to Figure 22. From the following viewpoints, it was confirmed that the runoff and inundation analysis model could reproduce observed phenomenon well.

- The peak discharge and peak time at Batubeulah station were well reproduced by the simulation model.
- Regarding the discharge at Serpong station, observed data could not capture a distinct peak discharge, and the observed data is constant over 6 hours after reaching almost 600 m^3/s. It is guessed that the peak discharge during the flood in January 2020 exceeded the observable discharge at Serpong station.
- Regarding the inundation areas, there were actually a few inundation spots along the Cisadane River. The inundation spot upstream of Serpong station was well reproduced.



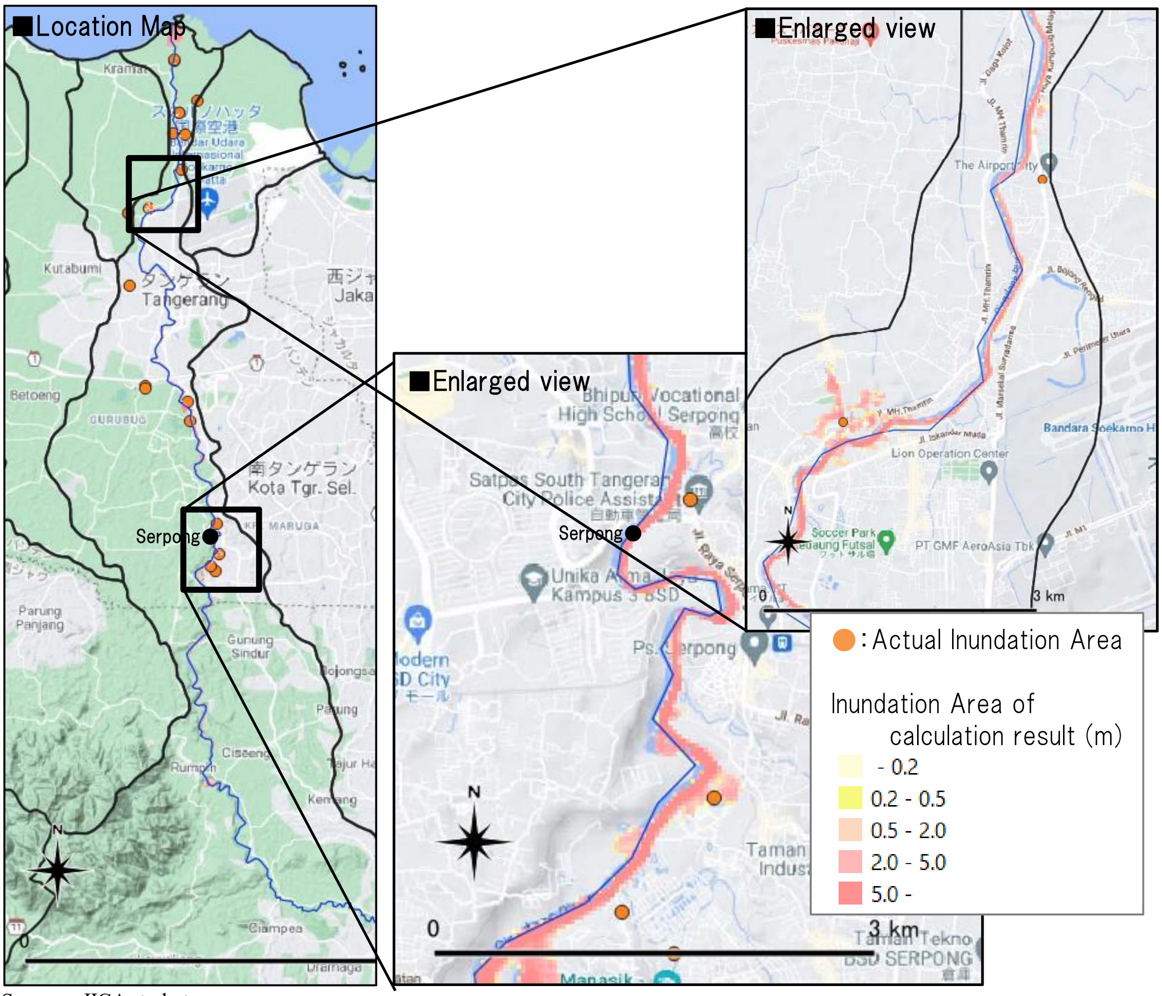
Source：JICA study team

Figure 20 Reproduction of discharge (Batubeulah station)



Source：JICA study team

Figure 21 Reproduction of discharge (Serpong station)



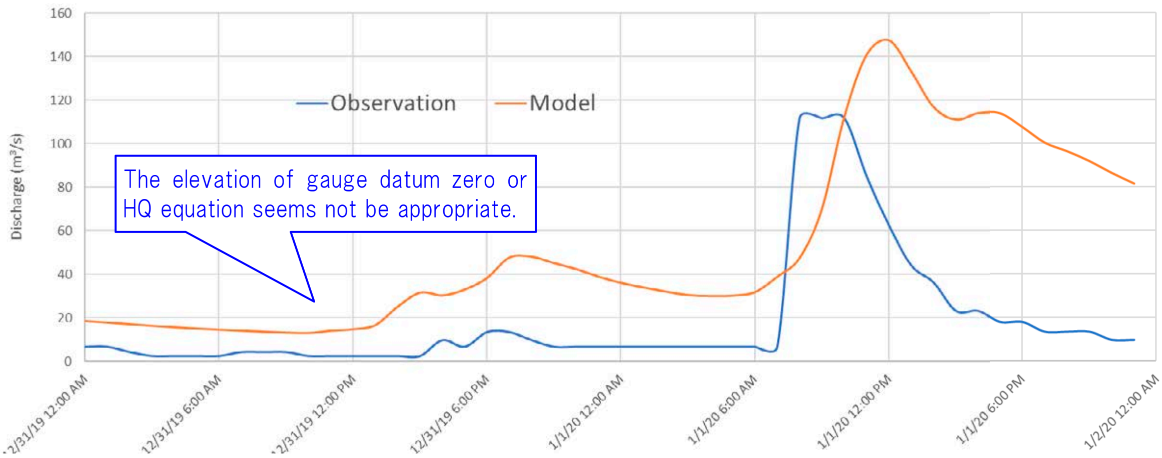
Source：JICA study team

Figure 22 Reproduction of inundation area (the Cisadane River Basin)

(3) The Ciliwung River Basin

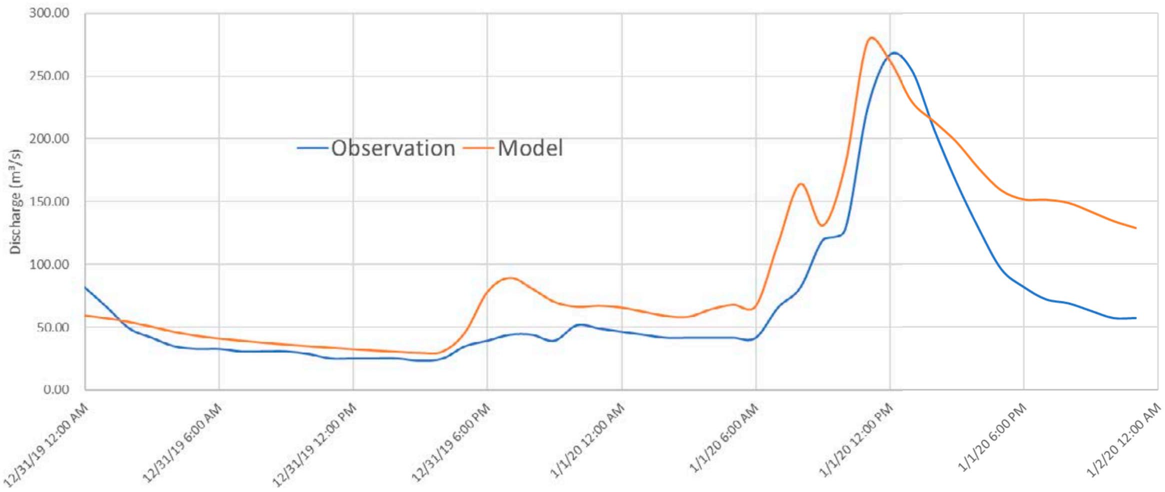
Hydrographs and inundation maps of the Ciliwung River Basin are shown in Figure 23 to Figure 26. From the following viewpoints, it was confirmed that the runoff and inundation analysis model could reproduce the observed phenomenon at Depok, Manggarai and downstream area of the basin.

- The base flow is about 10 m^3/s larger than the observed data at Katulampa station. The elevation of the gauge datum zero or HQ equation seems not be appropriate. In addition, since the actual gate operation during the flood at the Katulampa weir is uncertain, it is necessary to collect and set the gate operation during the flood.
- The peak discharge and peak time at Depok station were well reproduced by the simulation model.
- The water level at Manggarai weir was well reproduced by the simulation model. The water level varies by the effect of gate operation.
- The inundation area was well reproduced outside of east and west diversion channel.



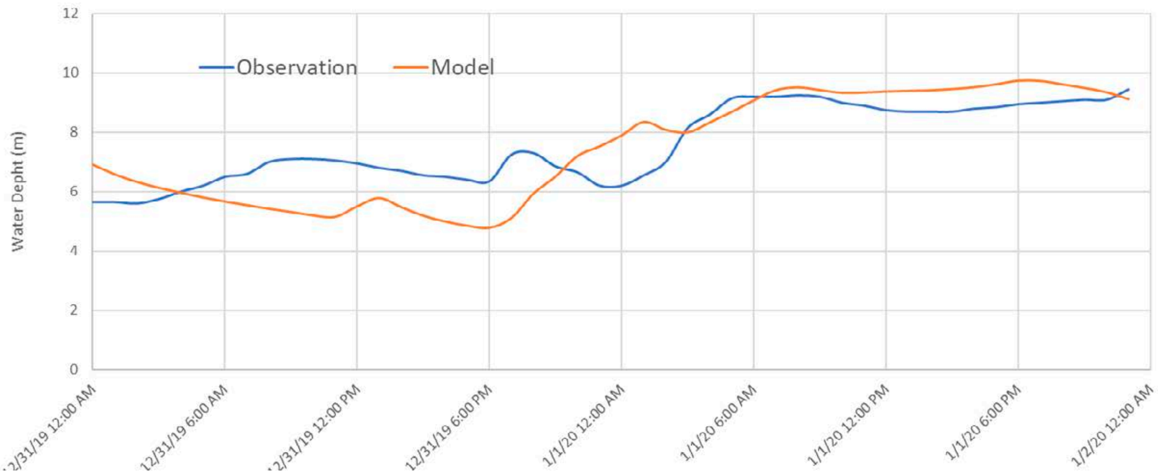
Source：JICA study team

Figure 23 Reproduction of discharge (Katulampa station)



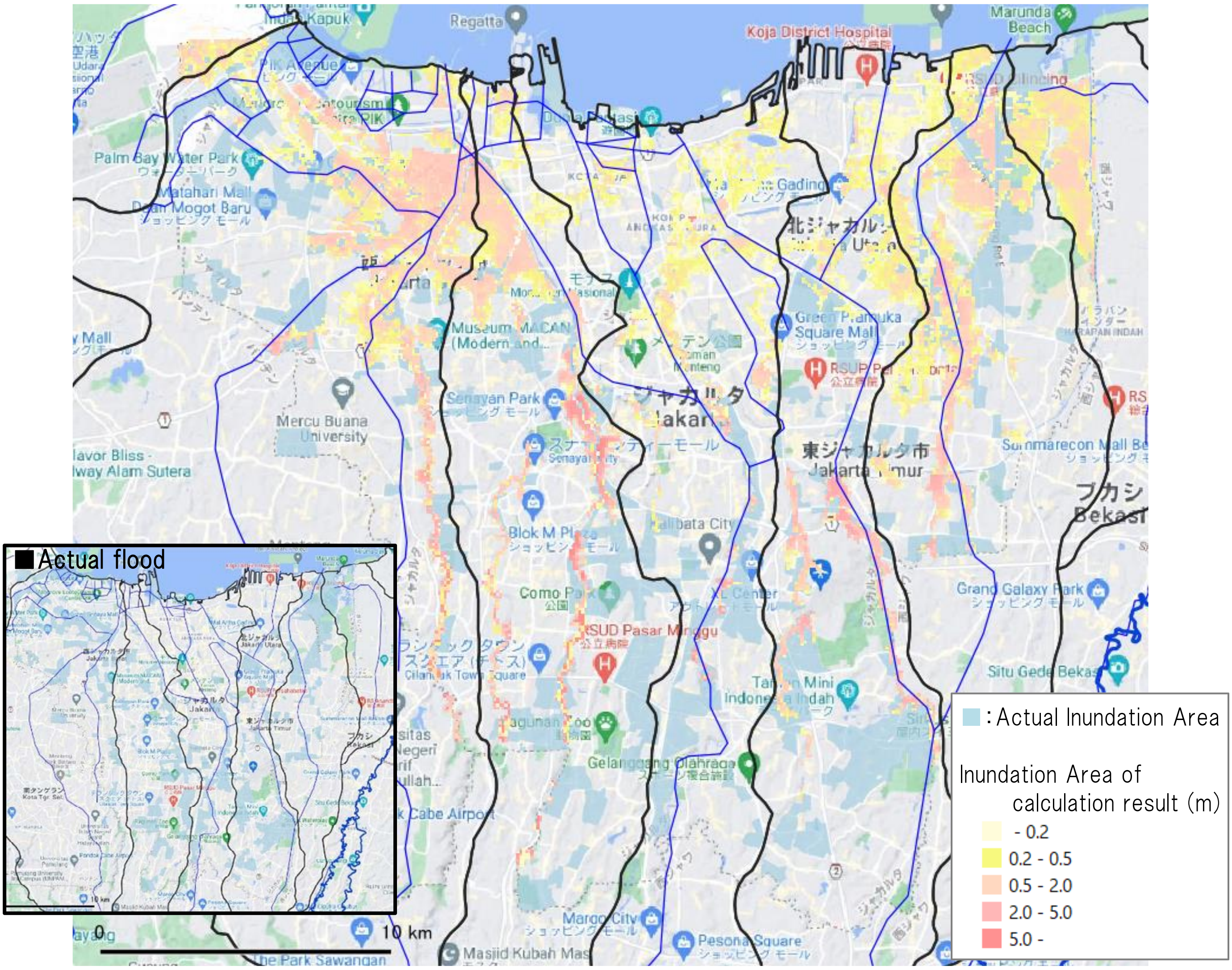
Source：JICA study team

Figure 24 Reproduction of discharge (Depok station)



Source：JICA study team

Figure 25 Reproduction of water level (Manggarai station)



Source：JICA study team

Figure 26 Reproduction of inundation area (the Ciliwung River Basin)

4.4 Flood simulation of 50-year return period

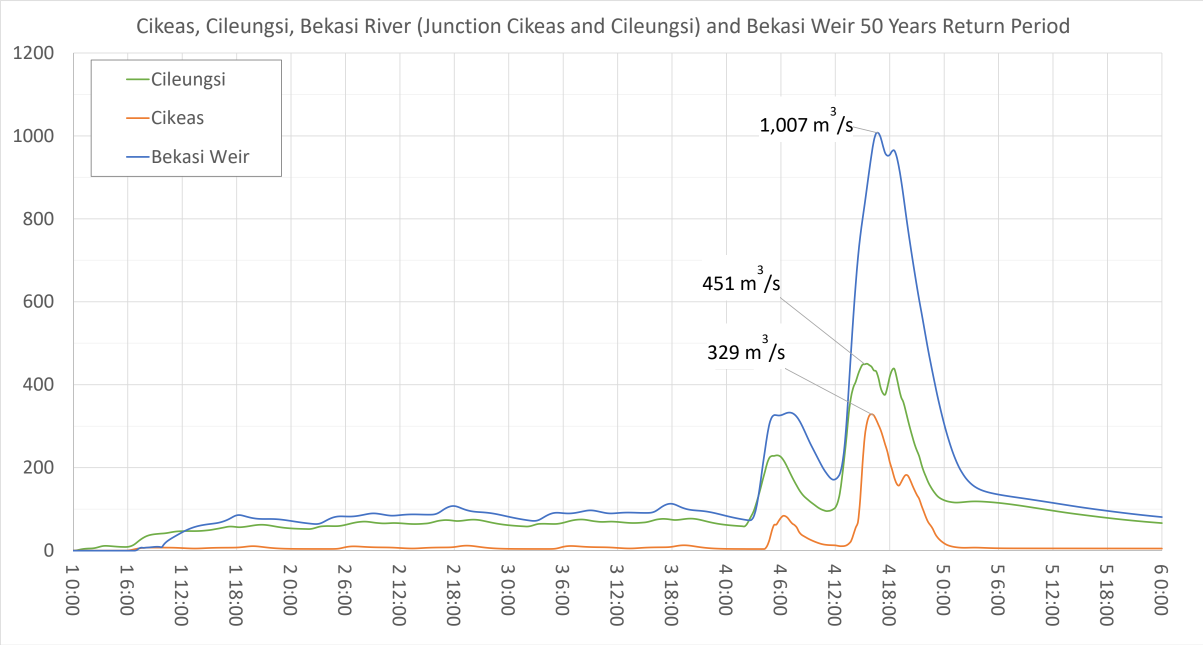
Flood simulation of 50-year return period was carried out in the Bekasi River basin to review the design discharge. The Cisadane and Ciliwung River basins would follow the existing plan of design discharge.

(1) Runoff analysis

Observed rainfall of the flood in January 2020 was enlarged to 50-year return period, and the design discharge was estimated by the runoff simulation model. Hydrographs at the Bekasi weir, Cileungsi and Cikeas are shown in Figure 27 and discharge distribution in Figure 28. These discharges are the results of runoff calculations without inundation.

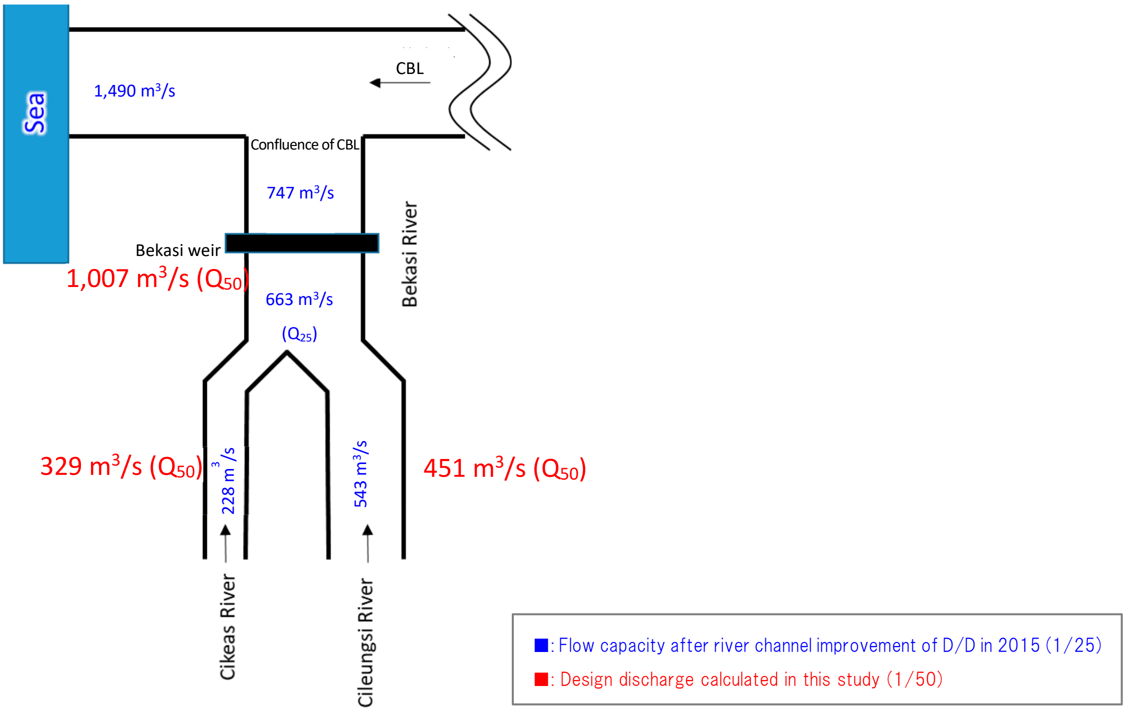
The design discharge at Bekasi weir of 50-year return period is 1,007 m^3/s.

Based on the D/D in 2015, the river channel improvement at upstream of Bekasi weir is now in progress. The flow capacity after completion of river channel improvement will be 663 m^3/s (25-year return period, D/D in 2015). Once the discharge of 1,007 m^3/s is set as an updated design discharge, additional improvement of about 340 m^3/s is required.



Source：JICA study team

Figure 27 Hydrograph (50-year return period)

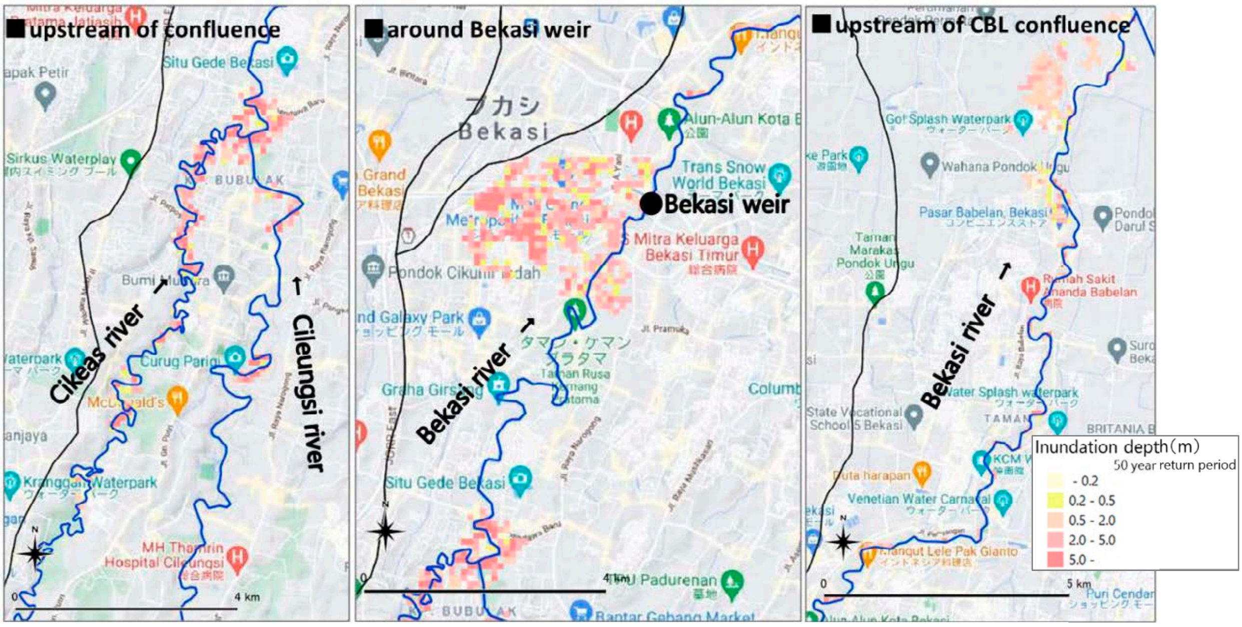


Source：JICA study team

Figure 28 Discharge Distribution (50-year return period)

(2) Runoff analysis

Observed rainfall of the flood in January 2020 was enlarged to 50-year return period, and the inundation area was estimated by the runoff and inundation simulation model. Inundation area at the Bekasi weir, Cileungsi and Cikeas are shown in in Figure 29 and Table 6.



Source：JICA study team

Figure 29 Inundation area (50-year return period)

Table 6 Inundation area (50-year return period)

Inundation depth	Area (km^2)
- 0.2	0.50
0.2 – 0.5	1.03
0.5 – 2.0	2.46
2.0 – 5.0	2.87
5.0 -	1.60
sum	8.46

Source：JICA study team

5 Comparison of HEC-HMS and SOBEK

The runoff analysis models developed by HEC-HMS and SOBEK are both distributed models. The target basin is divided into sub basins, and the basin average rainfall in each sub basin is given as input data, and the discharge is calculated by the unit hydrograph method. The main differences are the method of sub basin division, the method of basin average rainfall, and the runoff models.

Table 7 Comparison of runoff analysis (HEC-HMS and SOBEK)

	HEC-HMS	SOBEK
Purpose	Tentative design discharge	Runoff and inundation analyses
Model Type	Distributed model	Distributed model
Number of sub basin division	5	79
Method of basin average rainfall	Thiessen method	IDW method (inverse distance weighting)
Runoff model	SCS Unit hydrograph	Sacramento Model
River channel model	Lag method and Muskingum method	Muskingum method

Source：JICA study team

A comparison of the reproduction about the flood in January 2020 is shown below.

Gunung Putri (Cileungsi) station is located on the Cileungsi River, upstream of the Bekasi River, and the catchment area is 212 km^2. As shown in Figure 30, the peak discharge and the timing were well reproduced by both models. The HEC-HMS model gave a good matching near the peak, but the SOBEK model gives a good matching in the rising stage before the peak.

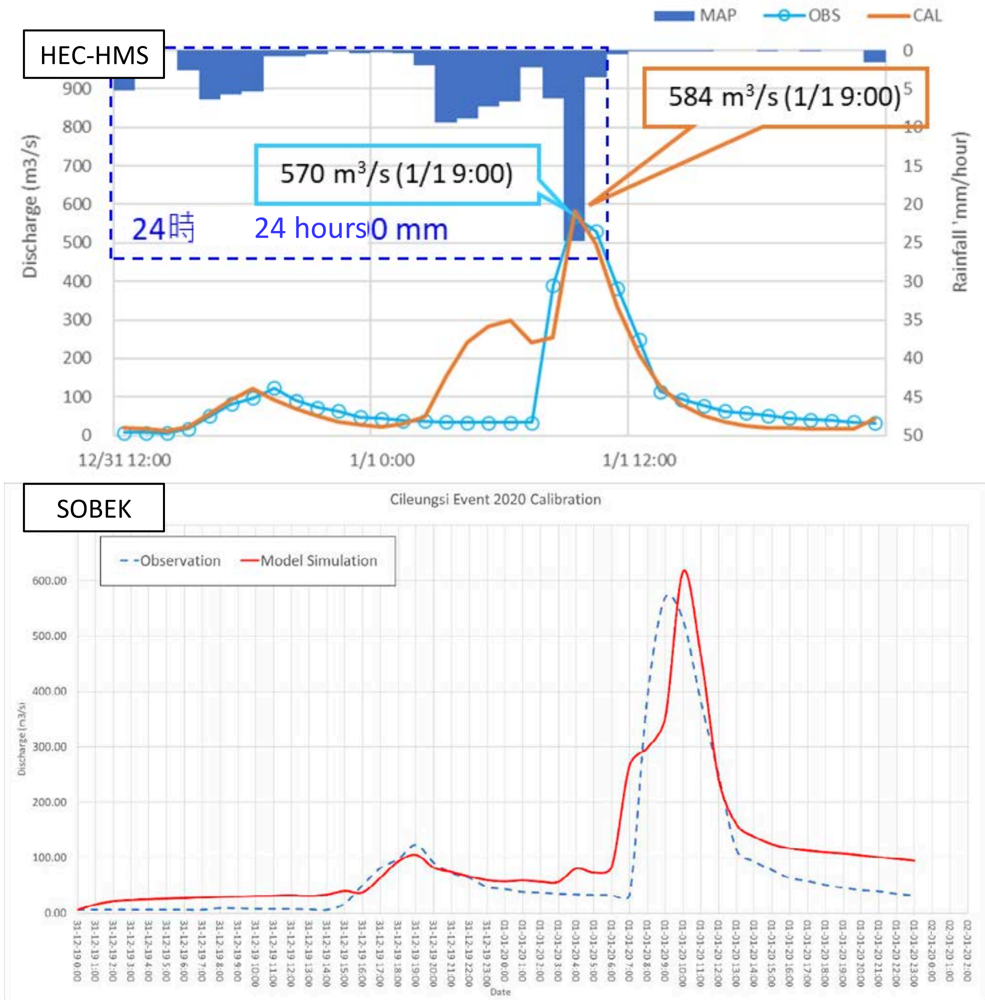


*Chart Legend (MAP: Basin Mean Rainfall; OBS: Observed Flows; CAL: Calculated Flows)

Source：JICA study team

Figure 30 Comparison of reproduction results at Gunung Putri (Cileungsi) station

The Bekasi weir is located on the middle of the Bekasi River, and the catchment area is 385 km^2. As shown in Figure 31, both results of HEC-HMS and SOBEK show certain gaps from the observed data. Actually, the observed discharge is the data that was calculated based on the observed water level and the gate opening of the weir. The reproduced discharge is the inflow into the weir, while the observed data includes effect of gate operation. Therefore, although there are considerable differences with the observed data, the discharge volume is almost the same, and both reproduction discharges were judged appropriate as a phenomenon at the weir.

Regarding the difference between 2 models, the peak discharge of SOBEK is faster, the hydrograph is sharper, and the peak discharge is smaller than that of the HEC-HMS.

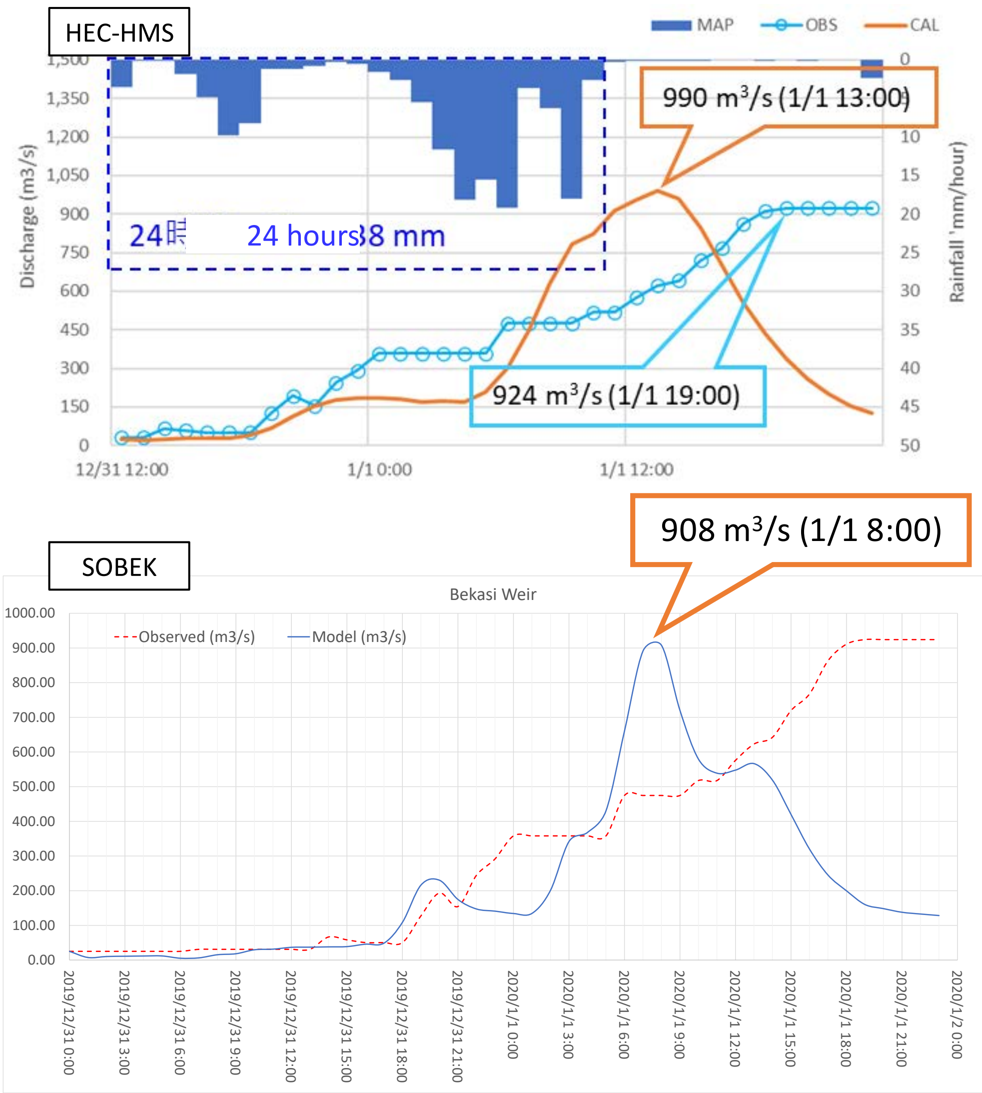


*Chart Legend (MAP: Basin Mean Rainfall; OBS: Observed Flows; CAL: Calculated Flows)

Source : JICA study team

Figure 31 Comparison of reproduction result at Bekasi weir

Attachment 5-2 Basis for calculating the cost of the Bekasi River flood in January 2020

I. Amount of direct Damage ***2,895,416*** ***24,128***

(a) Damage to the buildings

Inundation depth (m)	Area (km2)		Households				Damage Retio	Damage (mil. Rupiah)			
			Permanent House	Non-permanent House	Shop/Office	Manufacture		Permanent House	Non-permanent House	Shop/Office	Manufacture
	8.46	100.0%	25,185.4	5,037.0	1,767.0	14.0		175.000	119.000	1,320.000	19,500.000
-0.2	0.50	5.9%	1,488.5	297.7	104.4	0.8	3.2%	8,336	1,134	4,411	516
0.2 - 0.5	1.03	12.2%	3,066.3	613.3	215.1	1.7	9.2%	49,368	6,714	26,126	3,058
0.5 - 2.0	2.46	29.1%	7,323.4	1,464.7	513.8	4.1	11.9%	152,510	20,741	80,709	9,447
2.0 - 5.0	2.87	33.9%	8,544.0	1,708.8	599.4	4.7	26.6%	397,723	54,089	210,477	24,635
5.0 - .	1.60	18.9%	4,763.2	952.6	334.2	2.6	58.0%	483,465	65,750	255,852	29,946
										IDR	1,885,005
										JPY	15,708

(b) Damage to the asset

Inundation depth (m)	Area (km2)		Households				Damage Retio		Damage (mil. Rupiah)			
			Permanent House	Non-permanent House	Shop/Office	Manufacture	HH Goods	Commerce /Industry (Assets & Inventry)	Permanent House	Non-permanent House	Shop/Office	Manufacture
sum	8.46		3,619.00	5,037.00	1,767.00	14.00			35	24	13	29
-0.2	0.5	5.9%	1,488.50	297.70	104.43	0.83	2.1%	15.5%	1,094	150	214	4
0.2 - 0.5	1.03	12.2%	3,066.31	613.25	215.13	1.70	14.5%	36.0%	15,562	2,134	1,022	18
0.5 - 2.0	2.46	29.1%	7,323.42	1,464.66	513.81	4.07	32.6%	72.0%	83,560	11,459	4,883	85
2.0 - 5.0	2.87	33.9%	8,543.99	1,708.77	599.44	4.75	50.8%	137.5%	151,912	20,833	10,880	189
5.0 - .	1.6	18.9%	4,763.20	952.62	334.18	2.65	92.8%	186.3%	154,709	21,217	8,218	143
											IDR	488,287
											JPY	4,069

(c) Damage to the infrastructure

Total of Damage Costs to Bldgs. & Assets × 0.22 = Damage Costs to Infrastructure

IDR	522,124
JPY	4,351

II. Amount of indirect Damage

(a) Loss of revenue (industrial / commercial unit)

Value Added Amount (Rp/Employee/ Day) × Average No. of Employee per unit × Flood Duration = Loss of Income

(i) Commercial Unit

Inundation depth (m)	Area (km2)		No. of Commercial Unit	Average No. of Employee per unit	Value Added Amount (Rp/Employee/day)	Flood Duration Suspention + Stagnation/2	Damage Amount (mil Rp)
sum	8.46		1,767.00				
-0.2	0.5	5.9%	104.43	10	600,000	6.00	3,760
0.2 - 0.5	1.03	12.2%	215.13	10	600,000	8.80	11,359
0.5 - 2.0	2.46	29.1%	513.81	10	600,000	12.60	38,844
2.0 - 5.0	2.87	33.9%	599.44	10	600,000	20.60	74,091
5.0 - .	1.6	18.9%	334.18	10	600,000	45.20	90,631
						IDR	218,684
						JPY	1,822

(ii) Industrial Unit

Inundation depth (m)	Area (km2)		No. of Commercial Unit	Average No. of Employee per unit	Value Added Amount (Rp/Employee/day)	Flood Duration Suspention + Stagnation/2	Damage Amount (mil Rp)
sum	8.46		4.00				
-0.2	0.5	5.9%	0.24	180	800,000	6.00	204
0.2 - 0.5	1.03	12.2%	0.49	180	800,000	8.80	617
0.5 - 2.0	2.46	29.1%	1.16	180	800,000	12.60	2,110
2.0 - 5.0	2.87	33.9%	1.36	180	800,000	20.60	4,025
5.0 - .	1.6	18.9%	0.76	180	800,000	45.20	4,924
						IDR	11,881
						JPY	99

(b) Loss of revenue from water utilities

(i) Household

Inundation depth (m)	Area (km2)		No. of Affected Users	Average Water Soled/User/Day	Water Sales Tariff	Flood Duration Suspention + Stagnation/2	Damage Amount (mil Rp)
sum	8.46		25,185.42				
-0.2	0.5	5.9%	1,488.50	0.642	5,538	6.00	32
0.2 - 0.5	1.03	12.2%	3,066.31	0.642	5,538	8.80	96
0.5 - 2.0	2.46	29.1%	7,323.42	0.642	5,538	12.60	328
2.0 - 5.0	2.87	33.9%	8,543.99	0.642	5,538	20.60	626
5.0 - .	1.6	18.9%	4,763.20	0.642	5,538	45.20	765
						IDR	1,847
						JPY	15

(ii) Non-household

Inundation depth (m)	Area (km2)		No. of Affected Users	Average Water Soled/User/Day	Water Sales Tariff	Flood Duration Suspention + Stagnation/2	Damage Amount (mil Rp)
sum	8.46		1,781.00				
-0.2	0.5	5.9%	1,488.50	0.270	735	6.00	2
0.2 - 0.5	1.03	12.2%	3,066.31	0.270	735	8.80	5
0.5 - 2.0	2.46	29.1%	7,323.42	0.270	735	12.60	18
2.0 - 5.0	2.87	33.9%	8,543.99	0.270	735	20.60	35
5.0 - .	1.6	18.9%	4,763.20	0.270	735	45.20	43
						IDR	103
						JPY	1

(c) Loss of revenue from electrical utilities

Inundation depth (m)	Area (km2)		No. of Affected Users	Average Electricity Sold (kwH/customer/day)	Electricity Sales Tariff (Rp/KwH)	Flood Duration Suspention + Stagnation/2	Damage Amount (mil Rp)
sum	8.46		32,003.42				
-0.2	0.5	5.9%	1,488.50	23.000	735	6.00	151
0.2 - 0.5	1.03	12.2%	3,066.31	23.000	735	8.80	456
0.5 - 2.0	2.46	29.1%	7,323.42	23.000	735	12.60	1,560
2.0 - 5.0	2.87	33.9%	8,543.99	23.000	735	20.60	2,975
5.0 - .	1.6	18.9%	4,763.20	23.000	735	45.20	3,640
						IDR	8,782
						JPY	73

	1.0yen = Rp.	120.0
I. Amount of direct Damage		
(a) Damage to the buildings	1,885,004.9	15,708.4
(b) Damage to the asset	488,286.7	4,069.1
(c) Damage to the infrastructure	522,124.2	4,351.0
Sub Total I.	2,895,415.7	24,128.5
II. Amount of Indirect Damage		
(a) Loss of income (industrial / commercial unit)		
(i) Commercial Unit	218,684.4	1,822.4
(ii) Industrial Unit	11,881.0	99.0
(b) Loss of revenue from water utilities		
(i) Household	1,847.0	15.4
(ii) Non-household	103.1	0.9
(c) Loss of revenue from electrical utilities	8,782.0	73.2
Sub Total II.	241,297.5	2,010.8
Total	3,136,713.3	26,139.3

Chapter6 Non-structural measures

6.1 Evaluation of non-structural measures

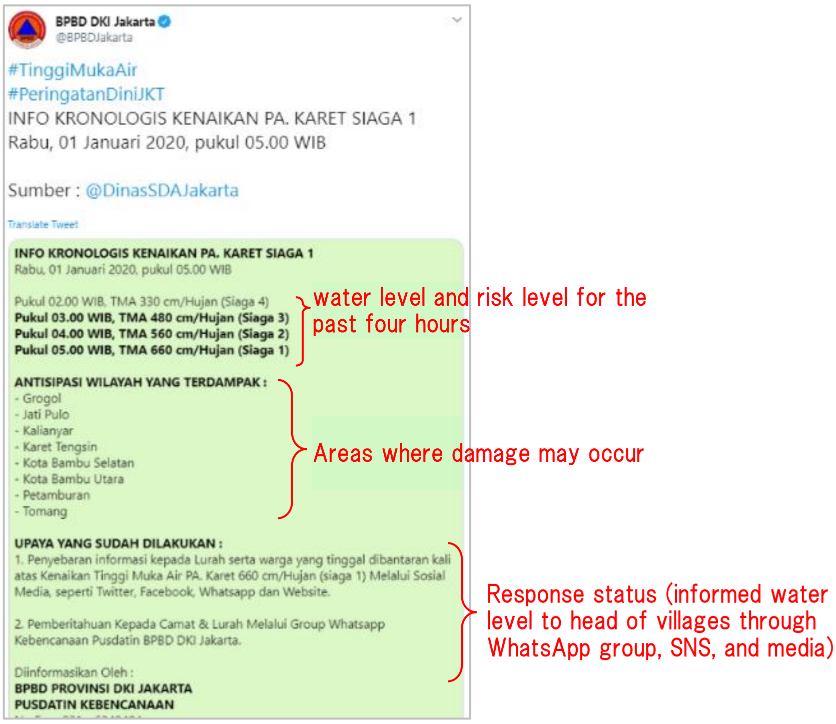
Regarding non-structural measures, emergency response to the flood in 2020, existing plans, and the conditions of hydrological observatories are reviewed.

6.1.1 Emergency response to the flood in January 2020

(1) Communication system

During the flood in January 2020, BPBD and Dinas SDA issued flood warnings based on the water levels in JABODETABEK, and information was disseminated to residents via head of villages. However, the contents of the warning are only the height of the water level, the risk level, and the area where damage is predicted (see Figure 6-1). Residents did not know when and where to evacuate and what to do, so they evacuated to a place they considered safe.

In order to minimize the casualty caused by floods, it is necessary to clearly indicate when and where residents should evacuate.



Source: SNS of BNPB DKI Jakarta

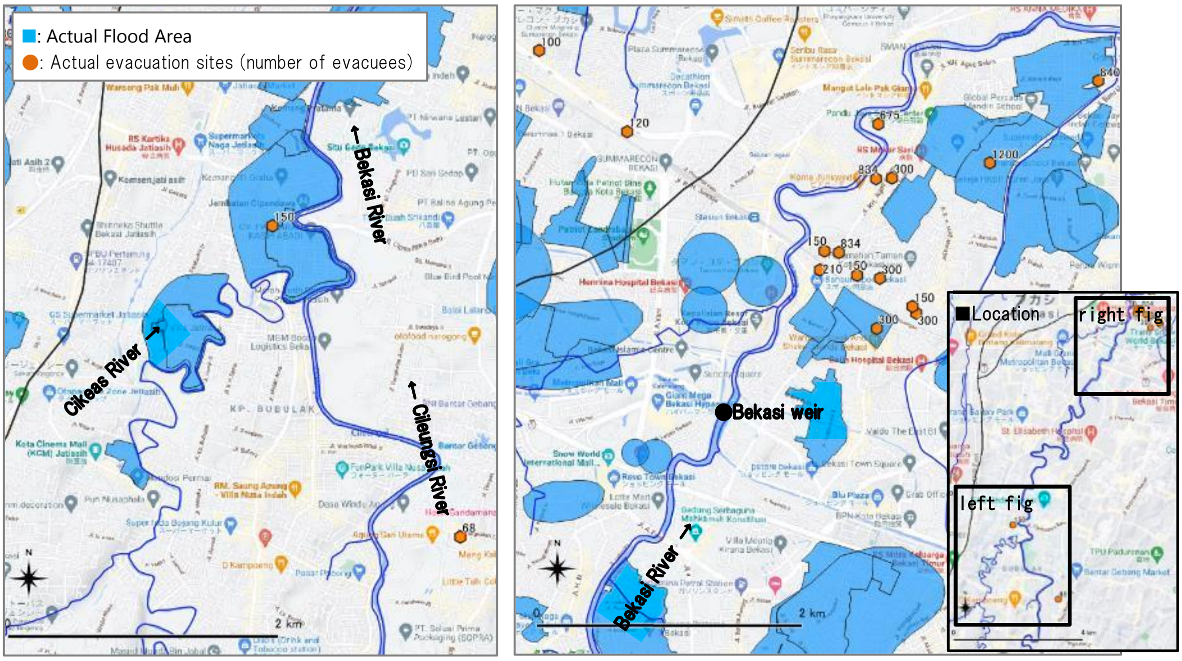
Figure 6-1 Information from BNPB during the flood in January 2020

According to Bekasi City, since the day of the flood in January 2020 was a New Year holiday and the occurrence of heavy rain had not been predicted in the information from BMKG, monitoring of water level and preparation for issuing early warnings were insufficient.

(2) Evacuation site

Figure 6-2 shows the location of evacuation sites in Bekasi City during the floods in January 2020. Mosques, schools, district offices, and other facilities are used as evacuation sites even though they have risk of flooding, such as actual flood area or just next to the Bekasi River. In addition, evacuation sites are concentrated in the downstream of the Bekasi weir, so it is deemed that the location and risk of flood damage were not considered.

It is necessary to use a place where safety can be ensured even during flooding as evacuation sites, because using a dangerous place will cause more human damage.



Source: JICA study team based on Kota Bekasi

Figure 6-2 Location of evacuation sites in Bekasi city

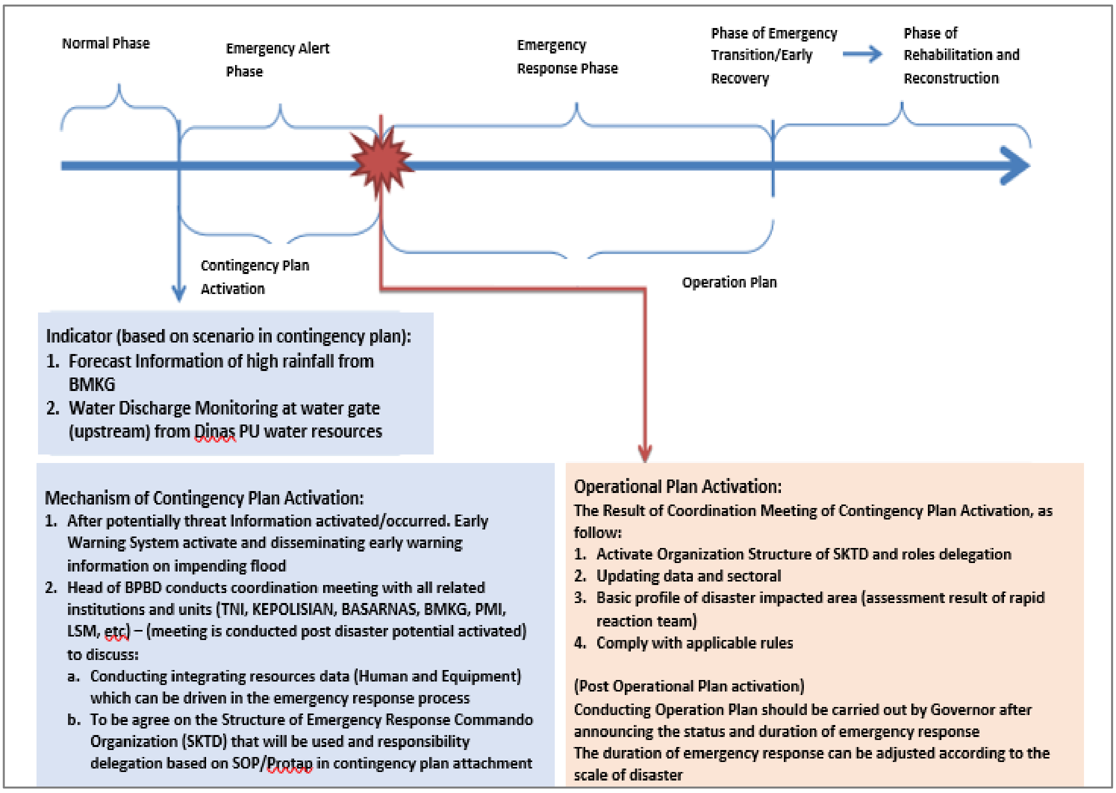
6.1.2 Existing plans for early warning and evacuation

(1) Emergency timeline

A municipal emergency response plan (Renkon) has been formulated by local governments, and the action plan of the local government for the emergency is described in it. In the emergency response plan, each action plan before and after the occurrence of a disaster is described for the response flow in an emergency. It states that it is necessary to issue early warning before disaster occurs, to hold joint meetings with other organizations, and to grasp the damage situation and share information after a disaster occurs. However, it does not specify details including timing, coordination system, and matters to be discussed regarding evacuation.

The Whats App is mainly used for communication between related organizations in case of emergency, and the contents of communication between related organizations via Whats App include the river water level, flood damage situation, and the necessity of evacuation preparation. In addition, the provided information is different depending on the municipality or the person in charge. For example, Bekasi city have never collected CCTV images from BBWS during flooding.

The BPBD instructed the heads of villages to advise residents on where to evacuate and what to bring. However, the heads of villages did not inform their residents about the evacuation sites or their personal belongings, and it seems that they passed only what they received from BPBD on to the residents. Residents who were affected by the flood inundation in January 2020 told during hearings that they had not any knowledge or education about flood preparedness.



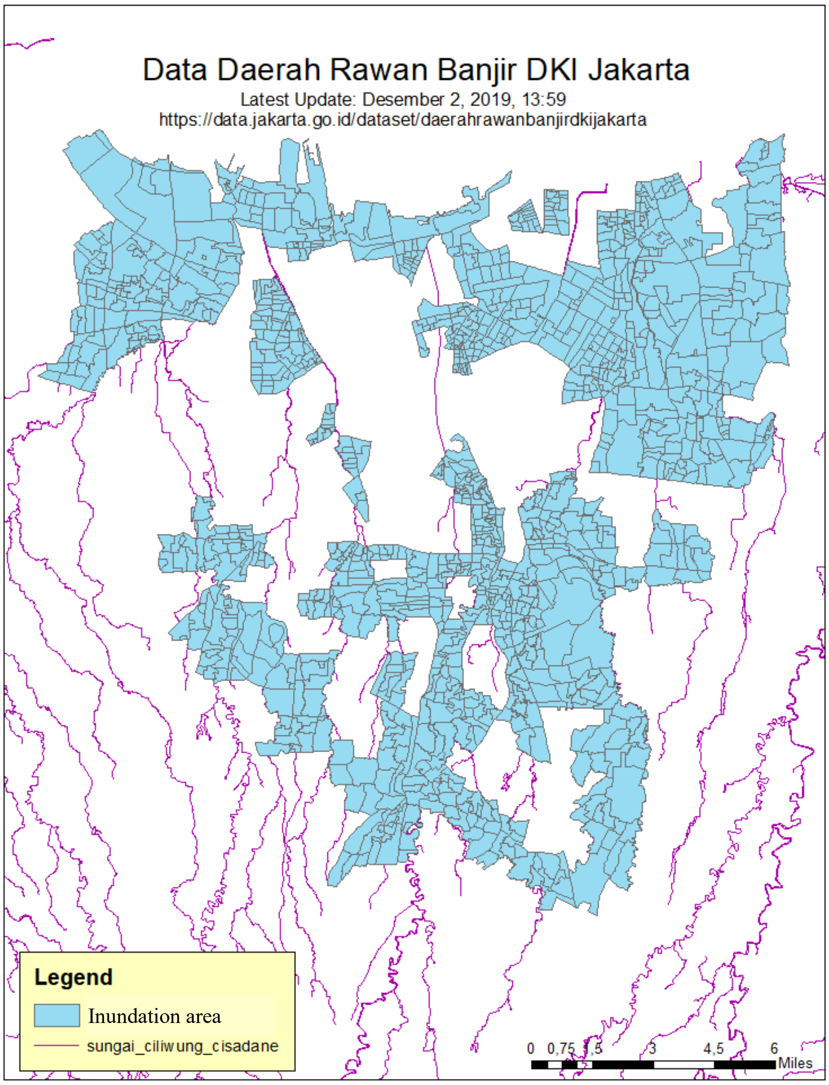
Source: Renkon DKI, 2015

Figure 6-3 Flow of Emergency Response

(2) Flood Hazard Map

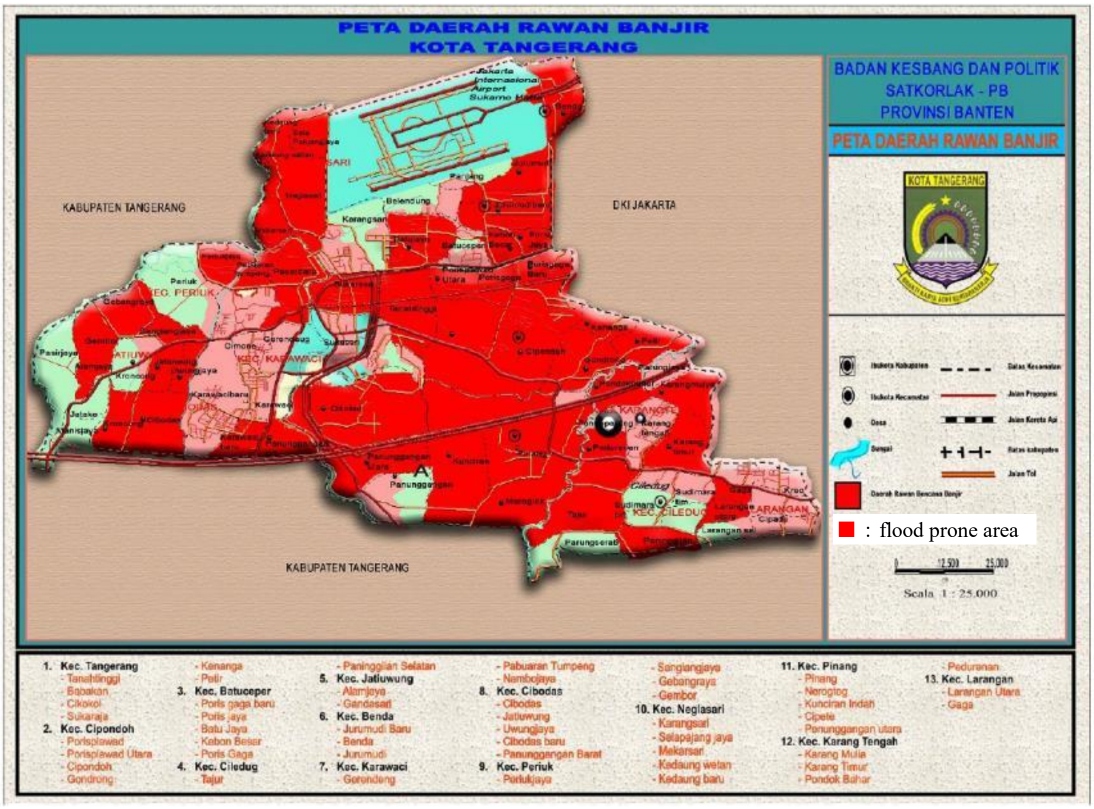
Flood hazard maps (Flood inundation estimation area, inundation depth, evacuation sites, evacuation route, etc. are shown.) to facilitate smooth evacuation during floods have not been developed in JABODETABEK.

In each municipality, a map showing the actual inundation area of past floods or inundation risk has been prepared as shown in Figure 6-4~Figure 6-6. These maps do not show the target areas which people need to evacuate from or to, so they cannot lead evacuation actions well in an emergency.



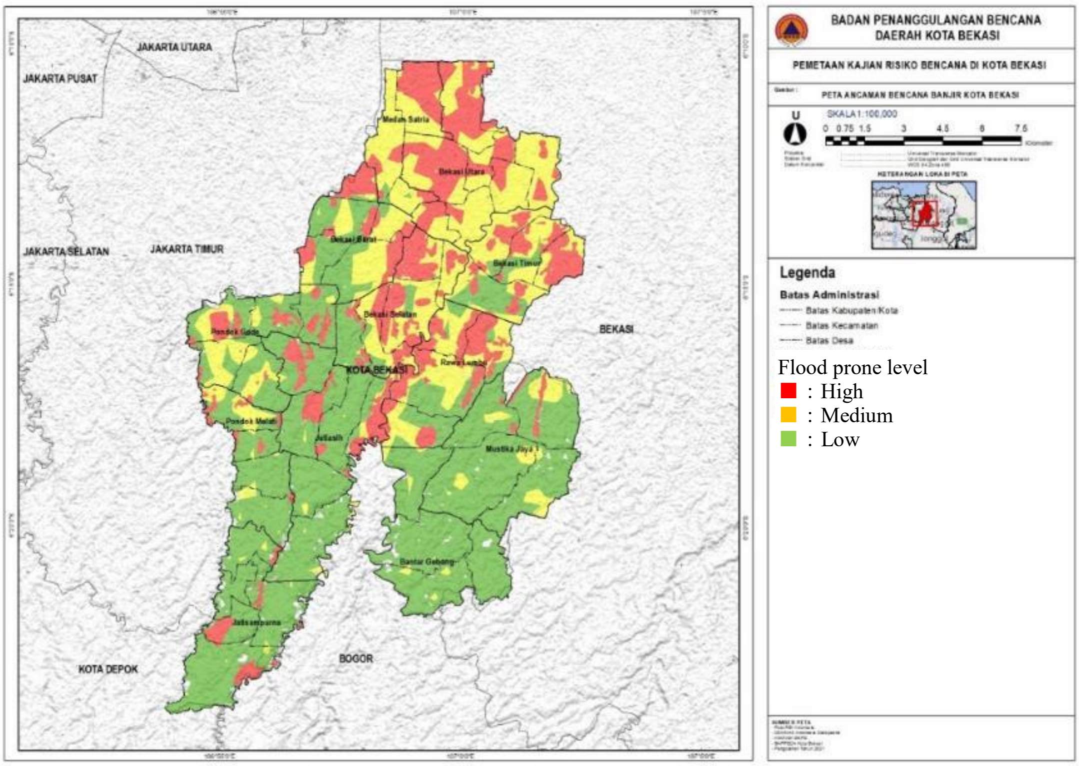
Source: DKI Jakarta

Figure 6-4 Map of actual inundation area (DKI Jakarta)



Source: Kota Tangerang

Figure 6-5 Flood Risk Map（Tangerang City）

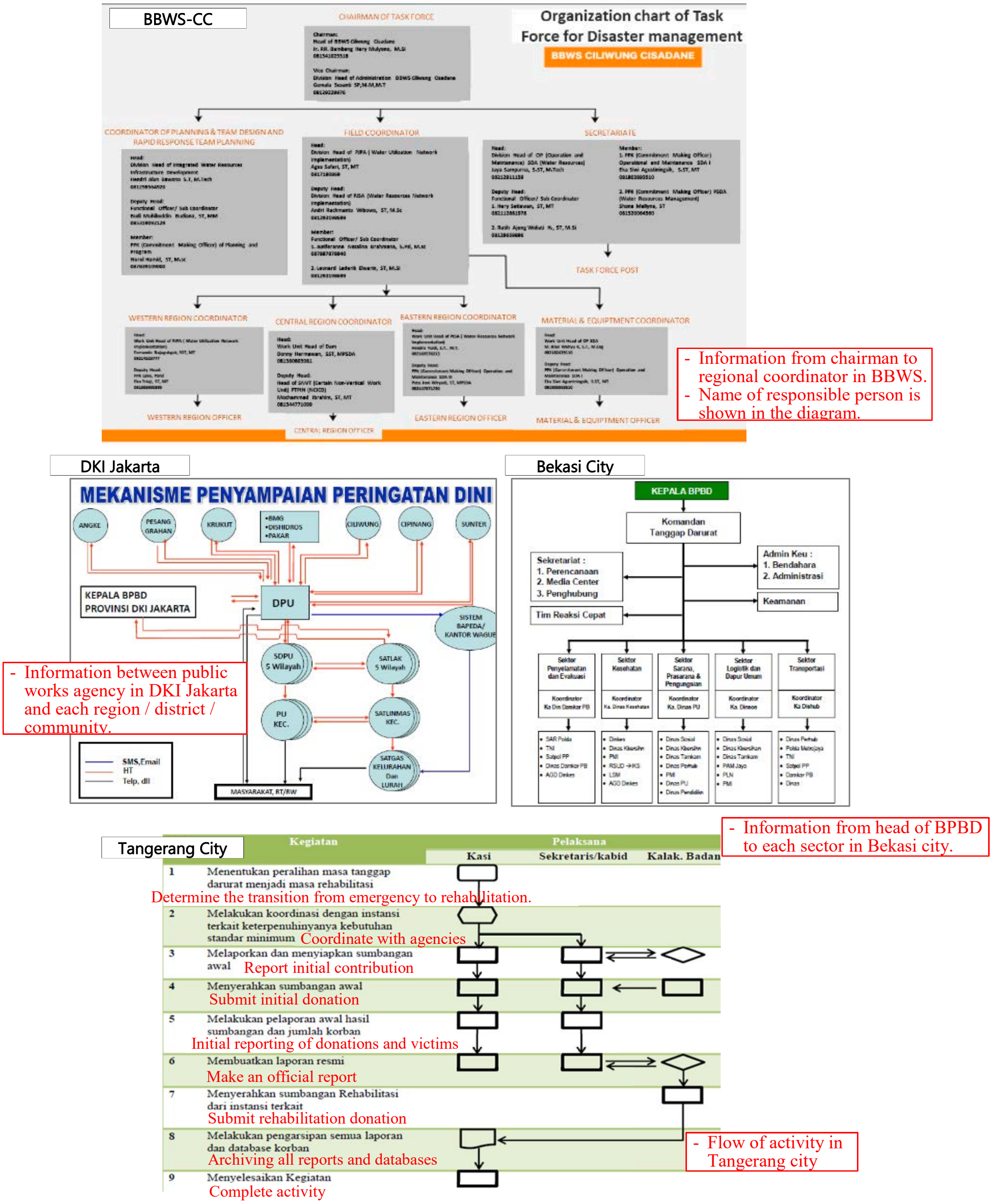


Source: Kota Bekasi

Figure 6-6 Flood Risk Map (Bekasi City)

(3) Communication system

BBWS-CC and local governments have formulated a plan for the communication system in the event of a disaster, but their plans are limited to internal ones within their own organizations. Although the necessity of communication with external organizations is stated in the local government plan, the communication networks are not specified.



Source: BBWS-CC, DKI Jakarta, Kota Bekasi, Kota Tangerang

Figure 6-7 Communication system for cooperation in the event of a disaster

(4) Information and warning to residents

Residents are provided with alerts and evacuation warning as "push-typed" information from the head of the village through Whats App. For example, in Bekasi city, warnings and information are delivered through the Whats App Group "Kompi 887", which includes all the village heads.

In addition, flood information is provided in each organization's web page, application, and SNS such as Facebook, Twitter, and Instagram.

Table 6-1 Tools for Providing Information to Residents

Region	Agency	Social Media (account name)		Smartphone Application	Website
		Twitter	Instagram		
Central Government	BMKG	infoBMKG	infobmkg	Info BMKG	http://web.meteo.bmkg.go.id/id/pengamatan/pengamatan-harian
	BNPB	BNPB_Indonesia	bnpb_indonesia	InaRISK	https://petabencana.id https://gis.bnpb.go.id/
	PUPR (BBWS Ciliwung Cisadane)	-	-	-	http://sdatelemetry.com/newfms/#!/datapda.php http://tech4water.com/# http://bbwscc.sdatelemetry.com/ https://buletin-jfews.pusair-pu.go.id/
DKI Jakarta	BPBD Jakarta	BPBDJakarta	bpbddkijakarta	-	https://bpbd.jakarta.go.id/
	Dinas SDA Jakarta	DinasSDAJakarta	dinas_sda	-	http://poskobanjirdsda.jakarta.go.id/Default.aspx
Bekasi City	Dinas SDA Province	dinassda_jabar	dkijakarta	JAKI (Jakarta Kini)	https://pantaubanjir.jakarta.go.id/
	BPBD Kota Bekasi	BPBDKotaBekasi	bpbdkotabekasi	-	https://www.bekasikota.go.id/
Bekasi Kab	BPBD	bpbdkab_bekasi	bepbe_kabbekasi	-	http://bpbd.bekasikab.go.id/
Kota Bogor	BPBD	bpbdkotabogor	bpbd.kotabogor	-	http://bpbd.kotabogor.go.id/
Kab Bogor	BPBD	bpbd_kabbogor	bpbdkabbogor	-	http://bpbd.bogorkab.org/
Depok	Citygov	pemkotdepok		-	https://www.depok.go.id/
	Dinas PUPR	DinasPUPR		-	-
Tangerang City	BPBD	bpbd_tng	bpbdkotatangerang	-	https://bpbd.tangerangkota.go.id/
	Citygov	Kota_Tangerang	tangerang kota	-	https://www.tangerangkota.go.id
Kab Tangerang	BPBD	relawanBPBD_TGR	bpbd.kabtangerang	-	https://bpbd.bantenprov.go.id/
Tangerang Selatan	BPBD	BPBDKotaTangsel	bpbdtangerangselatan	-	https://www.tangerangselatankota.go.id

Source: JICA study team

Source: BPBD Jakarta, BMKG

Figure 6-8 Utilization of SNS

A civil society community called KP2C (Komunitas Peduli Cieas Cileungsi) is active in the Cikeas, Cileungsi and Bekasi River basins. Activities include (1) distributing daily water levels to registered members via Whats App and (2) managing KP2C's own CCTV.

Currently, KP2C does not collaborate with BBWS-CC or BPBD, but only operates on its own. It is expected that the establishment of a system to cooperate with relevant organizations will further facilitate the provision of information on early warnings and evacuation activities.

CCTV images

Daily information of water level


Info Komunitas Peduli Sungai Cileungsi Cikeas (KP2C)

Level Siaga:
Hulu Cileungsi: **Normal**
Hulu Cikeas: **Normal**
P2C: **Normal**

Rabu, 02/02/2022

Hulu Cileungsi
BATAS NORMAL 100 cm
Jam 06.30 tma 10 (mendung tipis)

Hulu Cikeas
BATAS NORMAL 200 cm
Jam 06.30 tma 85 (mendung tipis)

Pertemuan Cileungsi - Cikeas (P2C)
BATAS NORMAL 350 cm
Jam 06.30 tma < 200

(Jika data P2C berbeda dg pandangan di lapangan adalah krn perbedaan metodologi pengamatan)

Source: KP2C

Figure 6-9 Information from KP2C

(5) Risk level

The standard water levels (SIAGA I, II, III, IV), which indicate four risk levels, are set for each water level observatory, and it is stipulated that when the water level exceeds the standard water levels, this water level information is shared with relevant organizations.

However, there is no uniform policy for determining the standard water levels, and each station sets the standard water levels based on the past flood water levels. Target safety level may vary from station to station even for the same hazard (SIAGA I-IV). Colors used to indicate he risk levels (SIAGA I-IV) are also different depending on the station.

BBWS

TINGKAT SIAGA UNTUK **SUNGAI CILIWUNG**

STASIUN / POS PIKET	SIAGA IV	SIAGA III	SIAGA II	SIAGA I
Gadog	80 cm	80 - 150 cm	150 - 200 cm	> 200 cm
Katulampa	80 cm	80 - 150 cm	150 - 200 cm	> 200 cm
Depok	200 cm	200 - 270 cm	270 - 350 cm	> 300 cm
Manggarai	s/d 750 PP	750 - 850 PP	850 - 950 PP	> 950 PP
PA. Karet	s/d 450 PP	450 - 550 PP	550 - 600 PP	> 600 PP

Ket :
- PP : Peil Priok (Benchmark)

TINGKAT SIAGA UNTUK **KOTA /KAB. BEKASI**

STASIUN / POS PIKET	SIAGA IV	SIAGA III	SIAGA II	SIAGA I
Stasiun Cileungsi	< 1.20 m	1.20 m - 2.40 m	2.40 m - 3.50 m	> 3.50 m
Stasiun Cikeas	< 1.20 m	1.20m - 2.40 m	2.40 m - 3.50 m	> 3.50 m
Stasiun Villa Nusa Indah	19.00 mdpl - 20.20 mdpl	20.20 mdpl - 23.00 mdpl	23.00 mdpl - 23.50 mdpl	> 24.00 mdpl

TINGKAT SIAGA UNTUK **SUNGAI CISADANE**

STASIUN / POS PIKET	SIAGA IV	SIAGA III	SIAGA II	SIAGA I
Stasiun Batubelah	< 3.50 m	3.50 m - 4.50 m	4.50 m - 5.50 m	> 5.50 m
PA. Pasar Baru	+ 550 cm	+ 900 - + 1100 cm	+ 1100 - + 1200 cm	> + 1200 cm

DKI Jakarta

SIAGA 4	SIAGA 3	SIAGA 2	SIAGA 1
NORMAL	WASPADA	SIAGA	AWAS

PINTU AIR	BATAS SIAGA			
	NORMAL	SIAGA III	SIAGA II	SIAGA I
Bendung Katulampa	<80	80-149	150-199	>200
Pos Depok	<200	200-269	270-349	>350
PA Manggarai	<750	750-849	850-949	>950
PA Karet	<450	450-549	550-599	>600
Pos Krukut Hulu	<150	150-249	250-299	>300
Pos Pesanggrahan	<150	150-249	250-349	>350
Pos Angke Hulu	<150	150-249	250-299	>300
Waduk Pluit	<-51	-51-0	1-45	≥ 46
Pasar Ikan	<170	170-199	200-249	>250
Pos Cipinang Hulu	<150	150-199	200-249	>250
Pos Sunter Hulu	<140	140-199	200-249	>250
PA Pulogadung	<550	550-699	700-769	>770

Source: BBWS, DKI Jakarta

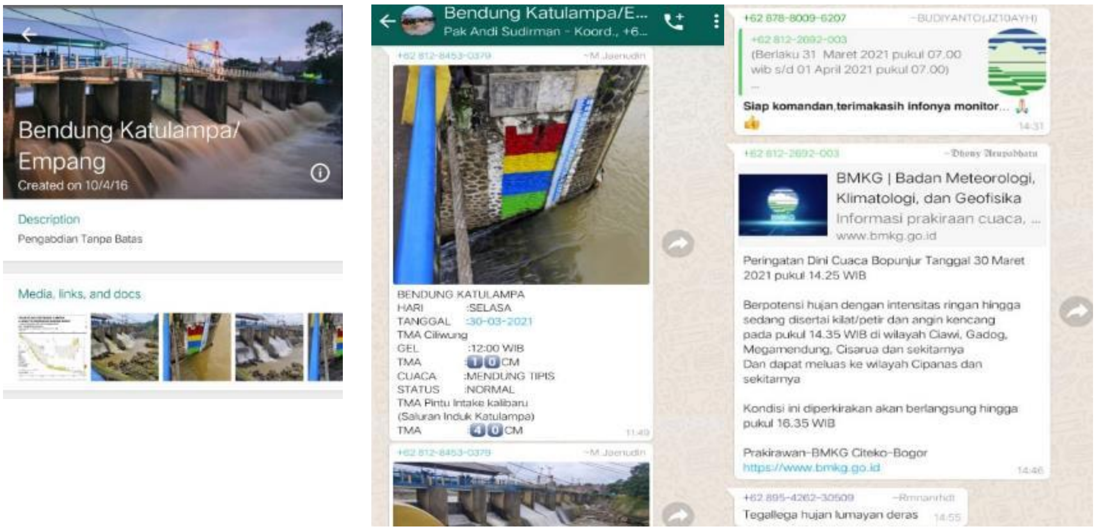
Colors used to illustrate them are not uniform.

Figure 6-10 Risk level of each observatory (BBWS-CC, DKI Jakarta)

(6) Establishment of original communication system

In the Katulampa weir on the upper Ciliwung River, apart from the municipal emergency response plan (Rencana), its own collaborative communication system of Whats App group was established to share emergency information. The Whats App group includes representatives from BPBD, BMKG, Dinas SDA, the police, and the media, and broadcasts relevant information to all parties including local governments.

The establishment of an original communication system may enable flexible responses during emergency, but inappropriate decisions might be made. In order to ensure that appropriate actions are taken during emergency, it is necessary to clarify its position by reflecting the current original communication system in the municipal emergency response plan.



Source: WhatsApp group of Bendung Katulampa

Figure 6-11 Original communication system in Katulampa weir (example of Whats App Group)

(7) Government ordinance on issuance of warning

Government ordinance No. 21 of Indonesia determines the procedure and responsible agency for issuing early warnings.

① Appropriate agencies will continue to monitor disaster conditions, including hydrological data observations.

② Observation data and analysis data are provided to BNPB and BPBD as the judgment material of issuing the early warning.

③ Based on the provided data, BNPB and BPBD make a judgment for issuing early warning.

— Chapter 19 —

(1) Early warning as referred to Chapter 15 -b shall be made to take prompt and appropriate action in order to reduce the risk of disaster and to prepare emergency response actions.

(2) Early warning as referred to in paragraph (1) is carried out by:

a. observing disaster situation;

b. analyze the data from observations;

c. make decisions based on the analysis results;

d. disseminate the results of the decision; and

e. take action by the community.

(3) Appropriate organizations conduct observation and monitoring of the disaster situation

(3) Observation of disaster situation as referred to in paragraph (2) -a is carried out by authorized agencies/institutions according to the type of disaster threat, and the public to obtain data on disaster situation that are likely to occur.

(4) Observation data and analysis data are provided to BNPB and BPBD as a judgment material for issuing early warning

(4) The authorized agency/institution as referred to in paragraph (3) submits the results of the analysis to BNPB and/or BPBD accounting to the location and level of the disaster, as a basis for making decisions and determining early warning actions.

(5) When the early warning is determined, promptly the decision as referred to in paragraph (4) is discriminated through and must be carried out by government institutions, private broadcasting institutions, and mass media to mobilize resources.

(5) as soon as BNPB / BPBD issue early warning, it will be widely disseminated.

(6) The mobilization of resources as referred to in paragraph (5) is treated the same as the mechanism for mobilizing resources during an emergency response.

(7) BNPB and/or BPBD coordinate the actions taken by the community as referred to in paragraph (2) -e to save and protect the community.

Source: PERATURAN PEMERINTAH REPUBLIK INDONESIA, NOMOR 21, TAHUN 2008, PASAL 19
Government ordinance No. 21, 2008, Implementation of Disaster Management, Chapter 19

Figure 6-12 Government ordinance on issuance of early warning

6.1.3 Hydrological observatory

Hydrological data were collected in this study, but due to data missing and abnormal values at many observatories and periods, many of them could not be utilized. Since the accumulation of hydrological data is indispensable for understanding rainfall characteristics and studying flood control and water utilization, it is an urgent issue to improve the data quality and observation method of the currently operating observatories. Examples of missing data and abnormal values are shown below.

(1) Missing data for long period

A number of observatories have periods in which rainfall data were not continuous and data were not recorded well.

- BBWS-CC：Rawa Gede Station, Jati Jajar Station

BMKG：Stasiun Meteorogi Kemayoran Station, Stasiun Meteorogi Maritime Tanjung priok Station, ARG Pulomas Station, ARG Kelapa Gading Station, ARG Manggarai Station, AWS Halim Perdana Kusumah Station, ARG Tomang Station, ARG Lebak Bulus Station, ARG Ciganjur Station, AWS BSD Serpong Station, AWS Staklim Tangerang Selatan Station, ARG Bekasi Station, AWS Stamet Cengkareng Station, ARG Kebun Raya Bogor Station

▼Rawa Gede station

NO	TANGGAL	JAM	CURAH HUJAN	STATUS
1	30-Dec-19	1:00	0.00 mm	Cerah
2	1-Jan-20	12:00	0.00 mm	Cerah
3	1-Jan-20	13:00	0.00 mm	Cerah
4	2-Jan-20	0:00	0.00 mm	Cerah

▼Jati Jajar station

NO	TANGGAL	JAM	CURAH HUJAN	STATUS
222	1-Jan-20	5:00	0.00 mm	Cerah
223	1-Jan-20	13:00	0.00 mm	Cerah
224	1-Jan-20	22:00	0.00 mm	Cerah
225	1-Jan-20	23:00	0.00 mm	Cerah
226	2-Jan-20	0:00	0.00 mm	Cerah
227	2-Jan-20	1:00	0.00 mm	Cerah
228	2-Jan-20	10:00	0.00 mm	Cerah
229	2-Jan-20	11:00	0.00 mm	Cerah
230	6-Jan-20	11:00	0.00 mm	Cerah
231	6-Jan-20	12:00	0.00 mm	Cerah

Discontinuous time
(Missing data when there is no data)

Source: BBWS-CC

Figure 6-13 Example of missing data (BBWS-CC)

▼Kemayoran meteorological station

name_station	latt_statio	long_stati	datetime_lkp_hour	sum_hourl
AWS Stamet 745 Kemayoran	-6.15595	106.842	2019/12/31 14:00	NA
AWS Stamet 745 Kemayoran	-6.15595	106.842	2019/12/31 15:00	NA
AWS Stamet 745 Kemayoran	-6.15595	106.842	2019/12/31 16:00	NA
AWS Stamet 745 Kemayoran	-6.15595	106.842	2019/12/31 17:00	NA
AWS Stamet 745 Kemayoran	-6.15595	106.842	2019/12/31 18:00	NA
AWS Stamet 745 Kemayoran	-6.15595	106.842	2019/12/31 19:00	NA
AWS Stamet 745 Kemayoran	-6.15595	106.842	2019/12/31 20:00	NA
AWS Stamet 745 Kemayoran	-6.15595	106.842	2019/12/31 21:00	NA
AWS Stamet 745 Kemayoran	-6.15595	106.842	2019/12/31 22:00	NA
AWS Stamet 745 Kemayoran	-6.15595	106.842	2019/12/31 23:00	NA
AWS Stamet 745 Kemayoran	-6.15595	106.842	2020/1/1 0:00	NA
AWS Stamet 745 Kemayoran	-6.15595	106.842	2020/1/1 1:00	NA
AWS Stamet 745 Kemayoran	-6.15595	106.842	2020/1/1 2:00	NA
AWS Stamet 745 Kemayoran	-6.15595	106.842	2020/1/1 3:00	NA
AWS Stamet 745 Kemayoran	-6.15595	106.842	2020/1/1 4:00	NA
AWS Stamet 745 Kemayoran	-6.15595	106.842	2020/1/1 5:00	11
AWS Stamet 745 Kemayoran	-6.15595	106.842	2020/1/1 7:00	37.3

missing data

Source: BMKG

Figure 6-14 Example of missing data (BMKG)

(2) "0 mm" during rainfall

There are several stations which recorded 0 mm rainfall while rainfall was observed at their neighbouring stations.

- BBWS-CC：Cawang Station, Pasir Jaya Station, Kemensos Station
- BMKG：ARG Plumas Station, ARG Bekasi Station

▼Cawang station

205	31-Dec-19	12:00	0.00 mm	Cerah
206	31-Dec-19	13:00	0.00 mm	Cerah
207	31-Dec-19	14:00	0.00 mm	Cerah
208	31-Dec-19	15:00	0.00 mm	Cerah
209	31-Dec-19	16:00	0.00 mm	Cerah
210	31-Dec-19	17:00	0.00 mm	Cerah
211	31-Dec-19	18:00	0.00 mm	Cerah
212	31-Dec-19	19:00	0.00 mm	Cerah
213	31-Dec-19	20:00	0.00 mm	Cerah
214	31-Dec-19	21:00	0.00 mm	Cerah
215	31-Dec-19	22:00	0.00 mm	Cerah
216	31-Dec-19	23:00	0.00 mm	Cerah
217	1-Jan-20	0:00	0.00 mm	Cerah
218	1-Jan-20	1:00	0.00 mm	Cerah
219	1-Jan-20	2:00	0.00 mm	Cerah
220	1-Jan-20	3:00	0.00 mm	Cerah
221	1-Jan-20	4:00	0.00 mm	Cerah
222	1-Jan-20	5:00	0.00 mm	Cerah
223	1-Jan-20	6:00	0.00 mm	Cerah
224	1-Jan-20	7:00	0.00 mm	Cerah
225	1-Jan-20	8:00	0.00 mm	Cerah
226	1-Jan-20	9:00	0.00 mm	Cerah
227	1-Jan-20	10:00	0.00 mm	Cerah
228	1-Jan-20	11:00	0.00 mm	Cerah
229	1-Jan-20	12:00	0.00 mm	Cerah

▼Pasir Jaya station

204	31-Dec-19	12:00	0.00 mm	Cerah
205	31-Dec-19	13:00	0.00 mm	Cerah
206	31-Dec-19	14:00	0.00 mm	Cerah
207	31-Dec-19	15:00	0.00 mm	Cerah
208	31-Dec-19	16:00	0.00 mm	Cerah
209	31-Dec-19	17:00	0.00 mm	Cerah
210	31-Dec-19	18:00	0.00 mm	Cerah
211	31-Dec-19	19:00	0.00 mm	Cerah
212	31-Dec-19	20:00	0.00 mm	Cerah
213	31-Dec-19	21:00	0.00 mm	Cerah
214	31-Dec-19	22:00	0.00 mm	Cerah
215	31-Dec-19	23:00	0.00 mm	Cerah
216	1-Jan-20	0:00	0.00 mm	Cerah
217	1-Jan-20	1:00	0.00 mm	Cerah
218	1-Jan-20	2:00	0.00 mm	Cerah
219	1-Jan-20	3:00	0.00 mm	Cerah
220	1-Jan-20	4:00	0.00 mm	Cerah
221	1-Jan-20	5:00	0.00 mm	Cerah
222	1-Jan-20	6:00	0.00 mm	Cerah
223	1-Jan-20	7:00	0.00 mm	Cerah
224	1-Jan-20	8:00	0.00 mm	Cerah
225	1-Jan-20	9:00	0.00 mm	Cerah
226	1-Jan-20	10:00	0.00 mm	Cerah
227	1-Jan-20	11:00	0.00 mm	Cerah
228	1-Jan-20	12:00	0.00 mm	Cerah

▼Kemensos station

205	31-Dec-19	12:00	0.00 mm	Cerah
206	31-Dec-19	13:00	0.00 mm	Cerah
207	31-Dec-19	14:00	0.00 mm	Cerah
208	31-Dec-19	15:00	0.00 mm	Cerah
209	31-Dec-19	16:00	0.00 mm	Cerah
210	31-Dec-19	17:00	0.00 mm	Cerah
211	31-Dec-19	18:00	0.00 mm	Cerah
212	31-Dec-19	19:00	0.00 mm	Cerah
213	31-Dec-19	20:00	0.00 mm	Cerah
214	31-Dec-19	21:00	0.00 mm	Cerah
215	31-Dec-19	22:00	0.00 mm	Cerah
216	31-Dec-19	23:00	0.00 mm	Cerah
217	1-Jan-20	0:00	0.00 mm	Cerah
218	1-Jan-20	1:00	0.00 mm	Cerah
219	1-Jan-20	2:00	0.00 mm	Cerah
220	1-Jan-20	3:00	0.00 mm	Cerah
221	1-Jan-20	4:00	0.00 mm	Cerah
222	1-Jan-20	5:00	0.00 mm	Cerah
223	1-Jan-20	6:00	0.00 mm	Cerah
224	1-Jan-20	7:00	0.00 mm	Cerah
225	1-Jan-20	8:00	0.00 mm	Cerah
226	1-Jan-20	9:00	0.00 mm	Cerah
227	1-Jan-20	10:00	0.00 mm	Cerah
228	1-Jan-20	11:00	0.00 mm	Cerah
229	1-Jan-20	12:00	0.00 mm	Cerah

Observed value is 0mm during heavy rain.

Source: BBWS-CC

Figure 6-15 Example of 0 mm during rainfall (BBWS-CC)

▼ARG Plomas station

name_station	latt_statio	long_stati	datetime_lkp_hour	sum_hourl
ARG Pulomas	-6.16666	106.881	2017/1/20 18:00	0
ARG Pulomas	-6.16666	106.881	2017/1/20 19:00	0
ARG Pulomas	-6.16666	106.881	2017/1/20 20:00	0
ARG Pulomas	-6.16666	106.881	2017/1/20 21:00	0
ARG Pulomas	-6.16666	106.881	2017/1/20 22:00	0
ARG Pulomas	-6.16666	106.881	2017/1/20 23:00	0
ARG Pulomas	-6.16666	106.881	2017/1/21 0:00	0
ARG Pulomas	-6.16666	106.881	2017/1/21 1:00	0
ARG Pulomas	-6.16666	106.881	2017/1/21 2:00	0
ARG Pulomas	-6.16666	106.881	2017/1/21 3:00	0
ARG Pulomas	-6.16666	106.881	2017/1/21 4:00	0

2017/2/20 ~ 21
Observed value is 0 mm
during heavy rain

Source: BMKG

Figure 6-16 Example of 0 mm during rainfall (BMKG)

(3) Consecutive same value

The data showed that the same amount of rainfall continued at regular intervals over a long period of time.

- BMKG：AWS BSD Serpong Station, ARG Manggarai Station

▼AWS BSD Serpong Station

name_station	latt_statio	long_static	datetime_lkp_hour	sum_hourl
AWS BSD Serpong	-6.2792	106.65	2019/12/30 15:00	0.2
AWS BSD Serpong	-6.2792	106.65	2019/12/30 16:00	0
AWS BSD Serpong	-6.2792	106.65	2019/12/30 17:00	0
AWS BSD Serpong	-6.2792	106.65	2019/12/30 18:00	0
AWS BSD Serpong	-6.2792	106.65	2019/12/30 19:00	0
AWS BSD Serpong	-6.2792	106.65	2019/12/30 20:00	0
AWS BSD Serpong	-6.2792	106.65	2019/12/30 21:00	0
AWS BSD Serpong	-6.2792	106.65	2019/12/30 22:00	0.2
AWS BSD Serpong	-6.2792	106.65	2019/12/30 23:00	0
AWS BSD Serpong	-6.2792	106.65	2019/12/31 0:00	0
AWS BSD Serpong	-6.2792	106.65	2019/12/31 1:00	0
AWS BSD Serpong	-6.2792	106.65	2019/12/31 2:00	0
AWS BSD Serpong	-6.2792	106.65	2019/12/31 3:00	0
AWS BSD Serpong	-6.2792	106.65	2019/12/31 4:00	0.2
AWS BSD Serpong	-6.2792	106.65	2019/12/31 5:00	0
AWS BSD Serpong	-6.2792	106.65	2019/12/31 6:00	0
AWS BSD Serpong	-6.2792	106.65	2019/12/31 7:00	0
AWS BSD Serpong	-6.2792	106.65	2019/12/31 8:00	0
AWS BSD Serpong	-6.2792	106.65	2019/12/31 9:00	0
AWS BSD Serpong	-6.2792	106.65	2019/12/31 10:00	0
AWS BSD Serpong	-6.2792	106.65	2019/12/31 11:00	0.2

Consecutive same value at constant intervals

Source: BMKG

Figure 6-17 Example of continuous same value (BMKG)

(4) Abnormal value

Some of the daily rainfall and hourly rainfall values during floods were judged to be abnormal by taking into consideration rainfall records at nearby observatories.

- BBWS-CC：PLTA Krakak Station
- BMKG：ARG Tomang Station

▼PLTA Krakak Station

Lokasi : PLTA KRACAK
Tahun : 2015

Tanggal	2015												Keterangan
	Jan	Feb	Maret	April	Mei	Juni	Juli	Agst	Sep	Okt	Nop	Des	
1	35.5	-	-	40.4	-	-	-	20.5	-	-	5.5	6.5	
2	4.5	-	7.8	2.3	-	71	-	-	-	-	80	-	
3	10.7	-	-	-	7.2	-	-	-	-	-	30.3	6	
4	5.5	-	-	8.7	-	-	-	-	-	-	35	36	
5	-	-	-	5.4	70.1	-	-	-	-	-	10.4	7.2	
6	34.25	-	20	3.2	0.3	10	-	-	-	-	-	60	
7	-	-	-	-	-	-	-	-	-	49.2	-	7	
8	-	-	-	-	-	-	-	-	5	16.5	91.1	-	
9	-	-	23.3	8.4	33.7	9	-	-	5.6	11.03	29	56.5	
10	-	-	-	-	-	7	-	-	-	-	-	4.8	
11	-	-	-	76	-	-	-	-	-	-	10.55	20.5	
12	4.5	-	-	30.4	-	-	-	1030	-	-	95	27	
13	4	-	-	-	30.55	-	-	-	-	-	20.65	15	
14	-	-	18	10.5	10	20.25	-	-	-	-	-	-	
15	-	-	25	-	50.2	-	-	-	-	-	73.4	6.5	
16	-	-	20.6	19.5	43.1	-	-	-	-	-	28.4	10.6	
17	-	-	-	-	-	-	-	-	-	-	5.5	4	
18	17.2	-	30.6	-	5	-	-	-	-	-	23.9	9.4	
19	87	-	30.2	0.5	100	-	-	-	-	-	10	15.2	
20	3.5	-	24.7	8.3	-	-	-	-	-	6	21.4	25.7	
21	100.1	-	41.6	13.8	-	-	23	-	-	-	7.7	-	
22	18	-	3.6	-	-	-	-	-	-	-	6	0.5	
23	-	-	-	-	-	-	-	-	-	-	-	10.32	
24	-	-	8.7	20.9	-	-	-	-	-	-	15.5	7.6	
25	50.5	-	-	-	-	-	-	-	66	-	160	-	
26	-	-	-	-	-	-	17.4	-	-	-	-	6.7	
27	2	-	70	5.5	-	-	-	-	10.8	51.3	-	-	
28	8	-	8.8	10	-	-	-	-	82.4	-	58	-	
29	-	-	40.4	7	-	5	20.5	-	-	90	10.4	0.7	
30	5	-	80.8	-	-	16	-	15.5	-	-	40.3	1.2	
31	4	-	39.2	-	-	-	-	-	-	-	-	-	
Rata-rata	**23.2**	**#DIV/0!**	**29.0**	**15.9**	**35.0**	**19.8**	**20.3**	**355.3**	**34.0**	**37.3**	**37.7**	**15.0**	
Maksimum	**100.1**	**0.0**	**80.8**	**76.0**	**100.0**	**71.0**	**23.0**	**1030.0**	**82.4**	**90.0**	**160.0**	**60.0**	
Minimum	**2.0**	**0.0**	**3.6**	**0.5**	**0.3**	**5.0**	**17.4**	**15.5**	**5.0**	**6.0**	**5.5**	**0.5**	
Jml. Hari Hujan	**17**	**0**	**17**	**17**	**10**	**7**	**3**	**3**	**5**	**6**	**23**	**23**	

Daily rainfall 1,030 mm.
No rainfall was observed at other observatories on the same day, and August was dry season.

Source: BBWS-CC

Figure 6-18 Example of abnormal value (BBWS-CC)

▼ARG Tomang Station

name_station	latt_statio	long_statio	datetime_lkp_hour	sum_hourl
ARG Tomang	-6.1667	106.78	2019/12/31 15:00	NA
ARG Tomang	-6.1667	106.78	2019/12/31 16:00	NA
ARG Tomang	-6.1667	106.78	2019/12/31 17:00	NA
ARG Tomang	-6.1667	106.78	2019/12/31 18:00	NA
ARG Tomang	-6.1667	106.78	2019/12/31 19:00	NA
ARG Tomang	-6.1667	106.78	2019/12/31 20:00	NA
ARG Tomang	-6.1667	106.78	2019/12/31 21:00	NA
ARG Tomang	-6.1667	106.78	2019/12/31 22:00	NA
ARG Tomang	-6.1667	106.78	2019/12/31 23:00	NA
ARG Tomang	-6.1667	106.78	2020/1/1 0:00	215.4
ARG Tomang	-6.1667	106.78	2019/12/31 7:00	0
ARG Tomang	-6.1667	106.78	2019/12/31 8:00	0
ARG Tomang	-6.1667	106.78	2019/12/31 9:00	0

Hourly rainfall 215.4 mm.
The data was missing for 12 hours until this time.

Source: BMKG

Figure 6-19 Example of abnormal value (BMKG)

(5) Discrepancy between hourly data and daily data

The total daily rainfall calculated from hourly rainfalls is not equal to the observed daily rainfall. Even if the boundary time of day is shifted, the amount of daily rainfall does not match. It is necessary to improve the accuracy so that the values agree with each observation method.

- BBWS-CC : Gadog Station, KpKelapa Station, SumurBatu Station, Cigudeg Station, KampusUI Station, LengkongBarang Station, JerukPurut Station, VillaPamulang Station, Cawang Station (ARR), RancaSumur Station (ARR)
- BMKG : Stasiun Meteorogi Siteko (Puncak) Station, AWS Puspiptek Serpong Station, AWS Digi Stamet Cengkareeng Station

▼Total daily rainfall calculated from hourly rainfall

	Gadog	KpKelapa	SumurBatu	Cigudeg	KampusUI	LengkongBarang	JerukPurut	VillaPamulang	Cawang_ARR	RancaSumur_ARR	ogi Citeko (Puncak)	Puspiptek Serpong	Cengkareng
2019/12/31	76.50	5.50	4.00	0.50	2.00	0.00	0.50	0.00	0.00	0.10	44.00	0.00	0.00
2020/1/1	68.00	167.00	22.50	219.50	107.00	149.00	161.50	228.00	179.60	0.90	336.60	66.20	140.80

▼daily rainfall

	Gadog	KpKelapa	SumurBatu	Cigudeg	KampusUI	LengkongBarang	JerukPurut	VillaPamulang	Cawang_ARR	RancaSumur_ARR	ogi Citeko (Puncak)	Puspiptek Serpong	Cengkareng
2019/12/31	95.50	148.50	251.00	290.00	107.50	85.50	102.00	112.00	109.00	34.00	57.50	0.00	0.00
2020/1/1	34.00	6.10	25.10	11.20	155.20	27.00	13.00	52.50	51.00	23.50	60.00	55.20	148.00

Not equal

Source: JICA study team based on observed data by BBWS-CC and BMKG

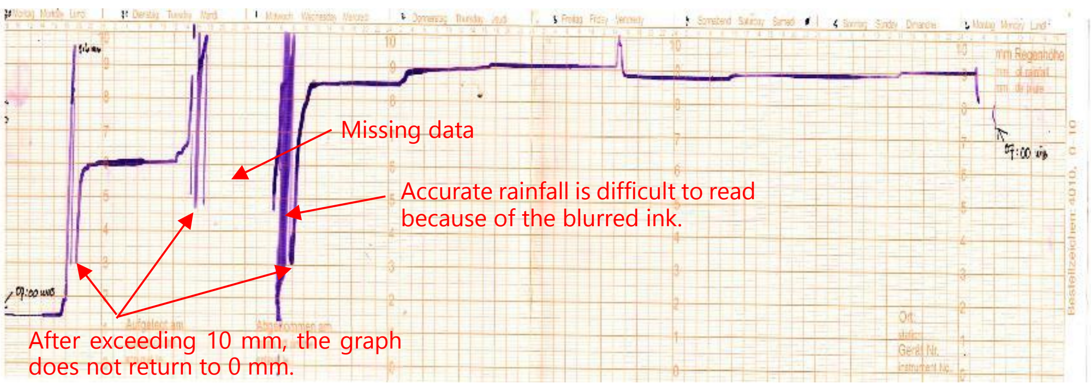
Figure 6-20 Example of the discrepancy between hourly and daily data

(6) Inappropriate recording paper

Regarding the rainfall gauges using recording paper, there were gauges of which recorded graphs are very strange. It is necessary to confirm the installation status at the site.

- BBWS-CC : Pasir Jaya Station

▼Pasir Jaya Station (Automatic Rainfall Recording)



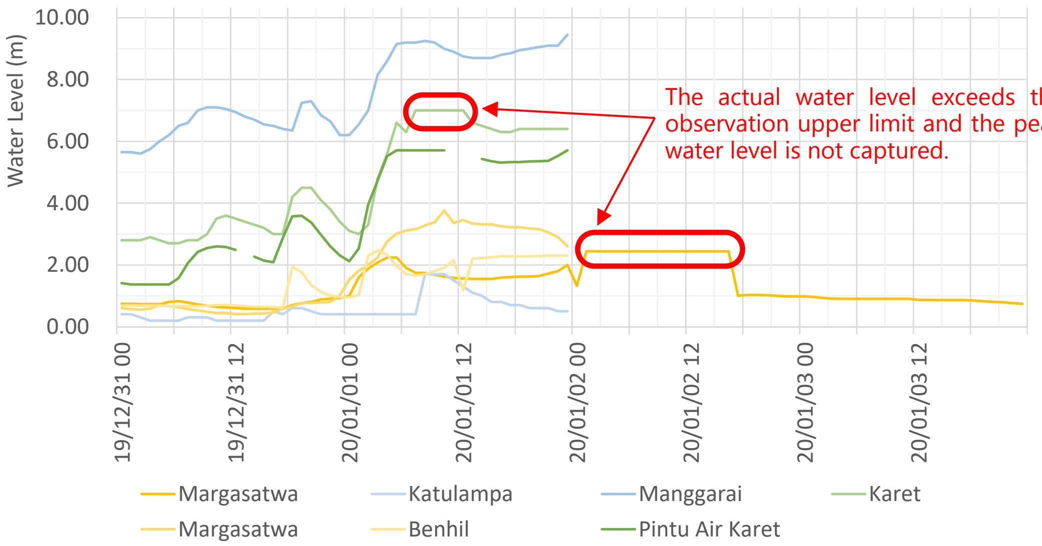
Source: BBWS-CC

Figure 6-21 Inappropriate recording paper

(7) Exceeding the observation limit of water level

Some cases that the peak water level and its time during a flood were not recorded because the water level exceeded the upper observation limit at the water level observatory were found. It is necessary to review the upper limit of observable water levels in consideration of the intensification of floods.

- BBWS-CC : Margasatwa Station, Karet Station, Serpong Station, Cikeas Station



Source: JICA study team

Figure 6-22 Example of exceeding observation limit

(8) Weather Forecast by BMKG

Figure 6-23 shows the weather forecast by BMKG at around 20:00 on 31st December, the day before the flood of 1st January 2020. On the next day, 1st January, the weather in central Jakarta was forecast to be cloudy with localized rain in the evening.

Actually, it started raining from around 16: 00 on 31st December, and reached the peak of rainfall at around 6: 00 on 1st January the next day.

One of the reasons why Bekasi City did not sufficiently monitor the water level and prepare to issue early warning before flooding was that the occurrence of heavy rain was not predicted by the rainfall information of BMKG.

BMKG INFO - Tomorrow's Weather Forecast Wednesday 1 January 2020: Beware of Thunderstorms in the Following 4 Regions

Tuesday, 31 December 2019 20:51 WIB

TRIBUNNEWSWIKI.COM - The Meteorology, Climatology and Geophysics Agency (BMKG) released its weather forecast on Wednesday, January 1, 2020.

Quoted from the official BMKG website, from the 33 city forecasts released, thunderstorms will occur in the Surabaya, Bandar Lampung, Mataram, and Pinang areas.

The following is the weather forecast for Wednesday, January 1, 2020 in 33 cities in Indonesia:

6. Central Jakarta

Morning: Cloudy
Afternoon: Cloudy
Evening: Local Rain
Early morning: Cloudy

Source：Tribunnews.wiki.com

Figure 6-23 Weather forecast by BMKG (as of 31st December, 2019)

6.2 Flood early warning system

It is necessary to establish a flood early warning system so that residents can evacuate before flood occurs and to minimize the casualty caused by the flood. Based on the present situation of the early warning and the evacuation during the flood (see chapter 6.1.1 and chapter 6.1.2), the followings were examined.

- Target area
- Related organizations for communication system
- Flood hazard map
- Water level for issuing warnings

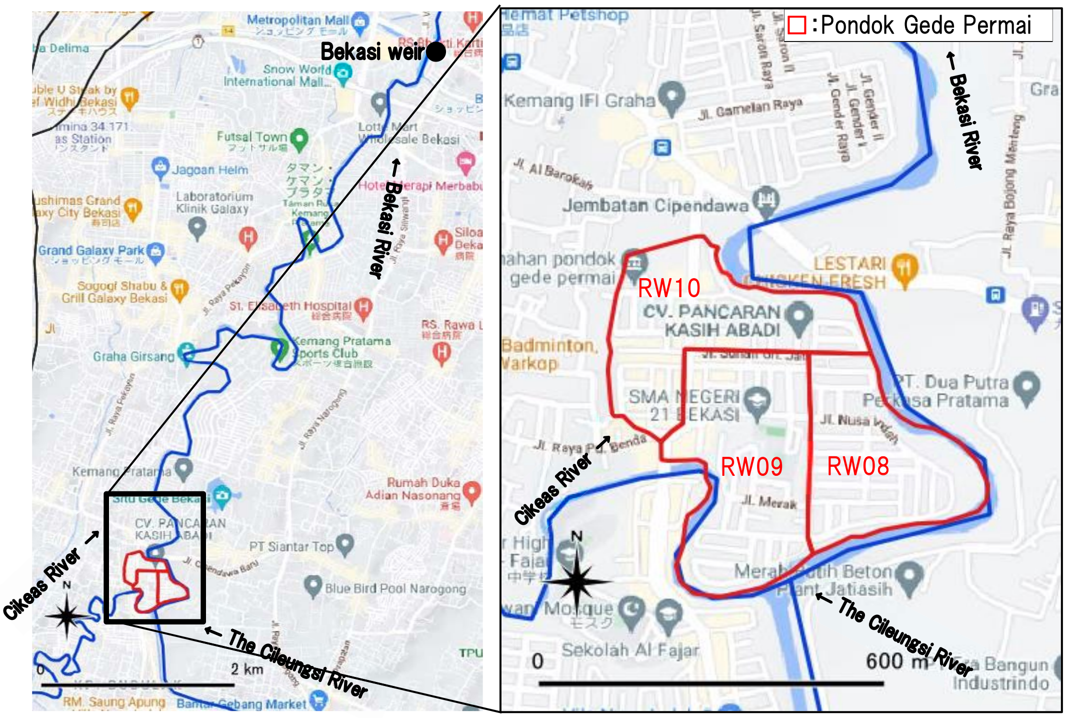
It is noted that hearings had been also conducted on the early warning system in JABODETABEK in the past project. Refer to "FY 2021 Study on Smart JAMP (March 2022), MLIT" for details.

6.2.1 Target area

Pondok Gede Permai in the Bekasi River basin was selected as the target area for the flood early warning system examination for the following reasons. It should be noted that the study policy for this area can be extended to the construction of flood early warning systems in other basins and other areas (For Example, the Cisadane River basin uses real-time water level data at Serpong station and Batu Beulah station).

- In January 2020, flooding caused severe damage in Bekasi ; 10 casualties*[1] and 150,000 evacuees*[2]. During the flood, 25 evacuation sites*[1] were used. (*1: Results of interviews with BPBD and Kota Bekasi, *2: Information from BNPB (see chapter 2.1.2 (2)))
- Flood occurs almost every year around the confluence of Cikeas River and Cileungsi River. The damage by the flood in January 2020 was especially severe in these years.
- In Pondok Gede Permai area, water overflowed from the river dike, and inundation occurred over a wide area inside the dike. Part of the parapet wall dike collapsed by overtopping.

Pondok Gede Permai is a part of Jatirasa village in Bekasi, a residential area consisting of 3 RWs (community unit). In pondok gede permai, the population is approx. 5,500 people, the area is approx. 24 ha, and is located on the left bank of the Bekasi River around the confluence of Cikeas and Cileungsi Rivers.

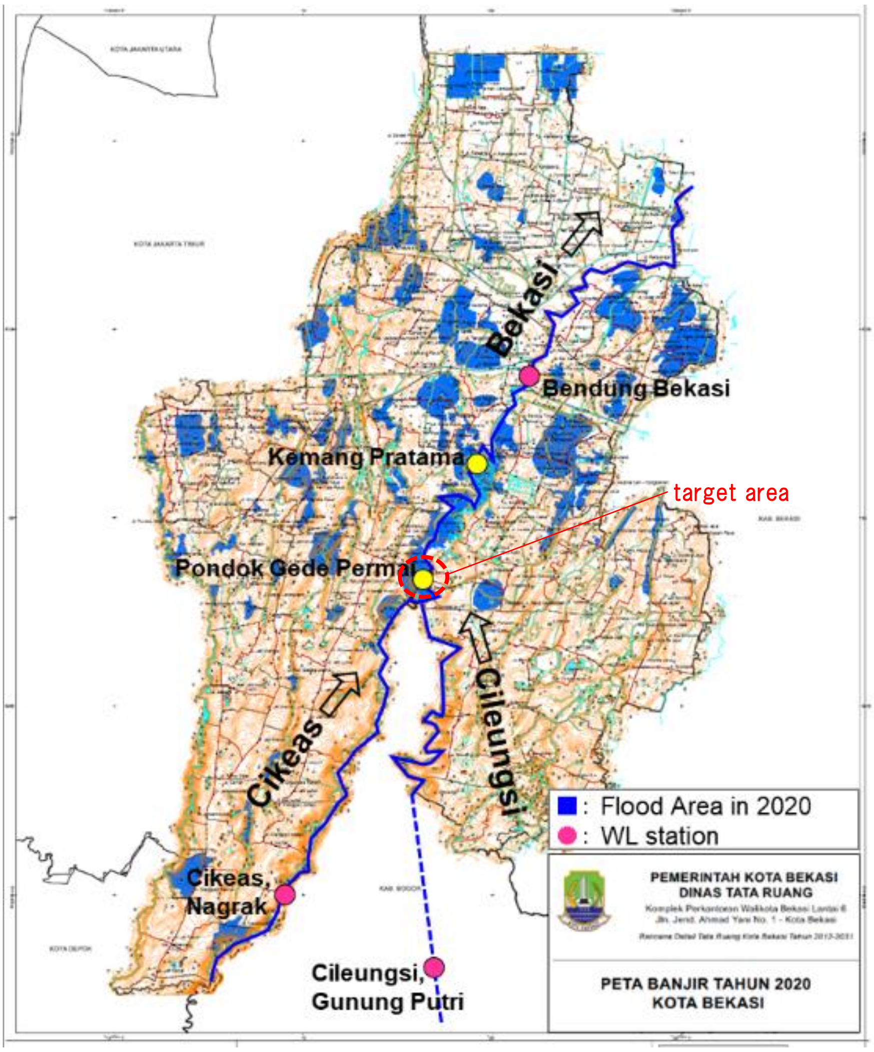


Source： JICA study team

Figure 6-24 Location map of Pondok Gede Permai

Source：residents in Pondok Gede Permai

Figure 6-25 Inundation in Pondok Gede Permai area (during the flood in January 2020)



Source: JICA study team based on Kota Bekasi

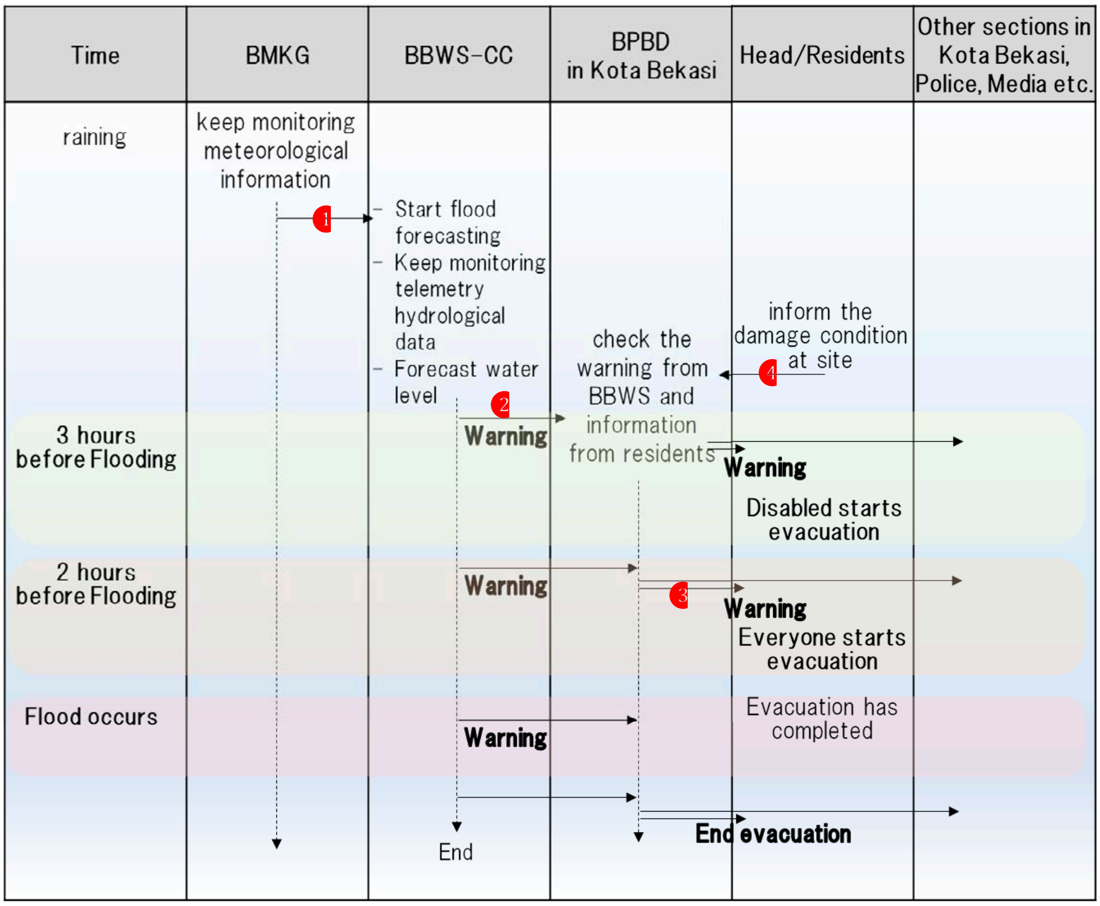
Figure 6-26 Actual inundation area in Bekasi City

6.2.2 Related organizations for communication system

Communication system for emergency is already established within each organization, but communication system with other related organizations and matters to be shared are not clearly established yet, and depends on the response at the time. BPBD issues warning of evacuation to residents via the heads of villages, but the determination of timing and location of evacuation are left up to each resident.

In order for residents to evacuate before the flood occurs and to minimize the human damage caused by the flood, it is necessary to establish a system for smooth communication of information necessary for evacuation through cooperation between the following related organizations. The flow of information dissemination between the related organizations is shown in Figure 6-27 and Table 6-2.

- BMKG (manage and forecast rainfall data)
- BBWS-Ciliwung Cisadane (manages rivers and hydrological data)
- BPBD (an agency that compiles municipal disaster prevention information and has the authority to issue warnings)
- Head of villages and residents



Source: JICA study team

Figure 6-27 Flow of Communication

Table 6-2 Flow of Communication

No.※	From and To	information	tool	when
①	BMKG ↓ BBWS	Information of rainfall	Whats App group	From 1 day before heavy rain is expected to occur through when rain ends
②	BBWS ↓ BPBD, Bekasi city	Information of water level, evacuation orders, evacuation site		3 hours and 2 hours before flooding is expected to occur
③	BPBD, Bekasi city ↓ Head of villages and residents			
④	Head of villages and residents ↓ BPBD, Bekasi	Information of water level, damage situation and evacuation situation etc.		When a rise of water level, flood damage, damage to structures, etc. due to heavy rain has been confirmed

※No. Corresponds to the red letters in Figure 6-27.
Source: JICA study team

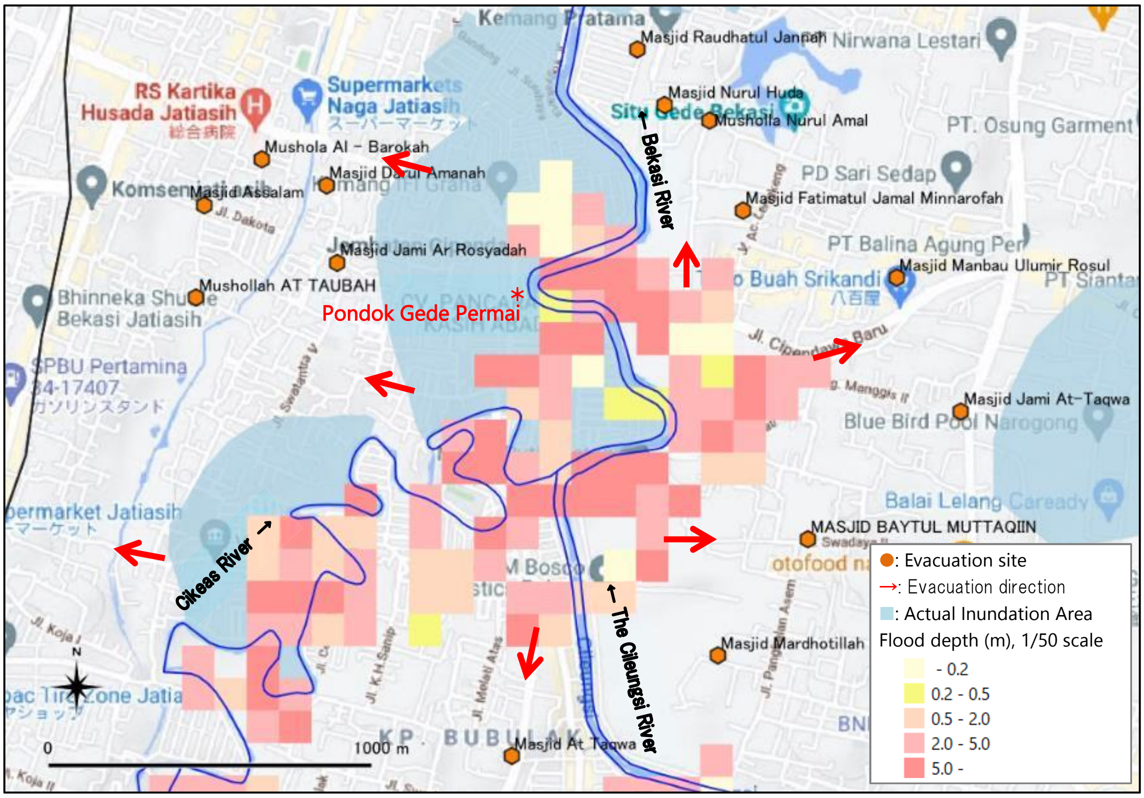
6.2.3 Flood Hazard Map

The specific timing and location of evacuation for residents during flood are not included in the information from BPBD or the heads of villages, but their determination is left to the judgment of each resident. In order for residents to evacuate to safe places at the right time when early warning is issued, it is necessary to specify safe place even during floods in advance. It is also important to understand the inundation risk of the evacuation route.

Based on the inundation analysis and actual evacuation sites, a "Flood Hazard Map" for facilitating the smooth evacuation during floods in the target area was prepared. By this, the evacuation sites and evacuation direction were clarified.

The location of the evacuation sites was selected from the following viewpoints. It is necessary to confirm the capacity of each facility and the availability during the emergency.

- Facilities located outside of the inundation area in which several evacuation sites were established during the flood in January 2020.
- Mosques in the area (There are many examples of using mosques as evacuation site during past flood.)



Source: JICA study team

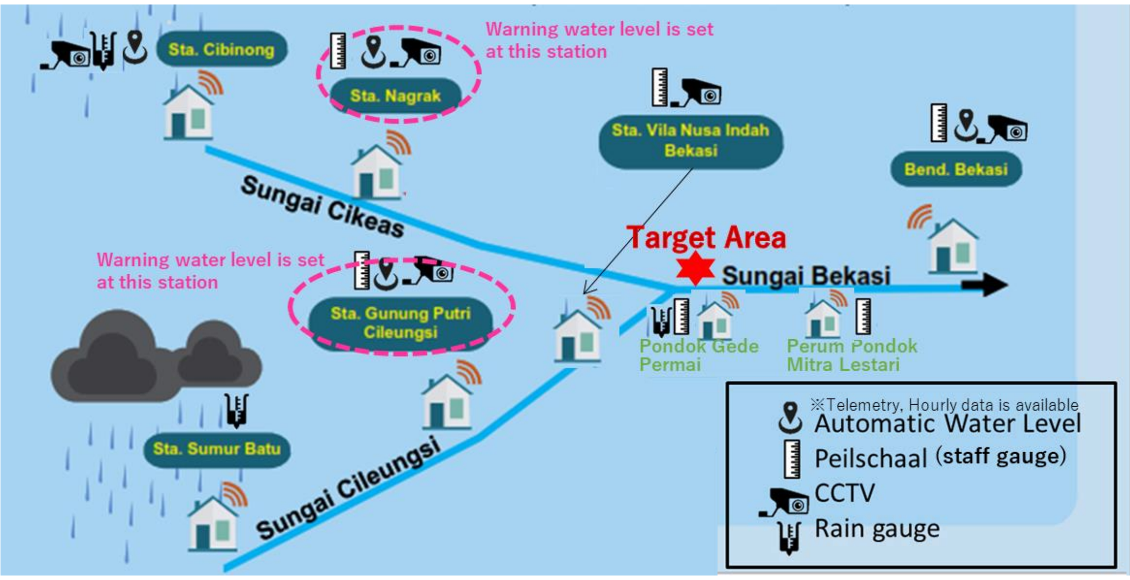
Figure 6-28 Flood Hazard Map (Pondok Gede Permai area)

6.2.4 Water level for issuing warnings

In order to reduce the human damage caused by floods, it is necessary to set the criteria for issuing warnings at appropriate times in the basin. Warning water level for evacuation judgment was examined based on flood characteristics of the basin. The warning water level examined in this section is an example of the examination procedure, and it is necessary to set an appropriate warning water level by reviewing each specification based on the latest characteristics of rivers.

A lead time for evacuation activities was set considering the times for the local governments and related organizations to prepare evacuation sites and for residents to move to there after the warning was issued. It is assumed that it takes three hours for people with disabilities and children, and 2 hours for other residents.

Figure 6-29 shows the location of water level observatories for which the criteria of warnings are set, and Figure 6-30 shows an image of early warning system.

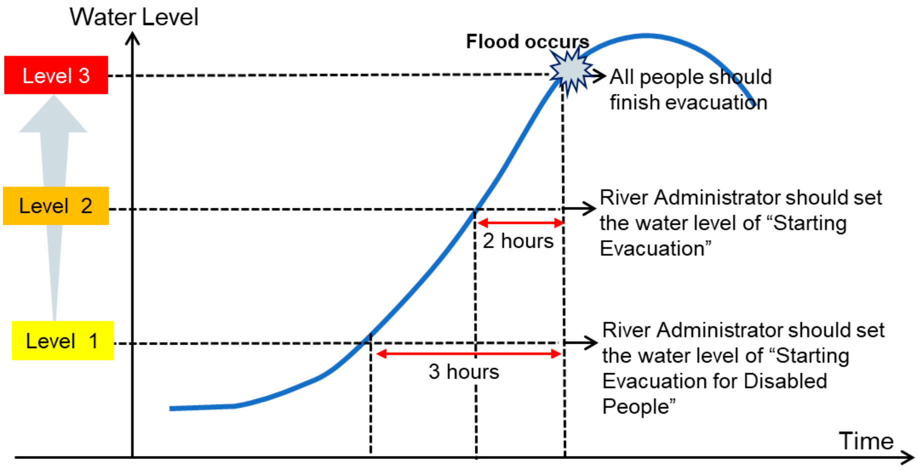


Siaga 1	:	water level data with "WL Observer or CCTV" is observed at every **15 min**	**Emergency**
Siaga 2	:	water level data with "WL Observer or CCTV" is observed at every **30 min**	
Siaga 3	:	water level data with "Telemetry (1 hour), WL Observer or CCTV" is observed at every **30 min - 1 hour**	
Siaga 4	:	water level data with "Telemetry (1 hour), WL Observer or CCTV " is observed at every **2-3 hour**	**Normal**

WL Observer: person who have responsibilities to observe and record water level every day and maintain WL station.

Source: JICA study team based on material from BBWS-CC

Figure 6-29 Location of water level observatories



Source: JICA study team

Figure 6-30 Image of early warning system

(1) Warning water level for evacuation judgment at upstream observatory

Warning water levels for evacuation judgment were set at Nagrak water level station (along the Cikeas River) and Gunung Putri water level station (along the Cileungsi River) located in the upstream of the target area (Pondok Gede Permai). A cross-sectional view at the target site is shown in Figure 6-32, and the calculation methods and results of the warning water level are shown in Figure 6-31, Table 6-3 and Figure 6-33.

■Calculation method of the warning water levels （see Table 6-3）

① Water level at which flooding starts in the target area (Pondok Gede Permai) was set. Regarding Figure 6-32, if the water level exceeds riverbank height EL 24.5 m on the left bank, roads and residential areas along the riverbank will be flooded.

② Discharge corresponding to the water level of ① is calculated from the H-Q equation at the target area （$Q = 7.427 \times (H - 14.581)^2$） . In addition, discharges at the two upstream tributaries are calculated with the ratio of design discharge.

③ Water level is calculated by the discharge of (2) and the H-Q equation.

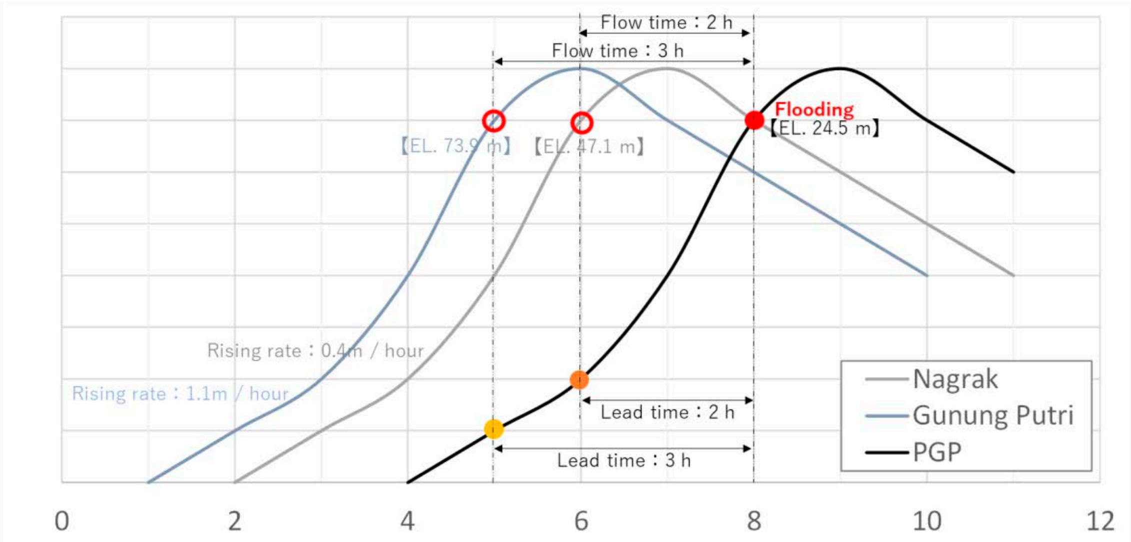
④ A lead time was set so that the local governments and related organizations can prepare evacuation sites and residents can evacuate to the evacuation site after the warning was issued. It is assumed that it takes three hours for people with disabilities and children, and 2 hours for other residents.

⑤ Rising rates of water levels at the observatory stations are calculated based on the observed data during the flood in January 2020.

⑥ The flow time from the upstream station to the target area is calculated with the Kraven's formula and the runoff simulation model.

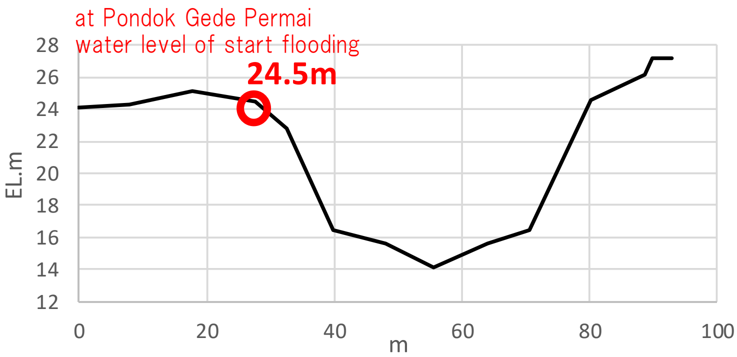
⑦ During the lead time set in ④ (excluding ⑥ : flow time), water level that is expected to rise at the upstream station is calculated.

⑧ Water level at which residents need to start evacuation is calculated. Warning water levels are also set for the two cases of lead time.



Source: JICA study team

Figure 6-31 Image of calculating warning water level



Source: JICA study team

Figure 6-32 Cross section (Pondok Gede Permai)

Table 6-3 Warning water level for evacuation judgment (upstream observatory)

Calculation of warning water level (start evacuation 2 hours before flooding)

No.		unit		memo
①	Flooding starts at PGP	EL.m	24.5	sheet01
②	Discharge of ①	m^3/s	729.2	by①, HQeq and Q50 discharge distribution ratio
	Discharge at Nagrak	m^3/s	280.4	
	Discharge at GunungPutri	m^3/s	431.7	
③	Water level of ② at Nagrak	EL.m	47.1	by② and HQeq
	Water level of ② at GunungPutri	EL.m	73.9	
④	lead time	hour	2.0	
⑤	rising rate of water level at Nagrak	m/hour	0.4	hydrograph of the flood in 2020
	rising rate of water level at GunungPutri	m/hour	1.1	
⑥	Flow time from Nagrak to PGP	hour	2.0	Kraven's formula, simulation model
	Flow time from GunungPutri to PGP	hour	3.0	
⑦	rising height of water level during lead time at Nagrak	m	0.0	⑤×(④-⑥)
	rising height of water level during lead time at GunungPutri	m	-1.1	
⑧	Evacuation recommendation at Nagrak	EL.m	**47.1**	③−⑦
	Evacuation recommendation at GunungPutri	EL.m	**75.0**	

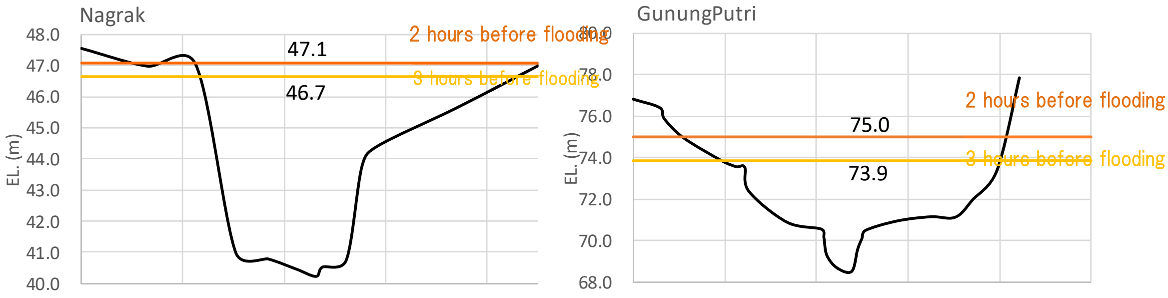
Calculation of warning water level (start evacuation 3 hours before flooding)

No.		unit		memo
①	Flooding starts at PGP	EL.m	24.5	sheet01
②	Discharge of ①	m^3/s	729.2	by①, HQeq and Q50 discharge distribution ratio
	Discharge at Nagrak	m^3/s	280.4	
	Discharge at GunungPutri	m^3/s	431.7	
③	Water level of ② at Nagrak	EL.m	47.1	by② and HQeq
	Water level of ② at GunungPutri	EL.m	73.9	
④	lead time	hour	3.0	
⑤	rising rate of water level at Nagrak	m/hour	0.4	hydrograph of the flood in 2020
	rising rate of water level at GunungPutri	m/hour	1.1	
⑥	Flow time from Nagrak to PGP	hour	2.0	Kraven's formula, simulation model
	Flow time from GunungPutri to PGP	hour	3.0	
⑦	rising height of water level during lead time at Nagrak	m	0.4	⑤×(④-⑥)
	rising height of water level during lead time at GunungPutri	m	0.0	
⑧	Evacuation recommendation at Nagrak	EL.m	**46.7**	③−⑦
	Evacuation recommendation at GunungPutri	EL.m	**73.9**	

Source: JICA study team

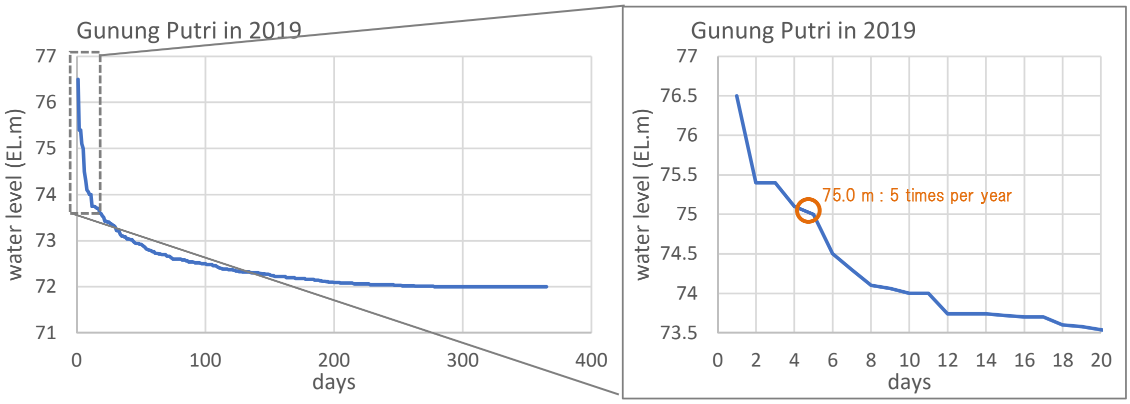
Disabled people and children need to start evacuating at a time when the water level reaches 46.7 m at Nagrak station and 73.9 m at Gunung Putri station. Others need to start evacuation when the water level reaches 47.1 m at Nagrak station and 75.0 m at Gunung Putri station.

The frequency of warnings at Gunung Putri station is 5 times per year based on the flow regime in 2019. In order to reduce the frequency of warnings and to enhance the accuracy of the flood forecasting as much as possible, it is necessary to shorten the lead times and to monitor water levels at multiple stations.



Source: JICA study team

Figure 6-33 Warning water level for evacuation judgment (upstream observatory)



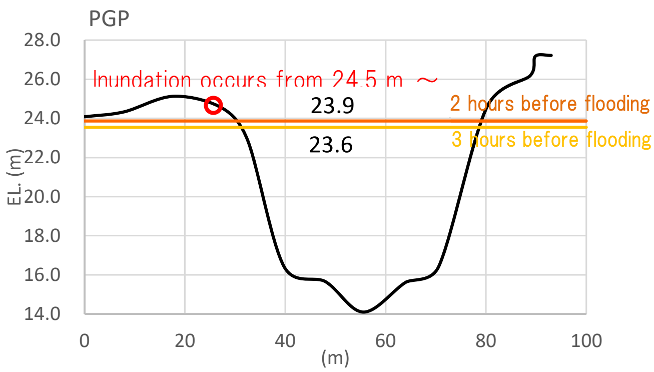
Source: JICA study team

Figure 6-34 Warning frequency

(2) Warning water level for evacuation judgment at Pondok Gede Permai

Warning water level for evacuation judgment was set in the target area (Pondok Gede Permai). Pondok Gede Permai station has a scale of water level (there is no telemetry system or CCTV), so residents can determine when to evacuate by checking the water level by their selves. The calculation methods and results of the warning water level are shown in Figure 6-35 and Table 6-4. Regarding the explanation of calculation method, see 6.2.4(1).

Disabled people and children need to start evacuating at a time when the water level exceeds 23.6 m. Others need to start evacuation when the water level exceeds 23.9 m.



Source: JICA study team

Figure 6-35 Warning water level for evacuation judgment (PGP)

Table 6-4 Warning water level for evacuation judgment (PGP)

Calculation of warning water level (start evacuation 2 hours before flooding)

No.		unit		memo
①	Flooding starts at PGP	EL.m	24.5	sheet01
②	Discharge of ①	m^3/s	729.2	by① and HQeq
③	Water level of ②	EL.m	24.5	by② and HQeq
④	lead time	hour	2.0	
⑤	rising rate of water level	m/hour	0.3	simulation model
⑥	Flow time to PGP	hour	0.0	—
⑦	rising height of water level during lead time	m	0.6	⑤×(④-⑥)
⑧	Evacuation recommendation at Nagrak	EL.m	**23.9**	③−⑦

Calculation of warning water level (start evacuation 3 hours before flooding)

No.		unit		memo
①	Flooding starts at PGP	EL.m	24.5	sheet01
②	Discharge of ①	m^3/s	729.2	by① and HQeq
③	Water level of ②	EL.m	24.5	by② and HQeq
④	lead time	hour	3.0	
⑤	rising rate of water level	m/hour	0.3	simulation model
⑥	Flow time to PGP	hour	0.0	—
⑦	rising height of water level during lead time	m	0.9	⑤×(④-⑥)
⑧	Evacuation recommendation at Nagrak	EL.m	**23.6**	③−⑦

Source: JICA study team

(3) Attention

Regarding the criteria for issuing early warning, it is necessary to pay attention to the followings.

- The warning water levels at the target area and the two observatory stations located upstream of the target area were examined. Before and during the actual flood, it is necessary to monitor the real-time water levels at these three points and prepare for the issuance of warnings. However, since the upstream stations are located on the tributaries, there is a possibility that the flood warning will be wrong depending on the rain area. In order to avoid this, it is necessary to keep monitoring the water levels at all the three points, monitor the water level at multiple stations, and observe the rain distribution in real time.
- The warning water level examined in this section is an example of the examination procedure, and it is necessary to set an appropriate warning water level by reviewing each specification (such as HQ equation at the target area and upstream observatory, rising height of water level based on observed data of several past floods and so on) based on the latest characteristics of rivers.
- It is necessary to continuously grasp flood conditions by CCTV in addition to water level data of the telemetry system. During floods, CCTV image data is distributed to BBWS-CC at an interval of 15 minutes. By utilizing the water level read from the CCTV, it is possible to issue warning at an appropriate timing even when the water level is rapidly rising during flood. (See Figure 6-36)
- As for the water level data of the telemetry system, data is automatically acquired every one hour, and the data is accumulated by BBWS-CC as the administrator. During flood, the water level could rise significantly in an hour, causing delays in issuing warnings and increasing flood damage. It is proposed to improve the telemetry system so that data could be acquired in a shorter interval such as 10 minutes.
- In normal times, water levels are manually observed in addition to the automatic observation and recording. It is stipulated as a rule that the water level observers should report the water level every 15 minutes during floods. However, it is very dangerous to approach rivers during floods, and there is a possibility of human damage. Therefore, such manual water level observation during floods should be avoided. It is proposed to introduce and popularize telemetry systems with automatic water level gauge and CCTV that can be remotely operated as the substitute.
- KP2C (Komunitas Peduli Cikeas Cileungsi), a community of civil society activists, is posting its own CCTV images on social media. Real-time CCTV images are very effective for informing residents of the severity and imminent danger of flooding. It is expected that BBWS and local governments will also promote evacuation activities by disclosing CCTV images that they manage.

Source: BBWS-CC

Figure 6-36 CCTV Monitoring Room in BBWS-CC

No	Lokasi CCTV	No	Lokasi CCTV
1.	Bendung Katulampa-S. Ciliwung	10.	PDA Cikeas Nagrak-S. Cikeas
2.	Jemb. Panus Depok-S. Ciliwung	11.	Villa Nusa Indah-S. Clleungsi
3.	Pintu Air Manggarai-S. Ciliwung	11.	Bendung Bekasi
4.	PDA Batubeulah-S. Cisadane	13.	Polder Kalimati
5.	PDA Serpong-S. Cisadane	14.	Underpass Kemayoran
6.	Bendung Pasar Baru-S. Cisadane	15.	Weir 1-Kanal Banjir Timur
7.	Bendung Cibongas	16.	Weir 2-Kanal Banjir Timur
8.	PDA Cileungsi-S. Cileungsi	17.	Weir 3-Kanal Banjir Timur
9.	PDA Mayor Oking-S. Cikeas		

Source: BBWS-CC

Figure 6-37 Images of CCTV monitoring (managed by BBWS-CC)

6.2.5 Example of extension to other basins

In this study, an early warning system was examined in Pondok Gede Permai area of the Bekasi River basin, because of the severe damage. This policy can be extended to other basins and other areas. For example, the following is a tentative example study for the Cisadane River basin.

Target area : area around confluence of the Sabi River and Pasar Baru weir

WL stations : Serpong station, Batu Beulah station

*Both stations have telemetry system of water level and CCTV.

Source: JICA study team

Figure 6-38 Example of early warning in the Cisadane River basin

6.3 Hydrological observatory

Based on the present state of hydrological observation data (see chapter 6.1.3), the necessity of improving the data quality and observation method are shown below.

6.3.1 Improvement of hydrological observatory

Stable operation of existing hydrological observatories and the accumulation of appropriate data are essential for the study of flood control and water utilization. Observatories that need to be improved are described below.

(1) Observatories which need improvement

A list and a location map are provided for observatories requiring improvement.

Table 6-5 Rainfall stations requiring improvement

No.	Observatory	Administrator	Location latitude (°S), longitude (°E)		problem
1	Rawa Gede	BBWS-CC	-6.6714	106.8834	missing data
2	Jati Jajar	BBWS-CC	-6.4095	106.8698	missing data
3	Cawang	BBWS-CC	-6.3427	106.8834	Observation value 0mm
4	Cawang (ARR)	BBWS-CC	-6.3427	106.8834	discrepancy of daily rainfall
5	Pasir Jaya	BBWS-CC	-6.7284	106.7967	Observation value 0 mm, recording paper
6	Kemensos	BBWS-CC	-6.5199	106.8169	Observation value 0mm
7	PLTA Kracak	BBWS-CC	-6.6170	106.6436	abnormal value
8	Gadog	BBWS-CC	-6.6534	106.8692	discrepancy of daily rainfall
9	KpKelapa	BBWS-CC	-6.4553	106.8140	discrepancy of daily rainfall
10	SumurBatu	BBWS-CC	-6.5747	106.8829	discrepancy of daily rainfall
11	Cigudeg	BBWS-CC	-6.5476	106.5331	discrepancy of daily rainfall
12	KampusUI	BBWS-CC	-6.3612	106.8238	discrepancy of daily rainfall
13	LengkongBarang	BBWS-CC	-6.4646	106.7263	discrepancy of daily rainfall
14	JerukPurut	BBWS-CC	-6.2793	106.8149	discrepancy of daily rainfall
15	Villa Pamulang	BBWS-CC	-6.3430	106.7230	discrepancy of daily rainfall
16	RancaSumur (ARR)	BBWS-CC	-6.2945	106.3961	discrepancy of daily rainfall
17	Stasiun metrorogi Kemayoran	BMKG	-6.1556	106.8400	missing data
18	Stasiun Meteorogi Maritim Tanjung priok	BMKG	-6.1078	106.8805	missing data
19	ARG Pulomas	BMKG	-6.1667	106.8809	missing data, observed value 0 mm
20	ARG Kelapa Gading	BMKG	-6.1666	106.9136	missing data
21	ARG Manggarai	BMKG	-6.2075	106.8487	missing data, consecutive same value
22	AWS Halim Perdana Kusumah	BMKG	-6.2625	106.8971	missing data
23	ARG Tomang	BMKG	-6.1667	106.7800	missing data, abnormal value
24	ARG Lebak Bulus	BMKG	-6.3043	106.7774	missing data
25	ARG Ciganjur	BMKG	-6.3443	106.7990	missing data
26	AWS BSD Serpong	BMKG	-6.2792	106.6503	missing data, consecutive same value
27	AWS Staklim Tangerang Selatan	BMKG	-6.2500	106.7600	missing data
28	ARG Bekasi	BMKG	-6.3636	107.1725	missing data, observed value 0 mm

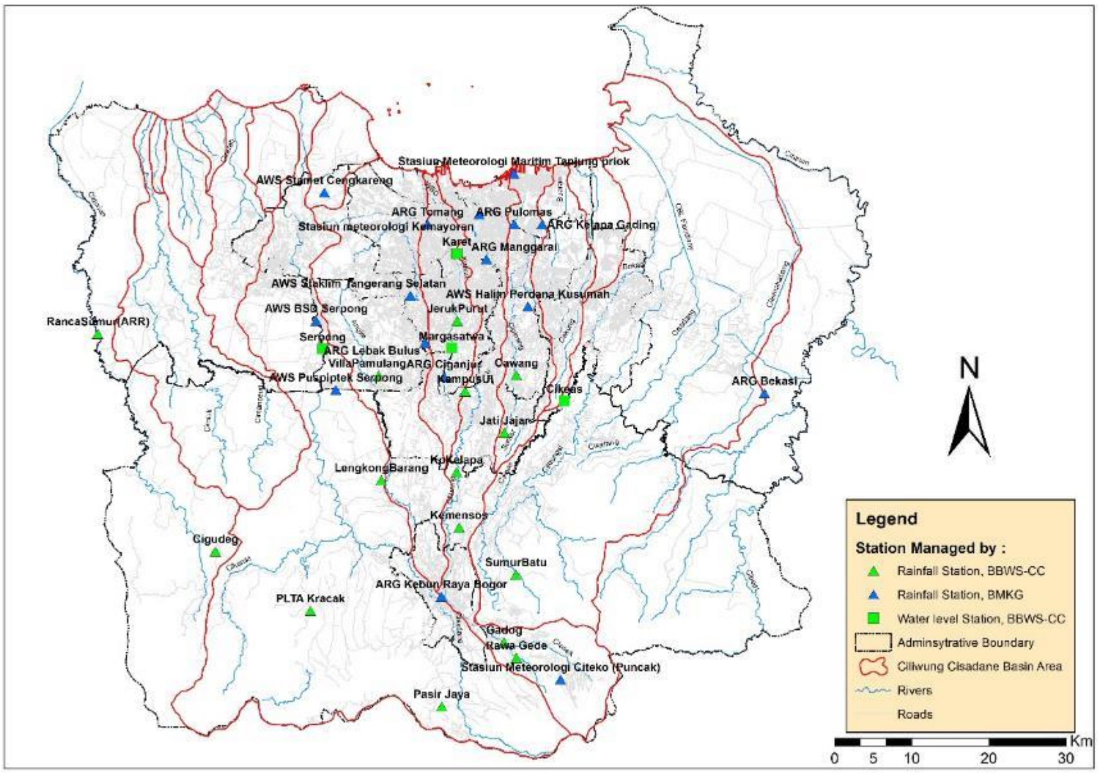
No.	Observatory	Administrator	Location latitude (°S), longitude (°E)		problem
29	AWS Stamet Cengkareng	BMKG	-6.13	106.66	missing data, discrepancy of daily rainfall
30	ARG Kefun Raya Bogor	BMKG	-6.6004	106.7962	missing data
31	Stasiun Meteorogi Siteko (Puncak)	BMKG	-6.6968	106.9350	discrepancy of daily rainfall
32	AWS Puspiptek Serpong	BMKG	-6.3598	106.6733	discrepancy of daily rainfall

Source: JICA study team

Table 6-6 Water-level stations requiring improvement

No.	Observatory	Administrator	Location latitude (°S), longitude (°E)		problem
1	Margasatwa	BBWS-CC	-6.311	106.808	Exceeding the observation limit
2	Karet	BBWS-CC	-6.201	106.814	Exceeding the observation limit
3	Serpong	BBWS-CC	-6.312	106.658	Exceeding the observation limit
4	Nagrak (Cikeas)	BBWS-CC	-6.3726	106.9394	Exceeding the observation limit

Source: JICA study team



Source: JICA study team

Figure 6-39 Hydrological stations requiring improvement

(2) Hydrological observatories at same location

The following is a list and location map of observatories with multiple equipment at the same location.

For observatories where multiple types of observation equipment are installed by the same manager at the same location, real-time data can be monitored by prioritizing the use of telemetry systems. Regarding the observatories with multiple equipment of different organizations, it is desirable to improve the data quality by comparing observation results of the multiple equipment.

Table 6-7 Rainfall observatories at same location

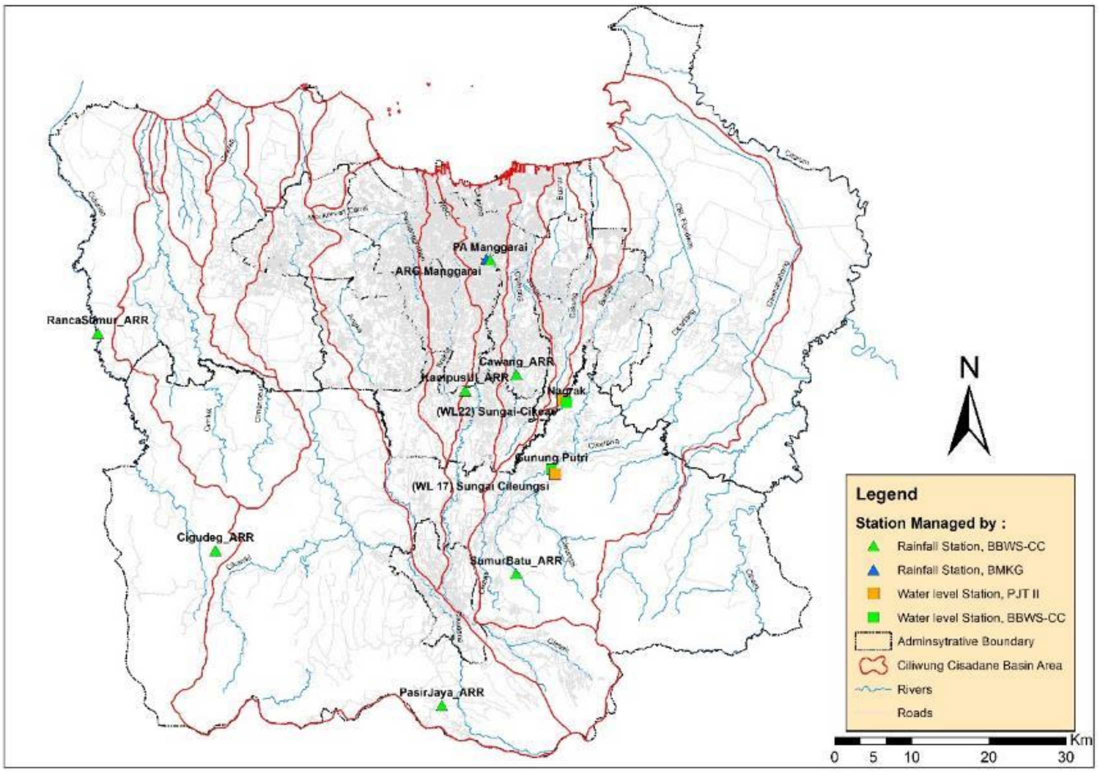
No.	Observatory	Administrator	Location latitude (°S), longitude (°E)		Multiple observation equipment
1	Cawang_ARR	BBWS-CC	-6.3427	106.8834	Telemetry type and recording paper type
2	KampusUI_ARR	BBWS-CC	-6.3612	106.8238	Telemetry type and recording paper type
3	PasirJaya_ARR	BBWS-CC	-6.7284	106.7967	Telemetry type and recording paper type
4	RancaSumur_ARR	BBWS-CC	-6.2945	106.3961	Telemetry type and recording paper type
5	SumurBatu_ARR	BBWS-CC	-6.5747	106.8829	Telemetry type and recording paper type
6	Cigudeg_ARR	BBWS-CC	-6.5476	106.5331	Telemetry type and recording paper type
7	ARG Manggarai PA Manggarai	BMKG BBWS-CC	-6.2075 -6.2076	106.8487 106.8485	BMKG, BBWS-CC

Source: JICA study team

Table 6-8 Water level observatories at same location

No.	Observatory	Administrator	Location latitude (°S), longitude (°E)		Multiple observation equipment
1	Nagrak (WL 22) Sungai-Cikeas	BBWS-CC PJT II	-6.3726 -6.3714	106.9394 106.9377	BBWS-CC, PJT II
2	Gunung Putri (WL 17) Sunkai Cileungsi	BBWS-CC PJT II	-6.4533 -6.4534	106.9243 106.9244	BWS-CC, PJT II

Source: JICA study team



Source: JICA study team

Figure 6-40 Hydrological observatories at same location

6.3.2 Proposal of a new observatory

- From the viewpoint of issuing early warning, it is proposed to install telemetry water level observatories capable of monitoring real-time data around the confluence of the Cikeas and Cileungsi rivers, which are regularly affected by flood.
- It is proposed to introduce telemetry water level observatories at locations where water levels are manually read and recorded by observers in order to prevent human damage by floods and to stabilize data accuracy.
- In order to grasp the rainfall situation in JABODETABEK area, it is proposed to introduce radar rainfall gauges with high observation accuracy. Since locally intense rainfall often occurs in Jakarta, there is a limit to grasp rainfall situation only by ground observation stations.

6.3.3 Operation Center

In JABODETABEK, a variety of infrastructure facilities, such as hydrological stations, pumping stations, intake weirs and so on are being operated. It is proposed to establish an operation center which integrates these operation conditions and related information. The establishment of the operations center is expected to perform the following tasks efficiently and appropriately.

- Real-time monitoring of rainfall and water levels, as well as inundation analysis, enable preventive measures to be taken before flood damage occurs.
- Simulation of inundation analysis and real-time monitoring of inundated areas will enable rapid and effective response to inundation damage.
- The accelerated coordination of information with related agencies will enable prompt and effective assistance to victims.
- Information sharing of information on rainfall, water levels, flooding area and so on in real time will improve residents' awareness of disaster prevention and reduction of flood damage.
- The establishment of a hydrological and meteorological observation network will enable efficient planning of flood control projects.

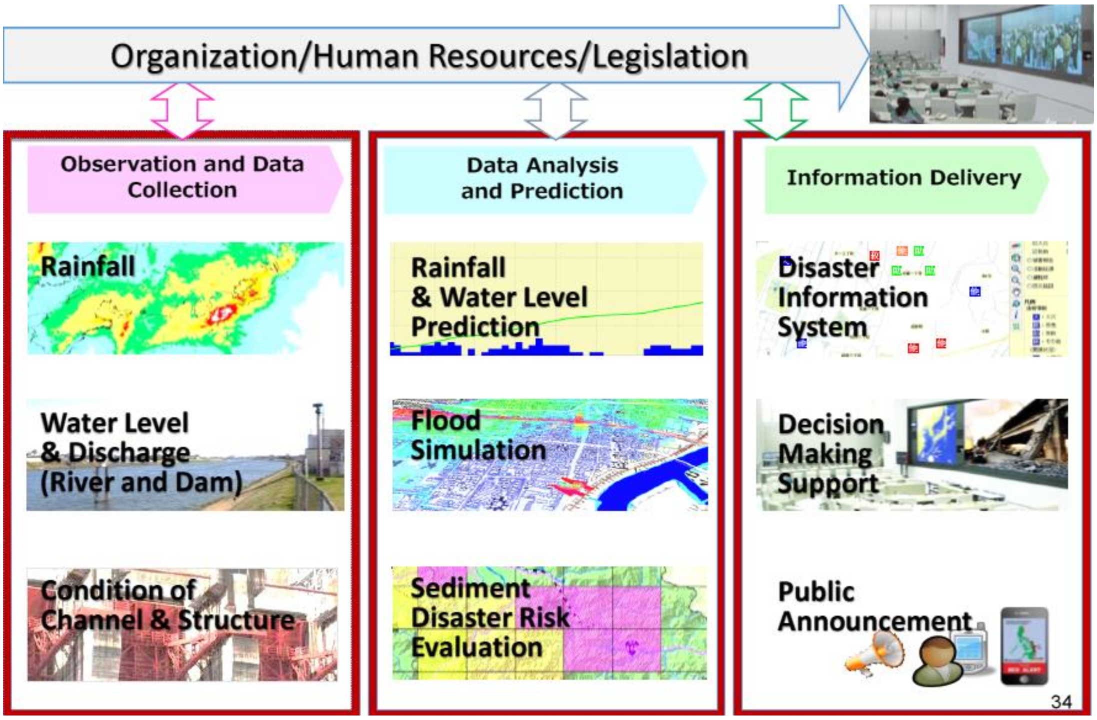
The functions required of the operation center are as follows. In the future, it is also expected to expand its functions as a comprehensive disaster prevention center in response to the smart city.

① Data management : By centrally managing data, multiple organizations will share the data they are observing. Rainfall, river level, dam inflow, dam reservoir level, operation status of infrastructure facilities, etc.

② Data analysis and prediction : Based on the collected observation data and operational status, the damage prediction will be performed. Prediction of rainfall and water level, prediction of inundation area, risk analysis of sediment disaster, etc.

③ Consideration of emergency response and provision of information : Based on information obtained through collection and prediction, it will be possible to efficiently consider emergency response and issue warnings. In addition, disseminating information and collaboration with relevant organizations will be promptly made.

Figure 6-41 Image of operation center



Source: JICA study team

Figure 6-42 System of operation center

6.4 JFEWS Improvements

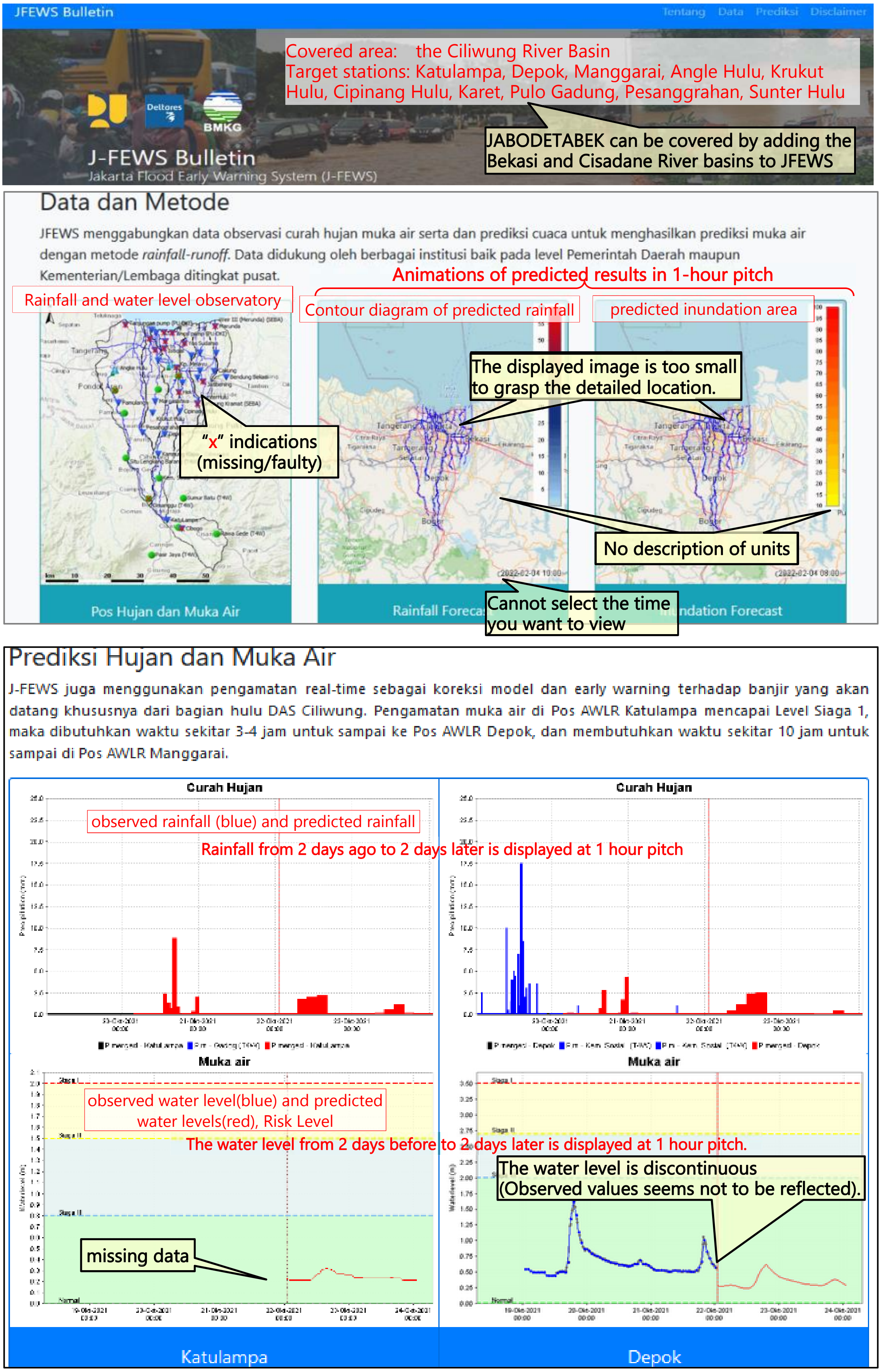
The Jakarta Flood Early Warning System (JFEWS), which is operated and managed jointly by PUPR and BMKG, publishes the observed and predicted water level and rainfall on its website.※ Figure 6-43 shows the current operation status and points to be improved. Details of points to be improved are shown below.

- JABODETABEK can be fully covered by adding the Bekasi and Cisadane River basins into JFEWS.
- There are several observatories that seem to be missing data or faulty. The maintenance or improvement of the observatories is necessary.

- It is necessary to devise an easy-to-see display for use in disaster prevention activities (enable to select the time you want to display, enlarge the displayed image, display units, etc.).
- The observed water level and the predicted water level are discontinuous, and it is guessed that observed data is not reflected for the prediction.
- By utilizing the improved JFEWS in the Operation Center (proposed in chapter 6.3.3), it will contribute to emergency response, disseminating warnings, information provision, etc. in case of flood.

For details on the JFEWS improvements, see "FY 2021, Study on Smart JAMP (March 2022), MLIT".

※ https://buletin-jfews.pusair-pu.go.id/



Source: JICA study team based on JFEWS

Figure 6-43 JFEWS web page

6.5 Others

6.5.1 Participation of residents and private sectors

The following considerations are necessary in the future regarding the participation of residents and private sectors in activity of flood mitigation. In addition, it is necessary to examine measures to ensure that successful pilot cases are horizontally spread to relevant municipalities. ((1) Evacuation drills, (2) flood prevention teams, (3) river and channel cleaning campaigns, etc.)

Evacuation drills will be conducted in cooperation with relevant organizations and residents based on the contents of Chapter 6.2, assuming the occurrence of flooding. Similar evacuation drills were carried out in Jeneberang River basin in Indonesia (see Figure 6-44), so it will be a helpful example.

Cleanup activities were carried out in some areas of the Bekasi River basin after the flood in January 2020. Under the direction of the Bekasi Mayor, the ASN (municipal civil servants) mobilized to remove mud and waste. Drainage channels that became useless due to a huge amount of garbage are a problem in JABODETABEK, they might worsen flood damage. In the future, it is necessary to establish a system to carry out regular river cleaning in cooperation with residents and the private sector.

Source: FY2019 Information Collection and Prospective Corporation Study for Overseas Development of Disaster Risk Reduction and Water Infrastructure Sector, MLIT

Figure 6-44 Example of evacuation drill

6.5.2 Spatial Planning (Building and Use Regulations)

Regarding the relationship between spatial planning and flood control, urbanization of the basin may reduce the infiltration of rainwater and increase flood damage. On the other hand, it is possible to control flood damage by greening the city by adopting green infrastructure and so on. In order to prevent the urban area from expanding significantly beyond the current situation or plan, and to improve the safety level of flood control, it is necessary to promote land use based on the spatial planning formulated by each local government.

The following is a summary of the legal regulations and status of spatial planning being promoted by each local government.

➡ The Governor's ordinance on spatial planning formulated by each local government are stipulated based on Presidential ordinance No. 54/2008, which is effective for flood control. It is necessary to comply with these plans and proceed urban development and flood control.

(1) JABODETABEKPUNJUR

According to the Presidential ordinance (No.54 / 2008) on spatial planning for JABODETABEKPUNJUR district (Jakarta, Bogor, Depok, Tangerang, Bekasi, Puncak and Cianjur), spatial planning for flood control such as securing green space is specified (see Figure 6-45). Each local government has formulated ordinances on spatial planning based on the presidential ordinance, and they are effective for flood control.

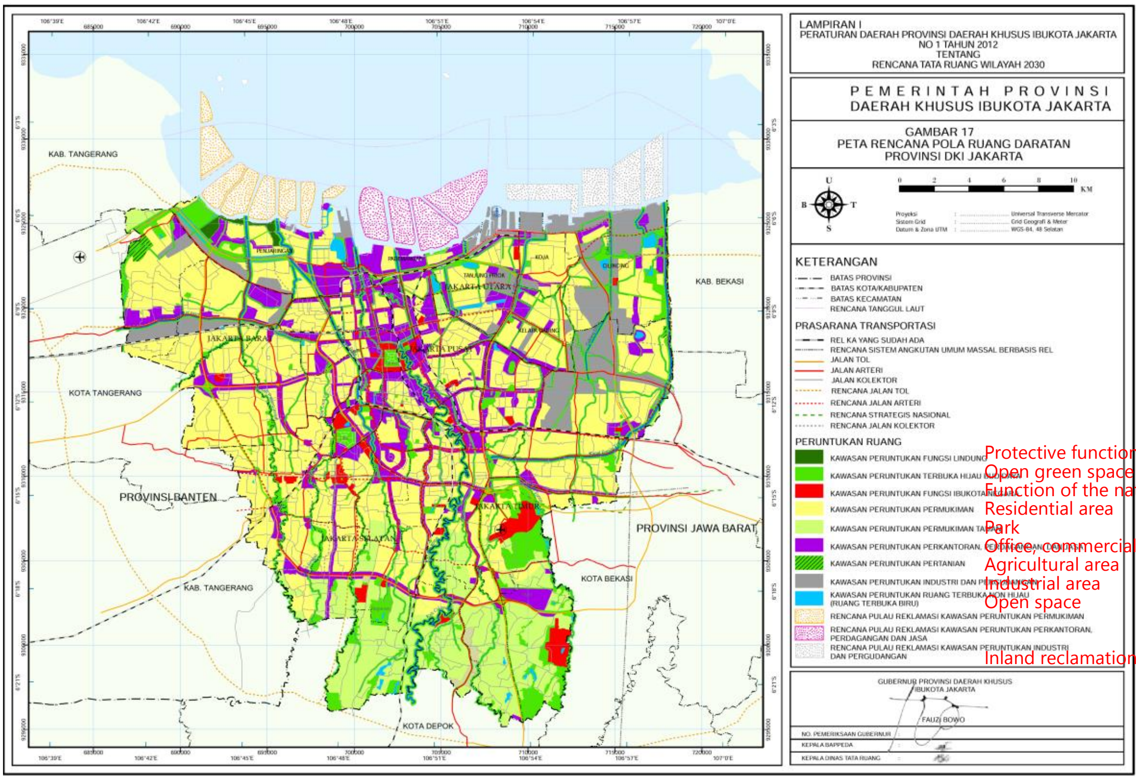
Chapter 3 Spatial planning for the Jabodetabekpunjur area has a role as a reference for the implementation of development related to water and soil conservation efforts, efforts to ensure the availability of ground water and surface water, flood prevention, and economic development for the welfare of the community.

Source: PERATURAN PRESIDEN REPUBLIK INDONESIA, NOMOR 54, TAHUN 2008, Pasal 3

Figure 6-45 Presidential ordinance, Chapter3 (JABODETABEKPUNJUR)

(2) DKI Jakarta

The Regional law of DKI Jakarta No. 1/2012 (Regional Spatial Planning in 2030) has formulated a plan to increase the area of water areas and retention pond in DKI Jakarta to 5% or more of the total area, and expand the water storage function. In addition, a map of land use plan for DKI Jakarta is formulated (see Figure 6-46 and Figure 6-47).



Source: DKI Jakarta : Regional Law of DKI Jakarta Province No. 1 / 2012 on Spatial Planning 2011-2031

Figure 6-46 Map of land use plan (DKI Jakarta)

Chapter 45
The increase in the water body ratio includes channels, rivers, flood canals, lakes, and reservoirs in 2030 covering an area of at least 5% of the total area. For this reason, Green Open Space (RTH) will be designed so that it can be partially used for temporary water storage during high rainfall. What is meant by “at least 5%” of the entire area is 5% of the area of Jakarta, but it must also be 5% of the area of each polder.

Source: DKI Jakarta : Regional Law of DKI Jakarta Province No. 1 / 2012 on Spatial Planning 2011-2031

Figure 6-47 Spatial planning, Chapter45 (DKI Jakarta)

(3) Kota Bekasi and Kab Bekasi

The Regional law of Kota Bekasi No. 13/2011 (Spatial Planning) and the Regional law of Kab Bekasi No. 12/2011 (Spatial Planning) have formulated spatial plans for Kota and Kab Bekasi. However, the map of land use plan has not been released. In order to ensure the implementation of land use regulations, it is necessary to formulate a map of land use plan for the Bekasi area.

From the D/D of the Bekasi River basin, about 72% of Kota Bekasi is currently used as building and yards, and about 20% as gardens (see Table 6-9).

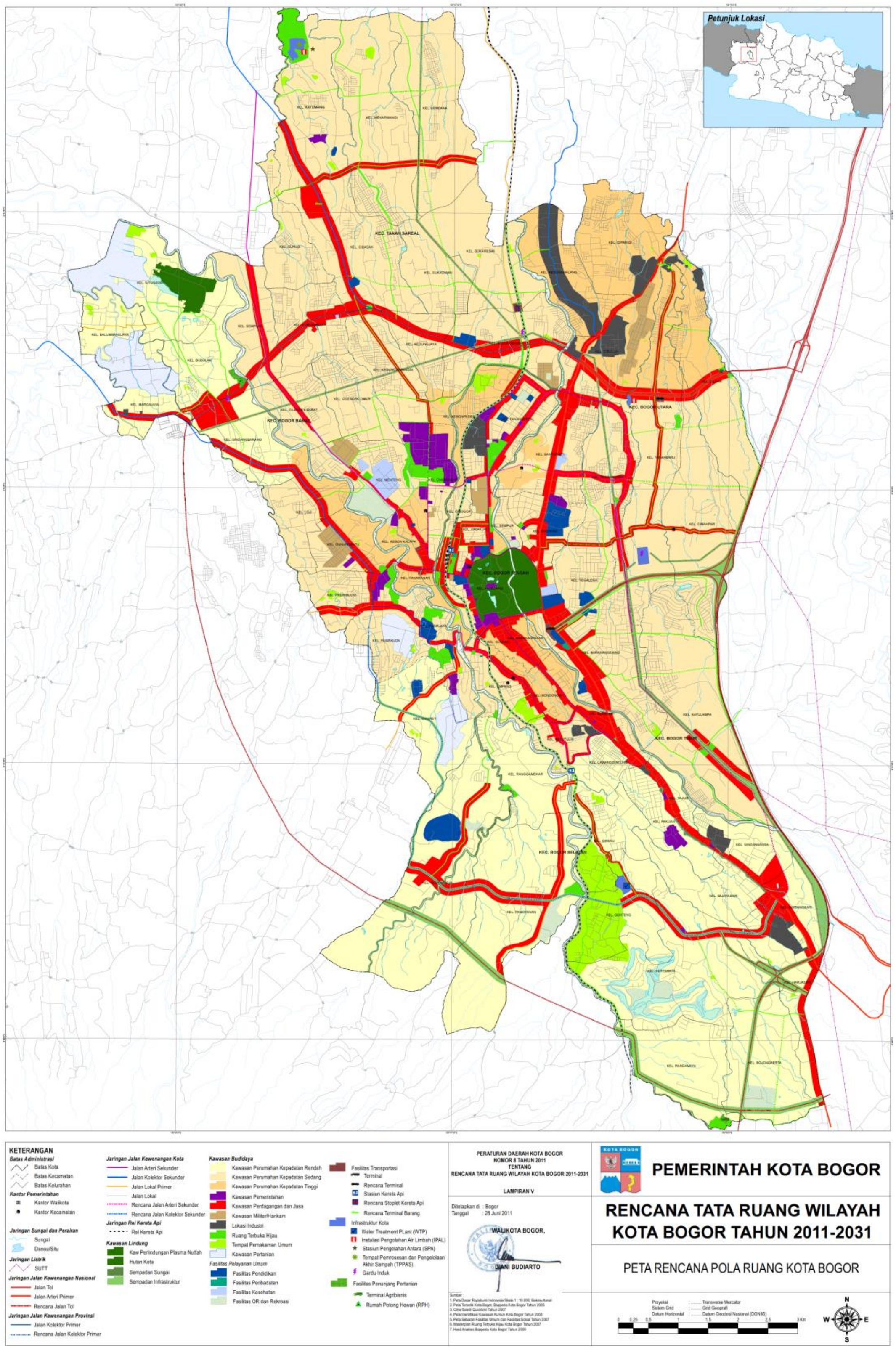
Table 6-9 Spatial planning (Kota Bekasi)

Land Use	Area	%
Paddy fields	491 ha	2.3 %
Buildings and yards	15,086 ha	71.7 %
Gardens	4,285 ha	20.4 %
Ponds	69 ha	0.3 %
else	1,118 ha	5.3 %
Sum	21049 ha	—

Source：Bekasi river basin Detail Design, 2015

(4) Kota Bogor

The Regional law of Kota Bogor No.8 /2011 (Regional Spatial Planning) has formulated a map of land use plan (see Figure 6-48).



Source: Bogor city regulations No. 8/2011 on Spatial Planning 2011-2031

Figure 6-48 Map of land use plan (Kota Bogor)

(5) Kota South Tangerang and Kab Tangerang

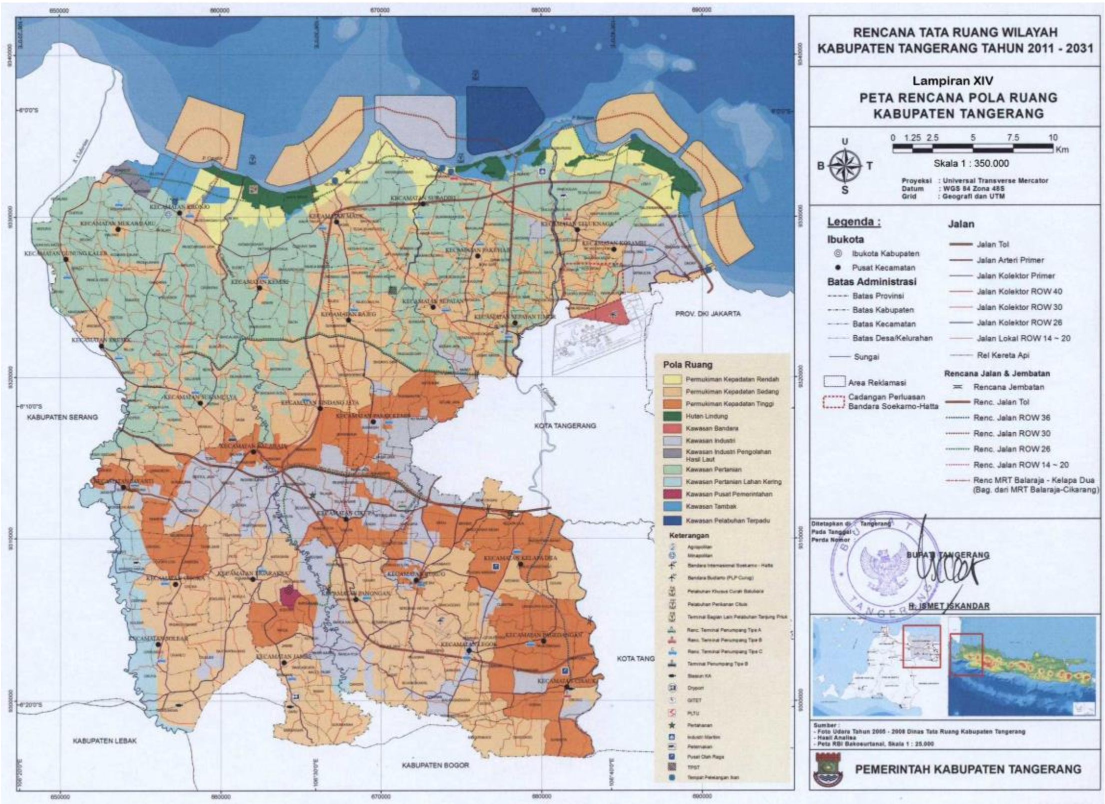
The Regional law of Kota South Tangerang No.9 /2019 (Regional Spatial Planning) and the regional law of Kab Tangerang No.13 / 2011 (Regional Spatial Palanning) have formulated spatial plans for Kota and Kab Tangerang. In addition, a map of land use plan for Kab Tangerang is formulated (see Figure 6-49).

According to the D/D of the Cisadane River basin, about 27% of the Cisadane River basin is currently used as paddy fields (irrigation paddy and rainfed rice fileds) and about 17% as residential areas (see Table 6-10).

Table 6-10 Spatial planning (the Cisadane River basin)

Land Use	Area (km^2)	%
Scrub	137.39	9.05
Forest	195.83	12.90
Irrigation Paddy	237.58	15.65
Rainfed Rice Fields	165.47	10.90
Moor	141.49	9.32
Settlement	256.25	16.88
Plantation	308.93	20.35
etc	75.14	4.95
Sum	1,518.08	—

Source： the Cisadane River basin Detail Design, 2010

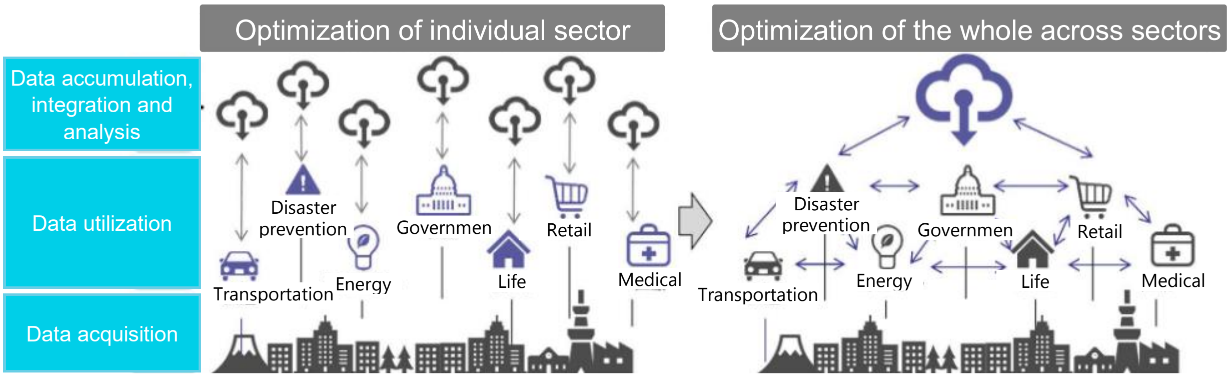


Source: Regional regulation of Tangerang regency No. 13/2011 on Spatial Planning 2011-2031

Figure 6-49 Map of land use plan (Kab Tangerang)

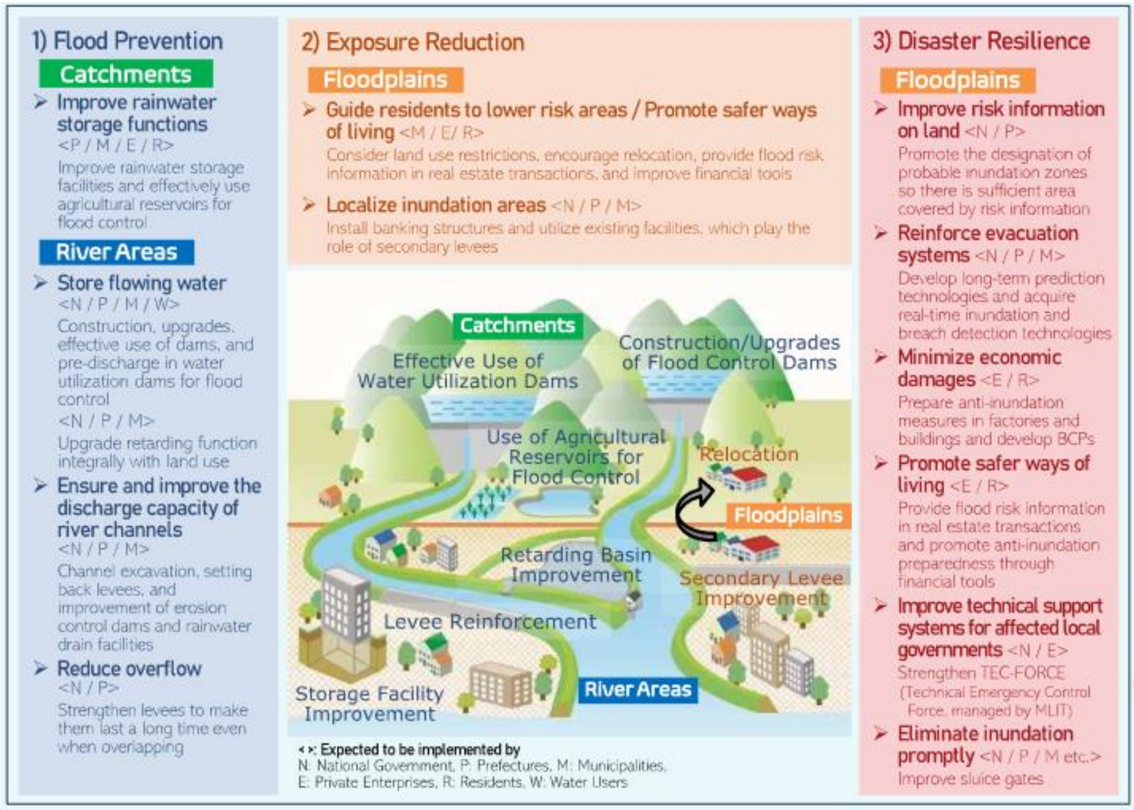
(6) Others

The Zero ΔQ Policy (Policy to control runoff and prevent flooding as much as possible) has been promoted in Indonesia, and it is expected that the experience of Japan such as basin-wide comprehensive flood disaster prevention, land use regulation, Polluter Pays Principle and smart cities would be referred to and adapted to Indonesian policy.



Source: Realizing Smart Cities, MLIT

Figure 6-50 Example of smart city



Source: Promotion of flood control in the Basin, MLIT

Figure 6-51 Example of basin-wide comprehensive flood disaster prevention

Chapter7 Sediment Disaster Countermeasure

7.1 Assessing the Sediment Disaster Situation

7.1.1 Overview of Disaster

Heavy rains from December 31, 2020 to January 1, 2021 caused massive flooding and sediment disasters in southern Jakarta and Jabodetabek area. Record rainfall was observed in Bogor with 377 mm of daily rainfall at Halim rainfall station. Accordingly, many sediment disasters occurred in Bogor Regency namely in Sukajaya, Nanggung, Jasinga, and Cigudeg districts. These disasters killed 17 people, injured 529 people, and damaged 5,496 residential houses. In addition to life loss and house damage, sediment disasters also caused disruption of lifelines such as roads, electicity supply, etc.

The area with high density of sediment disasters occurrence is presented below.

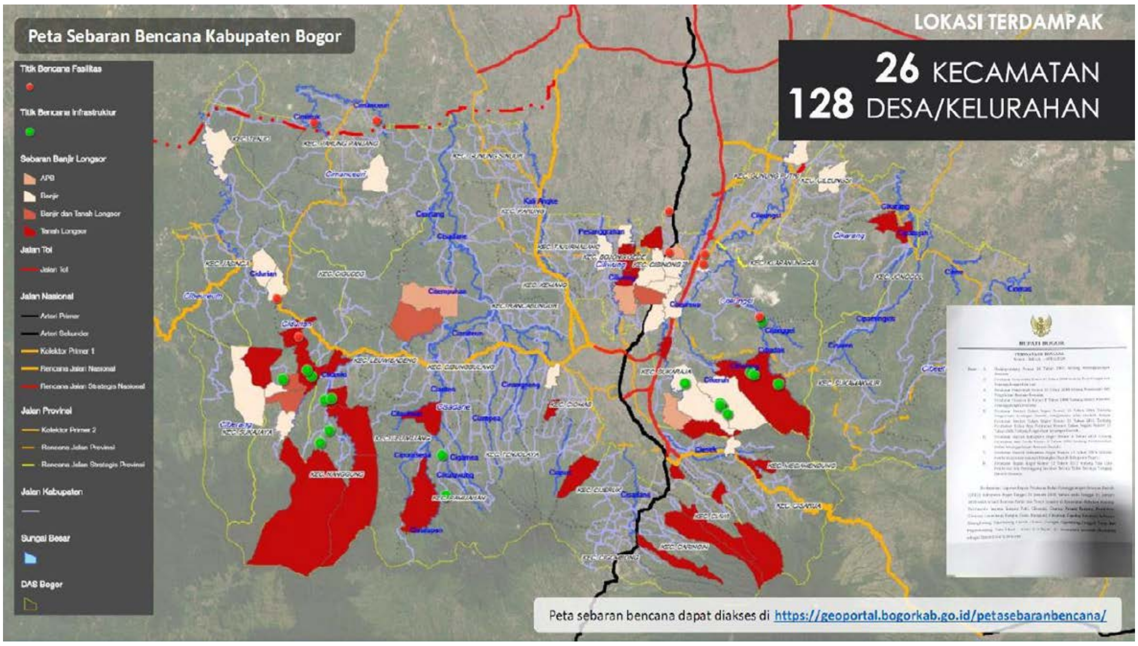


Figure 7-1 Area where sediment disasters occurred in January 2021 (area with red color)

Source: Bogor Regency Gov, Bencana Tahun 2020 Di Kabupaten Bogor

7.1.2 Sediment Disaster Occurrence

(1) Occurrence Area

Occurrence of sediment disaster was concentrated in four districts in the southern part of Bogor Regency, West Java Province i.e. Sukajaya, Nanggung, Jasinga, and Cigudeg District.

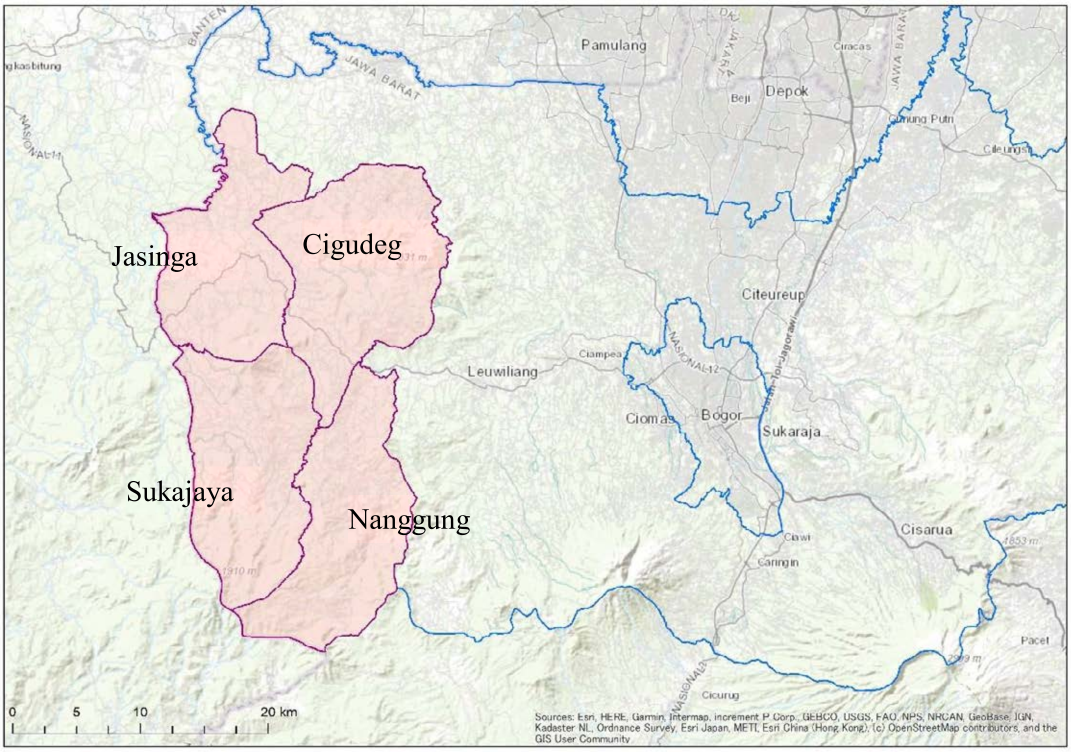


Figure 7-2 Main Occurrence Area of Sediment Disaster

(2) Type of Sediment Disasters

Photographs of the disaster site are presented below. The disasters are classified into slope failure and debris flow according to their mechanism and the mobility of the sediment.

Slope failure

Torrential rains caused widespread and simultaneous failures of steep slopes. Steep slopes of more than 30° collapse abruptly due to reduction of its retaining forces under the influence of rainfall or earthquake. The sediment mass of slope failure completely vacates from the originating zone in a high rate of movement (often faster than 1 m/s) and deposited on the lower slopes. Hence, if a slope failure occurs near a residential area, many people fail to escape and resulting in higher rate of fatalities.

Figure 7-3 Example of slope failure

Source: https://www.cnnindonesia.com/nasional/20200105192400-22-462591/foto-tanah-longsor-di-sukajaya-bogor/2

Debris Flow

Debris flow is a phenomenon where sediment, driftwood, and water on the hillside or riverbed mobilized downward at a high speed under the influence if a continuous rain or torrential rain. In comparison to slope failure, debris flow have a relatively higher water content ratio. In addition, slope failures that occurred in the upper part of the river may transform to debris flows when the mass from slope failure mixed with water flowing at the bottom of the valley and mobilizes downward.

Further, in areas where the valley shape is not clear, sediment from slope failure transformed to mud and flowed downstream. In such case, distinguishing slope failure and debris flow is very difficult.

https://kumparan.com/kumparannews/foto-pencarian-3-korban-longsor-di-sukajaya-bogor-1saJquKcfMM/full

https://regional.kompas.com/read/2020/01/07/14412631/longsor-di-bogor-3-warga-yang-hilang-belum-ditemukan?page=all

Figure 7-4 Example of debris flow

(3) Topographical Characteristics

The topography of the disaster area was confirmed using 3D topographic map (AW3D) which published publicly. The area is mountainous with mountain ridges in a north-south direction due to the influence of rivers flowing from south to north. In addition, small rivers or streams have developed along the main rivers due to slope erosion of mountain ridges by rainwater and other factors.

The area has few flat terrains (slope of 0-5°), where they are distributed in small terraces along the rivers. Many alluvial fans are formed by mudslide in the past, which indicated that the area has always been at risk of disaster.

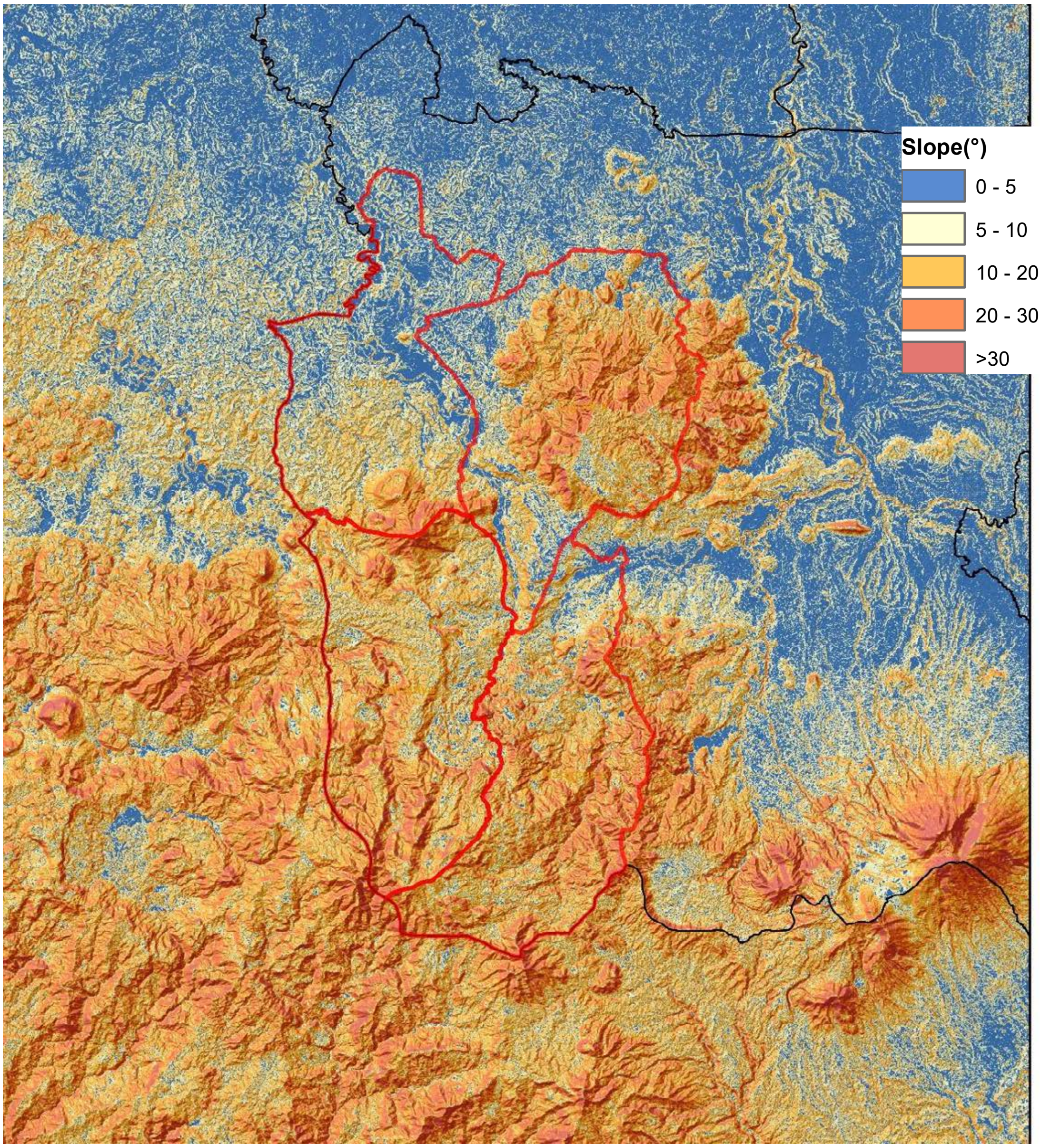


Figure 7-5 Topography of the disaster area

(5) Geological Characteristics

Geologic map of the area is presented in the figure below.

Geology of the area is composed of sedimentary rocks, mainly consisting of sandstone, mudstone, and limestone, which were formed during the Neogene Miocene. On top of this base rock, unconsolidated sediment such as Quartenary talus deposits are considered to be deposited on the slopes along the rivers, and riverbed sediment is considered to be deposited along the river.

Debit of small rivers increased and water level rose due to the downpour rainfall (heavy rainfall in a short period). As a result, debris flow mobilized downstream while eroding the lateral slope and riverbed sediments.

Gentle-sloped area is formed at the confluence of small rivers and medium-sized rivers. Many of these areas are considered to be alluvial fans created by past debris flows, where houses are built and farmlands are developed on it. Sediments transported by small rivers are assumed to be deposited on such fans or flowed further downstream, hence houses and farmlands on the fans are potentially damaged.

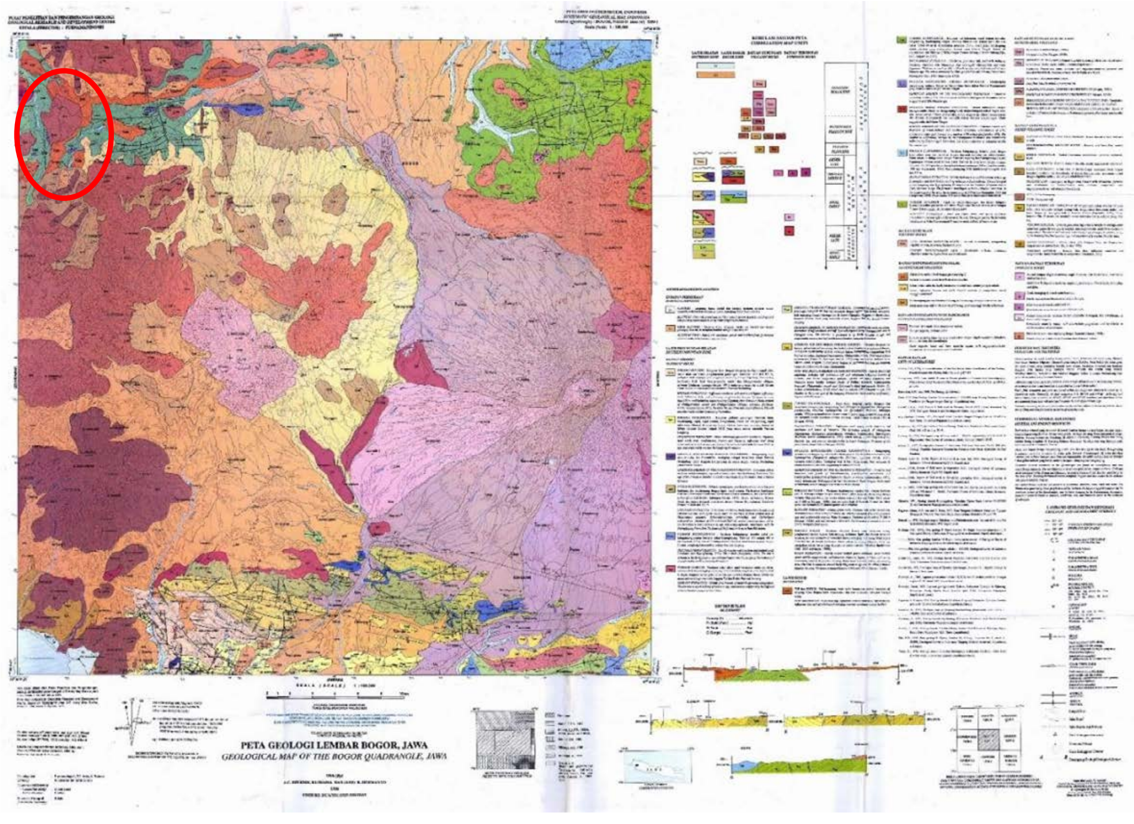


Figure 7-6 Geology of the disaster area

Source: PUSAT PENELITIAN DAN PENGEMBANGAN GEOLOGI GEOLOGICAL RESEARCH AND DEVELOPMENT CENTRE

(6) Land Use Characteristics

Land use in the disaster area and its surrounding is shown in the figure below.

All four districts are mostly forested area, including dense and sparse forest. Dense forest (dark green color) exists in the southern part of Sukajaya District, the entire Nanggung District, southern part of Jasinga District, and northern part of Cigudeg District. Meanwhile, sparse forest (light green color) are concentrated in the northern part of Sukajaya and Jasinga district, as well as in the southern part of Cigudeg district.

Agricultural land (orange color) is widely distributed in Cigudeg District. However, in other districts, agricultural land is small and limited to small flat areas along the rivers.

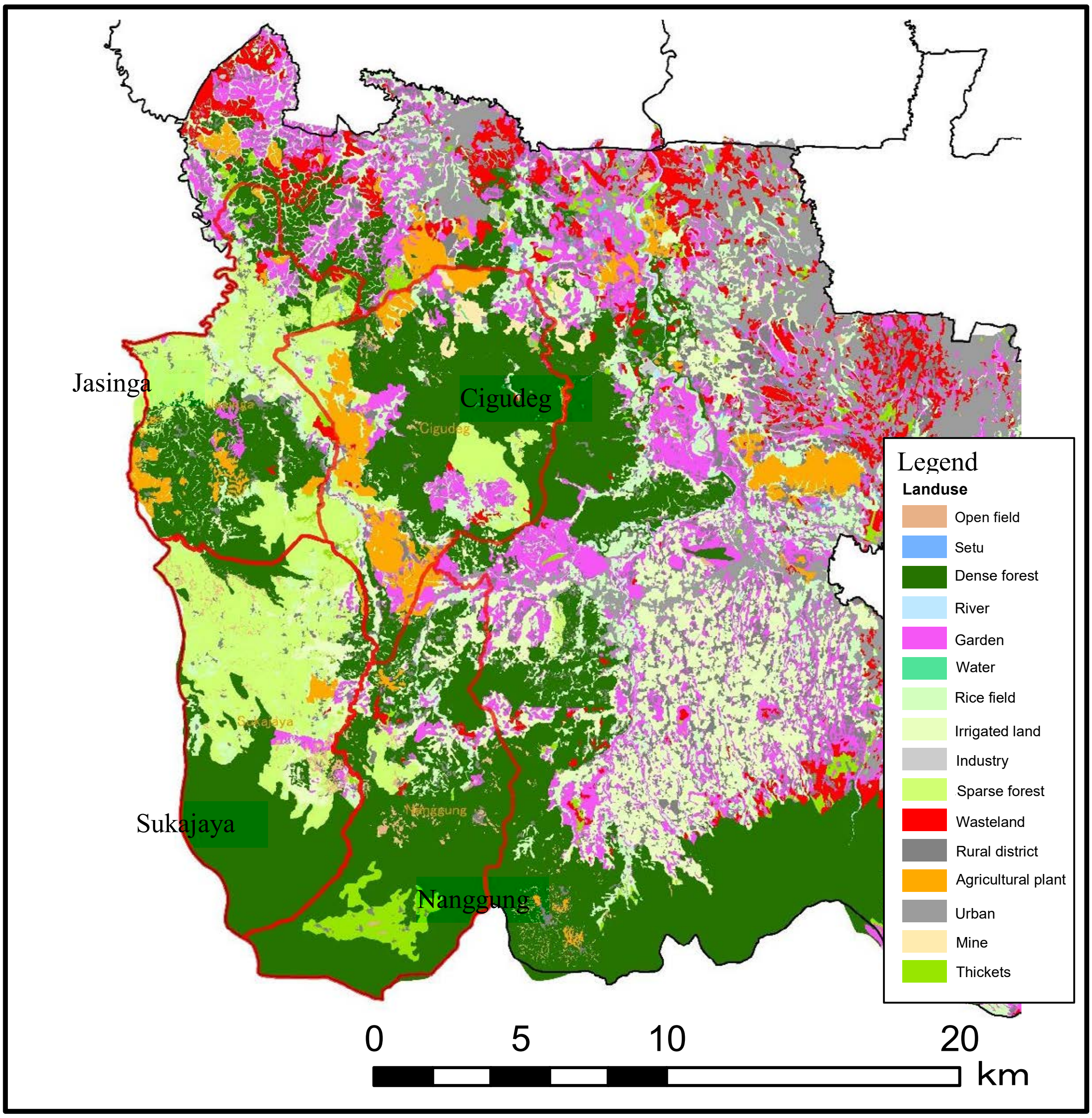


Figure 7-7 Land use map

Source: created by the survey team based on GIS data

7.2 Analysis of the Main Causative Factor for Sediment Disaster

7.2.1 Overview

The factors causing sediment disasters are analyzed by identifying the area of disaster occurrence and its topographical characteristics. Since a long time has passed since the disaster occurred and it occurred over a wide area, field survey was not conducted. Instead, satellite image was used to interpret the extent of the sediment disaster occurrence.

Two types of satellite images were compiled, i.e. before and after the disaster occurrence. These images were compared to identify the area where sediment disaster had occurred. In addition, the on-site topographic analysis was performed based on a 3D topographic map of the area, by creating the contour lines and analyzing the flow direction. From this analysis, gradients of the slopes and streams were obtained.

7.2.2 Identification of disaster area by satellite image interpretation

Two types of satellite images were used for this study, i.e. SPOT satellite images with 1.5 m resolution and Pleiades satellite images with 0.5 m resolution. First, wide-area photo interpretation was conducted using the SPOT satellite images, then Pleiades satellite imagery and topographic analysis was performed in detailed areas where disasters are concentrated.

(1) Wide-area interpretation

An area of 400 km^2 of the four district were selected in acquiring the SPOT satellite images. This 400 km^2 area is focused on the mountainous area near the boundaries of Sukajaya and Nanggung districts where sediment disasters are particularly concentrated.

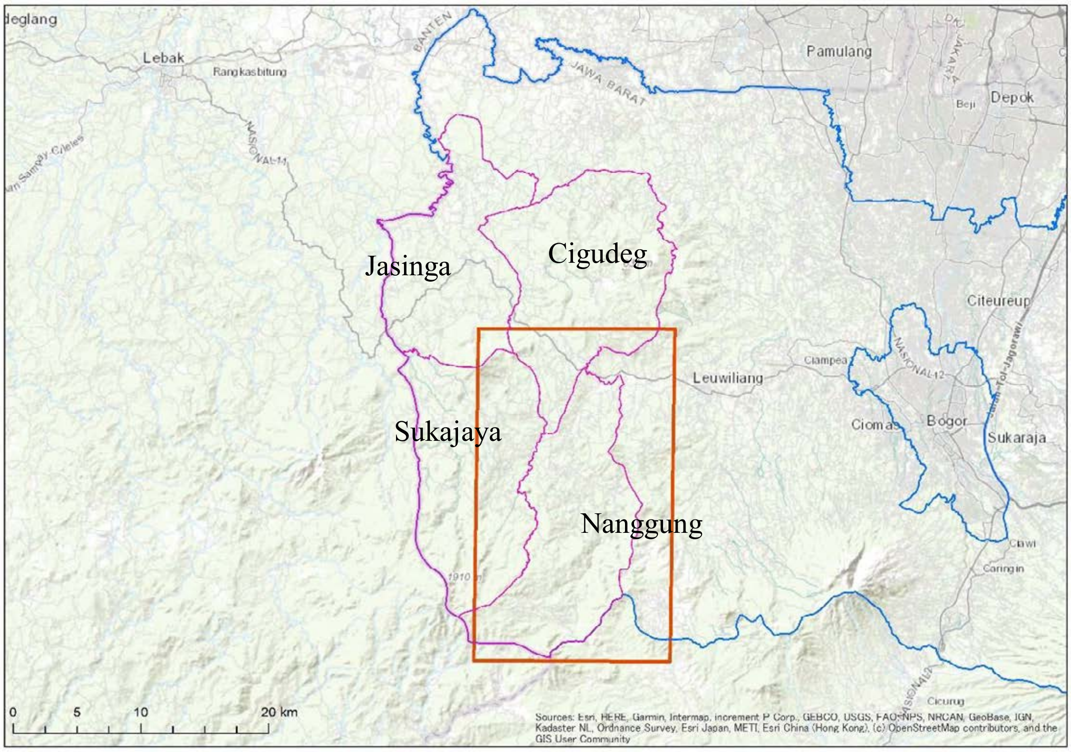


Figure 7-8 SPOT satellite image acquisition range of 400 km^2 (brown rectangle)

The results of wide-area interpretation are presented in the overall and enlarged figures below. The interpretation result indicated that sediment disasters are concentrated in the central part of the 400 km^2 area. The enlarged figures showed that more disasters occurred in the northern part rather than the southern part. These sediment disasters mainly occurred along rivers, small streams, and slopes.

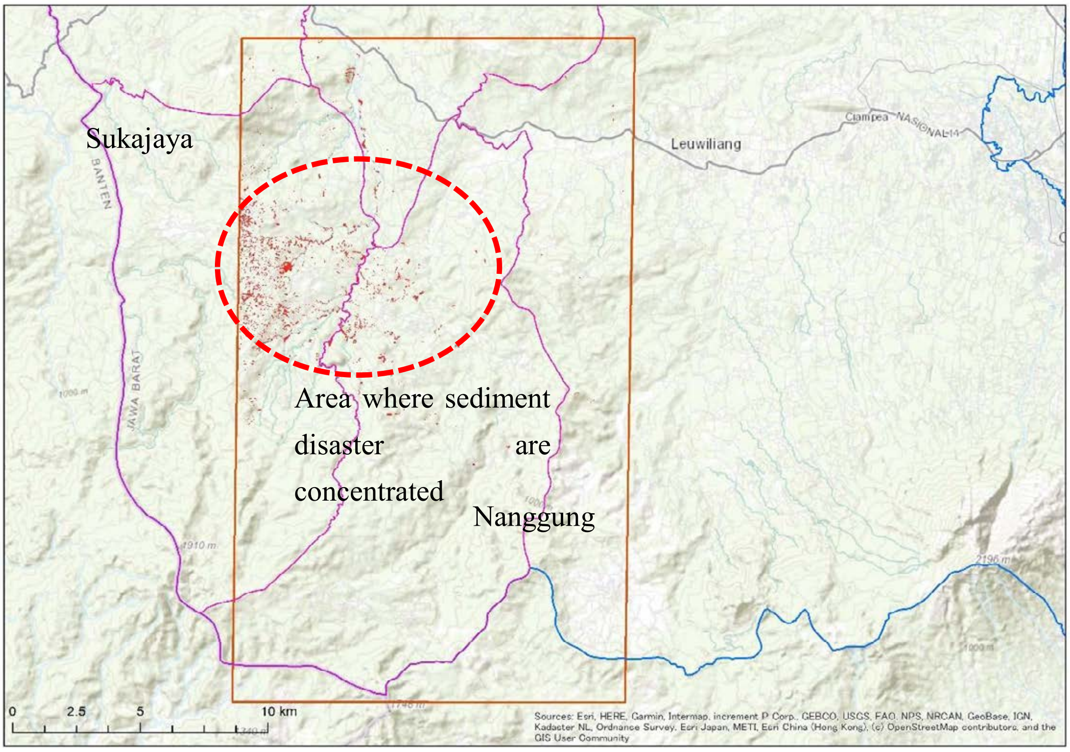


Figure 7-9 Result of wide-area satellite images interpretation (red colored area is the sediment disaster area)

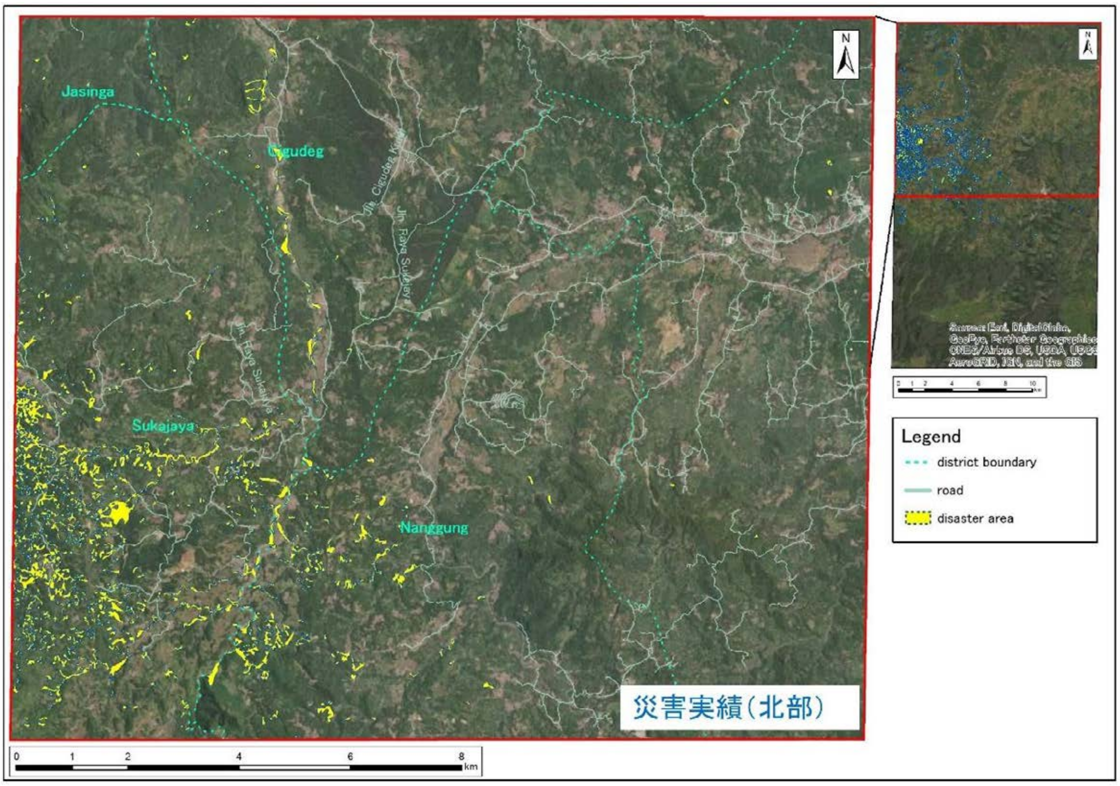


Figure 7-10 Result of wide-area satellite image interpretation for northern part (enlarged)

(Yellow colored area is the sediment disaster area)
Source: Survey team

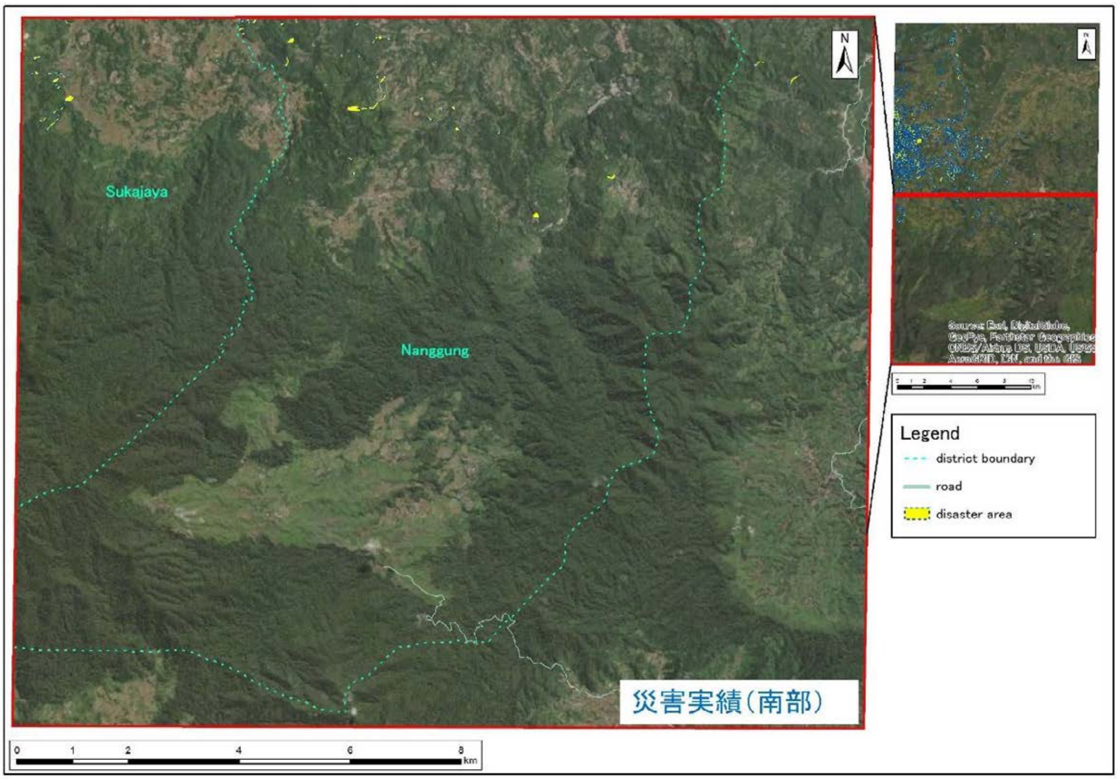


Figure 7-11 Result of wide-area satellite image interpretation for southern part (enlarged).

(Yellow colored area is the sediment disaster area)
Source: Survey team

(2) Detailed interpretation

Of the 400 km^2 area where wide-area interpretation was conducted, an area of 50 km^2 where sediment disasters were particularly concentrated was selected, as shown in in the bold red line in the figure below. For this 50 km^2 area, a detailed interpretation was conducted using high-precision satellite images (0.5 m resolution of Pleiades satellite images).

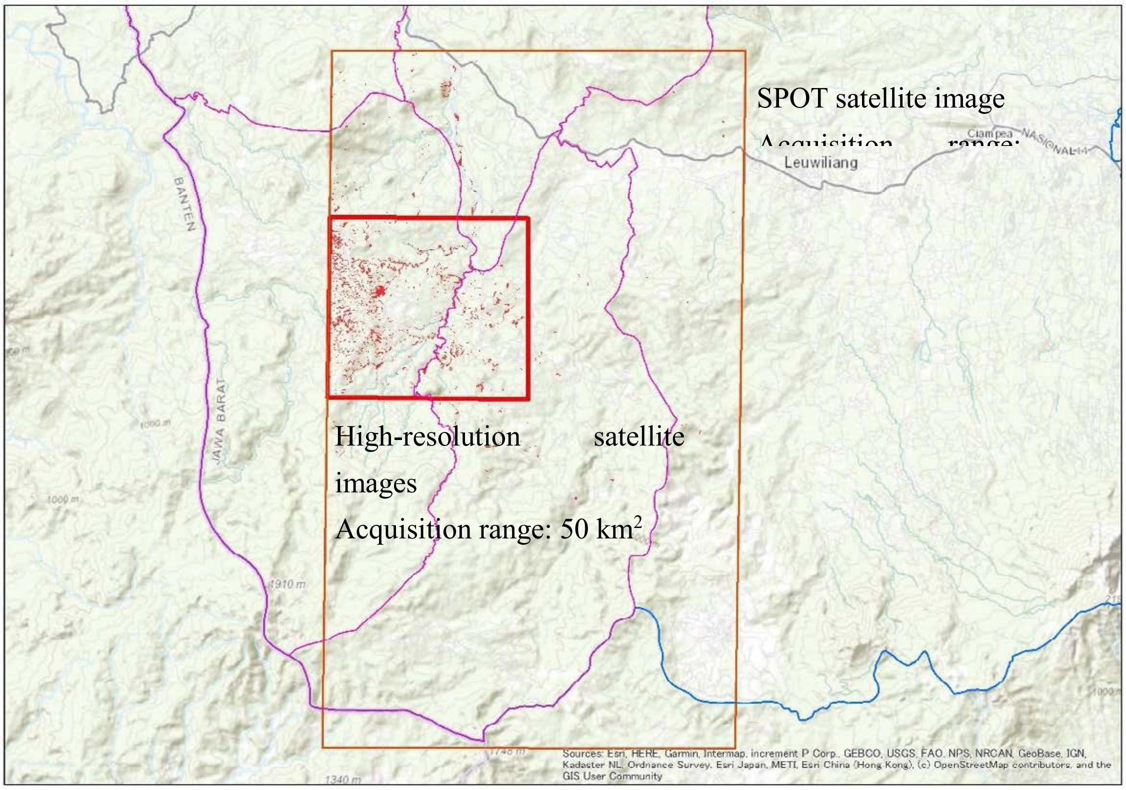


Figure 7-12 A 50 km^2 area for detailed satellite images interpretation (thick red line)

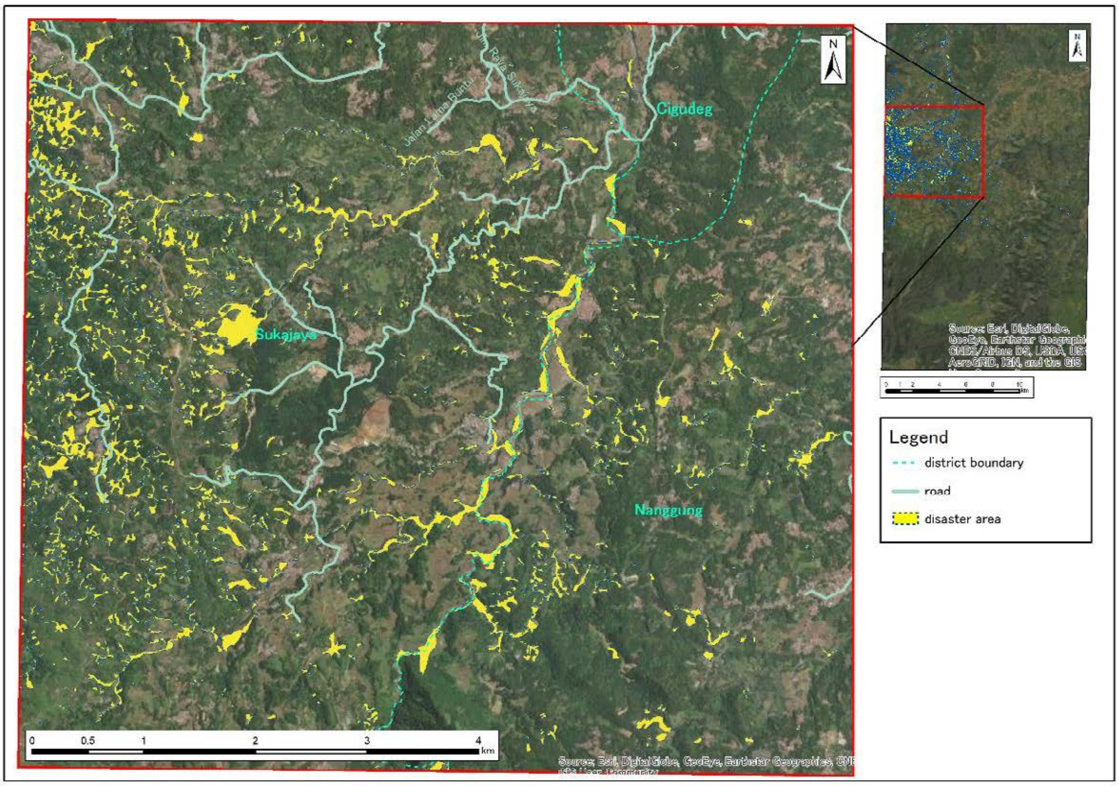


Figure 7-13 Result of detailed satellite images interpretation for the 50 km^2 area (yellow colored area is the sediment disaster area)

Source: Survey team

7.2.3 Local topographic analysis using topographic map

Using the AW3D topographic map provided by Restec, analysis of slope classification, river gradient, etc. for the 50 km^2 area was conducted.

(1) Slope gradient

Slope gradient was categorized according to the following classification and the result is presented in the figure below.

Table 7-1 Classification of the slope gradient

Gradient range	Color	Remarks
0-2°	White	2° was set as the threshold because it is considered as the gradient where deposition of debris flow ends. Within the range of this category, the possibility of sediment disaster occurrence and mobility is considered to be low.
2-10°	Green	10° was set as the threshold value because it is considered as the end of transport zone of a debris flow. Within this range of slope gradient, sediment from a debris flow may reach the area.
10-30°	Orange	Threshold value of 30° was selected because the slope with high possibility of slope failure is considered to be 30° or higher. Within this range of gradient, sediment and large gravel from a debris flow may reach the area as well as the sediment from a slope failure.
>30°	Red	On area with gradient of more than 30°, slopes with high potential for slope failure are considered to exist.

The result of slope gradient analysis and classification indicated the following characteristics:

- Very few area are in white color (0-2°), partly due to its mountainous location. The green color (2-10°) are distributed along the rivers and on the flat terrain at the top of slopes. Debris flow sediment may accumulate along the river when debris flow occurs.
- The majority of the non-riverine area is above 10° and many areas have gradient of above 30° where slope failure is considered to be likely to occur.

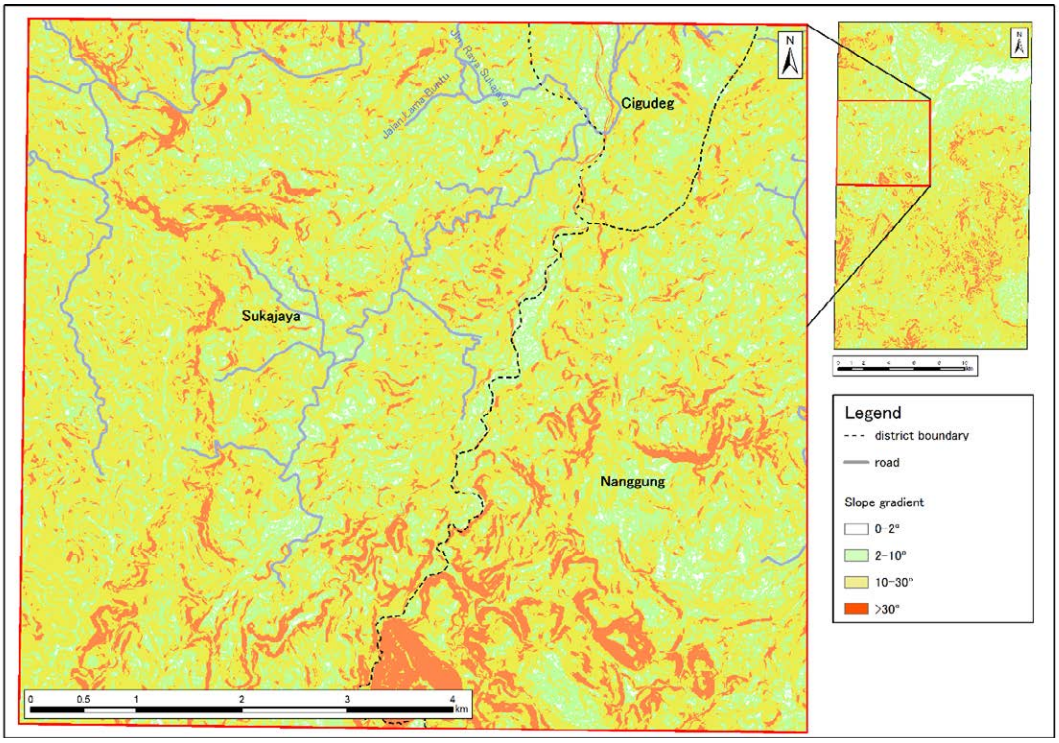


Figure 7-14 Result of slope gradient classification for the 50 km^2 area

(2) Assessment of the relationship between slope gradient and sediment disaster occurrence

Characteristics of the sediment disasters were identified by overlaying the occurrence area and the slope gradient map as shown in the figure below. From this assessment, we obtained the following characteristics:

- Sediment disasters occurred in gentle slope gradient areas along the main river.

The main river is located on the boundary between Nanggung and Sukajaya district (dotted line). In respect to their slope gradient, the areas close to the main river are categorized as white (0-2°) or green (2-10°) where they are relatively gentler than the residential area yet they are disaster-prone areas. Mobility of the mass from debris flows and sediment flows that occurred in the upstream area or the small mountain streams along the main river may reach these areas.

- Many disaster sites are located on slopes of 30° or more.

These disasters which occurred on slopes of 30° or more are considered as slope failure. Some of them were fluidized and are considered to have flow downstream as debris flow or sediment flow.

- Disasters occurred on slope in the western part of the target area.

Sediment disasters in the western part of the target area occurred on slopes of 15-30°. Satellite images also showed that slope failures have occurred from the ridge to the valley of foothills which is considered to have gradient of more than 30°. In such slopes, many houses are distributed directly above or below the slope. When the slope collapses, these houses are potentially to be damaged.

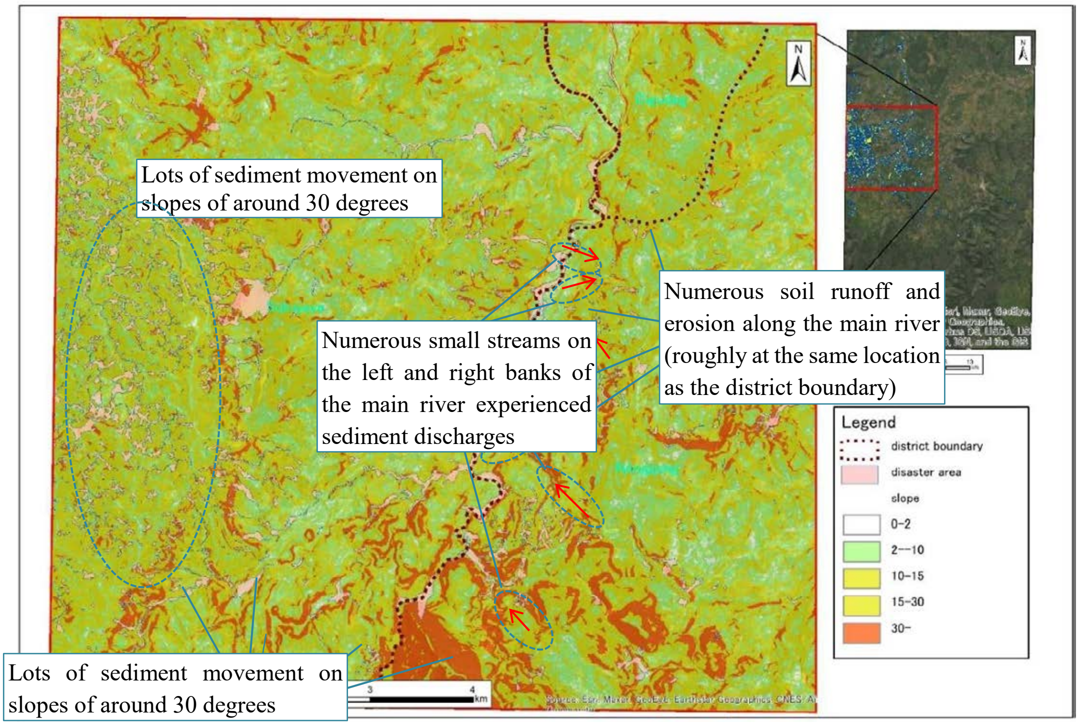


Figure 7-15 Assessment of the relationship between the extent of sediment disaster occurrence and slope gradient

(3) Riverbed Gradient

After conducting the flow direction analysis, river line within the target area was extracted. Further, riverbed gradient was also analyzed.

In regards to sediment transport pattern based on riverbed gradient, riverbed gradient of more than 10° is classified as the debris flow transport zone, while riverbed gradient of 2-10° is classified as the deposition zone (Figure 7-16).

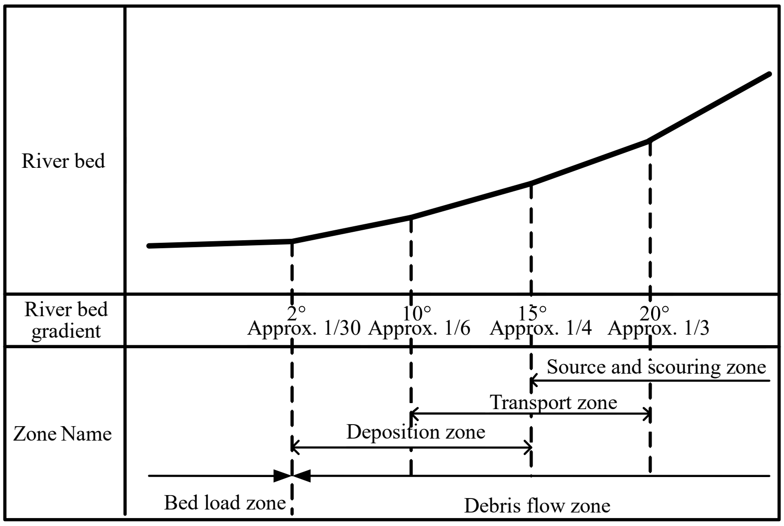


Figure 7-16 Changes of sediment transport pattern based on riverbed gradient

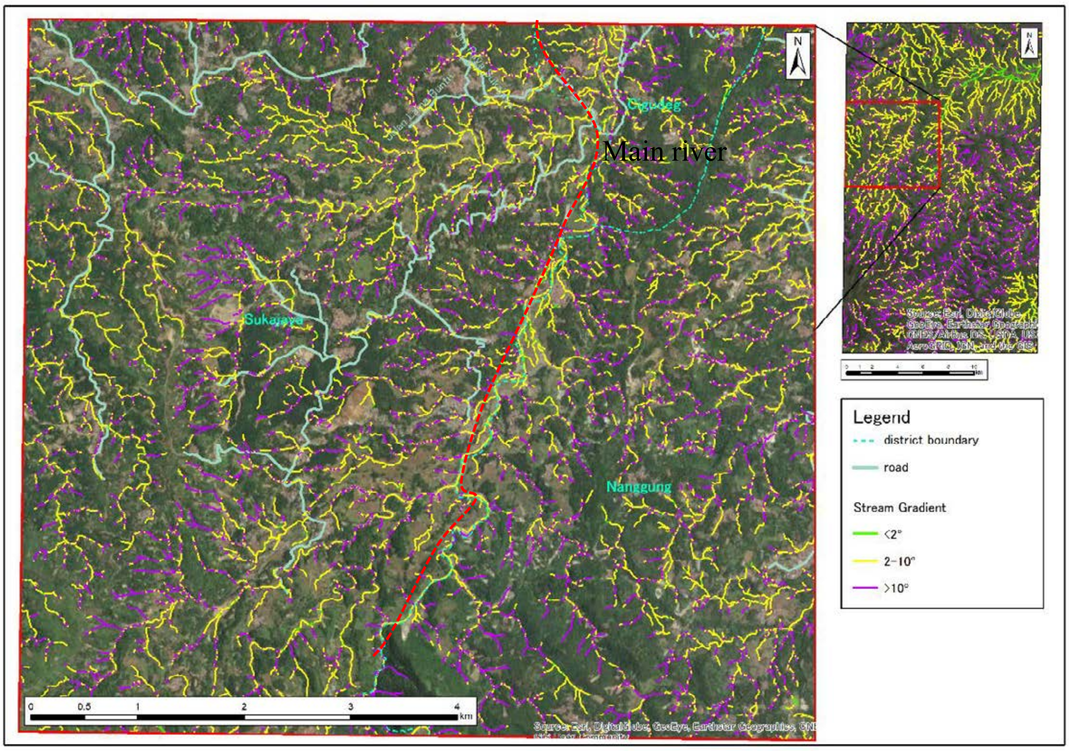


Figure 7-17 Analysis of riverbed gradient

From the analysis of riverbed gradient, we obtained the following characteristics:

- Some parts on the main river have gradient of less than 2° (green line), but most of the main river have riverbed gradient of 2-10° (yellow line).
- Tributaries of the main river mostly have riverbed gradient of more than 10° on its upper reaches, which are the areas where debris flows occur. Further, many tributaries do not have riverbed of less than 2° even in their lower reaches. Hence, if a debris flow occurs in such tributaries, the sediment has high possibility to mobilize into the main river.

(4) Risk Area of Debris Flow

Depending on the accuracy of the base map used, analysis of flow direction may extract a river terrain that actually not prone to debris flow as a river terrain prone to debris flow. Hence, such error was visually observed and excluded from the analysis. Then, the risk area in a river prone to debris flows is determined. As shown in the figure below, the risk area extends from the valley exit to a riverbed gradient of 2°. The spread of debris flow on a flat terrain is considered to be 30° to the left and right of a valley exit. The result of the assessment of debris flow risk area is presented below.

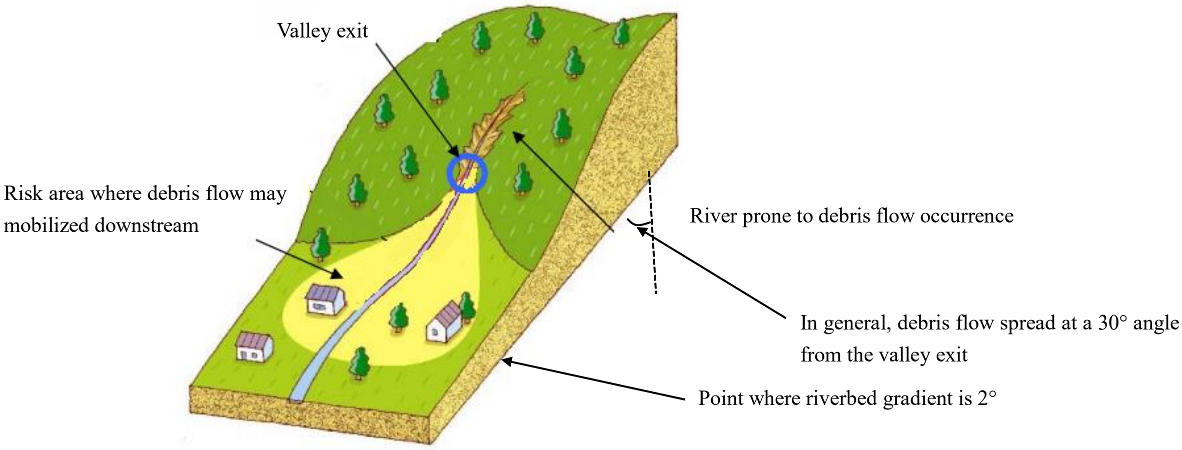


Figure 7-18 Conceptual diagram of debris flow risk area

Source: MLIT, with modification by the survey team

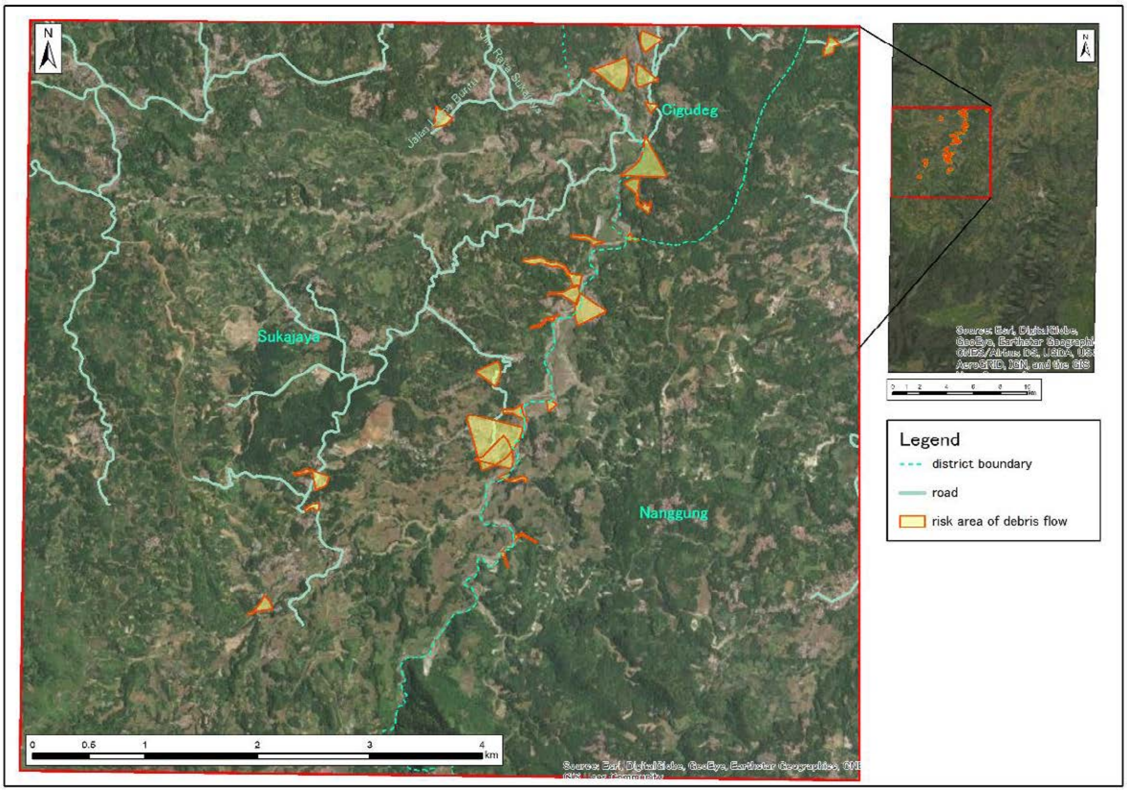


Figure 7-19 Result of debris flow risk area assessment

Source: Survey team

(5) Risk Area of Slope Failure

In principal, slope failures are more likely to occur on a steep slope of 30° or more. Areas with high risk of sediment movement from a slope failure are the 10 m space above the steep slope and the 50 m (or twice the slope's height) space below the steep slope, as shown in the figure below. Since estimation of slope height from satellite images is difficult, we selected the high risk area where residential houses are distributed within the (i) 10 m space above a steep slope and (ii) 50 m space from the bottom of a steep slope. The result of the assessment of slope failure risk area is presented below.

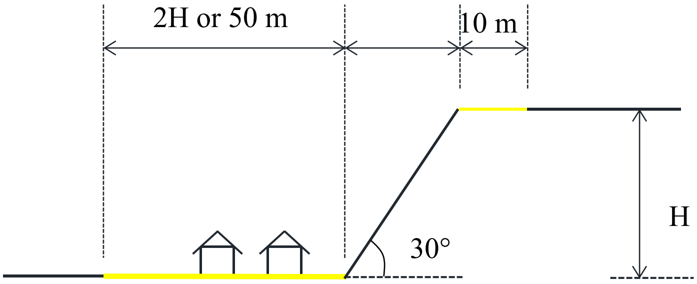


Figure 7-20 Conceptual diagram of slope failure risk area

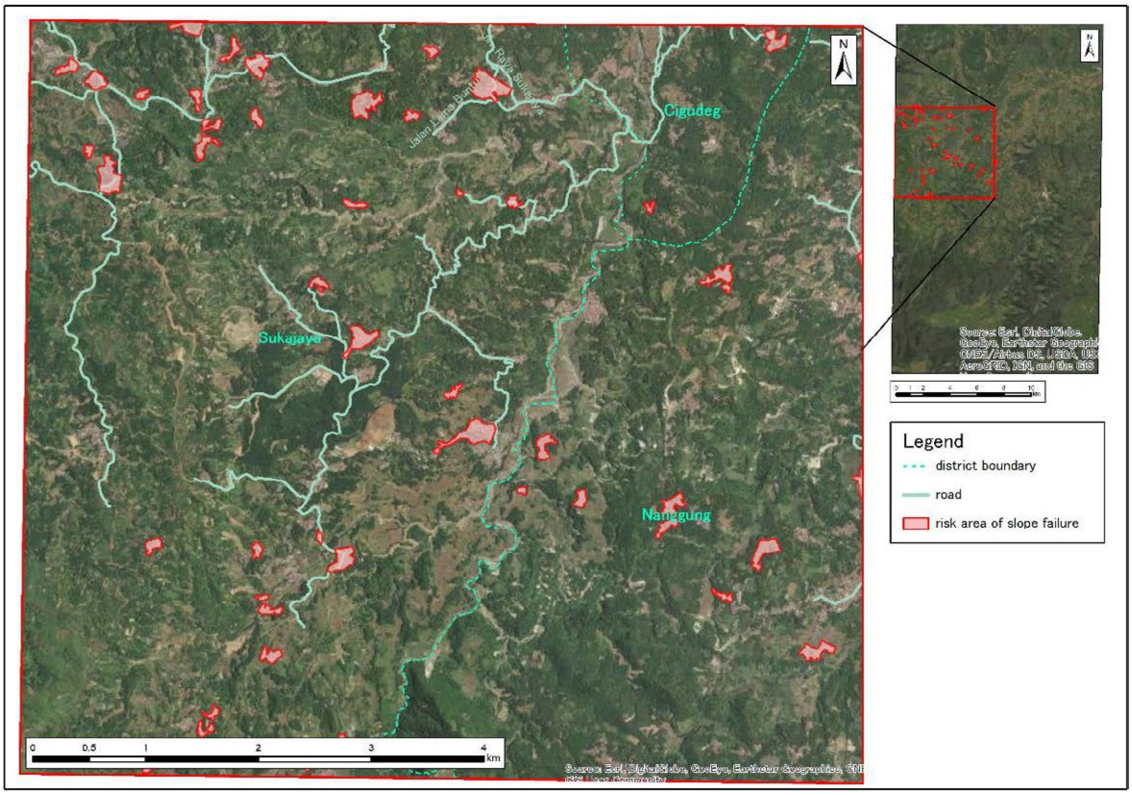


Figure 7-21 Result of slope failure risk area assessment

Source: Survey team

(6) Assessment of Priority Rivers for Maintenance

The rivers where debris flow may occur and shall be prioritized for maintenance are assessed based on several indicators. These indicators are including the number of residence, important arterial roads, important public facilities, etc. However, since the target area is located in a mountaineous area and has few important roads or public facilities, the priority assessment was depended on the number of residential houses.

The number of houses potentially affected by debris flow varies from zero to 587. They are classified into: less than 25 houses (yellow), 26-50 houses (orange), and more than 51 houses (red). Area with high priority are those in red and orange which are scattered along the main river as shown in the figure below.

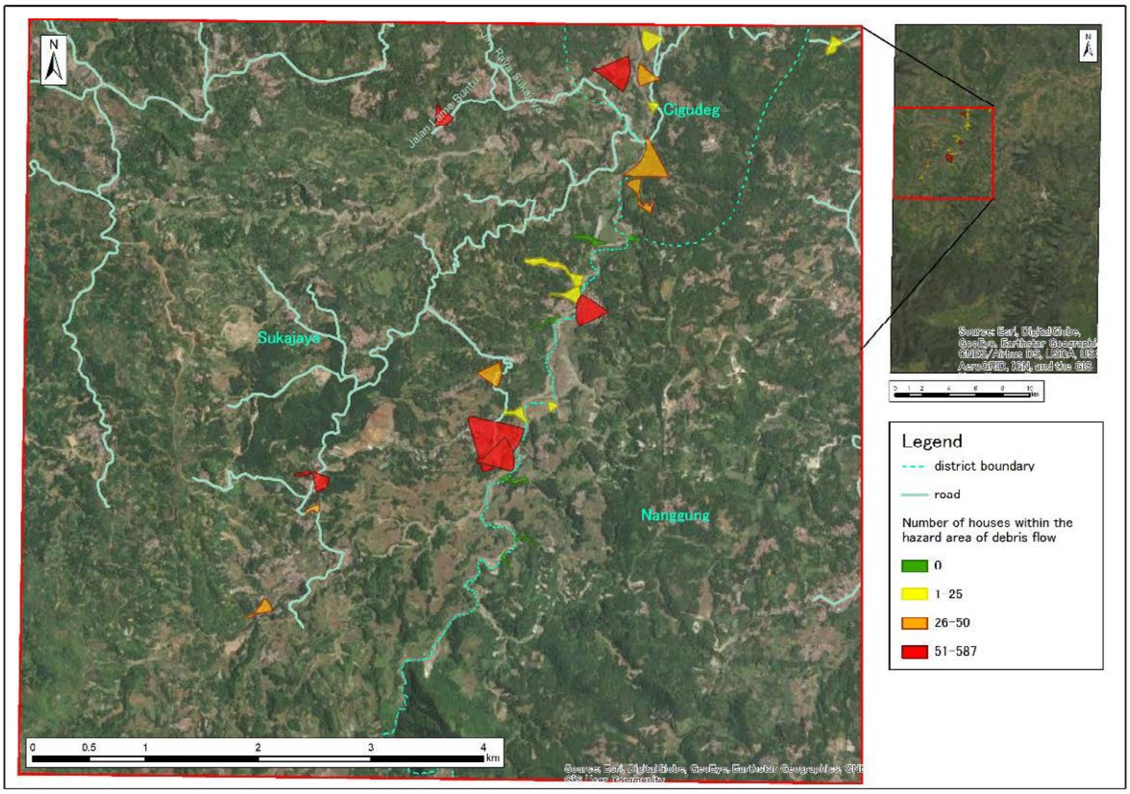


Figure 7-22 Result of assessment of maintenance priority (debris flow)

Source: Survey team

(7) Assessment of Priority Slopes for Maintenance

Priority assessment was conducted on areas where slope failures potentially occur in a similar manner to priority assessment for debris flow. Accordingly, the priority for slope failures was evaluated based on the number of residential houses. We categorized the result as: less than 10 houses (yellow), 11 to 20 houses (orange), and more than 21 houses (red). Area with high priority are those in red which distributed mainly near the slopes in Sukajaya District.

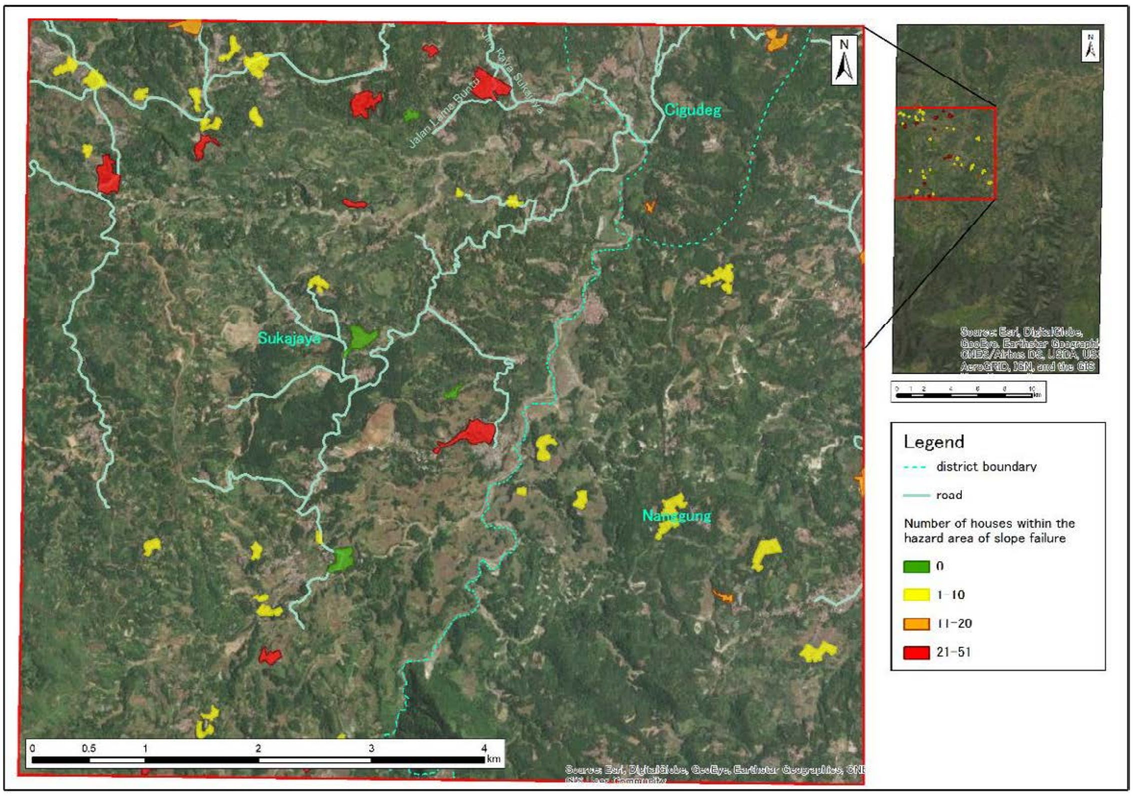


Figure 7-23 Result of assessment of maintenance priority (slope failure)

Source: Survey team

7.3 Conclusion

From the analysis, we found that sediment disasters occurred mainly near the center of Sukajaya and Nanggung Sub-district. In the target area, the types of sediment disasters are slope failures and debris flows. Slope failures occurred on slopes with gradient of 15-30°, particularly in Sukajaya Sub-district. While debris flows occurred mainly near the main river, i.e. the boundary of Sukajaya and Nanggung Sub-district. The main river mainly have riverbed gradient of 2-10°, which indicated that it is the deposition zone for debris flow and hence the area near the river has a risk to be damaged by sediment mobilization. Further, we analyzed the priority area and river for maintenance based on the number of houses within the risk area of debris flows and slope failures. The largest number of houses is 587 with two converging debris flow risk areas, which located in Kiarapandak Village, Sukajaya Sub-district.

7.4 Recommendation

The target area of this study is located in mountainous region with numerous risk area for sediment disasters. This study revealed that only few flat areas exist, which distributed along the main river and has a risk of being damaged by the mobilization or deposition of debris flows generated in small tributaries in the upstream. In contrast, steep slopes are distributed widely, where many slope failures occurred during the heavy rainfall of 2020. Some of these slope failures transformed to debris flows and caused damaged downstream.

However, this study is limited to identifying the sediment disaster occurrence area based on satellite image analysis. Such method is considered reliable and effective, moreover when a high-resolution satellite images are utilized in the analysis. Field survey is required to increase the accuracy of such desk analysis. By conducting field survey, the actual disaster area, any distinguish characteristics of the disaster, mechanism of the disaster, as well as the affected area can be confirmed.

Further, current study only identified the disaster area and potentially damaged area, but planning of measures is an important key in reducing the disaster risk. Measures for sediment disaster are classified into structural and non-structural measures as follows:

Structural measures

- Sabo dam to prevent debris flow
- Channel works and consolidation works to stabilize the river
- Retaining walls to prevent slope failures

Non-structural measures

- Mapping of risk area
- Establishment of warning and evacuation system
- Improvement of observation system by rain gauge installation
- Regulation on land use and building structure

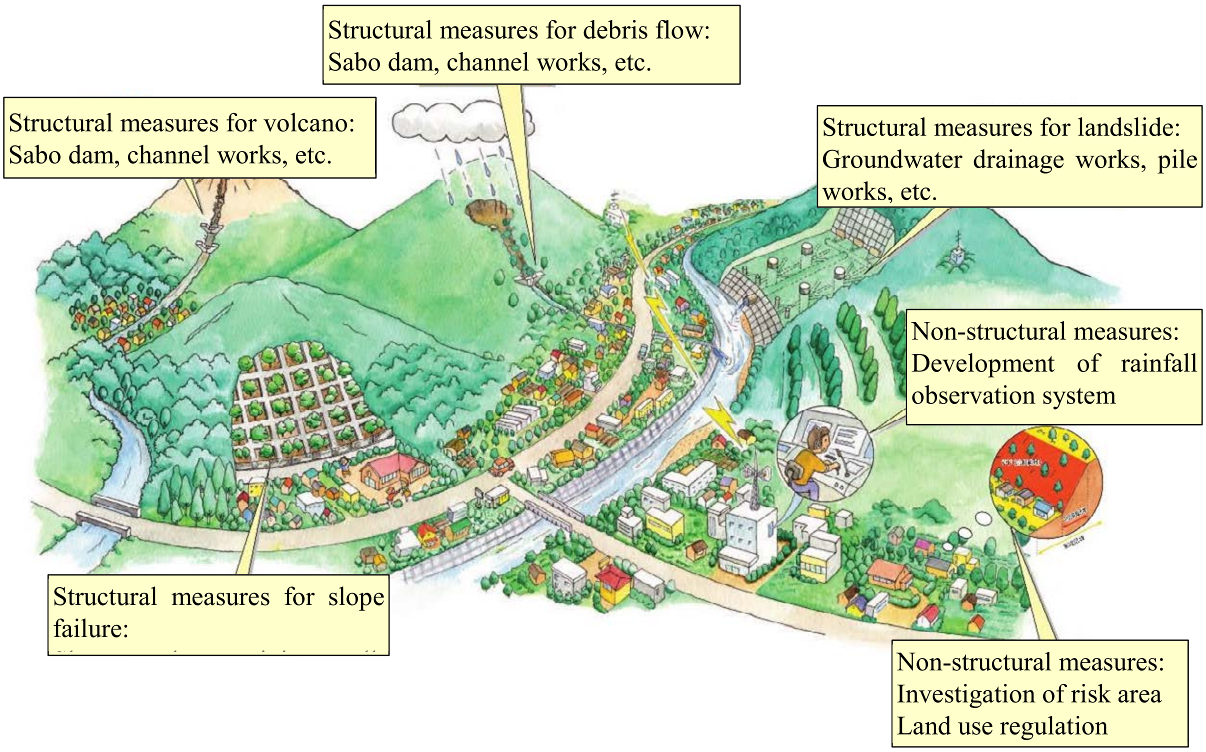


Figure 7-24 Comprehensive sediment disaster countermeasures

Source: Fukui Prefecture (modified by the Survey team)

Combination of structural and non-structural measures is considered as an effective and comprehensive measures against sediment disaster in accordance with the priority area mentioned in this study. We summarized the recommendation for each priority area below.

Structural measures

- Short- and medium-term plan: the areas indicated as red (high risk area) are need to be prioritized for landslide countermeasures development. Structural measures such as Sabo dam in these red areas should be prioritized.
- Long-term plan: areas indicated in orange and yellow should be improved by construction of Sabo dam or other structural measures. In addition, channel works should be conducted along the main river to control sediment deposition and river erosion.

Non-structural measures

- Short- and medium- term plan: development and sharing of risk maps shall be prioritized.
- Development of a warning and evacuation system including the preparation of evacuation plans should be started in the short- or medium-term plan and maintained in the long-term plan.

- Long-term plan: measures that are difficult to be conducted in short- or medium-term plan should be promoted in the long term plan, i.e. improvement of rainfall information system, land use regulation, and building structure regulation.

Table 7-2 Recommendation of sediment disaster countermeasures

	Short- and medium-term plan	Long-term plan
Structural measures	• Sabo dam (for red area)	• Sabo dam (for orange and yellow area) • Channel works in main river
Non-structural measures	• Development of risk map • Development of warning and evacuation system	• Development of warning and evacuation system • Improvement of rainfall observation system • Land use regulation • Building structure regulation

Chapter8 Climate Change Impact Assessments and Adaptation Measures

8.1 Study Approach

8.1.1 Objectives

This study aims to assess impacts of climate change on flood in and around the nation's capital, Jakarta through gathering and analyzing related study reports and climate projection data. It also aims to make recommendations on measures to reduce flood risks that are expected to increase in the future (in other words, climate change adaptation measures).

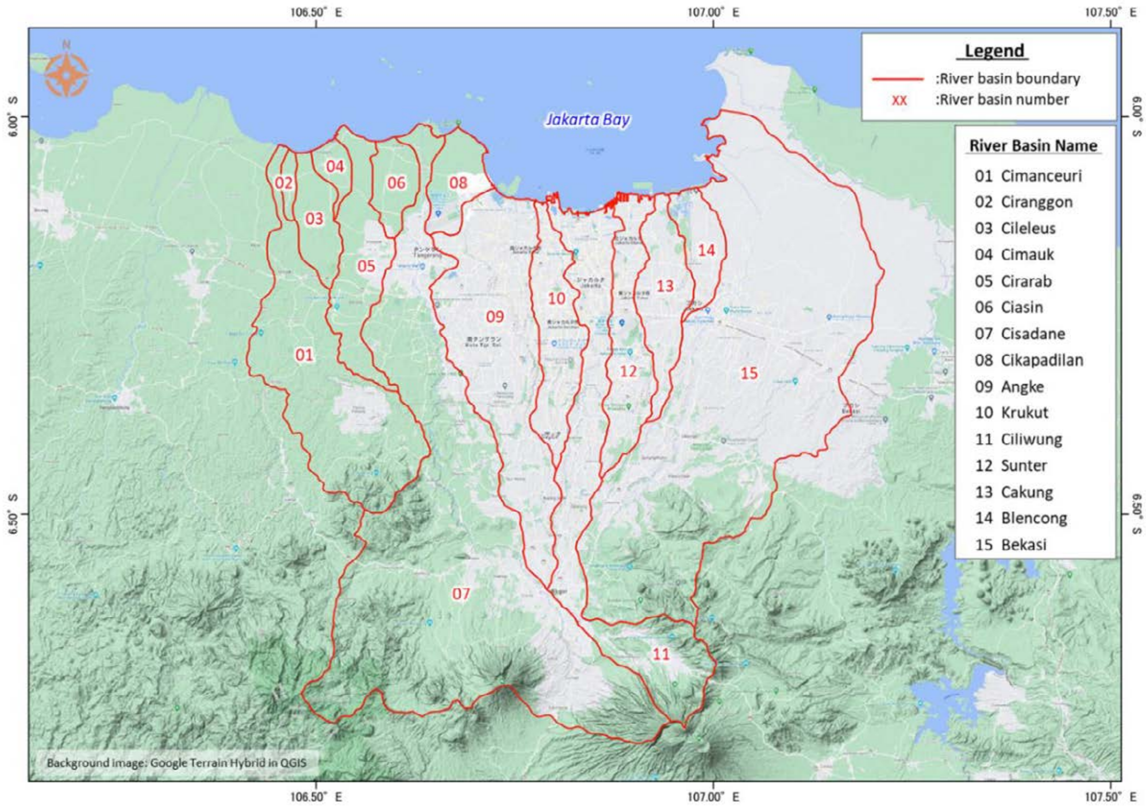
8.1.2 Study Approach

In examining adaptation measures, it is necessary to first assess impacts of climate change on the target disaster. In case of flood, impacts on rainfall and sea level are key factors for the assessment. This study basically aims to estimate the change rate of rainfall and the sea level rise by using existing climate change projection data as generally practiced for the climate change impact assessment. In this study, collecting existing climate change projection data from BMKG and Bappenas, the change rates of heavy rainfall and mean sea level between the present and the future (year 2045) based on RCP4.5 scenario were evaluated.

Secondly, examples of climate change adaptation measures in other countries were collected and organized, and recommendations were made for climate change adaptation measures targeting Jakarta based on these examples.

8.1.3 Study Area

The study area is 15 river basins under the jurisdiction of the BBWS Ciliwung-Cisadane.



Source: JICA Study Team

Figure 8-1 Study Area

Table 8-1 15 River Basins Under BBWS Ciliwung-Cisadane

No.	River Basin	Area (km^2)
01	Cimanceuri	469
02	Ciranggon	17
03	Cileleus	84
04	Cimauk	32
05	Cirarab	68
06	Ciasin	179
07	Cisadane	1,376
08	Cikapadilan	87
09	Angke	499
10	Krukut	171
11	Ciliwung	438
12	Sunter	178
13	Cakung	143
14	Blencong	81
15	Bekasi	1,447
Total		5,269

8.2 Climate Change Impact Assessment from Flood Control Perspective

8.2.1 Climate Change Impact Assessment in Indonesia

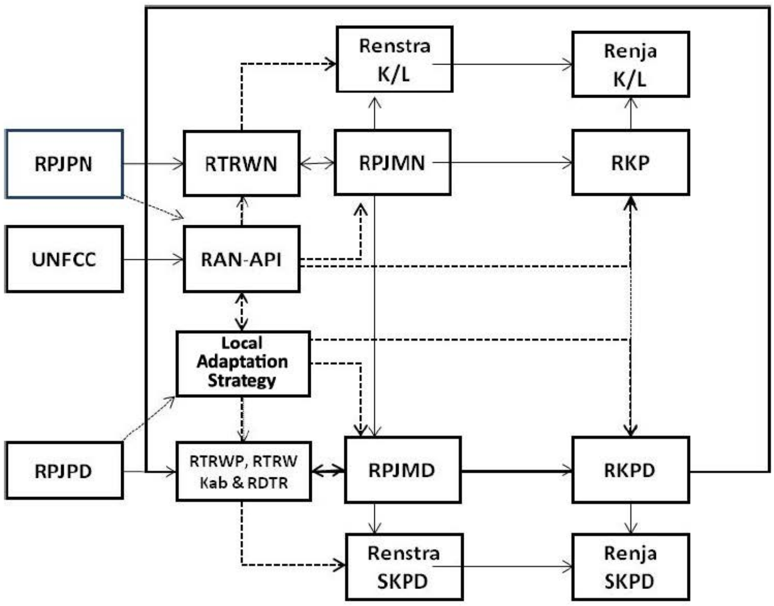
(1) Response to Climate Change

In Indonesia the National Action Plan on Climate Change Adaptation (RAN-API) was published in 2013. The action plan is comprised of action plans of adaptation measures for priority sectors and those across sectors for the short term (2013-2014), mainstreaming of the climate change adaptation plan in the National Mid-term Development Plan (RPJMN : 2015-2019)[1], and policy direction of the long-term climate change adaptation plan. The RAN-API secretariat, of which main tasks are mainstreaming of climate change adaptation measures in policies and action plans of ministries and development plans of local governments, started operations in 2015. The Ministry of National Development Planning (BAPPENAS), as a coordination body belonging to the RAN-API secretariat, coordinates among related ministries and agencies.

There is no specific legal basis for RAN-API unlike the Presidential Order 2011-61 for the National Action Plan on Greenhouse Gas (RAN-GRK). However, RANAPI directly supports the implementation of the RPJMN (National Midterm Development Plan) and can be regarded as the legal basis[2].

[1] The Long-term National Development Strategy Plan (RPJPN 2005-2025) covers 20 years, and the National Mid-term Development Plan covers 5 years.

[2] Quoted from" Project for Strengthening Institutional and Policy Framework on Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) Integration [ASEAN], Final report, JICA, 2018".



Note:
RPJPN: Long Term National Development Planning; RPJPD: Long Term Regional National Development Planning; RTRWN: National Spatial Planning; RTRW Kab: District Spatial Planning; RDTR: Detailed Spatial Planning; Renstra K/L: Line Ministries's Strategic Plan; RPJMN: Mid Term National Development Planning; RPJMD: Mid Term Regional Development Planning; Renstra SKPD: Local Government Agency's Strategic Planning; Renja K/L: Line Ministry Work Plan; RKP: Government Work Plan; RKPD: Local Government Work Plan; Renja SKPD: Local Government Agency's Work Plan

Source： National Action Plan for Climate Change Adaptation (RAN-API) Synthesis Report (2013)

Figure 8-2 Position of RAN-API in Nation Development Framework

(2) Interviews with Related Organizations

As described in 8.1 Study Approach, this study basically uses results of existing studies on climate change impact assessment done by related organizations. Therefore, interviews with BMKG which is responsible for impact assessment on climate aspects, and BIG which is responsible for impact assessment on mean sea level, as well as BAPPENAS, were conducted as summarized in Table 8-2.

In addition, the water resources management strategy plan (POLA, 2015) for the Ciliwung-Cisadane River Basin was also reviewed. Information of flood control measures for the Ciliwung-Cisadane River Basin that was gathered from the POLA and interviews with the BBWS is summarized in Table 8-3.

Table 8-2 Summary of Interviews with BMKG, BAPPENAS and BIG

Organization	Participants	Interview Date
BMKG、BAPPENAS	BMKG • Ms. Anni Arumsari Fitriany (Head of Cooperation Department) • Mr. Ardhasena Sopaheluwakan (Head of Research and Development of Climatology) BAPPENAS • Mr. Ewin S Winata (Head of Water Resources and Organization Section) • Mr. Aditya Taufani (Staff) • Mr. Zahra Bilqis (Staff)	2020/10/19
BIG	• Mr. Ibnu Sofyan (Head of Bureau Planning, Human Resources and Legal)	2020/10/27

Note: Data/information were provided after the hearings too.

Table 8-3 Information on Climate Change Adaptation for Flood Control in Indonesia (as of the end of 2020)

Item	Contents
Basic Plan	✓ RAN-API is being updated (The existing one is the 5-year plan from 2015 to 2019). (*In the interview with BMKG it was told that the new version was supposed to be released at the end of 2020, but it was finally published as KPBI (Climate Resilience Development Policy) on April 1, 2021.)
Water Resource Management Strategy Plan (POLA) for the Ciliwung-Cisadane River Basin, 2015	✓ The POLA estimated increases of annual and daily rainfall, and flood discharge at 2030. It says that the change rate of annual rainfall would be +/-3%, the daily rainfall would increase by +0.3mm/day in the rainy season and by -0.3mm/day in the dry season, and the flood discharge would increase +3%.
Projection Method	✓ BMKG: Future climate data (temperature, rainfall, etc.) have been projected based on the results of Global Climate Models (GCMs) with dynamic downscaling by Regional Climate Models (RCMs). ✓ BIG: Future sea level rise has been projected based on a trend analysis of highly precise sea level observation data. BIG is now progressing with a research on projection of future sea level rise by using coupled atmospheric-ocean GCMs.
Applied Climate Scenario	✓ RCP4.5 and RCP 8.5
Selected GCM	✓ BMKG: All of the projection data owned by BMKG are from atmospheric GCMs. Among them, the projection datasets produced by the SEACLID/CORDEX-SEA Project* are the most important ones. They include GCMs of CNRM, CSIRO, MPI, HadGEM, IPSL, EC-EARTH, and GFDL. ✓ BIG: BIG conducts future climate projection by Coupled Atmosphere and Ocean GCMs, which are currently in the research phase. The applied GCMs are unknown.
Downscaling	✓ BMKG: Spatial resolution is 0.25 degrees (about 25 km) for the entire Southeast Asia, and 5 km for Java Island (now ongoing). Temporal resolution is 3 and 6 hours for a GCM(CSIRO), and a day for the other GCMs. ✓ BIG: Spatial resolution is 5km for Java Island, and 25 km for the ocean models. Temporal resolution is still unknown.
Reflection to Flood Control Planning	✓ PUSAIR will evaluate the change rates of heavy rainfall and sea level rise that are applied to flood control planning.

*SEACLID/CORDEX-SEA Project

The SEACLID/CORDEX-SEA project is a collaborative project that aims to develop Regional Climate Models (RCMs, models for downscaling of GCM results) targeting Southeast Asia. ASEAN countries, Japan, Australia, UK, Germany, etc. participate in the project as presented in Table 8-4. BMKG is the focal agency for Indonesia.

Since 2013, the project has been implementing downscaling by the RCMs based on GCM projection data that belong to CMIP5 (Coupled Model Intercomparison Project Phase 5), and climate change impact assessment based on the downscaled results.

Table 8-4 Institutions that Are Participated in SEACLID/CORDEX-SEA Project

Country	Institutions
Malaysia	Universiti Kebangsaan Malaysia (UKM) National Hydraulic Research Institute of Malaysia (NAHRIM) Malaysian Meteorological Department (MMD)
Indonesia	Indonesian Agency for Meteorology, Climatology & Geophysics (BMKG)
Vietnam	Vietnam National University, Hanoi University of Science (VNU HUS) University of Science and Technology of Hanoi (USTH)
Thailand	Ramkhamhaeng University (RU) Chulalongkorn University (CU)
The Philippines	Ateneo de Manila University (ADMU) Manila Observatory (MO)
Cambodia	Pannasastra University of Cambodia (PUC) Kyoto University
Lao PDR	Department of Meteorology and Hydrology (DMH)
Australia	Commonwealth Scientific and Industrial Research Organisation (CSIRO)
United Kingdom	Hadley Centre, UKMO
South Korea	Apec Climate Center (APCC)
Hong Kong SAR	The Chinese University of Hong Kong (CUHK)
Sweden	Swedish Meteorological Hydrological Institute (SMHI)
Germany	Climate Service Center Germany (GERICS)
Japan	Meteorological Research Institute (MRI)

Source: SEACLIE/CORDEX-SEA Project website (http://www.ukm.edu.my/seaclid-cordex/)

(3) National Plan related to Climate Change Adaptation

When the interview with BMKG was held in October 2020, RAN-API that was published in 2013 was being updated, and was supposed to be renamed RAN-KI (National Action Plan on Climate Resilience) and published at the end of 2020. However, the publication was postponed, and it was finally published as KPBI (Climate Resilience Development Policy) on April 1, 2021.

Table 8-5 National Plans Related to Climate Change Adaptation

Bahasa	English	Publication Year
Rancana Aksi National – Perubahan Iklim (RAN-API)	National Action Plan on Climate Change Adaptation	2013
Rencana Aksi Nasional – Ketahanan Iklim (RAN-KI)	National Action Plan on Climate Resilience	- (Renamed as KPBI)
Kebijakan Pembangunan Berketahanan Iklim (KPBI)	Climate Resilience Development Policy	April 1, 2021

(4) Review of KPBI

As a result of reviewing KPBI, there are four priority sectors in climate change adaptation, namely marine and coast, water resources, agriculture and health. Impact assessment results and adaptation policies on the four sectors, of national level, are described in KPBI. However, there is no description about those especially for flood control of local level.

It is noted that KPBI was planned based on future atmospheric projection data by ensemble models under the RCP4.5 scenario as presented in Table 8-6.

Table 8-6 Climate Projection Method and Potential Hazard for our Priority Sectors

Komponen	Sektor Kelautan dan Pesisir		Sektor Air	Sektor Pertanian	Sektor Kesehatan
	Kelautan	Pesisir			
Proyeksi Iklim	• **Proyeksi Iklim Atmosferik** Data historis temperatur dan curah hujan yang diproyeksikan dengan menggunakan *ensemble model* berdasarkan Skenario RCP4.5. • **Proyeksi Iklim Laut** Data historis tinggi permukaan laut dan suhu permukaan laut yang diproyeksikan dengan menggunakan beberapa model berdasarkan Skenario RCP4.5.				
Potensi Bahaya	**Tinggi gelombang:** • Potensi tinggi gelombang laut (peningkatan >1m) yang dapat mengganggu keselamatan pelayaran untuk kapal <10 GT. • Wilayah kewenangan kabupaten/kota sejauh 4 mil dari garis pantai sesuai dengan RZWP3K.	**Kerentanan Pesisir:** Tingkat kerentanan pesisir (CVI) kelas 4 (tinggi) dan 5 (sangat tinggi)	**Kekeringan & Penurunan Ketersediaan Air:** Potensi kekeringan dan ketersediaan air pada kelas tinggi dan sangat tinggi	**Penurunan Produksi Padi:** • Potensi penurunan produksi sebesar >5%. • Wilayah dengan luas lahan sawah >1.500 ha.	**Parameter Iklim:** • Proyeksi kenaikan suhu > 0,7°C (2020-2045). • Proyeksi kenaikan intensitas curah hujan > 100 mm/bulan (2020-2045). **Kejadian Luar Biasa Penyakit:** • Potensi rasio kejadian DBD pada kelas tinggi dan sangat tinggi. • *Insidence rate* DBD > 49/100.000 penduduk. • Tingkat endemisitas malaria sedang (*Annual Paracite Incidence*/API 1-5) dan tinggi (API > 5). • Tingkat kejadian penyakit pneumonia > 100 dalam kurun waktu 2017-2019.

*The red line was drawn by JICA Project Team
Source: KPBI 2020-2045

(5) Climate Change Impact Assessment by BMKG

Some examples of existing studies on climate change impact assessment by BMKG were presented by the head of BMKG at the release event of KPBI on April 1, 2021. Regarding the examples, their climate change impact assessment maps for the entire country and Java Island are available at the website of BMKG (https://www.bmkg.go.id/iklim/?p=proyeksi-perubahan-iklim). Following two maps that seem to be the most related to this study among them were downloaded from the website.

A) Peta (Atlas) Proyeksi Iklim Indonesia(Indonesia Climate Projection Map (Atlas))

B) Peta (Atlas) Proyeksi Iklim Resolusi Tinggi Wilayah Java(Java Region High Resolution Climate Projection Map (Atlas))

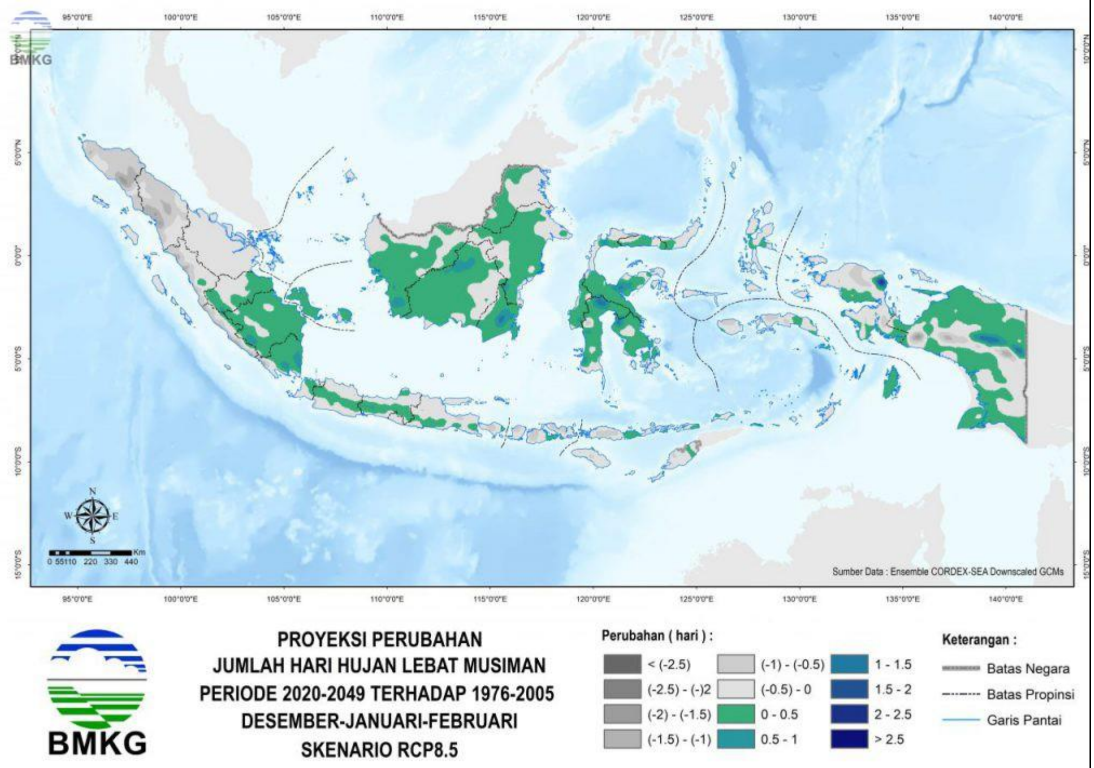
Table 8-7 Climate Change Impact Assessment Maps by BMKG

Item	Map A	Map B
Area	Entire country	Java Island
Climate Model	Ensemble average of six GCM/RCM projection data that have been dynamical downscaled by SEACLID/CORDEX-SEA Project	GCM: MIROC5 RCM: Downscaled by BMKG Climate Change Information Center (the used RCM is unknown)
Future Climate Scenario	RCP4.5 and RCP8.5	RCP4.5
Spatial Resolution	25 km x 25 km	4 km x 4 km
Data Period	Historical: 1976-2005 Near future: 2020-2049	Current: 2006-2014 Near future: 2032-2040
Maps (Map titles have been translated to English by Google Translator)	1. Seasonal Cumulative Precipitation Change Projection Map 2. Map of Projected Number of Seasonal Heavy Rainy Days 3. Seasonal Dry Day Number Projection Map 4. Seasonal Rainy Days Projection Map 5. Projected Map of Changes in Number of Longest Seasonal Successive Dry Days 6. Projected Map of Changes in Number of Seasonal Longest Consecutive Rainy Days 7. Projected Annual Average Temperature Change Map 8. Projected Annual Maximum Temperature Change Map 9. Projected Annual Minimum Temperature Change Map 10. Annual Diurnal Temperature Variation Projection Map 11. Map of Projected Changes in the Number of Seasonal Heavy Rainy Days 12. Projected Map of Changes in the Number of Seasonal Extreme Rainy Days 13. Seasonal Maximum Daily Rainfall Projection Map 14. Seasonal Maximum 5-Day Cumulative Rainfall Projection Map 15. Projected Map of Daily Seasonal Rain Intensity Change 16. Projected Map of Changes in Early Rainy Season 17. Projected Map of Changes in the Length of the Rainy Season	1. Changes in seasonal rainfall values 2. Changes in the value of the frequency of seasonal heavy rain 3. Changes in the number of days without seasonal rain 4. Changes in index number of seasonal consecutive dry days 5. Changes in the number of seasonal consecutive wet days index 6. Changes in the value of the seasonal heavy rain fraction Changes in the seasonal heavy rain fraction 7. Changes in temperature-related parameter values (mean, maximum and minimum, diurnal variation)

*Maps in red are more related to flood.

Since the eight maps in red in Table 8-7 that are more related to flood are quoted below for reference. It is noted that the map titles and legends have been translated into English by Google Translator.

(MAP A) 2. Map of Projected Number of Seasonal Heavy Rainy Days



(Google Translation)

Title: Projected changes in the number of days of seasonal heavy rain for the period 2020-2049 against 1976-2005 December-January-February scenario RCP8.5

Legend 1: Change (day)

Legend 2: Description/ National Borders, Provincial Boundaries, Coastline

(Explanation)

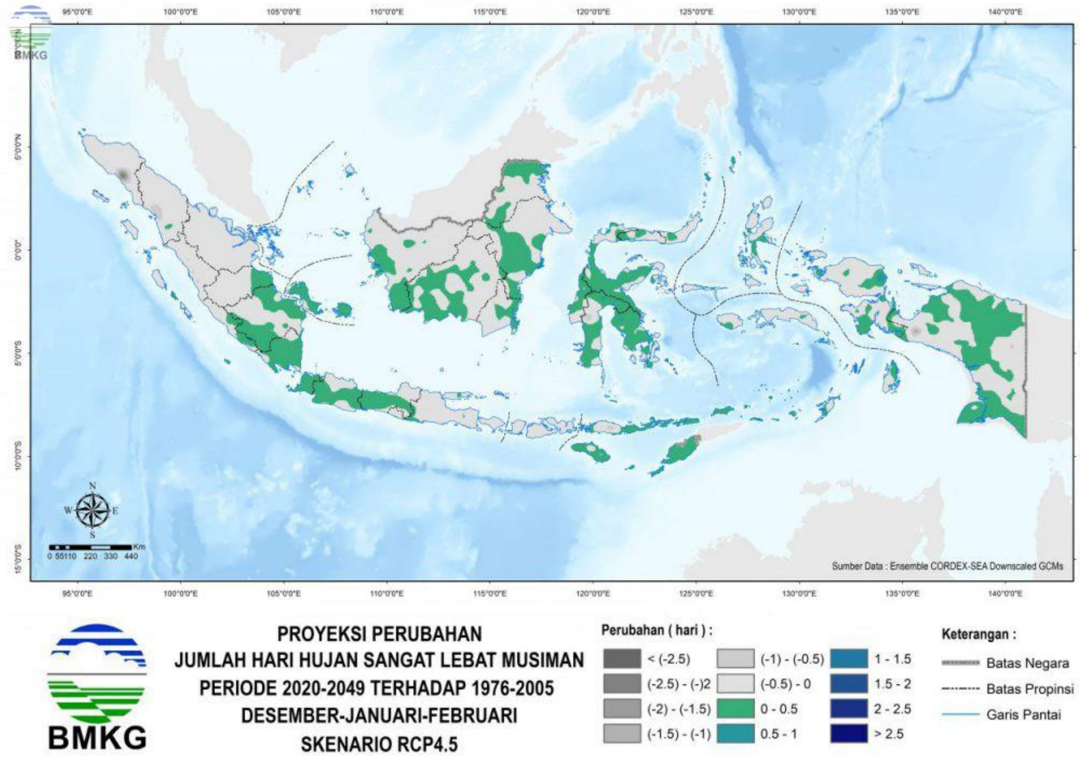
The number of days of heavy rainfall (The definition of "heavy rainfall" is unknown) in the rainy season (December to February) has been projected to increase in the green to dark blue areas (past period: 1976 to 2005, future period: 2020 to 2049, based on the ensemble climate projection data downscaled by the CORDEX-SEA project under the RCP4.5 scenario).

The number of heavy rainfall days in the rainy season tends to increase along the mountain ranges in the study area.

Source: BMKG HP (https://www.bmkg.go.id/iklim/?p=proyeksi-perubahan-iklim)

Figure 8-3 Climate Change Impact Assessment Maps Released by BMKG Climate Change Information Center (1/8)

(MAP A) 11. Map of Projected Changes in the Number of Seasonal Heavy Rainy Days



(Google Translation)

Title: Projected changes in the number of heavy seasonal rainy days for the period 2020-2049 against 1976-2005 December-January-February scenario RCP4.5

Legend 1: Change (day)

Legend 2: Description/ National Borders, Provincial Boundaries, Coastline

(Explanation)

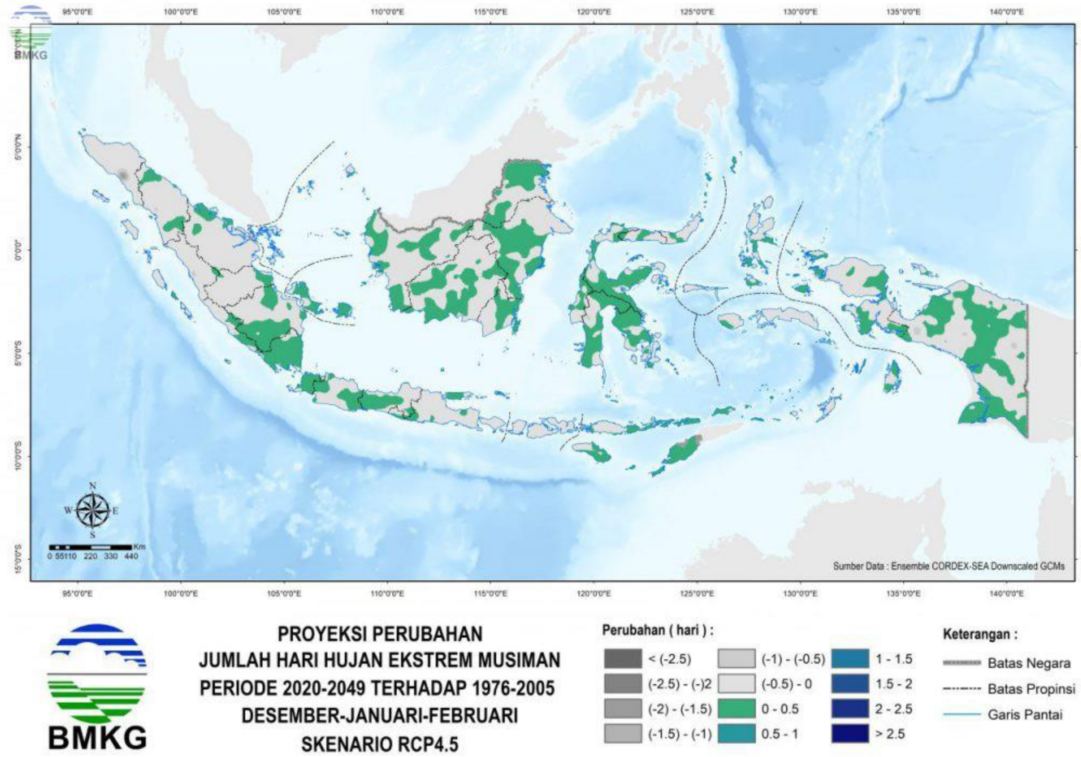
The number of days of heavy rainfall (The definition of "heavy rainfall" is unknown, but this heavy rainfall of No.2 seems heavier than that of No. 11 because the No.2 map is for heavy rainfall (hujan lebat) and the No.11 map is for very heavy rainfall (hujan sangat lebat)) in the rainy season (December to February) has been projected to increase in the green to dark blue areas (past period: 1976 to 2005, future period: 2020 to 2049, based on the ensemble climate projection data downscaled by the CORDEX-SEA project under the RCP4.5 scenario).

The number of heavy rainfall days in the rainy season tends to increase in the areas centering on the mountain areas and including the urban areas of Jakarta in the study area.

Source: BMKG HP (https://www.bmkg.go.id/iklim/?p=proyeksi-perubahan-iklim)

Figure 8-3 Climate Change Impact Assessment Maps Released by BMKG Climate Change Information Center (2/8)

(MAP A) 12. Projected Map of Changes in the Number of Seasonal Extreme Rainy Days



(Google Translation)

Title: Projected changes in the number of seasonal extreme rainy days for the period 2020-2049 against 1976-2005 December-January-February scenario RCP4.5

Legend 1: Change (day)

Legend 2: Description/ National Borders, Provincial Boundaries, Coastline

(Explanation)

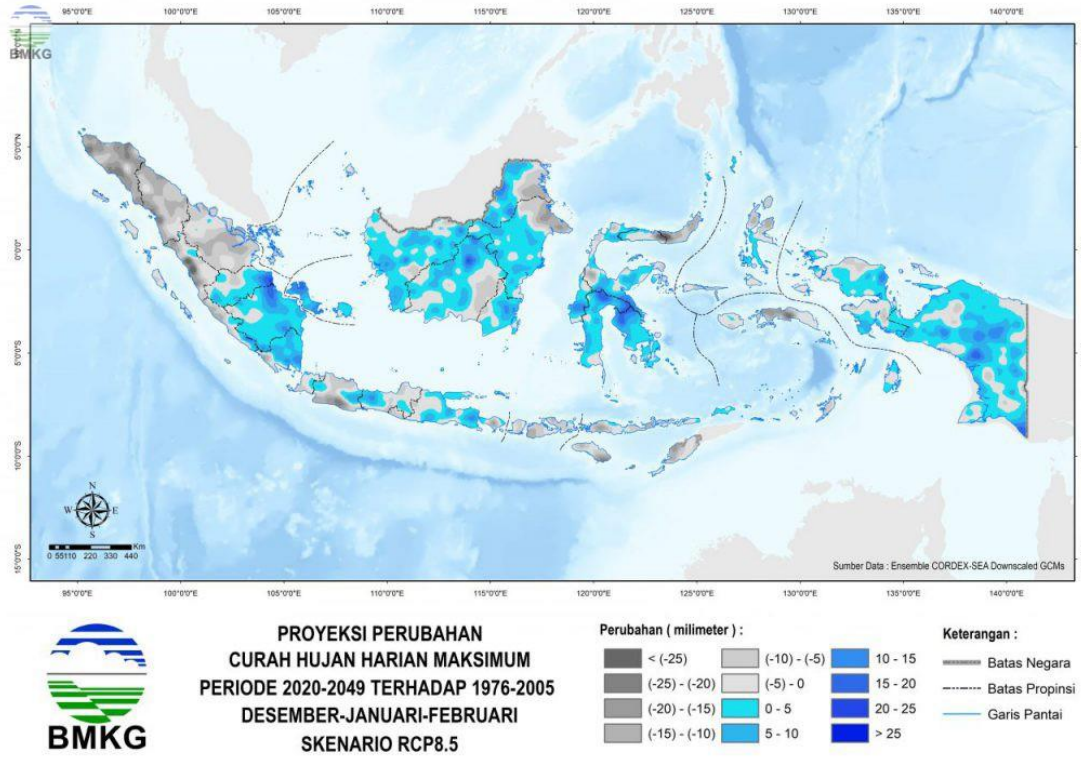
The number of days of abnormally heavy rainfall (The definition of "abnormally heavy rainfall" is unknown) in the rainy season (December to February) has been projected to increase in the green to dark blue areas (past period: 1976 to 2005, future period: 2020 to 2049, based on the ensemble climate projection data downscaled by the CORDEX-SEA project under the RCP4.5 scenario).

The number of abnormally heavy rainfall days in the rainy season tends to increase in southern Jakarta (Depok, Bogor, etc.) that is the upper river basins of rivers flowing in the urban areas of Jakarta in the study area.

Source: BMKG HP (https://www.bmkg.go.id/iklim/?p=proyeksi-perubahan-iklim)

Figure 8-3 Climate Change Impact Assessment Maps Released by BMKG Climate Change Information Center (3/8)

<u>(MAP A) 13. Seasonal Maximum Daily Rainfall Projection Map</u>



(Google Translation)

Title: Projected changes in maximum daily rainfall for the period 2020-2049 against 1976-2005 December-January-February scenario RCP8.5

Legend 1: Change (millimeter)

Legend 2: Description/ National Borders, Provincial Boundaries, Coastline

(Explanation)

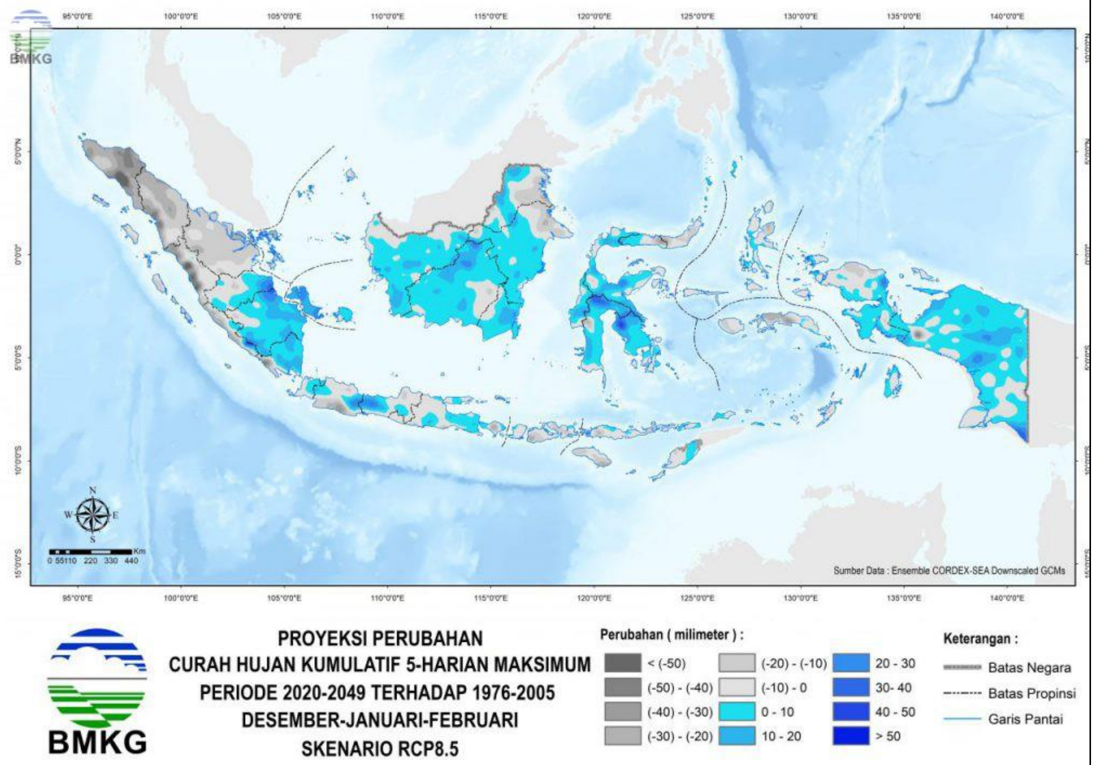
The maximum daily in the rainy season (December to February) has been projected to increase in the light blue to blue areas (past period: 1976 to 2005, future period: 2020 to 2049, based on the ensemble climate projection data downscaled by the CORDEX-SEA project under the RCP8.5 scenario).

The maximum daily rainfall in the rainy season tends to increase in southern Jakarta (Depok, Bogor, etc.) that is the upper river basins of rivers flowing in the urban areas of Jakarta in the study area.

Source: BMKG HP (https://www.bmkg.go.id/iklim/?p=proyeksi-perubahan-iklim)

Figure 8-3 Climate Change Impact Assessment Maps Released by BMKG Climate Change Information Center (4/8)

(MAP A) 14. Seasonal Maximum 5-Day Cumulative Rainfall Projection Map



(Google Translation)

Title: Projected 5-day maximum cumulative rainfall change for the period 2020-2049 against 1976-2005 December-January-February scenario RCP8.5

Legend 1: Change (millimeter)

Legend 2: Description/ National Borders, Provincial Boundaries, Coastline

(Explanation)

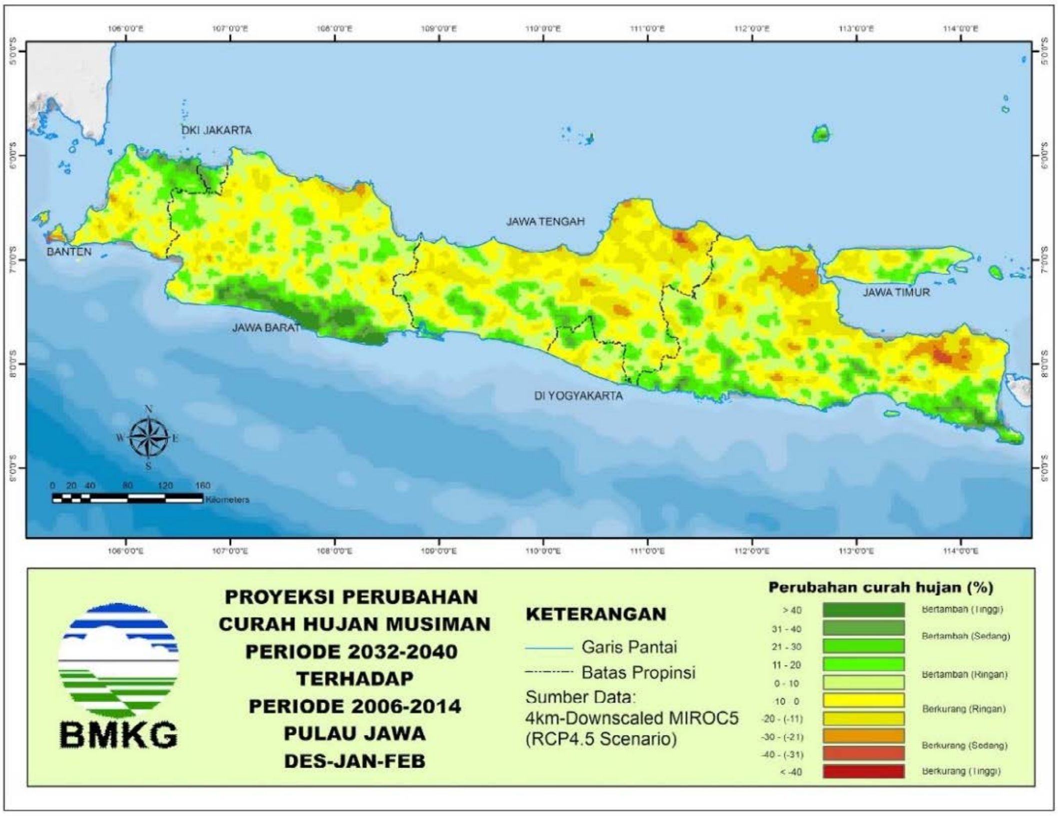
The maximum 5-day rainfall in the rainy season (December to February) has been projected to increase in the light blue to blue areas (past period: 1976 to 2005, future period: 2020 to 2049, based on the ensemble climate projection data downscaled by the CORDEX-SEA project under the RCP8.5 scenario).

The maximum 5-day rainfall in the rainy season tends to increase in the urban areas of Jakarta and around its southern and western areas in the study area.

Source: BMKG HP (https://www.bmkg.go.id/iklim/?p=proyeksi-perubahan-iklim)

Figure 8-3 Climate Change Impact Assessment Maps Released by BMKG Climate Change Information Center (5/8)

<u>(MAP B) 1. Changes in seasonal rainfall values</u>



(GoogleTranslation)

Title: Projected changes in seasonal rainfall for the period 2032-2040 against 2006-2014 Java Island December-January-February

Legend 1: Description/ Coastline, Provincial Boundaries, Source Data

Legend 2: change in rainfall (%)

(Explanation)

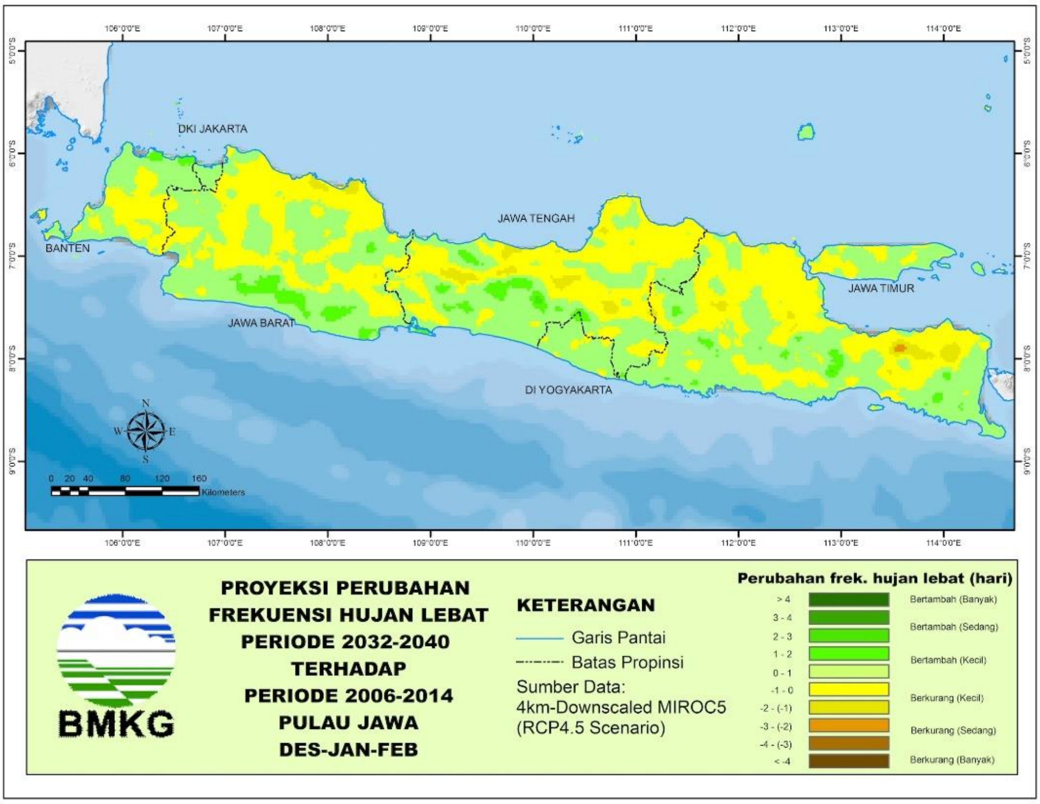
The total rainfall in the rainy season (December to February) has been projected to increase in the pea green to green areas (past period: 2006 to 2014, future period: 2032 to 2040, based on the climate projection data downscaled with a resolution of 4km by using a global climate model, MIROC5 by the BMKG Climate Change Information Center under the RCP4.5 scenario).

Regarding the study area, the total rainfall in the rainy season tends to increase in the urban areas of Jakarta, but it tends to decrease in some areas of the southern mountain areas that are the upper river basins of the rivers flowing in the urban areas.

Source: BMKG HP (https://www.bmkg.go.id/iklim/?p=proyeksi-perubahan-iklim)

Figure 8-3 Climate Change Impact Assessment Maps Released by BMKG Climate Change Information Center (6/8)

<u>(MAP B) 2. Changes in the value of the frequency of seasonal heavy rain</u>



(Google Translation)

Title: Projected changes in the frequency of heavy rain for the period 2032-2040 against 2006-2014 Java Island December-January-February

Legend 1: Description/ Coastline, Provincial Boundaries, Source Data

Legend 2: change in the frequency of heavy rain (day)

(Explanation)

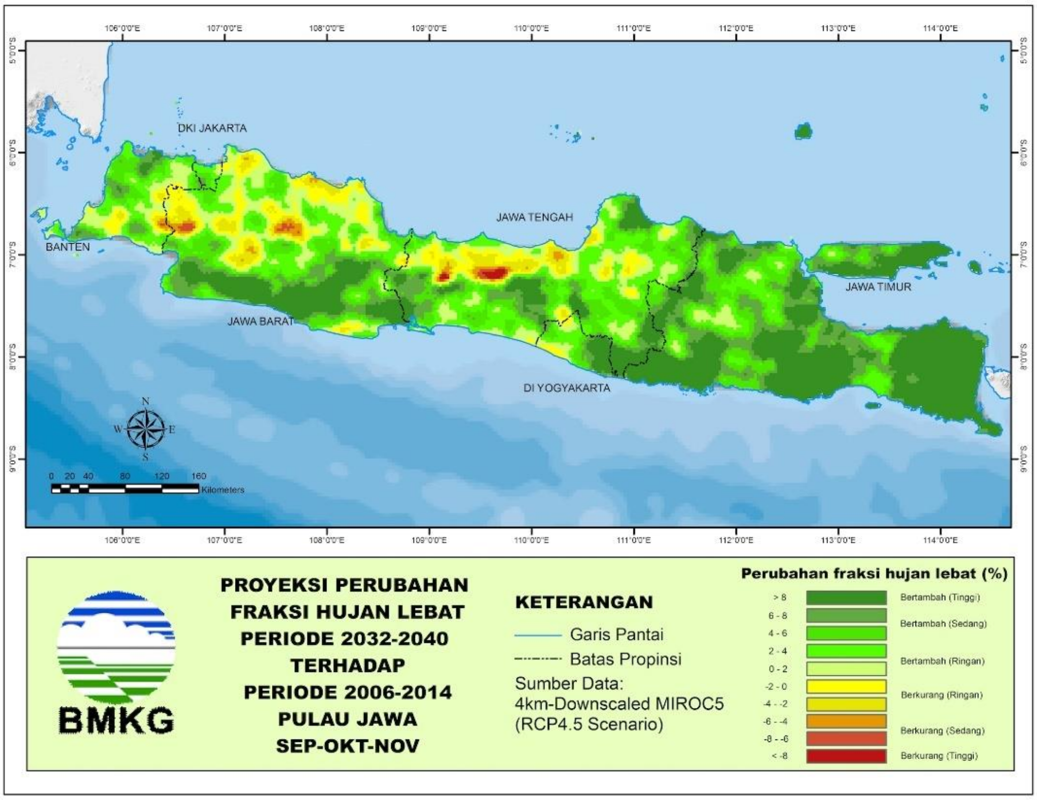
The frequency of heavy rainfall (The definition of "heavy rainfall" is unknown) in the rainy season (December to February) has been projected to increase in the pea green to green areas (past period: 2006 to 2014, future period: 2032 to 2040, based on the climate projection data downscaled with a spatial resolution of 4km by using a global climate model, MIROC5 by the BMKG Climate Change Information Center under the RCP4.5 scenario).

Regarding the study area, the frequency of heavy rainfall in the rainy season tends to increase in the urban areas of Jakarta and its southern areas, but it tends to decrease in the considerably large area of the Bekasi River Basin.

Source: BMKG HP (https://www.bmkg.go.id/iklim/?p=proyeksi-perubahan-iklim)

Figure 8-3 Climate Change Impact Assessment Maps Released by BMKG Climate Change Information Center (7/8)

(MAP B) 6. Changes in the value of the seasonal heavy rain fraction Changes in the seasonal heavy rain fraction



(Google Translation)

Title: projection of changes in the heavy rain fraction for the period 2032-2040 to 2006-2014 on the island of Java September-October-November

Legend 1: Description/ Coastline, Provincial Boundaries, Source Data

Legend 2: change in heavy rain fraction (%)

(Explanation)

The fraction of heavy rainfall (The definition of "heavy rainfall" is unknown) between September and November has been projected to increase in the green to dark blue areas (past period: 2006 to 2014, future period: 2032 to 2040, based on the climate projection data downscaled with a resolution of 4km by using a global climate model, MIROC5 by the BMKG Climate Change Information Center under the RCP4.5 scenario).

The fraction of heavy rainfall tends to increase in the urban areas of Jakarta and its southern areas.

Source: BMKG HP (https://www.bmkg.go.id/iklim/?p=proyeksi-perubahan-iklim)

Figure 8-3 Climate Change Impact Assessment Maps Released by BMKG Climate Change Information Center (8/8)

8.2.2 Climate Change Impact Assessment Based on Future Climate Projection Data

This subsection describes the assessment of climate change impact on flood, especially focusing on changes of heavy rainfall and sea level, based on future climate projection data provided by BMKG and Bappenas. The provided datasets which are summarized in the following table were originally developed by the SEACLID/CORDEX-SEA Project. It is noted that the ensemble average dataset of multiple climate models (referred to as "ensemble model" hereinafter) provided by Bappenas was used in KPBI. It was told that some of the eight datasets provided by BMKG might be members of the ensemble model, but the detail information of the ensemble model could not be obtained.

Table 8-8 Climate Projection Datasets Provided by Counterpart Organizations

No.	Outline of Dataset	Provider	Date of Reception
1	Ensemble average dataset of multiple climate models	Bappenas	December 2020
2	Eight kinds of climate projection datasets (Refer to Table 8-9 for details)	BMKG	November 2020

* No.1 dataset was provided by Bappenas, but it had been originally prepared by BMKG.

Table 8-9 Details of Climate Projection Datasets provided by BMKG

Ensemble member	GCM	RCM	Projection Periods of 21st Century		
			Early (2011–2040)	Mid (2041–2070)	End (2071–2099)
1	CNRM-CM5 (CNRM, France)	RegCM4 (ICTP, Italy)	x	x	x
2	HadGEM2-ES (Hadley Centre, UK)	RegCM4 (ICTP, Italy)	x	x	x
3	MPI-ESM-MR (MPI-M, Germany)	RegCM4 (ICTP, Italy)	x	x	x
4	EC-Earth (EC-Earth consortium)	RegCM4 (ICTP, Italy)	x	x	x
5	CSIRO MK3.6 (CSIRO, Australia)	RegCM4 (ICTP, Italy)	x	x	x
6	CNRM-CM5 (CNRM, France)	RCA4 (SMHI, Sweden)	x	x	x
7	MPI-ESM-LR(MPI, Germany)	ROM(GERICS-AWI, Germany)[b]	x	x	x
8	HadGEM2-ES (Hadley Centre, UK)	RCA4 (SMHI, Sweden)	x	x	x
9	ACCESS1.0 (CSIRO, Australia)	CCAM (CSIRO, Australia)[a]		x	
10	MRI-AGCM (MRI, Japan)	NHRCM (MRI, Japan)[c]			x
11	HadGEM2-AO (Hadley Centre, UK)	WRF (NCAR USA)	x	x	x
12	HadGEM2-ES (Hadley Centre, UK)	PRECIS (Hadley Centre, UK)[a]	x	x	x
13	CCSM4 (NCAR, USA)	CCAM (CSIRO, Australia)[a]		x	
14	CNRM-CM5 (CNRM, France)	CCAM (CSIRO, Australia)[a]		x	

[a]Only RCP8.5
[b]50 km × 50 km resolution with larger domain size to cover warm pool of western Pacific Ocean
[c]Baseline period (1981–2000), end of 21st period (2080–2099)

* Eight datasets enclosed by the red line are those provided by BMKG.

Source: Tangang F, et al. (2020)[3]

[3] Tangang F, et al (2020) Projected future changes in rainfall in Southeast Asia based on CORDEX-SEA multi-model simulations, Climate Dynamics (2020) 55:1247-1267. https://doi.org/10.1007/s00382-020-05322-2

(1) Climate Change Impact Assessment Based on Ensemble Model Data

(i) Provided Data

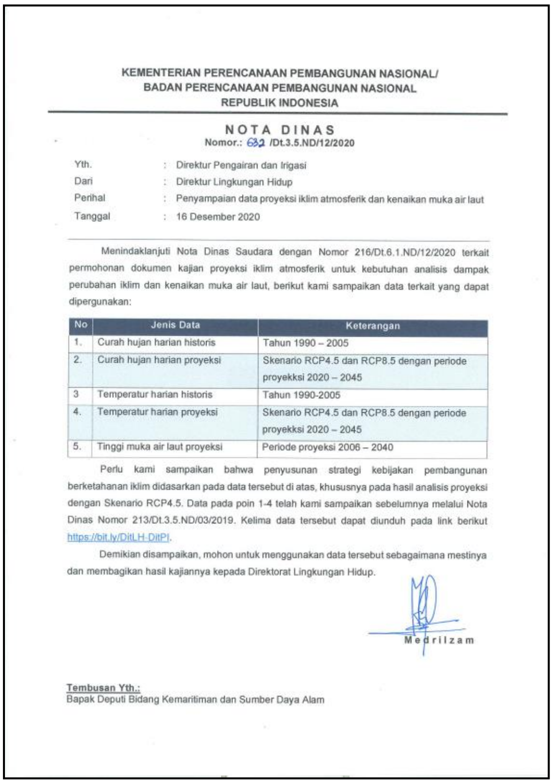
Five types of climate projection data shown in Table 8-10 were received from Bappenas in December 2020. These data were the same as those presented in the official document of Figure 8-4, and were used as back data for KPBI too. Since the official document says that KPBI would be prepared especially based on the climate projection under the RCP4.5 scenario, the climate change impact assessment in this subsection is also made based on climate projection data under the RCP4.5 scenario.

Coverage areas of rainfall projection data (No. 1 and 2) and sea level rise projection data (No. 5) are presented in Figure 8-5.

Table 8-10 Climate Change Projection Data provided by Bappenas

No.	Data Type	Notes
1	Historical daily rainfall	Time period: 1990-2005
2	Projected daily rainfall	Time period: 2020-2045, Scenario: RCP4.5 and RCP8.5
3	Historical daily temperature	Time period: 1990-2005
4	Projected daily temperature	Time period: 2020-2045, Scenario: RCP4.5 and RCP8.5
5	Trend of sea level rise	Target Period 2006-2040

* Temperaturfe data (No. 3 and 4) have not been used for this study.



KEMENTERIAN PERENCANAAN PEMBANGUNAN NASIONAL/
BADAN PERENCANAAN PEMBANGUNAN NASIONAL
REPUBLIK INDONESIA

NOTA DINAS
Nomor.: 632 /Dt.3.5.ND/12/2020

Yth. : Direktur Pengairan dan Irigasi
Dari : Direktur Lingkungan Hidup
Perihal : Penyampaian data proyeksi iklim atmosferik dan kenaikan muka air laut
Tanggal : 16 Desember 2020

Menindaklanjuti Nota Dinas Saudara dengan Nomor 216/Dt.6.1.ND/12/2020 terkait permohonan dokumen kajian proyeksi iklim atmosferik untuk kebutuhan analisis dampak perubahan iklim dan kenaikan muka air laut, berikut kami sampaikan data terkait yang dapat dipergunakan:

No	Jenis Data	Keterangan
1.	Curah hujan harian historis	Tahun 1990 – 2005
2.	Curah hujan harian proyeksi	Skenario RCP4.5 dan RCP8.5 dengan periode proyekksi 2020 – 2045
3	Temperatur harian historis	Tahun 1990-2005
4.	Temperatur harian proyeksi	Skenario RCP4.5 dan RCP8.5 dengan periode proyekksi 2020 – 2045
5.	Tinggi muka air laut proyeksi	Periode proyeksi 2006 – 2040

Perlu kami sampaikan bahwa penyusunan strategi kebijakan pembangunan berketahanan iklim didasarkan pada data tersebut di atas, khususnya pada hasil analisis proyeksi dengan Skenario RCP4.5. Data pada poin 1-4 telah kami sampaikan sebelumnya melalui Nota Dinas Nomor 213/Dt.3.5.ND/03/2019. Kelima data tersebut dapat diunduh pada link berikut https://bit.ly/DitLH-DitPI.

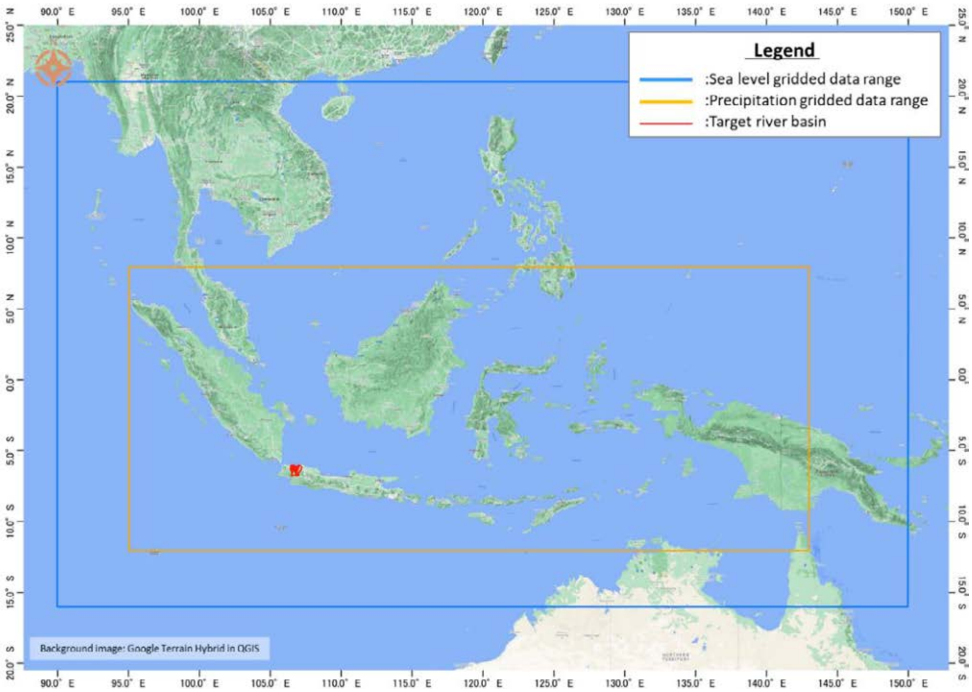
Demikian disampaikan, mohon untuk menggunakan data tersebut sebagaimana mestinya dan membagikan hasil kajiannya kepada Direktorat Lingkungan Hidup.

Medrilzam

Tembusan Yth.:
Bapak Deputi Bidang Kemaritiman dan Sumber Daya Alam

Source: Bappenas

Figure 8-4 Official Document on Provision of Climate and Sea level Rise Projection Data (Addressed from Environment Director to Water Resources and Irrigation Director)



Source: JICA Study Team

Figure 8-5 Coverage Areas of Sea level Rise and Rainfall Projection Data

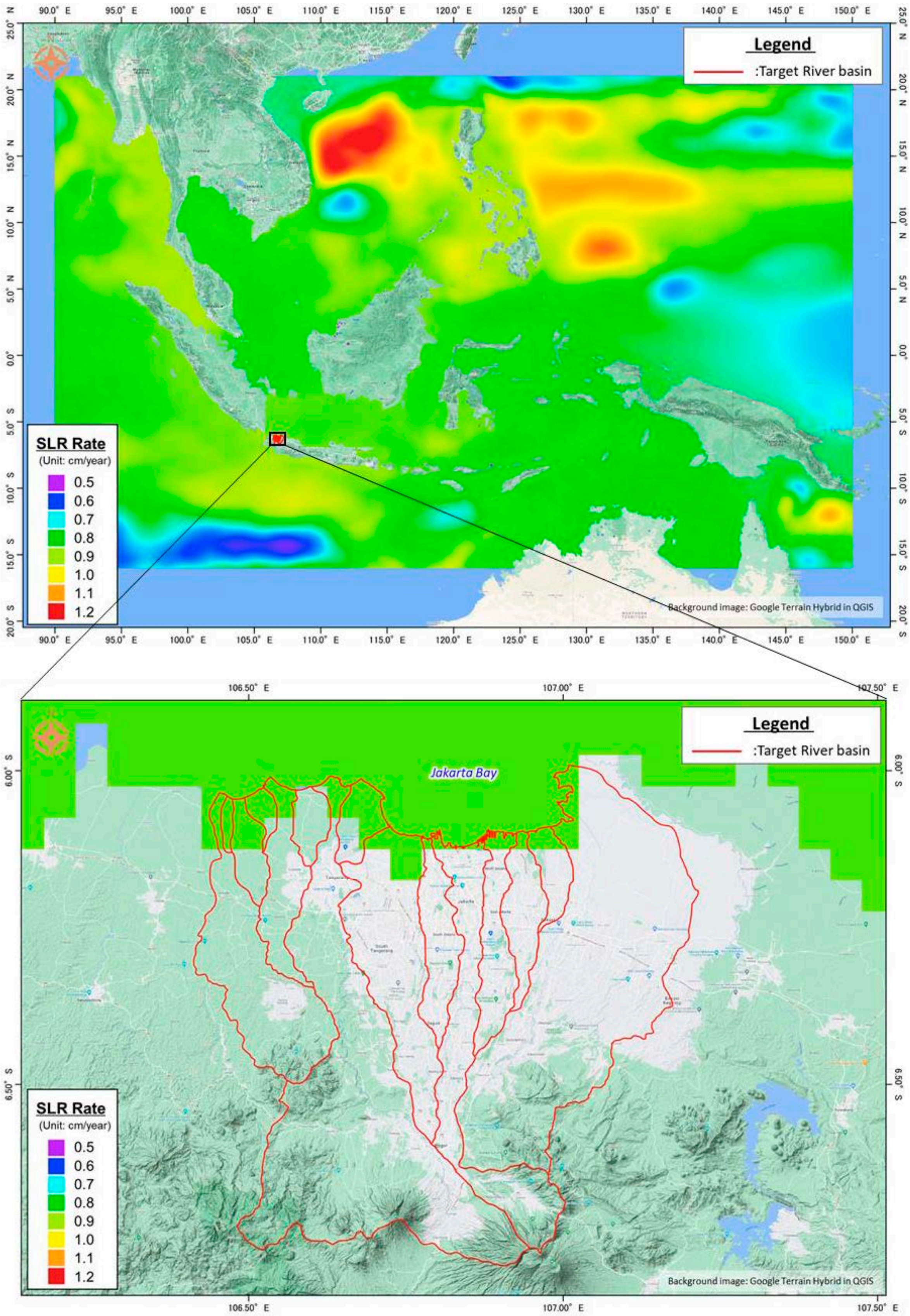
(ii) Estimation of Sea level Rise

The sea level rise projection data provided by Bappenas (No. 5 of Table 8-10)is shown in Figure 8-6. The data contains sea level rise rate per year (unit: cm/year), and the grid square size is about 5.5km x 5.5km. Comparing Figure 8-6 to Figure 8-7 included in a scientific report on sea level rise (KAJIAN BASIS ILMIAH PROYEKSI IKLIM LAUT 2018) prepared by Bappenas and USAID, the data sources of the two figures would be the same. Conditions for the estimation of the sea level rise rate of the report are presented in Table 8-11.

Table 8-11 Conditions for Estimation of Sea Level Rise Rate

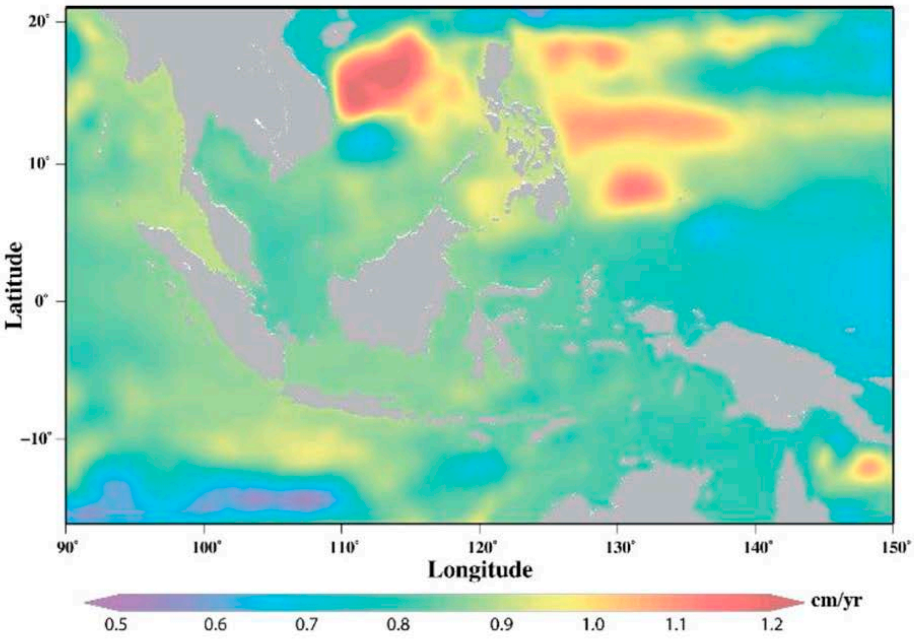
Item	Contents
Climate Scenario	SRES A1B (AR4) and RCP4.5 (AR5)
Ocean Model	Simulation Period：2006 - 2040 Model：The ocean general circulation model, HYCOM (HYbrid Coordinate Ocean Model), downscaled to an horizontal resolution of 5km x 5km by nesting to a regional ocean modeling system (ROMS). Boundary Conditions: Climate projection data by a GCM, MIROC-5

Since Figure 8-7 illustrates the sea level rise rate under the RCP4.5 scenario, the sea level rise projection data provided by Bappenas would also be under the RCP4.5 scenario. According to the provided projection data, the sea level rise around the Jakarta Bay is 0.870cm/year, which is adopted in this study too.



Source: Created by JICA Study Team based on the provided data, No.5 from Bappenas

Figure 8-6 Sea Level Rise Rate under RCP4.5 Scenario(2006-2040)



Source: KAJIAN BASIS ILMIAH PROYEKSI IKLIM LAUT 2018 (Bappenas)
(Google Translation: Study of the scientific basis of marine climate projections)

Figure 8-7 Sea Level Rise Rate under RCP4.5 Scenario(Quoted from the scientific report)

(iii) Estimation of Heavy rainfall Change Rate

A) Provided Data

Rainfall projection data provided by Bappenas is an ensemble average dataset of multiple datasets produced through the dynamical downscaling of projection results of GCMs by using Regional Climate Models (RCMs). It is noted that detail information of the rainfall projection data including the composition of ensemble members could not been obtained.

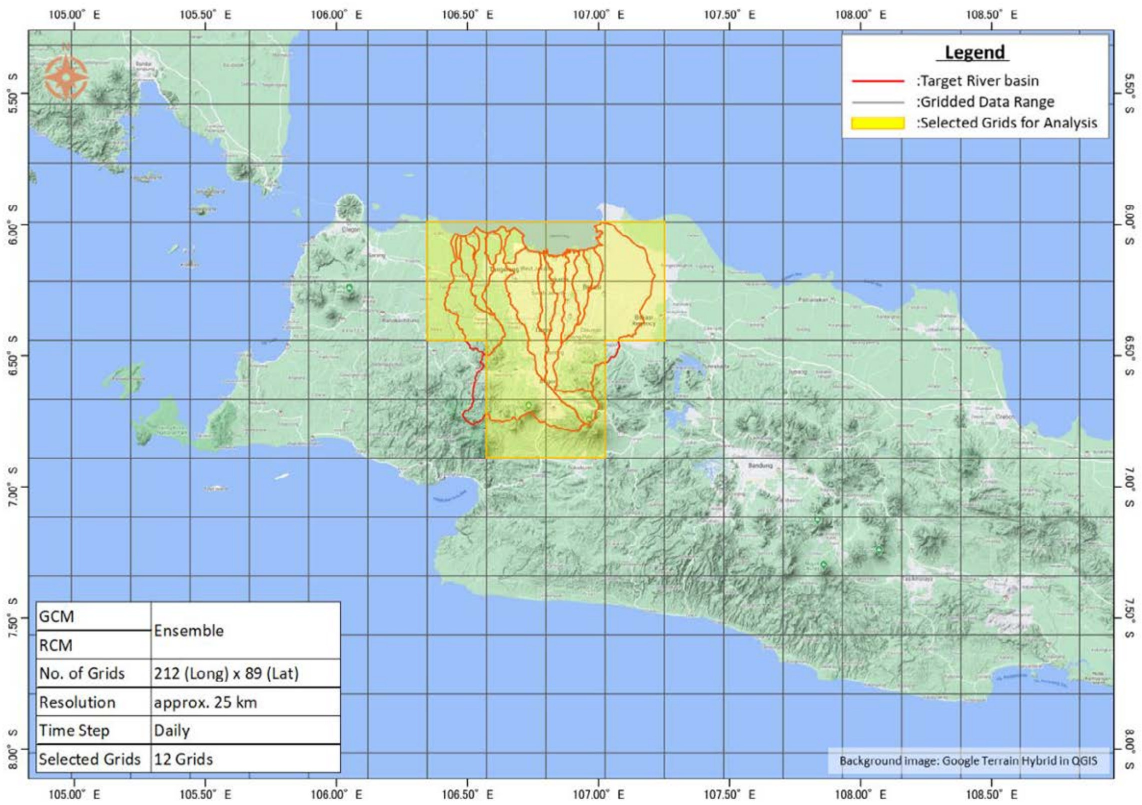
Outline of the rainfall projection data is summarized in Table 8-12. Regarding the spatial resolution, the grid square size is about 25 km x 25 km, and the data area covers 18,868 grid squares, namely 212 squares in the longitude direction and 89 squares in the latitude direction. The temporal resolution is a day, and the data period of historical data is 16 years from 1990 to 2005, and that of future data is 26 years from 2020 to 2045.

Table 8-12 Outline of Rainfall Projection Data

Case	Spatial Resolution		Temporal Resolution		
	Grid Square Size	Grid Square No.	Time Step	Period	Data No.
Historical	approx. 25km x 25 km	212 (Long) times 89 (Lat) = 18,868	a day	1990/1/1 – 2005/12/30	5,839
Future (RCP4.5)				2020/1/1 – 2045/12/31	9,490
Future (RCP8.5)					

*Leap years are excluded, and data of 2005/12/31 is lacking.

12 grid squares in each of which the target 15 river basin area occupies 20% or more of the square area were selected for the following estimation of heavy rainfall change rate, as shown in Figure 8-8. The basin average rainfall of the entire 15 river basin area was estimated simply as an arithmetic average of rainfall of the selected 12 grid squares.



Source: JICA Study Team

Figure 8-8 Selection of Grid Squares for Target River Basins (Ensemble Model)

B) Analysis Method

As a result of an interview on June 28, 2021 with Dr. Leo Eliasta, head of the river and coastal department of PUPR, he answered that specific policy or guideline have not yet been established for the development of flood control plan that incorporates climate change impacts in Indonesia. Therefore, since the target watersheds in this study (see Section 8.1.3) are relatively similar with watersheds in Japan in terms of catchment area scale and flooding timescale, it was decided to refer to the policies and technical reports currently underway in Japan to develop a flood control plan incorporating climate change impacts.

Future design rainfall should be set up for flood control planning in consideration of climate change. The future design rainfall with climate change can be designed by multiplying the design rainfall without climate change by a heavy rainfall change rate. The heavy rainfall change rate is a rate how many times heavy rainfall will increase as an impact of climate change. It is estimated by comparing future and historical (current) rainfalls that have been projected by using the same climate models to avoid influences of biases that are associated with climate models. Since this study is concerned with flood, the duration of the future design rainfall should be the same as the design rainfall duration as described in Table 8-13 which is usually determined in consideration of flood concentration time. However, it was assumed to be a day from the following reasons:

- Since the 15 river basins (refer to Table 8-1)are small and their river gradients are relatively steep, the flood concentration time seems to be less than 24 hours (a day) or about a day at the maximum;
- Since the obtained projection rainfall data are daily data as seen in Table 8-12 rainfall in shorter duration cannot be discussed.

Regarding the return period of the design rainfall, two cases of 50 and 100 years are adopted because a flood control plan with a safety level of 50- or 100-year return period is proposed in this project. This method is the same as the one proposed in “Proposal for "Flood Control Plans Based on Climate Change" (Technical Study Group on Flood Control Plans Based on Climate Change, October 2019, Ministry of Land, Infrastructure, Transport and Tourism (MLIT) Japan) presented in Table 8-14, although analyses of design rainfall duration and rainfall areas have not been conducted in this study.

The data periods of the provided data are 16 years from 1990 to 2005 for the historical case (current climate without climate change) and 26 years from 2020 to 2045 for the future case (future climate with climate change). Therefore, if annual maximum rainfall values are extracted for each of the selected grid squares or for the entire 15 river basin area, the data numbers for the statistical analysis to estimate the probable rainfalls with the target return periods becomes as small as 16 for the current and 26 for the future climate. These samples are not enough to conduct a statistical analysis to estimate probable rainfalls. To solve this problem, it was decided to adopt the Station Year Method that statistically processes multiple grid square data in and around the study area (refer to Table 8-13). Specifically, annual maximum daily rainfalls for each of the 12 selected grid squares shown in Figure 8-8 were extracted for the target data period and they were treated together as a kind of composite sample. By setting the target data period to be 16 years for both the current and future climate cases, namely from 2030 to 2045 even for the future climate, the total number of data for the statistical analysis became 192 (12 grid squares x 16 years).

Summarizing the above, the heavy rainfall change rate was calculated for probable daily rainfalls of 50- and 100-year return periods by comparing those of current and future climates. The probable rainfalls were estimated through the statistical analysis on the data sample consisting of 192 annual maximum daily rainfall data extracted from the 12 selected grid squares. It is also noted that the RCP4.5 scenario is adopted for the future climate scenario as explained in 8.2.2(1)(i)Provided Data.

The annual daily maximum rainfall samples extracted from the 12 grid squares are summarized in Table 8-15, and their histogram is presented in Figure 8-9.

Table 8-13 Quotation on Heavy Rainfall Change Rate (1/2)

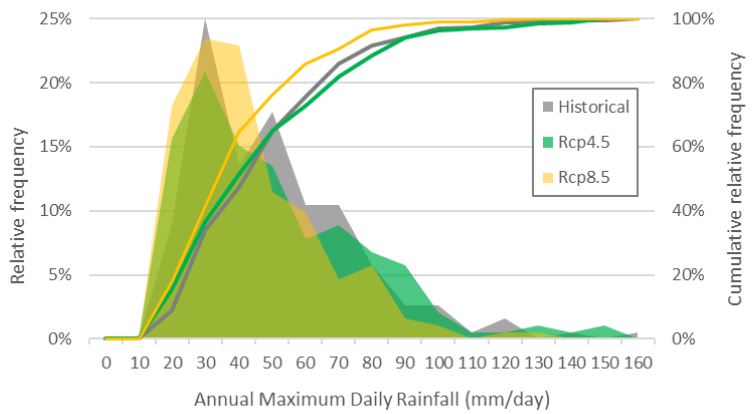
Quoted from the Project Research Report of the National Institute for Land and Infrastructure Management (NILIM), Ministry of Land, Infrastructure, Transport and Tourism (MLIT) Japan "Study on Climate Change Adaptation Measures in Rivers and Coasts" (No. 56, April 2017)
From the rainfall projection data of the climate prediction model, the "rainfall change rate d", which is the future change rate of the annual maximum rainfall of each design rainfall duration to the current, was calculated for each of the 109 river systems under direct administration of MLIT. At this time, the number of projection data of the climate prediction model is insufficient to obtain the statistical characteristics related to the occurrence of the annually maximum rainfall at the target point. For this reason, by dividing the entire Japan into several regions each of which can be judged to have almost equivalent climate characteristics within it, and by using the Station Year Method that statistically processes multiple grid square data in and around the region together as a kind of composite sample, a large number of sample data can be secured. Annual maximum rainfall data for each region are extracted for the current climate and future climate respectively, and the "rainfall change rate d" is estimated.

Table 8-14 Quotation on Heavy Rainfall Change Rate (2/2)

Quoted from "Proposal for Flood Control Planning Considering Climate Change Impacts" (Technical Study Group on Flood Control Plan Based on Climate Change, October 2019, MLIT Japan)
(Calculation conditions and concept of evaluation)
• When considering changes in rainfall, first calculate the rate of rainfall between the current climate and the future climate (rainfall change rate), and then multiply the past rainfall by the change rate to obtain the future rainfall. • At this time, by treating certain areas in which rainfall characteristics are regarded almost uniform as a regional unit, the number of rainfall data corresponding to the target rainfall area could be increased when analyzing the rainfall, and then the analysis reliability could be enhanced. It could be also easier to analyze changes in meteorological factors that cause flood disasters. *snip* • The rainfall change rate is calculated by comparing the current and future rainfalls of 100-year return period that are estimated through the Depth-Area-Duration (DAD) analysis using the current and future climate projection data of d4PDF (5km, SI-CAT) and d4PDF (5km, yamada) for each of rainfall durations and rainfall areas of six Sea Surface Temperature (SST) patterns.

Table 8-15 Annual Maximum Daily Rainfall Samples for Estimation of Heavy Rainfall Change Rate

Case/Sample	Grid Square Size	Selected Grid Square No.	Time Period	Time Step	No. of data
Historical	approx. 25km x 25km	12 squares	1990/1/1 - 2005/12/31 (16 years)	a Day	192
RCP4.5			2030/1/1 - 2045/12/31 (16 years)		
RCP8.5					



*The area graph (left vertical axis) indicates relative frequency, and the polygonal line graph (right vertical axis) does cumulative relative frequency.

*The number of the sample data (N) is 192.

Figure 8-9 Histogram of Annual Maximum Daily Rainfall Sample Data

C) Results of Heavy Rainfall Increase Rates

Probable rainfalls were estimated through the statistical analysis on the 192 annual maximum daily rainfall data, using the hydrological statistics utility (ver1.5). For quantifying the fitness of extreme distribution models to the data, the Standard Least-Squares Criterion(SLSC) which is widely used in flood control planning in Japan was applied. Estimated SLSC values for several probability distribution models were presented in Table 8-16. As it is generally recommended that models with a SLSC value of 0.04 or less be selected, the General Extreme Value (GEV) distribution that gave the least average SLSC value of the three cases (Historical, RCP4.5 and RCP8.5). The 3-parameter lognormal distribution (quantile method) also gave the same SLSC value, but the GEV distribution was prioritized because the Guideline for Small and Midium River Planning (Draft), 1999, MLIT Japan says, as presented in Table 8-17, that the Gumbel distribution, the GEV distribution and the Square-root exponential type maximum distribution that are based on the extreme value theory should be given priority.

Table 8-16 Estimated SLSC Values (Case of Ensemble Data)

Probability Distribution Model	Abbreviation	SLSC			
		Historical	RCP4.5	RCP8.5	Average
Exponential distribution	EXP	0.030	0.039	0.030	0.033
Gumbel distribution	Gumbel	0.021	0.031	0.025	0.026
Square-root exponential type maximum distribution	SqrtEto	0.018	0.033	0.025	0.025
Generalized extreme value distribution	GEV	0.016	0.031	0.023	0.023
Log-Pearson Type III Distribution (Real coordinate space)	LP3Rs	0.023	0.047	0.035	0.035
Log-Pearson Type III Distribution (Log coordinate space)	LogP3	0.017	0.032	0.023	0.024
Iwai method	Iwai	0.017	0.034	0.023	0.025
Ishihara Takase method	IshiTaka	0.019	–	–	–
3-parameter lognormal distribution (quantile method)	LN3Q	0.016	0.032	0.021	0.023
3-parameter lognormal distribution (Slade II)	LN3PM	0.021	–	–	–
2-parameter lognormal distribution (Slade I, L-moments method)	LN2LM	0.021	0.036	–	–
2-parameter lognormal distribution (Slade I, Moments method)	LN2PM	0.021	0.037	–	–

Table 8-17 Quotation on Evaluation of Fitness of Probability Distribution Models

Quoted from the Guideline for Small and Medium River Planning (Draft) (Technical Study Group on Small and Medium River Planning, MILT Japan, September 1999)

In evaluating the fitness of the probability distribution models, various distributions should be examined, but the Gumbel distribution, the GEV distribution, and the Square-root exponential type maximum distribution all of which are based on the extreme value theory are given priority. If none of the three models meets the fitness criteria, the lognormal distribution and the lognormal Pearson type III distribution also should be evaluated.

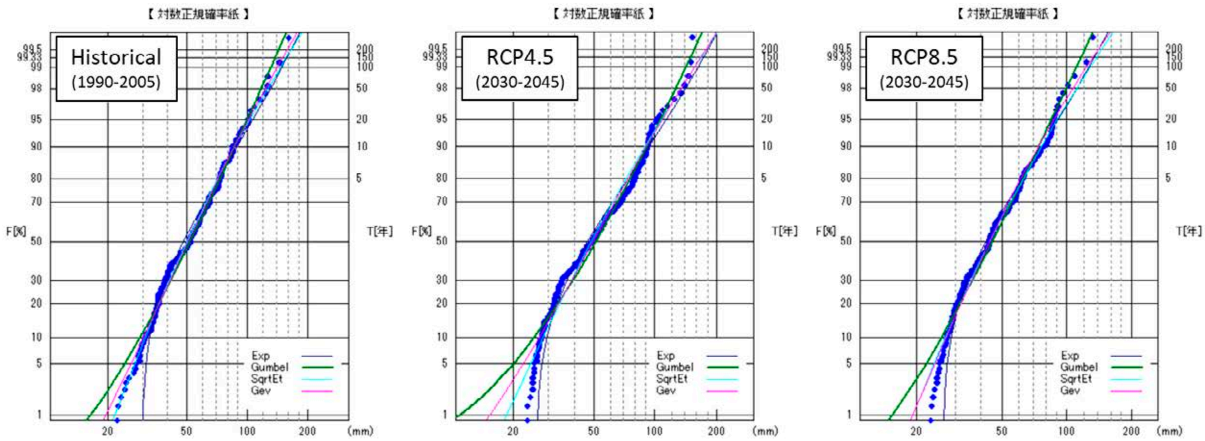
Estimated probable rainfalls and heavy rainfall change rates are presented in Table 8-18, and their plotting on the lognormal probability papers is also presented in Figure 8-10. As explained in the analysis method, the change rates of probable rainfalls of 50- and 100-year return periods under the RCP4.5 scenario are adopted as the heavy rainfall change rates. They were estimated at 1.089 and 1.102 respectively, and both are rounded to 1.1.

However, it is noted that the estimated change rates of probable rainfalls of the RCP8.5 scenario are all less than 1, indicating future decrease, and that the change rates of the RCP4.5 scenario are also not very larger than 1.

Table 8-18 Estimated Probable Rainfalls and Heavy Rainfall Change Rates (Case of Ensemble Data)

Return Period (year)	Probable Rainfall (mm/day)			Change Rate		
	Historical	RCP4.5	RCP8.5	Historical	RCP4.5	RCP8.5
2	50.5	49.6	43.7	1	0.982	0.865
3	60.1	60.6	51.7	1	1.008	0.860
5	71.4	73.5	61.3	1	1.029	0.859
10	86.5	90.9	74.3	1	1.051	0.859
20	101.9	108.9	87.9	1	1.069	0.863
30	111.2	119.8	96.2	1	1.077	0.865
50	123.2	134.2	107.3	1	1.089	0.871
80	134.8	148.0	118.0	1	1.098	0.875
100	140.4	154.7	123.3	1	1.102	0.878
150	150.9	167.4	133.2	1	1.109	0.883
200	158.6	176.8	140.6	1	1.115	0.887

*Red values in the columns of change rate mean that the probable rainfalls will increase in future. On contrary, blue values mean a decrease in rainfall.



*Number of Sample Data： N=192,
Blue points denote annual maximum daily rainfall data

Figure 8-10 Plotting on Lognormal Probability Papers

(iv) (Reference) Change of Basin Average Monthly and Annual Rainfalls

To further look into characteristics of the rainfall projection data used in the above, change rates of the basin average monthly and annual rainfalls in the whole 15 river basins were examined. The time lengths for the current and future rainfall were set to be 16 years, namely from 1990 to 2005 for the current rainfall and from 2030 to 2045 for the future rainfall to estimate the change rate by comparing those of the same time length.

Table 8-19 Data used for Estimation of Bain Average Rainfall

Case	Spatial Resolution		Temporal Resolution			Selected Grid Square No. for BAR
	Grid Square Size	Grid Square No.	Time Step	Period	Data No.	
Historical	approx. 25km x 25km	212 (Long) times 89 (Lat) = 18,868	a day	1990/1/1 - 2005/12/30	5,839	12 grid squares
Future (RCP4.5)				2030/1/1 - 2045/12/31	5,840	
Future (RCP8.5)						

*Basin average rainfall (BAR) is simply calculated as arithmetic average.

*Leap years are not included, and data on December 31, 2005 were lacking.

A) Change Rate of Basin Average Rainfall

Estimated basin average monthly rainfalls and their change rates were presented in Table 8-20, and the monthly rainfalls were compared in Figure 8-11.

According to the table and figure, the future rainfalls tend to decrease very slightly in both cases of the RCP4.5 and RCP8.5 scenarios. However, no significant change is seen.

Table 8-20 Basin Average Monthly Rainfalls and their Change Rates

Rainy/ Dry	Month	Average Monthly Rainfall (mm/month)			Change Rate		
		Historical	RCP4.5	RCP8.5	Historical	RCP4.5	RCP8.5
Rainy	Jan	466	447	426	1	0.958	0.914
	Feb	435	435	455	1	1.001	1.046
	Mar	477	471	462	1	0.988	0.968
	Apr	376	394	386	1	1.048	1.027
Dry	May	275	258	261	1	0.939	0.949
	Jun	180	159	169	1	0.883	0.939
	Jul	146	154	146	1	1.060	1.002
	Aug	174	182	181	1	1.051	1.041
	Sep	245	250	235	1	1.019	0.956
	Oct	354	362	382	1	1.023	1.079
Rainy	Nov	430	443	410	1	1.029	0.951
	Dec	414	393	375	1	0.949	0.906
Rainy		2,598	2,582	2,513	1	0.994	0.967
Dry		1,373	1,366	1,373	1	0.995	1.000
Total		3,971	3,948	3,886	1	0.994	0.979

*Hisotrical: 16 years (1990-2005), Future (RCP4.5/RCP8.5): 16 years (2030-2045)

*Red values in the columns of change rate mean that the probable rainfalls will increase in future. On contrary, blue values mean a decrease in rainfall.

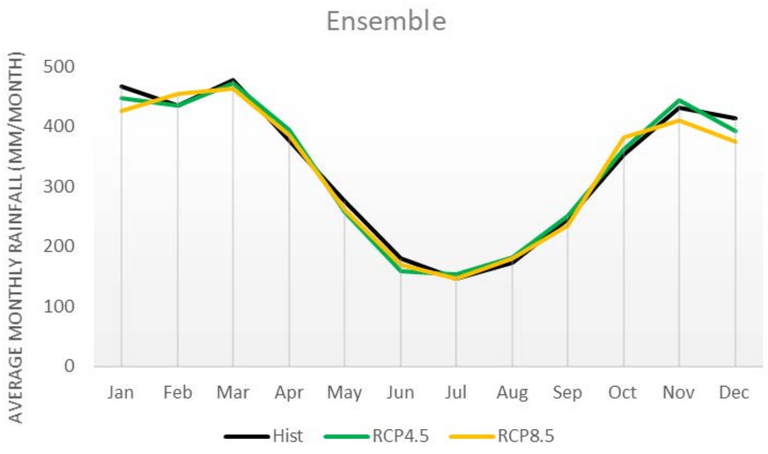


Figure 8-11 Comparison of Monthly Rainfalls

B) Change Rate of Basin Average Annual and Seasonal Rainfall

Estimated basin average annual and seasonal rainfalls and their change rates are presented in Table 8-21, and the annual rainfalls of the current and future climates are compared in Figure 8-12 and Figure 8-13.

According to the table and figure, the annual rainfall tends to decrease very slightly in both cases of the RCP4.5 and RCP8.5 scenarios (About 1% reduction for the RCP4.5 and about 2% reduction for the RCP8.5). Their standard deviation (SD) will increase about 5% for the RCP4.5 and about 9% for the RCP8.5, indicating a trend that the yearly fluctuation of annual rainfall will increase.

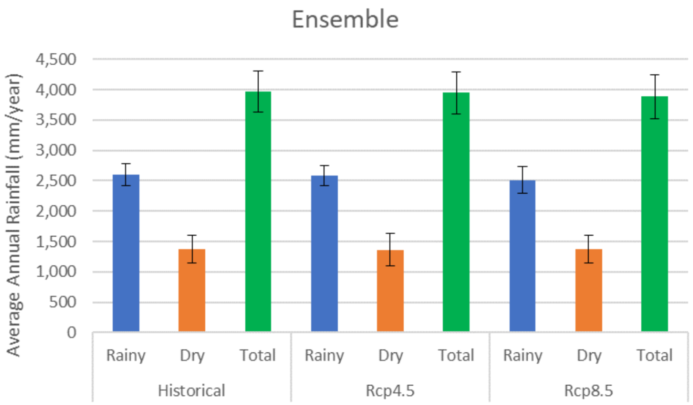
Table 8-21 Estimated Basin Average Annual Rainfall and Change Rates

Case	Annual Rainfall (mm/year)			Standard Deviation (SD)		
	Rainy	Dry	Total	Rainy	Dry	Total
Historical	2,598	1,373	3,971	184	222	332
RCP4.5	2,582	1,366	3,948	170	268	349
RCP8.5	2,513	1,373	3,886	224	225	362
Change Rate (RCP4.5/Historical)	0.994	0.995	0.994	0.922	1.204	1.051
Change Rate (RCP8.5/Historical)	0.967	1.000	0.979	1.220	1.011	1.092

*Hisotrical: 16 years (1990-2005), Future (RCP4.5/RCP8.5): 16 years (2030-2045)

*Rainy Season: November-April, Dry Season: May-October

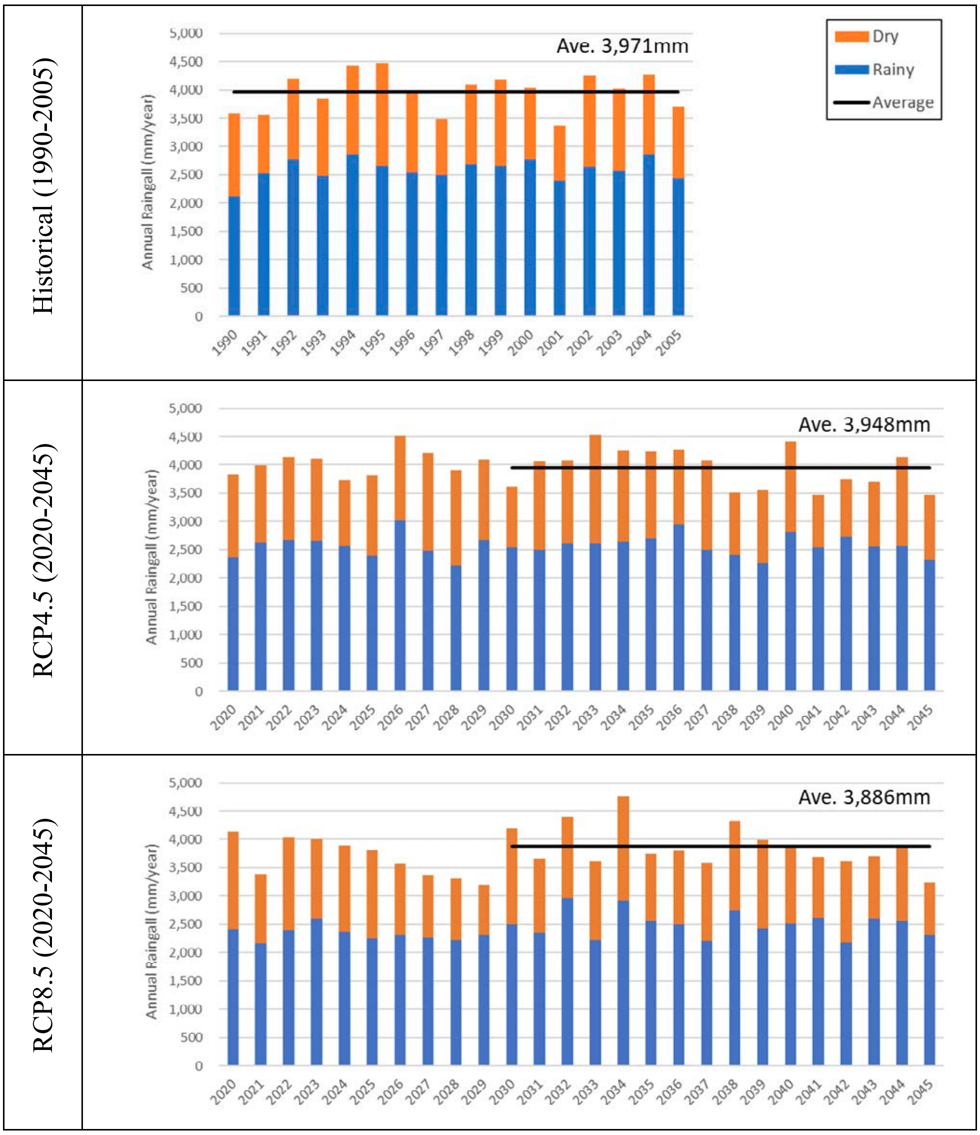
*Red values in the columns of change rate mean that the probable rainfalls will increase in future. On contrary, blue values mean a decrease in rainfall.



*Rainy Season: November-April, Dry Season: May-October

*Error bars show standard deviation (N=16, Historical: 1990-2005, RCP4.5/8.5: 2030-2045)

Figure 8-12 Comparison of Seasonal and Annual Rainfalls



*Average annual rainfall was calculated for 16 years (Historical: 1990-2005, Future: 2030-2045)

Figure 8-13 Annual Rainfall in Time Series

(v) (Reference) Spatial Distribution of Rainfall Projection Data

Colored rainfall distribution maps were prepared by calculating average annual rainfall and average annual maximum daily rainfall of each grid square of the entire data coverage area to identify the spatial distribution characteristics of the rainfall projection data. The data periods are from 1990 to 2005 for the historical data (current climate) and from 2030 to 2045 for the future data (future climate). Findings on the spatial distributions of the average annual rainfalls and the average annual maximum daily rainfalls and on their change rates from the current climate to the future one are discussed as follows:

Table 8-22 Rainfall Projection Data Used for Checking Spatial Distribution

Case	Spatial Resolution		Temporal Resolution		
	Grid Square Size	Grid Square No.	Time Step	Period	Data No.
Historical	approx. 25km x 25km	212 (Long) times 89 (Lat) = 18,868	a day	1990/1/1 - 2005/12/30	5,839
Future (RCP4.5)				2030/1/1 - 2045/12/31	5,840
Future (RCP8.5)					

*Leap years are not included, and data on December 31, 2005 were lacking.

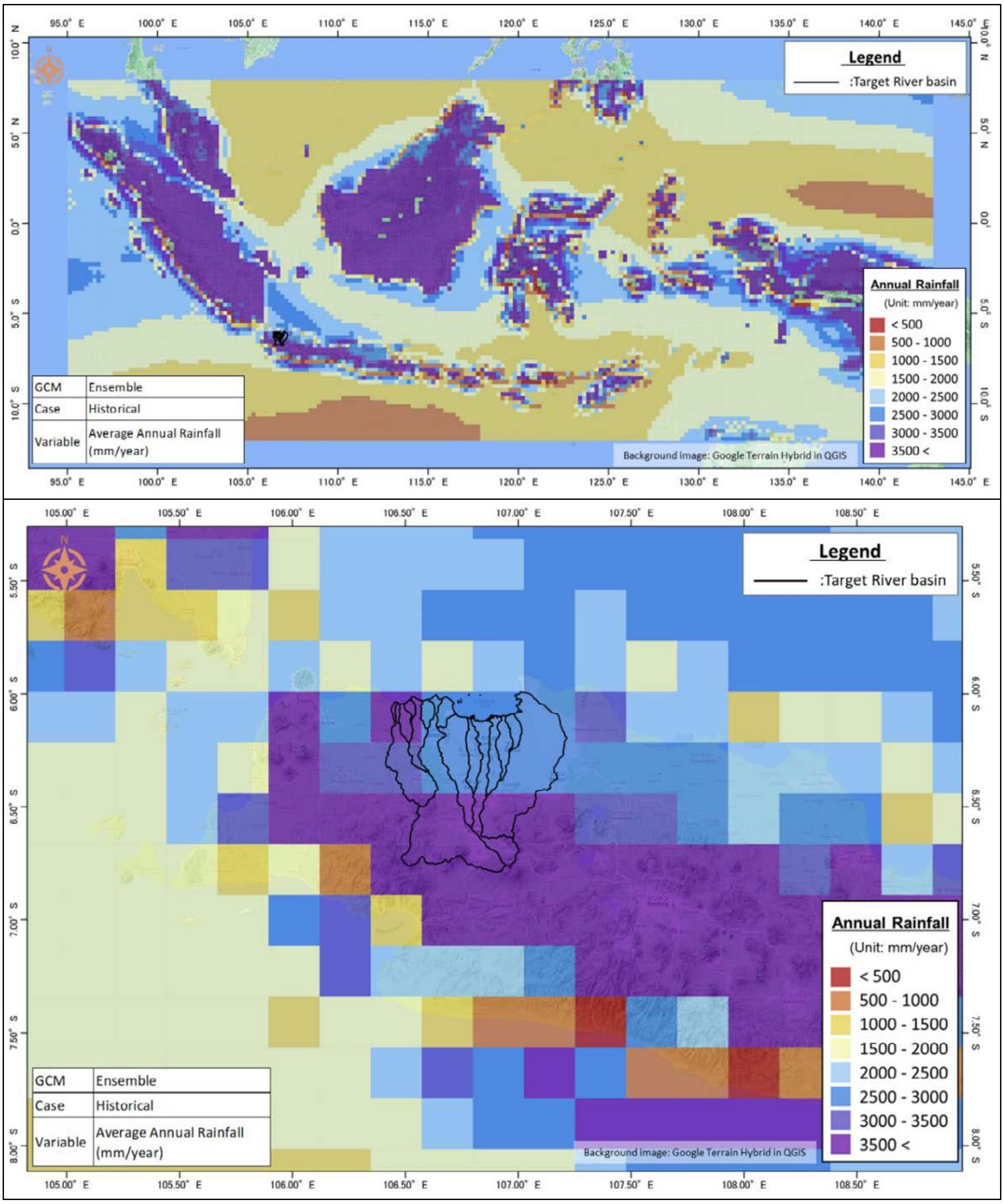
C) Spatial Distribution of Average Annual Rainfall

Spatial distribution maps of average annual rainfalls of the three cases (historical, RCP4.5 and RCP8.5) are shown in Figure 8-14, Figure 8-15 and Figure 8-16, respectively.

The spatial variation of average annual rainfall of all the three cases is generally larger on the land surface than on the sea surface. This is probably because land topography was well reflected by dynamical downscaling with the regional climate models. A tendency that the annual rainfall is generally larger on the land surface than on the sea surface is also seen in the figures.

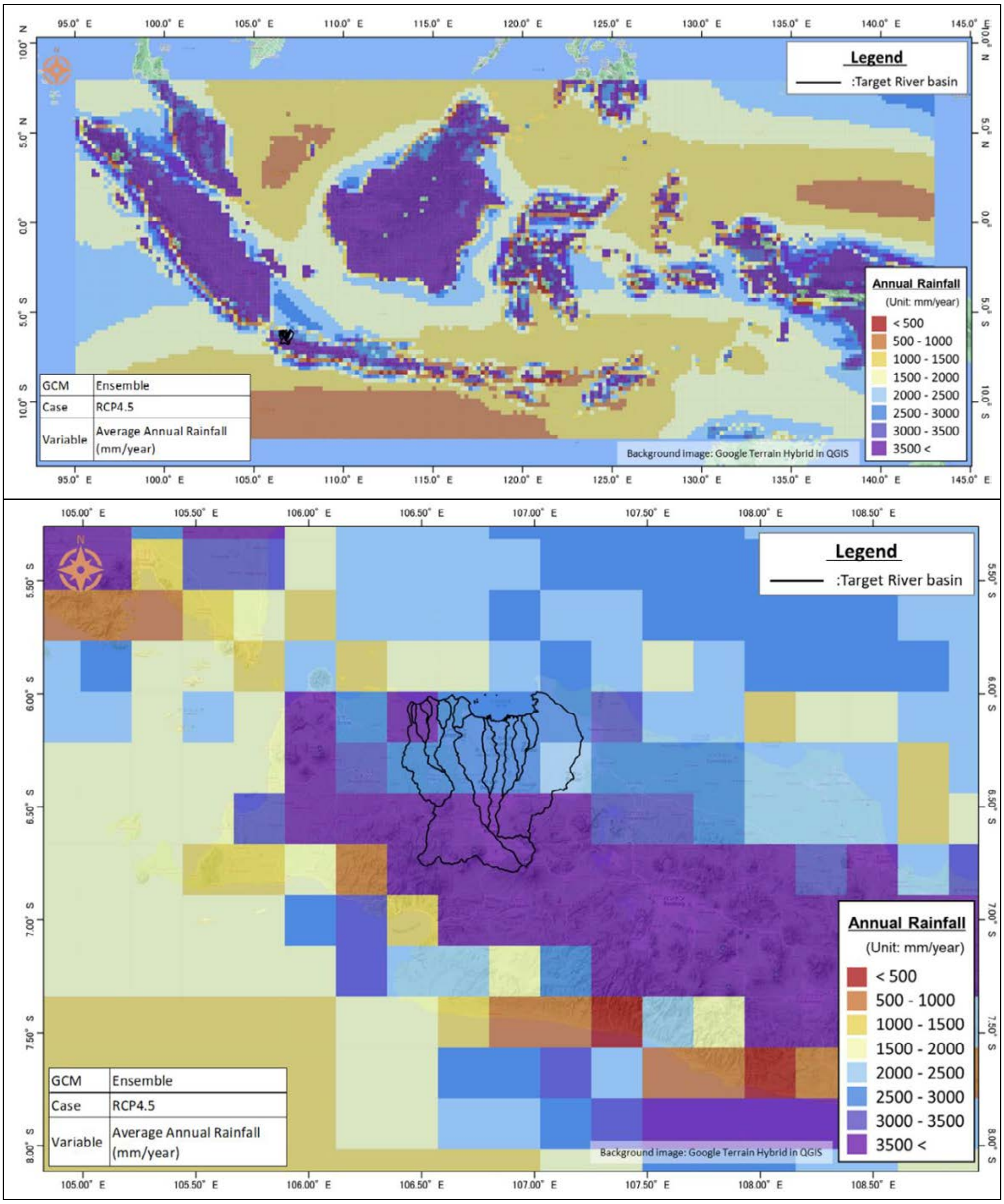
As for the study area, the average annual rainfall seems generally larger in the upper (southern) area than the lower (northern) area.

There is seen no significant change of the average annual rainfall between the current and future climates.



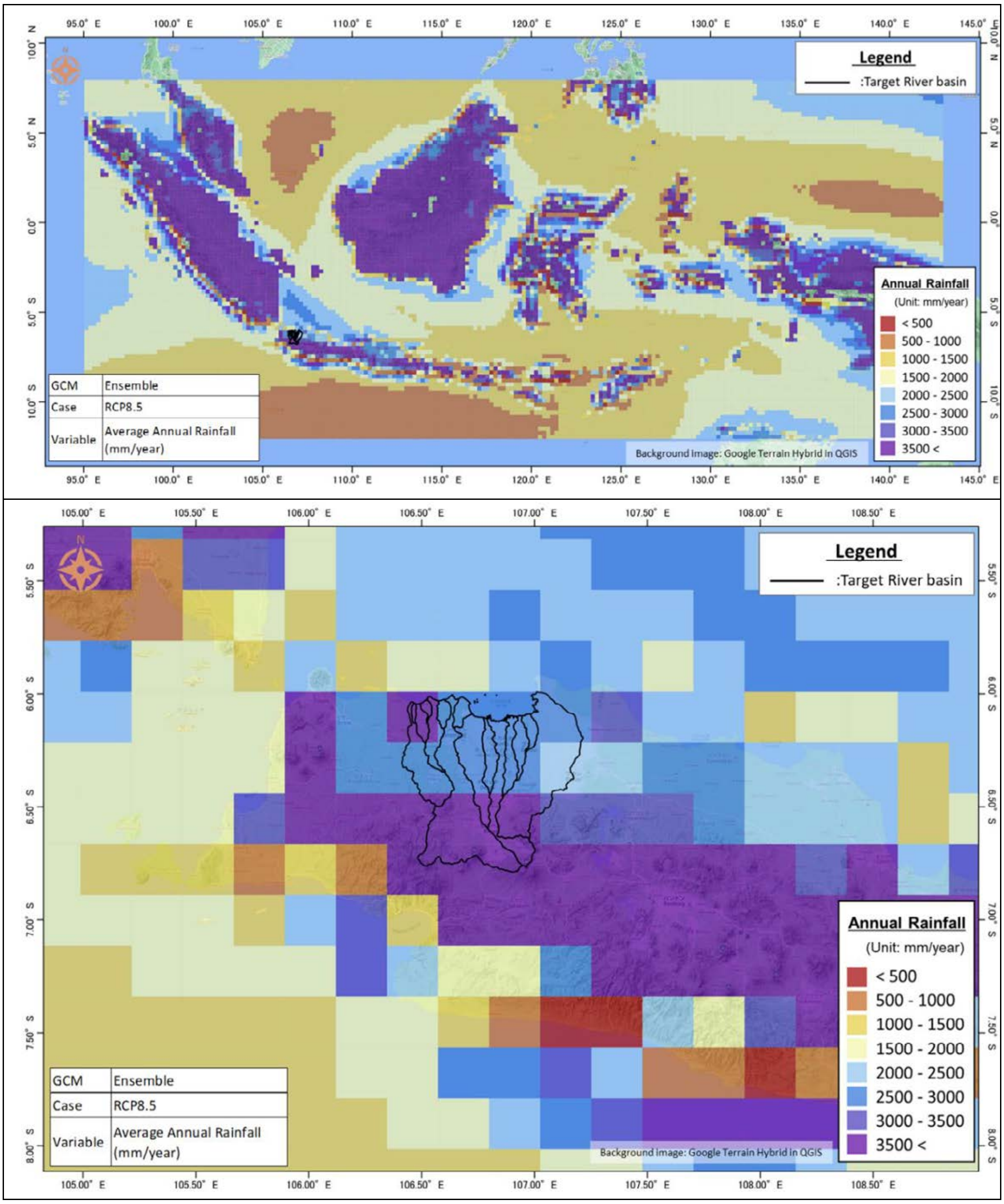
* Entire data area map (upper) and detail map around the study area (lower)

Figure 8-14 Spatial Distribution of Average Annual Rainfall (Historical: 1990-2005)



* Entire data area map (upper) and detail map around the study area (lower)

Figure 8-15 Spatial Distribution of Average Annual Rainfall (RCP4.5: 2030-2045)



* Entire data area map (upper) and detail map around the study area (lower)

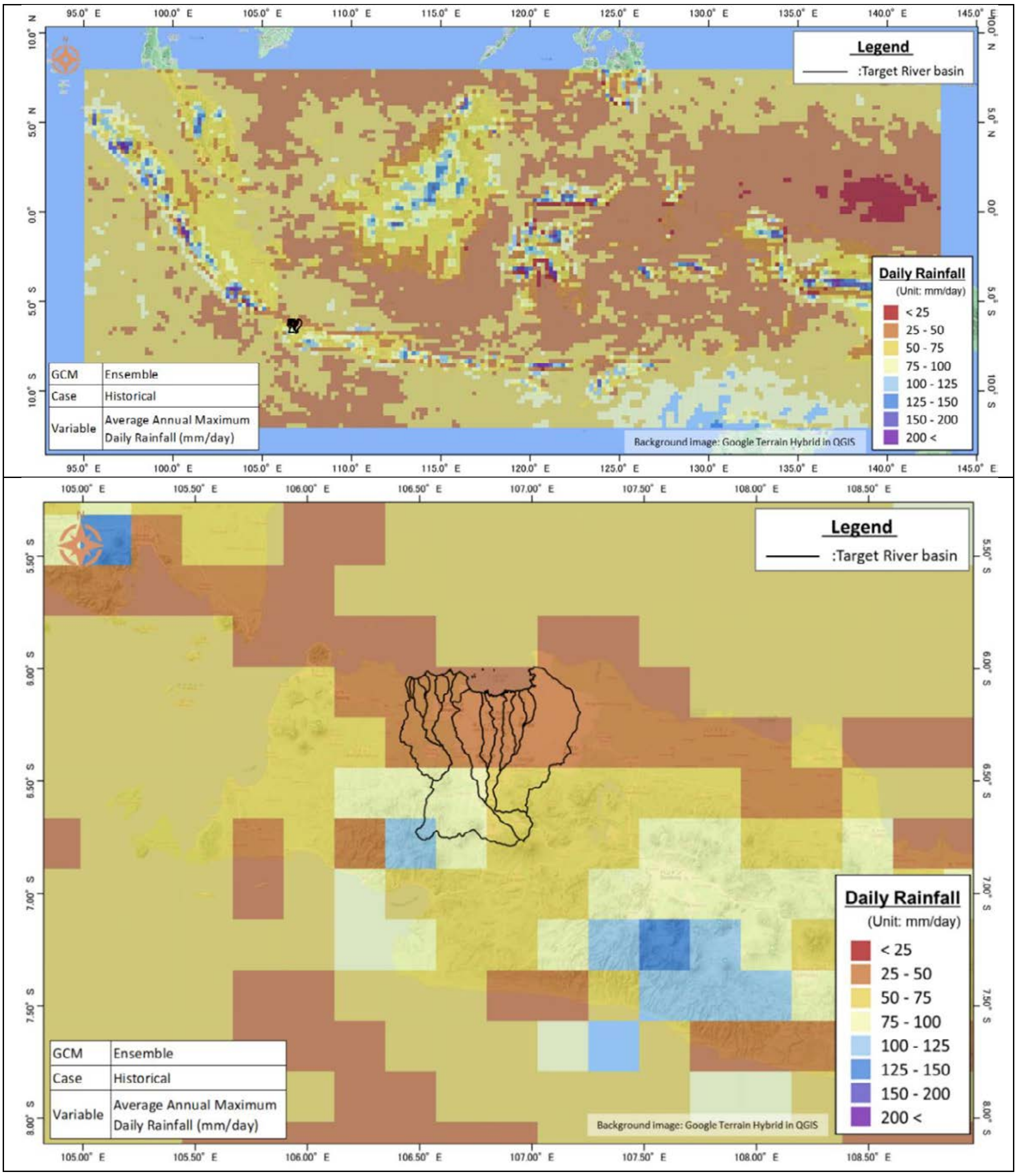
Figure 8-16 Spatial Distribution of Average Annual Rainfall (RCP8.5: 2030-2045)

D) Spatial Distribution of Average Annual Maximum Daily Rainfall

Spatial distribution maps of average annual maximum daily rainfalls of the three cases (historical, RCP4.5 and RCP8.5) are shown in Figure 8-17, Figure 8-18 and Figure 8-19, respectively.

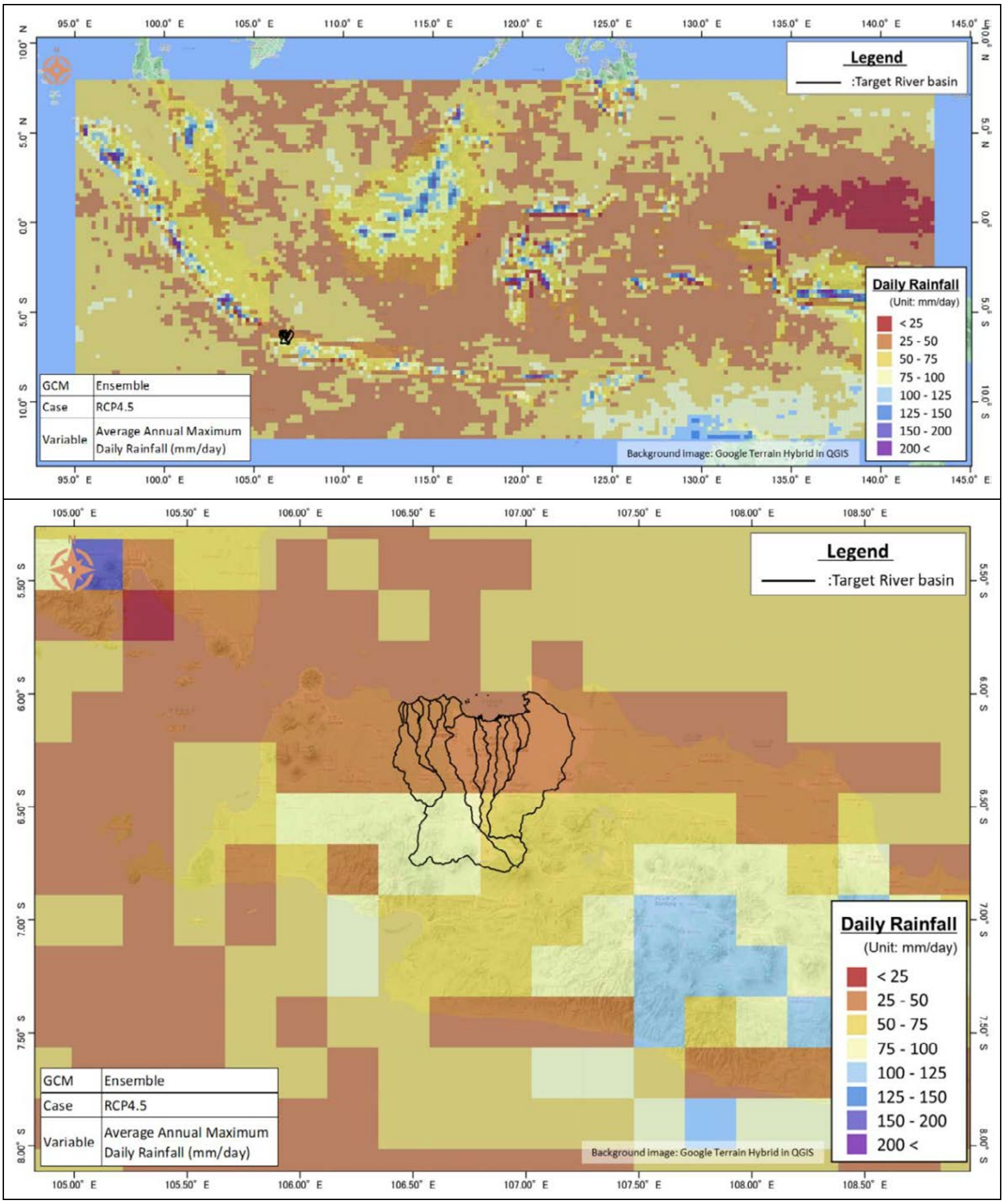
The spatial variation of average annual maximum daily rainfall of all the three cases is generally larger on the land surface than on the sea surface. This is probably because land topography was well reflected by dynamical downscaling with the regional climate models. A tendency that the annual maximum daily rainfall is generally larger on the land surface than on the sea surface is also seen in the figures.

As for the study area, the annual maximum daily rainfall seems generally larger in the upper (southern) area than the lower (northern) area.



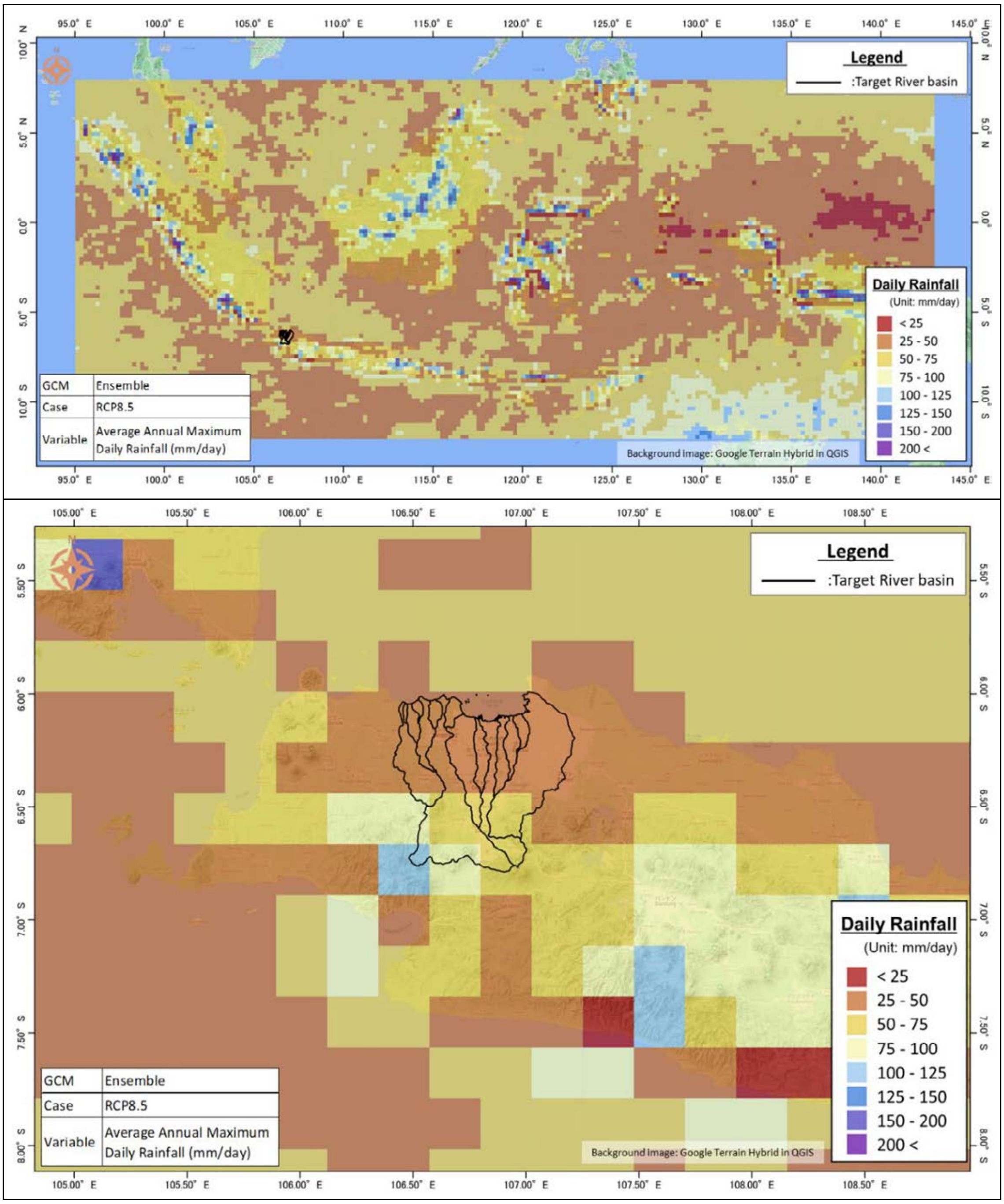
* Entire data area map (upper) and detail map around the study area (lower)

Figure 8-17 Spatial Distribution of Average Annual Maximum Daily Rainfall (Historical: 1990-2005)



* Entire data area map (upper) and detail map around the study area (lower)

Figure 8-18 Spatial Distribution of Average Annual Maximum Daily Rainfall (RCP4.5: 2030-2045)



* Entire data area map (upper) and detail map around the study area (lower)

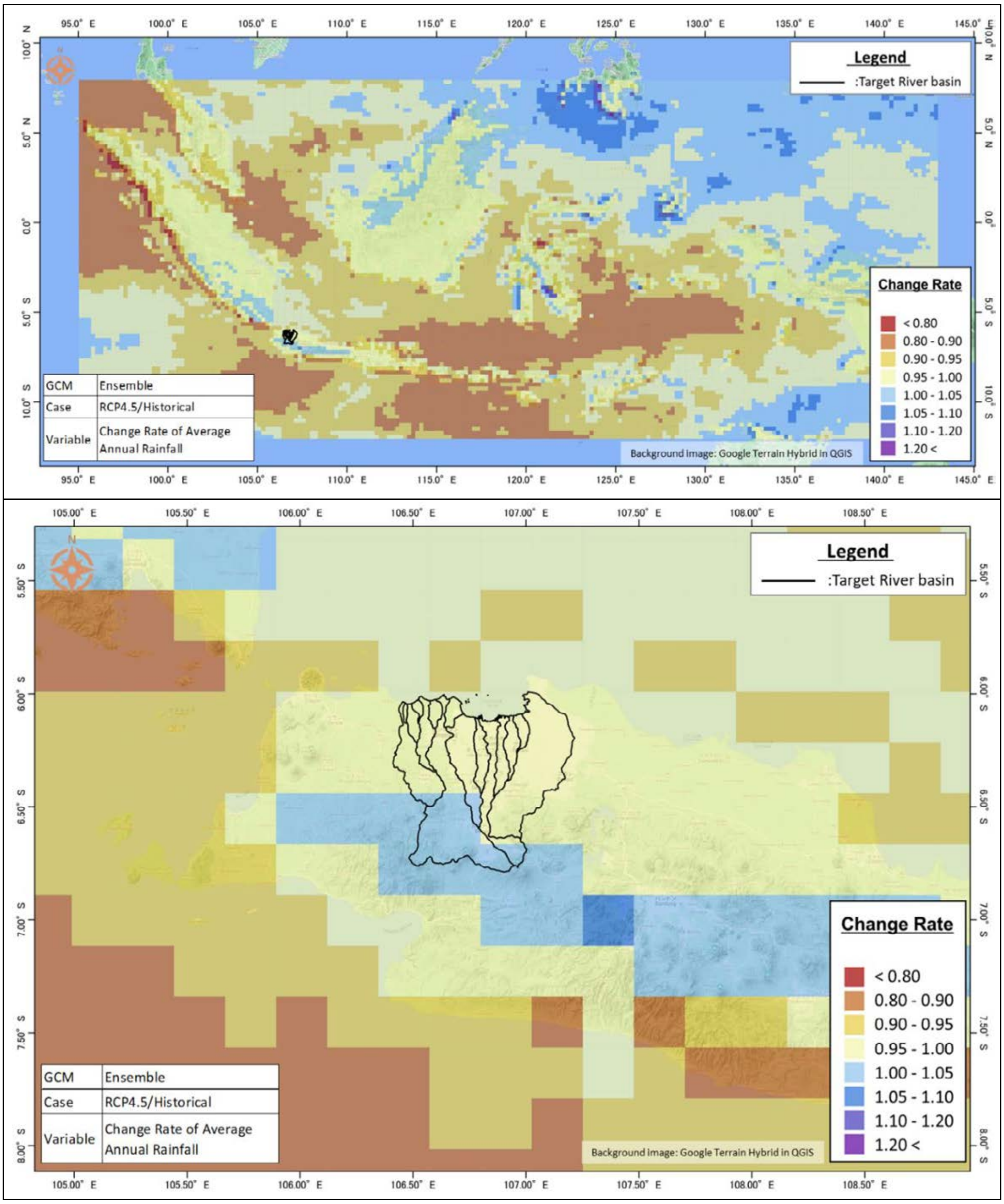
Figure 8-19 Spatial Distribution of Average Annual Maximum Daily Rainfall (RCP8.5: 2030-2045)

E) Spatial Distribution of Change Rate of Average Annual Rainfall

Spatial distribution maps of change rates of average annual rainfalls of the two cases (RCP4.5/Historical and RCP8.5/Historical) are shown in Figure 8-20 and Figure 8-21, respectively.

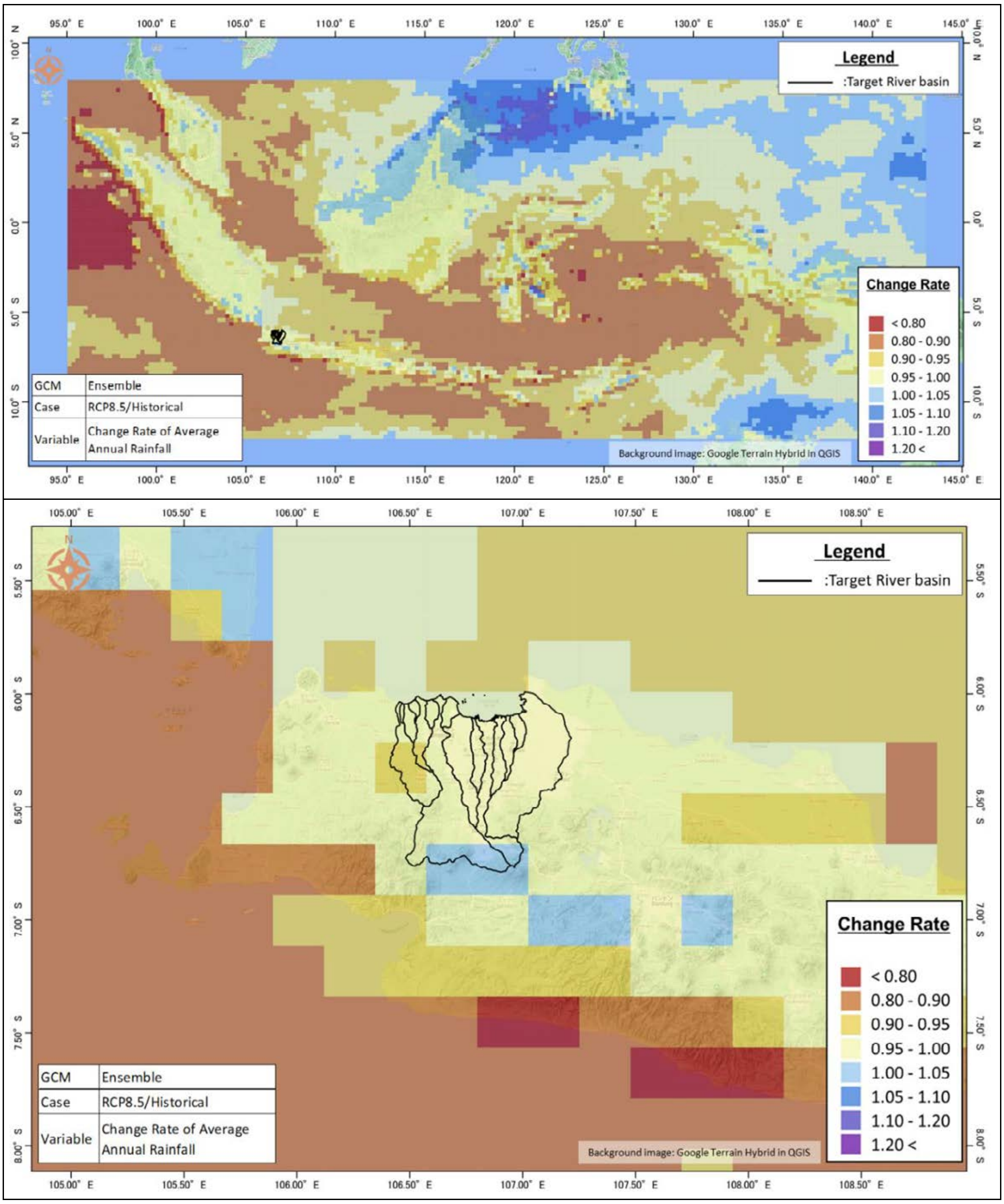
The average annual rainfall tends to increase in the future in and around the Java Island except for the southern mountain area. This tendency is clearer in the RCP8.5 case than the RCP4.5 case.

As for the study area, in the RCP4.5 case a tendency that the average annual rainfall will slightly increase in the upper (southern) area and will slightly decrease in the lower (northern) area is seen. The same tendency is also seen in the RCP8.5 case, but the decreasing tendency is stronger in the RCP8.5 case than the RCP4.5 case.



* Entire data area map (upper) and detail map around the study area (lower)

Figure 8-20 Spatial Distribution of Change Rate of Average Annual Rainfall (RCP4.5/Historical)



* Entire data area map (upper) and detail map around the study area (lower)

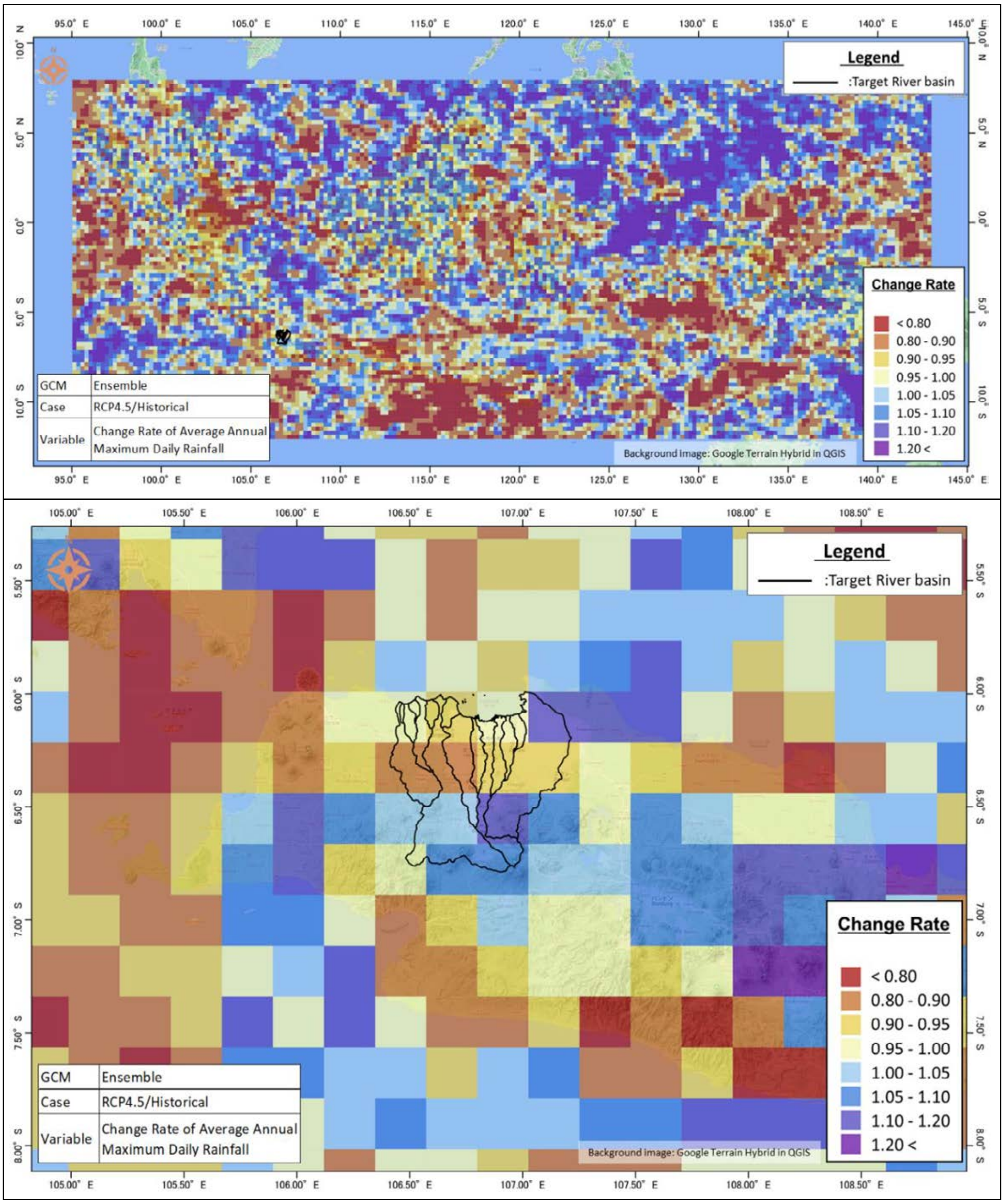
Figure 8-21 Spatial Distribution of Change Rate of Average Annual Rainfall (RCP8.5/Historical)

F) Spatial Distribution of Average Annual Maximum Daily Rainfall

Spatial distribution maps of change rates of average annually maximum daily rainfalls of the two cases (RCP4.5/Historical and RCP8.5/Historical) are shown in Figure 8-22 and Figure 8-23, respectively.

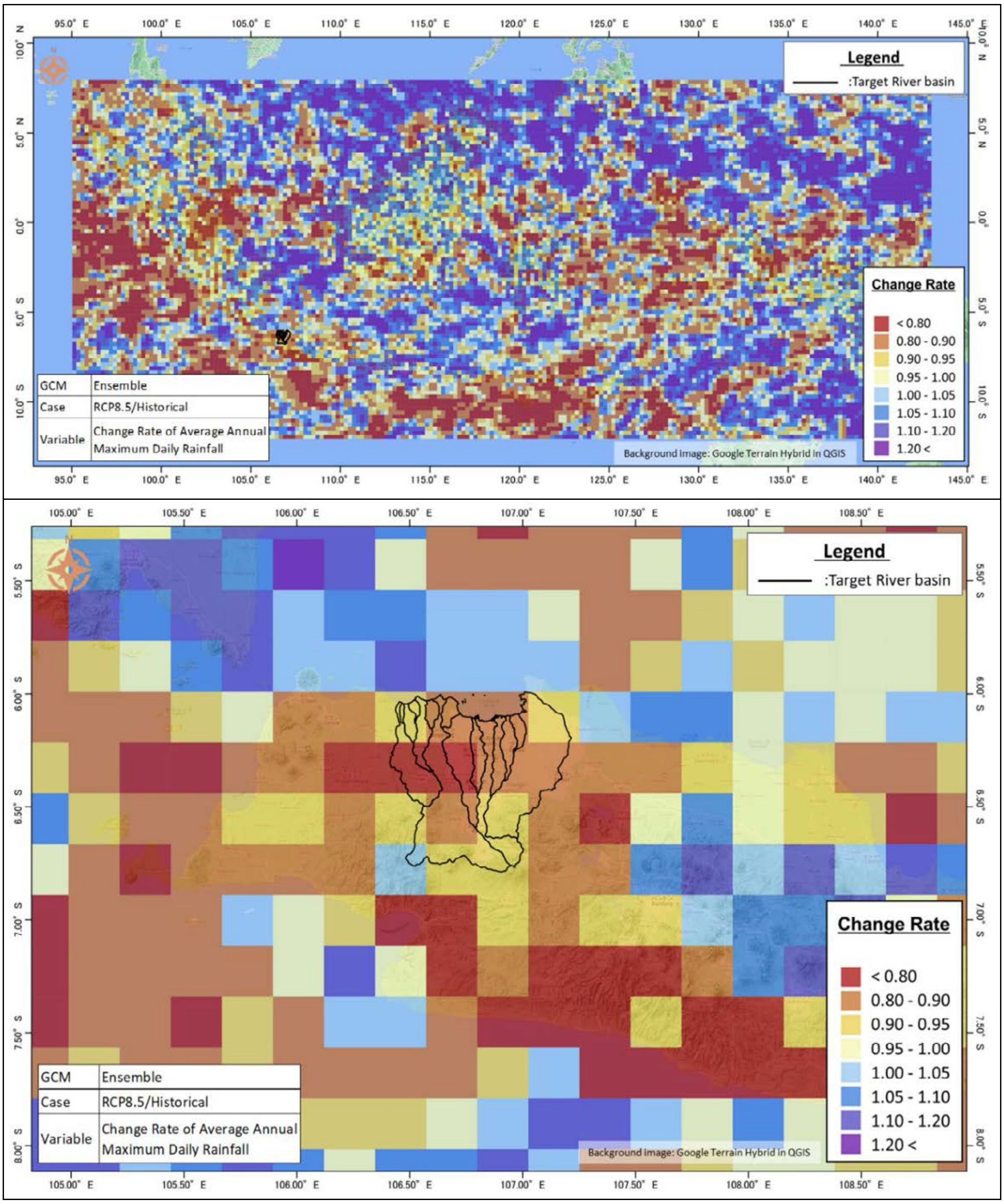
The spatial variation of the change rate of average annual maximum daily rainfall is generally larger than that of the average annual rainfall.

As for the study area, in the RCP4.5 case a tendency that the average annual maximum daily rainfall will slightly increase in the upper (southern) area and will slightly decrease in the lower (northern) area is seen. In the RCP8.5 case the average annual maximum daily rainfall tends to decrease in the entire study area.



* Entire data area map (upper) and detail map around the study area (lower)

Figure 8-22 Spatial Distribution of Change Rate of Average Annual Rainfall (RCP4.5/Historical)



* Entire data area map (upper) and detail map around the study area (lower)

Figure 8-23 Spatial Distribution of Change Rate of Average Annual Rainfall (RCP8.5/Historical)

(2) Climate Change Impact Assessment Based on Eight Types of Rainfall Projection Datasets

(i) Estimation of Heavy Rainfall Change Rate

A) Provided Data

Eight types of rainfall projection datasets as presented in Table 8-23 were provided by BMKG. Each dataset contains projection data of the current climate (historical) and the two future climate scenarios (RCP4.5 and RCP8.5). The datasets were all produced through downscaling of projected outputs of GCMs by RCMs. Five different GCMs and three different RCMs have been used to produce the datasets. Depending on the RCM, the spatial resolution and grid location is different. The temporal resolution is the same, a day for all the datasets, but the data periods are slightly different among the datasets.

BMKG provided datasets of which temporal resolutions are three or six hours too, but they were not used in this study because they were outputs of only one combination of CSIROMK3.6 and REGCM and it is difficult to compare with the other model combinations.

Table 8-23 Eight Types of Rainfall Projection Datasets Provided by BMKG

No.	GCM	RCM	Source	Spatial Resolution		Time Step	Past period		Future period	
				Grid Size	Grid No.		Year	Data No.	Year	Data No.
1	CNRM	RCA	BMKG	approx. 25 km	9 (Long) x 11 (Lat)	Daily	1981/1/1 - 2005/12/31	9,131	2006/1/1 - 2050/12/31	16,436
2	CNRM	REGCM	BMKG	approx. 25 km	9 (Long) x 10 (Lat)		1980/1/1 - 2005/12/31	9,497	2006/1/1 - 2050/12/31	16,436
3	CSIROMK3.6	REGCM	BMKG	approx. 25 km	9 (Long) x 10 (Lat)		1979/12/25 - 2005/12/17	9,483	2005/12/18 - 2050/12/6	16,411
4	ECEARTH	REGCM	BMKG	approx. 25 km	9 (Long) x 10 (Lat)		1980/1/1 - 2005/12/31	9,497	2006/1/1 - 2050/12/31	16,436
5	HADGEM	RCA	BMKG	approx. 25 km	9 (Long) x 11 (Lat)		1980/7/21 - 2005/3/11	9,000	2005/3/12 - 2049/7/18	16,200
6	HADGEM	REGCM	BMKG	approx. 25 km	9 (Long) x 10 (Lat)		1980/7/21 - 2005/3/11	9,000	2005/3/12 - 2049/7/18	16,200
7	MPI	REGCM	BMKG	approx. 25 km	9 (Long) x 10 (Lat)		1980/1/1 - 2005/12/31	9,497	2006/1/1 - 2050/12/31	16,436
8	MPI	ROM	BMKG	approx. 55 km	5 (Long) x 5 (Lat)		1985/1/1 - 2005/12/31	7,670	2006/1/1 - 2050/12/31	16,436
Ensemble			Bappenas	approx. 25 km	212 (Long) x 89 (Lat)	Daily	1990/1/1 - 2005/12/30	5,839	2020/1/1 - 2045/12/31	9,490

*The datasets were developed by the SEACLID/CORDEX-SEA Project (http://www.ukm.edu.my/seaclid-cordex/)

*GCM: General Circulation Model, RCM: Regional Climate Model

*Regarding the data period, some of the datasets don't start on January 1 or don't end on December 31. The JICA Study Team asked BMKG about this issue, but their yearly complete datasets were not provided.

*The ensemble average data provided by Bappenas, which was used in 8.2.2(1) are also described in the lowest row for comparison.

The grid locations of the three RCMs are shown in Figure 8-24, Figure 8-25 and Figure 8-26 respectively. Grid squares in each of which the target 15 river basin area occupies 20 % or more of the grid square area were selected for the following analysis. Namely 11 grid squares were selected for the two RCMs of RCA and REGCM, and 4 grid squares were selected for the ROM. The threshold value, 20% was determined so that the number of selected grid squares for RCA and REGCM could be the same. The basin average rainfall of the entire 15 river basin area that is discussed in 8.2.2(2)(ii) is calculated simply as an arithmetic average of rainfalls of the selected grid squares.

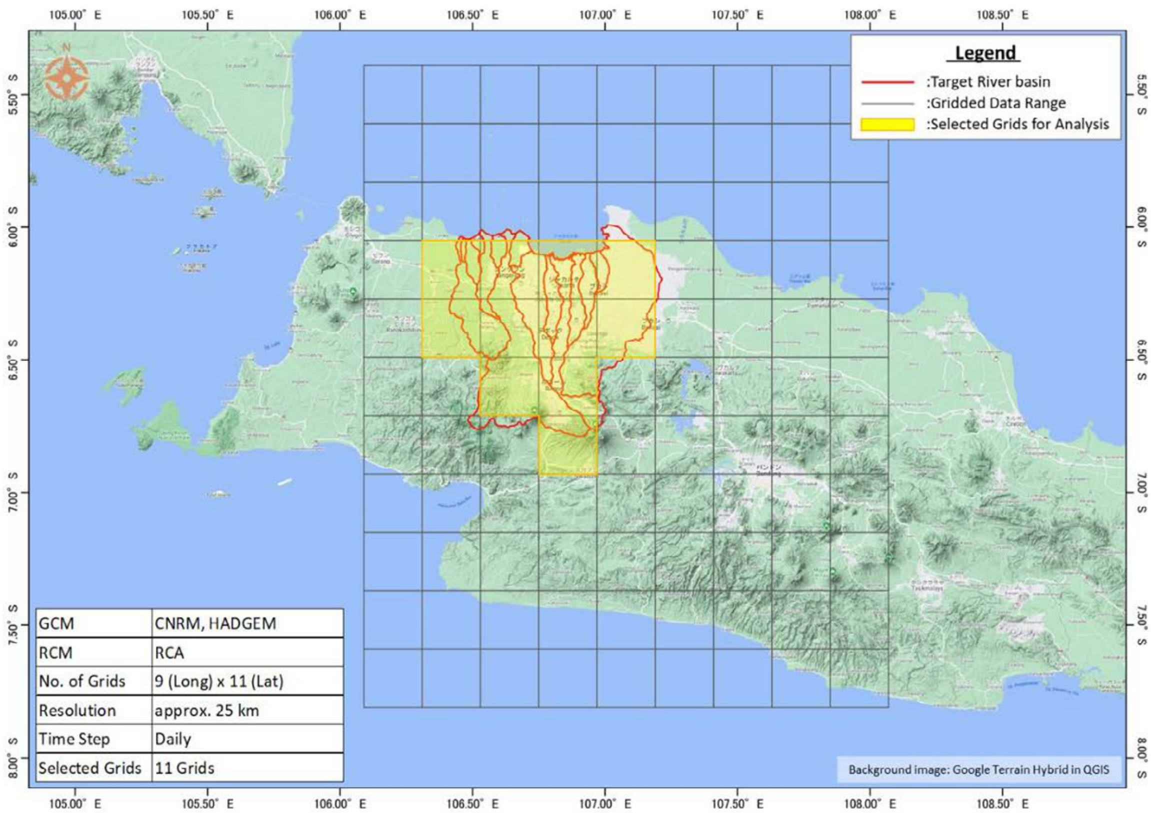


Figure 8-24 Grid Location and Selected Grid Squares for Analysis(RCA)

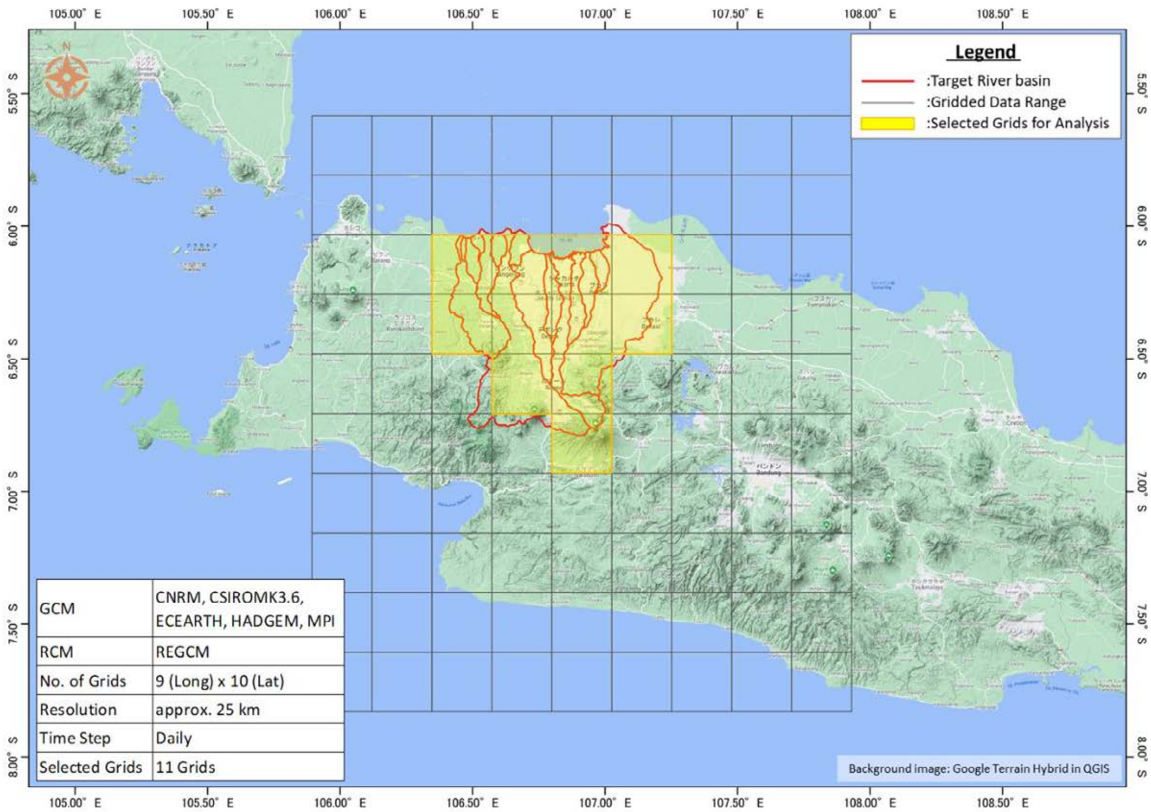


Figure 8-25 Grid Location and Selected Grid Squares for Analysis(REGCM)

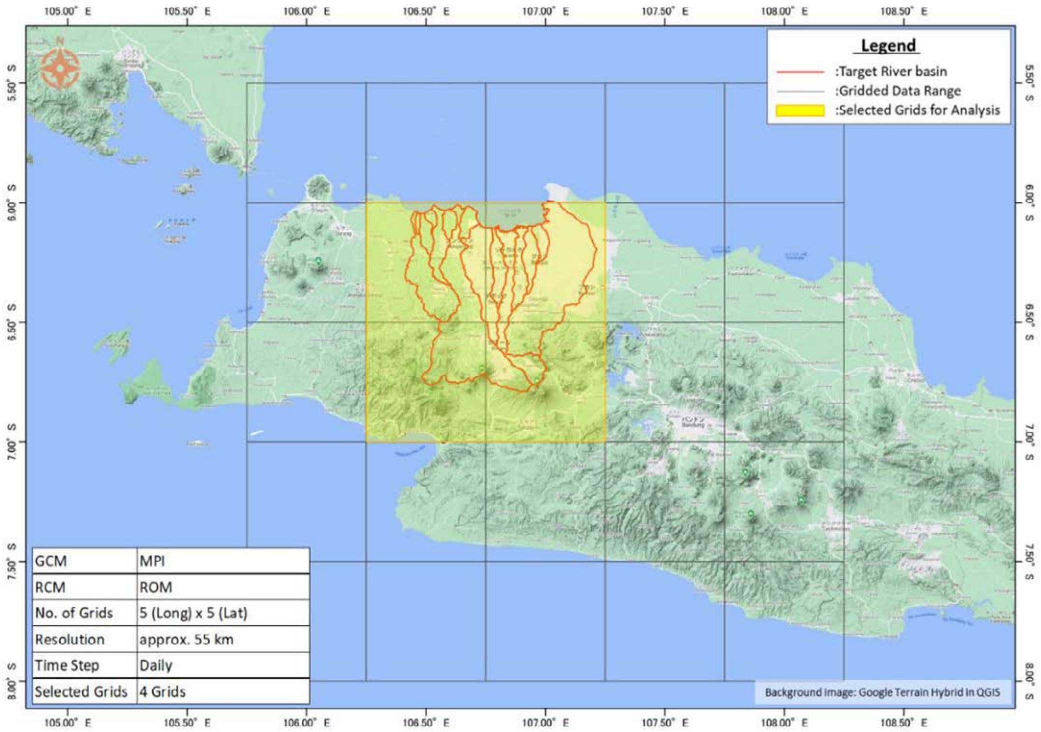


Figure 8-26 Grid Location and Selected Grid Squares for Analysis(ROM)

B) Analysis Method

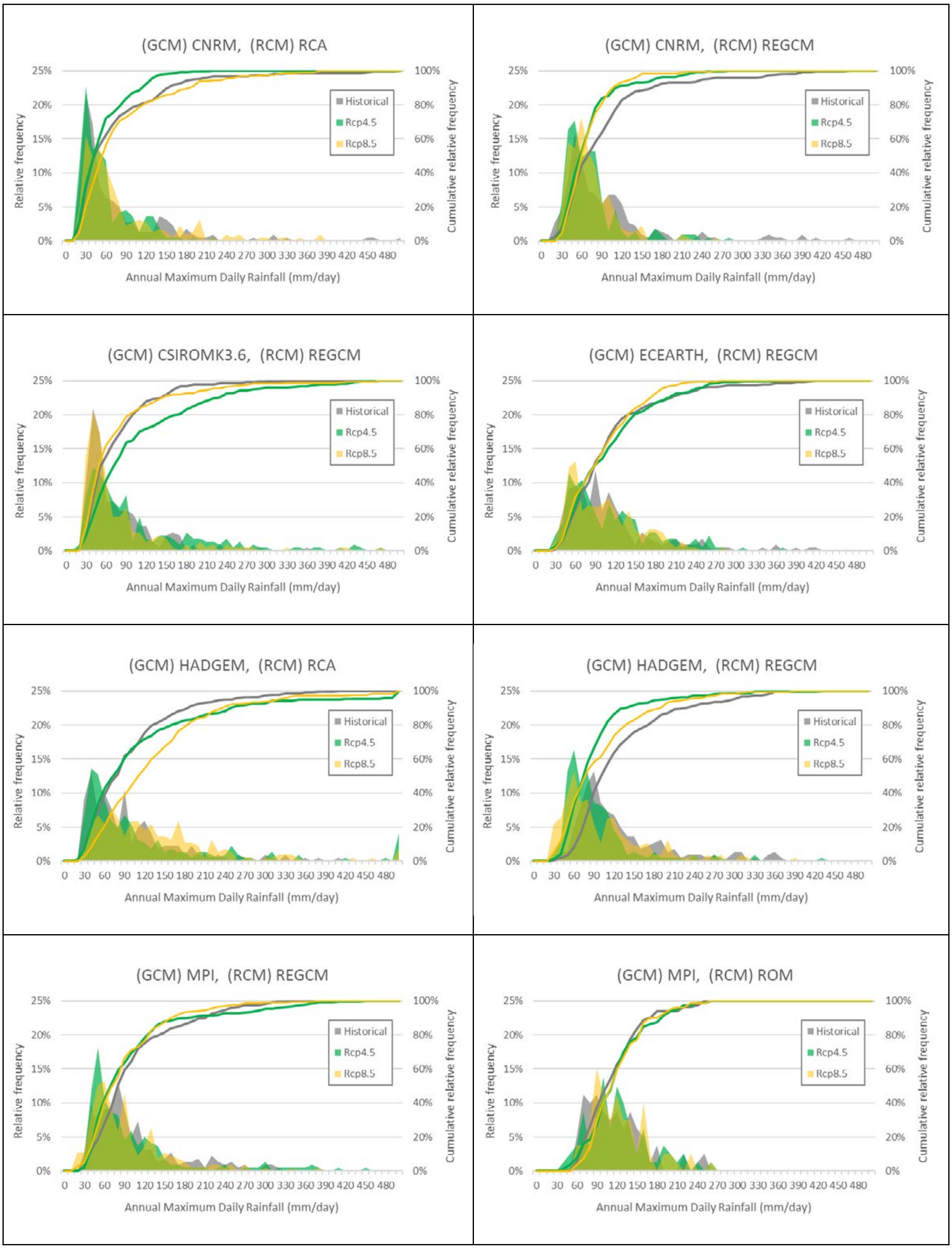
The analysis method is the same as the one that is described in B)Analysis Method. The future design rainfall with climate change is estimated by multiplying the design rainfall without climate change by the heavy rainfall change rate. The heavy rainfall change rate is a rate how many times heavy rainfall will increase as an impact of climate change. It is estimated by comparing future and historical (current) rainfalls that have been projected by using the same climate models to avoid influences of biases that are associated with climate models.

The heavy rainfall change rate is calculated for probable daily rainfalls of 50- and 100-year return periods by comparing those of current and future climates in this study. The probable rainfalls are estimated through the statistical analysis on the dataset sample consisting of annual maximum daily rainfall data extracted from the selected grid squares depending on the RCM. The data periods for the statistical analysis were set to be the same for all the datasets for convenience of comparison, namely 20 years from 1985 to 2004 for the current climate and 20 years from 2030 to 2049 for the future climate. The annual maximum daily rainfall samples that were prepared by the Station Year Method Station are summarized in Table 8-24, and their histograms are shown in Figure 8-27.

Table 8-24 Annual Maximum Daily Rainfall Samples for Estimation of Heavy Rainfall Change Rate

RCM	Grid Square Size	Selected Grid Square No.	Historical Period	Future Period	No. of Data
RCA	approx. 25km x 25km	11 squares	1985/1/1 - 2004/12/31 (20 years)	2030/1/1 - 2049/12/31 (20 years)	220
REGCM	approx. 25km x 25km	11 squares			
ROM	approx. 55km x 55km	4 squares			80

*Future data from July 19, 2049 to December 31, 2049 of the datasets of which GCM is HADGEM were lacking.



*The area graph (left vertical axis) indicates relative frequency, and the polygonal line graph (right vertical axis) does cumulative relative frequency.

*The number of the sample data (N) is 80 only for the case with MPI as GCM and ROM as RCM, but 220 for the other cases.

Figure 8-27 Histogram of Annual Maximum Daily Rainfall Sample

C) Estimation of Heavy Rainfall Change Rate

Estimation of probable rainfalls was conducted through the statistical analysis on the 220 or 80 annual maximum daily rainfall data, using the hydrological statistics utility (ver1.5). For quantifying the fitness of extreme distribution models to the data, the Standard Least-Squares Criterion(SLSC) which is widely used in flood control planning in Japan was applied. Estimated SLSC values for several extreme distribution models were presented in Table 8-25. As it is generally recommended that models with a SLSC value of 0.04 or less be selected, the General Extreme Value (GEV) distribution that gave small enough SLSC values for all the cases was adopted.

Table 8-25 Estimation of SLSC(Eight Types of Rainfall Projection Datasets)

No.	GCM & RCM	Case	SLSC			
			EXP	Gumbel	SqrtEt	GEV
1	(GCM) CNRM, (RCM) RCA	Historical	0.061	0.100	0.085	0.034
		RCP4.5	0.025	0.043	0.041	0.034
		RCP8.5	0.031	0.069	0.062	0.033
2	(GCM) CNRM, (RCM) REGCM	Historical	0.053	0.086	0.057	0.024
		RCP4.5	0.042	0.074	0.061	0.023
		RCP8.5	0.029	0.047	0.021	0.015
3	(GCM) CSIROMK3.6, (RCM) REGCM	Historical	0.025	0.061	0.049	0.027
		RCP4.5	0.025	0.059	0.052	0.034
		RCP8.5	0.064	0.104	0.093	0.025
4	(GCM) ECEARTH, (RCM) REGCM	Historical	0.025	0.054	0.033	0.020
		RCP4.5	0.034	0.028	0.029	0.028
		RCP8.5	0.052	0.027	0.038	0.029
5	(GCM) HADGEM, (RCM) RCA	Historical	0.016	0.048	0.031	0.023
		RCP4.5	0.060	0.099	0.088	0.033
		RCP8.5	0.032	0.055	0.023	0.019
6	(GCM) HADGEM, (RCM) REGCM	Historical	0.033	0.050	0.040	0.032
		RCP4.5	0.053	0.086	0.056	0.017
		RCP8.5	0.017	0.034	0.022	0.022
7	(GCM) MPI, (RCM) REGCM	Historical	0.031	0.045	0.036	0.032
		RCP4.5	0.051	0.085	0.077	0.032
		RCP8.5	0.014	0.042	0.018	0.015
8	(GCM) MPI, (RCM) ROM	Historical	0.040	0.028	0.027	0.025
		RCP4.5	0.050	0.019	0.036	0.018
		RCP8.5	0.039	0.017	0.021	0.016

*EXP: Exponential distribution, Gumbel: Gumbel distribution, SqrtEt: Square-root exponential type maximum distribution, GEV: Generalized extreme value distribution

Estimated probable rainfalls of Gev and rainfall change rates for probable daily rainfalls of the 50- and 100 year return periods are presented in Table 8-26, Table 8-27 and Table 8-28 respectively. As discussed in B)Analysis Method, the change rates of probable daily rainfalls of 50- and 100-year return periods under the RCP4.5 scenario are adopted as the heavy rainfall change rate. Assuming that the eight types of datasets are of the same level of reliability, they were treated evenly, and the change rates were determined to be the upper quartile (75 percent) of the box plotting of eight values from the following reasons:

- A severer scenario should be adopted to formulate a safer flood control plan under climate change.
- Since the climate models include uncertainties in their projection results, those that give extreme values such as the maximum and minimum values should be avoided.

In conclusion, the heavy rainfall change rates were estimated at 1.3 for the daily rainfall of the 50-year return period and 1.4 for the daily rainfall of the 100-year return period, rounding 1.246 and 1.356 respectively.

However, it is also noted that the cases that the estimated probable rainfalls will decrease is more than those that they will increase in both RCP4.5 and RCP8.5 scenarios.

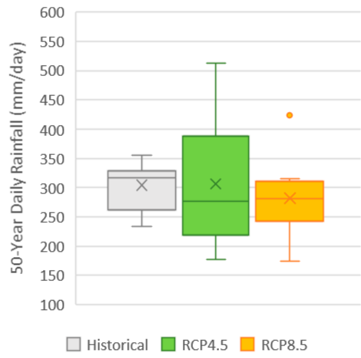
Table 8-26 Estimation of Probable Rainfalls (Eight types of Rainfall Projection Datasets)

No.	GCM & RCM	Case	Probable Rainfall (mm/day) with different return periods (year)										
			2	3	5	10	20	30	50	80	100	150	200
1	(GCM) CNRM, (RCM) RCA	Historical	58.3	76.9	103.1	146.8	203.7	245.1	307.9	378.5	417.1	497.1	562.5
		RCP4.5	52.7	65.7	82.3	106.6	134.3	152.5	177.8	203.9	217.3	243.4	263.5
		RCP8.5	67.0	87.8	116.1	161.3	217.5	257.0	315.3	378.9	412.9	482.0	537.4
2	(GCM) CNRM, (RCM) REGCM	Historical	78.2	99.7	128.5	173.8	229.1	267.3	323.0	383.0	414.8	478.9	529.8
		RCP4.5	66.5	79.7	97.0	123.8	156.0	177.9	209.5	243.1	260.8	296.2	324.0
		RCP8.5	69.2	81.7	96.9	118.0	140.7	154.9	173.9	192.6	202.0	219.8	233.1
3	(GCM) CSIROMK3.6, (RCM) REGCM	Historical	65.8	81.7	102.6	134.5	172.2	197.8	234.2	272.7	292.8	332.7	364.0
		RCP4.5	86.6	114.8	152.4	210.7	281.2	329.6	399.7	474.6	514.2	593.6	656.3
		RCP8.5	62.0	78.5	101.9	141.3	193.3	231.4	289.8	356.0	392.4	468.3	530.7
4	(GCM) ECEARTH, (RCM) REGCM	Historical	98.1	122.0	152.4	197.3	248.8	282.6	330.0	378.8	404.0	453.2	491.0
		RCP4.5	101.3	126.2	156.0	196.7	239.4	265.7	300.6	334.6	351.4	383.0	406.5
		RCP8.5	98.1	119.3	143.1	173.6	203.2	220.5	242.3	262.5	272.1	289.7	302.3
5	(GCM) HADGEM, (RCM) RCA	Historical	85.6	109.9	140.8	186.3	238.3	272.5	320.1	369.2	394.4	443.8	481.7
		RCP4.5	86.5	117.2	161.0	234.8	332.1	403.6	512.9	637.0	705.3	847.6	964.7
		RCP8.5	118.7	152.7	195.0	255.5	322.3	365.1	423.6	482.6	512.4	570.0	613.6
6	(GCM) HADGEM, (RCM) REGCM	Historical	114.0	138.5	170.0	216.7	270.4	306.0	355.9	407.6	434.2	486.6	527.0
		RCP4.5	82.3	98.3	119.4	151.6	189.8	215.6	252.6	291.7	312.1	352.8	384.6
		RCP8.5	90.8	114.4	143.5	184.8	230.2	259.1	298.4	337.8	357.7	395.9	424.8
7	(GCM) MPI, (RCM) REGCM	Historical	92.8	116.3	145.9	189.2	238.0	269.8	314.0	359.1	382.1	427.1	461.4
		RCP4.5	81.1	103.1	133.4	182.4	244.4	288.5	354.1	426.4	465.5	545.2	609.6
		RCP8.5	82.7	103.5	129.4	167.0	209.0	236.2	273.6	311.5	330.9	368.3	396.9
8	(GCM) MPI, (RCM) ROM	Historical	114.0	132.5	153.9	181.7	209.4	225.8	246.9	266.7	276.3	293.9	306.6
		RCP4.5	120.2	140.2	162.1	189.2	214.7	229.3	247.2	263.4	271.0	284.7	294.4
		RCP8.5	120.3	137.9	157.8	183.5	208.8	223.7	242.5	260.1	268.6	284.0	295.1

*Probable rainfall values were evaluated by fitting the generalized extreme value distribution (GEV)

Table 8-27 Estimation of Daily Rainfall of 50-year Return Period (Eight Types of Rainfall Projection Datasets)

No.	GCM	RCM	50-Year Rainfall (mm/day)			Change Rate		
			Historical	RCP4.5	RCP8.5	Historical	RCP4.5	RCP8
1	CNRM	RCA	307.9	177.8	315.3	1	0.577	1
2	CNRM	REGCM	323.0	209.5	173.9	1	0.649	0
3	CSIROMK3.6	REGCM	234.2	399.7	289.8	1	1.707	1
4	ECEARTH	REGCM	330.0	300.6	242.3	1	0.911	0
5	HADGEM	RCA	320.1	512.9	423.6	1	1.602	1
6	HADGEM	REGCM	355.9	252.6	298.4	1	0.710	0
7	MPI	REGCM	314.0	354.1	273.6	1	1.128	0
8	MPI	ROM	246.9	247.2	242.5	1	1.001	0
Max			355.9	512.9	423.6	1	1.707	1
75%			324.8	365.5	302.6	1	1.246	1
50%			317.1	276.6	281.7	1	0.956	0
25%			292.7	237.8	242.5	1	0.694	0
Min			234.2	177.8	173.9	1	0.577	0



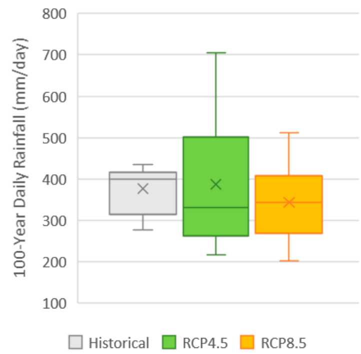
*Red values in the columns of change rate mean that the probable rainfalls will increase in future. On contrary, blue values mean a decrease in rainfall.

*75% denotes the upper quartile, 50% does the median, and 25% does the lower quartile.

*The figure in the right is a box plot for the daily rainfalls of 50-year return period.

Table 8-28 Estimation of Daily Rainfall of 100-year Return Period (Eight Types of Rainfall Projection Datasets)

No.	GCM	RCM	100-Year Rainfall (mm/day)			Change Rate		
			Historical	RCP4.5	RCP8.5	Historical	RCP4.5	RCP8
1	CNRM	RCA	417.1	217.3	412.9	1	0.521	0.
2	CNRM	REGCM	414.8	260.8	202.0	1	0.629	0.
3	CSIROMK3.6	REGCM	292.8	514.2	392.4	1	1.756	1.
4	ECEARTH	REGCM	404.0	351.4	272.1	1	0.870	0.
5	HADGEM	RCA	394.4	705.3	512.4	1	1.788	1.
6	HADGEM	REGCM	434.2	312.1	357.7	1	0.719	0.
7	MPI	REGCM	382.1	465.5	330.9	1	1.218	0.
8	MPI	ROM	276.3	271.0	268.6	1	0.981	0.
Max			434.2	705.3	512.4	1	1.788	1.
75%			415.4	477.7	397.5	1	1.353	1.
50%			399.2	331.8	344.3	1	0.925	0.
25%			359.8	268.5	271.2	1	0.696	0.
Min			276.3	217.3	202.0	1	0.521	0.



*Red values in the columns of change rate mean that the probable rainfalls will increase in future. On contrary, blue values mean a decrease in rainfall.

*75% denotes the upper quartile, 50% does the median, and 25% does the lower quartile.

*The figure in the right is a box plot for the daily rainfalls of 50-year return period.

(ii) Change of Basin Average Monthly and Annual Rainfalls(Reference)

To further look into characteristics of the rainfall projection data used in the above change rates of the basin average monthly and annual rainfalls of the entire area of the 15 river basins were examined. The basin average rainfall of the entire 15 river basin area was estimated simply as an arithmetic average of rainfalls of the selected grid squares. The time lengths for the current and future rainfalls were set to be 20 years, namely from 1985 to 2004 for the current rainfall and from 2030 to 2049 for the future rainfall to estimate the change rate by comparing those of the same time length.

Table 8-29 Data Used for Estimation of Basin Average Rainfalls

No.	GCM	RCM	Spatial Resolution		Selected Grid No. for MAP	Time Step	Past period	Future period
			Grid Size	Grid No.				
1	CNRM	RCA	approx. 25 km	9 (Long) x 11 (Lat)	11 grids	Daily	1985/1/1 - 2004/12/31 (20 years)	2030/1/1 - 2049/12/31 (20 years)
2	CNRM	REGCM		9 (Long) x 10 (Lat)				
3	CSIROMK3.6	REGCM						
4	ECEARTH	REGCM						
5	HADGEM	RCA		9 (Long) x 11 (Lat)				
6	HADGEM	REGCM		9 (Long) x 10 (Lat)				
7	MPI	REGCM						
8	MPI	ROM	approx. 55 km	5 (Long) x 5 (Lat)	4 grids			

*The datasets were developed by the SEACLID/CORDEX-SEA Project (http://www.ukm.edu.my/seaclid-cordex/)

*GCM: General Circulation Model, RCM: Regional Climate Model, MAP: Mean Areal Precipitation for the target river basins

*The datasets No. 6 and No. 7 lack the data between 19 JUL 2049 and 31 DEC 2049.

A) Change of Basin Average Monthly Rainfall

Estimated basin average monthly rainfalls of the eight datasets were presented in Table 8-30, Figure 8-28, Figure 8-29 and Figure 8-30.

Figure 8-28 shows monthly rainfalls of the ensemble averages of the eight datasets presented in Table 8-30. There is seen a clear change that the future average monthly rainfall decreases in the dry season but increase in the rain season for both cases of the RCP4.5 and RCP8.5 scenarios. Carefully looking at monthly rainfalls of each dataset in Figure 8-30, an abnormal seasonal variation of monthly rainfall is found in two datasets of Nos. 5 and 6 of which GCM is HADGEM. Considering that the data periods of the HADGEM datasets don't start on January 1 and don't end on December 31, it is suspected that there was something wrong in extracting HADGEM data although it could not be clarified by hearing to BMKG because the datasets were produced by the SEACLID/CORDEC-SEA project.

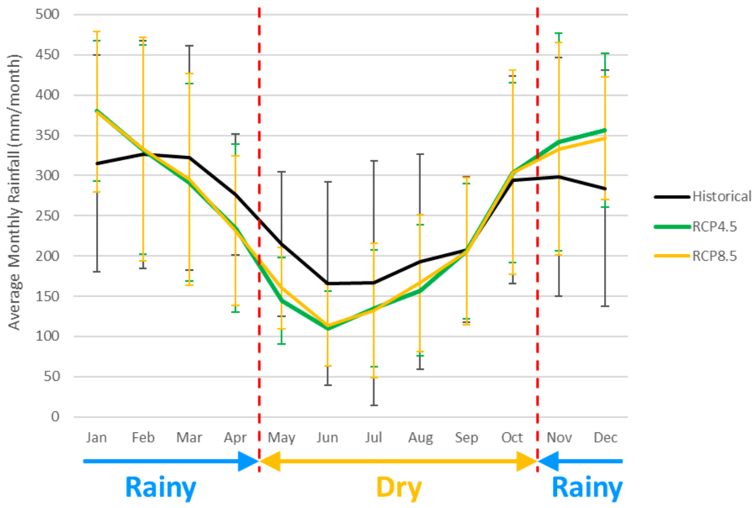
Therefore, it might be rational to exclude the HADGEM datasets (Nos 5 and 6). Figure 8-29 shows monthly rainfalls of the ensemble averages of the six datasets except for the HADGEM datasets. There is neither significant seasonal change seen for the RCP4.5 nor RCP8.5 scenarios in the figure. However, it is noted that the monthly rainfall of January, the rain-richest month will increase about 4% for the RCP4.5 scenario about 3% for the RCP8.5 scenario respectively.

Table 8-30 Estimated Basin Average Monthly Rainfalls

No.	GCM & RCM	Case	Average Monthly Rainfall (mm/month)											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	(GCM) CNRM, (RCM) RCA	Historical	198	174	179	180	91	25	15	27	37	86	197	230
		RCP4.5	209	185	203	197	88	31	45	42	54	112	162	205
		RCP8.5	199	170	208	174	105	27	22	34	44	96	155	234
2	(GCM) CNRM, (RCM) REGCM	Historical	511	516	427	292	166	53	63	114	168	244	335	310
		RCP4.5	487	476	425	330	111	62	79	104	180	246	282	335
		RCP8.5	487	523	444	327	139	50	59	118	140	237	265	320
3	(GCM) CSIROMK3.6, (RCM) REGCM	Historical	372	468	487	326	232	148	145	149	201	285	290	280
		RCP4.5	473	537	423	294	187	123	121	139	201	235	243	430
		RCP8.5	469	483	453	286	178	117	104	137	202	198	256	305
4	(GCM) ECEARTH, (RCM) REGCM	Historical	377	385	354	352	207	122	110	211	297	496	615	584
		RCP4.5	361	328	327	379	205	140	188	226	348	513	618	506
		RCP8.5	374	355	329	285	181	144	168	233	287	498	629	483
5	(GCM) HADGEM, (RCM) RCA	Historical	90	130	165	232	247	247	263	245	201	154	98	67
		RCP4.5	305	200	150	83	69	130	188	242	258	304	279	274
		RCP8.5	299	169	138	106	111	156	216	266	263	294	281	349
6	(GCM) HADGEM, (RCM) REGCM	Historical	180	227	288	314	410	456	526	506	348	324	177	158
		RCP4.5	387	252	181	127	143	191	280	296	276	406	452	442
		RCP8.5	409	242	203	154	178	192	295	303	362	473	413	424
7	(GCM) MPI, (RCM) REGCM	Historical	447	473	524	366	232	151	131	173	262	455	390	400
		RCP4.5	451	458	457	328	230	111	97	105	193	325	414	388
		RCP8.5	497	487	451	377	269	123	99	121	176	358	332	382
8	(GCM) MPI, (RCM) ROM	Historical	347	239	152	151	134	125	78	115	151	313	287	242
		RCP4.5	369	223	165	139	122	88	82	103	138	287	285	274
		RCP8.5	299	232	137	142	120	102	97	119	173	277	335	272
Ensemble Average of the 6 datasets without No.5 & No.6 datasets		Historical	375	376	354	278	177	104	90	132	186	313	352	341
		RCP4.5	392	368	333	278	157	93	102	120	185	286	334	356
		RCP8.5	388	375	337	265	165	94	91	127	170	277	329	333
Change Rate		Historical	1	1	1	1	1	1	1	1	1	1	1	1
		RCP4.5	1.044	0.979	0.942	1.000	0.887	0.891	1.129	0.911	0.998	0.915	0.948	1.045
		RCP8.5	1.033	0.998	0.952	0.955	0.934	0.901	1.013	0.965	0.915	0.886	0.933	0.975
Standard Deviation of the 6 datasets		Historical	96	127	143	83	52	48	44	57	84	136	131	122
		RCP4.5	95	132	113	83	53	37	44	55	88	121	147	99
		RCP8.5	110	135	126	82	54	41	45	58	72	126	147	81

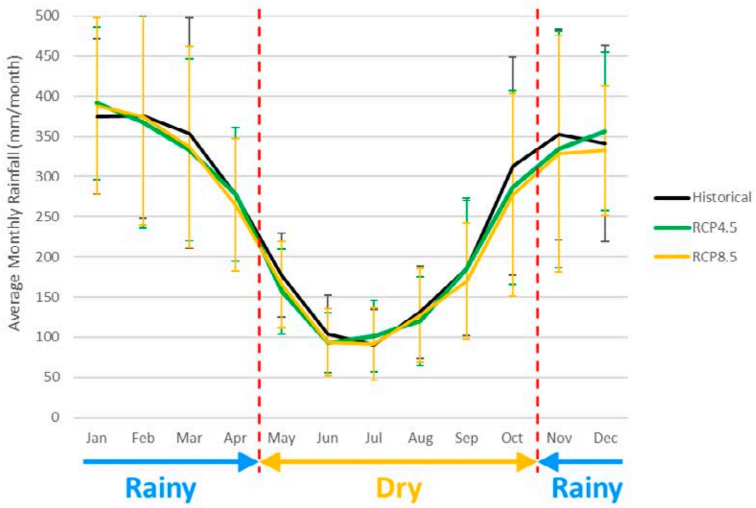
*Rainy Season: November-April, Dry Season: May-October

*Since the 2 cases (GCM: HADGEM, RCM: RCA and REGCM) lack the future projection data between 19 Jul 2049 and 31 Dec 2049 in both RCP4.5 and RCP8.5 scenarios, average monthly rainfall was calculated between 2030-2048 for July to December.



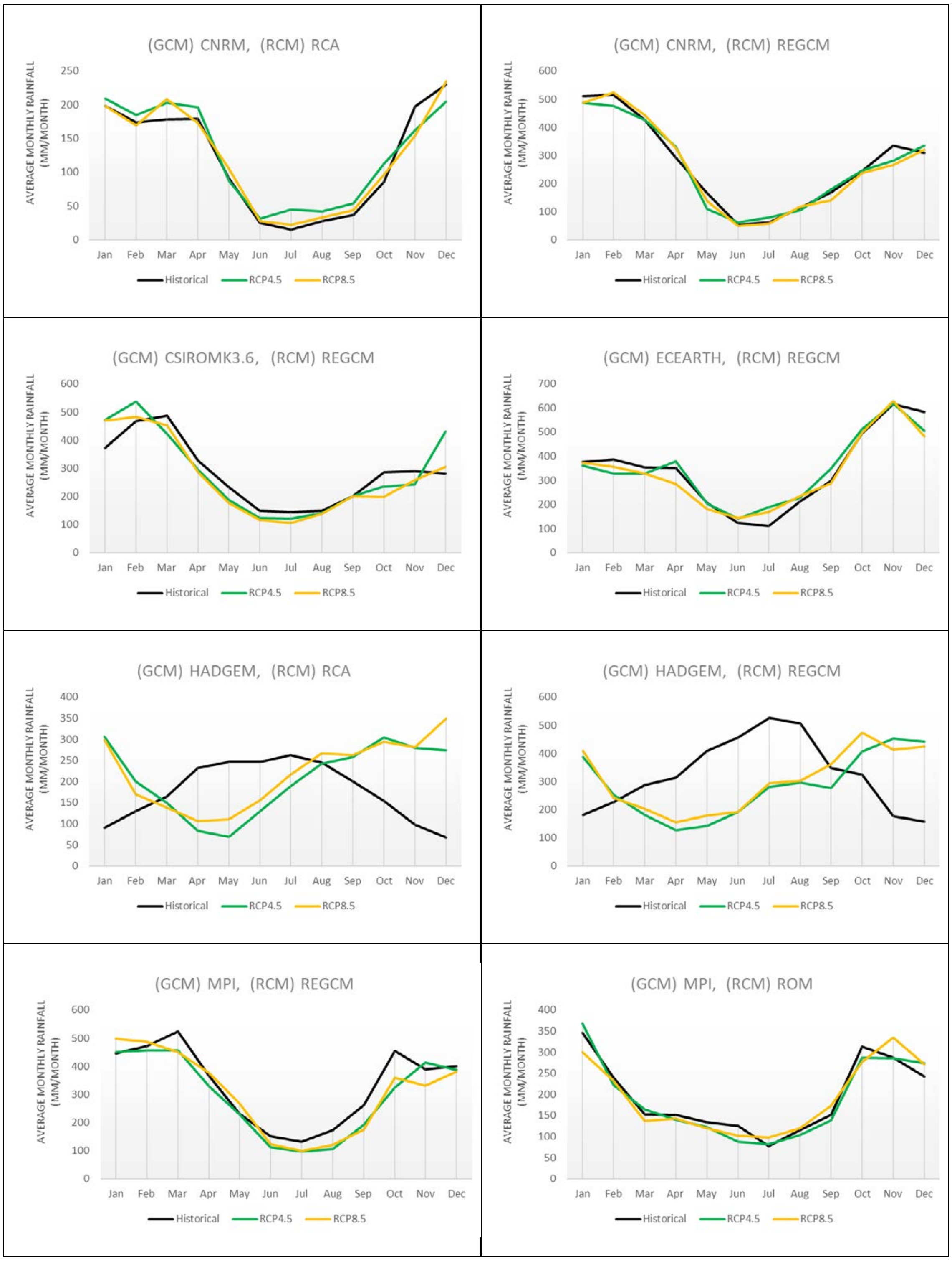
*Error bars show standard deviation (N=8, 8 datasets)

Figure 8-28 Comparison of Monthly Rainfall (Ensemble Average of Eight Datasets)



*Error bars show standard deviation (N=6, without the "GCM: HADGEM" cases)

Figure 8-29 Comparison of Monthly Rainfall (Ensemble Average of Six Datasets)



*Since the 2 cases (GCM: HADGEM, RCM: RCA and REGCM) lack the future projection data between 19 Jul 2049 and 31 Dec 2049 in both RCP4.5 and RCP8.5 scenarios, average monthly rainfall was calculated between 2030-2048 for July to December.

Figure 8-30 Basin Average Monthly Rainfalls of Eight Datasets

B) Change of Basin Average Annual and Seasonal Rainfalls

Basin average annual rainfalls and their change rates for the eight datasets were estimated as presented in Table 8-31 and Figure 8-31. Similarly, basin average seasonal rainfalls (rainy season: November to April, dry season: May to October) and their change rates were also estimated as presented in Table 8-32 and Figure 8-32.

According to the estimation results under the RCP4.5 scenario, basin average annual rainfalls of four datasets will increase in future, but those of the four other datasets will decrease on the contrary. However, the arithmetic average and median of the change rates were estimated at 0.977 and 0.991 respectively, indicating a tendency of slight decrease.

As for the RC8.5 scenario, basin average annual rainfalls of two datasets will increase in future, but those of the six other datasets will decrease on the contrary. The arithmetic average and median of the change rates were estimated at 0.979 and 0.957 respectively, indicating a tendency of slight decrease.

Table 8-31 Estimated Basin Average Annual Rainfall and Their Change Rates

No.	GCM	RCM	Average Annual Rainfall (mm)			Change Rate		
			Historical	RCP4.5	RCP8.5	Historical	RCP4.5	RCP8.5
1	CNRM	RCA	1,437	1,533	1,467	1	1.067	1.021
2	CNRM	REGCM	3,198	3,118	3,109	1	0.975	0.972
3	CSIROMK3.6	REGCM	3,382	3,406	3,189	1	1.007	0.943
4	ECEARTH	REGCM	4,110	4,138	3,965	1	1.007	0.965
5	HADGEM	RCA	2,138	2,504	2,639	1	1.171	1.234
6	HADGEM	REGCM	3,914	3,432	3,647	1	0.877	0.932
7	MPI	REGCM	4,005	3,554	3,670	1	0.888	0.916
8	MPI	ROM	2,334	2,274	2,305	1	0.974	0.988
Average			3,065	2,995	2,999	1	0.977	0.979
Max			4,110	4,138	3,965	1	1.007	0.965
75%			3,937	3,462	3,653	1	0.880	0.928
50%			3,290	3,262	3,149	1	0.991	0.957
25%			2,285	2,447	2,556	1	1.071	1.118
Min			1,437	1,533	1,467	1	1.067	1.021

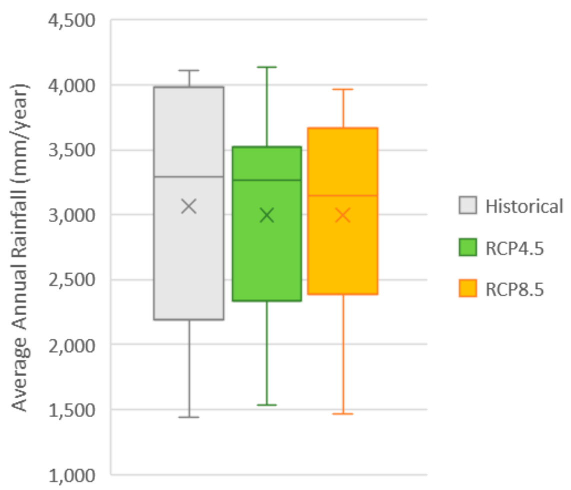


Figure 8-31 Box Plotting of Basin Average Annual Rainfalls by Climate Scenarios

Regarding basin average seasonal and annual rainfalls, their averages, medians and quartiles were estimated from the six datasets excluding the two HADGEM datasets that include an abnormal variation of current monthly rainfalls as discussed in 8.2.2(2)(ii) Change of Basin Average Monthly and Annual Rainfalls(Reference.

According to the estimation results under the RCP4.5 scenario, basin average rainy season rainfalls of three datasets will increase in future, but those of the three other datasets will decrease on the contrary. However, the arithmetic average and median of the change rates were estimated at 0.935 and 0.905 respectively, indicating a tendency of decrease.

As for the RC8.5 scenario, basin average rainy season rainfall of one dataset will increase in future, but those of the five other datasets will decrease on the contrary. The arithmetic average and median of the change rates were estimated at 0.979 and 0.957 respectively, indicating a tendency of decrease.

Table 8-32 Basin Average Annual and Seasonal Rainfalls and Their Change Rates

Item	Period	Rainy/ Dry/ Total	1 CNRM RCA	2 CNRM REGCM	3 CSIROMK3.6 REGCM	4 ECEARTH REGCM	5 HADGEM RCA	6 HADGEM REGCM	7 MPI REGCM	8 MPI ROM	Average	Max	75%	50%	25%	Min
Annual Rainfall (mm/year)	Historical	Rainy	1,157	2,390	2,222	2,667	782	1,344	2,601	1,418	2,076	2,667	2,548	2,306	1,619	1,157
		Dry	280	808	1,159	1,443	1,356	2,570	1,404	916	1,002	1,443	1,343	1,038	835	280
		Total	1,437	3,198	3,382	4,110	2,138	3,914	4,005	2,334	3,065	4,110	3,937	3,290	2,285	1,437
	RCP4.5	Rainy	1,161	2,336	2,400	2,519	1,319	1,840	2,495	1,454	1,940	2,519	2,424	2,088	1,420	1,161
		Dry	372	782	1,006	1,619	1,185	1,592	1,060	821	1,054	1,619	1,287	1,033	811	372
		Total	1,533	3,118	3,406	4,138	2,504	3,432	3,554	2,274	2,995	4,138	3,462	3,262	2,447	1,533
	RCP8.5	Rainy	1,138	2,366	2,253	2,455	1,349	1,845	2,525	1,417	1,919	2,525	2,388	2,049	1,400	1,138
		Dry	328	742	936	1,510	1,290	1,802	1,146	888	1,080	1,802	1,345	1,041	852	328
		Total	1,467	3,109	3,189	3,965	2,639	3,647	3,670	2,305	2,999	3,965	3,653	3,149	2,556	1,467
Change Rate	RCP4.5/ Historical	Rainy	1.003	0.977	1.080	0.945	1.687	1.369	0.959	1.026	0.935	0.945	0.951	0.905	0.877	1.003
		Dry	1.329	0.968	0.868	1.122	0.874	0.620	0.755	0.895	1.053	1.122	0.958	0.995	0.971	1.329
		Total	1.067	0.975	1.007	1.007	1.171	0.877	0.888	0.974	0.977	1.007	0.880	0.991	1.071	1.067
	RCP8.5/ Historical	Rainy	0.983	0.990	1.014	0.921	1.725	1.373	0.971	1.000	0.924	0.947	0.937	0.889	0.865	0.983
		Dry	1.174	0.919	0.807	1.046	0.952	0.701	0.816	0.969	1.078	1.249	1.002	1.003	1.020	1.174
		Total	1.021	0.972	0.943	0.965	1.234	0.932	0.916	0.988	0.979	0.965	0.928	0.957	1.118	1.021

*75% denotes the upper quartile, 50% does the median, and 25% does the lower quartile.

*Red values in the columns of change rate mean that the rainfalls will increase in future. On contrary, blue values mean a decrease in rainfall.

*Averages, medians and quartiles of rainfalls were estimated from the six datasets, excluding the two HADGEM datasets that include abnormal monthly rainfalls.

*Rainy Season: November-April, Dry Season: May-October

*Error bars show standard deviation (N=20, Historical: 1985-2004, RCP4.5/8.5: 2030-2049)

*Since the two cases (GCM: HADGEM, RCM: RCA and REGCM) lack the future projection data between 19 Jul 2049 and 31 Dec 2049 in both RCP4.5 and RCP8.5 scenarios, average annual rainfall was calculated between 2030-2048 (N=19).

Figure 8-32 Comparison of Basin Average Annual and Seasonal Rainfalls by Climate Scenario

(iii) Spatial Distribution of Rainfall (Reference)

Colored rainfall spatial distribution maps were prepared by calculating average annual rainfall and average annual maximum daily rainfall of each grid square of the entire data coverage area to identify the spatial distribution characteristics of the rainfall projection data. The data periods are 20 years from 1985 to 2004 for the historical data (current climate) and from 2030 to 2049 for the future data (future climate).

Since the rainfall projection data by the GCMs contain uncertainties and biases, the tendencies of the spatial distribution of rainfall and the future change of rainfall within the same model were discussed in the followings, not paying special attention to the projection data values.

Table 8-33 Data Used for Examination of Spatial Distribution of Rainfall

No.	GCM	RCM	Spatial Resolution		Time Step	Past period	Future period
			Grid Size	Grid No.		Year	Year
1	CNRM	RCA	approx. 25 km	9 (Long) x 11 (Lat)	Daily	1985/1/1 - 2004/12/31 (20 years)	2030/1/1 - 2049/12/31 (20 years)
2	CNRM	REGCM		9 (Long) x 10 (Lat)			
3	CSIROMK3.6	REGCM					
4	ECEARTH	REGCM					
5	HADGEM	RCA		9 (Long) x 11 (Lat)			
6	HADGEM	REGCM		9 (Long) x 10 (Lat)			
7	MPI	REGCM					
8	MPI	ROM	approx. 55 km	5 (Long) x 5 (Lat)			

*The datasets were developed by the SEACLID/CORDEX-SEA Project (http://www.ukm.edu.my/seaclid-cordex/)
*GCM: General Circulation Model, RCM: Regional Climate Model
*The datasets No. 6 and No. 7 lack the data between 19 JUL 2049 and 31 DEC 2049.

A) Spatial Distribution of Average Annual Rainfall

Spatial distribution maps of average annual rainfalls of the three cases (historical, RCP4.5 and RCP8.5) are shown in Figure 8-33, Figure 8-34 and Figure 8-35 respectively.

The average annual rainfall of all the three cases is generally larger in the mountainous areas. There is also seen a tendency the average annual rainfall is smaller in the south of the mountain range of southern Java. However, the tendency is not clear for the datasets No. 8 of which RCM is ROM, due to its coarse spatial resolution.

As for the study area, the average annual rainfall seems generally larger in the upper (southern) area than the lower (northern) area. The average annual rainfall is generally larger for the datasets of which RCM is REGCM than those of RCA.

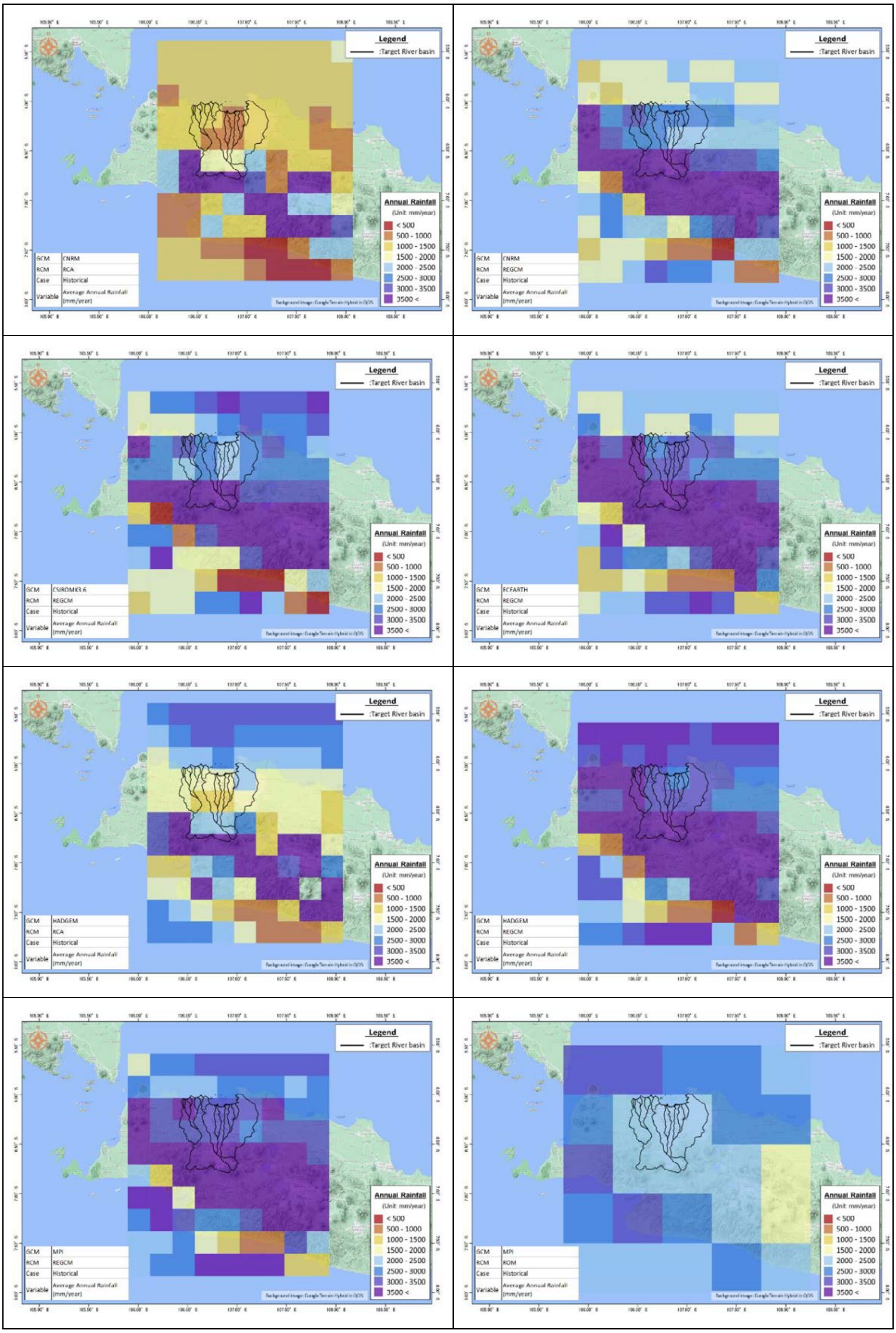


Figure 8-33 Spatial Distribution of Average Annual Rainfall (Historical: 1985-2004)

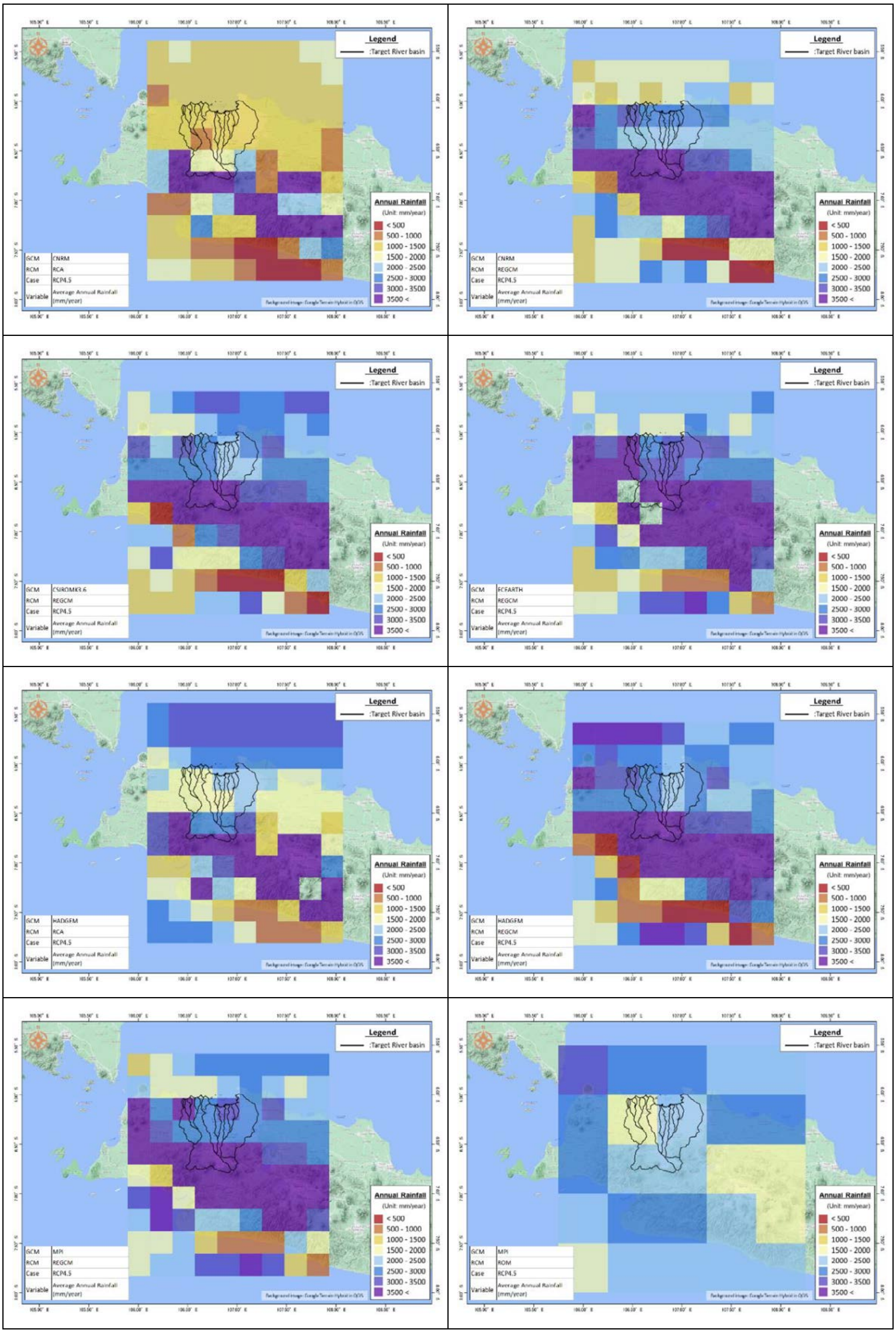


Figure 8-34 Spatial Distribution of Average Annual Rainfall (RCP4.5: 2030-2049)

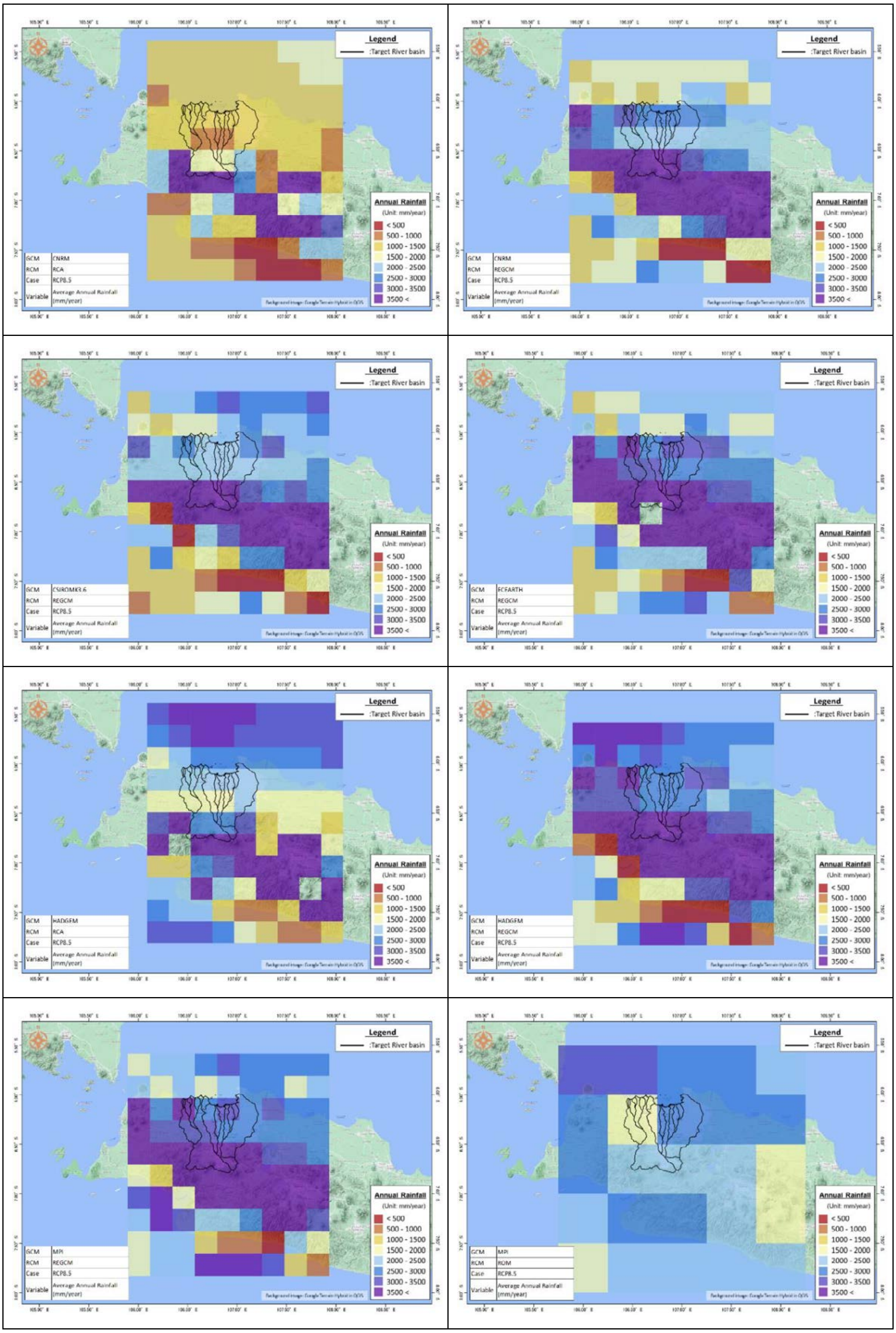


Figure 8-35 Spatial Distribution of Average Annual Rainfall (RCP8.5: 2030-2049)

B) Spatial Distribution of Average Annual Maximum Daily Rainfall

Spatial distribution maps of average annual maximum daily rainfalls of the three cases (historical, RCP4.5 and RCP8.5) are shown in Figure 8-36Figure 8-37 and Figure 8-38 respectively.

A tendency that the average annual maximum daily rainfall is generally larger in the mountainous areas is seen in all the datasets of the three climate scenarios.

As for the study area, the average annual maximum daily rainfall seems generally larger in the upper (southern) area than the lower (northern) area.

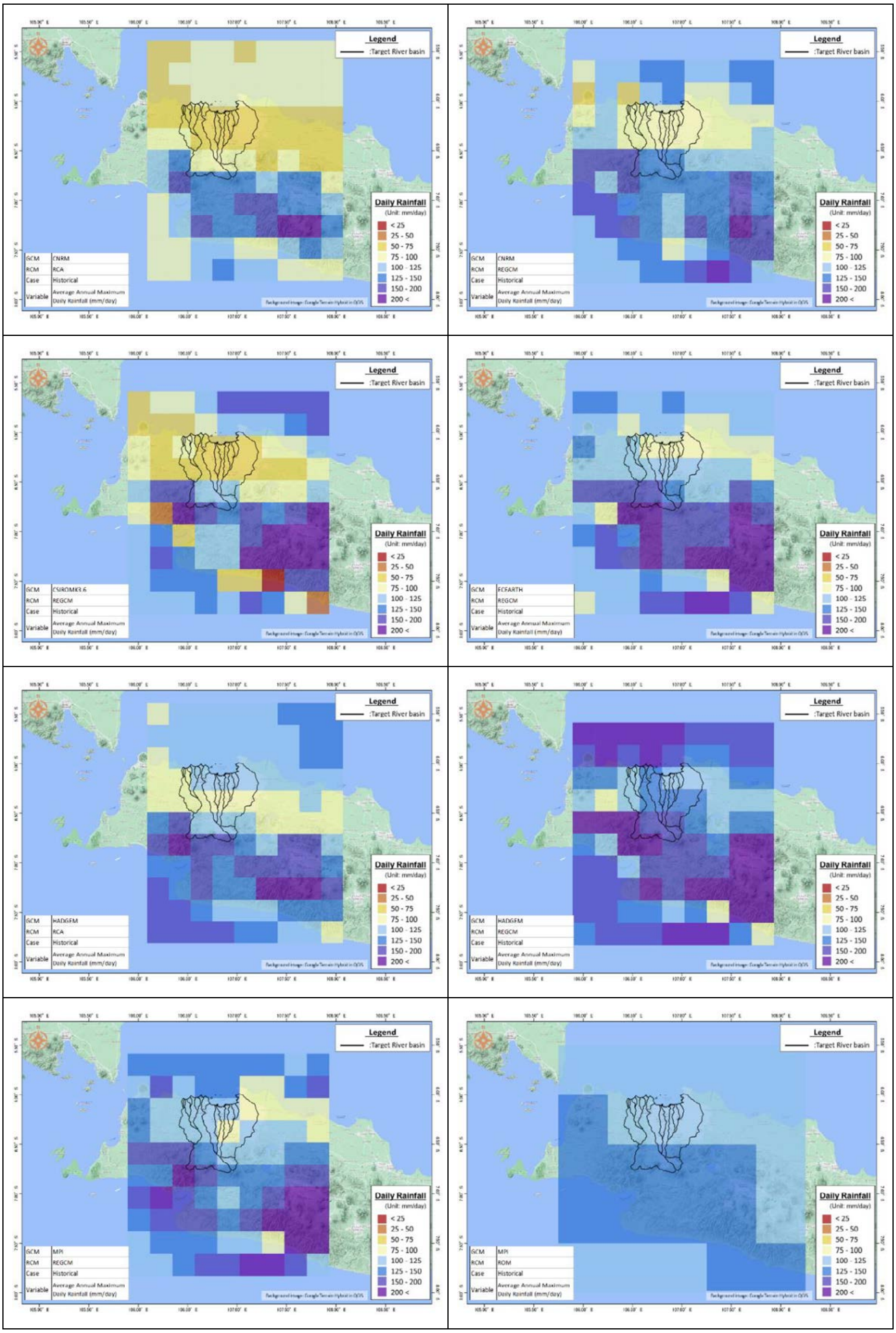


Figure 8-36 Spatial Distribution of Average Annual Maximum Daily Rainfall (Historical: 1985-2004)

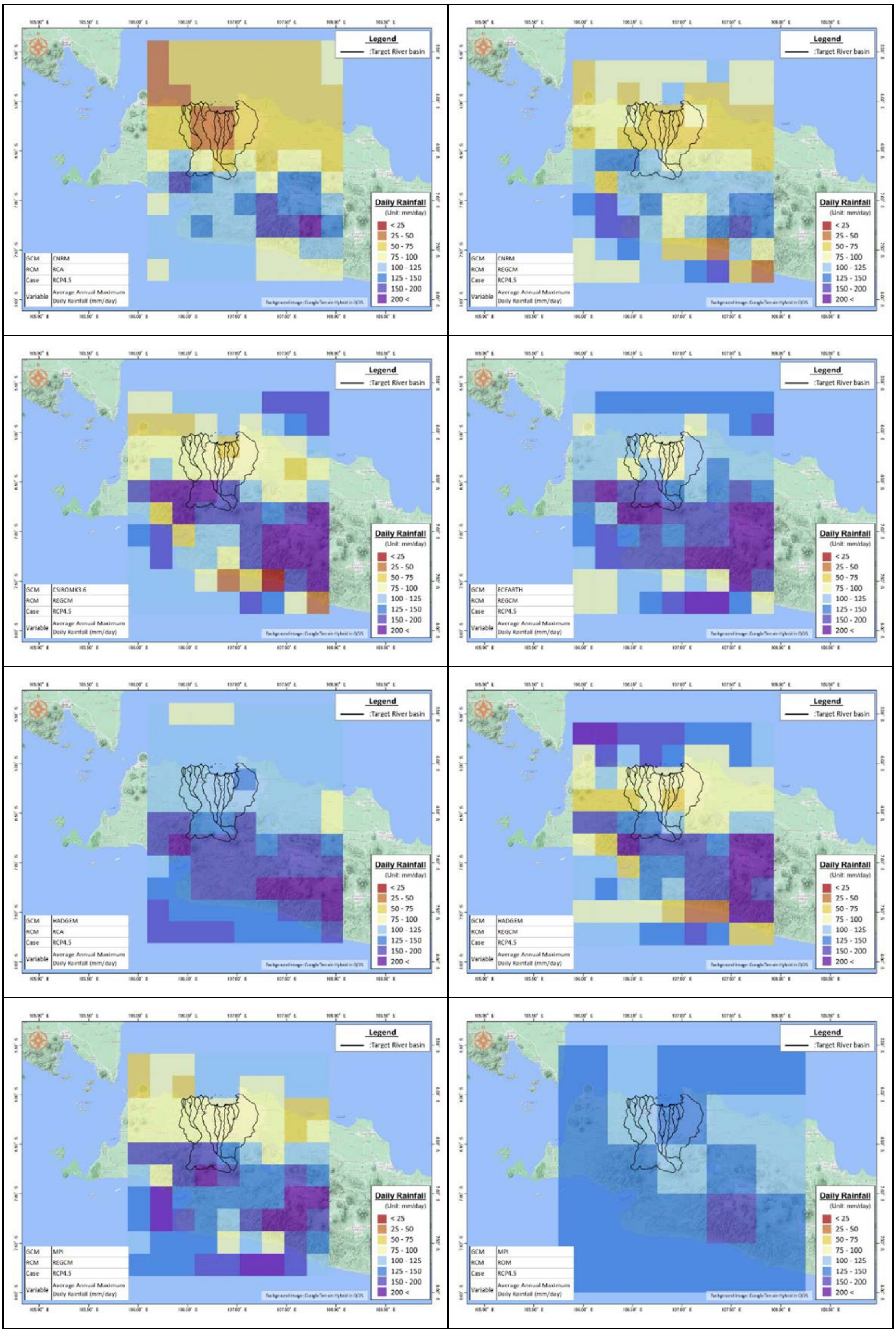


Figure 8-37 (b) Spatial Distribution of Average Annual Maximum Daily Rainfall (RCP4.5: 2030-2049)

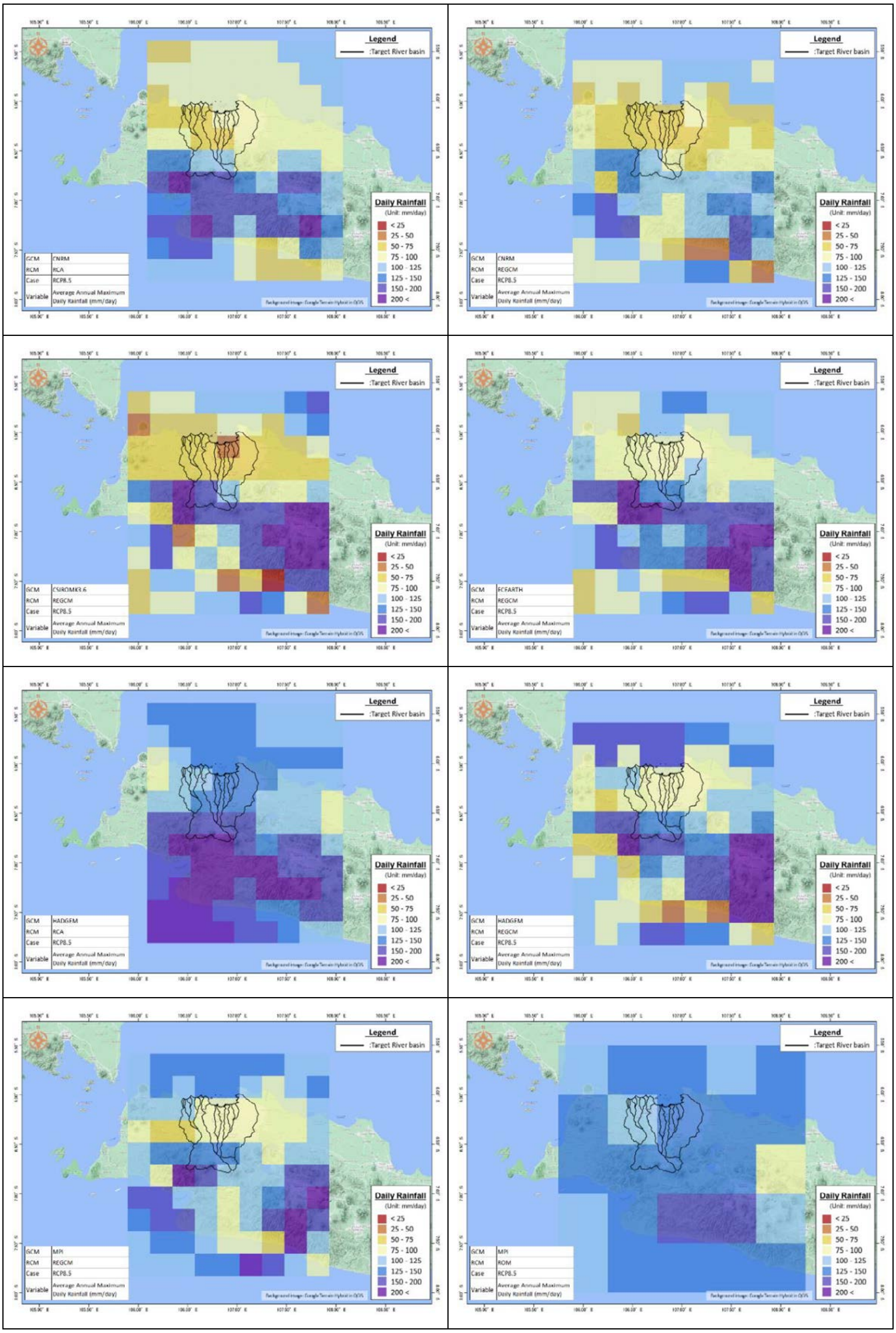


Figure 8-38 (b) Spatial Distribution of Average Annual Maximum Daily Rainfall (RCP8.5: 2030-2049)

C) Spatial Distribution of Change Rate of Average Annual Rainfall

Spatial distribution maps of change rates of average annual rainfall of the two cases (RCP4.5/Historical and RCP8.5/Historical) are shown in Figure 8-39 and Figure 8-40 respectively.

The distribution patterns are different, depending on the dataset. Regarding the change rates in the study area of the case of RCP4.5/Historical, a clear increasing tendency is seen for the datasets Nos. 1 (CNRM, RCA) and 5 (HAGEM, RCA), but a clear decreasing tendency is seen for the Nos. 6 (HADGEM, REGCM) and 7 (MPI, REGCM). As for the other datasets, grid squares of increase and decrease are mixed.

Regarding those of the case of RCP8.5/Historical, an increasing tendency is seen for the datasets Nos. 1 (CNRM, RCA) and 5 (HAGEM, RCA), but a decreasing tendency is generally seen for the other datasets except for No. 8 (MPI, ROM).

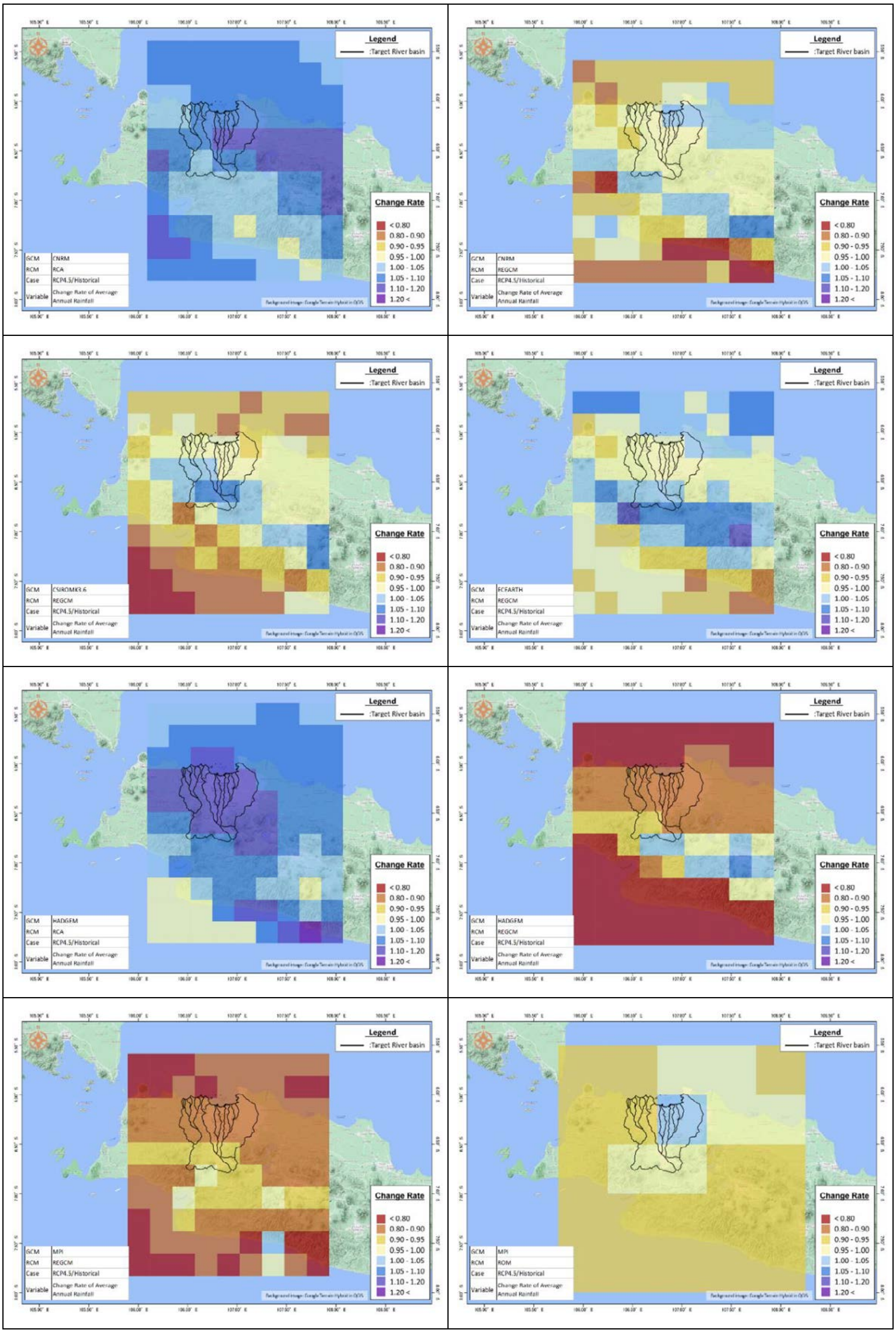


Figure 8-39 Spatial Distribution of Change Rate of Average Annual Rainfall (RCP4.5/Historical)

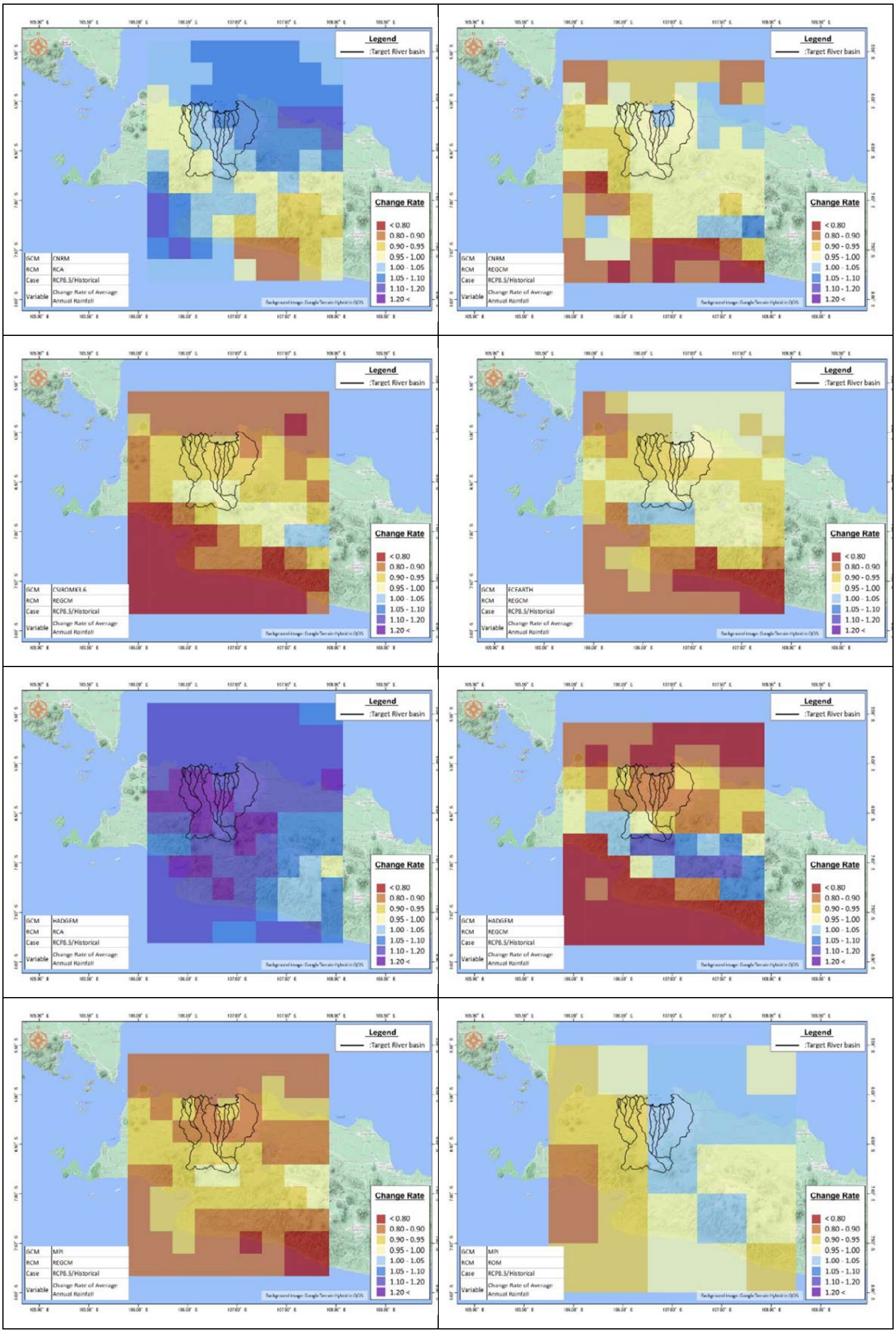


Figure 8-40 Spatial Distribution of Change Rate of Average Annual Rainfall (RCP8.5/Historical)

D) Spatial Distribution of Change Rate of Annual Maximum Daily Rainfall

Spatial distribution maps of change rates of average annual maximum daily rainfall of the two cases (RCP4.5/Historical and RCP8.5/Historical) are shown in Figure 8-41 and Figure 8-42 respectively.

The distribution patterns are different, depending on the dataset. Regarding the change rates in the study area of the case of RCP4.5/Historical, a clear increasing tendency is seen for the datasets No. 5 (HADGEM, RCA), but a clear decreasing tendency is seen for the Nos. 1 (CNRM, RCA), 2 (CNRM, REGCM) and 6 (HADGEM, REGCM). As for the other datasets, grid squares of increase and decrease are mixed.

Regarding those of the case of RCP8.5/Historical, an increasing tendency is seen for the datasets Nos. 1 (CNRM, RCA) and 5 (HAGEM, RCA), but a decreasing tendency is seen for the datasets Nos. 2 (CNRM, REGCM) and 6 (HAGEM, REGCM). As for the other datasets, grid squares of increase and decrease are mixed.

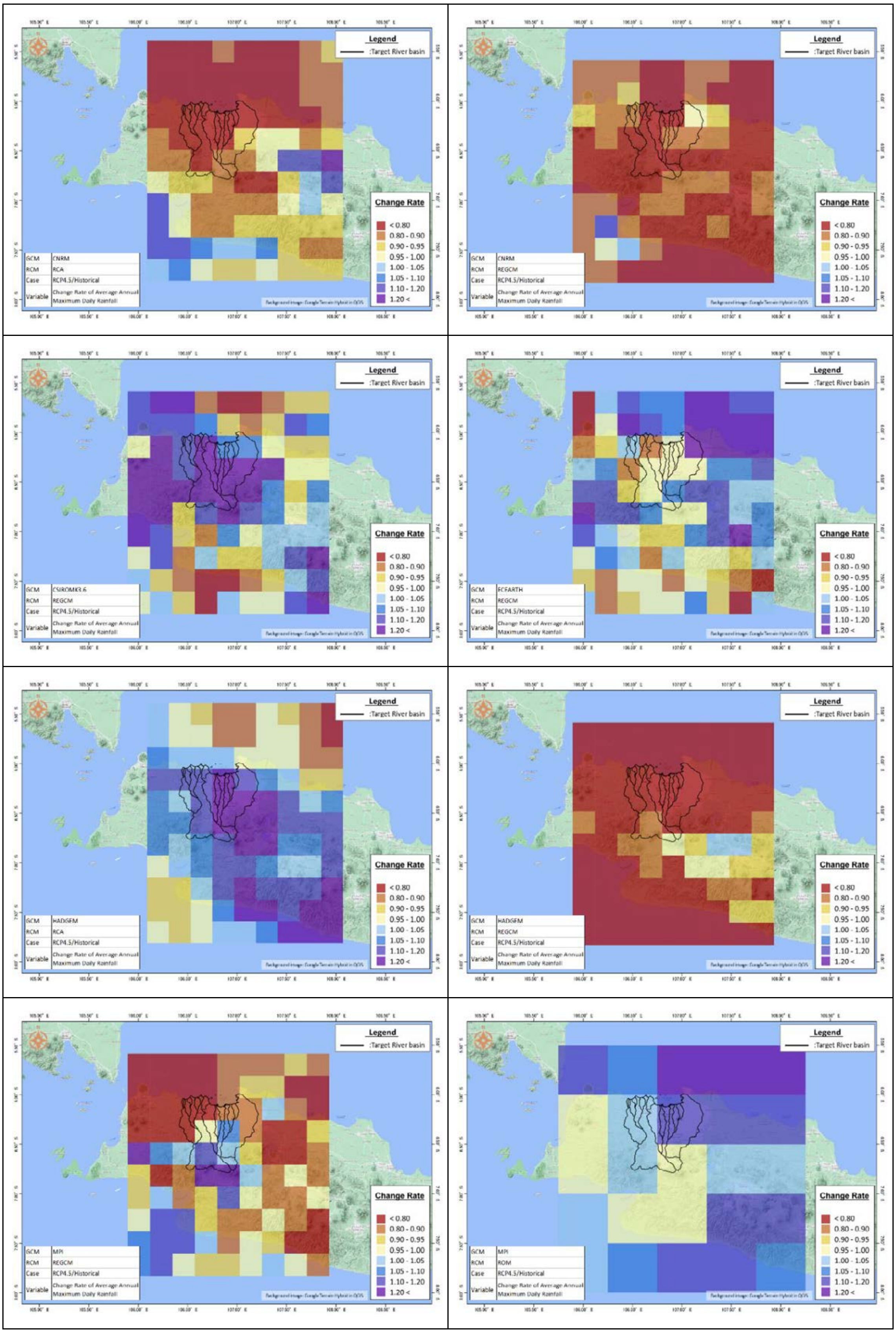


Figure 8-41 Spatial Distribution of Change Rate of Average Annual Maximum Daily Rainfall (RCP4.5/Historical)

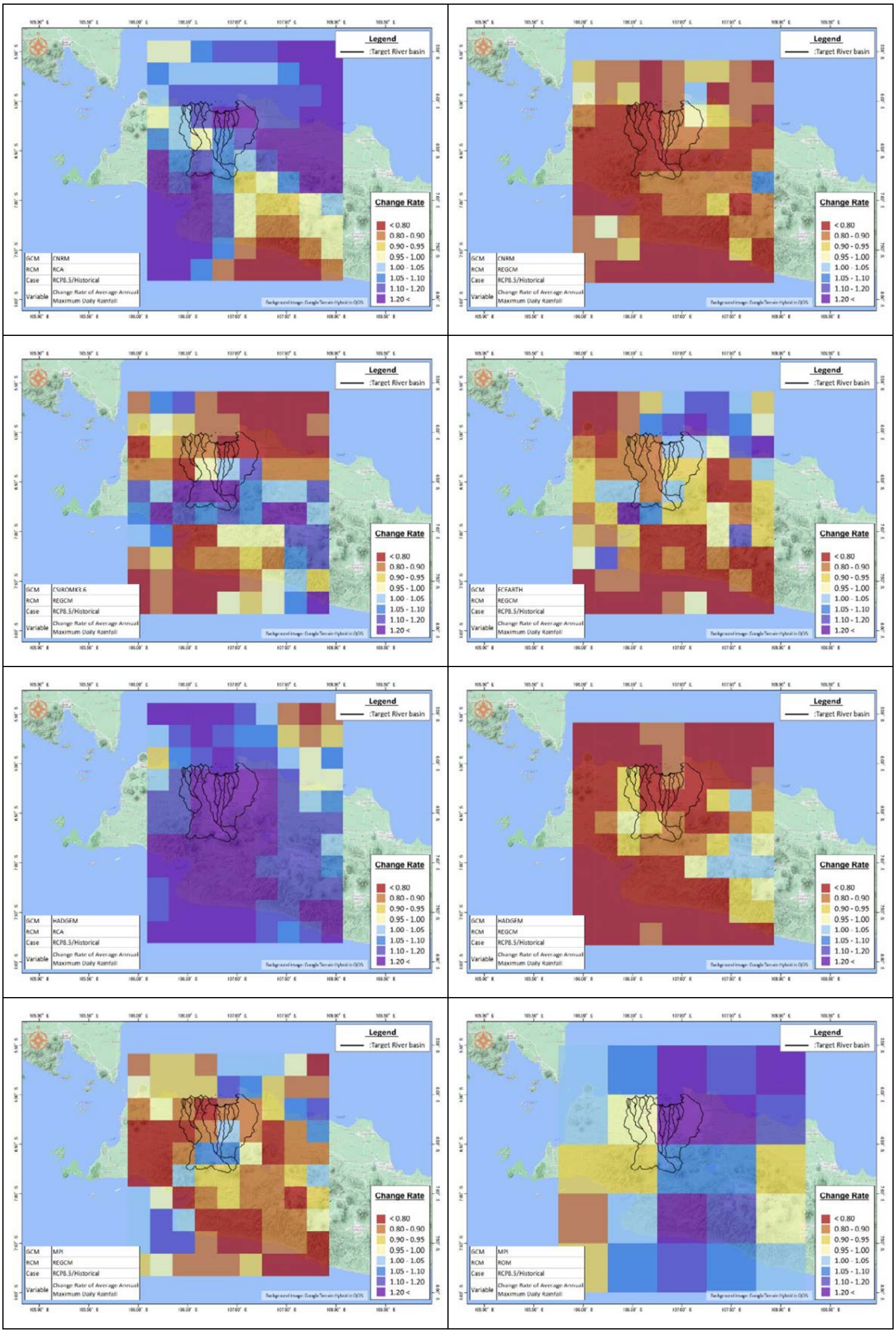


Figure 8-42 Spatial Distribution of Change Rate of Average Annual Maximum Daily Rainfall (RCP8.5/Historical)

E) Distribution Maps for Each Dataset

The above distribution maps of annual rainfall, annual maximum daily rainfall and their change rates were rearranged for each of the eight datasets as shown in figures from Figure 8-43 through Figure 8-50. Each figure includes a short description on the future changes of the annual rainfall and the annual maximum daily rainfall in the study area.

- Under the RCP4.5 scenario the average annual rainfall tends to clearly increase, but the average annual maximum daily rainfall tends to clearly decrease.
- Under the RCP8.5 scenario both of the average annual rainfall and average annual maximum daily rainfall tend to increase.

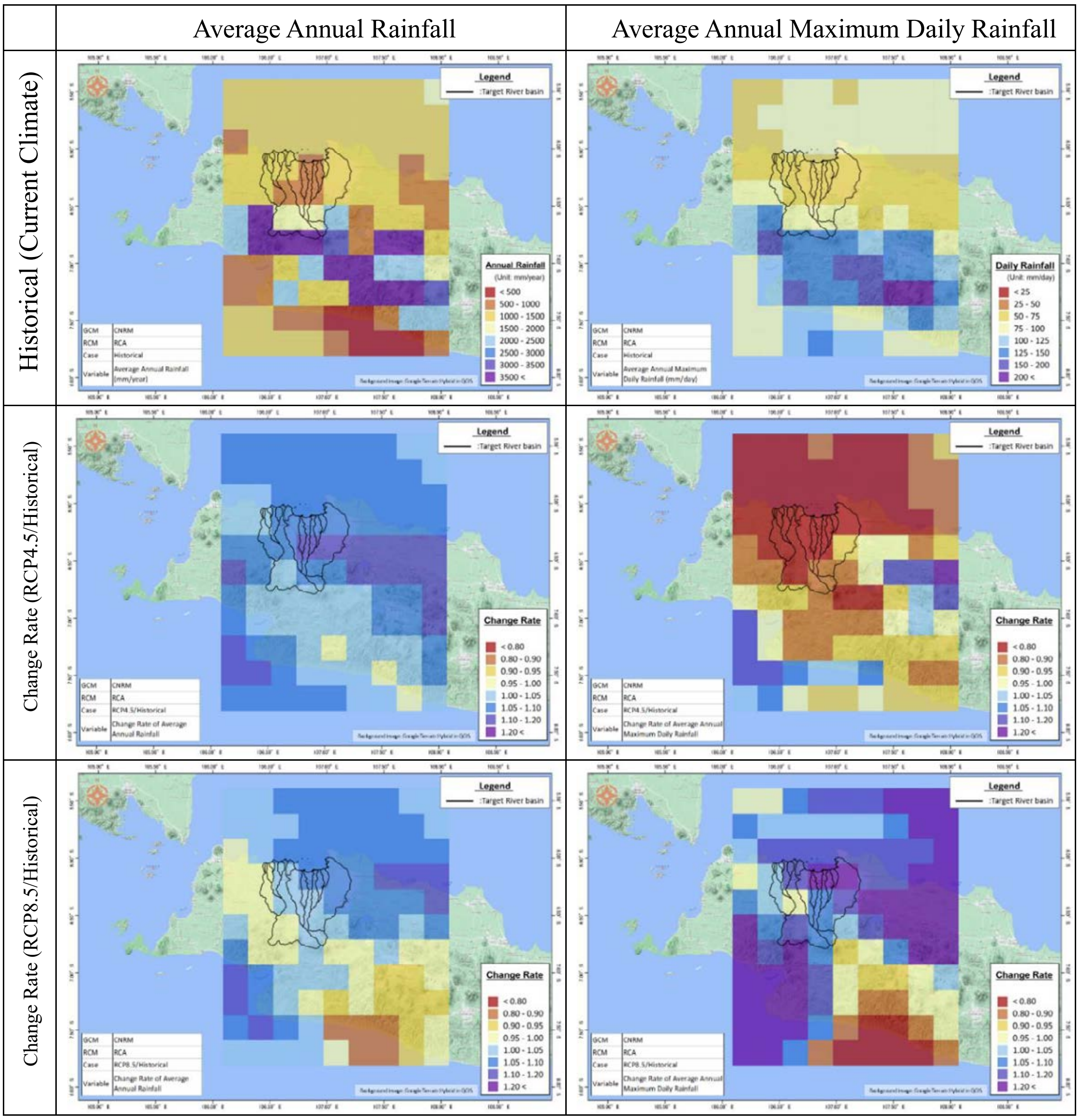


Figure 8-43 Distribution Maps of Each Dataset (No.1 GCM:CNRM, RCM:RCA)

- Under the RCP4.5 scenario the average annual rainfall tends to slightly decrease, but the average annual maximum daily rainfall tends to clearly decrease.
- Under the RCP8.5 scenario the average annual rainfall tends to slightly decrease, but the average annual maximum daily rainfall tends to clearly decrease.

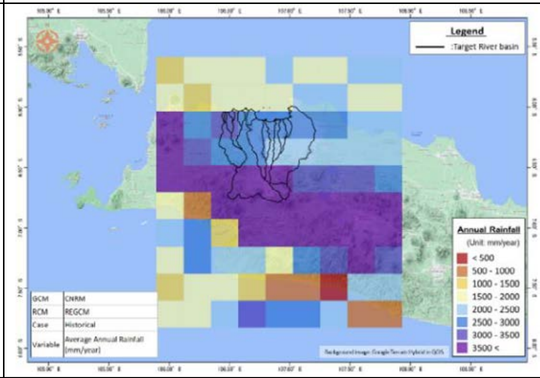
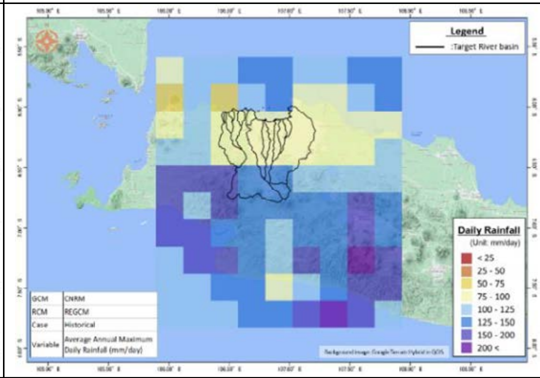
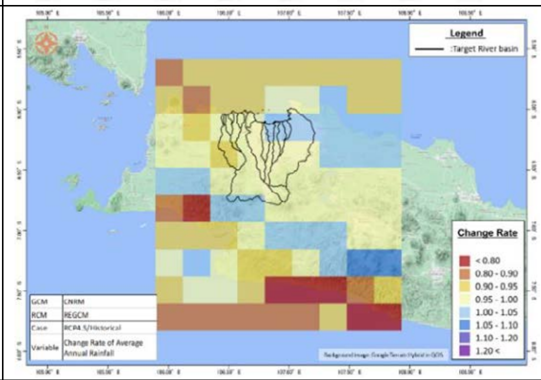
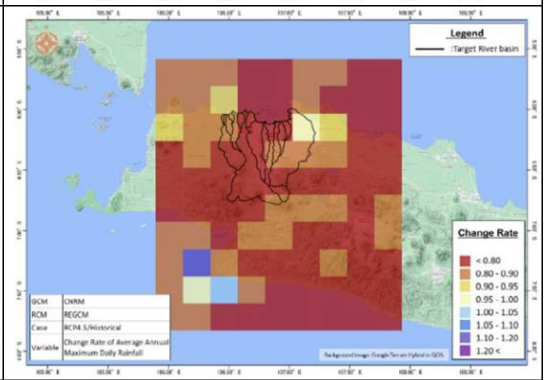
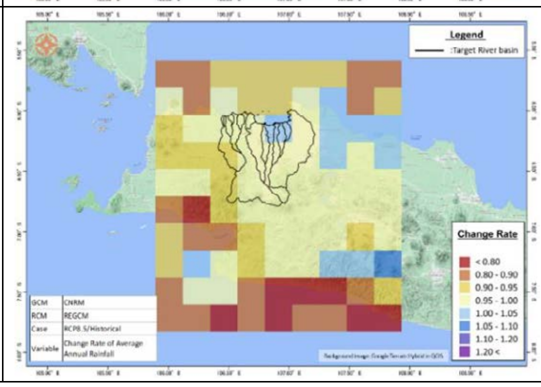
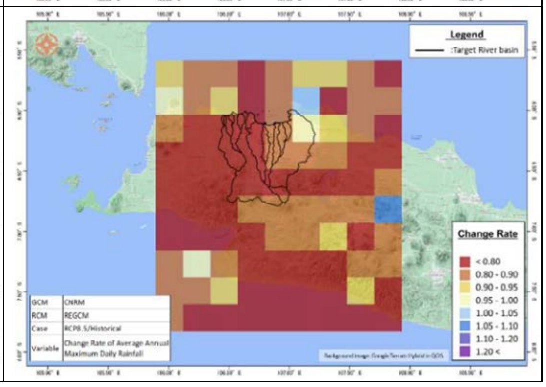
	Average Annual Rainfall	Average Annual Maximum Daily Rainfall
Historical (Current Climate)		
Change Rate (RCP4.5/Historical)		
Change Rate (RCP8.5/Historical)		

Figure 8-44 Distribution Maps of Each Dataset (No.2 GCM:CNRM, RCM:REGCM)

- Under the RCP4.5 scenario the average annual rainfall tends to increase in the upper area but slightly decrease in the lower area. The average annual maximum daily rainfall tends to clearly increase.
- Under the RCP8.5 scenario the average annual rainfall tends to clearly decrease. The average annual maximum daily rainfall tends to increase in the upper (southern) area but decrease in the lower (northern) area.

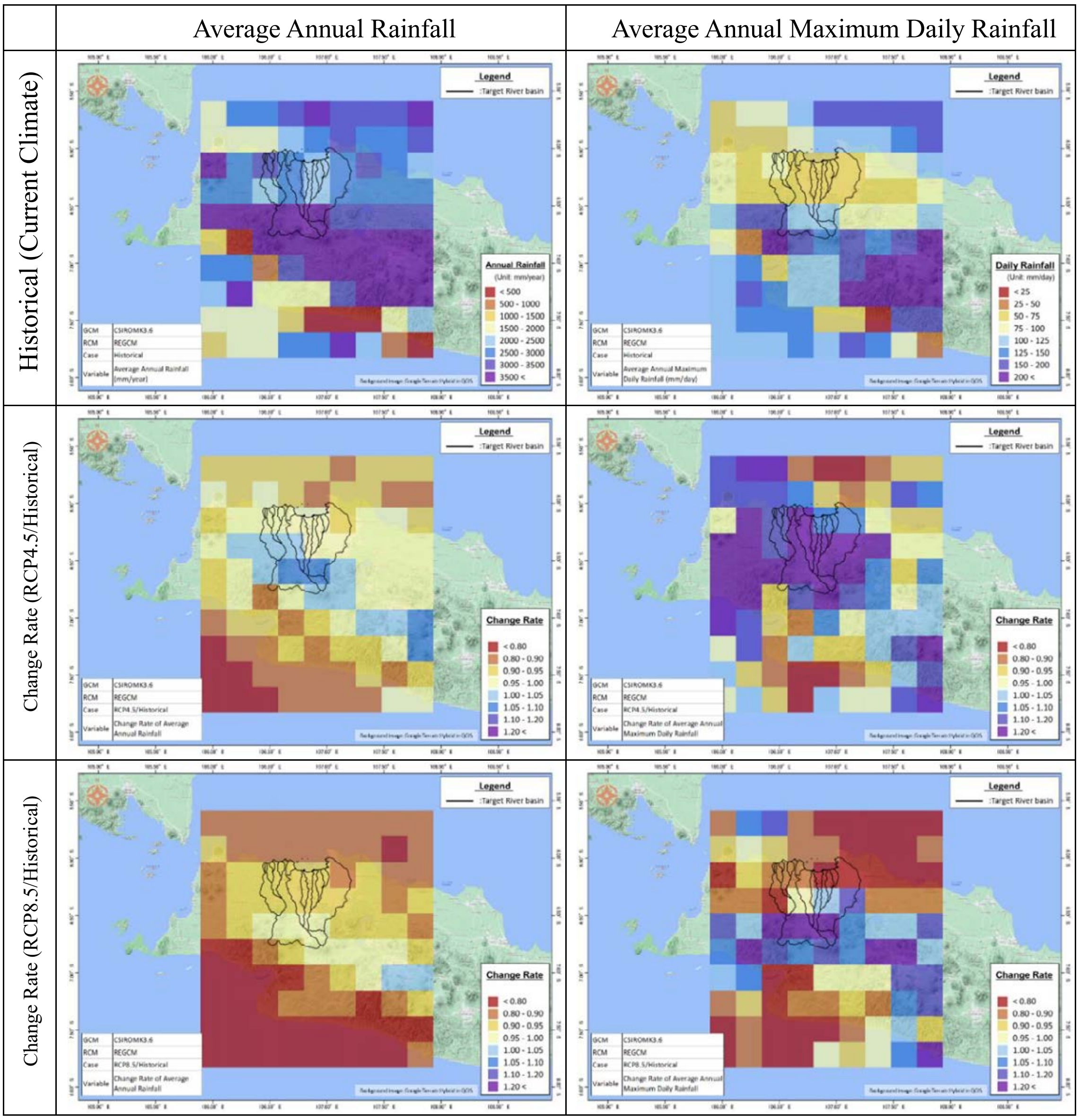


Figure 8-45 Distribution Maps of Each Dataset (No.3 GCM:CSIROMK3.6, RCM:REGCM)

- Under the RCP4.5 scenario the average annual rainfall tends to increase in the upper area but slightly decrease in the lower area. The future change of the average annual maximum daily rainfall is different, depending on the grid square.
- Under the RCP8.5 scenario the average annual rainfall tends to clearly decrease. The average annual maximum daily rainfall tends to slightly decrease.

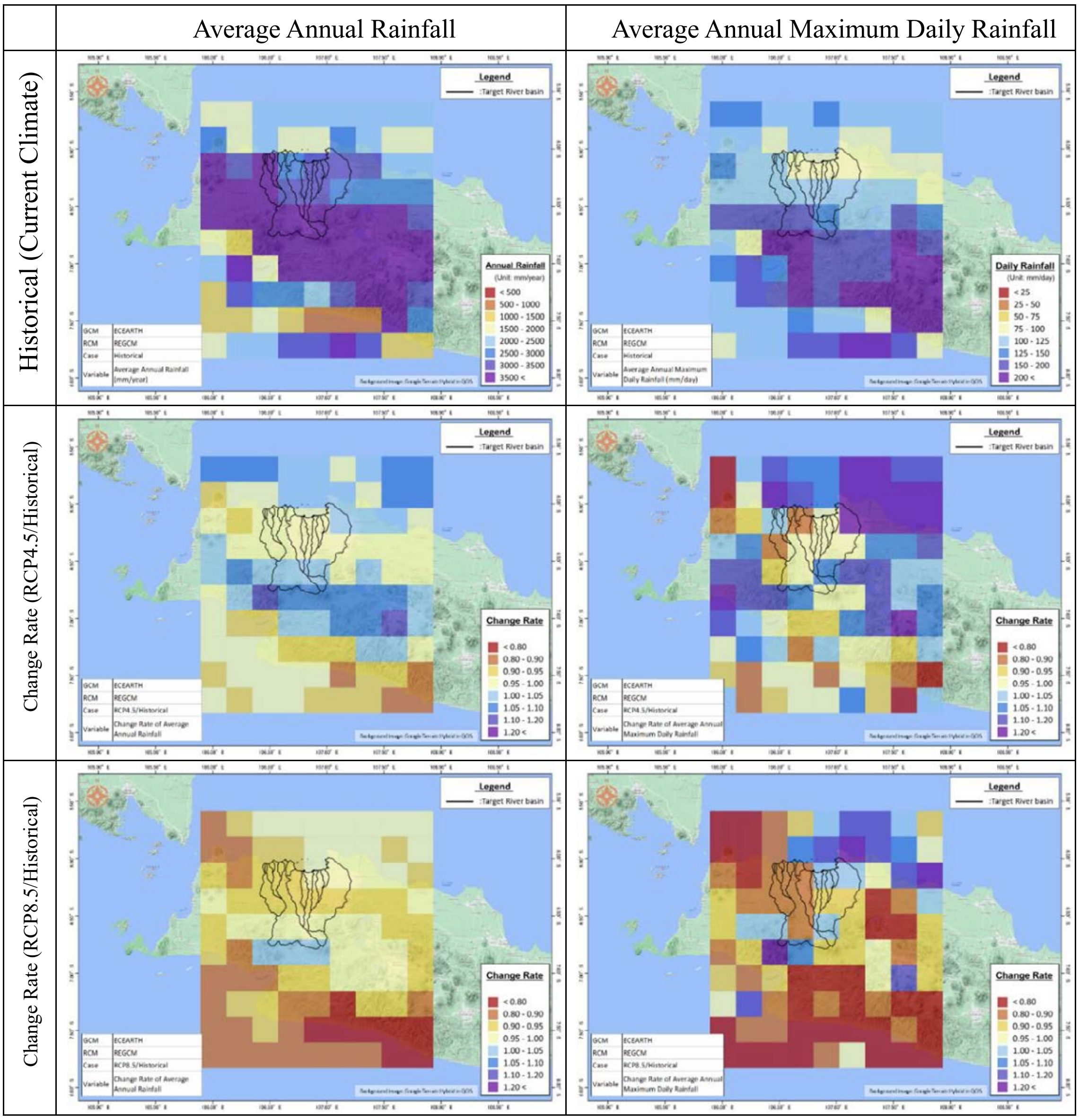


Figure 8-46 Distribution Maps of Each Dataset (No.4 GCM:ECEARTH, RCM:REGCM)

- Under the RCP4.5 scenario both of the average annual rainfall and the average annual maximum daily rainfall tend to clearly increase.
- Under the RCP8.5 scenario both of the average annual rainfall and the average annual maximum daily rainfall tend to clearly increase.

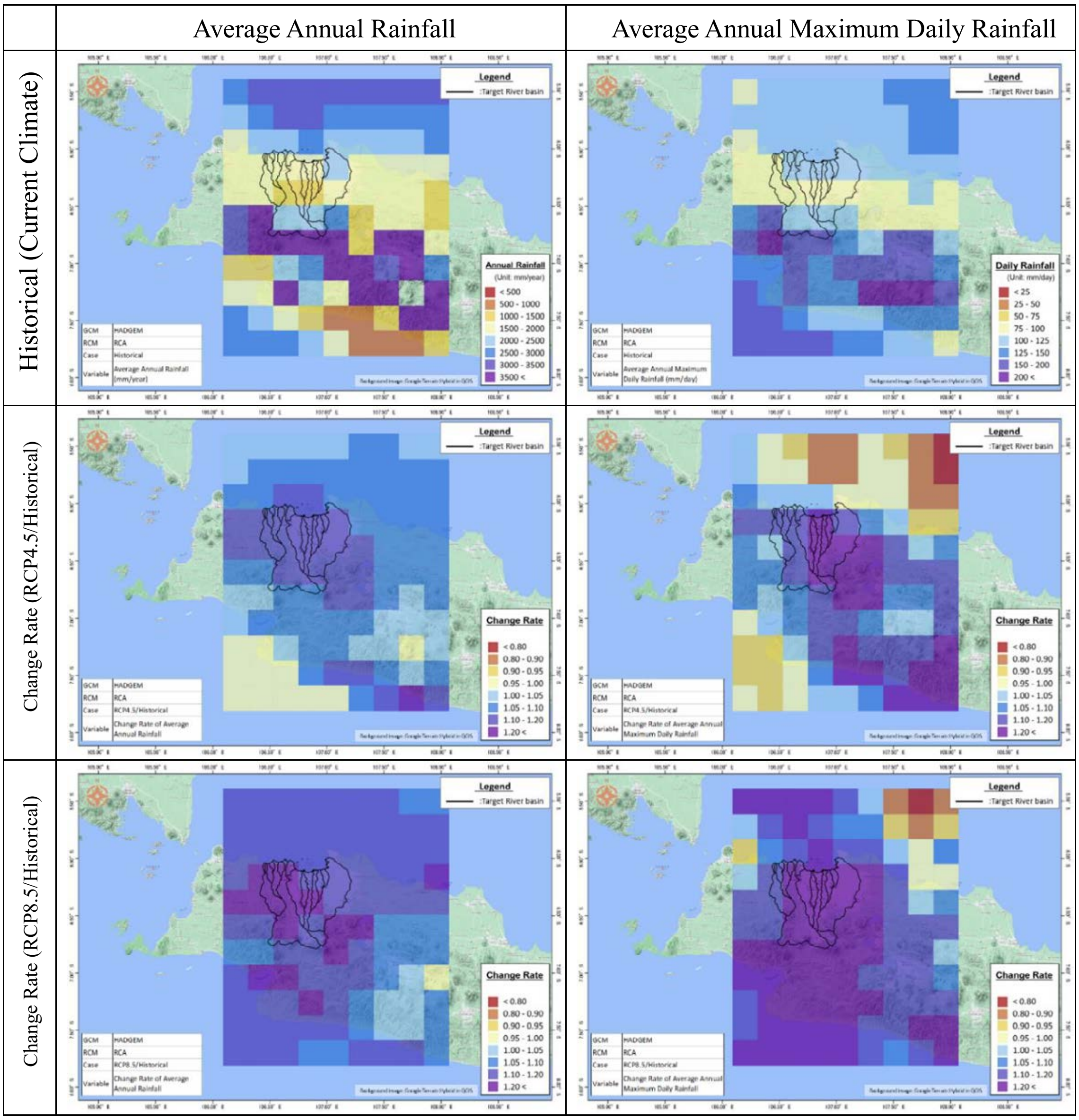


Figure 8-47 Distribution Maps of Each Dataset (No.5 GCM:HADGEM, RCM:RCA)

- Under the RCP4.5 scenario the average annual rainfall tends to slightly increase in the upper-most area but clearly decrease in the lower area. The average annual maximum daily rainfall tends to clearly decrease.
- Under the RCP8.5 scenario the average annual rainfall tends to increase in the upper-most area but clearly decrease in the lower area. The average annual maximum daily rainfall tends to clearly decrease.

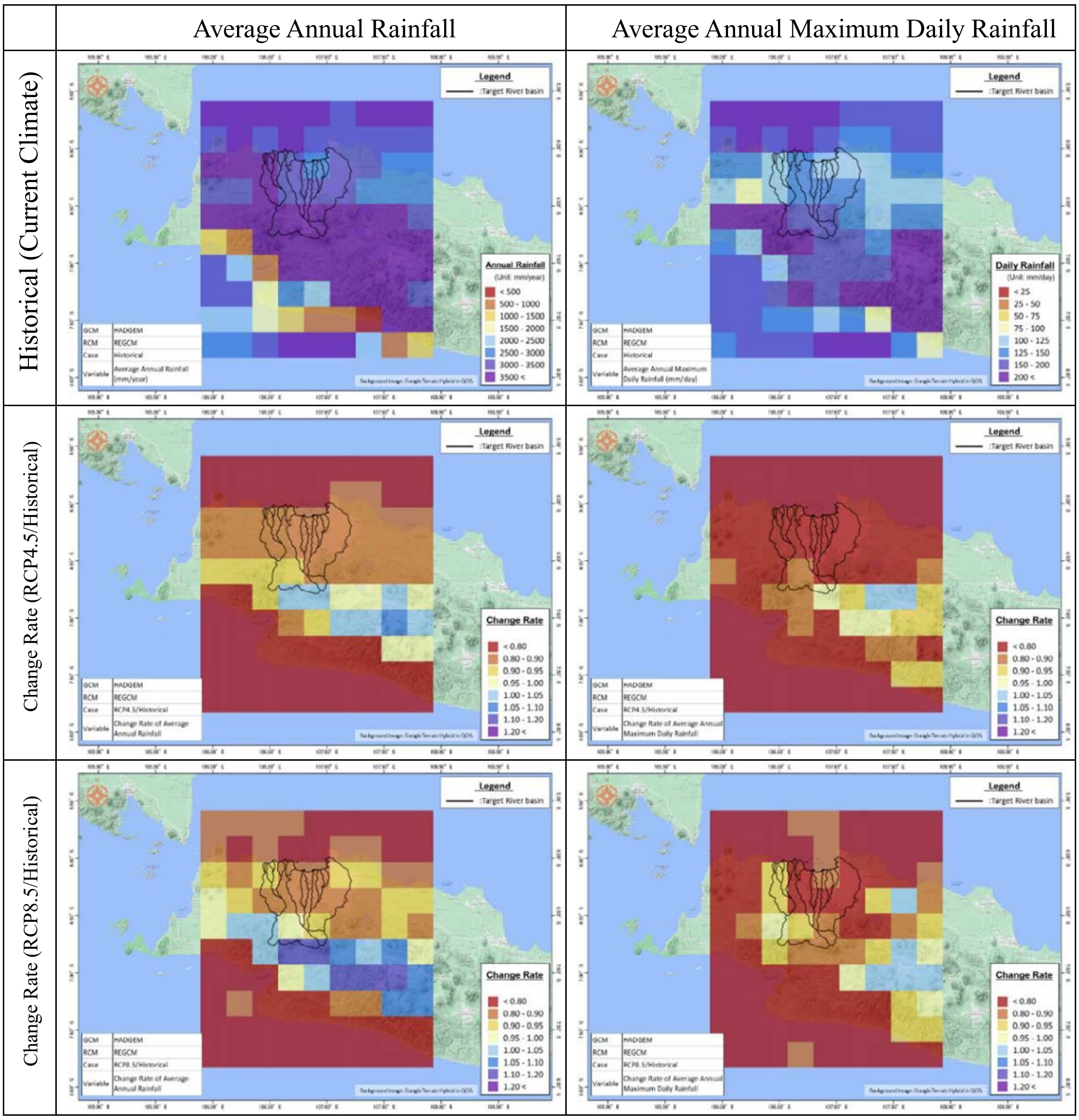


Figure 8-48 Distribution Maps of Each Dataset (No.6 GCM:HADGEM, RCM:REGCM)

- Under the RCP4.5 scenario the average annual rainfall tends to clearly decrease, but the change of the average annual maximum daily rainfall is different, depending on the grid square.
- Under the RCP8.5 scenario the average annual rainfall tends to clearly decrease, but the change of the average annual maximum daily rainfall is different, depending on the grid square.

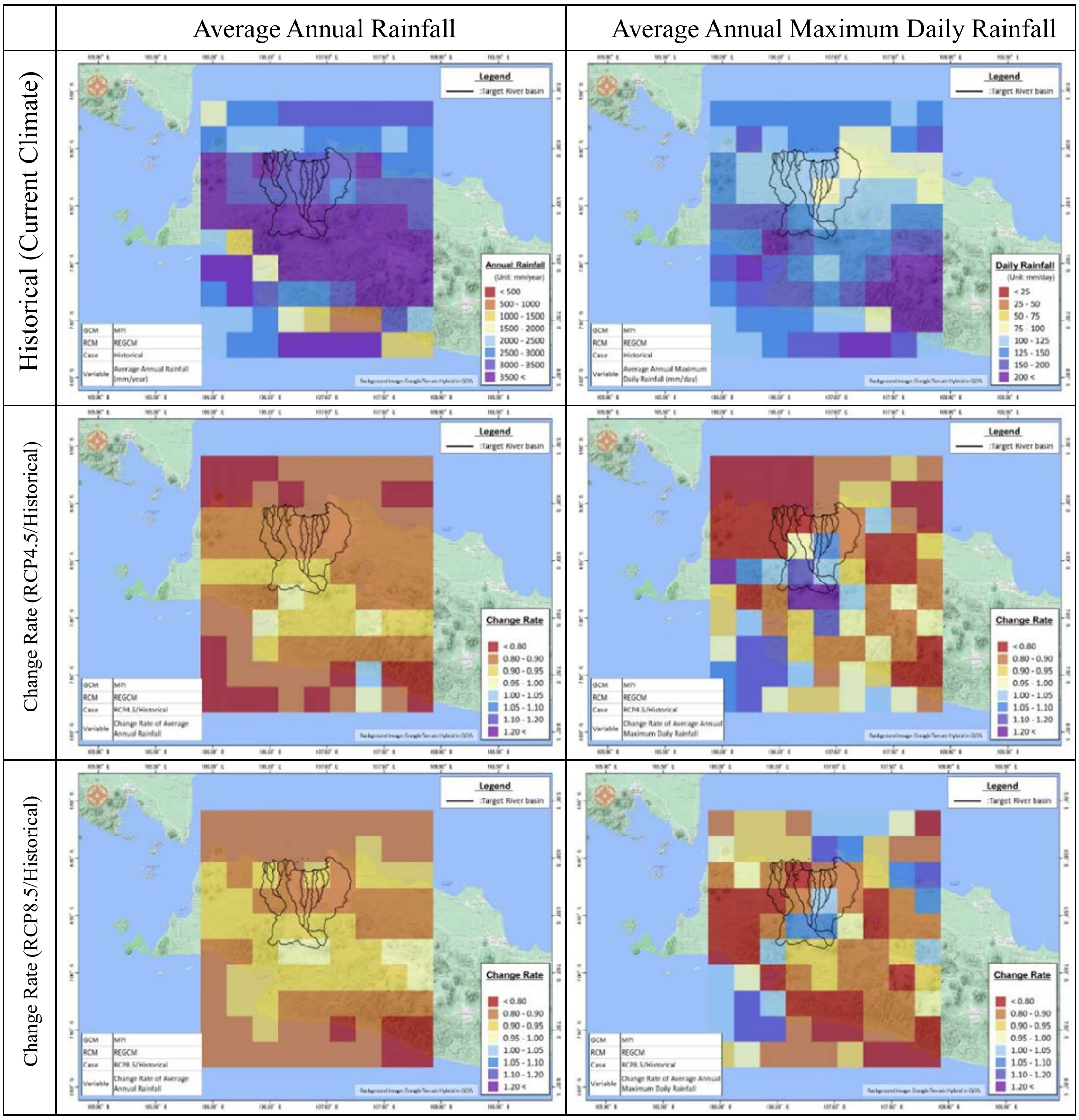


Figure 8-49 Distribution Maps of Each Dataset (No.7 GCM:MPI, RCM:REGCM)

- Under the RCP4.5 scenario the average annual rainfall tends to increase in the eastern part of the lower area, but it tends to decrease in the other areas. The average annual maximum daily rainfall tends to increase except for the eastern part of the upper area.
- Under the RCP8.5 scenario the average annual rainfall tends to increase in the eastern side and decrease in the western side. Similarly, the average annual maximum daily rainfall tends to increase in the eastern side and decrease in the western side.

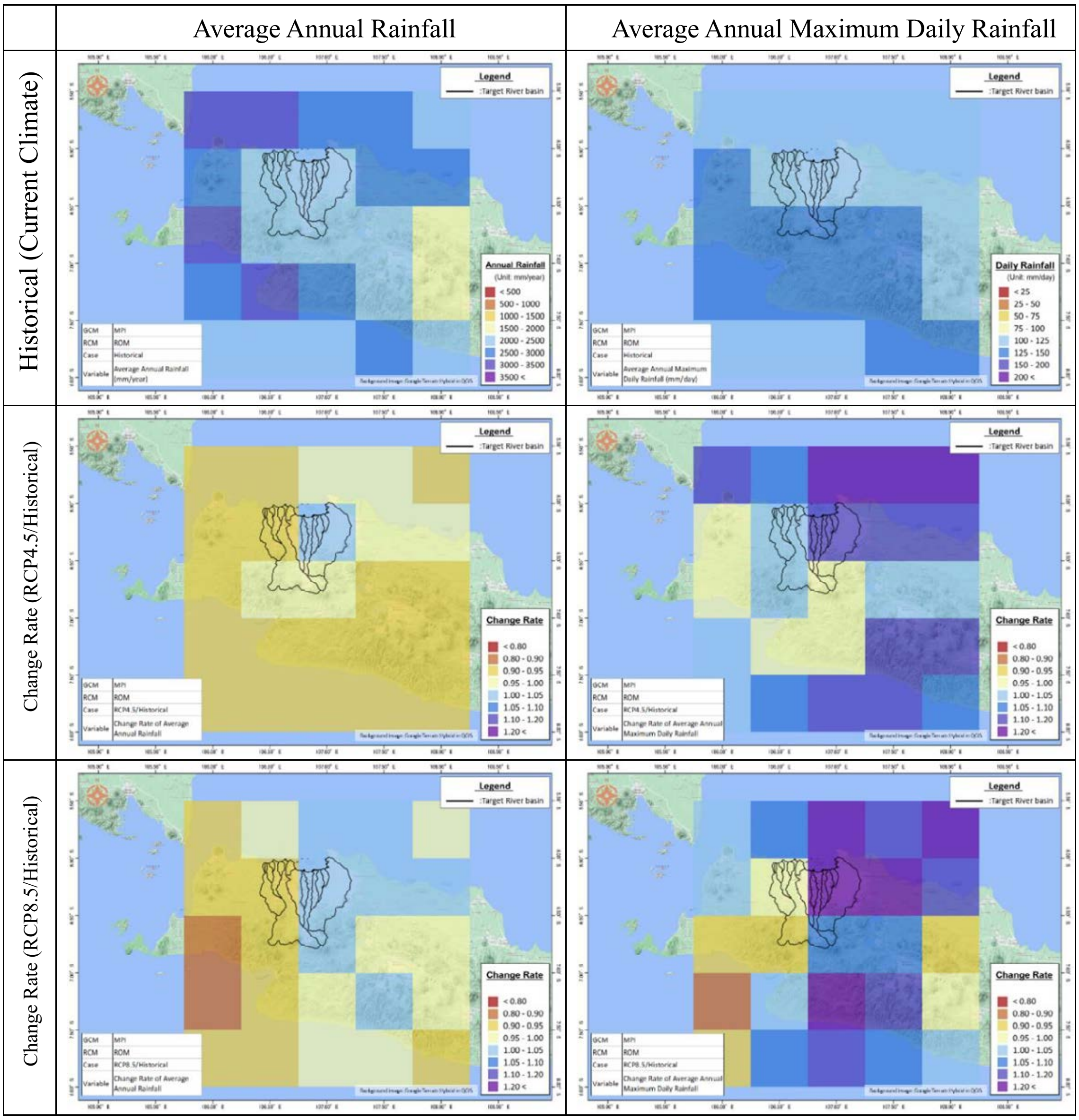


Figure 8-50 Distribution Maps of Each Dataset (No.8 GCM:MPI, RCM:ROM)

(3) Conclusions

Conclusions of the estimation of sea level rise and heavy rainfall change rate based on the future climate projection data provided by Bappenas and BMKG are summarized in Table 8-34.

Table 8-34 Conclusion on Climate Change Impact Assessment

Item	Contents
Future Climate Scenario	✓ RCP4.5 Scenario
Sea Level Rise	✓ The sea level rise rate of 0.870 cm/year that was estimated for the Bay of Jakarta based on the sea level rise projection data from 2006 to 2040 was adopted. Accordingly, the sea level will rise by 26.1 cm in 30 years.
Heavy Rainfall Change Rate	✓ Based on the climate projection data by the ensemble model, the heavy rainfall change rate in 2045 was estimated at 1.1 for both of the 50- and 100-year return periods. ✓ Based on the eight types of climate projection datasets, the heavy rainfall change rates in 2045 were estimated at 1.3 for the 50-year return period and 1.4 for the 100-year return period.

8.3 Recommendations on Climate Change Adaptation to Flooding

8.3.1 Examples of Climate Change Adaptation Measures in Other Countries

In considering climate change adaptation measures, the examples in other countries that have been implementing climate change adaptation measures are summarized in Table 8-35. A variety of adaptation measures have been implemented, including the upgrade of flood control plan (such as revision of design discharge) incorporating climate change impacts, the preparation of flood hazard maps and risk maps, and land-use regulations. These examples will contribute for considering climate change adaptation in Jakarta.

Table 8-35 Examples of Climate Change Adaptation Measures in Other Countries

Types of adaptation measures	Case Examples
Flood control plan and design	- [Netherlands] Upgrading the design discharge of the Rhine River at Lovis with an annual exceedance probability of 1/1,250 (from 15,000 m3/s to 16,000 m3/s) (Source-1) - [UK] National guidelines provide the rate of change in future flood discharge and sea level rise based on climate change projections. For example, the capacity of flood control facilities in the Thames River basin (with an annual exceedance probability of 1/200) was planned in anticipation of a 20% increase in flood discharge, and the safety of dam bodies and spillways was designed for a 70% increase in flood discharge. (Source-1) - [Germany] For example in Bayern etc., based on future rainfall predicted by climate change projection models, flood discharge is computed using runoff models, and the climate change coefficients are calculated by the ratio of the discharge by annual exceedance probability between the present (1971–2000) and the future (2021–2050), and the design discharge (generally 1/100 annual exceedance probability) is increased accordingly. For dike construction, lands adjacent to dikes are acquired in advance, assuming that the dike height will be raised in the future. In addition, the bridges are designed from the beginning with a discharge increased by the climate change coefficients, and new structures such as revetments are designed so that they can easily cope with the need for raising in the future. (Source-1) - [Italy] In Venice, the Moses Project for coping with sea level rise up to 60 cm is underway to install movable weirs to prevent storm surges. (Source-1) - [USA] In the Army Corps of Engineers' program for civil engineering projects, three unique scenarios for future sea level rise that exceed the predictions in the IPCC's Fifth Assessment Report will be developed, and a comparison of alternatives will be conducted for the entire life cycle including planning, design, construction, and maintenance. (Source-1) - [Philippines] After the PAGASA's study (A study on the likely influences of climate change in the Philippines in 2011) and the IPCC Fifth Assessment Report (2013), the revised Design Guidelines, Criteria and Standards (DGCS) in 2015 recommended to incorporate a 10% increase in rainfall intensity and to allow for a 0.3 m sea level rise in the design. (Source-3) - [Japan] Japan has changed its policy to incorporate climate change impacts into flood control planning after the publication of the "Recommendation on flood control planning considering climate change" by the technical review committee of the Ministry of

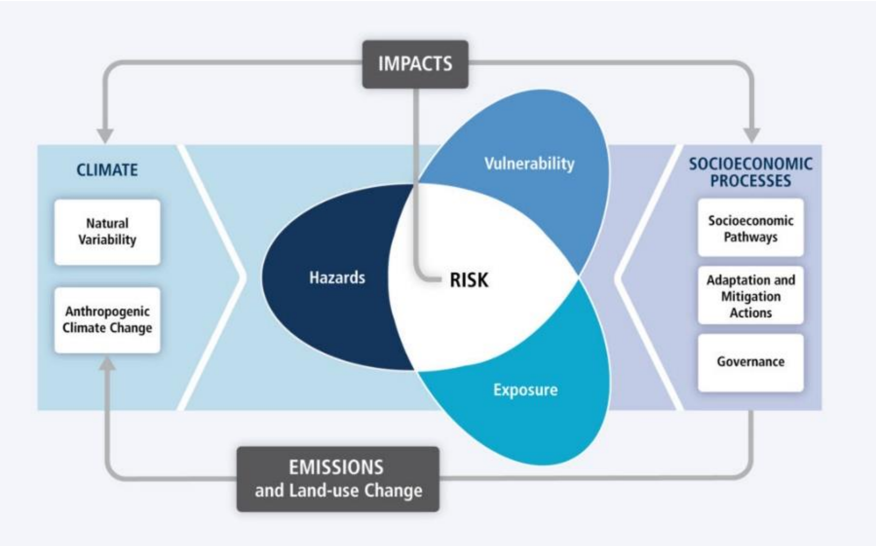
	Land, Infrastructure and Transport (MLIT) in October 2019. According to the "Proposal to address water related disasters considering climate change" by the Social Infrastructure Improvement Council released in July 2020, although there are uncertainties in the climate change projections and the projected results may be reviewed in the future, it is certain that rainfall will increase in the future. Taking it into account that the construction of flood control facilities will take a certain amount of time, it is desirable to revise the policy for river improvement and set targets considering climate change. In the future, design discharge will be revised incorporating climate change impacts in order from rivers where the design peak discharge is exceeded due to large-scale flooding, and rivers where the discharge allocation between dams and river channels in flood control plan needs to be changed. (Source-3)
Flood hazard mapping	- [EU] The European Union (EU) promulgated the Directive No. 2007/60/EC on the assessment and management of flood risks in 2007, which is designed to prepare flood hazard and risk mapping for various types of floods ranging from high-frequency events to low-frequency or extreme events. Depending on the Member State, 3 to 17 levels of flood inundation maps are published for each frequency of occurrence, with an annual exceedance probability of 1/2 to 1/10, 000. (Source-1) - [USA] Flood hazard mapping with annual exceedance probability of 1/100 and 1/500 are prepared. (Source-1) - [Japan] Flood hazard mapping for design rainfall (in principle, annual exceedance probability of 1/100 to 1/200 for first-class river) was published first. After the revision of the Flood Fighting Act in 2015, flood hazard mapping for the probable maximum precipitation is also published. (Source-3)
Land-use Regulations, etc.	- [UK] As for facilities that are highly vulnerable to flooding, construction is allowed only if they pass the screening process on land that is subject to flooding with an annual exceedance probability of 1/100 to 1/1,000, while construction is prohibited in principle on land that is subject to flooding with an annual exceedance probability of 1/100 or more. (Source-1) - [France] There have long been legally enforceable zones based on flood risk, with no building allowed in high flood risk areas and building restrictions (e.g., 20 cm above the base flood level) in medium flood risk areas. (Source-1) - [USA] Executive Order 11988 (1977) requires that when federal funds are spent on the construction of critical facilities in floodplains subject to flooding with a 1/500 annual exceedance probability, the responsible federal agency must consider alternatives and make damage assessments to minimize damage. In floodplains subject to flooding with a 1/100 annual exceedance probability, the purchase of land and buildings and the construction financed by federal loans must be covered by flood insurance. In addition, Executive Order 13690, issued in 2015, revised the target floodplains as follows: (i) the elevation and flood hazard area that result from using a climate-informed science approach that uses the best-available, actionable hydrologic and hydraulic data and methods that integrate current and future changes in flooding based on climate science; (ii) the elevation and flood hazard area that result from using the freeboard value, reached by adding an additional 2 feet to the base flood elevation for non-critical actions and by adding an additional 3 feet to the base flood elevation for critical actions; (iii) the area subject to flooding with a 1/500 annual exceedance probability; or (iv) the elevation and flood hazard area that result from using any other

	method identified in an update to the Federal Flood Risk Management Standard (FFRMS). (Source-1)
Support tools for climate risk information and climate change adaptation	- [UK] The United Kingdom's Climate Information Program (UKCIP) provides maps of climate projection results and supporting tools for businesses and municipalities. (Source-2) - [Germany] The platform for climate change adaptation (Kompass) supports enterprises, local governments and school education. (Source-2) - [France] Drias, a website for providing climate change related information and the results of climate change projections across France, and Wiklimat, a website for providing the database of local adaptation examples, are publicly available. (Source-2) - [USA] US-EPA, NOAA, and other organizations have created and posted various videos on their websites to support climate change adaptation, including guidance on local governments' adaptation planning, best practices for adaptation, and the effects of climate change in the present/future and public awareness, etc. (Source-2) - [Japan] The Adaptation Information Platform for Climate Change (A-PLAT) provides information to meet user needs, tools to support adaptation actions, and good practices as an information base to support adaptation efforts by local governments, businesses, citizens, and other entities. (Source-2)

Source-1: "Report on Climate Change Adaptation Measures against Water-Related Disasters (August 2015, Social Infrastructure Development Council of Japan)" Source-2: Prepared by JICA Study Team based on "Summary of the Issues by the Sub-Committee on Climate Change Impact Assessment -Support Document- (January 2017, the Ministry of the Environment of Japan)" Source-3: Prepared by JICA Study Team

8.3.2 Recommendations on Climate Change Adaptation Measures

Recommendations on climate change adaptation measures against floods are made by being categorized into measures against hazards, exposures and vulnerabilities, which are elements of flood risks. It is assumed here that flood control measures (river channel improvement, construction of dikes and storage facilities, etc.) based on existing flood control plans will be steadily implemented.



Source : IPCC AR5 WGII SPM Figure SPM.1

Figure 8-51 Conceptual Diagram of Floor Risk Considering the Impacts of Climate Change

(1) Adaptation to Hazard

Recommended adaptation measures to reduce flood inundation as much as possible are listed below.

- Dike Strengthening
  The dikes should be strengthened with the aim of creating "tough dike" that are less likely to break even when overflowing. As a result, the dikes are expected to have a disaster mitigation effect against floods that exceed the design discharge (excess floods). In the Bekasi River basin, one of the target river basins, the concrete retaining wall structure of the dikes collapsed during the flood in 2021, causing more damage. In view of the possibility of further intensification of floods due to climate change, it is necessary to consider strengthening the dikes.

- Enhancing flood control functions of existing dams
  Standard operation procedures (SOP) of existing dams and weirs should be reviewed to make maximum use of them, including irrigation and hydropower dams. As an example, in cooperation with flood prediction technology, when the occurrence of a flood is predicted, the dam storage capacity for water use is released in advance and used temporarily as flood control capacity. Other measures include increasing flood control capacity by raising dam bodies or renovating discharge facilities, measures against sedimentation, and reviewing the operation of weirs.

- Drainage Improvement
  It is necessary to construct drainage pump stations to drain flood water as soon as possible in case of flood, and to make drainage pump stations and sewerage facilities water-resistant in order not to be failed due to flood water.

- Enhancing rainfall-runoff control
  Temporary on-site storage during heavy rainfall events will reduce short-term runoff. Examples include the construction of retention ponds, mandatory installation of rainwater harvesting and infiltration facilities in public facilities and large commercial facilities, subsidy programs for rainwater harvesting facilities for buildings and residences, and permeable pavement, etc. For areas where assets are extremely concentrated, such as the Jakarta metropolitan area, underground storage facilities are also a candidate.

- Conservation of natural retarding basins
  Although the areas of natural retarding basins are very limited in the target river basins, retarding basins are very effective for reducing flood peak discharge because of the sharp flood hydrographs by their hydrometeorological and geographical characteristics in the target river basins. They are also important as flood control measures in terms of other alternative measures being limited. Since the target rivers flow through Jakarta

metropolitan area, it is very difficult to increase flow capacity of the rivers by widening due to the high level of land development up to the river's edge.

(2) Adaptation Measures to Reduce Exposure

Recommended adaptation measures to reduce exposure to floods are listed below.

- Enhancement of flood inundation risk information
  In addition to inundation risk information of historically flooded area and flood hazard areas corresponding to design floods in flood control plans, inundation risk information can be provided for very infrequent large-scale floods (1/500, 1/1000, etc., as in the case of Europe and the United States) and for the probable maximum rainfall (as in the case of Japan). This information can lead to promote and upgrade evacuation activities and land use planning.
- Adaptation in community planning and housing
  Based on inundation risk information of the land, residential areas and urban functions should be guided to low-risk areas. Examples include land use regulations and flood insurance requirements for areas at high risk of frequent inundation, as well as improvements in housing such as building pilot structures.

(3) Adaptation Measures to Reduce Vulnerability

Recommended adaptation measures for mitigation of flood damage and early recovery and reconstruction are listed below.

- Strengthening evacuation system
  It is necessary to improve information for disaster prevention and mitigation and how to disseminate it to people, secure safe evacuation sites, and enhance disaster risk management capacity of residents and local businesses. An example is the creation and dissemination of easy-to-understand flood hazard maps that include flood hazard area, evacuation centers, dangerous spots during evacuation (e.g., under path that are impassable during flooding), and facilities requiring supports during disasters (hospitals, nursing homes, kindergartens, etc.). Other examples include the dissemination of push-type disaster related information via smartphones and water-level videos that is likely to lead to evacuation actions, evacuation drills, and support for formulating business continuity plans (BCPs).
- Upgrading flood early warning system
  The Jakarta Flood Early Warning System (JFEWS), jointly operated by PUPR and BMKG, has been developed in the Jakarta area, and real-time water levels and the measured and predicted rainfalls are available on the website. In the future, it is

necessary to improve the accuracy of this warning system, expand the target area, and strengthen cooperation with flood control facilities such as dams and evacuation systems.

(4) Revision of Design Discharge in Flood Control Plan

The design hyetograph and design hydrograph in the flood control plan are revised to take into account future increases in heavy rainfall and sea level rise based on future projected results by climate and ocean models. Increasing the design discharge in flood control plan can prevent damage from flooding up to the newly revised design discharge.

Increasing the design discharge involves a great deal of expense, effort, and social impacts, and thus requires careful decision making. On the other hand, the results of future projections by climate models inevitably involve uncertainty, and it is said that projected results highly depend on model type, initial values of parameters and other factors. Therefore, in Japan, for example, non-structural measures mainly have been taken against the flood discharge increase due to climate change such as upgrading flood hazard maps and flood forecasting and warning systems and raising the awareness of local residents.

In recent years, however, the reliability and stability of future projected data have been greatly improved with the development of large ensemble climate data* produced by extensive simulations using climate models. In addition, floods intensified by climate change impacts have been occurring more frequently in many parts of the world, and climate change adaptation becomes an urgent common issue over the world. Although climate change projection has a wide range of values, river improvement and urban development projects that take a long time to complete must begin taking measures based on assessments of future climate change, otherwise their plans will have to be revised and additional measures will have to be implemented, which may lengthen the project period of river improvement and increase the cost of such projects. Considering the expected improvement in the accuracy of future climate projections, it is recommended that flood control planning be shifted to take into account the climate change impacts.

Chapter9 Summary of Proposal and Future Development

9.1 Summary of Proposal

The project components proposed in this study with the intention of forming future loan projects are shown in Table 9-1.

Table 9-1 Project components proposed in this study

Target Rivers / Area	Type of works	Main Specifications
Sabi River (Cisadane River Tributary)	River improvement at Confluence	● Riverbed excavation and embankment
	Gates, Detention ponds, Pump, Additional box culvert across irrigation canal	● Gate: B10m x H6m x 2 units ● Retarding basin capacity: 125 thousand m^3 ● Pump 20 m^3/s ● Box culvert: B3m x H5m x 3 sets
Jakarta West	River Improvement	● Bottleneck elimination, river bed excavation ±1m
	Detention ponds	● Pesanggrahan upstream: total storage capacity 3.8 million m^3 ● Krukut, Mampamg upstream: total storage 2.3 m^3
	Underground channel	● Route 1 Pesanggrahan: inner diameter 7 m, distance 8 km, flow 80 m^3/s ● Route 2 Barat 2: inner diameter 3.5 m, distance 5 km, flow 50 m^3/s ● Route 3 Krukut, Mampamg: I.D. 7 m, distance 8.5 km, flow 70 m^3/s ● Route 4 Downstream: I.D. 10 m, distance 7 km, flow 200 m^3/s
New Polder "Timur 2"	Riverbed excavation and bank protection	● Flow rate 200 m^3/s, extension 9.8 km, excavation 317 thousand m3
	Retarding basin and drainage pump	● 3 locations, drainage rate 10 m^3/s x 3, total regulating reservoir capacity 2.6 million m^3
Bekasi River	Detention ponds	● 8 locations ● Total storage capacity 6.59 million m^3
	Floodgate operation improvement and ancillary facilities at Bekasi weir	● Complete telemetry system for gate operation ● Complete set of pump equipment for supplying drinking water during low water, 5 m^3
Non-structural measures	Early warning system	● Water level observation equipment, telemetry system, hazard maps
	Hydrological observation network development	● Maintenance and repair: 36 locations ● New: telemetry water-level gauges, radar rain gauges
	Operation center	● Data management, flood forecasting and warning, emergency measures

9.2 Project Cost

The approximate construction and project costs of structural measures, which are mentioned in the relevant chapters, are summarized in Table 9-2. The total project cost is estimated at US$ 2.4 billion (JPY 280 billion). It is noted that the cost except construction cost such as non-structural measures, consulting service, land acquisition and administration are estimated with assuming at 30% of construction cost.

Table 9-2 Approximate Project Cost

Component	Cost (USD mil.)	
Cisadane: Sabi	17	
Barat 2: Drainage Pump	378	1,536
Barat 2: Underground Channel Lowermost Section	414	
Barat 2: Pesanggrahan (Underground Channel: 207, Retarding Basin: 83, River Excavation: 43)	333	
Barat 2: Lower Angke-Grogol (Underground Channel: 62, Retarding Basin: 0, River Excavation: 17)	79	
Barat 2: Krukut-Mampang (Underground Channel: 258, Retarding Basin: 50, River Excavation: 24)	332	
Timur 2: Cakung Drain	188	
Bekasi: 8 Retention Ponds and Bekasi Weir (Gate Operation System, Pump for Water Supply)	139	
Construction Cost	1,880	
Non-structural Measures, Consulting Service, Land Acquisition, Administration, Tax, Contingency, etc. (30% of Construction Cost)	564	
Project Cost	2,444	

The proposed components for each target river/area is evaluated as economically feasible as shown in Table 9-3. However, it requires tremendous investment. A staged project implementation is planned for Barat 2 of which construction cost shares more than 70% of total construction cost. As shown in Figure 9-1, the construction cost for each stage varies US$ 0.79 to 6.2 billion (JPY 9.2 to 72 billion). Cost reduction shall be considered in the next study and implementation plan shall be made with comprehensive evaluation of cost, urgency and effect of each stage of project.

Table 9-3 Effects of Proposed Components

Area	Design Scale (Years)	Effects for Design Scale Floods	Expected Damage Reduction (Rp. Billion)
Cisadane: Sabi	25	3,619 houses	496
Barat 2	100	31 km^2 589 thousand houses	56,548
Timur 2	100	6 km^2 118 thousand houses	5,339
Bekasi	50	8.64 km^2	3,140

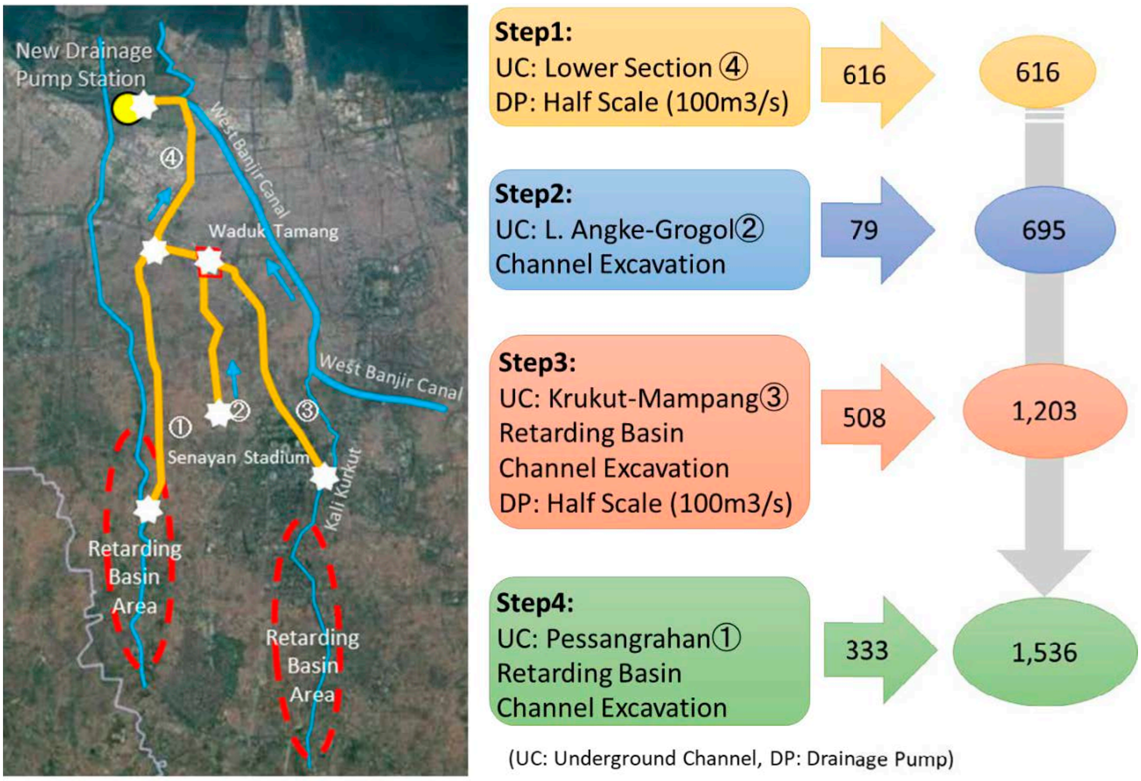


Figure 9-1 Staged Implementation for Barat 2

9.3 Implementation Schedule

The implementation schedules of underground channel, detention ponds for Bekasi and Barat 2, and the flood control in Timur 2 and Sabi areas are estimated considering difficulty of design and construction, and work quantity. Assuming that the all the component is implemented in one project, the common schedule is applied for F/S, project appraisal, and consultant selection. The required period of project stages by components are summarized in Table 9-4 while the implementation schedules are shown in Figure 9-2 to Figure 9-5. The construction of underground channel requires the longest implementation period for 13 years.

Table 9-4 Required Period by Project Stage

Unit: years

Stage / Measures	F/S	Project Appraisal and Consultant Selection	Detailed Design	Contractor Selection	Construction
Underground Channel	1.5	2	2.5	1.5	6.5
Detention Ponds			1.5	1	3
Timur 2			1.5	1	4
Sabi River			2	1	2

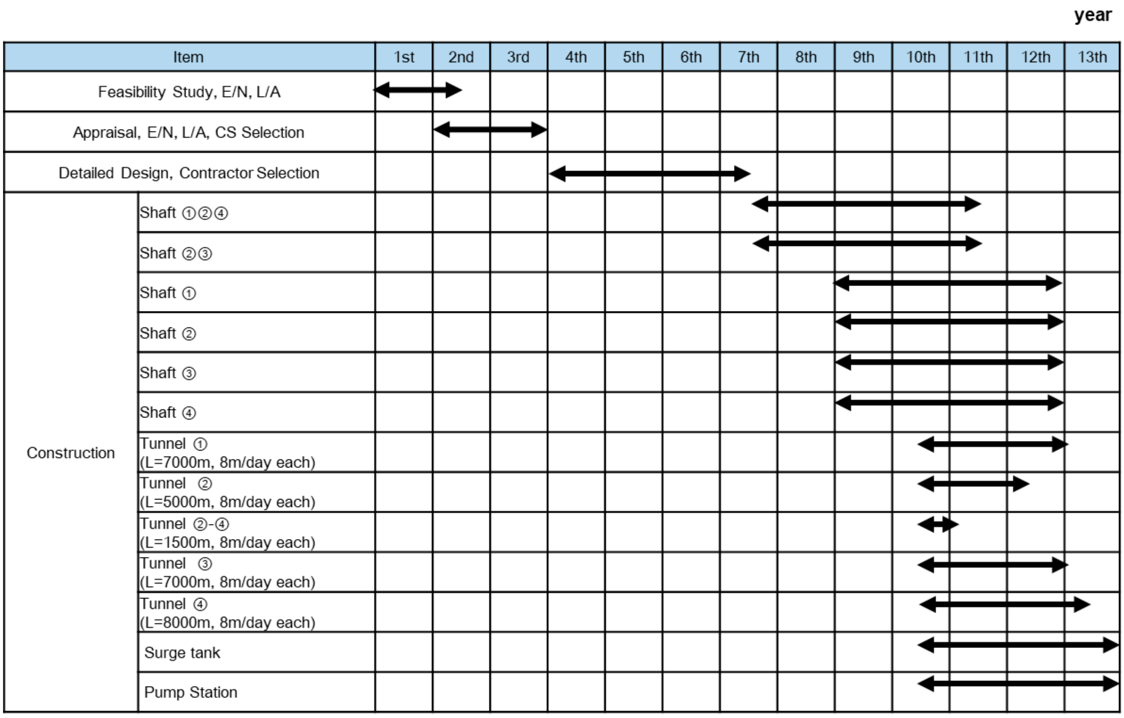


Figure 9-2 Implementation Schedule of Underground Channel

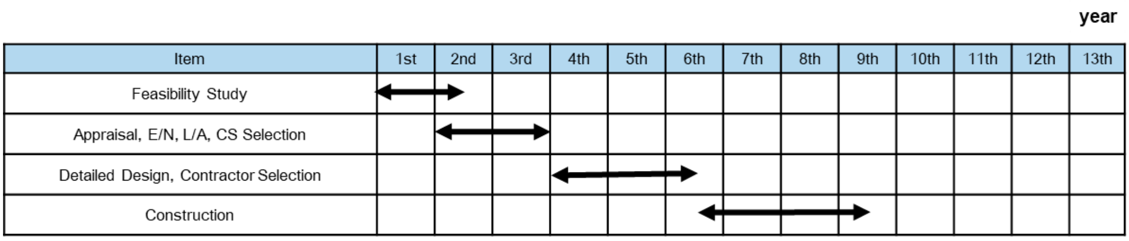


Figure 9-3 Implementation Schedule of Detention Ponds (Bekasi, Barat 2)

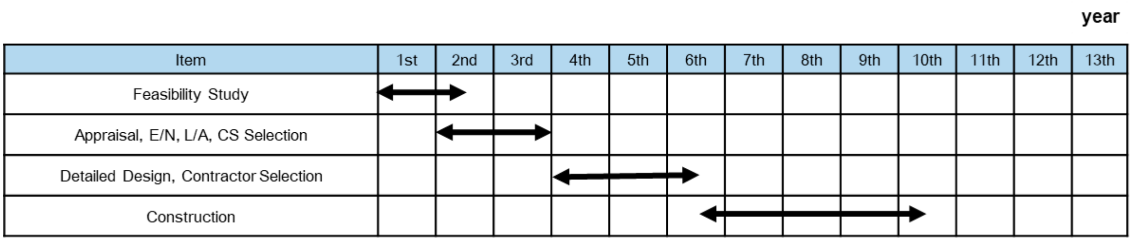


Figure 9-4 Implementation Schedule of Timur 2

year

Item	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th
Feasibility Study	↔												
Appraisal, E/N, L/A, CS Selection		↔	↔										
Detailed Design, Contractor Selection				↔	↔	↔							
Construction							↔	↔					

Figure 9-5 Implementation Schedule of Sabi River

9.4 Environmental Consideration

EIA shall be conducted while the review of project component in the next study. Current expected items of social and environmental consideration are as follows.

- Underground Channel:
  Resettlement for construction of vertical shaft may not be required. Excavation volume is estimated as 1.7 million m^3 and huge amount of waste soil might be generated.
- Detention Ponds:
  Candidate locations are selected where there is no house. Huge amount of waste soil might be generated depending of the topography of the locations.
- Timur 2:
  Waste soil volume is estimated as 310 thousand m^3. Several dozens of resettlement might be required along the river course.
- Sabi River:
  No significant impact is expected.

9.5 Points of Attention in Next Study

The proposed components shall be re-evaluated its adequacy through F/S because the study has been conducted with limited site information under restriction of trip and field activities due to COVID-19. In the F/S, urgency and effect of flood control measures shall be examined for each component. Then, adequacy and feasibility shall be evaluated comprehensively through technical feasibility evaluation and study on cost and work period reduction measures. Special attentions shall be given to the followings.

- Underground Channel:
  - Selection of Vertical Shaft Locations considering Land Acquisition and Flood Control Effects
  - Design of Economic Channel Alignment
  - Depth of Channel considering Affects to Mining Utilities and Economic Efficiency
  - Possibility of Gravity Flow Application and Measures for Minimizing of Pump Capacity

- Selection of Priority Route considering urgency and Effects
- Detention Ponds:
    - Possibility as Detention Ponds Development for Candidate Locations
    - Selection of Optimal Type of Detention (Underground Reservoir)
    - Added Values as Green Infrastructure
- Timur 2:
    - Optimal Design of Channel considering Landuse of Surrounding Areas
- Sabi River:
    - Landuse and Possibility of Land Acquisition for Retarding Basins