

**The Republic of Indonesia
Directorate General of Water Resources
Ministry of Public Works**

**The Project for Capacity Development
of Mt. Semeru Volcanic Disaster
Structural Measure Planning
in The Republic of Indonesia**

**Project Completion Report
Annex (7)
Final Report**

February 2025

Japan International Cooperation Agency (JICA)

Yachiyo Engineering Co., Ltd.

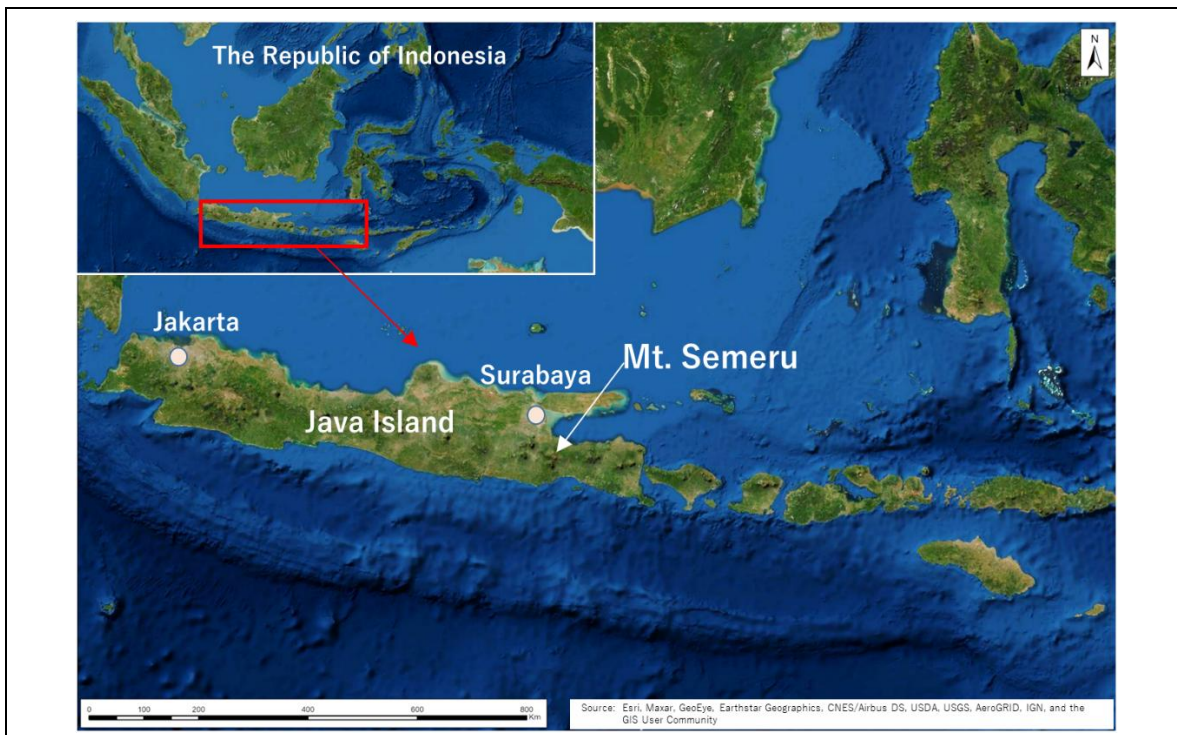


Figure 1 Location map of Mt. Semeru

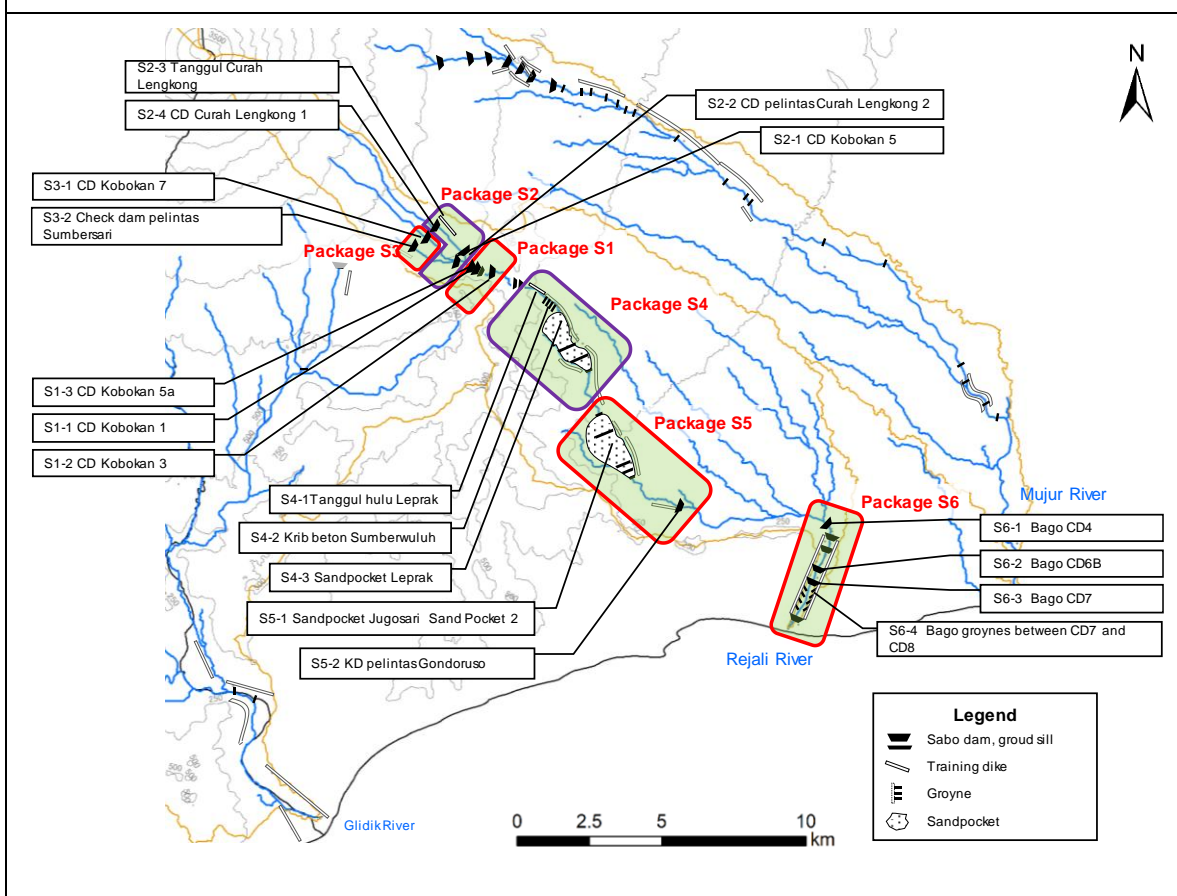








Figure 2 Location map of sabo facilities studied in this Planning (packages enclosed by purple lines).

	
<p>Figure 3 S2-1 CD Kobokan 5 The main dam has collapsed. The structure was constructed with stone masonry.</p>	<p>Figure 4 S2-2 CD Pelintas Curah Lenkong 2 The main dam has collapsed.</p>
	
<p>Figure 5 S2-3 Tanggul Curah Lengkong A dike with gabions has been constructed as an emergency measure. A flow channel has been formed along the arrow on the left-hand side of the photo.</p>	<p>Figure 6 S4-1 Tanggul Leprak 26 An emergency dike has been constructed with gabions. The river-side sedimentation level is several meters higher than the dike crest.</p>
	
<p>Figure 7 S4-3 DD Leprak 2 Both main dam and sub-dam have collapsed.</p>	<p>Figure 8 S4-3 DD Leprak 3 The dispersion dam structure is almost completely buried, and only the crest is visible.</p>

The Project for Capacity Development of Mt. Semeru Volcanic Disaster Structural Measures
Planning in The Republic of Indonesia

Final Report

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Abbreviations

Abbreviation	English	Bahasa Indonesia
ALOS2	Advanced Land Observing Satellite 2	-
AMDAL	Environmental Impact Assessment	Analisis Mengenai Dampak Lingkungan Hidup
BBWS	River Basin Organization	Balai Besar Wilayah Sungai
BINTEK	Directorate of Technical Development	Direktorat Bina Teknik
BNPB	National Agency for or Disaster Countermeasure	Badan Nasional Penanggulangan Bencana
CVGHM	Center for Volcanology and Geological Hazard Mitigation	Pusat Vulkanologi dan Mitigasi Bencana Geologi
DEMNAS	National Digital Elevation Model	Digital Elevation Model Nasional
DGWR	Directorate General of Water Resources	Direktoral Jenderal Sumber Daya Air
DKPP	Department of Food Security and Agriculture	Dinas Ketahanan Pangan dan Pertanian
DLH	Department of Environment	Dinas Lingkungan Hidup
DPUTR	Department of Public Works and Spatial Planning	Dinas Pekerjaan Umum dan Tata Ruang
EIA	Environmental Impact Assessment	-
ESDM	Ministry of Energy and Mineral Resources	Kementerian Energi dan Sumber Daya Mineral
GVP	The Smithsonian Institution's Global Volcanism Program	-
JAXA	Japan Aerospace Exploration Agency	-
LiDAR	Light Detection And Ranging	-
MPW	Ministry of Public Works	Kementerian Pekerjaan Umum
OJT	On the job training	-
PDM	Project Design Matrix	-
PU	Ministry of Public Works	Kementerian Pekerjaan Umum
PVMBG	Center for Volcanology and Geological Hazard Mitigation	Pusat Vulkanologi dan Mitigasi Bencana Geologi
RD	Record of Discussion	-
RPJMN 2020-2024	National Middle Term Development Plan 2020-2024	Rencana Pembangunan Jangka Menengah Nasional 2020-2024
SPPL	Statement of Environmental Management and Monitoring Capability	Surat Pernyataan Kesanggupan Pengelolaan dan Pemantauan Lingkungan Hidup
SNI	Indonesian National Standard	Standar Nasional Indonesia
UKL-UPL	Environmental Management and Monitoring Plan	Upaya Pengelolaan Lingkungan Hidup dan Upaya Pemantauan Lingkungan Hidup
VEI	Volcanic Explosivity Index	-

SUMMARY

1. Background and the Purpose of the Project

(1) Background and Purpose of the Project

Mt. Semeru in East Java experiences eruptions larger than medium scale almost every 5 years. The eruption that occurred on December 4, 2021 resulted in 57 deaths, more than 10,400 evacuees and 1,027 damaged houses. The pyroclastic flow burned houses and agricultural fields. Its sediments deposited on the riverbed overflowed the existing dikes as debris flows, causing damage to villages. The large amount of volcanic ejecta from the eruption will be discharged as debris flows in the coming rainy seasons, exposing residents to the risk of debris and flooding disasters. Urgent and drastic countermeasures are needed.

However, although the Directorate General of Water Resources, Ministry of Public Works (DGWR-MPW), which is responsible for volcanic sabo, has identified sediment control from eruptions as one of its key programs, there is needs for capacity for detailed planning of volcanic sabo facilities, particularly the technology required for structural measures against frequent debris flows originated with pyroclastic deposits, such as the case of the 2021 eruption. It is urgently needed to improve engineers' capacity on planning and designing such structures.

The project is intended to provide the technical support required for the detailed design of sabo facilities at Mt. Semeru, in order to establish an autonomous sabo project implementation system for the relevant agencies, thereby contributing to volcanic disaster risk reduction.

(2) Target Area, Project Duration and Relevant Organization of Indonesian Government

The target area is mainly the Rejali River basin, which flows through the foothills of Mt. Semeru, The project period is 25 December 2023~21 January 2025.

Implementing organization of Indonesian side are Directorate General of Water Resources, Ministry of Public Works (DGWR-MPW) with Directorate of Rivers and Coasts, Directorate of Water Resources Management System and Strategy, Directorate of Water Resources Engineering Development, Technical Implementation Unit for Sabo Dams, and BBWS Brantas as the basin management office.

(3) Project Activities

• Method of Cooperation

Work related to the planning, design, and preparation of tender documents for sabo facilities will be carried out in collaboration with BBWS-Brantas staff and the consultant members. Capacity building will be carried out through collaboration works. The topographical/geological surveys, planning, design, and preparation of bidding documents will be practiced in collaboration with BBWS, and the contents will be shared with the relevant departments within the DGWR-MPW, with the goal of ensuring that the results of this support are systematically established in the whole organization.

• Outputs

The four outputs of the Project are shown below:

Output 1: The capacity to conduct basic research and information gathering necessary to implement the detailed design of sabo facilities will be strengthened.

Output 2: The capacity to review sabo facility specifications and facility locations based on field survey results is strengthened.

Output 3: The capacity to prepare detailed design for sabo facilities is strengthened.

Output 4: The capacity to prepare environmental and social considerations is strengthened

2. Natural Conditions

Mt. Semeru is one of the most active volcanoes with an altitude of 3,676 m, located near the eastern tip of the island of Java. Its topography comprises a conical stratovolcano with a broad fan at the foot of the volcano. The fan continues to grow, covering the base rock mountainous terrain and is widely distributed to the south and south-east. The Rejali River, the target river of the project, flows almost in a straight line from the crater of Mt. Semeru to the south-east, crosses the basement rock mountainous area between the S2 and S4 areas. South of S4, it flows along the basement rock mountainous area to the west, emptying into the Indian Ocean.

In recent years, eruptions with relatively large pyroclastic flows have occurred every 5-7 years, with eruptions above VEI 3 occurring in 1981, 1985, 1988, 1994 and 2002-2003. In addition, smaller eruptions have continued to occur since 2017.

The largest pyroclastic flows on record occurred after the eruptions of December 2021 and December 2022. These pyroclastic flows caused debris flows that overflowed the dikes of the Rejali River, resulting in disasters of residential areas being covered with sediment.

The sabo facilities established in the Rejali River basin have suffered scouring and burial damage as a result of the large amount of sediment movement. In addition, the dikes were in a situation where the capacity of sediment that could be trapped by the next eruption was insufficient.

3. Basic Policy on Preliminary Detailed Design

(1) Assumption Specified in the Review Master Plan (2024)

The Volcanic Sediment Control Plan for Semeru Volcano was prepared in 1984 as a Master Plan ('Master Plan (1984)'). The Review Master Plan (2024) updated the conditions established in the Master Plan (1984) based on new phenomena that have occurred since then, such as the December 2021 eruption. Specifically, new assumptions were made on the frequency and size of target pyroclastic flows, sediment sources were redefined, and the policy for locating sabo facilities was reviewed taking into account the river channel fluctuations. In addition, the rainfall that generates frequent debris flows during the post-eruption rainy season and design sediment run-off volume were updated based on the latest hydrological data. The sediment control effect of sabo facilities in the 3 river basins of Mt. Semeru are shown in the table below.

Table -1 Sediment control effect by sabo facilities in the review master plan (2024)

River	Design excess sediment discharge volume (m ³)	Sediment control volume (m ³)			Sediment control rate (%)		
		Existing sabo facilities (As of 2023)	Proposed and existing sabo facilities	Sediment control effect by the proposed sabo facilities	Existing sabo facilities (As of 2023)	Proposed and existing sabo facilities	Sediment control effect by the proposed sabo facilities
	(A)	(B)	(C)	(D)=(C)-(B)	(E)=(B)/(A)	(F)=(C)/(A) (Max100%)	(G)=(F)-(E)
Mujur	2,056,000	1,224,900	2,059,000	834,100	59.6%	100%	40.4%
Rejali	4,143,000	1,708,000	4,155,300	2,447,300	41.2%	100%	58.8%
Glidik	2,911,000	75,900	2,913,100	2,837,200	2.6%	100%	97.4%
合計	9,110,000	3,008,800	9,137,000	6,128,200	33.0%	100%	67.0%

Source: Prepared by JICA Project Team

(2) Sediment Discharge and Movement in Rejali River

The eruption of Mt. Semeru in December 2021 and December 2022 generated large pyroclastic flows that flowed down the Rejali River and deposited on the riverbed. Debris flows generated by subsequent rainfall inundated the left bank of the river in the upper and midstream reaches (S2 and S4 areas).

(3) Selection of Priority Development Areas

The S2 area in the upstream basin and the S4 area in the midstream basin of Rejali River were selected as priority areas, since these areas were inundated by debris flows in 2021 and 2022 as described above and have the potential to deposit large volumes of pyroclastic flows during future eruptions.

(4) Basic Policy for Facility Development and Sediment Management

In areas where debris flow overflow is concerned, the training dikes shall be safe against overflow by ensuring a height that takes into account the hydraulic jump. A new sabo dams of open type are constructed upstream of the existing sabo dam, so that the debris flow capturing function is achieved at an early stage.

Sediment removal shall be implemented by the sediment mining companies under the control of the Ministry of Energy and Mineral Resources (ESDM), and BBWS Brantas to the extent that it does not affect the safety of sabo facility. Sediment removal shall be carried out to the sediment management line in each area. Emergency sediment removal will be carried out after pyroclastic flow deposition. To ensure efficient implementation of sediment removal, access roads to the sediment deposition area shall be secured by making effective use of existing roads.

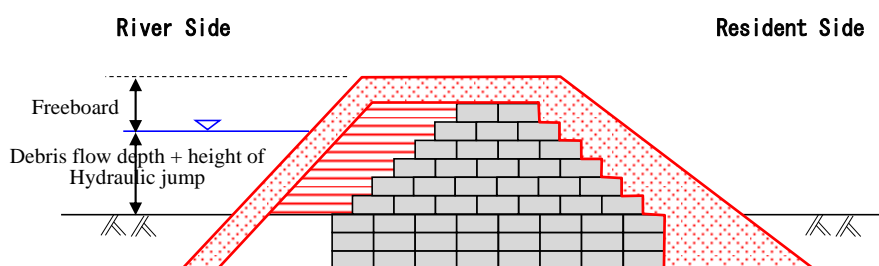


Figure -1 Basic shape of training dike

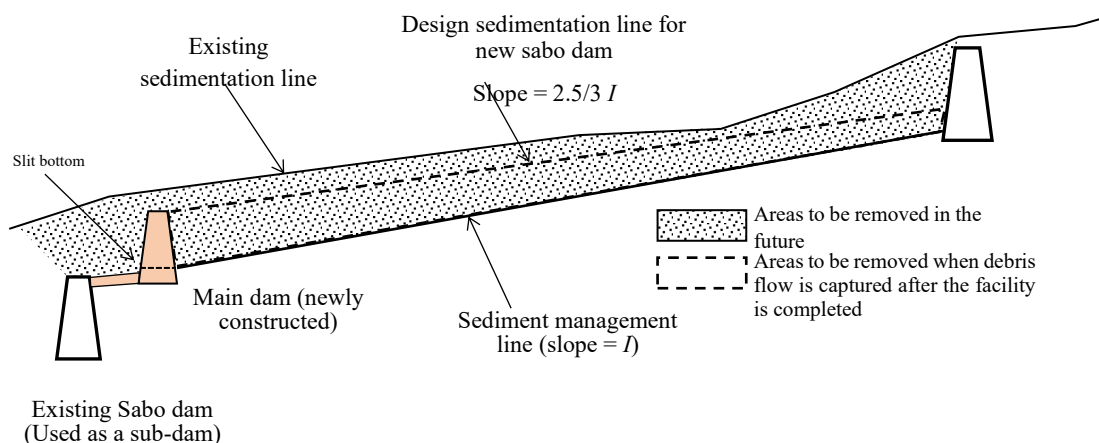


Figure -2 Schematic diagram of the sediment management policy

(5) Facility Plan for Upstream Section (S2 Area)

The priority facilities in S2 area are 2 sabo dams (CD Kobokan 5 and CD Pelintas Curah Lengkong 2) and a training dike (Tanggul Curah Lengkong). In areas where debris flow inundation is a concern, the height of the training dike will be 3 m higher than the riverbed elevation after pyroclastic flow deposition.

The sabo dam will be an open-type main dam and the existing dam will be a sub-dam to capture the debris flow to quickly achieve its debris flow capturing function.

(6) Facility Plan for Midstream Section (S4 Area)

The priority facilities in S4 area are 3 sabo dams (DD Leprak2, DD Leprak3, and KD Leprak3) and training dikes. In the area where debris flow inundation is of a concern (near Tanggul Leprak 24 to 26), the height of the training dike will be 3 m higher than the riverbed elevation after pyroclastic flow deposition.

The sabo dams shall be a new open type main dam and the existing dam shall be used as a sub-dam to achieve its debris flow capturing function quickly.

(7) Sediment Control Volume of Sabo Facilities After Construction

The following table shows the control volume of the sabo facilities after the designed improvements.

Table -2 Sediment control volume

Sediment control volume (m ³) Current situation	Sediment control volume (m ³) after the construction of designed facility
1,708,000	1,651,500 (Reconstruction) + 2,503,800 (Rehabilitation) = 4,155,300

Source: Prepared by JICA Project Team

(8) Basin Design of the S2 and S4 Areas

The basic design of the priority sabo facilities in the S2 and S4 areas is as follows

Sabo dam:

The main dams are newly constructed and of the open type (S2 area: conduit type, S4 area: slit type). The existing dams will be utilized as sub-dams. In S2 area, road function as a river crossing structures will be added to the crest of the sabo dams. The dam height shall be set such that debris flow inundation may not take place upstream.

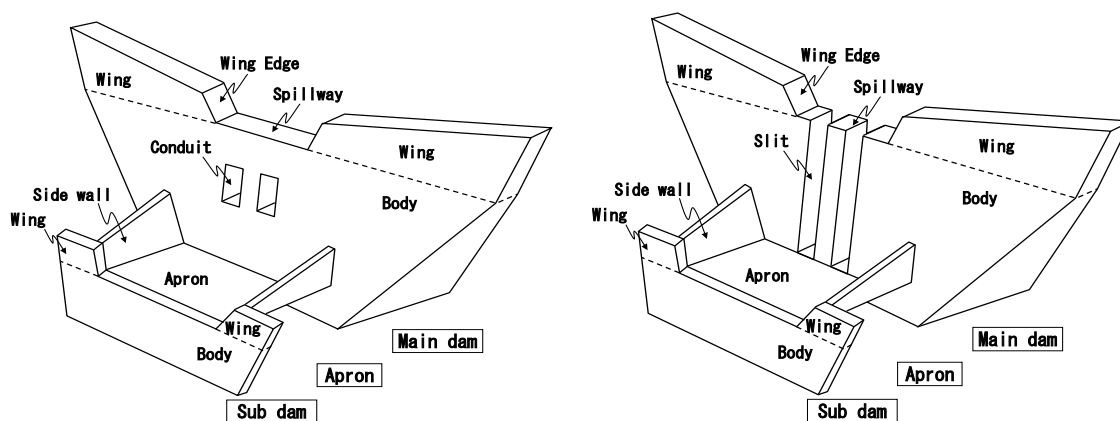


Figure -3 Schematic diagram of open-type sabo dams (left: conduit type, right: slit type)

Training dike:

The existing dike material, gabions, will be utilized as are. Cobble stone concrete (cyclop) will be used for the dike material, and concrete will be used for the surface protection of the dike slope to improve its durability.

4. Preliminary Detailed Design

(1) Sabo Dams

The detailed design was in accordance with “SNI 2851-2021 Desain Sabodam, 2021”. However, items not included in this technical standard were supplemented with old version of Indonesian technical standards and guidelines, Japanese technical standards, etc.

Stability calculations were performed for both cases of debris flow and flooding based on the standards. The upstream and downstream slope gradients were set as follows.

Table -3 Determination of crest width and Slope

Construction package	Facility name	Total crest width	Downstream Slope	Upstream Slope
S2 Area	CD Kobokan5	10.0m (Road Width 6.0m)	0.2	0.2
	CD Pelintas Curah Lengkong2	10.0m ((Road Width 6.0m)	0.2	0.2
S4 Area	KD Leprak3	3.0m	0.2	0.5
	DD Leprak3	3.0m	0.2	0.4
	DD Leprak2	3.0m	0.2	0.3

Source: Prepared by JICA Project Team

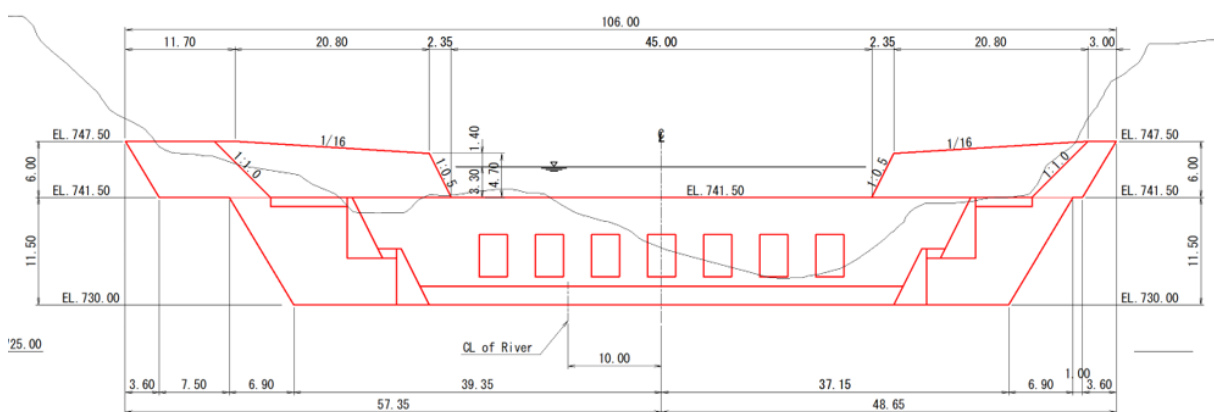


Figure -4 Drawing of sabo dam (open-type(conduit type) (Front view of CD Pelintas Curah Lengkong 2)

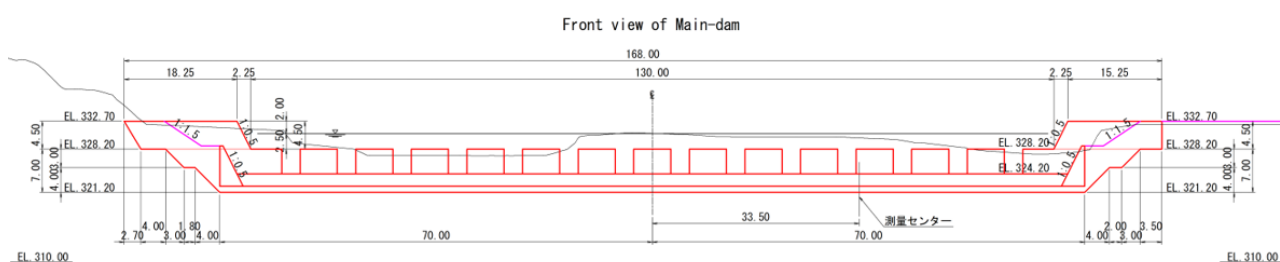


Figure -5 Drawing of sabo dam (open-type (slit type) (Front view of KD Leprak3)

(2) Training Dikes

The design of the training dike was in accordance with “Pd T-16-2004-A_Perencanaan Teknis Tanggul pada Sungai Lahar, 2004”. Based on this standard, the width of the crest is set 4 m, stable slope gradient of the embankment is set 1:1.5, and the foundation depth is set 1.5 m.

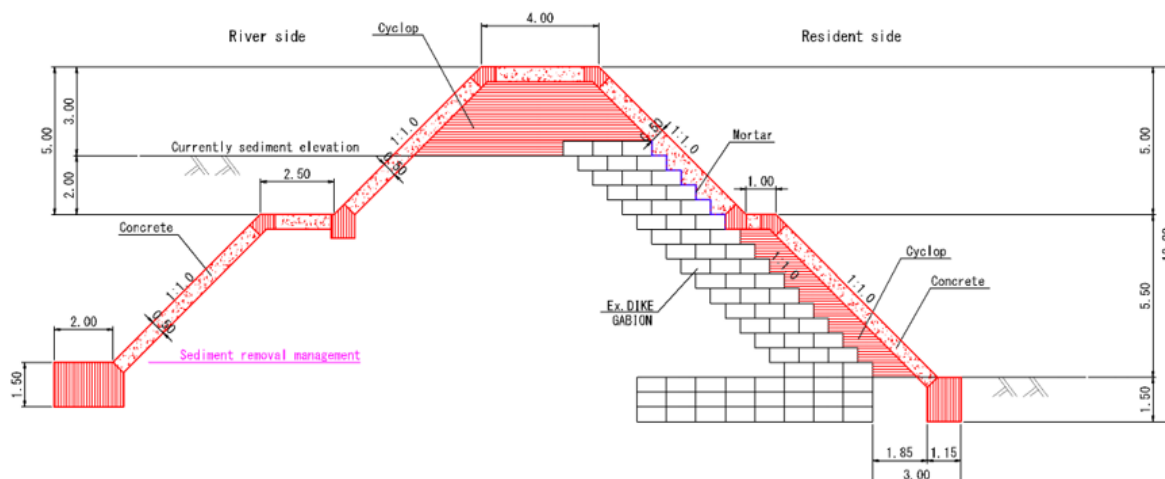


Figure -6 Drawing of training dike (Tanggul Leprak 24,25,26)

5. Construction Plan

(1) Scope of Work

The main work to be carried out in this project is outlined in Table -4.

Table -4 Facilities and main work types

Area	Facility Name	Main Works Types
S2	<ul style="list-style-type: none"> - CD Kobokan 5 - CD Pelintas Curah Lengkong 2 - Tanggul Curah Lengkong 	<ol style="list-style-type: none"> 1. Preparation work <ul style="list-style-type: none"> • Equipment and material yard • Workers accommodation and management office setup • Mobilization and demobilization of heavy equipment • Temporary roads 2. Sabo dams <ul style="list-style-type: none"> • Concrete work • Rubble concrete work (cyclopean concrete) • Reinforcing steel work, formwork work, scaffolding work • Diversion work (temporary cofferdam, sandbag work) 3. Diversion dikes <ul style="list-style-type: none"> • Excavation work, embankment work • Concrete work • Geotextile work
S4	<ul style="list-style-type: none"> - Krib Hulu Leprak - Tanggul Leprak 22 - Tanggul Leprak 23 - Tanggul Leprak 24 - Tanggul Leprak 25 - Tanggul Leprak 26 - KD Leprak 3, - DD Leprak 2, - DD Leprak 3 - Tanggul Leprak XVII Kebondeli 2021 - Tanggul Emergency, - Tanggul Leprak II-D 	

Source: Prepared by JICA Project Team

(2) Project Schedule Calculation

The entire project is divided into S2 area (3 facilities) and S4 area (14 facilities). The period from the start to completion for both the S2 and S4 areas is expected to be 24 months (2 years).

(3) Quality Control Plan

The main items that require quality control are mainly divided into concrete work, reinforcement work form work, and earthwork. Table -5 shows the proposed quality control

items for concrete work, which is the major work in this project.

Table -5 Quality control items for concrete work (draft)

Control Item		Test Method	Test Frequency
Material	Cement	Quality certificate, chemical and physical test results	Per material
	Water	Component test results	Per material
	Admixture	Quality certificate, composition analysis table	Per material
	Fine Aggregate	Oven-dried specific gravity	At every material change
		Grain size distribution, coarse grain ratio	
		Clay lumps and fine particles ratio	
Coarse Aggregate	Oven-dried specific gravity	At every material change	
	Grain size distribution (mixed)		
Mixing Test		Compressive strength test (specimen cube)	For every mix
During Pouring	Slump (Concrete)		For each pour
	Air content		
	Temperature		
Strength		Compressive strength test (7 days, 28 days)	As per specified frequency

Source: Prepared by JICA Project Team, referring to the SNI 03-1972-1990: Test method for concrete slump; SNI 03-1974-1990: Test method for compressive strength of concrete; SNI 03-2492-1991: Sampling and testing method for core concrete; and SNI 03-2834-1992: Procedure for normal concrete mix design.

(4) Items to be Noted in Construction

- **Adherence to labor standards**

The employer shall comply with Indonesian labor laws when hiring workers, as well as respect appropriate working conditions and customs associated with the employment, prevent disputes with workers, and ensure safety related to occupational accidents.

- **Safety measures during construction**

In this project, ensuring construction safety during high-water periods through rainy seasons is the top priority. Pre-identifying evacuation actions and locations, establishing an emergency communication system, and thoroughly collecting information with BNPB's local volcano monitoring facilities or by setting up monitoring cameras / rain gauge equipment, are essential.

- **Environmental preservation during construction**

Considering the impact on the surrounding environment, waste materials and surplus soil from the demolition of existing structures shall be disposed to designated sites. In addition, measures for dust, turbid water, etc. generated during construction shall be prepared.

- **Emphasis on concrete quality control**

The quality of the concrete will have a large impact on the lifespan of the concrete structures planned in this project. To construct high-quality concrete, the quality control shall be a priority during the construction on materials such as aggregates, sand, water, cement, and forms, specification of the mixing plant, regulations for concrete transport, and pouring / curing.

6. Construction Costs

The approximate construction costs required for this project are 2.30 billion Japanese Yen for S2 area and 2.74 billion Japanese Yen for S4 area.

Table -6 Estimation of Construction Costs

NO.	Item	Amount (Rp.)	Amount (Yen) ※reference	Ratio (%)
I	Preparation Work	1,536,358,000	14,738,661	0.64
II	Safety Management	1,805,747,000	17,322,976	0.75
III	CURAH LENGKONG DIKE WORKS	28,906,820,513	277,310,251	12.03
IV	CD PELINTAS CURAH LENGKONG 2 WORKS	27,343,402,705	262,311,998	11.38
V	CD KOBOKAN 5 WORKS	180,617,921,176	1,732,712,214	75.19
S2 Construction Cost		240,210,249,393	2,304,396,099	100.00

NO.	Item	Amount (Rp.)	Amount (Yen) ※reference	Ratio (%)
I	Preparation Work	1,830,158,000	17,557,157	0.64
II	Safety Management	1,874,927,000	17,986,637	0.66
III	LEPRAK UPPER DIVERSION DIKE	13,419,939,844	128,740,789	4.71
IV	LEPRAK 26 DIKE	39,411,503,961	378,084,267	13.82
V	LEPRAK 25 DIKE	30,721,494,766	294,718,868	10.77
VI	LEPRAK 24 DIKE	28,766,028,846	275,959,601	10.09
VII	LEPRAK 23 DIKE	27,235,354,049	261,275,461	9.55
VIII	KD LEPRAK 3 WORKS	16,702,611,171	160,232,264	5.86
IX	PEKERJAAN TANGGUL LEPRAK XVII KEBONDELI 2021	27,819,383,564	266,878,200	9.76
X	LEPRAK 22 DIKE	17,551,997,903	168,380,640	6.16
XI	LEPRAK II-D DIKE	15,756,346,579	151,154,514	5.53
XII	EMERGENCY DIKE	7,559,452,243	72,519,688	2.65
XIII	DD LEPRAK 2	29,838,675,459	286,249,765	10.46
XIV	DD LEPRAK 3	26,659,624,880	255,752,349	9.35
S4 Construction Cost		285,147,498,265	2,735,490,198	100.00

Source: Prepared by JICA Project Team

7. Overview of Environmental and Social Considerations Activities

(1) Update of Existing Environmental Assessment Reports

During the emergency response works following the 2021 eruption, it was determined that the required environmental assessment reports for S2 and S4 targeted in this project would be UKL-UPL. The reports were submitted by the Lumajang Regency Public Works and Spatial Planning Office (DPUTR) to the Lumajang Regency Environmental Office (DLH) and environmental approvals were obtained.

As a result of the comparison of the existing UKL-UPL with the preliminary detailed design results (draft), it was confirmed that all three packages remained within the UKL-UPL criteria—river length in the construction area under 15 km and excavation volumes under 500,000 m³—, so it was confirmed that no additional EIA was required, and the content of the existing UKL-UPL were updated accordingly.

(2) Updates in line with JICA Guidelines for Environmental and Social Considerations

The specific measures and monitoring items related to environmental and social considerations are summarized at the end of the chapter as "Matrix of Environmental Management and Monitoring Standards". This matrix was checked against the scopes of impacts to be assessed in JICA Guidelines to confirm the specific measures and monitoring contents. Furthermore, in consultation with BBWS Brantas and the DLH of Lumajang Regency, the missing items were added and the missing parts were updated. The main aspects that were missing in the existing UKL-UPL were as follows

1. Specificity of the measures to be described in the environmental management standards
2. Feasibility of monitoring (method of implementation, frequency, location)
3. Social environmental issues such as land use, impact on existing social infrastructure and gender.
4. Establishment of a grievance redress mechanism

The update was carried out based on the deficiencies identified, and the main points 1 and 2 were incorporated into the updated content.

It was confirmed that the project primarily involves rehabilitation and reconstruction of existing facilities along rivers, thus no new land acquisition and involuntary resettlement are required.

(3) Recommendations for environmental and social considerations

Following the submitted updated UKL-UPL, the environmental approval necessary for a construction permit was obtained on December 10, 2024. With regard to the scope that could not be included in the update of the UKL-UPL, which already has a fixed format, the following have been compiled as recommendations for environmental and social considerations to be taken into account for ongoing project development.

1. Monitoring temporary land renting during construction
2. Strategy to Minimize Soil Excavation and Its Implementation
3. Consideration Regarding Utilization of Access Roads Adjacent to Residential Areas
4. Establishment of a Grievance Redress Mechanism
5. Gender-Inclusive Construction Planning

CHAPTER 1 BACKGROUND AND PURPOSE OF THE PROJECT

1.1 Background of the Project

1.1.1 Background

The Republic of Indonesia is prone to volcanic eruptions, floods, and other natural disasters, which contribute to economic and social losses. The country ranks third in the world in the number of volcanoes, with 129 active volcanoes. Volcanic eruptions cause disasters such as ash fall, pyroclastic flows, and debris flows, which have a significant impact on human lives, property, and social and economic infrastructure. Addressing volcanic and sediment-related disasters is extremely important for promoting regional security and sustainable growth. Therefore, the Indonesian government has set disaster management as one of the seven development priorities in its National Medium-Term Development Plan (RPJMN 2020-2024), which was formulated in January 2020, and has included countermeasures against volcanic eruption in the plan. Under these circumstances, JICA has been supporting volcanic eruption and sediment-caused disaster countermeasures for Mt. Semeru and Mt. Merapi for many years, and construction of volcanic Sabo facilities has been carried out with yen loans.

Mt. Semeru in East Java experiences small eruptions almost every year. Debris flows, originated with volcanic ejecta and triggered by rainfall, occur every few years. Eruptions larger than medium scale also occur almost every 5 years. The eruption that occurred on December 4, 2021 resulted in 50 deaths, more than 10,400 evacuees and 1,027 damaged houses (BNPB 2021.12.21). The pyroclastic flow burned houses and agricultural fields. The pyroclastic flow sediments deposited on the riverbed turned into debris flows and overflowed the existing dikes, causing damage to the villages. The bridge on the national highway, which is an important infrastructure in the area, was completely collapsed by the pyroclastic flow and debris flow. Mt. Semeru has been repeatedly erupting intermittently in small volcanic eruptions since before the latest eruption, and the area has always been at high risk of debris disasters. The large amount of volcanic ejecta from the eruption will discharge as debris flows with the coming rains, exposing residents to the risk of debris disaster and flooding during the rainy season. Urgent and drastic countermeasures are needed.

Although the Directorate General of Water Resources, Ministry of Public Works ('DGWR-MPW), which is responsible for volcanic erosion control, has identified sediment control from eruptions as one of its key programs, there is needs for capacity for detailed planning of volcanic sabo facilities, particularly the technology required for structural measures against frequent debris flows caused by pyroclastic deposits, such as the case of the 2021 eruption. It is urgently needed to improve engineers' capacity to implement planning and design.

During June 2022 ~ March 2024, JICA conducted the "Data Collection Survey on Volcanic Disaster Reduction in East Java and Bali Islands in the Republic of Indonesia". In this survey, in order to study disaster reduction measures for the three volcanoes of Semeru, Kelud, and Agung, the information necessary to set up basic policies for reconstruction, to review the master plan for Mt Semeru, to prioritize the areas and projects, to improve the human resources/systems related to volcano countermeasures and to strengthen evacuation measures, were collected. "The Project for Capacity Development of Mt. Semeru Volcanic Disaster Structural Measure Planning" (hereinafter referred to as "The Project") provides the technical support necessary for the implementation of the detailed design of the volcanic sabo facility of Mt. Semeru. Since the eruption in 2021, the Indonesian government has positioned it as a project of high importance and urgency.

1.1.2 Project Title

The title of the Project is "The Project for Capacity Development of Mt. Semeru Volcanic Disaster Structural Measures Planning in The Republic of Indonesia"

1.1.3 Objective

The project is intended to provide the technical support required for the implementation of the detailed design of sabo facilities at Mt. Semeru, in order to establish an autonomous sabo project

implementation system for the implementing agencies, thereby contributing to volcanic disaster risk reduction.

1.2 Target area and project duration

The target area is mainly the Rejali River basin, which flows through the foothills of Mt. Semeru and is the main project basin. The project period is set for 25 December 2023~21 February 2025.

1.3 Organization of Indonesian Government

Implementing Organization:

Directorate General of Water Resources, Ministry of Public Works (DGWR-MPW).

Relevant Organization:

Directorate of Rivers and Coasts, Directorate of Water Resources Management System and Strategy, Directorate of Water Resources Engineering Development, Technical Implementation Unit for Sabo Dams, and BBWS Brantas as the basin management office.

1.4 Project Implementation

The Project will be implemented under a Record of Discussion (RD) signed on 4 October 2023, with the Directorate General of Water Resources of the Ministry of Public Works as the implementing agency, as described above. An organizational chart of the Directorate General of Water Resources is shown in Figure 1-1.

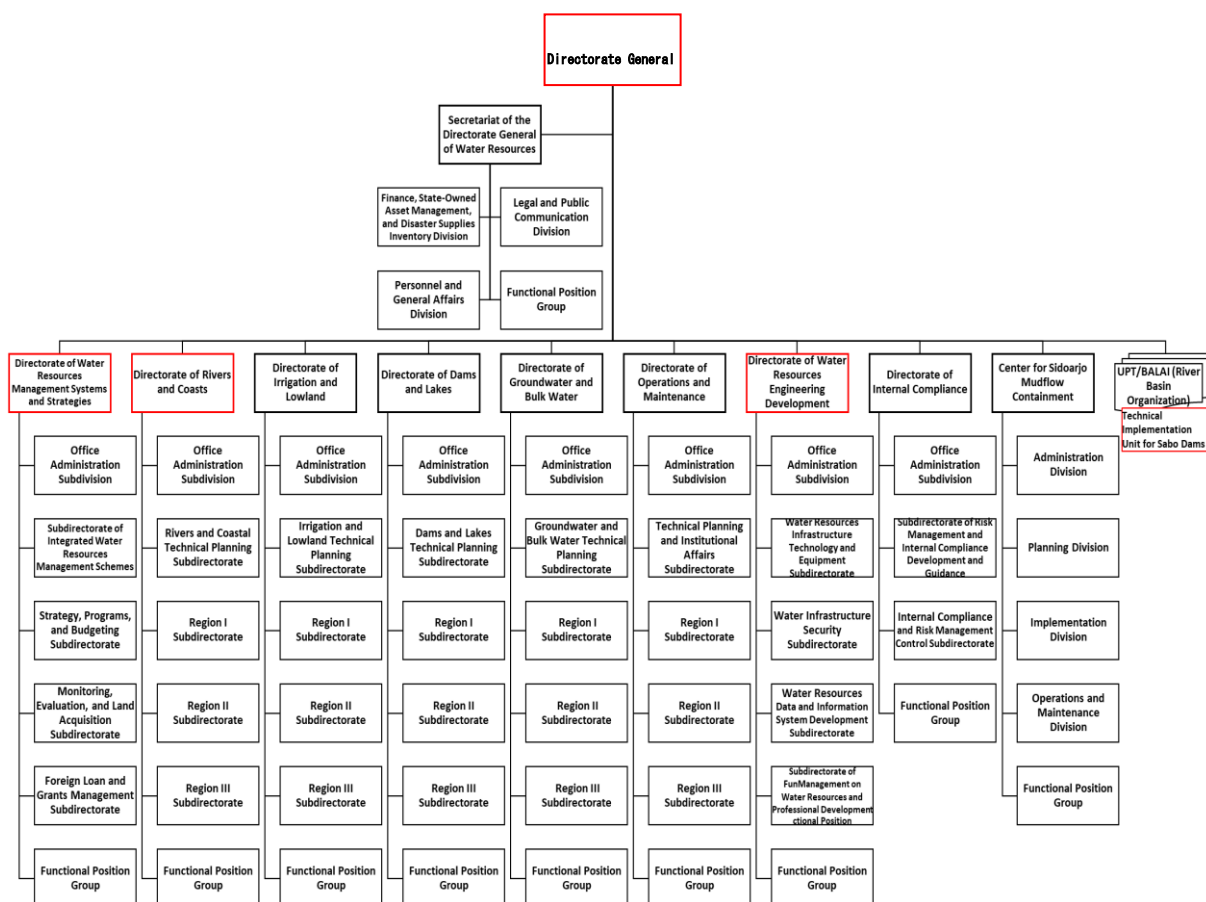


Figure 1-1 Organization chart of Directorate General of Water Resources

1.5 Project Activities

1.5.1 Method of Cooperation

Work related to the planning, design, and preparation of tender documents for sabo facilities will be carried out in collaboration with BBWS-Brantas staff, and capacity building will be carried out through collaboration works. The survey, planning, design, and preparation of bidding documents will be prepared in cooperation with BBWS, and the contents will be shared with the relevant departments within the DGWR-MPW, with the goal of ensuring that the results of this support are systematically established.

In this way, activities to improve the capacity are based on on-the-job training. A design meeting or other similar workshop-style briefing session will be set up at the appropriate stages to explain the survey and design work performed by the consultant, and to deepen understanding through a question-and-answer session.

1.5.2 Outputs

The four outputs of the Project are shown below:

Output 1: The capacity to conduct basic research and information gathering necessary to implement the detailed design of sabo facilities will be strengthened.

Output2: The capacity to review sabo facility specifications and facility locations based on field survey results is strengthened.

Output 3: The capacity to prepare detailed design for sabo facilities is strengthened.

Output 4: The capacity to prepare environmental and social considerations is strengthened

The activities, outputs, project purpose, and overall goals of the Project are expressed in PDM shown in Appendix 1-1.

CHAPTER 2 NATURAL CONDITIONS

Mt. Semeru is located near the eastern tip of Java Island in Indonesia, and at 3,676 meters above sea level, it is one of the most active volcanoes in the world. It is also known as Mahameru, meaning “great mountain”. Together with Mt. Bromo to the north, the area around the summit is designated as the Bromo Tengger Semeru National Park.

The frequent small-scale eruptions at the summit crater eject andesitic magma, as well as highly viscous lava, which flows out to form a conical mountain body. Maeno et al. (2018)¹⁾ reported the following eruption history based on field surveys of the southeastern to southwestern foothills of Mt. Semeru.

There are many topographic features and deposits that indicate flank eruptions. These are the result of activity by basaltic magma around the 3rd to 11th centuries, which transitioned from lava flows to explosive eruptions, and also included activity that formed pyroclastic cones on the flanks of the mountain.

- From the 11th century to present, eruptions have mainly been caused by andesitic magma from the summit.
- In the 15th and 16th centuries, thick pyroclastic fall deposits were formed on the southwest side, and pyroclastic flows generated by a series of activities buried the ruins in the area.
- Explosive eruptions occurred 3 centuries ago with andesite magma at the summit, and eruptions of a scale far greater than the current activity occurred repeatedly 19 centuries ago.
- In recent years, eruptions accompanied by relatively large-scale pyroclastic flows have occurred every 5-7 years.



Figure 2-1 View of Mt. Semeru from the southeast on February 27, 2024

2.1 Topography of Mt. Semeru and the target river

The topography around Mt. Semeru can be broadly divided into hills formed from the ejecta of Mount Bromo in the north and a volcanic piedmont fan fed by Mt. Semeru, a new crater in the south. The caldera of Mount Bromo is formed by a large-scale explosive eruption. The south side of Mt. Semeru is a conical stratovolcano with a wide volcanic fan spreads out below it. The fan continues to grow as it covers the bedrock mountain range, and is widely distributed in the south and southeast. The Rejali River, the target river of this project, flows in a straight line from the crater of Mt. Semeru to the southeast, crosses the bedrock mountains between S2 and S4 areas²⁾, and flows along the south

1) Maeno, F., Nakada, S., Yoshimoto, M., Shimano, T., Zaennudin, A., Prambada, O., Eruptive history and event tree of Semeru volcano, Indonesia,” Japan Geoscience Union SVC41-06, Earthquake Research Institute, University of Tokyo, 2018.

2) Note: The Rejali River Sabo construction package is divided into S1 to S6 in the “Information Gathering and Confirmation Survey on Volcanic Disaster Prevention in Eastern Java and Bali, Indonesia, and Final Report on the Basic Policy for Reconstruction of Mt. Semeru, Mt. Kelud, and Mt. Agung Final Report, March 2024, p.3-21, and the location of each of these construction packages is shown in Figure 3-13 in Chapter 3, 3-3 below. In this chapter, these construction package numbers are used to explain the facility

west of S4 before emptying into the Indian Ocean.

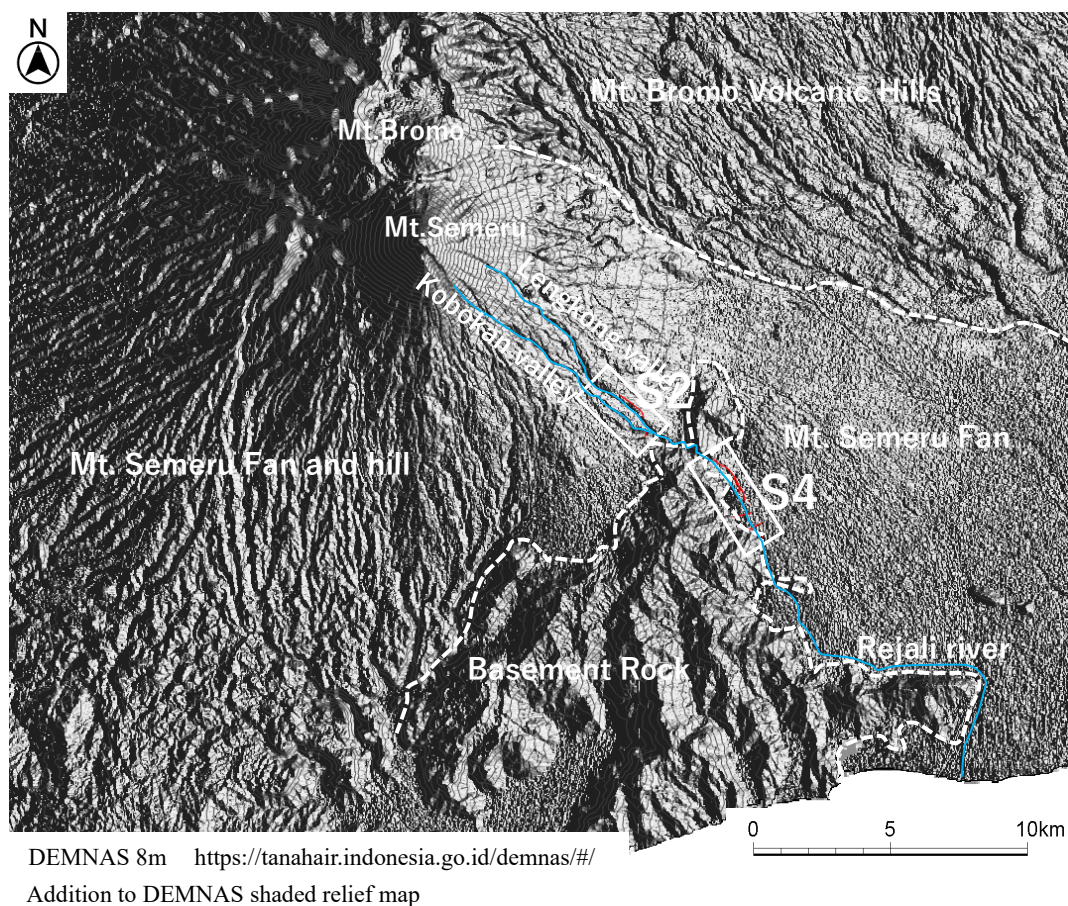


Figure 2-2 Overview of the topography of Mt. Semeru and the target river

2.2 Geology of Mt. Semeru

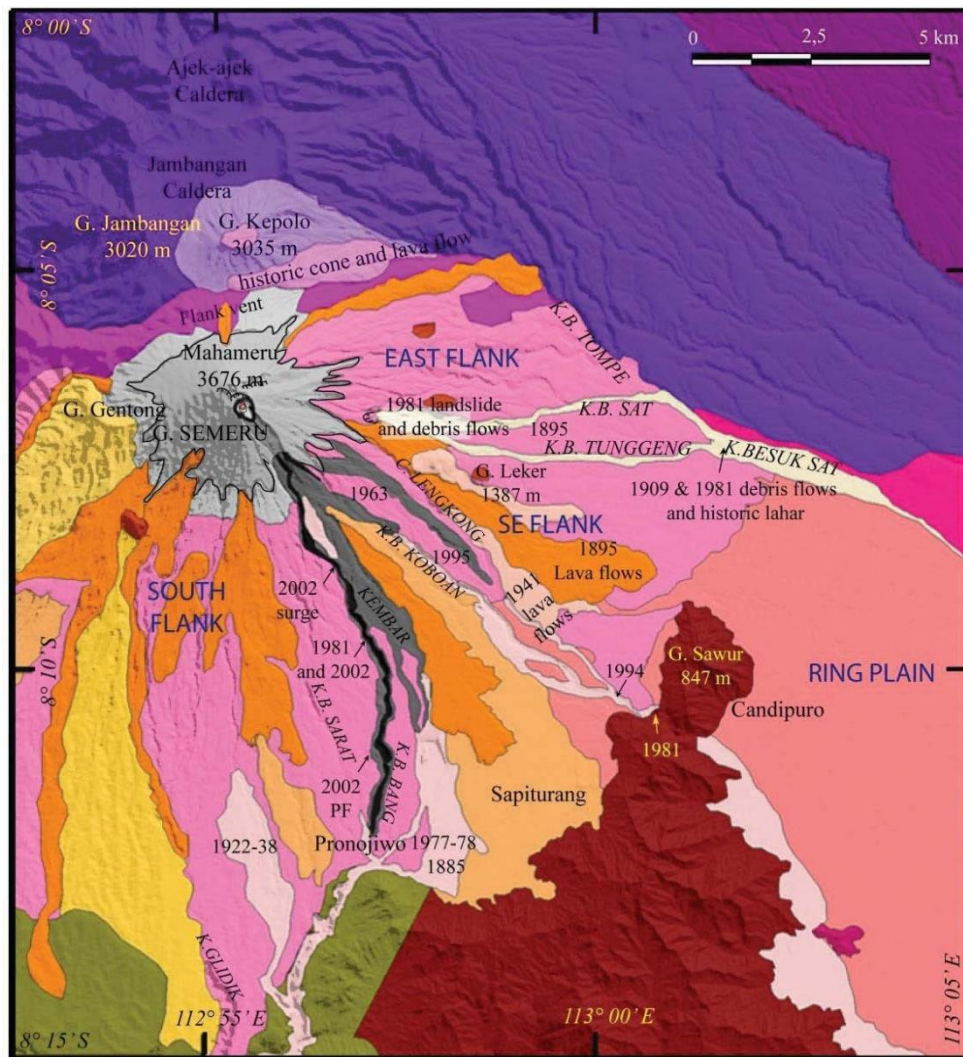
The geology of Mt. Semeru is composed of the Semeru volcanic complex and bedrocks (Figure 2-3)³⁾. The bedrocks consist of volcanic and sedimentary rocks from the Oligocene to the Miocene, and formed an erosion mountain range that is different from Mt. Semeru. They are distributed on the southeastern foothill slope of Mt. Semeru, more than 12 km from the summit.

Mt. Semeru is a volcanic complex consisting of two volcanoes: Mount Mahameru (the old Mt. Semeru) and Mt. Semeru (the young Mt. Semeru). The volcanic rocks (Tengger/Jembangan volcanic rocks) that erupted from the old crater on the north side are from the pre- to late Pleistocene. Meanwhile, the volcanic rocks of Mt. Semeru that erupted from the new crater on the south side are from the late Pleistocene to the Holocene (the present day). The older Tengger/Jembangan volcanic rocks are distributed to the north of the crater of Mt. Semeru, while the newer eruptions of Mt. Semeru are distributed on the southern slopes, including the area around the summit. The Semeru volcanic rocks mainly consist of those that erupted from the historical period to the present day, and are classified as lava, pyroclastic flow (block and ash flow), and lahars (volcanic mudflows). The lava flows from 1895 and 1941 can be clearly identified topographically as they flowed down from the crater to about 10 km away. Since the late 1900s, the main ages of deposition for lahars and pyroclastic flows are also known. The 2002 pyroclastic flow and lahar flowed down the Glidik River

location area. In addition, as a result of the study in Chapter 3, Section 3-3, it has been confirmed that the detailed design of this project will be implemented for S2 and S4.

3) A. Solikhin, "Geology, tectonics and post-2001 eruptive activity," HAL Id: tel-01555688, Université Blaise Pascal DOCTOR OF PHILOSOPHY in Volcanology, 2015, <https://theses.hal.science/tel-01555688/>.

basin to the south of the summit for more than 10 km.



Semeru Volcanic complex

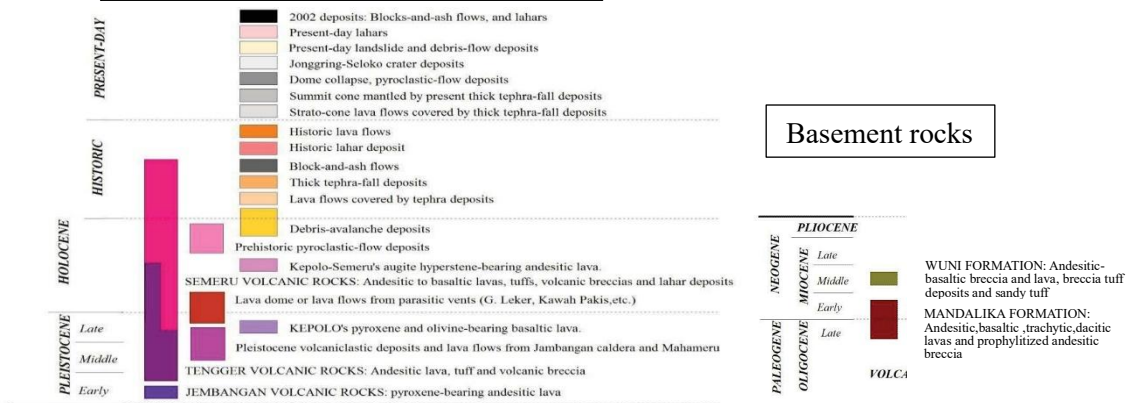


Figure 2-3 Geological map of the Semeru volcano³⁾

2.3 Evolution of the crater and eruption disaster history

2.3.1 Evolution of the crater

The outflow and transport routes of the crater lava that generates pyroclastic flows and lahars have been analyzed using satellite data, microtremor analysis result, etc. Since the crater of Mt. Semeru shifted from the Mahameru crater to the southeast, it has been reported that there has been a collapse of the crater, lava flows, and the expansion of erosion valleys due to the collapse of the crater wall on the southeast side (Figure 2-4)³⁾.

Comparing Google Earth satellite images since 2014, it can be seen that the erosion valley had been flowing down in a straight line to the south-southeast between 2019 and 2022, it changed direction to the south-east, and that the pyroclastic flow and lahars disasters since December 2021 were concentrated in the Rejali River basin (Figure 2-5).

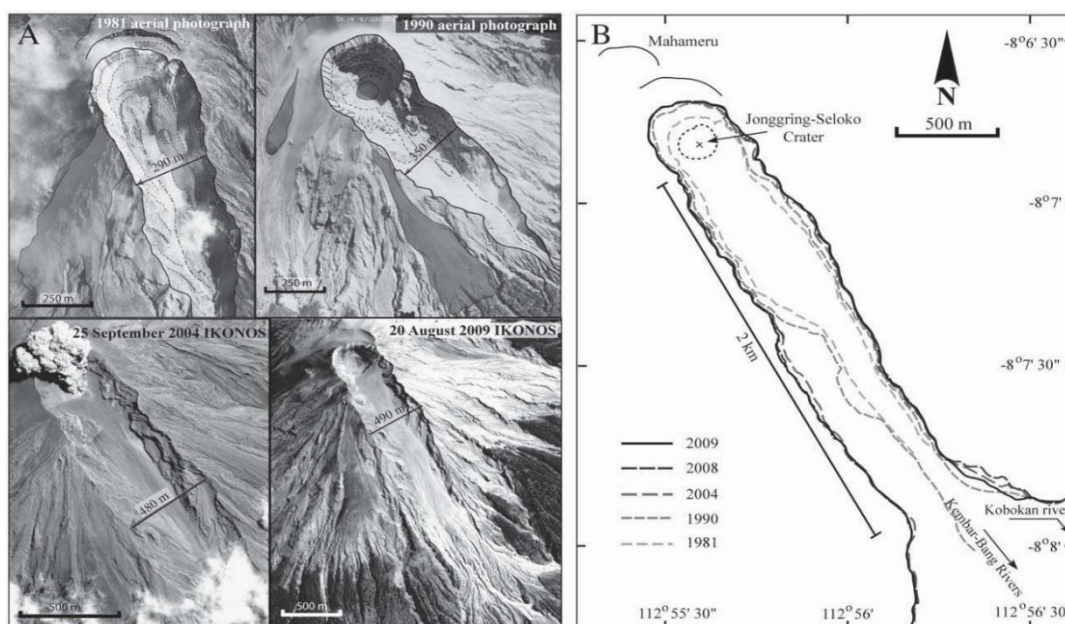


Figure 2-4 Changes in the crater (aerial photographs from 1981 and 1990, and satellite images from 2004 and 2009)³⁾

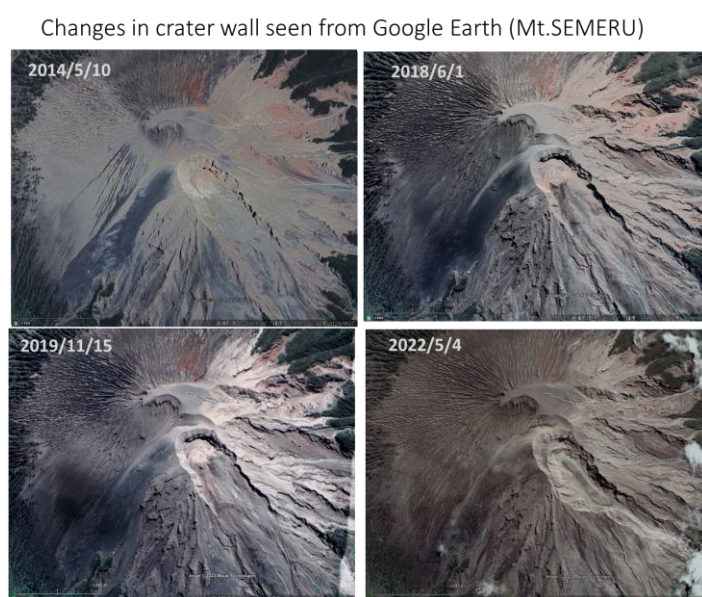


Figure 2-5 Changes in the crater since 2014 (Google Earth satellite images)

2.3.2 Eruption Disaster History

The volcanic activity of Mt. Semeru is reported daily by the Pusat Vulkanologi dan Mitigasi Bencana Geologi (PVMBG, English: Center for Volcanology and Geological Hazard Mitigation (CVGHM)), which is under the Geological Agency of the Ministry of Energy and Mineral Resources of Indonesia, based on analysis of data from earthquake monitoring network and direct observations. In addition, information on volcanic eruptions, pyroclastic flows, and debris flows is published by The Smithsonian Institution's Global Volcanism Program (GVP)³.

Thouret et al. have also systematically compiled the eruption history, flow direction, damage to villages, eruption style, etc. of Mt. Semeru from 1884 to 2003 as shown in the excerpts of 1981-2023 in Table 2-1. The table also includes eruption disaster history from 2004 onwards based on the GVP information. Eruptions of VEI 3 or greater (shown in bold in the table) occurred in 1981, 1985, 1988, 1994, and 2002-2003, for example. In addition, since 2017, small-scale eruptions have continued, and in December 2021 and December 2022, the largest pyroclastic flows confirmed in history occurred. Further, Figure 2-6 shows the locations of major cities and the areas flooded by lahars in the 20th century (shown in gray) as summarized by Thouret et al. (2007).

Table 2-1 History of eruptions at Mt. Semeru (1981-2023)

Reported date	Valley, flank, direction and distance	Victims; Damage (D)	Event and deposits*	Observed activity, magnitude, and aftermath
28, 29, 30 March, 3, 5 April 1981	C.Lengkong, Kembar, Bang, SE 10 km; Glidik, S, 7 to 11 km,	252 victims, 152 wounded 365 victims. Widespread	PFs, hot Lh, Aval., Df Hot Lh, overbank	Do. coll. $6.2 \times 10^6 \text{ m}^3$ Landslide on E flank (1,600-2,000 m asl), $6.0 \times 10^6 \text{ m}^3$
14 May 1981	Besuk Sat, Tengah, Tunggeng, Mujur, E, 30 km	Damage: 918 ha rice, 16 devastated villages, evacuation		
May 1982–16 Jan-1983	C. Lengkong, Kembar, Kobokan, SE, 3.5–4 km; Glidik, S, 7.5 km	No victim? Damage to villages	Lh, Pf, Aval.	Several villages relocated before Lh flowed down to S, $6 \times 10^6 \text{ m}^3$
10 May 1985 , 15–18 August 1985	Vent area (collapse), Tretes, Kobokan, Kembar SE 5 km. Unusual lahars in dry season	70? (Front near Pronojiwo) Damage to Jugosari village, Liprak	Tf, Aval., Pf? Lh	Expl., 1-km high columns, do. coll.; Pf deposit $5 \times 10^6 \text{ m}^3$
1986 July 1987	Rejali, Tretes, Kobokan, C. Lengkong, SE, 5 km		Lh, Tf, Aval.	D. to villages, arable land Expl., do. gr.
10-May-1988	Kembar, Tretes, Kobokan, C. Lengkong; SE, 7 km		Tf, Pf, Aval.	Expl., do gr, $5 \times 10^6 \text{ m}^3$
21-Dec-1990	Jonggring-Seloko vent Kembar, Kobokan		Fire fountain Aval	“Strombolian” expl., coll. of the crater floor?
1991	Scar, Kembar, SSE, 0.5 km		Aval.	Lava extrusion
1992	Vent area	3 Victims; damage to arable Land and houses	Tf	Expl., 1-km high column
3-Feb-1994	Scar, Kobokan, Lengkong; 11.5 km; Kembar SSE, 7.5 km (750 m asl)	8 Victims, 275 evacuated; Sumbersari covered; 1.5 km ² plantation, Oroombo and Renteng devastated	Bl-a-a-Fs; $6.3 \times 10^6 \text{ m}^3$, Ps, Tf ; post-event Lh	Do. coll. and ash-cloud Ps
20-Jul-1995	Kembar, Kobokan, C. Lengkong, SE 7.5–11.5 km (840 m asl)	Several villages evacuated, arable land devastated	Bl-a-a-Fs ; $5.5 \times 10^6 \text{ m}^3$ post- event Lh	Do. coll.
August–September 1996	Kembar, SSE, 2 km		Tf, Aval.	Do.gr. and coll., Pf., high columns
July–November 1997	Vent area, scar SE, 2 km; C. Lengkong	2 Tourists on 2 September 1997	Ballistics; Tf dispersed 46×18.5 km to the WNW	Expl.: 3.7–4.9-km high columns
March–Sept 1999	Vent area, scar, Kembar, SSE, 2 km		Aval.	Expl.; do. gr.; 9-km high columns
May–July, December 2000	Vent area, Kembar, Kobokan, SE & SSE, 3 km	2 Volcanologists killed and 5 wounded, 27 July 2000	Tf 11 km; Pf	Expl., do. Gr.; high columns
2001–2002	Vent and scar, Kembar, 0.75–2.5 km		Tf; Aval.	High columns in June–September

Reported date	Valley, flank, direction and distance	Victims; Damage (D)	Event and deposits*	Observed activity, magnitude, and aftermath
23–29, 30 December 2002	Vent area and scar; Bang, SSE, 9 km Supit near Pronojiwo, 750 m asl; Kembar, SSE, 1.5–4 km, avalanches	No victim; damage on forest by ash-cloud surge; Supit (Pronojiwo) evacuated	Bl-a-a-F and wet Ps: 3.5×10^6 m ³ and hot Lh in K. Bang on 29 December 2002 .Tf 12 km; Lh	Activity increased since March 2002(Alert level 2). Expl.,high columns; do.coll.;
March–May 2003	Vent area and scar; Bang and Kembar SSE, 1.5–3.75 km		Aval.; Pf, Lh	Explosive activity; do. gr. and do. coll.; alert level 2, MODIS thermal alert
April-May 2020	Vent area and SSE 2km		lava flows 700-2,000m from the summit down to Kember, Bang, and Kobokan, pyroclastic flow 2km	
Sep2020-Feb2021	pyroclastic flows from the summit lava dome traveled 2-11 km down the Kobokan	thousands evacuated	Tf/pf. Aval 500-1500m Kember and Kobokan	ash plumes 2.4 and 6.1 km altitude,Pf/Bl-a-a-F/ Expl/do.go/do.coll
Dec-2021	pyroclastic flows into Kobokan river SE 15-17km	destroyed the Gladak Perak bridge, 45 people were died and About 10,400 evacuated	Bl-a-a-F : 8×10^6 m ³ in Kobokan on 4th December, 15-17km , hot Lahar 23km	ash plumes 15 km altitude,Pf/Bl-a-a-F; 16 km Kobokan River Expl/do.go/do.coll
Dec-2022	Vent area, Kobokan SE 4.5km	dozen deaths. About 2000 evacuated, flooding Curah Kobokan,	Bl-a-a-F,pf ; 6km. do.coll , Lahar 19km	ash plumes 15km,Pf/Bl-a-a-F; 6 km Kobokan River Expl/do.go/do.coll

Tf; tephra fall; Pf; pyroclastic flow; Bl-a-a-F; block-and-ash flow; Ps; pyroclastic surge; Aval; rockslide avalanche from lava extrusion or dome, Expl.;explosions; do. gr; dome growth; do. coll; dome collapse
 source: ⁴added by JICA Project Team

The gray flood area in Figure 2-6⁴⁾ indicated that there was a flood that hit the city of Lumajang in 1909, and after 1946, there were large-scale floods in the Glidik and the Rejali River in the southeast basin. Since 1982, there have been no major floods until December 2021 due to the effect of sand pockets built in the 1990s.

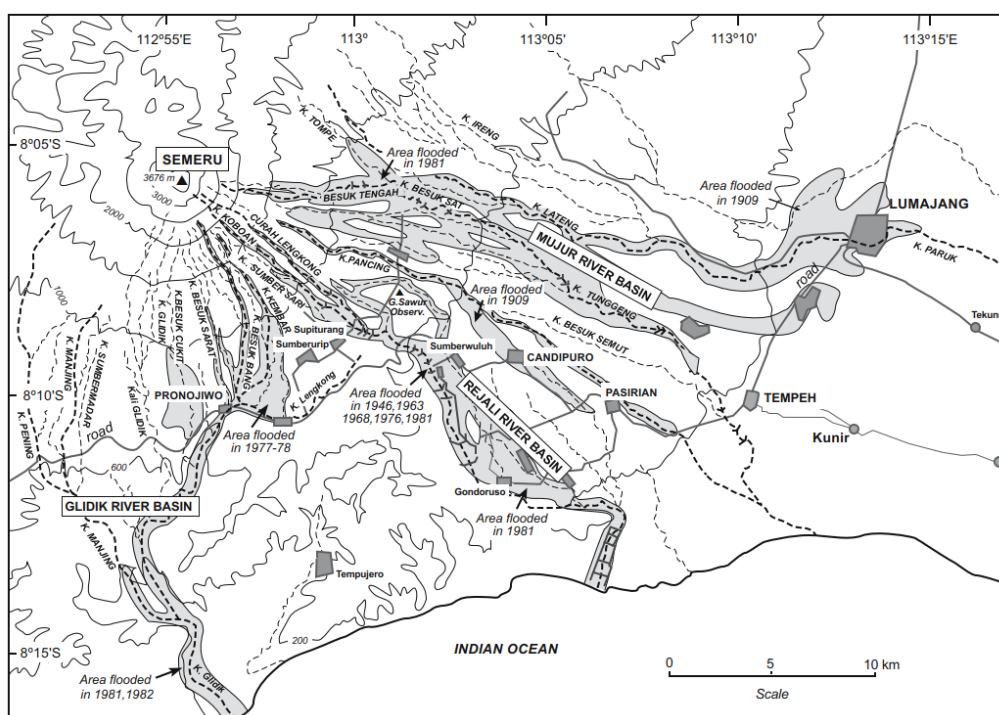


Figure 2-6 Map of the area flooded by lahar in the 20th century (gray)

4) Jean-Claude Thouret, Franck Lavigne, Hiroshi Suwa, Bambang Sukatja, Surono, “Volcanic hazards at Mount Semeru, East Java (Indonesia), with emphasis on lahars,” Bull Volcanology (2007) 70:221–244, 2007.

In December 2021 and December 2022, volcanic activity increased and two or more large-scale pyroclastic flows occurred. The volcanic activity of Mt. Semeru is organized and published by the PVMBG in the GVP⁵⁾.

(1) Pyroclastic flow in December 2021

Reported collapses of the lava dome in Semeru's Jonggring Seloko Crater and SE-flank flow during 1-6 December. On 1 December material collapsed from the unstable distal end of a 1-km-long lava flow in the SE-flank Kobokan drainage, sent a pyroclastic flow 700 m down the valley. At 13:30 on 4 December the seismic network recorded avalanche signals. At 15:20 a large pyroclastic flow produced a large rolling and expanding ash cloud that eventually rose to 15 km (50,000 ft) a.s.l. Reports from residents described darkness from airborne ash and rainy/foggy conditions. Pyroclastic material was deposited in two districts in the Lumajang Regency, while eight districts in the neighboring Malang regency were covered with ash. Preliminary estimation suggested that deposits extended at least 16 km SE from the summit.

According to BNPB (Badan Nasional Penanggulangan Bencana, English: National Agency for Disaster Countermeasure), the death toll from the 4 December collapse event rose to 48 by 13 December, 12 people were still missing, 21 were seriously injured, and 9,374 people were in 129 evacuation centers. The Alert Level remained at 2 (on a scale of 1-4), with a general exclusion zone of 1 km and extensions to 5 km in the SE sector. Approximately 11,658 people were in 52 evacuation centers by 14 December.

JAXA is analyzing the distance traveled by the pyroclastic flow in December 2021 (Figure 2-7). The pyroclastic flow flowed down in a straight line along the Rejali River on the southeast side and reached the upper part of the sand pocket (Leprak Sandpocket) in Area S4. The area where the topography changed significantly (in red) is shown. The distance from the top of the pyroclastic flow is estimated to be 15 to 17 km.

(2) Pyroclastic flow in December 2022

In November 2022, volcanic ash plumes rose to 1.5 km above the summit, and pyroclastic flows descended the southeastern flank of 4.5 km distance. In December, frequent eruptions of gas and ash occurred, and four pyroclastic flows moved 6 km down the southeastern flank from December 4 to 9. The volcanic plume rose to between 3.9 and 4.6 km. On December 4, at 02:46, a lava collapse occurred on the southeastern flank, triggering a series of pyroclastic flows that flowed mainly in the southeastern and southern direction for 5 to 13 km, and up to 19 km in the same direction. The gray to brown plume rose to an altitude of 5.1 km at 04:11 and flowed southeast and south, and at 09:18 a similar plume rose to an altitude of 8.6 km. The ejected white volcanic ash accumulated at a point 8 km from the summit, and ash fall was reported in an area 12 km east.

5) Global Volcanism Program, Department Of Mineral Sciences, National Museum Of Natural History, "January 2022 (BGVN 47:01)," https://volcano.si.edu/volcano.cfm?vn=263300#bgvn_202201, 2022.

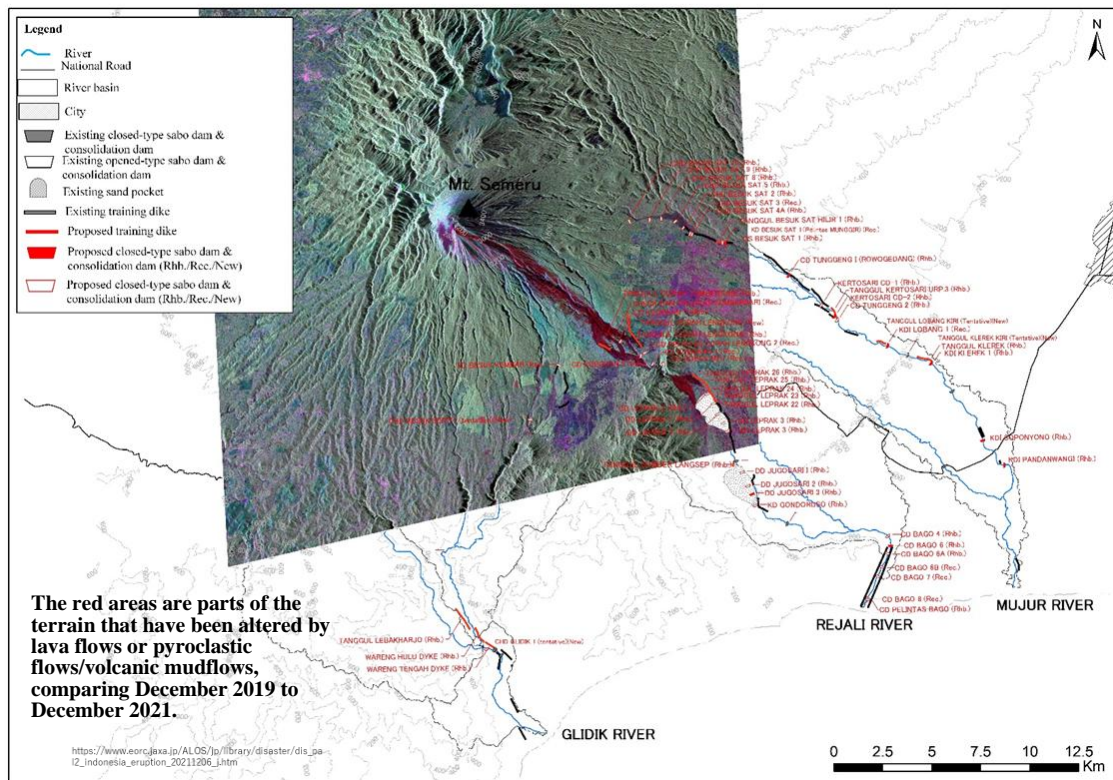


Figure 2-7 Overlay of JAXA's Synthetic Aperture Radar (ALOS2) differential analysis image and the location of Sabo facilities

Due to these two pyroclastic flows and the subsequent debris flows, the temporary training dike that was built on an emergency basis in S2 area and the upper 2 km section of the temporary dike in S4 area were overtopped by the debris flows, burying the residential area of the village. In addition, the sediment that moved downstream raised the riverbed, and on July 7, 2023, a debris flow overflowed the dike near the suspension bridge downstream of S4 area and flooded the area.

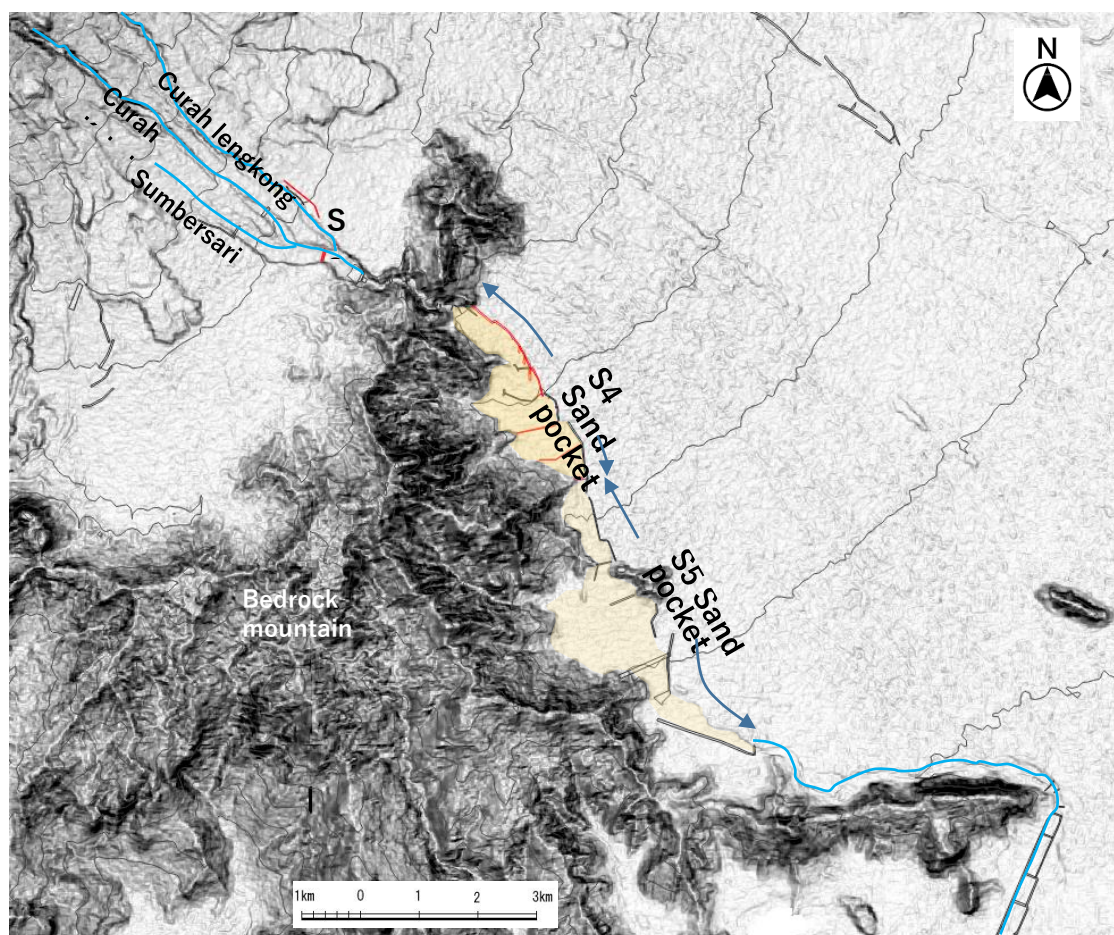
2.4 Topography and Geology of the Area Surrounding the Facility

2.4.1 Summary of the Sabo Facilities

The Sabo facilities in the Rejali River basin efficiently utilize the bedrock mountains to separate the highly flood-prone volcanic fan area with training dikes. Two sand pockets (Leprak sand pocket at S4 and Jugosari Sandpocket at S5) to regulate sediment runoff and the associated check dams (CD/KD/DD) are being arranged (Figure 2-8).

The upstream section (S2) is the section where the Curah Lengkong, Curah Kobokan, and Summersari valleys converge after partially eroding the lava flow topography of 1941 and 1895 (see Figure 2-8) and cross the bedrock mountains on the downstream side. The Gladak Perak Bridge, which is a key traffic point, is located near the exit of the bedrock mountains just upstream of Sand Pocket S4. Further downstream, it leads to the S4 sand pocket which is about 2 km² in area, and the S5 sand pocket which is about 3.7 km² in area.

The large amount of sediment that is newly erupted and flows down every five years needs to be temporarily stored in these sand pockets and then safely allowed to flow down or removed.



Addition to DEMNAS Slope Classification Map

Figure 2-8 Overview of the arrangement of Sabo facilities along the Rejali River

Figure 2-9 shows a geological cross-section (image) along the Rejali River. S2, S4, and S5 are divided by the bedrock mountains, but bedrock is also distributed in shallow areas (less than 100 m) in S4 and S5, and there are several constrictions in the bedrock. The main Sabo facilities were installed in these narrow sections at around 1990.

Looking at the longitudinal profile, even before the construction of the Sabo facilities, it is assumed that each narrow section had a function to regulate the sediment discharge and formed a depositional surface of an alluvial fan at volcanic foot.

Geological profile along the Rejali river

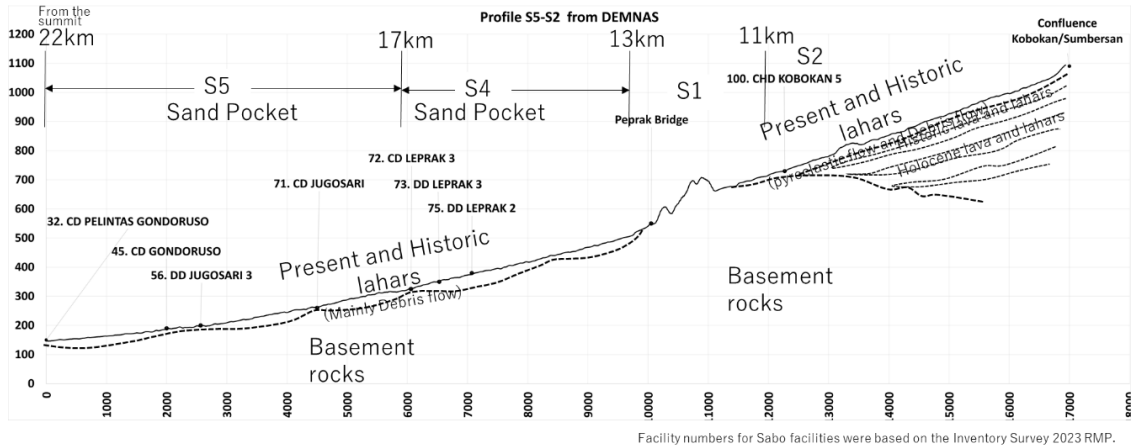
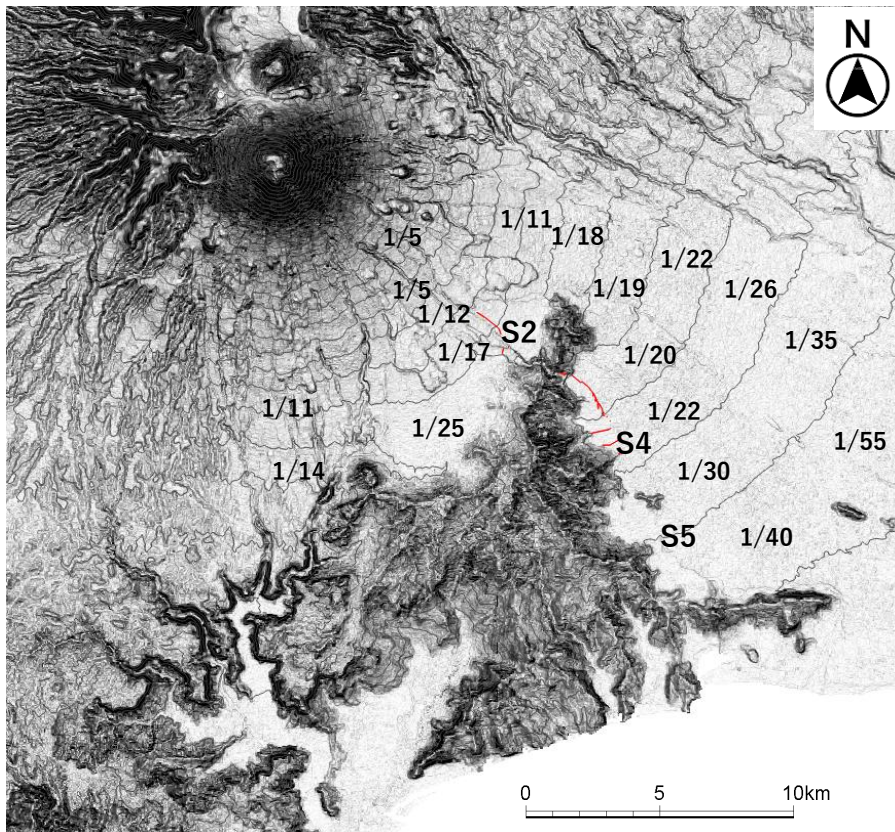


Figure 2-9 Geological longitudinal profile along the Rejali River (image)

2.4.2 Slope gradient of a volcanic alluvial fan

Looking broadly at the slope gradient of the fan-shaped alluvial fan from the DEMNAS 8 m mesh topographic map, the gradient of the volcanic alluvial fan, except for the summit cone of Mt. Semeru, becomes gentler from upstream to downstream (Figure 2-10). In areas where the flow is obstructed by the bedrock mountains, the slope is locally gentler. In the geological map shown in Figure 2-3, the fan slope (upper part) is mainly made up of pyroclastic flow deposits, and the slope of the fan with a gradient of less than 1/20 is mainly made up of lahars. The slope gradient is 1/17 to 1/20 near S2 in the upstream area, 1/20 to 1/22 at S4, and 1/30 to 1/40 at S5.



Addition to DEMNAS Slope Classification Map

Figure 2-10 Topographic gradient of the fan of Mt. Semeru

2.4.3 Characteristics of the depositional and erosional landforms at the upstream section (S2)

In October 2023, a LiDAR drone survey was conducted by BINTEK to determine the topography and landform conditions of the S2 and S4 sand pockets in the Rejali River basin. Although there are topographic maps and on-site photographs in existing documents, this is the first time since the construction of the facilities in 1990 that the sedimentation situation in the sand pockets has been confirmed in detail. Approximately two years have passed since the pyroclastic flow occurred in December 2021, and erosion has started within a valley width of 50 m, but a large amount of sediment deposit of the pyroclastic flow remains.

Figure 2-11 shows the topography data acquired by LiDAR with shaded relief as the background, 10-meter contour lines, Sabo facilities, and the flood area after 2021. In the upper reaches of the figure, the Lengkong River and Kobokan River flow closely together within a 500-m-wide lava plateau. Such condition caused repeated flow conflicts immediately after the occurrence of a pyroclastic flow. The debris flows that occurred in December 2021 and December 2022 flooded the left bank of the Lengkong River, burying the village and cultivated land. The flooded area can be identified from topographical data by the loss of artificial roads and cultivated land. The flooded area was restored to its pre-flood channel by a temporary training dike, and since then, erosional downcutting has begun in Lengkong River with a width of about 50 meters. However, because there is no difference in elevation between the volcanic alluvial fan and the river area (flood area), it is prone to flooding. There are two CD facilities installed at the southeastern end (lower reaches) as shown in the right bottom corner of the figure. The Lengkong and Kobokan rivers have erosional downcutting of about 20 m from the alluvial fan, and the bedrock is exposed in some places. The river channel is relatively stable, but it is easily buried by large-scale pyroclastic flows and debris flows, and is in a condition where it is easy to rise above the riverbed.

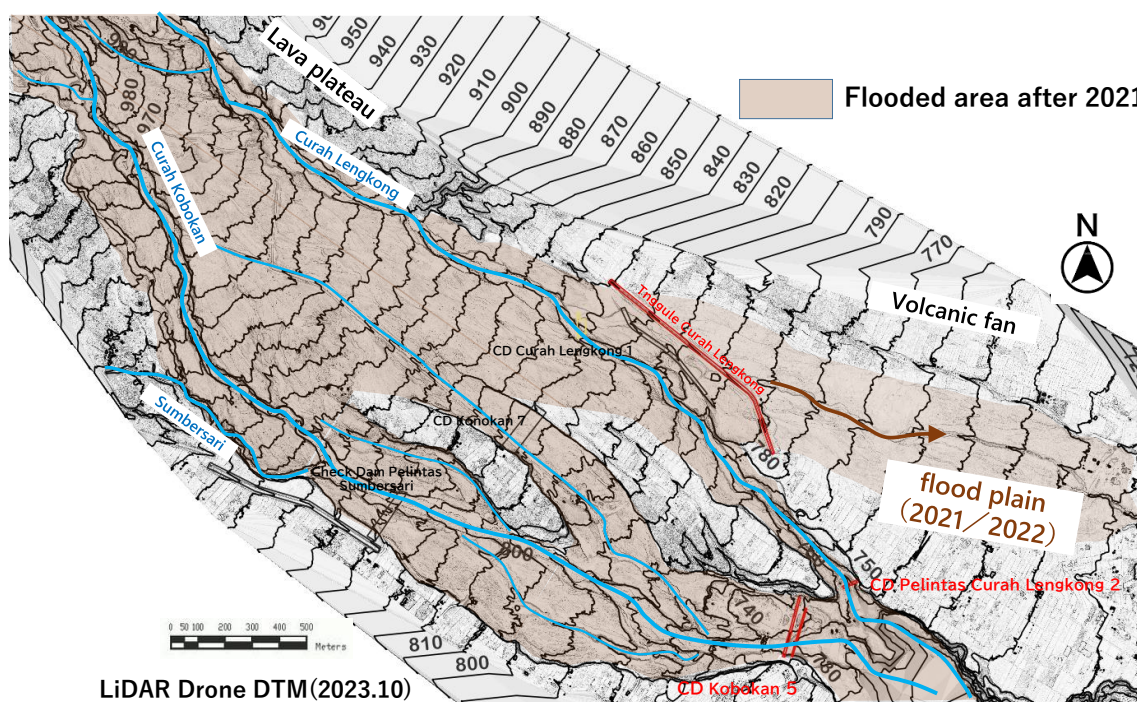


Figure 2-11 S2 Sand Pocket topography (shaded relief) and floodplain

Using topographic data acquired by LiDAR in October 2023, the heights of the high-level surface, the current riverbed surface, and the river side of the dike were measured for the S4 sand pocket (Figure 2-12, Figure 2-13). It has been about two years since the pyroclastic flow deposits were deposited in December 2021, but a large amount of sediment remains in the sand pocket, and erosion has begun to occur only in the stream area, which is about 100 m wide.

Looking at the difference in elevation between the high-level surface of the sediment in the sand pocket and the current riverbed, the difference in elevation is only a few meters at the downstream Sabo dam KD Leprak 3. However, at the upstream from the dispersion dam DD Leprak 1, the difference in elevation between the current riverbed and the high-level surface of the sediment and the height of the front of the training dike tends to be larger. In addition, the top of the spillway crest of the Sabo facilities located within S4 is buried at least from immediately after the pyroclastic flow occurred to October 2023. Furthermore, the facilities located upstream of S4 were buried deeper.

Alluvial fans are sedimentary landforms formed by pyroclastic flows and debris flows, and are therefore areas with a high risk of flooding. Even in the 1990s, when the training dike was constructed, it was built to a height of about 8 m based on the topography of the alluvial fan, rather than the current riverbed level. The river area (sand pocket) separated by the training dike temporarily stores the inflow of sediment from the upstream area supplied by volcanic activity. Sand pocket also has a sediment discharge control function through natural regulation (When a large amount of sediment is supplied, it will accumulate at a high gradient, but the sediment will be moved downstream by a small flood afterwards), so the upstream section of the sand pocket in particular has a high possibility of causing riverbed fluctuation. The sediment control facilities located within S4 are temporarily maintaining a high sedimentation surface in response to the increased volcanic activity in the 2020s (particularly in December 2021 and December 2022).

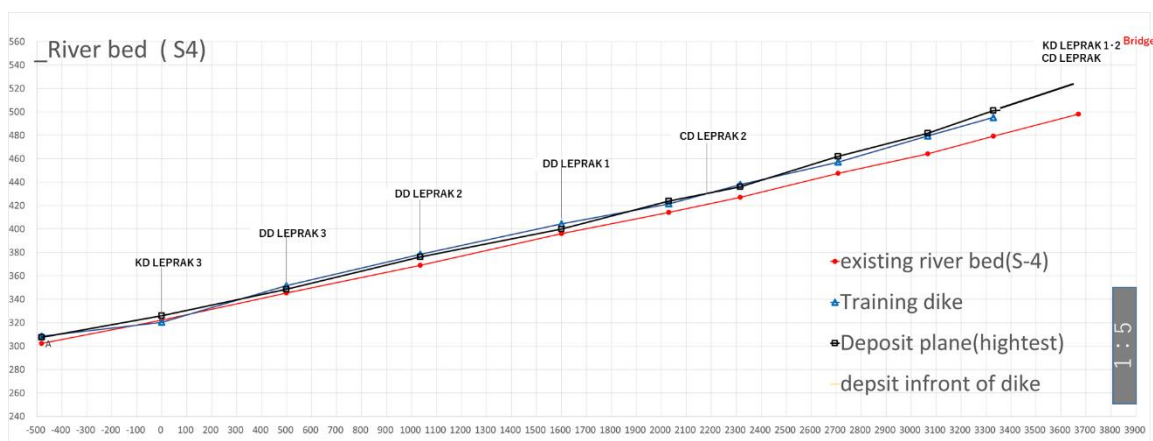
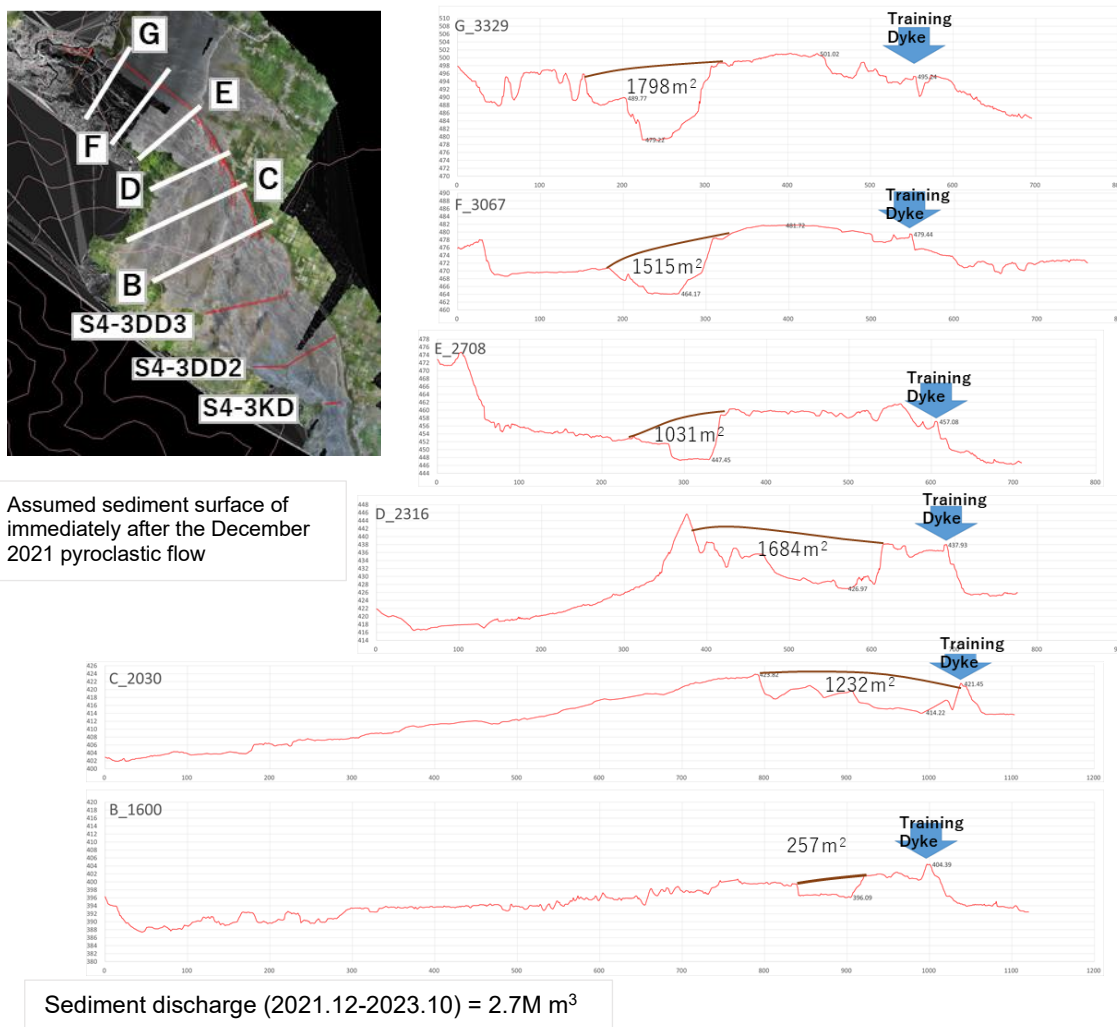


Figure 2-12 Longitudinal gradient of S4 sand pocket using LiDAR data obtained by BINTEK



2023.10 Created from LiDAR drone data acquired by Bintek

Figure 2-13 Cross-section of S4 sand pocket (upstream) and estimated sedimentation surface due to pyroclastic flow

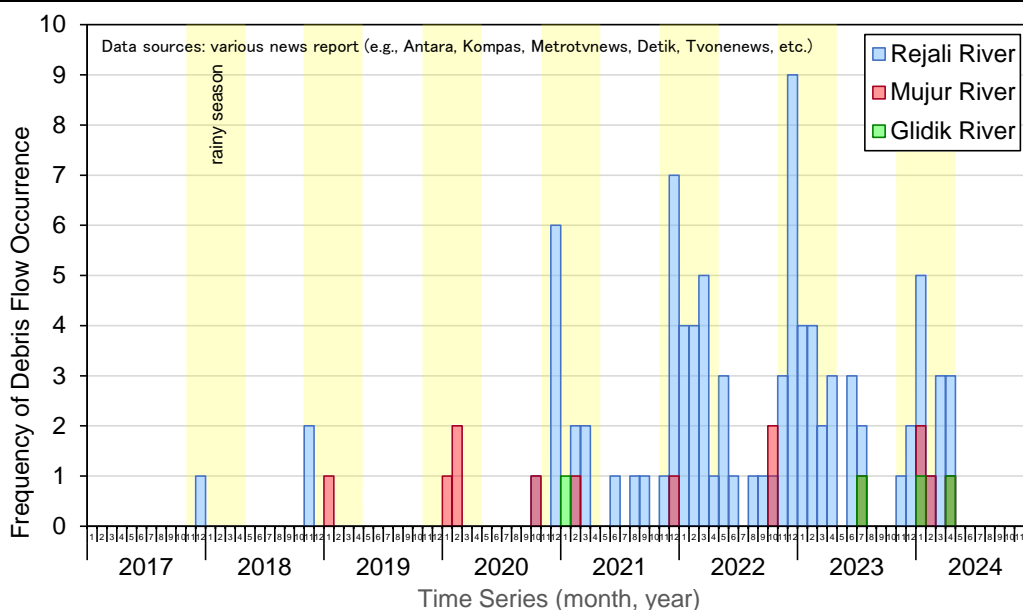
2.5 Frequency of Lahar and Debris Flow Occurrence

The occurrence of debris flows was collected from various media reports (Antara, Kompas, Metrotvnews, Detik, Tvonenevents, etc.) for the period of 2017-2024. There are few data before 2017, and of the 109 cases (81%) of the debris flows occurred during the rainy season (Figure 2-14, Table 2-2). Of the three rivers, the Rejali River had the most debris flows (91 times), followed by the Mujur River (14 times), and the Glidik River (4 times). The occurrence of debris flows has increased again since the December 2020 eruption, and since the December 2021 and December 2022 pyroclastic flow eruptions, debris flows have been concentrated in the Rejali River. The frequency of debris flows is very high immediately after an eruption, and then gradually decreases over time, but as of April 2024, they still occur multiple times a month.

In December 2021 and December 2022, debris flows overflowed the training dike in the Rejali River, burying residential areas with sediment of approximately 100 ha in 2021 (Sumberwuluh Village) and approximately 90 ha in 2022 (Curah Kobokan Village) (Fig. 2-15, Table 2-3). In addition, in July 2023, the sediment (approximately 1,000,000 m³) that had accumulated in the sand pocket was washed downstream by the debris flow, but the sand pocket sediment surface is still very high, and many of the Sabo dams are buried in sediment. In April 2024, this remaining sediment moved again and the training dike was damaged.

Table 2-2 Major media reports and precipitation amounts for debris flows and volcanic mudflows (1981-2023)

No.	Date	Rejali R.	Mujur R.	Glidik R.	Rainfall on the day (Curah Kobokan Sta.)
1	Feb 19, 2021	✓	✓		29 mm
3	Dec 21, 2021	✓	✓		n.d.
4	Oct 15, 2022	✓	✓		96 mm
5	Jul 7, 2023	✓	✓	✓	184 mm
6	Jan 31, 2024	✓		✓	n.d.
7	Apr 18, 2024	✓	✓		n.d.



Source; Compiled from media data

Figure 2-14 Occurrence of debris flows and volcanic mudflows

Table 2-3 Flooding and damage to Sabo facilities due to debris flows and volcanic mudflows (2017-2024)

Date	Dec 8, 2021	Dec 4, 2022	Jul 7, 2023	April 18, 2024
River	Rejali	Rejali	Rejali, Mujur, Glidik	Rejali, Mujur
Rainfall on the day	58 mm (Candipuro Sta.)	0 mm (C.Kobokan Sta.)	184 mm (C.Kobokan Sta.)	n.d.
Rainfall 1 week prior	145 mm (Candipuro Sta.)	112 mm (C.Kobokan Sta.)	386 mm (C.Kobokan Sta.)	n.d.
Worst impact	Overflow to Sumberwuluh	Overflow to Curah Kobokan	Destroyed 5 bridges, overflow	Damaged 7 Sabo facilities

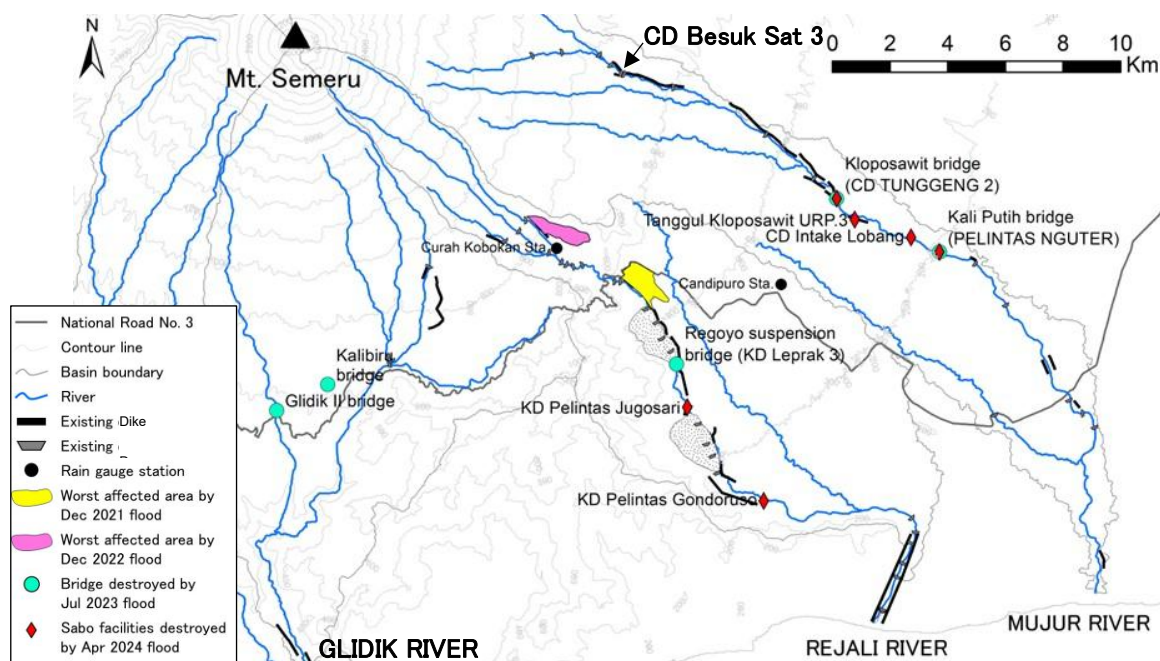


Figure 2-15 Flooding and damage to Sabo facilities due to lahars and debris flows (2017 onwards)

2.6 Burial and damage to Sabo facilities on the Rejali River

Figure 2-16 shows the location of Sabo facilities on the Rejali River, and Table 2-4 shows the damage of these facilities. The Sabo facilities in S2-S5, which were constructed in 1990, were buried by pyroclastic flows in 1977, 1981, 1985, 1988, 1994, 2002-2003, and 2017 and later. Most of these Sabo facilities have been buried by pyroclastic flows and debris flows associated with volcanic eruptions in 2021 and 2022. When sediment supply decreases, the riverbed may lower over a width of about 100 m along the river. However, as of early 2024, the riverbed lowering has not completed due to the large amount of sediment supply associated with the 2021 and 2022 eruptions. As a result, most of the Sabo facilities are buried under sediment as of early 2024. Among these, the S2 Sabo dam (CD KOBOKAN 5 and CD PELINTAS CURAH LENGKONG 2) in the upstream section has been partially destroyed (significantly worn) due to frequent sedimentation and passage of large amounts of sediment over a period of about 30 years. In addition, the dam bodies of upstream sites (CD CURAH LENGKONG 1, CD KOBOKAN 7 and CD PELINTAS SUMBERSARI) are considered to have been washed out, because the dam body was not found at the site and there are areas were scoured deeper than the dam foundation.

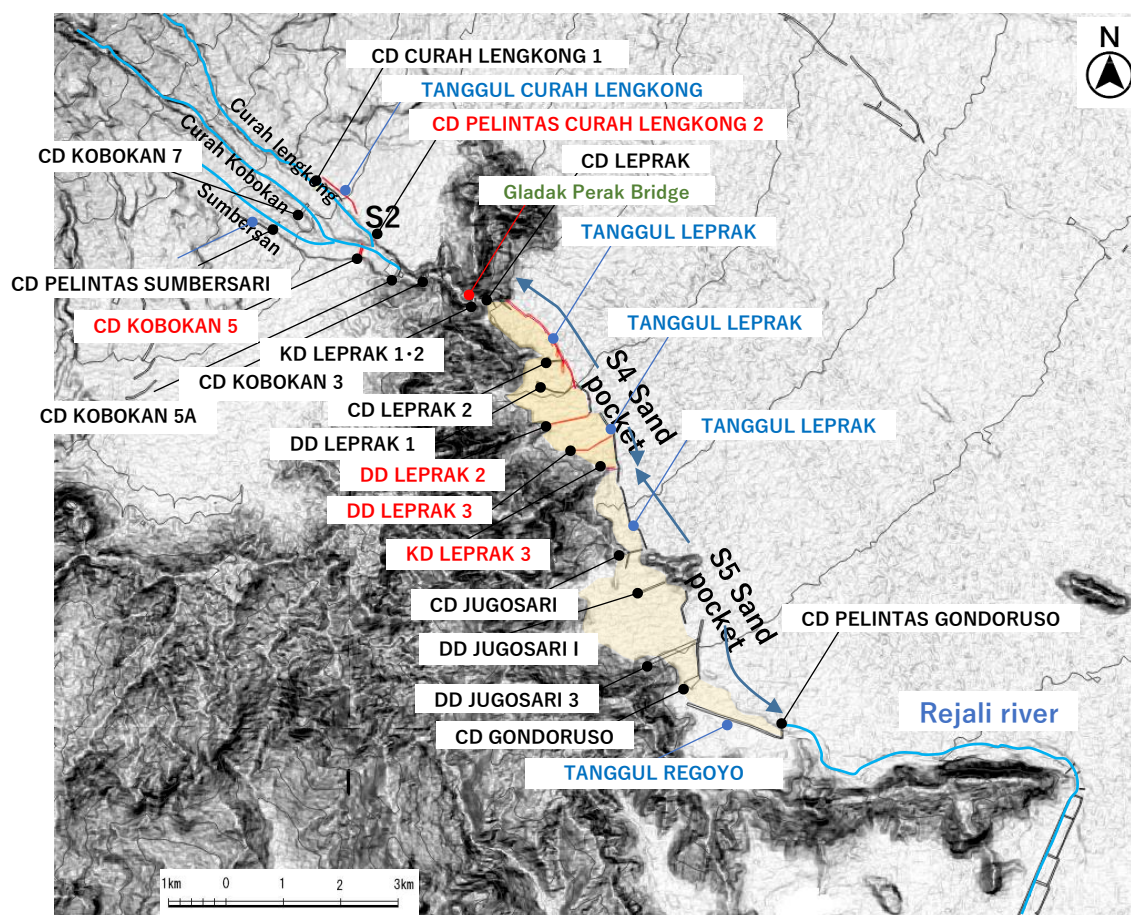


Figure 2-16 Location and names of Sabo facilities on the Rejali River

Table 2-4 Sabo dam sedimentation and damage

Pack age	RMP	Name	Dam Height (m)	Width (m)	Buried/damaged
S2	-	CD CURAH LENGKONG 1	7	75	Dam body has washed away.
	Rhb.	CD KOBOKAN 7	13	140	Dam body has washed away or is buried.
	-	CD PELINTAS SUMBERSARI	4.5	40	Dam body has washed away or is buried.
	Rec.	CD KOBOKAN 5	10	150	Exposed and damaged.
	Rec.	CD PELINTAS CURAH LENGKONG 2	5	30	Exposed and damaged.
S1	-	CD KOBOKAN 5A/1/2	14.5	100	damaged.
	Rec.	CD KOBOKAN 3	10	100	damaged.
S4	-	KD LEPRAK 1	8.5	30	Buried
	-	KD LEPRAK 2	8.5	30	Buried
		CD LEPRAK			Buried
	Rhb.	CD LEPRAK2	4	500	Buried and partially washed away.
	Rhb.	DD LEPRAK 1	4	680	Buried and partially washed away.
	Rec.	DD LEPRAK 2	4	820	Part of the top is exposed and partially washed away.
	Rhb.	DD LEPRAK 3	4	800	Part of the top is exposed and partially washed away.
S5		CD JUGOSARI	5	230	Part of the top is exposed
	Rhb.	DD JUGOSARI 1	4	900	Part of the top is exposed
	Rhb.	DD JUGOSARI 2	4	1680	Part of the top is exposed
	Rhb.	DD JUGOSARI 3	4	640	Part of the top is exposed
	Rhb.	CD GONDORUSO	4.5	280	Exposed to the s sub-dam of the Sabo dam
	-	CD PELINTAS GONDORUSO	6.5	130	The downstream face of the Sabo dam has lowered the river bed.

The GLAY Hatch Mark indicates the target facility. RMP: Review Master Plan (2024)

The Sabo facility S1, which is located in a gorge, was not confirmed on-site in this survey, but previous surveys have shown that the dam body is significantly worn and damaged.

The five facilities located in the upstream section of S4 (i.e., KD LEPRAK 1, KD LEPRAK 2, CD LEPRAK, CD LEPRAK 2, and DD LEPRAK 1) are buried entirely, and only a small part of the dam body concrete exposed in the lower cut section along the river channel.

The three facilities located in the downstream section of S4 (i.e., DD LEPRAK 2, DD LEPRAK 3, and KD LEPRAK 3) are lateral structures built using gabions and kneaded stone masonry. Although part of the crest is exposed, the sub-dam is completely buried and part of the current river channel has been washed away.

The condition of the dams located in the upstream section of S5 (i.e., CD JUGOSARI, DD JUGOSARI 1, DD JUGOSARI 2, DD JUGOSARI 3) is similar to the downstream section of S4 where a part of the crest is exposed but the sub-dam is completely buried.

The dam body of CD GONDORUSO, which is located in the downstream section of S5, is exposed and there is no sign of the sub-dam being buried (no significant damage). In addition, CD PELINTAS GONDORUSO, which is located at the lowest point of S5, is also used as a road. At the time of the survey (early 2024), there was a temporary build-up of sediment of 1 to 2 m higher than the dam body, but the downstream riverbed had lowered.

2.6.1 Damage and burial of the Curah Lengkong training dike

The S2 training dike in the upstream section was constructed at a point where the debris flow that occurred immediately after the pyroclastic flow in December 2021 flooded the Curah Lengkong River and flooded the volcanic alluvial fan on the east side. After the 2021 flood, an emergency temporary dike was constructed, but in December 2022, the debris flow again spread the flooding of the alluvial fan on the east side and greatly eroded the riverbank. As a result, all of the temporary

dike were washed away. After this disaster, the dike was moved back by about 70 m, and the current temporary dike was constructed using gabions (Figure 2-17).

Changes in Sabo facilities seen from Google Earth (S2-3)

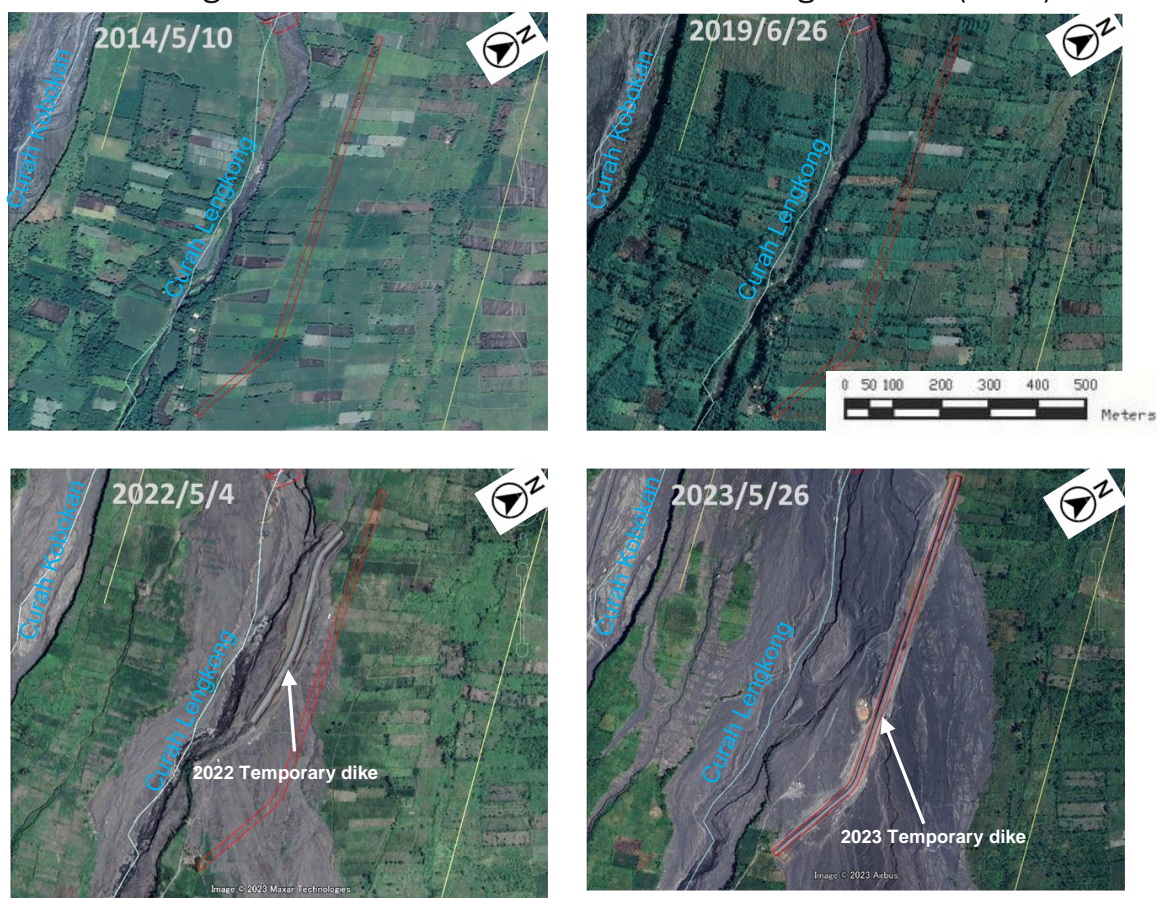


Figure 2-17 Changes in the training dike at TANGGUL CURAH LENGKONG

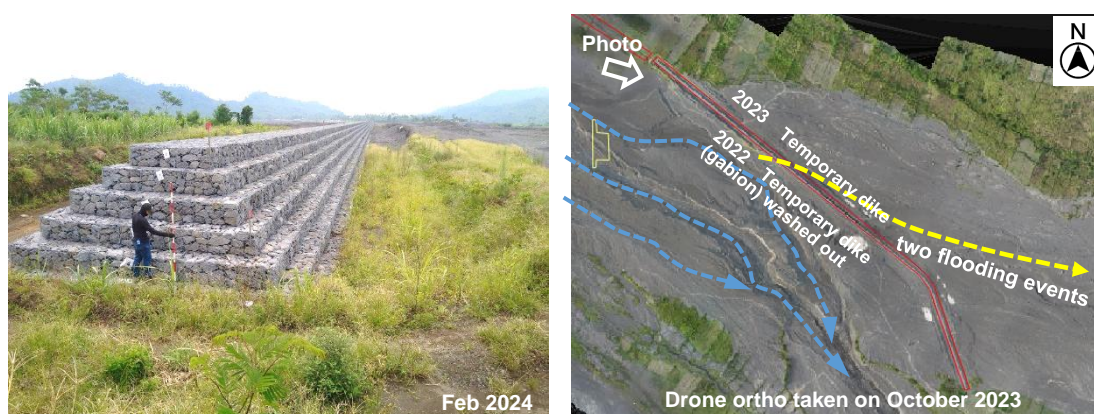


Figure 2-18 Installation of the 2023 TANGGUL CURAH LENGKONG

In December 2021 and December 2022, the river channel was filled by pyroclastic flows flowing down the Kobokan River. A few hours later, the debris flow that flowed down changed its course from near the present river channel and flooded the residential area. In both cases, the river valley was filled with pyroclastic flow deposits, and the river, which could flow freely, flooded the volcanic fan on the east side. In 2023, a provisional training dike (gabion) of 3 m high was constructed on the flooded fan (Figure 2-18).

2.6.2 Damage and burial of the LEPRAK training dike (northern half)

Figure 2-19 shows an aerial photograph (taken in 1996) of the Leprak training dike constructed in the upstream area of S4, and the condition of the training dike scouring in the section where the debris flow flooded the dike in December 2021. The Leprak training dike at S4 was constructed as a raised dike on the left bank alluvial fan when it was built in 1990. At that time, the riverbed was 20 m below the alluvial fan. The 2 km section north of the S4 training dike was once filled by pyroclastic flow in December 2021. The debris flow that occurred a few hours later changed course to the east after passing the Gladak Perak Bridge, where the pyroclastic flow had filled the valley and formed a hill. The debris flow crossed the northern end of the S4-1 dike, which had been buried by pyroclastic flow, and flowed down while scouring the dike (Figure 2-19, right). Since then, emergency work has been carried out to divert the river and excavate the accumulated pyroclastic flow, and the river has been restored to its original course (S4).



Figure 2-19 Overall view of Leprak training dike immediately after construction and dike eroded by debris flow (Dec 2021)

Approximately two years after the debris flow, a temporary gabion dike was built on the existing dike location as an emergency response. The river, which had been flooded, had eroded downwards and was flowing 10 to 20 meters below the dike (Figure 2-20).

In both flooded areas, the river channel was filled with pyroclastic flow deposits that exceeded the height of the training dike and the river. The river was able to flow freely, crossed over a soil structure that was vulnerable to scouring, and caused damage. The existing training dike is reinforced with concrete on the river side, but the land side is still made of earth, so it is thought that it was easily washed away.

The Curah Lengkong River was filled with pyroclastic flow that flowed down the Kobokan River that runs alongside it, while the mudslide that flowed down a few hours later changed its course from the vicinity of the current river channel and flooded the area.

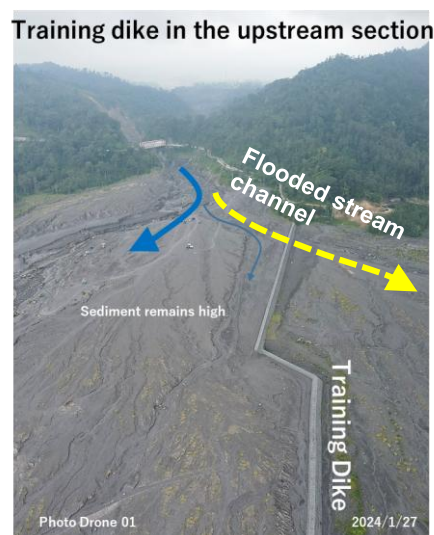


Figure 2-20 Leprak bird's view of the dike (northern half, Jan 2024)

2.6.3 Damage and sedimentation of the LEPRAK training dike (southern half)

Figure 2-21 shows a bird's eye view of the southern half of the Leprak training dike. The base of the dike has been buried due to the 1-2 m rise of the sedimentation surface, but a 3 m margin of height at the top remains. Near the suspension bridge at the lowest point, a section of the dike was raised using a gabion after a portion of the dike was washed away by a debris flow in July 2023. Although some parts of the river side of the training dike have been damaged by scouring, most sections show no signs of deformation or damage.



Figure 2-21 Photo of the LEPRAK training dike (southern half, Feb/2024)

2.6.4 Damage and burial of SABO facilities

Table 2-5 summarizes the degree of silting and damage to the Sabo dams in the project area based on the field survey. Immediately after the disaster, the YEC Indonesia Office conducted a survey of the damage in the area. JICA Project Team also conducted multiple on-site surveys in January and March 2024. However, the extent and location of the damage to the five Sabo facilities in question has not yet been accurately identified, as they have been buried. In the future, the material quality of the dam body will be confirmed through boring surveys that penetrate the dam body. This report is based on an evaluation of the conditions exposed on the surface. From the local conditions, the possibility of sliding, overturning, or subsidence caused by the foundation ground is considered low. In addition, there is almost no evidence of downstream riverbed lowering, so it is also unlikely that this is the cause.

S2-1 (CD KOBOKAN 5) is a 10 m high, 150 m wide Sabo dam constructed using kneaded stone masonry, where a section of about 40 m on the right bank of the main dam has collapsed. The foundation ground is thought to be well-compacted debris flow deposits. Old satellite image data shows that the right bank of the dam was washed away in July 2021, before the pyroclastic flow arrived. In addition, looking at the area around the washed-away dam, a history of repairs due to multiple erosion and dam washouts was confirmed. It is also confirmed that the newly repaired masonry has more voids and lower quality. Considering the fact that the dam crest line is straight and there are no cracks in the undisturbed section of the dam, it is unlikely that the dam has slipped, collapsed, or subsided due to the foundation ground. When the pyroclastic flow and debris flow occurred in December 2021, the right bank of the dam had already been eroded and washed away, and the entire dam was temporarily buried under pyroclastic flow deposits about 3 to 5 meters above the dam. Since then, the majority of debris flows have flowed down the right bank, where the dam has already been washed away. Since the 2021 pyroclastic flow, the amount of sediment has gradually decreased, but most of the sub-dams are still buried.

S2-2 (CD PELINTAS CURAH LENGKONG 2) is a 5 m high, 30 m wide sediment control dam constructed with high-quality concrete, and is the smallest of the sediment control dams surveyed. The foundation is made up of green tuff from the Neogene period, and is fresh, hard, good quality foundation with few cracks. There is evidence of scouring near the downstream end of the left bank abutment, but the concrete was anchored and adhered to the good foundation bedrock. The damage to the embankment is due to significant scouring (partial destruction) near the water channel, and there is no evidence of embankment uplift, tilting, or cracking. The upstream section of the Sabo dam

is located in a section where a large amount of debris flows overflows the dam and flows downstream.

S4-3 (DD LEPRAK 2) is a dispersion dam with a crest length of 820 m and a height of 4 m. It was constructed using masonry and gabion, and the foundation is presumed to be unconsolidated debris flow deposits. In the section other than the present river channel, the dam body is buried under sediment. The comparison results of LiDAR drone topography and the design drawings showed that the dam body was eroded and washed away in the present river channel section (Figure 2-22). In all of the satellite images confirmed in 2012, 2013, 2017, 2019 and 2021, the dam body was buried.

S4-3 (DD LEPRAK 3) is a dispersion dam with a crest length of 800 m and a height of 4 m. It was constructed using masonry and gabion, and the foundation is presumed to be unconsolidated debris flow deposits. In the section other than the current river channel, the dam body is buried under sediment. The LiDAR drone topography and the design drawings comparison indicated that the dam body was scoured and washed away in the current river channel section (Figure 2-22). In all the satellite images checked in 2012, 2013, 2017, 2019 and 2021, the dam body was buried.

S4-3 (KD LEPRAK 3) is a 130 m long, 8 m high dam. It was constructed using kneaded stone masonry and gabion, while the foundation is presumed to be unconsolidated debris flow deposits. Although part of the wing is exposed, the dam body including the current river channel, is buried. In the satellite images of 2012, 2013, 2017, and 2019, about half of the embankment was exposed, but the embankment was completely buried since December 2021.

The two S2 units have a large exposed portion of the dam body, so the extent of the damage and the factors involved can be identified. In contrast, the three S4 units downstream have been buried by sediment for more than 10 years and the details are unknown. However, the river crossing section, which is about 100 meters wide, has dropped below the water level due to the lowering of the riverbed, and it is thought that part of the dam body of DD Leprak 2 and DD Leprak 3 has been washed away. On-site, it is possible to see the concrete of the dam body that has been destroyed and the damaged gabion.

Table 2-5 Accumulation and damage to the SABO Facilities in the project area

No	RMP	Name	Dam height (m)	Dam length (m)	Burial situation	Dam body material, damaged parts, degree of damage, cause of damage
S2-1	Rec.	CD KOBOKAN 5	10	150	Exposure/damage	Dam body material: Rubble masonry (there are records of multiple repairs. The newer repairs are of relatively low quality) The right bank of the main dam body (about 40m) has collapsed (it had already collapsed by July 2021) The left bank and sub-dam remain buried Significant abrasion due to the concentrated flow of large amounts of sediment and stones on the right bank, and destruction due to the impact of debris flows
S2-2	Rec.	CD PELINTAS CURAH LENGKONG 2	5	30	Exposure/damage	The dam body material is relatively high-quality Co. There is significant abrasion near the water channel. About half of the dam body has been eroded (there is also a possibility of destruction due to the impact of debris flows). There is significant abrasion due to the large amount of sediment passing through, and destruction due to the impact of debris flows.
S4-3	Rec.	DD LEPRAK 2	4	820	Part of the crest is exposed/part of the dam has eroded away.	Materials used for the dam body: stone masonry and gabion. The current river (100-200m wide) has been eroded or the dam body has been washed away. The remaining section is buried and so is unknown.

						The river flow section has been eroded and destroyed by the passage of large amounts of debris flows.
S4-3	Rhb.	DD LEPRAK 3	4	800	Part of the crest is exposed/part of the dam has eroded away.	Materials used for the dam body: stone masonry and gabion. The current river (100-200m wide) has been eroded or the dam body has been washed away. The remaining section is buried and so is unknown. The river flow section has been eroded and destroyed by the passage of large amounts of debris flows.
S4-3	Rhb.	KD LEPRAK 3	8	130	Part of the crest is exposed/part of the dam has eroded away.	Materials used for the dam body: stone masonry and gabion. All parts except the wing are buried, so the details are unknown. There is a high possibility that abrasion and destruction occurred due to the passage of a large amount of debris flow in the river flow section.

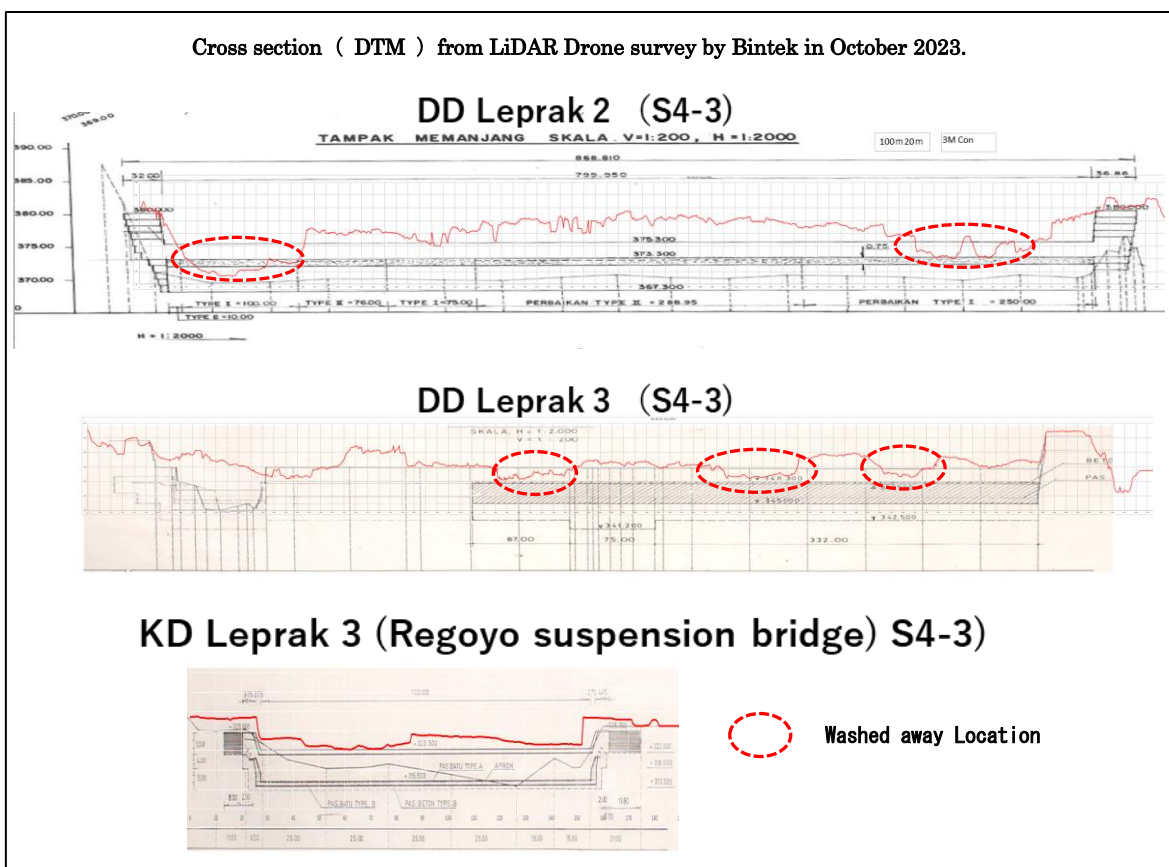


Figure 2-22 Overlay of the design drawings for DD Leprak 2, DD Leprak 3 and KD Leprak 3 and the topography

CHAPTER 3 BASIC POLICY ON PRELIMINARY DETAILED DESIGN

3.1 Assumptions Specified in the Review Master Plan (2024)

This section discusses the assumptions related to the detailed design of sabo facilities, derived from the volcanic sediment control plan for Mt. Semeru, which initially formulated in 1984 then revised in 2024 (hereafter referred to as the “Master Plan (1984)” and the “Review Master Plan (2024)” respectively).

The revisions made in 2024 are explained in detail in each section. A comparison of the basic conditions between the Master Plan (1984) and the Review Master Plan (2024) is presented in Table 3-1.

Table 3-1 Modification of basic conditions

Item	Master Plan (1984)	Review Master Plan (2024)
Evaluated tributaries for sediment transport	7 tributaries	9 tributaries
Targeted disaster for structural measures	Debris Flow	Debris Flow
Assumed volcanic crater location	Not specified	Jonggring-Seloko Crater
Scale of assumed eruption	Not specified	Specified (equivalent to VEI 2)
Reference points for Sabo planning	Specified	No change (clarified rationale based on sediment transport behavior)
Design rainfall	100-year return period rainfall	Cumulative rainfall exceeding the debris flow-triggering-threshold during the first year post-eruption
Rainfall threshold for triggering debris flow	Not specified	Specified
Planned excess sediment volume (10 ³ m ³)	Mujur: 5,040 Rejali: 5,220 Glidik: 4,500	Mujur: 2,056 Rejali: 4,143 Glidik: 2,911
Flood peak discharge calculation method	Calculated by the storage function method	Calculated by rational formula

*VEI : Volcanic Explosivity Index

3.1.1 Basic Conditions

(1) Target Rivers

The three major rivers that flow directly into the Indian Ocean i.e., Mujur, Rejali, and Glidik, which were identified in the Master Plan (1984), are also included in the Review Master Plan (2024) as rivers subject to the volcanic sediment control plan. In the Master Plan (1984), seven tributaries of these three main rivers were included. However, two tributaries i.e., Besuk Tompe and Summersari were added in the Review Master Plan (2024) with consideration of the fact that they are sources of unstable sediment (Table 3-2).

Table 3-2 Distribution of unstable sediment volume in tributaries

River name	Distribution of unstable sediment volume in tributaries		Remarks
	Master Plan (1984)	Review Master Plan (2024)	
Mujur	Besuk Tengah Sat	Besuk Tengah Sat	Addition of Besuk

River name	Distribution of unstable sediment volume in tributaries		Remarks
	Master Plan (1984)	Review Master Plan (2024)	
	Besuk Tunggeng	Besuk Tunggeng Besuk Tompe	Tompe
Rejali	Curah Lengkong Curah Kobokan	Curah Lengkong Curah Kobokan Sumbersari	Addition of Sumbersari
Glidik	Besuk Kembar Besuk Bang Besuk Supit	Besuk Kembar Besuk Bang Besuk Supit	No change

(2) Hazards Targeted in the Volcanic Sediment Control Plan

- ① **Pyroclastic flows:** The pyroclastic flows generated by the eruption on December 4, 2021 reached 17 km from the summit and caused extensive damage to residential areas. However, there are no effective structural countermeasures against pyroclastic flows, and pyroclastic flows are not included in the Master Plan (1984). Therefore, pyroclastic flows are not targeted for structural countermeasures. It should be addressed through coordination of non-structural measures with relevant agencies
- ② **Ashfall:** Ashfall from pyroclastic flows and phreatic eruptions promotes the formation of debris flows due to rainfall, but does not accumulate enough to increase the flow rate of debris flows. Therefore, when considering structural measures, the amount of ash fall is not evaluated.
- ③ **Lava flow:** The lava flow of Mt. Semeru has a slow flow velocity and a maximum reach of 6.5 km from the summit (1941~1942 eruption record), which is sufficiently distant from residential and cultivated areas. Therefore, since no direct damage occurs from the lava flow itself, it is not considered a target for structural countermeasures.
- ④ **Debris flows:** Debris flows generated by the re-movement of pyroclastic flow deposits and unstable sediment in river channels and slopes due to rainfall are targets for structural countermeasures. There has been no pyroclastic flow entered Mujur River basin since 1963, and given the topographical conditions, this trend is expected to continue. Therefore, structural countermeasures against debris flows are under the assumption that pyroclastic flows do not flow into Mujur River basin.

(3) Assumed Crater Location

The assumed location of the crater is the Jonggring-Seloko crater (current crater) at the summit of the Mt. Semeru. All eruptions of the Mt. Semeru have consistently originated from the Jonggring-Seloko crater for the past 200 years. The Master Plan (1984) also assumed an eruption from the Jonggring-Seloko crater, but it was not specifically defined. In contrast, the Review Master Plan (2024) clearly specified Jonggring-Seloko as the assumed crater.

(4) Assumed Eruption Scale

Structural measures for volcanic sediment control assume an eruption that occurs once every five years and generates about 8 million m³ of pyroclastic material in the Rejali or Glidik river basins. Considering that 19 eruptions with pyroclastic flows have occurred in the past 100 years, the interval between major eruptions with pyroclastic flows is set to 5 years.

The Volcanic Explosivity Index (VEI) is a relative measure of the explosion magnitude of a volcanic eruption. In the case of recorded eruptions of the Mt. Semeru, the majority of volcanic eruptions are classified as VEI 2 (volcanic material emitted is more than 1 million m³ but less than 10 million m³). In addition, the Indonesian Ministry of Energy and Mineral Resources estimated that the amount of sediment displaced by the eruption on December 4, 2021 was 8 million m³.

Considering these factors, the assumed scale of the eruption is equivalent to VEI 2 with sediment transport volume of 8 million m³.

(5) Sediment Control Design Reference Point

According to the Master Plan (1984), the sediment control reference points are divided into design reference points and supplementary reference points. The former is a point for evaluating the sediment control effect of the sabo facility on the amount of design excess sediment volume (the amount of sediment that needs to be controlled by sabo facilities). It is set near the boundary between the debris flow inundation/deposition zone and the bedload flow (around 1% riverbed gradient) (Figure 3-2). The supplementary reference point is the point where the design sediment discharge volume is determined i.e., at the boundary between the debris flow generation zone and the debris flow deposition zone (Figure 3-2). In addition, discharge points are established at the outlet of tributaries or immediately downstream of the confluence of multiple tributary rivers to determine the flood peak discharge. To maintain the consistency of the volcanic sediment control plan, the reference points in this survey shall be based on those set in the Master Plan (1984). Information on the design reference points, supplementary reference points, and discharge points is summarized in Table 3-3. The locations of these points are shown in Figure 3-1.

Table 3-3 Design reference points, supplementary reference points, and flow calculation points

River	Catchment area	Slope	Discharge point	Supplementary Reference Point	Design Reference Point	Remarks
	(km ²)	(1/ n)	○	●	◎	
Mujur	B. Tompe	69.8	17	1		
	B. Tengah - Sat	13.3	18	2		
		83.1	18	3		
	B. Tunggeng	86.9	24	4		
		8.7	20	5		
	Mujur (tributary)	95.7	24	6	✓	
		102.2	26	7		
		12.8	41	8		
		115.0	26	9		
	Pancing	172.8	101	10		✓
		179.3	72	11		
17.6		54	12			
Rejali	196.9	72	13			
	203.5	164	14			
	8.3	12	1			
	Curah Kobokan	7.9	20	2		
	Sumbersari	3.4	22	3		
	Rejali (tributary)	19.6	17	4		
		25.8	15	5	✓	
		64.5	49	6		
		15.8	28	7		
	80.3	49	8		✓	
126.5	66	9				
Glidik						
	Lengkong	26.6	17	1		
	B. Kembar	8.7	15	2		
	B. Bang	10.0	27	3		
	B. Supit	5.6	14	4		
		50.9	15	5	✓	
	Glidik (tributary)	91.1	43	6		
		31.6	45	7		
		122.7	43	8		
	Manjing	151.6	72	9		
		159.7	210	10		
311.4		72	11		✓	
	328.4	158	12			

Note :

- 1) Design reference points are the points where the sediment control effect of sabo facilities on the excess sediment discharge is evaluated.
- 2) Supplementary reference points are the points at the boundary between debris flow generation zone and deposition zone where the amount of design sediment discharge is determined.
- 3) Discharge points are established at the outlet of tributaries and immediately downstream of the confluence of several tributaries to determine flood peak discharge.

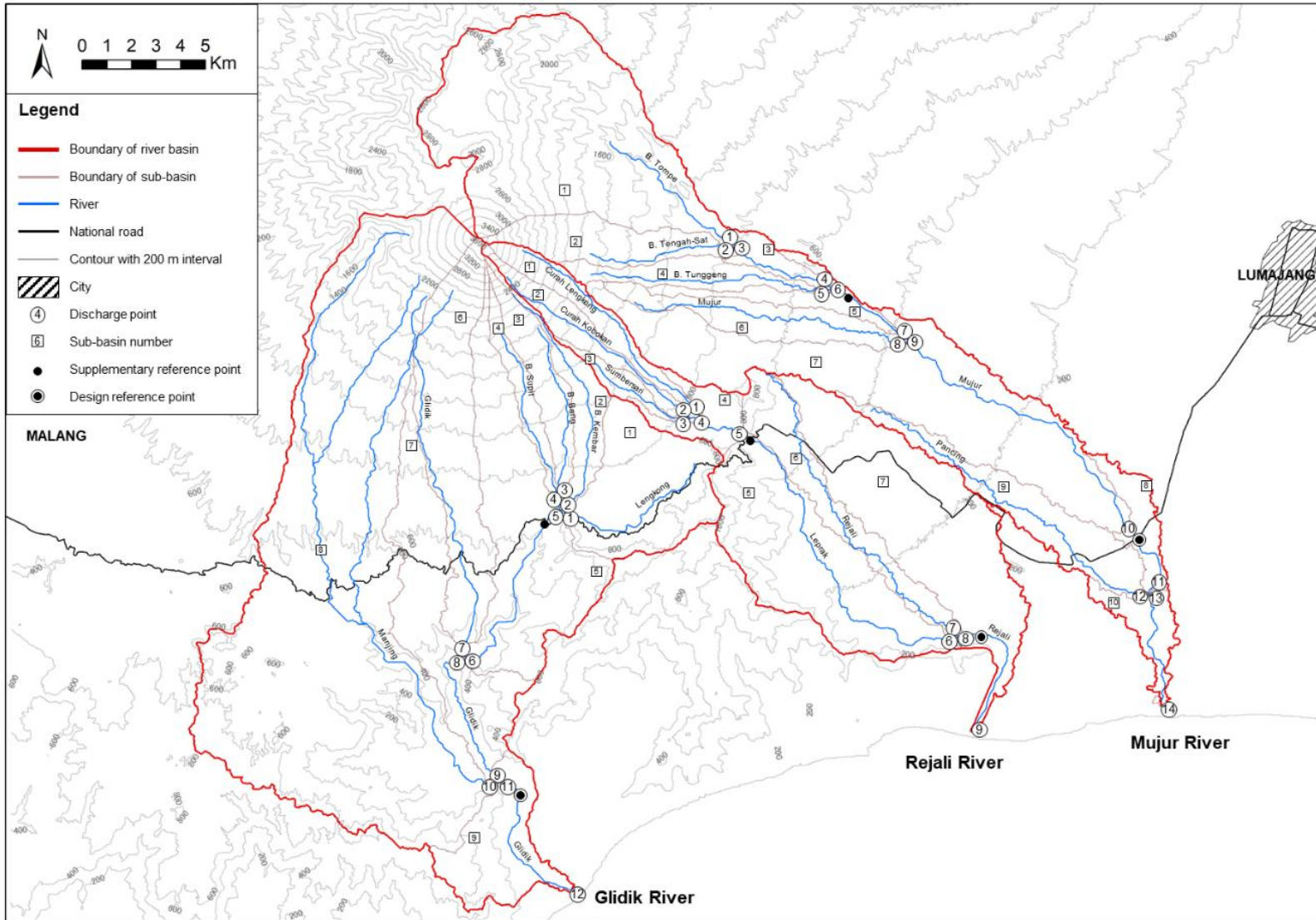


Figure 3-1 Design reference point, supplementary reference point, and discharge point

(6) Critical Rainfall of Debris Flow Occurrence

In the immediate aftermath of volcanic eruptions, debris flows occur frequently due to small amounts of rainfall, but over time, the surface of volcanic ejecta is coated with rainfall, and materials in gullies and riverbed are coarsen by the water flow, making it difficult for debris flows to occur (increasing the critical rainfall).

In the first year after the pyroclastic flow (2022), the actual critical rainfall for debris flow occurrence in Rejali River is 15 mm/day (48 mm/day in Mujur River). Based on the actual critical rainfall at the beginning of the second year and the trend of change in the critical rainfall after the eruptions of Mt. Merapi and Unzen Fugendake Volcano, the critical rainfall from the second year onwards was assumed as shown in Table 3-4. Although Glidik River was not affected by pyroclastic flows in 2021 and no debris flows occurred, but there is a risk of pyroclastic flows concentrating and flowing into it, similar with the Rejali River. Hence, the critical rainfall of Glidik River was assumed to be the same as Rejali River.

Table 3-4 Total rainfall causing debris flow

River	Rainfall Observation Station	Year of Rainfall Data Applied*	Critical Rainfall (mm/day)				Cumulative rainfall exceeding the critical rainfall for the generation of debris flows (mm/year)			
			1 st year	2 nd year	3 rd year	4 th year	1 st year	2 nd year	3 rd year	4 th year
Mujur	Besuk Sat	2011	48	68	97	134	756	576	342	142
Rejali	Curah Kobokan	2011	15	29	58	116	2,417	1,540	557	0
Glidik	Pronojiwo	1993	15	29	58	116	2,665	1,975	1,068	0

Note : * Rainfall data from specific year when annual rainfall was close to the mean annual rainfall were used.

(7) Design Sediment Discharge Volume

As explained in (6), in the Review Master Plan (2024), assuming that the debris flow occurs due to the average annual rainfall pattern on the second year onwards, the number of occurrences will decrease sharply. Further, the number of debris flow occurrences will be zero in the fourth year in Rejali River (in the fifth year in Mujur River).

Therefore, the rainfall causing debris flow occurrences was identified in the first year, where the debris flow occurrences were the highest. The debris flow volume from this rainfall was calculated using the debris flow discharge sediment volume equation to determine the possible sediment discharge volume. The smaller value between the possible sediment discharge volume and unstable sediment volume was taken as the design sediment discharge volume.

Table 3-5 summarizes the design amount of sediment discharge for each river. (For details on the calculation method, please refer to subchapter 4.4 Design Sediment Discharge Volume in the Review Master Plan (2024) and subchapter 3.1.3 Calculation of Basic Sediment Volume in this report)

Table 3-5 Design sediment discharge volume of each river

River	Design sediment discharge volume (10 ³ m ³)
Mujur	2,891
Rejali	6,885
Glidik	7,180

(8) Flood Peak Discharge for Structural Design

The flood peak discharge is used in the design of structures such as the overflow part of the sabo dam and the temporary cofferdam, and was calculated using rational formula after determining the design rainfall with a 100-year return period for each basin.

(Calculation of design rainfall)

These design rainfall values are summarized as shown in Table 3-6.

Table 3-6 Design rainfall

River	Objective: Calculate flood peak discharge
	100-year return period rainfall
Mujur	211 mm/day
Rejali	251 mm/day
Glidik	360 mm/day

(Calculation of peak discharge)

Table 3-7 shows the calculated peak discharge by rational formula at each reference point shown in Figure 3-1. In Glidik and Mujur rivers, there are points where the peak discharge at the downstream design reference point appears to be less than the peak discharge at the upstream of the supplementary reference point. Such calculation discrepancy is caused by the average flow velocity in the calculation of rational formula which was determined in stages according to the riverbed slope at the calculation point. Therefore, the larger value was adopted.

Table 3-7 Flood peak discharge calculated using rational formula

River	Reference point	Probable discharge (m ³ /sec)									
		2	3	5	10	20	30	50	100		
Mujur	B. Tompe	1	555	604	659	729	795	833	881	945	
	B. Tengah - Sat	2	119	129	141	156	170	178	188	202	
		3	660	719	785	867	946	991	1048	1124	
		4	560	610	666	736	803	841	890	954	
		5	72	79	86	95	103	108	115	123	
	B. Tunggeng	6	617	672	733	810	884	926	979	1050	
		7	570	621	677	748	816	856	905	971	
		Mujur (tributary)	8	90	98	107	119	129	136	143	154
	Pancing	9	641	698	762	842	919	963	1018	1092	
		10	625	680	743	820	895	938	992	1064	
		11	669	728	794	878	958	1004	1061	1138	
		12	106	115	126	139	152	159	168	181	
		13	734	799	872	964	1052	1102	1165	1250	
		14	626 (734)	682 (799)	744 (872)	822 (964)	897 (1052)	940 (1102)	994 (1165)	1066 (1250)	
Rejali	Curah Lengkong	1	74	81	90	100	111	116	124	134	
	Curah Kobokan	2	72	79	87	98	108	113	120	130	
	Sumbersari	3	44	48	53	60	66	69	74	80	
		4	174	191	212	237	261	275	292	315	
		5	204	225	249	279	307	323	344	371	
	Rejali (tributary)	6	312	344	380	425	468	493	525	567	
		7	109	120	132	148	163	172	183	197	
		8	388	428	473	530	584	615	653	706	
		9	542	598	661	739	814	858	912	985	
Glidik	Lengkong	1	265	326	394	480	562	610	669	749	
	B. Kembar	2	69	85	103	126	147	159	175	196	
		3	93	114	138	168	197	213	234	262	
		4	50	61	74	90	105	114	125	140	
	B. Supit	5	404	497	601	732	857	930	1020	1142	
		6	505	622	752	916	1073	1163	1276	1428	
		Glidik (tributary)	7	189	233	282	343	402	436	479	536
			8	680	838	1013	1233	1444	1566	1718	1923
	9		693	854	1032	1256	1472	1596	1750	1959	
	Manjing	10	470	579	700	852	998	1082	1187	1328	
		11	1423	1753	2119	2579	3022	3277	3594	4023	
		12	1172 (1423)	1444 (1753)	1745 (2119)	2124 (2579)	2489 (3022)	2699 (3277)	2960 (3594)	3313 (4023)	

Note:

Design reference point/Supplementary reference point

The value in () indicate the values that should be used as the design flow, considering the calculated flow from the upstream area.

3.1.2 Sediment Control Policy

Sediment control to reduce debris flow disasters shall be implemented based on the following policies. Two of the policies shown below i.e., (1) and (3), are in accordance with the Master Plan (1984), while the others have been newly established to set the design sediment discharge volume under different scenarios.

- (1) Sediment discharged from mountain area is to be discharged safely into the sea as much as possible.
- (2) The design excess sediment discharge volume shall be controlled by 100% with the total volume of the vacant sediment storage volume and the sediment regulating volume of sabo facilities for each target river.
- (3) The sediment control shall be implemented in the mountain area where the riverbed slope is 5% or more. In case it is difficult, it can be implemented also in the alluvial fan areas where the riverbed has slope of 1% to 5%.
- (4) The captured sediment needs to be properly removed artificially during the subsequent 4 years of interval of the successive major eruption.

Table 3-8 shows the relation between riverbed slope and sediment transport patterns with sediment control policies. Since the expected sediment movement differs depending on the riverbed slope, the sediment control policy for each riverbed slope is also different as shown in the figure. Figure 3-2 shows the location of the reference point, the slope of the riverbed, and the zoning of the sediment transport patterns.

Table 3-8 Expected sediment movement and sediment management policy

Riverbed Slope			Altitude (m)	Terrain	Reach of Pyroclastic Flow	Sediment Transport	Sediment Management Policy
5%	1/20	3°	500-640	(Mountain area)	In Glidik River, the riverbed slope reaches around 5%	Occurrence and origination of debris flows	capture and reduction of debris flows
1%	1/100	1°	50-60	(Alluvial fan area)	In Rejali River, the riverbed slope reaches around 4.5%	Debris flow inundation and deposition	Guide of debris flow

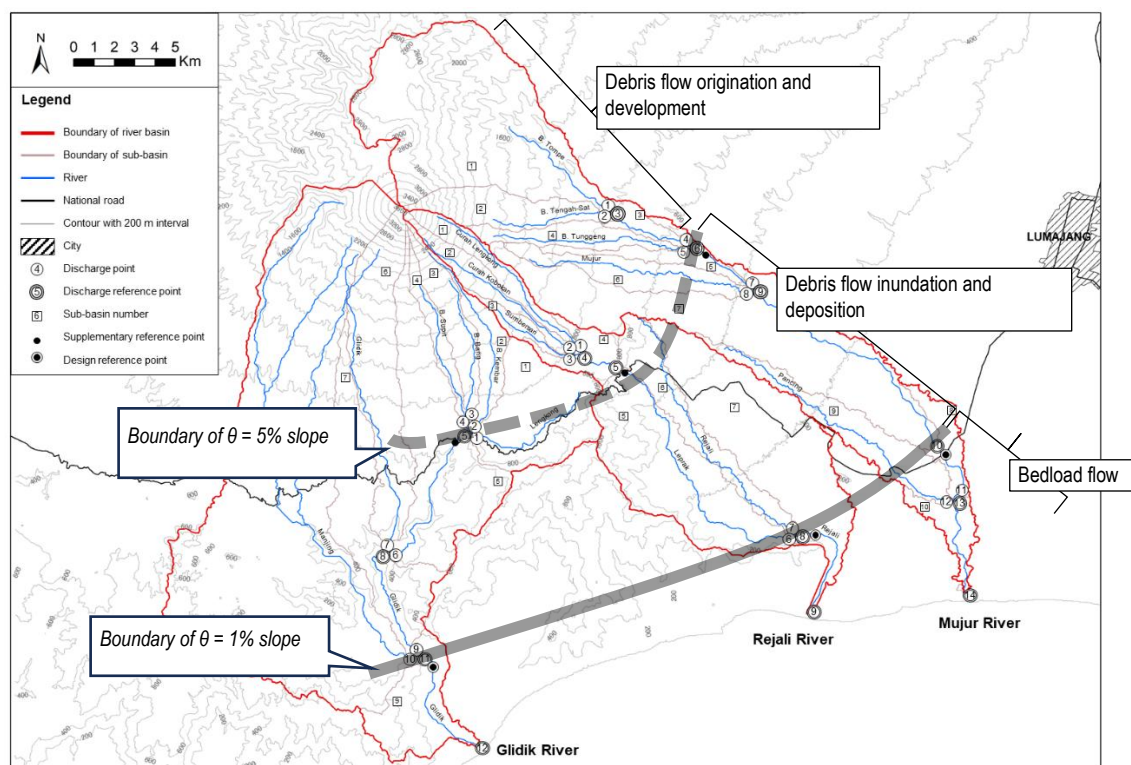


Figure 3-2 Zoning of sediment transport patterns

The details of the sediment control policy are as follows.

- (1) The riverbed slope near the river mouth is approximately 1.3% (1°). The sediment flowing downstream consists of fine particles with an average particle size of 1.4 mm, so the sediment transport capacity by bed load flow is relatively large. Therefore, the sediment should be safely discharged into the sea as much as possible.
- (2) The entire amount of design excess sediment discharge volume (100%) shall be controlled using the design storage volume of sabo facilities. It should be noted that in the volcanic region at the foot of the Mt. Semeru, new unstable sediment volume in the form of pyroclastic flow is supplied from upstream approximately every five years due to volcanic activity. This leads to an unlimited increase in sediment volume and prevention of sediment production is impossible. As a result, the design sediment production prevention volume (the volume of sediment that will be prevented from erosion by deposition upstream of the sabo dam) is not considered as a sediment control volume.
- (3) The capture of discharged sediment is basically carried out in mountainous areas with a riverbed gradient of 5% or higher, where mountain streams with a distinct valley shape are formed. However, since a large amount of sediment discharged by frequent debris flows after eruptions, the discharged sediment is also captured on the fan with a riverbed slope of 1%-5%, while taking measures to prevent flooding over the surrounding area.
- (4) The captured sediment by sabo facilities needs to be properly removed during the subsequent five-year eruption interval in order to restore the sediment control effect of the sabo facilities. Sand mining, which is currently being carried out by the private sector in three rivers, shall be continued and promoted under appropriate supervision. At the same time, if the amount of excavation by sand mining conducted by the private sector does not meet the required amount of sediment management, implementation of sediment excavation at public expense shall be considered.

3.1.3 Calculation of Basic Sediment Volume

The basic amount of sediment required for formulating the layout policy for sabo facilities is summarized in Table 3-9. The explanation of each sediment volume are as follows:

Unstable Sediment Volume: the amount of unstable sediment that exists in the upstream area. In the volcanic sediment control project of Mt. Semeru, it is calculated based on (existing unstable sediment volume) + (future unstable pyroclastic flow deposits). This refers to section 4.2 of the Review Master Plan (2024).

Possible Sediment Discharge Volume: the amount of sediment that flows down due to debris flows that occur by design rainfall. This refers to section 4.3 of the Review Master Plan (2024).

Design Sediment Discharge Volume: the volume of sediment that reaches the design reference point due to debris flows at the planned scale. The smaller value between the unstable sediment volume and the possible sediment discharge volume is considered as the design sediment discharge volume. This refers to Section 4.4 of the Review Master Plan (2024).

Design Allowable Sediment Discharge Volume: the volume of sediment that can be safely discharged downstream of the design reference point without causing sediment-related disasters. This refers to Section 4.5 of the Review Master Plan (2024).

Design Excess Sediment Volume: the amount of sediment that needs to be managed by the sabo facilities. This is calculated as: Design Sediment Discharge Volume – Design Allowable Sediment Volume. This refers to section 4.6 of the Review Master Plan (2024).

Table 3-9 Calculation of basic sediment volume

(Unit: 1,000 m³)

Item		River			
		Glidik	Rejali	Mujur	
(a) Unstable Sediment Volume	existing	(1)	968	1,649	4,942
	future	(2)	8,000	8,000	0
	total	(3) = (1)+(2)	8,968	9,649	4,942
(b) Possible Sediment Discharge Volume	(4)	7,180	6,885	2,891	
(c) Design Sediment Discharge Volume	(5) = Smaller values of (3) and (4)	7,180	6,885	2,891	
(d) Design Allowable Sediment Discharge Volume	(6)	4,269	2,742	835	
(e) Design Excess Sediment Discharge Volume	(7) = (5)-(6)	2,911	4,143	2,056	

3.1.4 Layout Policy and Selection of sabo Facilities

The layout policy of sabo facilities to achieve the sediment management policy is as follows.

(1) Capture of Debris Flow by sabo Dams, Sand Pocket, and Dispersion Dams

To capture debris flows, sabo dams are constructed in the stream sections with a clear valley shape within the debris flow origination and development zones. Meanwhile, sabo dams, sand pocket, and dispersion dams are constructed in the alluvial fans of the debris flow inundation and deposition zone.

(2) Diversion of Debris Flow using Training Dike and Channel Work

As described in (1), sand pockets and dispersion dam will be constructed in the alluvial fan within the debris flow inundation and deposition zone. However, since the channel depth in the alluvial fans is shallow (several meters), there is a high risk of overflow during large debris flows. When planning the training dike, it is necessary to take into account the occurrence of debris flows after the rise of

the riverbed due to pyroclastic flows, as occurred in December 2021. For this reason, training dikes will be installed in the debris flow inundation and deposition zone upstream of the reference point to guide the sediment, while channel works will be conducted in the bed load flow zone downstream of the dike to safely discharge sediment into the sea and to prevent damage and flooding.

(3) Adoption of Open-type sabo Dams

Sabo dams and dispersion dams will be open-type (conduit type, slit type) to maintain the capacity of the dam during normal times when debris flows do not occur (Figure 3-3). As a general rule, the existing closed-type sabo dams, groundsills, and dispersion dams will be changed to open-type sabo dams (conduit type, slit type if road functions are not added) that have a large sediment capture capacity (design sediment capture volume). The open-type dam to be adopted shall not be a backwater type, but a blockage type. In addition, since it is necessary to keep the water level higher than the upper end of the spillway, the sabo facility with a water intake system shall not be converted to an open-type type.

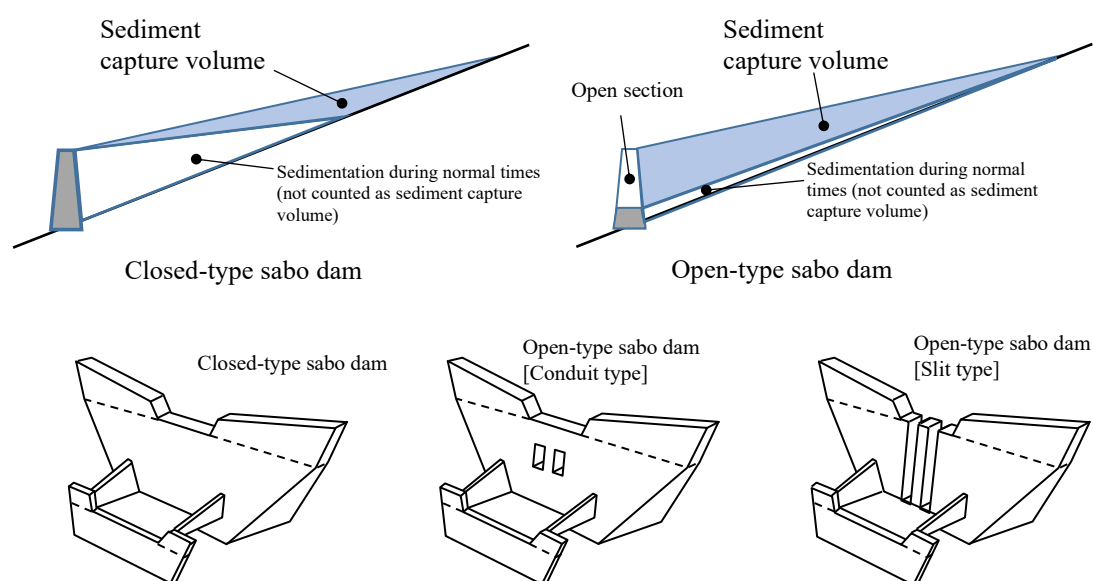


Figure 3-3 Closed-type/open-type sabo dam effects and conceptual diagrams of closed-type/open-type (conduit type/slit type) sabo dams

For sabo dams with wide openings in their body used as bridges, it is necessary to narrow the opening width when the dams are converted to conduit type. This reduces the amount of sediment released through the opening, resulting in a large amount of sediment accumulating upstream. Therefore, to avoid flooding from the upstream training dike, the dams will not be converted to conduit type sabo dams unless the riverbank heights on both banks are more than 10 m higher than the top height of the dam's overflow section.

(4) Construction of Access Roads for Maintenance

Maintenance roads for sediment management are built from main roads to the sediment deposition areas. While sand mining in the three rivers of Mt. Semeru is primarily carried out downstream of the supplementary reference points due to easier access, removing sediment upstream at large sabo dams is vital for restoring their sediment capture capacity. Hence, access roads to these facilities are planned.

(5) Dam Material

On December 4, 2021, the sabo dam in Curah Kobokan River was destroyed by pyroclastic flows and debris flows due to the failure of the inside of the dam body due to external forces, not abrasion or scouring. Most of the destruction caused by external forces occurs in places where debris flows

occur or where the slope of the riverbed is more than 5%. Since it is assumed that the damage caused by external forces is caused by insufficient strength of the masonry, which is the material of the sabo facility, it is necessary to use concrete that is much stronger than masonry. Therefore, concrete, which is significantly stronger than masonry, is required as the structural material for sabo dams subjected to external forces. Although sabo facilities are buried by pyroclastic flows, there are no reports of structural failures directly caused by pyroclastic heat or forces, thus no special structural considerations for pyroclastic flows are included.

(6) Preservation of Irrigation Intake Functions in sabo Facilities

Some of the sabo facilities on the three rivers have irrigation intakes. Even in normal times, a large amount of sediment flows into these water intakes, which can bury downstream channels and causing function loss. To prevent such damage, sand traps are installed at the water intake. In the case of sabo dams with an irrigation water intake function, a sand trap function is added to prevent clogging and destruction of irrigation facilities due to sediment inflow. Since these water intakes and sand traps were damaged as well as sabo facilities, these structures will be rehabilitated at the same time.

(7) Rehabilitation and Reconstruction of Existing sabo Dams

The planning of the sabo dam will be based on the existing facility layout. Damaged facilities will be reconstructed or rehabilitated if it is included in the plan. In addition, new facility layouts may be proposed. By restoring the storage capacity of the existing sabo dams, the design excess sediment discharge volume can be managed. Damaged facilities will either be rehabilitated or reconstructed.

3.1.5 Sabo Facility Layout Plan for Each River Basin

The draft layout plan for the sabo facility was examined based on the above-mentioned sabo facility layout policy. An overview of the proposed sabo facilities for each river basin is shown in Table 3-10 and Table 3-12, and the location of the proposed sabo facilities is shown in Figure 3-4.

There are a total of 59 river-crossing structures in the three river basins of the Mt. Semeru due to the construction of sabo dams and groundfills. However, some of these facilities are damaged. To capture 100% of the design excess sediment volume, it is necessary to improve the functions of four existing facilities to open type, construct two new river crossing structures, reconstruction of 12 river crossing structures, and rehabilitation of 27 river crossing structures.

The sediment control effect of the facility was calculated for each stage of (1) immediately after the construction of the facility (assuming that there is no damage, etc.), (2) the current conditions, and (3) upon completion of planned facilities, and summarized in Table 3-11. For Rejali River, the effect of each facility at the above three stages are summarized in Chapter 3.7.

Table 3-10 Number of existing and planned sabo facilities

River name	Number of existing river crossings sabo facilities	Planned Facilities				Total
		Status quo/functional improvement (open type) Number in () shows the facilities with improved functionality	New Construction	Reconstruction	Rehabilitation	
		(1)	(2)	(3)	(4)	
Mujur	22	5(2)	0	3	14	22
Rejali	29	8(0)	0	8	13	29
Glidik	8	7(2)	2	1	0	10
sum	59	20(4)	2	12	27	61

Note: River crossing structures refer to sabo dams, dispersion dams, and groundfills works.

Table 3-11 Sediment control volume of sabo facilities at Each Stage

unit : m³

River name	Immediately after existing facility construction (No damage.)	Current condition	After the construction of planned facilities				
			Conversion to open type	New	Reconstruction	Rehabilitation	Total
Mujur	1,926,400	1,224,900	30,000	0	249,500	1,779,500	2,059,000
Rejali	3,475,700	1,708,000	0	0	1,651,500	2,503,800	4,155,300
Glidik	101,100	75,900	209,500	2,665,800	37,800	0	2,913,100

In addition to the above, it is necessary to construct a new 1,700-meter-long dike and rehabilitate a 7,817-meter-long dike.

Table 3-12 Outline of the Proposed sabo Facility (Training Dike)

River name	Proposed dike extension (m)		
	New	Reconstruction	Rehabilitation
Mujur	1,100.0	0.0	2,681.8
Rejali	600.0	0.0	3,835.4
Glidik	0.0	0.0	1,300.0
Total	1,700.0	0.0	7,817.2

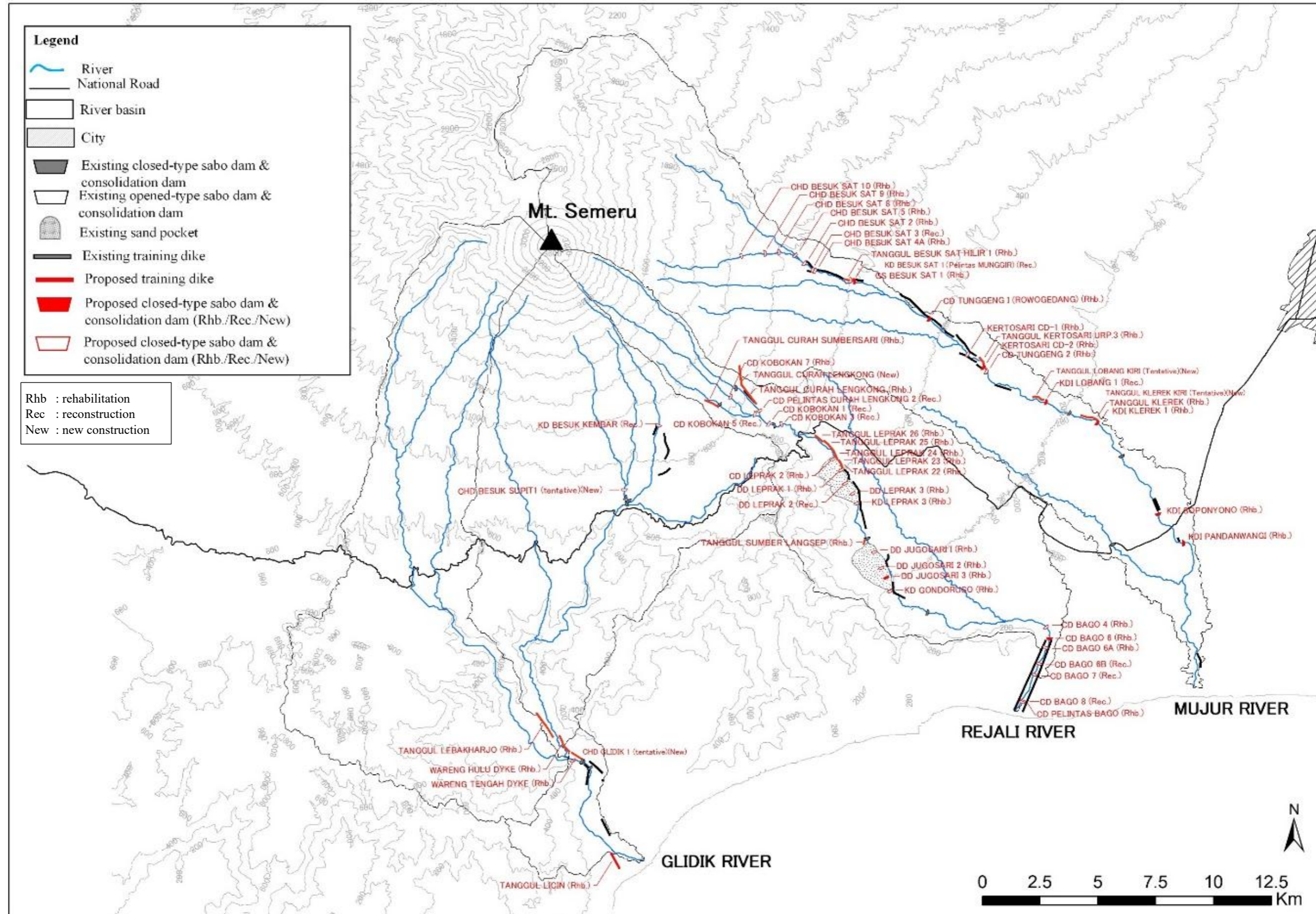


Figure 3-4 Planned sabo facilities in three river basins of Mt. Semeru

3.1.6 The Project for Sabo Facilities in the Rejali River

(1) Condition of Existing Facilities

Based on the characteristics of the river channel and the sediment movement phenomenon, the Rejali River can be divided into three section (Figure 3-7) i.e., (a) debris flow origination and development zone (from the summit of Mt. Semeru to the supplementary reference point (15 km from summit)), (b) debris flow inundation and deposition zone (from the supplementary reference point to the design reference point (20 km from summit), and (c) bed load flow zone (from the reference point to the river mouth (35 km from the summit)).

Direct hits from pyroclastic flows and debris flows have caused a large number of major damages to sabo facilities in the debris flow origination and development zones. In the debris flow inundation and deposition zone, the riverbed has risen due to frequent debris flows since the December 2021 eruption. In the bed load flow zone, the riverbed is declining and scouring to sabo facilities is occurring.

Since residential areas and agricultural land are mainly distributed in the debris flow inundation and deposition zones, it is necessary to protect these areas from debris flow inundation from the viewpoint of land use and conservation.

(2) Sabo Facility Layout

1) Debris Flow Origination and Development Zones

In this zone, it is necessary to install relatively high sabo dams in mountain streams with deep valley shapes to trap sediment and reduce the peak discharge of debris flows to downstream.

- To improve the sediment control effect of sabo facilities, the severely damaged sabo dams of CD Pelintas Curah Lengkong 2, CD Kobokan 7, CD Kobokan 5, CD Kobokan 1, and CD Kobokan 3 shall be converted from closed-type to open-type sabo dams (conduit type) through reconstruction and rehabilitation work.
- To reduce the potential impact of debris flow inundation, the existing dikes at Tanggul Curah Lengkong and Tanggul Curah Summersari will be strengthened and extended.

2) Debris Flow Inundation and Depositions Zones

To capture sediment and guide debris flow to downstream, Leprak sand pocket and Gondoruso sand pocket, which are sand pockets with a large capacity to trap sediment consisting of dams and training dikes in alluvial fans, will be reconstructed and rehabilitated and the training dikes will be strengthened as follows.

- In order to improve the sediment control effect, some groundsills and dispersion dams will be changed from closed-type to open-type (conduit type) through reconstruction and rehabilitation work.
- To reduce the potential impact of debris flow inundation, the existing dikes will be strengthened and heightened.

3) Bed Load Flow Zone

In this zone, channel works shall be carried out to discharge sediment into the sea. Bago channel works has been installed with consolidation dams. The completely destroyed Bago CD 6B, Bago CD 7, and CD Bago 8 need to be reconstructed. In addition, rehabilitation to the damaged Bago CD 4, CD Bago 6, CD Bago 6A and CD Pelintas are also needed.

The longitudinal map of the proposed sediment control facility is shown in Figure 3-5.

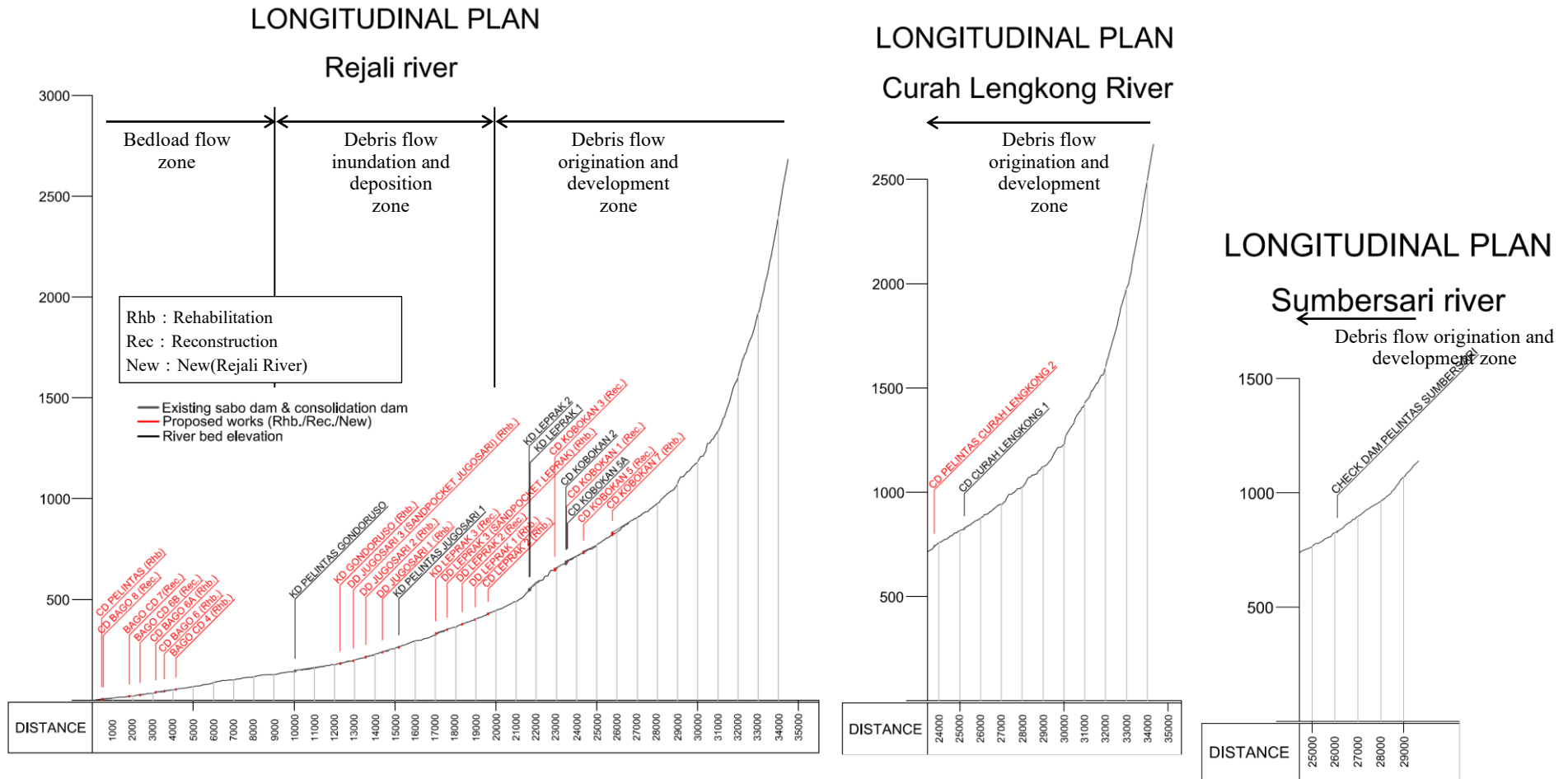


Figure 3-5 Longitudinal profile with sabo facilities (Rejali river)

3.1.7 Sediment Control Effect

Table 3-13 shows the effects of sediment maintenance by sabo facilities in the Review Master Plan (2024). The sediment balance map of the Rejali River is shown in Figure 3-6.

Table 3-13 Sediment control effect by sabo facilities in the review master plan (2024)

River	Design Excess Sediment Discharge Volume (m ³)	Sediment Control Volume (m ³)			Sediment Control Rate (%)		
		Existing sabo facilities (As of 2023)	Proposed and existing sabo facilities	Sediment Control Effect by the proposed sabo facilities	Existing sabo facilities (As of 2023)	Proposed and existing sabo facilities	Sediment Control Effect by the proposed sabo facilities
		(A)	(B)	(C)	(D)=(C)-(B)	(E)=(B)/(A)	(F)=(C)/(A) (Max100%)
Mujur	2,056,000	1,224,900	2,059,000	834,100	59.6%	100%	40.4%
Rejali	4,143,000	1,708,000	4,155,300	2,447,300	41.2%	100%	58.8%
Glidik	2,911,000	75,900	2,913,100	2,837,200	2.6%	100%	97.4%
合計	9,110,000	3,008,800	9,137,000	6,128,200	33.0%	100%	67.0%

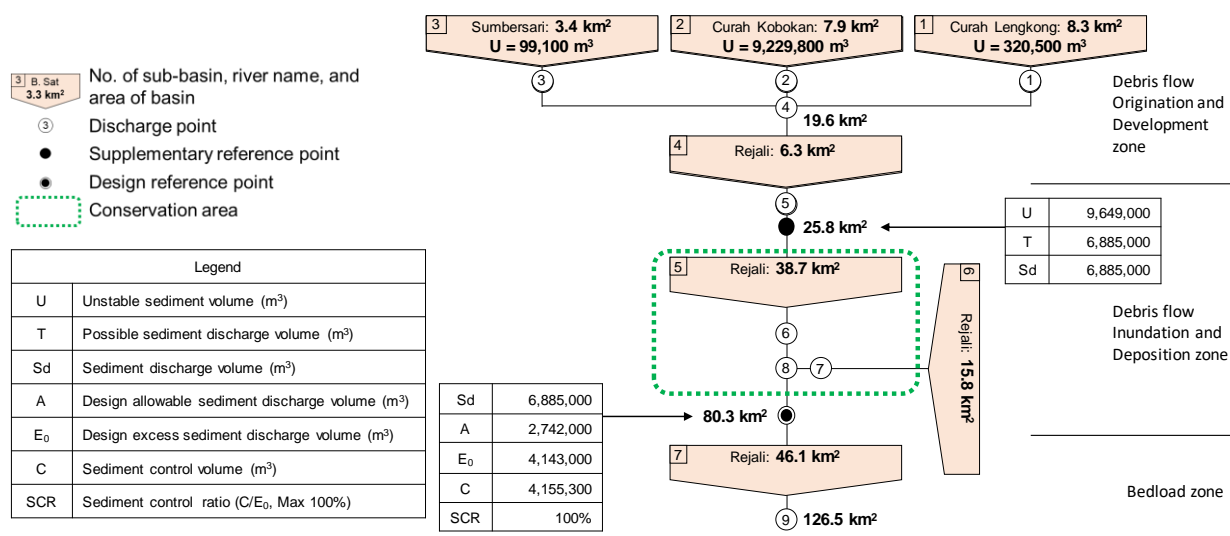


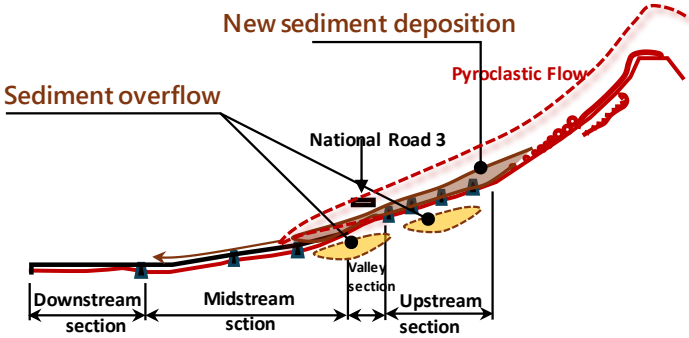
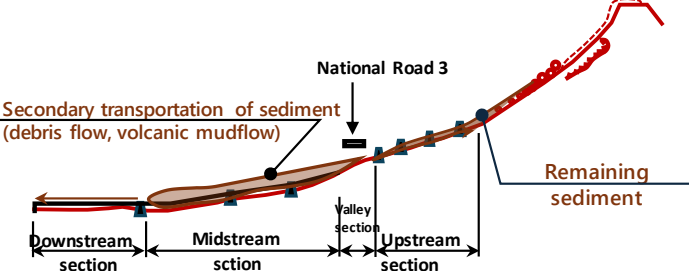
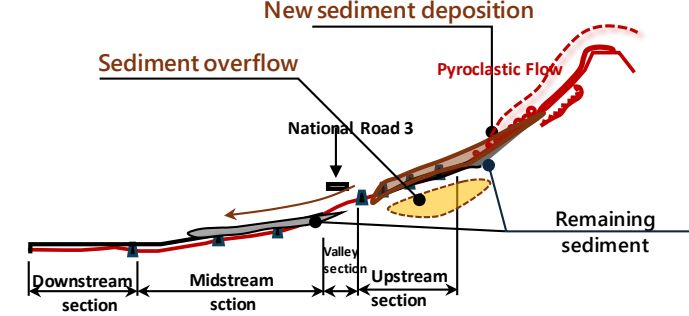
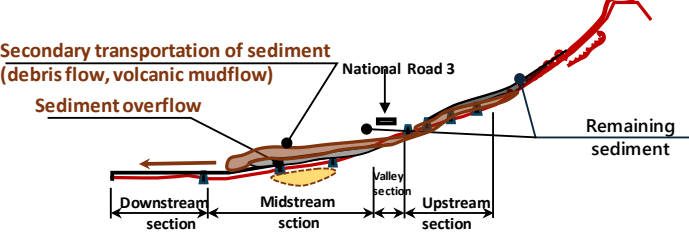
Figure 3-6 Sediment balance diagram after completion of the sabo facility in the review master plan (2024)

3.2 Sediment Discharge and Movement in Rejali River

3.2.1 Overview of Eruption Cycle and Sediment Movement

The eruption cycle and sediment movement in the Rejali River are shown in Table 3-14. As explained in Chapter 2 History Of Eruption Disasters, Mt. Semeru experienced large-scale pyroclastic flows in December 2021 and December 2022. Since these large-scale pyroclastic flows occurred in very short cycles, a significant volume of unstable sediment remained in the river channel. This was further compounded by the deposition of additional unstable sediment. Such accumulation has been a major contributing factor to the frequent occurrence of sediment-related disasters.

Table 3-14 Overview of eruption cycle and sediment movement (December 2021-August 2022)

Overview Diagram	Comment
<p>Phase 1: December 2021 Eruption</p> 	<ul style="list-style-type: none"> • The pyroclastic flow generated during the eruption flowed down to the upper part of the midstream. A large amount of sediment was deposited in the river channels in the upper and middle reaches of the river. • Subsequent debris flows, following the deposition of pyroclastic materials, flowed through the upstream and midstream regions. Due to the significant accumulation of sediment in the river channels, these debris flows caused flooding in both the upstream and midstream areas.
<p>Phase 2: Rainfall after the eruption in August 2022</p> 	<ul style="list-style-type: none"> • Sediment accumulated in the upper reaches of the river was eroded by rainfall and moved to the middle reaches of the river as debris flows. Some remained intact in the upper reaches.
<p>Phase 3: December 2022 When the volcano erupts again</p> 	<ul style="list-style-type: none"> • Pyroclastic flows from the eruption reached and deposited near the uppermost part of the upstream region. • Debris flows occurring after the pyroclastic flows flowed into the upstream region. Since sediment remained in the river channels, these debris flows caused flooding in the upstream area.
<p>Phase 4: Rainfall in March 2024</p> 	<ul style="list-style-type: none"> • Sediment that had accumulated in the upstream region was eroded by rainfall and transported downstream as debris flows, depositing in the midstream region. Some sediment remained in the upstream area. • In the midstream region, sediment remained in the river channels, which caused partial flooding of debris flows as it traveled through the midstream area.

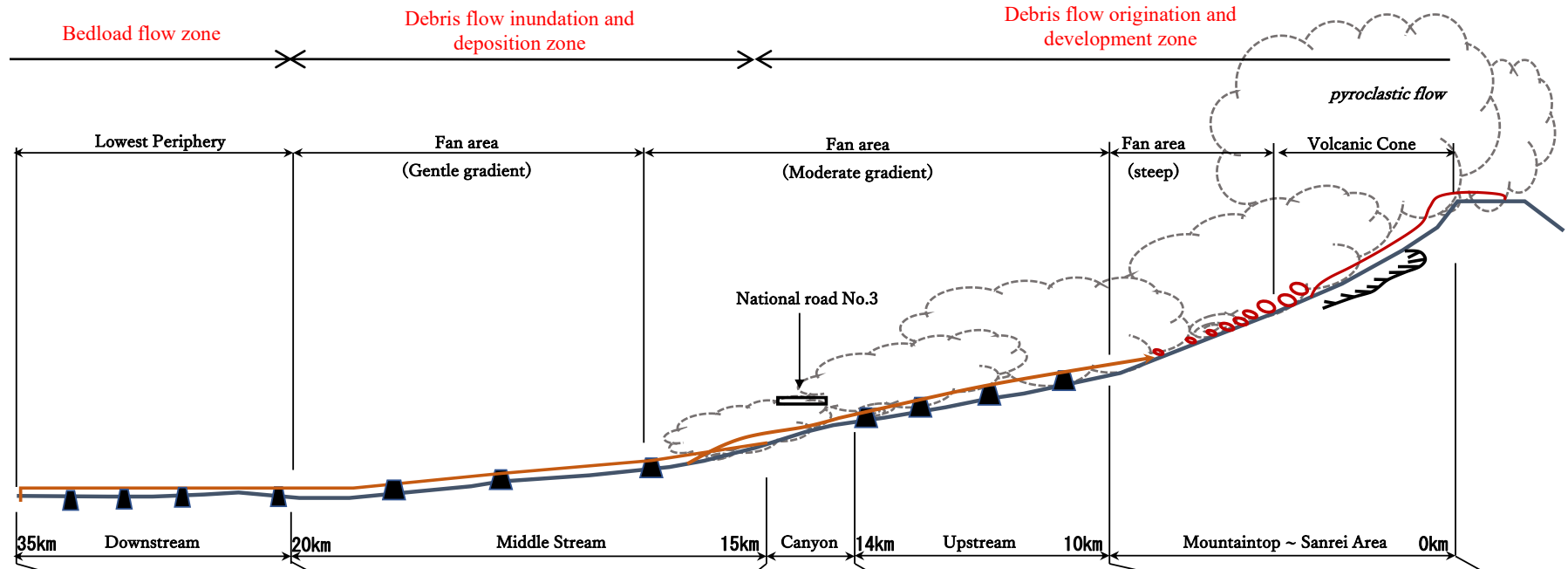
3.2.2 Current Status of Sediment Movement in Rejali River

The sediment movement in the Rejali River can be categorized into five sections: downstream, midstream, gorge/canyon, upstream, and summit-to-foothill. For each section, factors such as channel gradient, sediment transport characteristics, bed variation, flow characteristics, existing facilities, and sabo function evaluations have been assessed. The current state of sediment movement in the Rejali River is shown in Figure 3-7.

The pyroclastic flow in 2021 has reached the midstream section, and the pyroclastic flow sediment deposited in the riverbed is still eroding and depositing, resulting in the rapid riverbed fluctuation. In the midstream and upstream section, sediment flooded due to rainfall that occurred immediately after the eruption.

The specific situation of sediment movement caused by the eruption in 2021 is summarized below from the Review Master Plan (2024) report (Supporting Report A, pp.A-3-20~A-3-25):

- 1) The pyroclastic flow on December 4, 2021, flowed down to a point 17 km from the summit of Mt. Semeru.
- 2) Up to 5 km from the summit, sediment from pyroclastic flows was deposited over a wide area. On the left bank at 9 km from the summit, the riverbed that rose due to pyroclastic flow deposition, was flooded by a debris flow generated by rainfall (Figure 3-5). Therefore, a training dike made of gabions was built at this flood point. Currently, the riverbed has dropped by 8 to 10 m due to frequent debris flows (Figure 3-6).
- 3) A large area of 10 to 12 km from the summit was affected by pyroclastic flows (Figure 3-7). Frequent debris flows thereafter eroded pyroclastic flow deposits by 5 to 15 m in the vertical direction, damaging existing sabo dams (Figure 3-8).
- 4) In the narrow section of the river channel about 15 km from the summit, thick sediment carried by pyroclastic flows and debris flows was deposited (Figure 3-9). After that, the riverbed fluctuated greatly due to frequent debris flows, lowering the riverbed by 10 to 15 m (Figure 3-10).
- 5) In the section between the narrow part of the river channel and the 17 km point from the summit, sediment flooded the left bank (Figure 3-11). After that, the riverbed fluctuated due to frequent debris flows, and it dropped the riverbed by about 5 m (Figure 3-12).



	Downstream	Middle Stream	Canyon (Meandering section)	Upstream	Mountaintop ~ Foothill Area
Riverbed gradient	~1%	1%~5%	25%~35%	5%~25%	25%~
Sediment movement morphology	Sediments	Sediments, debris flows, volcanic mudflows	Pyroclastic flows, debris flows, volcanic mudflows	Pyroclastic flows, debris flows, volcanic mudflows	[Sediment Source] Pyroclastic Flow
Amount of riverbed variability	1m ~ 2m	2m ~ 5m	Up to 15 m or more	10m	-
Features of the flow	Meandering in a river	Drift in sand pocket There is a history of sediment flooding.	Severe disturbances due to meandering and falling	Drift, confluence, and diversion in rivers There is a history of sediment flooding.	Gully erosion develops
Condition of Existing Facilities	Damage and Corruption	Damage (including wear), collapse spillage, Buried	Damage (including wear), collapse spillage, Buried	Damage (including wear), collapse, spillage, burial	-

Source: JICA Research Team

Figure 3-7 Current status of sediment movement in Rejali river

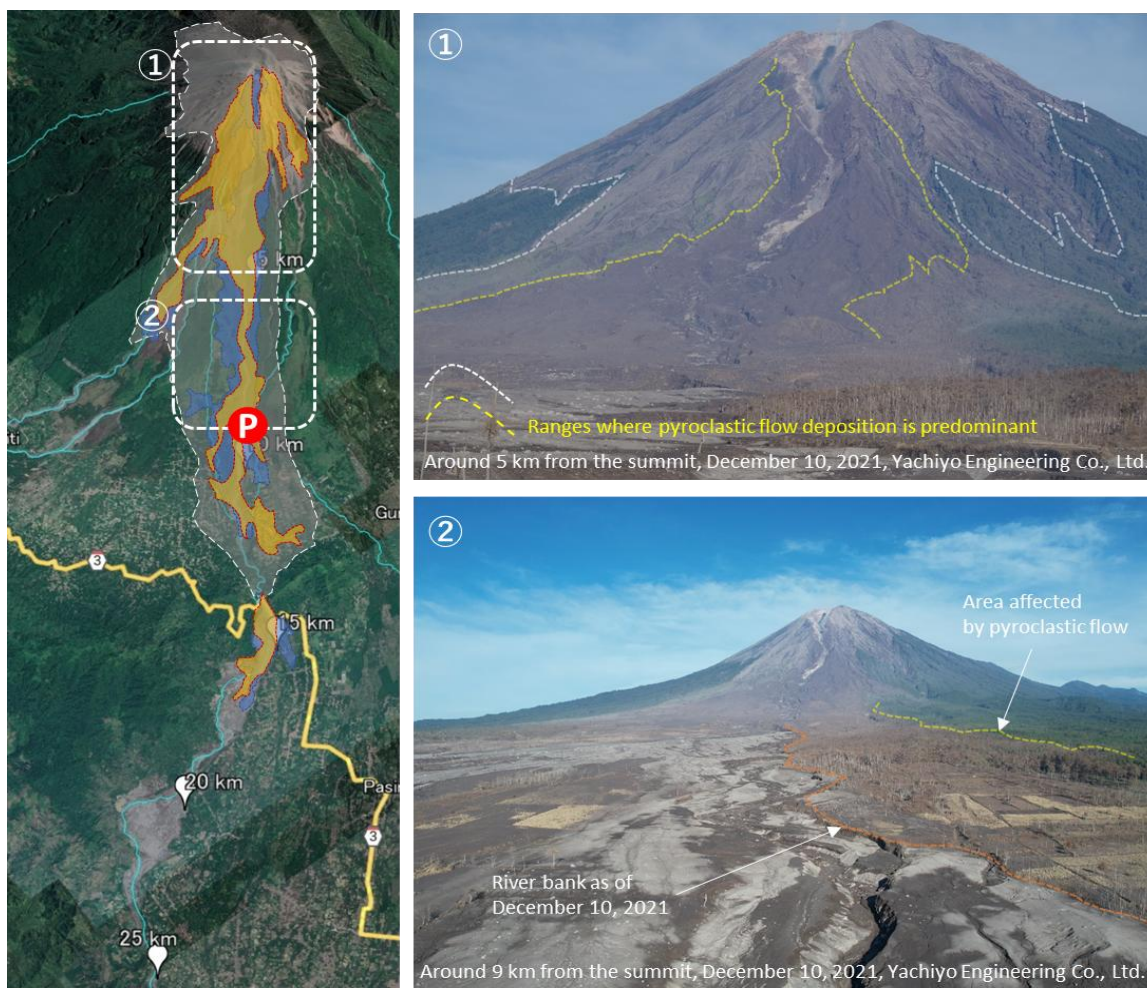


Figure 3-8 Distribution of pyroclastic flow deposits in the summit-to-foothill region (photographed in December 2021)



Source: Information Collection and Confirmation Survey on Volcano Disaster Prevention in Eastern Java and Bali, Indonesia Final Report 2024.3

The P point in the upper left figure is the position where the upper right figure was taken, and this figure is a photograph showing the P point, which is the shooting position.

Figure 3-9 River channel erosion status in Curah Kobokan (photographed in July 2022)

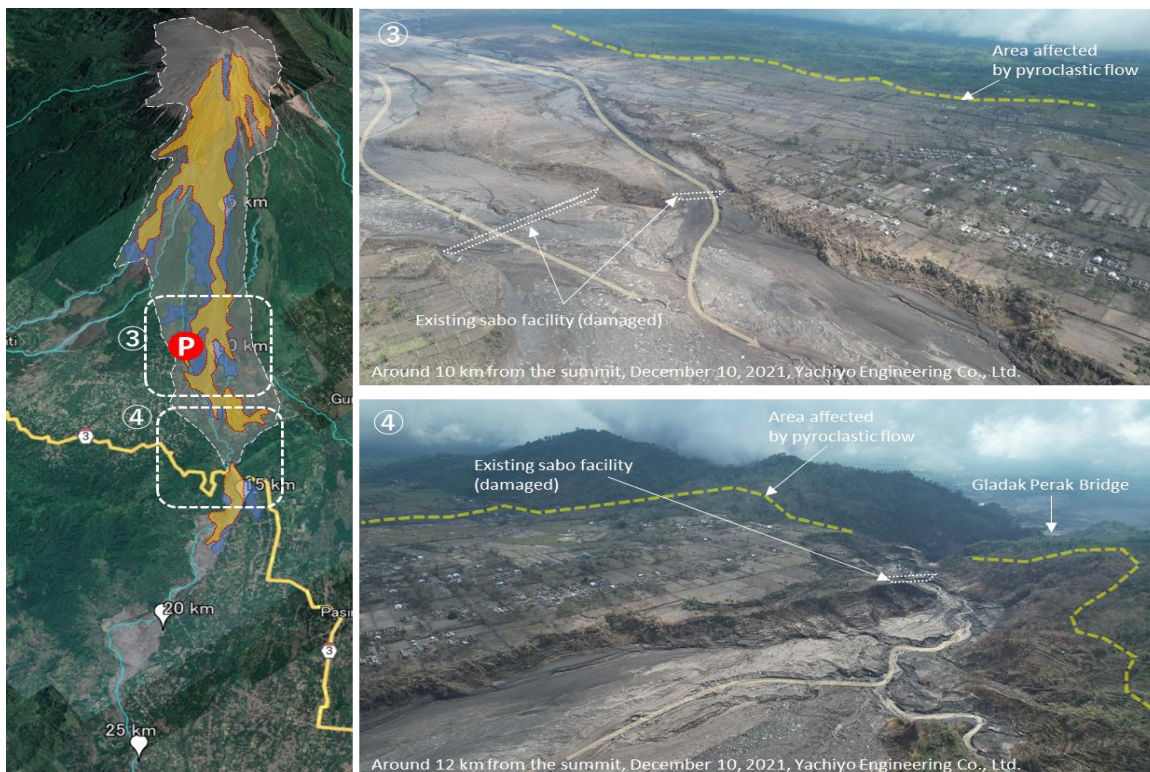


Figure 3-10 Distribution of pyroclastic flow deposits near the S2 area (photographed in December 2021)



Source: Information Collection and Confirmation Survey on Volcano Disaster Prevention in Eastern Java and Bali, Indonesia Final Report 2024.3

The P point in the upper left figure is the position where the upper right figure was taken, and this figure is a photograph showing the P point, which is the shooting position.

Figure 3-11 Riverbed condition in Curah Lengkong (photographed in July 2022)

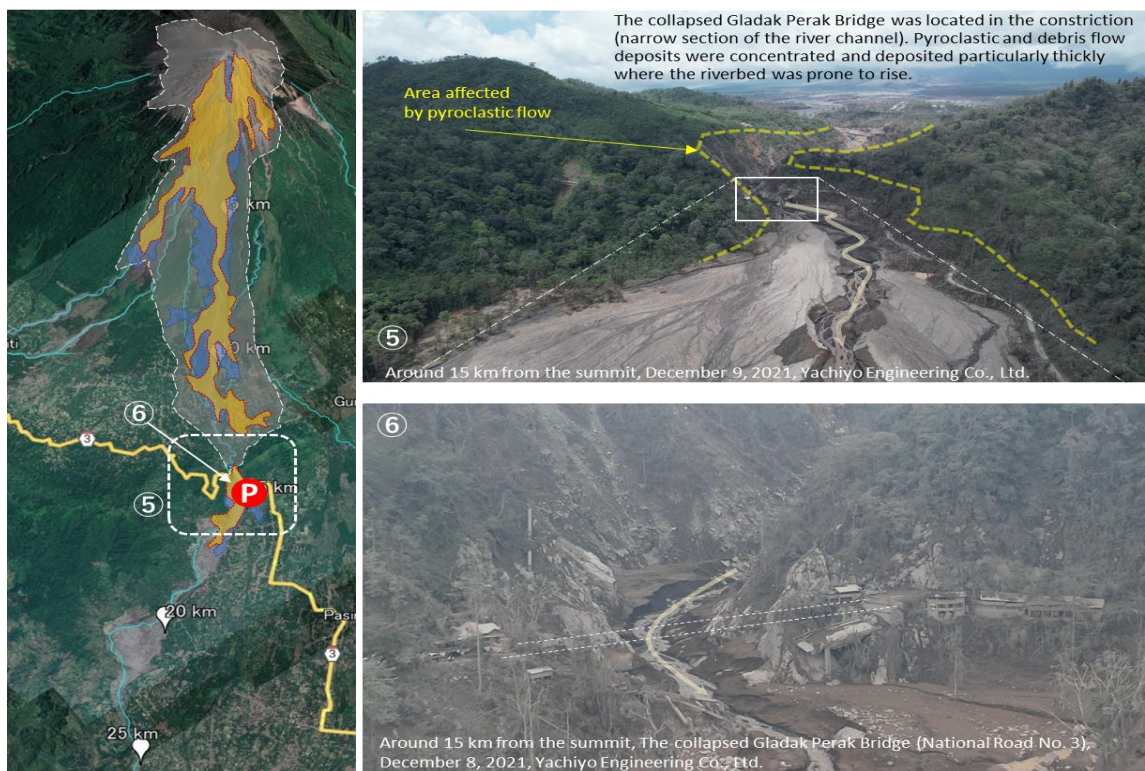


Figure 3-12 Distribution of pyroclastic flow deposits in the gorge section (photographed in December 2021)



Source: Information Collection and Confirmation Survey on Volcano Disaster Prevention in Eastern Java and Bali, Indonesia Final Report 2024.3

The P point in the upper left figure is the position where the upper right figure was taken, and this figure is a photograph showing the P point, which is the shooting position.

Figure 3-13 Lowering of the riverbed in the upper section of S4 (photographed in July 2022)

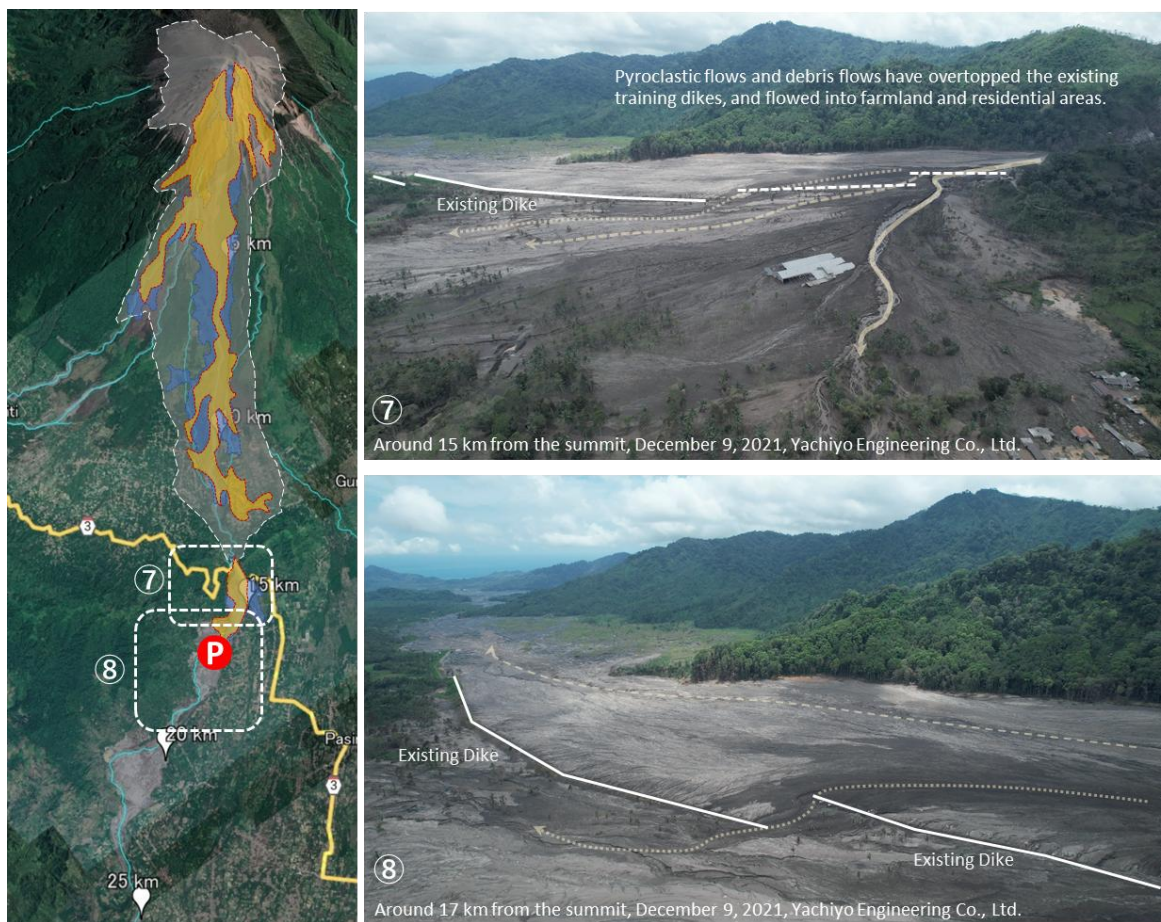


Figure 3-14 Distribution of pyroclastic flow deposits in the upper section of S4 (photographed in December 2021)



Source: Information Collection and Confirmation Survey on Volcano Disaster Prevention in Eastern Java and Bali, Indonesia Final Report 2024.3

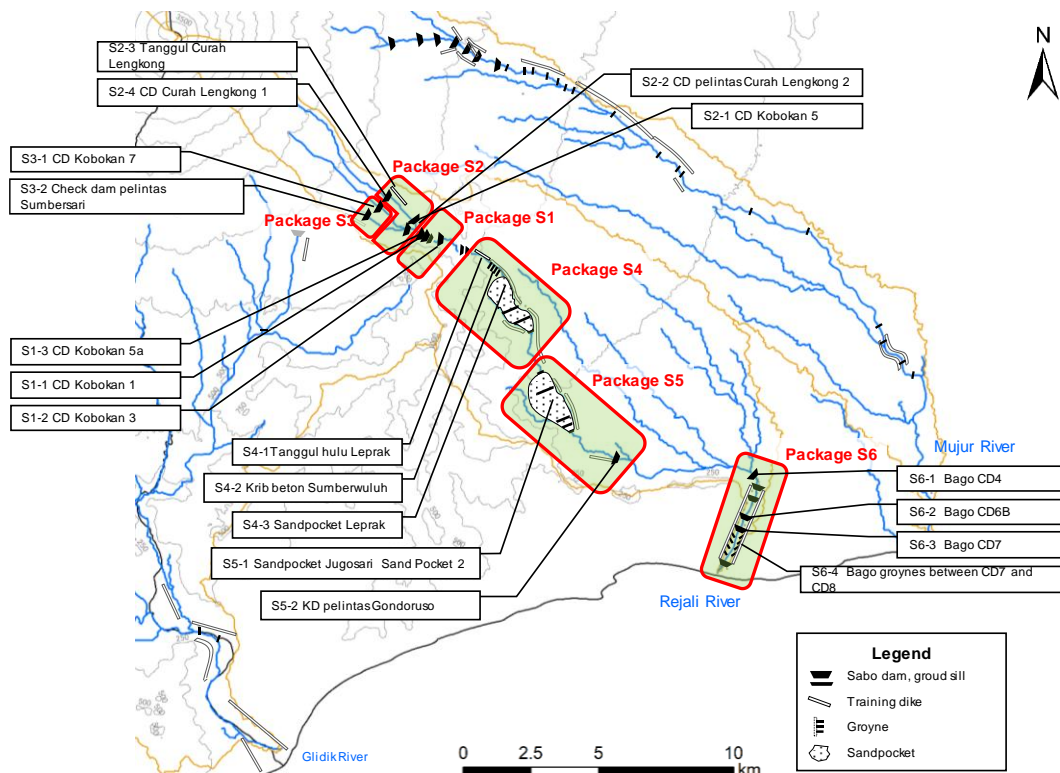
The P point in the upper left figure is the position where the upper right figure was taken, and this figure is a photograph showing the P point, which is the shooting position.

Figure 3-15 Channel erosion status in the S4 area (photographed in July 2022)

3.3 Selection of Priority Development Districts

3.3.1 Classification of Construction Packages

The construction packages in the Rejali River are divided into S1-S6 as shown in Figure 3-16. The priority measures for each package, as proposed in the Review Master Plan (2024) for each construction package are shown in Table 3-15.



Source: Final Report on Information Collection and Verification Survey for Volcano Disaster Prevention in Eastern Java and Bali Islands, Indonesia, March 2024

Figure 3-16 Construction packages for Rejali river

Table 3-15 Priority facilities for each construction package

Division	Package	Number	Facility name
Debris flow Origination and Development zone	S3	S3-1	CD Kobokan 7
		S3-2	Check Dam Pelintas Summersari
	S2	S2-1	CD Kobokan 5
		S2-2	CD Pelintas Curah Lengkong 2
		S2-3	Tanggul Curah Lengkong
		S2-4	CD Curah Lengkong
	S1	S1-1	CD Kobokan 5a
S1-2		CD Kobokan 1	
S1-3		CD Kobokan 3	
Debris flow Inundation and Deposition zone	S4	S4-1	Tanggul Hulu Leprak
		S4-2	Krib Beton Sumberwuluh
		S4-3	Sandpocket Leprak
	S5	S5-1	Sandpocket Jugosari Sand Pocket 2
		S5-2	KD Pelintas Gondoruso
Bedload Flow Zone	S6	S6-1	Bago CD 4
		S6-2	Bago CD 6B
		S6-3	Bago CD 7
		S6-4	Bago groin between CD 7 and CD 8

Source: Final Report on Information Collection and Verification Survey for Volcano Disaster Prevention in Eastern Java and Bali Islands, Indonesia, March 2024

3.3.2 Selection of High-Urgency Construction Packages

Due to the history of pyroclastic flows depositing large volumes of sediment in the river channels and the occurrence of debris flow flooding, the most recent issue is to control sediment inundation in the debris flow origination and development zone and in the debris flow inundation and deposition zone. In the immediate aftermath of the 2011 eruption, debris flows flooded these two sections, causing damage to residential areas. For this reason, in this study, it was decided to prioritize the development of measures in these two zones.

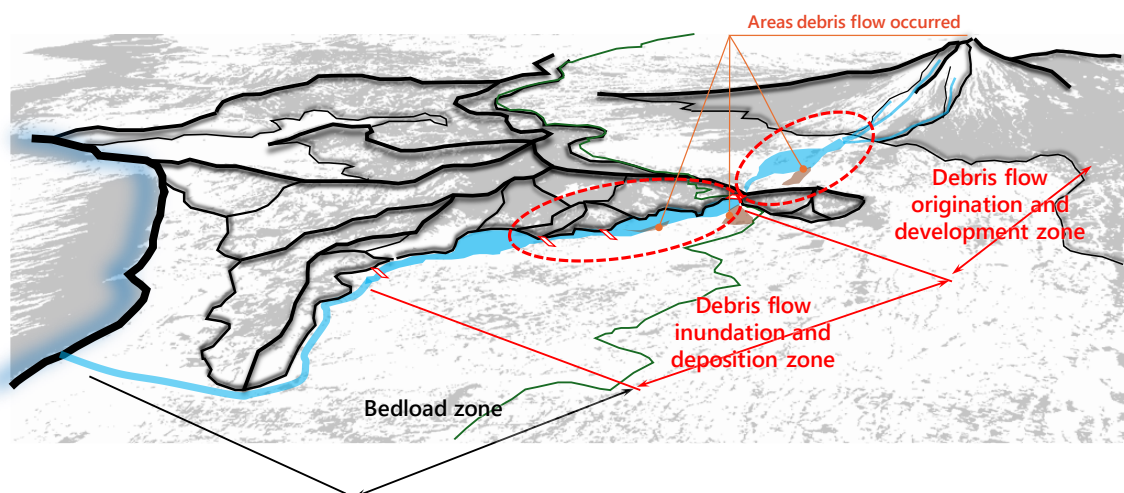


Figure 3-17 Sediment movement and priority development areas in the Rejali river

These two priority zones are encompassed by Construction Packages S1 to S4. Among these packages, debris flow flooded the S2 and S4 in 2021 and 2022. Given the high potential for significant pyroclastic flow deposition during future eruptions, S2 and S4 have been selected as priority areas for development.



Figure 3-18 Sediment disaster status in S2 and S4 (above: S2 area, bottom: S4 area)

*YEC Jakarta Office

Table 3-16 Selection of construction packages to be prioritized

Package	Asset Distribution Status	Riverbed Condition	Disaster history	Evaluation
S3	Houses, agricultural land, road	Due to the large amount of sediment flowing from upstream, the position of the river channel changed and the river channel was buried. The existing dam was also buried in sediment. Subsequently, the river channel was eroded, and the riverbed dropped by 8-10 m.	The land between the three rivers (mainly used as agricultural land) was damaged by sediment accumulation due to changes in river channels.	Due to the severe fluctuations of the riverbed, it is recommended to observe the situation for the time being.
S2	Housing, agricultural land, road	On the upstream side, the riverbed fluctuates rapidly, where the riverbed buried by large amount of sediment and then eroded by about 5-10 m. On the downstream side (near No. 5 and 6), there was no significant riverbed fluctuation as it did upstream.	Debris flows inundation occurred at the left bank of Curah Lengkong, damaging homes, farmland, and roads.	This area is selected as a priority area due to the possibility of pyroclastic flows flowing down and depositing during future eruptions, and due to the history of debris flow inundation in 2021 and 2022.
S1	National road No. 3 (on the bridge)	Field surveys have confirmed that erosion on the river banks and the river bed continues to progress.	The bridge was washed away by the debris flow.	River channel is severely eroded. Since the river channel is narrow and the construction is dangerous at this time (there is no place to evacuate), it is recommended to observe the situation for the time being.
S4	National road No. 3, bridges, houses, agricultural land, road	On the upstream side, the riverbed fluctuates rapidly, where the riverbed buried by large amount of sediment and then eroded by about 5-10 m. On the downstream side, there was no significant riverbed fluctuation as it did upstream, and it functions as a sand pocket	The bridge was washed away by the debris flow. Debris flow inundation occurred on the upper left bank of S4.	This area is selected as a priority area due to the history of debris flow inundation in 2021 and 2022.

Table 3-17 S1~S4 area list of existing facilities

Section	Package	No	Facility Classification	Facility Name	
【Priority Development Zone】 Debris Flow Origination and Development Zone	S3	1	Sabo dam	CD Pelintas Summersari	
		2	Sabo dam	CD Kobokan 7	
		3	Training dike	Tanggul Curah Summersari	
	【Priority Area】 S2	S1	4	Sabo dam	CD Curah Lengkong1
			5	Sabo dam	CD Kobokan 5
			6	Sabo dam	CD Pelintas Curah Lengkong2
			7	Training dike	Tanggul Curah Lengkong
【Priority Development Zone】 Debris Flow Inundation and Deposition Zone	【Priority Area】 S4	8	Sabo dam	CD Kobokan 5A	
		9	Sabo dam	CD Kobokan 1	
		10	Sabo dam	CD Kobokan 2	
		11	Sabo dam	CD Kobokan 3	
		12	Sabo dam	KD Leprak 1	
		13	Sabo dam	KD Leprak 2	
		14	Sabo dam	CD Leprak 2	
		15	Sabo dam	DD Leprak 1	
		16	Sabo dam	DD Leprak 2	
		17	Sabo dam	DD Leprak 3	
		18	Sabo dam	KD Leprak 3	
		19	Training dike	Tanggul Leprak 26	
		20	Training dike	Tanggul Leprak 25	
		21	Training dike	Tanggul Leprak 24	
		22	Training dike	Tanggul Leprak 23	
		23	Training dike	Tanggul Leprak 22	
		24	Training dike	Tanggul Leprak II-D	
		25	Training dike	Tanggul Leprak XVII Kebondeli 2021	
		26	Training dike	Emergency Dike	

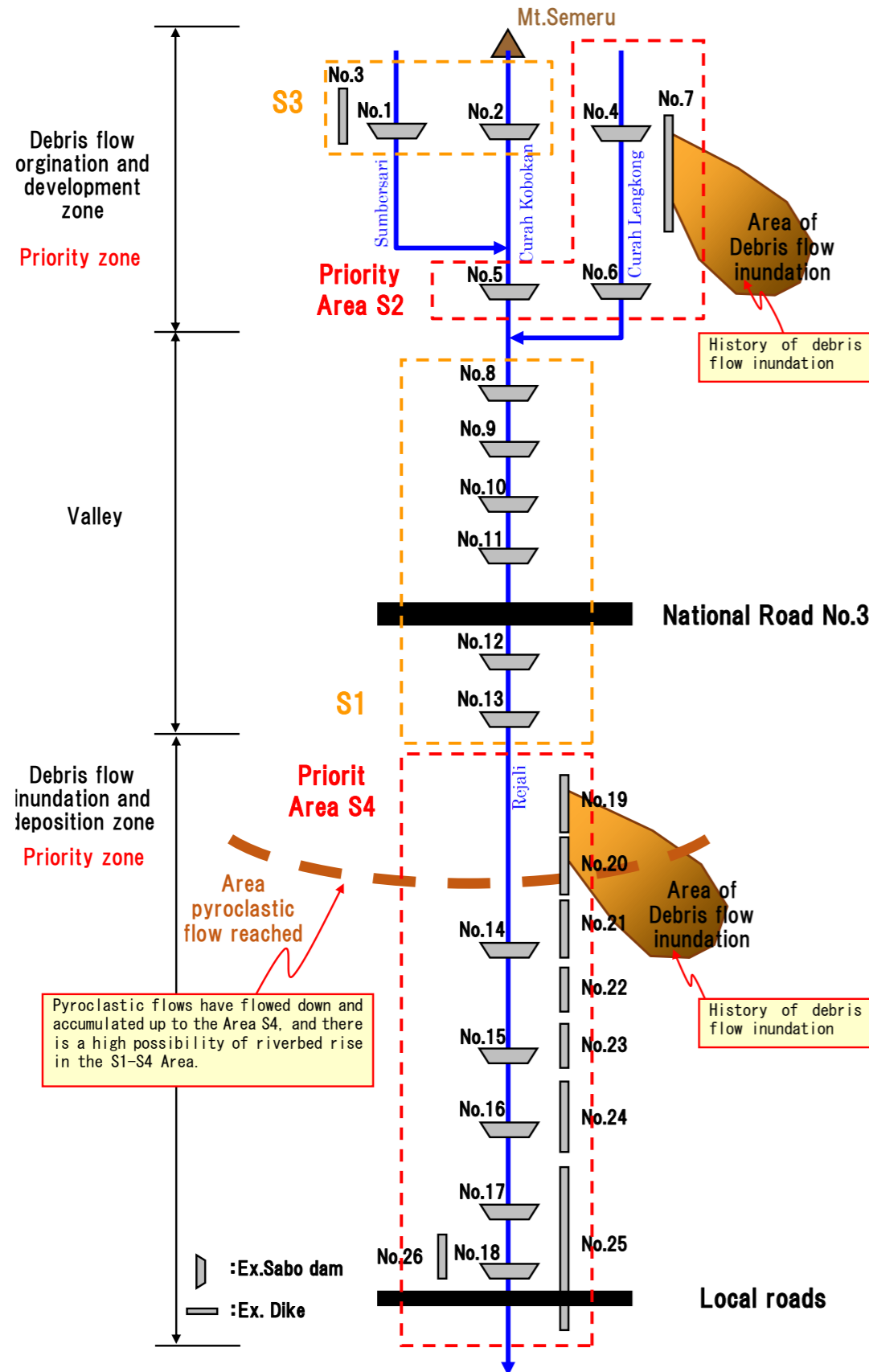


Figure 3-19 Rejali river construction package S1~S4 outline diagram

3.4 Basic Policies for Facility Development and Sediment Management Policy

As mentioned in 3.3.2, facility development will be prioritized in the S2 and S4 areas. In Rejali River, after the pyroclastic flow and debris flow in December 2021, on which the planning conditions of the Review Master Plan (2024) were based, a new pyroclastic flow occurred in December 2022 and a major debris flow occurred in July 2023. The river channel and sediment movement have changed the S2 and S4 areas as shown in Section 3.2.2. Therefore, the Review Master Plan (2024) facility development and sediment management policy will be revised as follows corresponding to the latest situation.

3.4.1 Basic Policy for Facility Development

Basic Policy 1: In areas where debris flow inundation is a particular concern, training dikes are constructed to minimize the risk of inundation during debris flow events.

The S2 and S4 areas have a history of debris flow inundation. While sediment excavation in the river channel shall be undertaken to prevent inundation (as detailed in Policies 3 and 4 below), training dikes shall be built with sufficient height to ensure safety even if sediment management after pyroclastic flow accumulation is delayed. Structures shall be designed to withstand inundation from the left bank as well.

Basic Policy 2: A new open-type sabo dam shall be constructed upstream of the existing sabo dam to ensure the debris flow storage function, and the existing dam shall be used as a sub-dam.

In order to realize the effect of debris flow storage in a relatively short period of time, a new open-type sabo dam shall be constructed upstream of the existing sabo dam. The existing dam shall be reconstructed, rehabilitated, and used as a sub-dam.

3.4.2 Sediment Management Policy

Basic policy 3: Sediment in the river channel is excavated down to the sediment management lines designated for each area.

In the river channels in the S2 and S4 areas, unstable sediment has been deposited due to frequent eruptions. The Review Master Plan (2024) stipulates that the interval between major eruptions with pyroclastic flows are five years, and the basic policy for facility development based on the premise of sediment management is being considered. For the S2 and S4 areas, sediment management lines described in (1) Sediment excavation will be carried out up to these lines. Following facility development, sediment captured by the sabo dam will be regularly removed up to the sediment management lines.

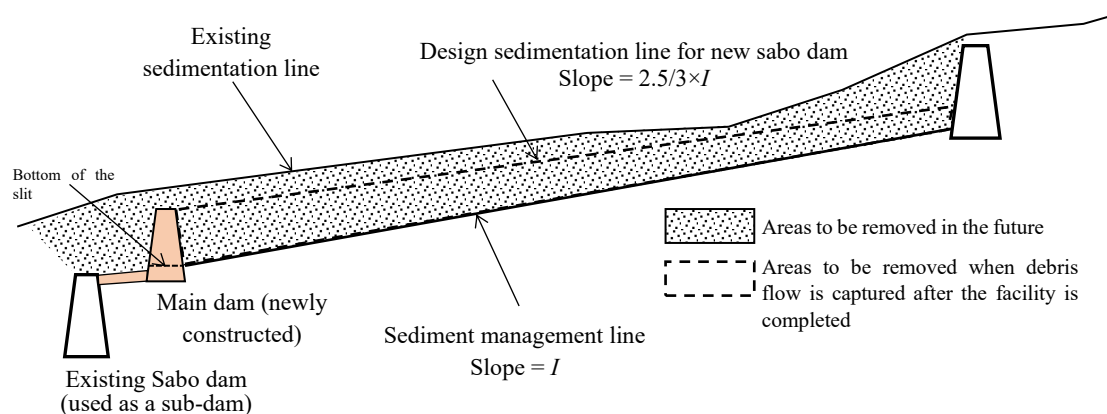


Figure 3-20 Schematic diagram of the sediment management policy

Basic Policy 4: Emergency sediment excavation is promptly conducted after pyroclastic flow deposition.

To reduce the risk of inundation by debris flows, emergency sediment excavation should be carried out as soon as possible after pyroclastic flow deposition and as far as possible to the sediment management line.

(1) Consideration of Sediment Management Lines

The sediment management lines for each area are defined as follows.

【S2 Area】

[Curah Lengkong River]

For Curah Lengkong River, the deepest riverbed shown in Figure 3-21 will be leveled, and the riverbed lines of $i=1/16$ at station No.12~No.35+30m, and $i=1/14.2$ upstream of No. 35+30m are used as the sediment management line. The riverbed gradient at CD Pelintas Curah Lengkong 2 is $i=1/16$, which is generally consistent with the average riverbed gradient in the same section set in the Review Master Plan (2024).

[Sumbersari River, Curah Kobokan River]

For Sumbersari River and Curah Kobokan River in the S2 area, the deepest riverbed in Figure 3-22 will be leveled, and the riverbed lines of $i=1/17.5$ at station No.10~No.70+70m, $i=1/15.0$ at No.70+70m~No. 120+80m, and $i=1/12.5$ upstream of No. 120+80m are used as the sediment management lines. The riverbed gradient at CD Kobokan 5 is $i=1/17.5$, which is generally consistent with the average riverbed gradient of the same section set in the Review Master Plan (2024).

【S4 Area】

[Rejali River]

For the sediment management policy in the S4 area, the riverbed line of $2.5/3$ of the average riverbed gradient of each of the existing dams set in the Review Master Plan (2024) is extended upstream from the bottom of the slit of the main dams (newly constructed) to form a sediment management line. It has been confirmed that the upper end of the line from each main dam reaches the sub-dam upstream. In Figure 3-23, the riverbed line with a gradient of $i=1/33.3$ at station No.10 ~ No.115 + 80m in the sand pocket section and $i=1/20$ in the upstream section is used as the sediment management line.

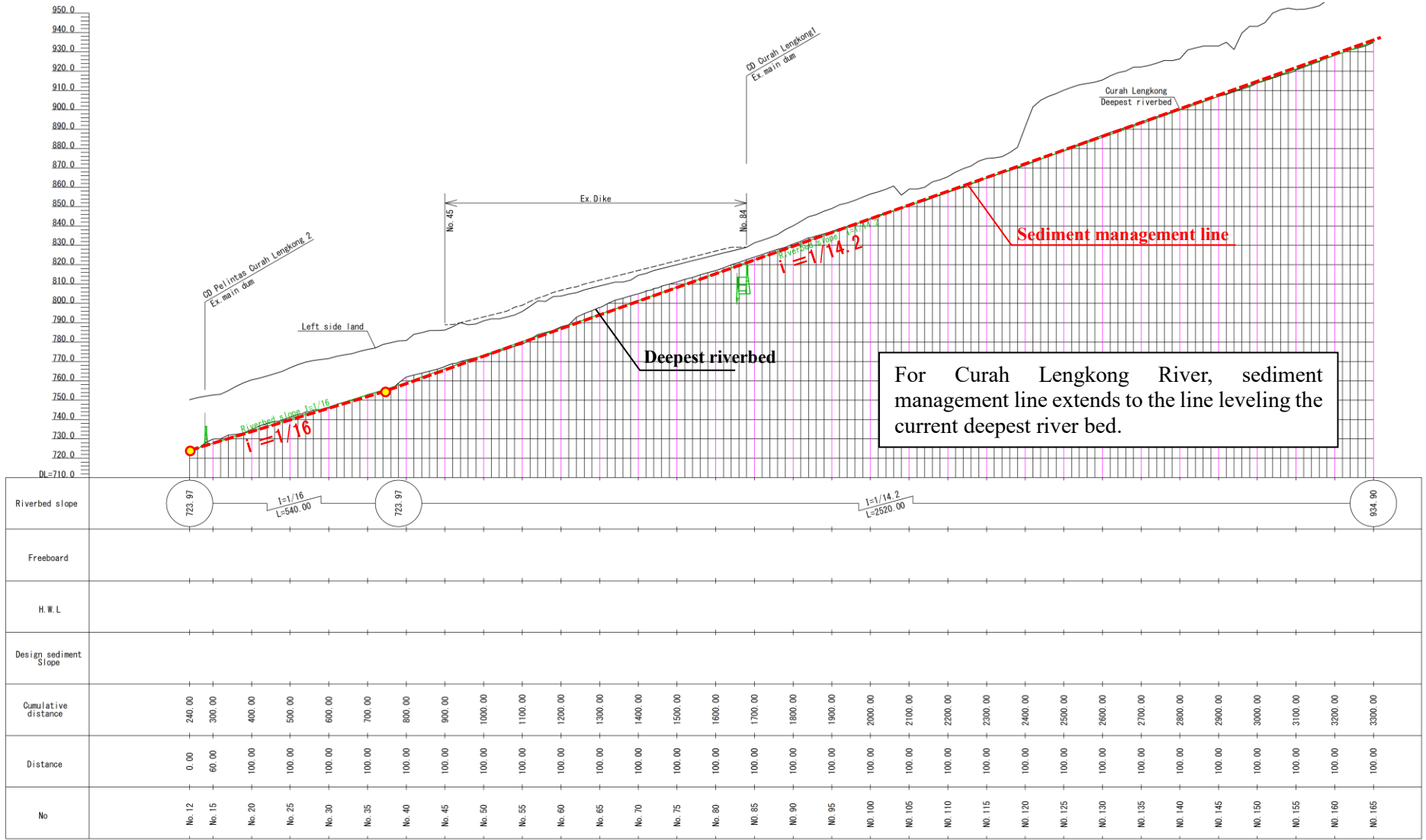


Figure 3-21 Curah Lengkong river (S2 area) sediment management line

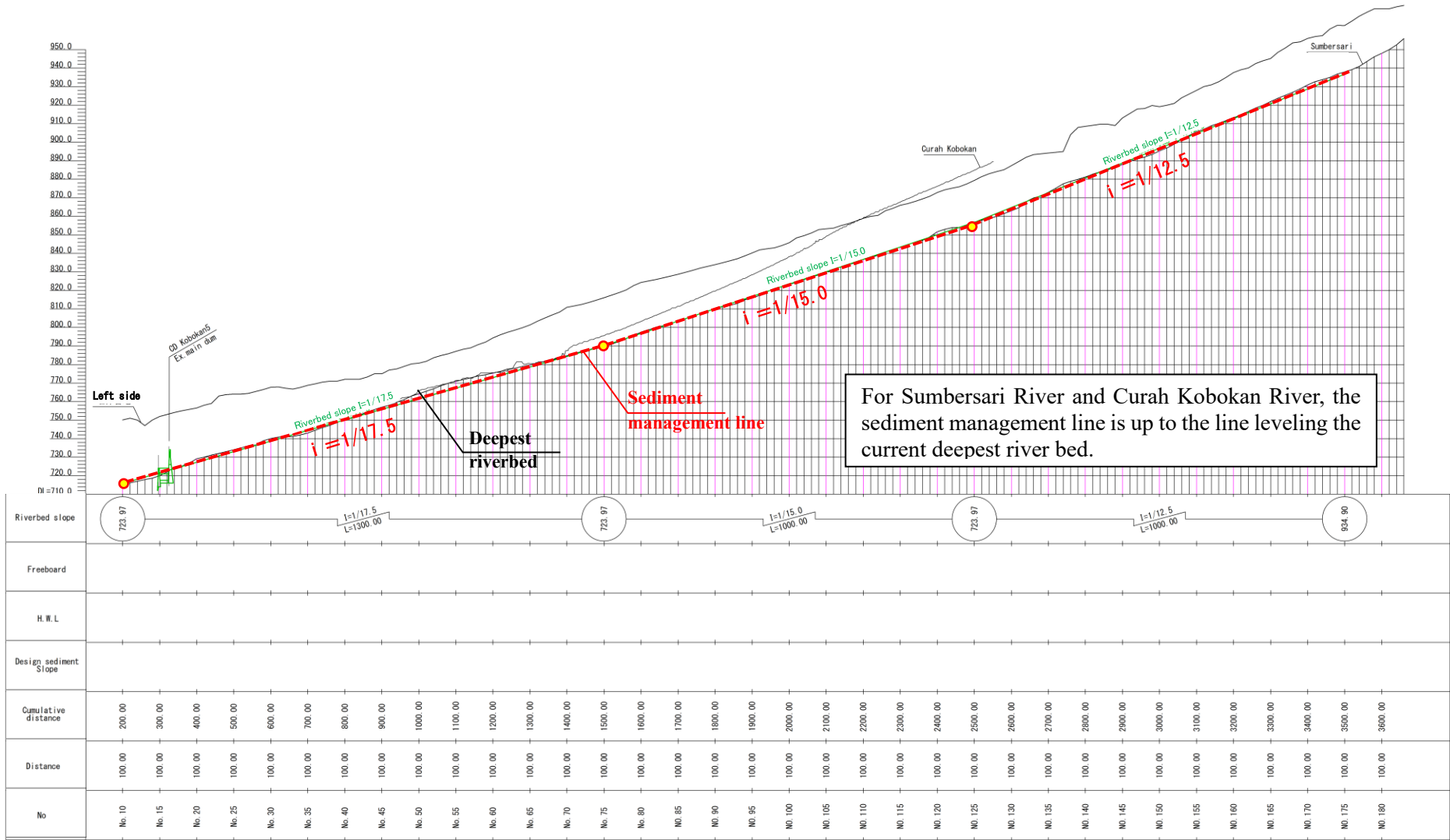


Figure 3-22 Sumbersari river and Curah Kobokan river (S2 area) sediment management line

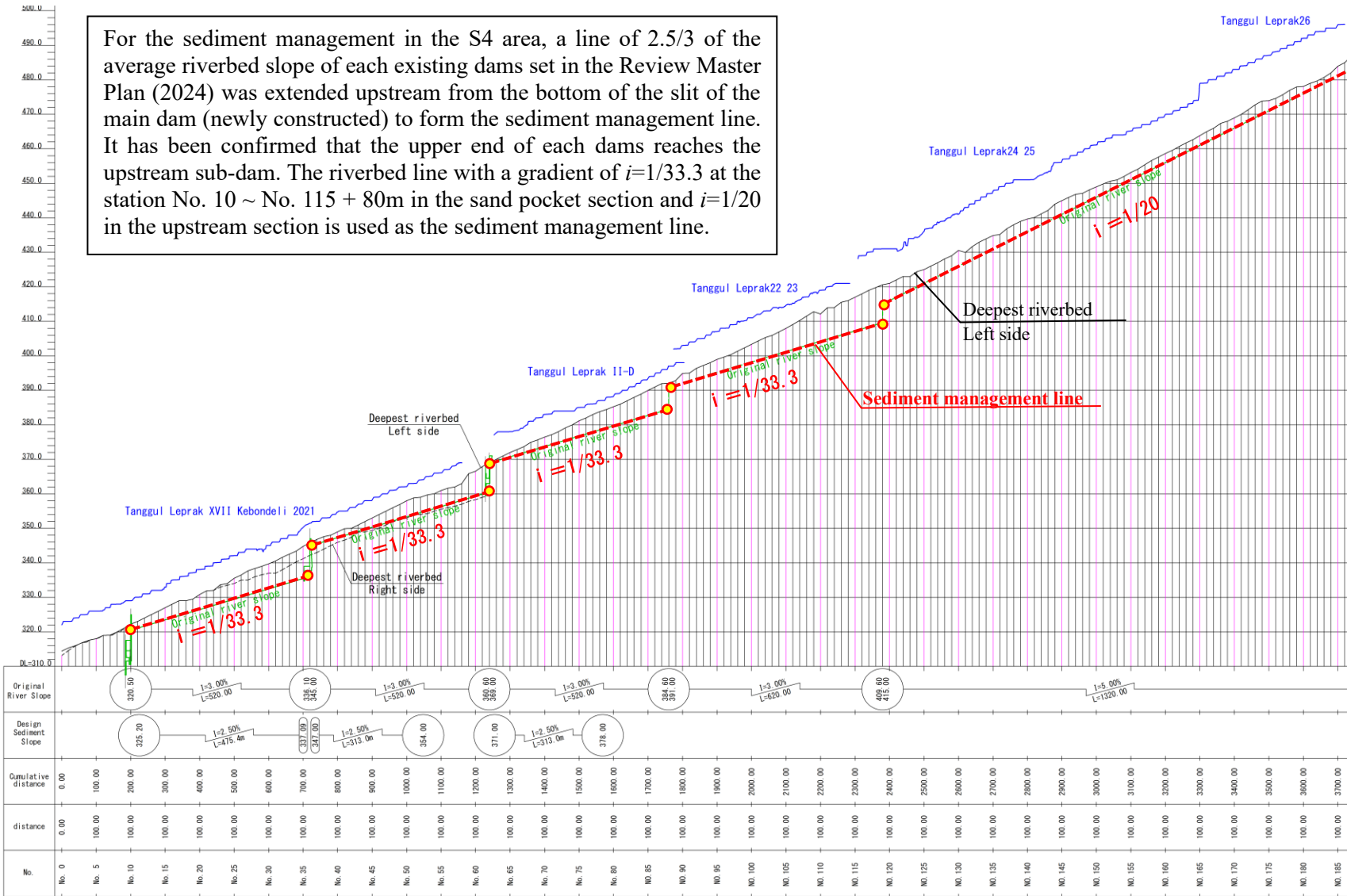


Figure 3-23 Rejali river (S4 area) sediment management line

(2) Access Road for Sediment Management

To implement sediment management effectively, the access roads in the S2 and S4 areas are planned as follows.

【Access road plan for the S2 area】

- The access road to the sediment deposition area downstream of the planned dam shall utilize the ancillary road of the sabo dam.
- The access road to the sediment deposition area upstream of the sabo dam shall extend the existing road to the sediment deposition area.

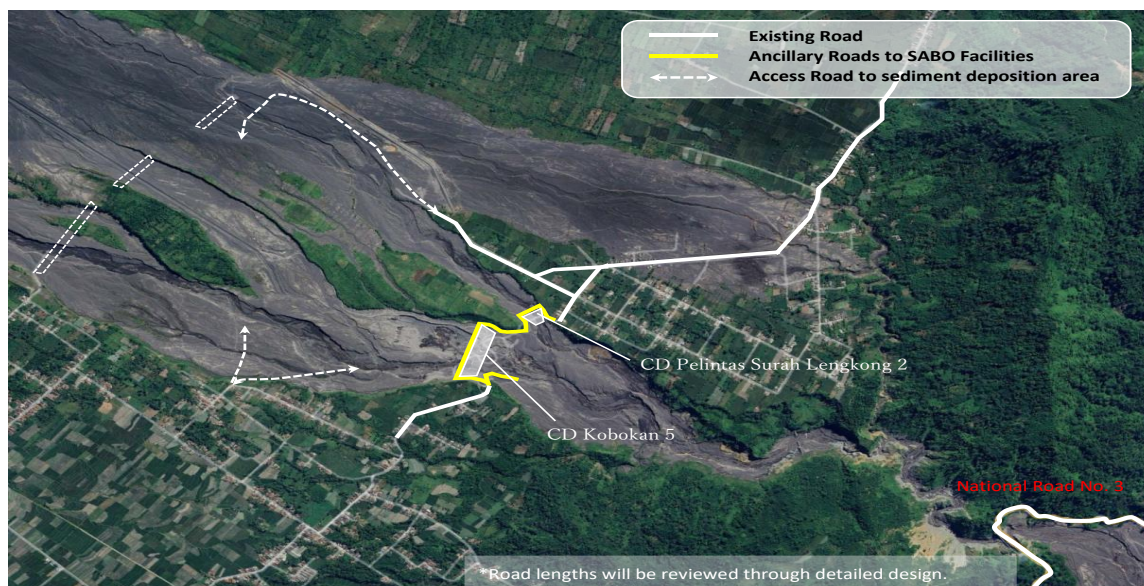


Figure 3-24 Maintenance access road plan for S2 area

【Access road plan for the S4 area】

- The access road to the sediment deposition area is planned to use the road between the existing dikes

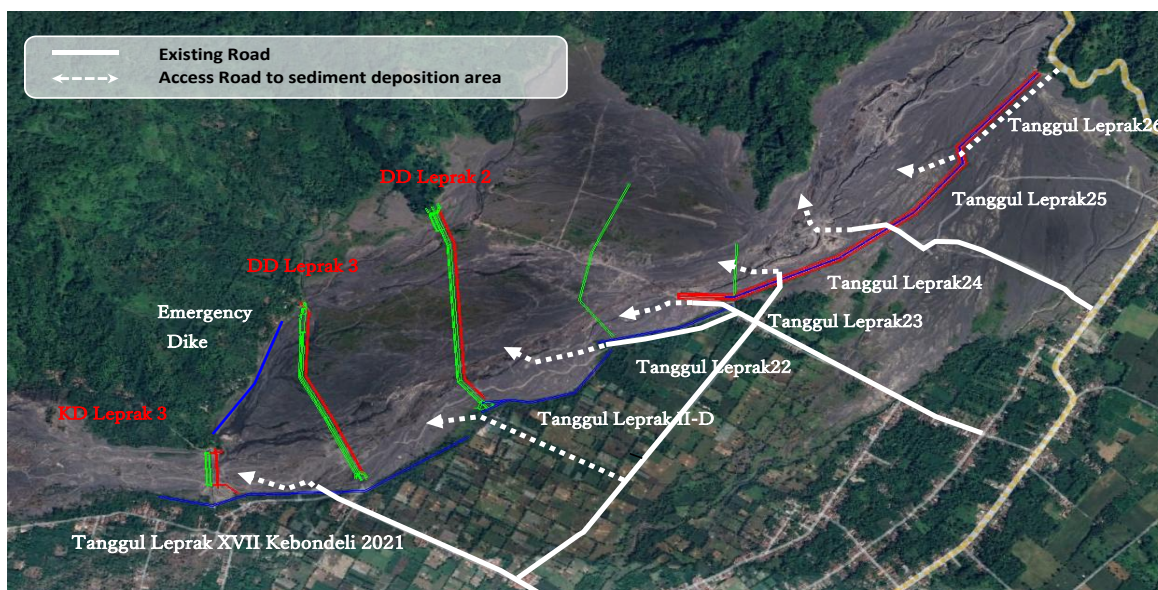


Figure 3-25 Maintenance access road plan for S4 area

(3) Amount of Sediment Management

Based on the current riverbed topography and sediment management policy, the estimated sediment volume to be excavated is as follows. The amount of sediment removal was calculated by multiplying the sediment control management area by the sediment management depth.

S2 Area	: $510 \times 10^3 \text{ m}^3$
S4 Area	: $1,990 \times 10^3 \text{ m}^3$
Total	: $2,500 \times 10^3 \text{ m}^3$

3.4.3 Sediment Removal Method

(1) Organizations Related with Sediment Removal

Urgent sediment removal should be carried out by BBWS/Brantas in principle, taking into account the urgency and safety of the site, as it needs to be carried out immediately after the pyroclastic flow or debris flow occurrence. On the other hand, sediment removal to ensure the amount of sediment to be captured in sabo dams in preparation for the next eruption should be carried out by sand mining companies, in principle, because it is necessary to excavate a large amount of sediment continuously and to consider the social demand for sediment removal to supply construction materials. Activities by sand mining companies will be managed by the Ministry of Energy and Mineral Resources, the responsible agencies in East Java Province and BBWS/Brantas.

(2) Licensing and Management Approaches to Sediment Mining Companies

The process for sediment mining companies to obtain a permit is as follows. The permit is valid for five years and sediment mining companies apply with a five-year mining plan.

- 1) Sand mining companies submit an online application to the Ministry of Energy and Mineral Resources (ESDM) for a permit to mine sediment.
- 2) Upon receipt of the application, ESDM will request ESDM East Java Province, SDA East Java Province and BBWS/Brantas to verify the contents of the application.
- 3) These agencies will make recommendations to ESDM on technical perspectives, such as presenting the extent of excavation that will not affect the safety of sabo facilities.
- 4) The ESDM issues the permit to the sand mining companies with these conditions.

BBWS/Brantas can control the sediment mining companies by providing a range of possible mining activities as indicated in 3) above and making it a condition of the permit. During the mining activities, if there are any violations, ESDM will order the mining companies to rectify the situation through provincial or regency ESDM.

In the future, it will be important for the relevant agencies to work together to improve the efficiency of mining activities by developing access roads to the mining areas and to monitor its progress by putting scales marked on diversion dikes to indicate excavated depth.

3.5 Facility Plan for Upstream Section (S2 Area)

3.5.1 Disaster Mechanism

(1) Situation in the Upstream Area

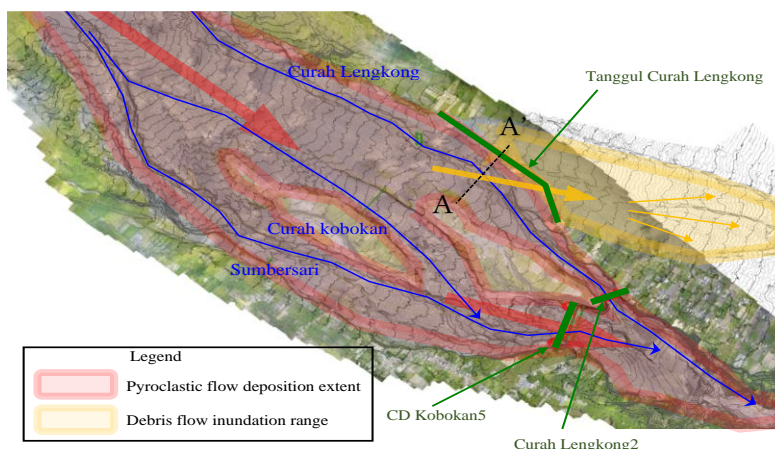
The upstream conditions were evaluated in May 2021 (before the eruption), May 2022 (after the 2021 eruption), and May 2023 (after the 2022 eruption). In Curah Kobokan River, where pyroclastic flows mainly flow, pyroclastic flows and frequent debris flows buried the river channel, causing debris flows to flow into Curah Lengkong River and Summersari River, raising its riverbeds, and resulting in debris flow inundation and damage along Curah Lengkong River.



Figure 3-26 Situation in the upstream area

(2) Overview of Affected Areas

The pyroclastic flows moved at high speeds along the valley as ash flows and deposited across the valley floor (red area in Figure 3-27). Subsequent rainfall eroded the pyroclastic deposits upstream, triggering debris flows. Part of the debris flows overtopped the left bank, near Tanggul Curah Lengkong, and caused inundation (marked in yellow in Figure 3-27).



Source: Investigation Team Report Based on LiDAR Drone Survey Results

Figure 3-27 Overview of affected areas in S2

(3) Time Series of Sediment Movement Phenomena

The time series of sediment movement phenomena in the A-A' section shown in Figure 3-27 are organized in Figure 3-28. The S2 area is the section where pyroclastic flows from the 2021 and 2022 eruptions flowed down the river channel. In this section, a large amount of pyroclastic flow was deposited in the river channel after the eruption and the river channel was buried (Figure 3-28 2)). Subsequently, debris flows moved over the pyroclastic deposits, but the blocked river channels caused them to overflow on the left bank which has little elevation difference (Figure 3-28 3)). Over time, sediment within the river channels has been eroded and transported downstream (Figure 3-28 4)).

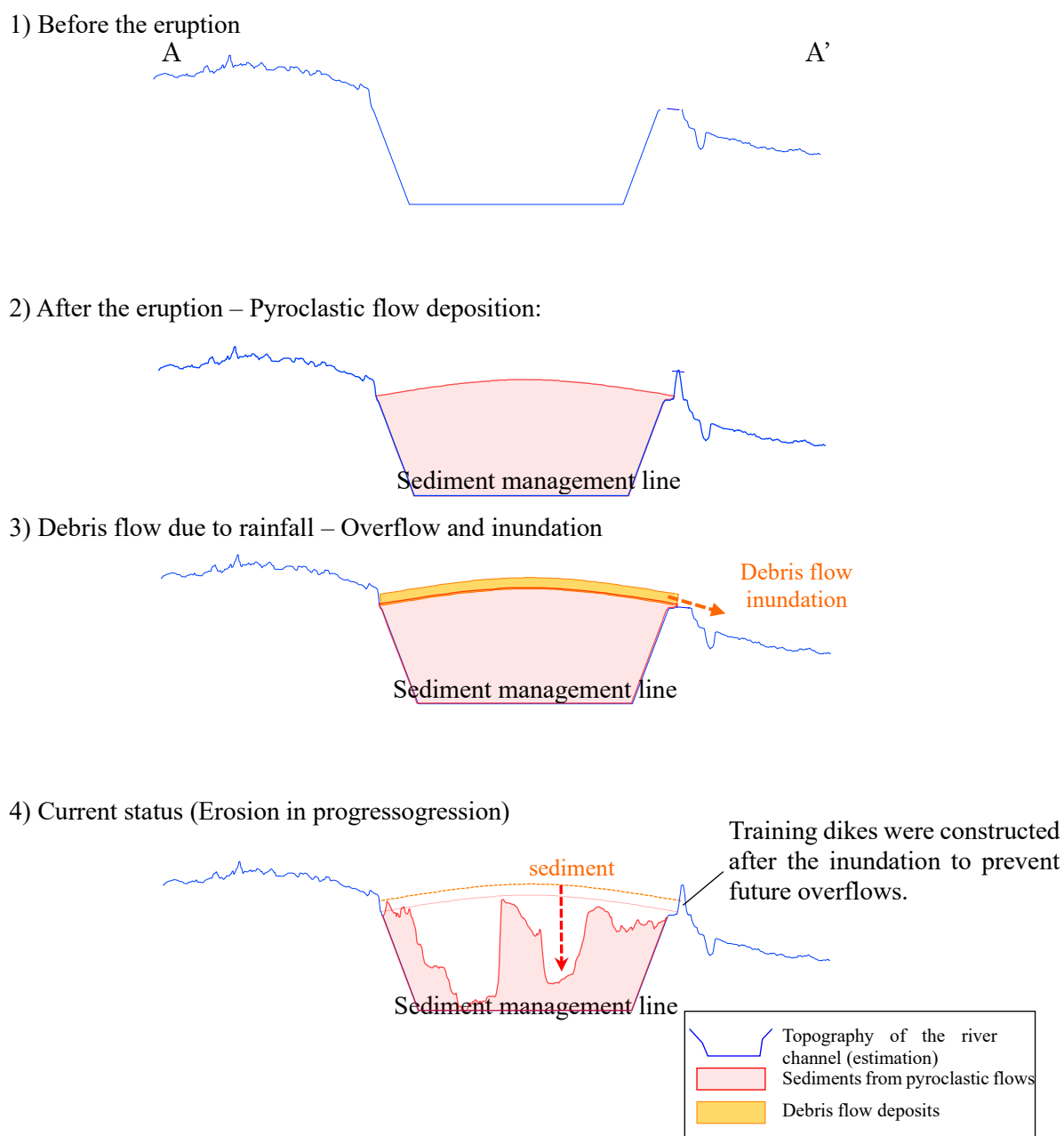


Figure 3-28 Sediment movement timeline along section A-A'

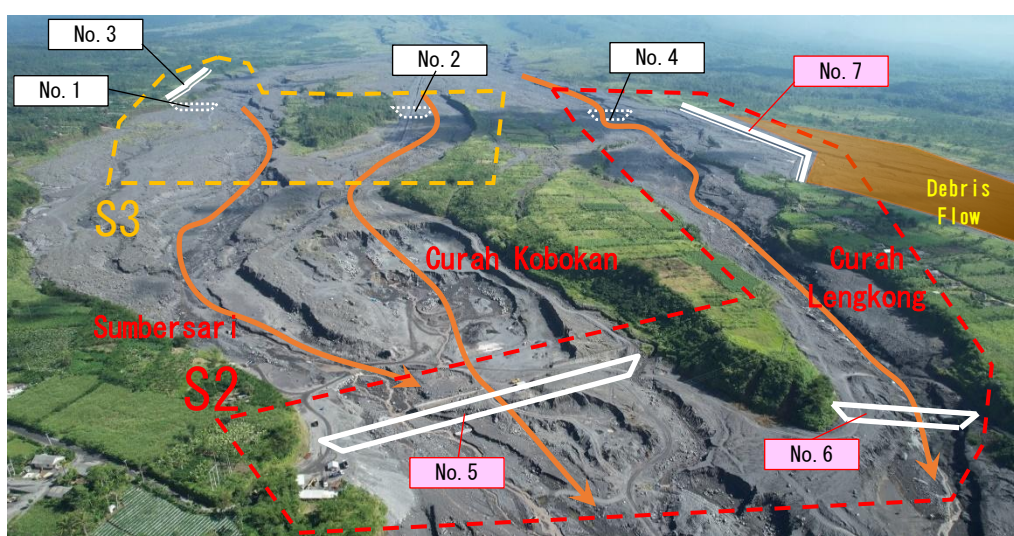
3.5.2 Identification of Target Facilities

An assessment was conducted to identify the target facilities within the S2 area. The existing sabo facilities in the S2 area are shown in Table 3-18. Three sabo dams (CD Curah Lengkong 1, CD Kobokan 5, CD Pelintas Curah Lengkong 2) and one training dike (Tanggul Curah Lengkong) exist in S2 area.

Since the upstream section of the S2 area is a section where the riverbed fluctuates rapidly, it is decided to monitor the sediment movement status of CD Curah Lengkong 1, while two other sabo dams (CD Kobokan 5, CD Pelintas Curah Lengkong 2) and one training dike (Tanggul Curah Lengkong) were selected as target facilities for this project.

Table 3-18 List of Existing Facilities in the S2 Area

Outline of Facility Layout					
Section	Package	No	Facility Type	Facility name	Evaluation
【Priority zone】 Debris flow origination and development zone	S2	4	Sabo dam	CD Curah Lengkong 1	Under observation
		5	Sabo dam	CD Kobokan 5	Target Facilities
		6	Sabo dam	CD Pelintas Curah Lengkong 2	Target Facilities
		7	Training dike	Tanggul Curah Lengkong	Target Facilities



* The number corresponds to the facility number in the figure in Table 3-18, and the pink number corresponds to the target facility.

Figure 3-29 Facility layout situations of S2 area

3.5.3 Facility Development and Sediment Management Policy for the S2 Area

In the S2 area, two different types of sediment movement phenomena (pyroclastic flows and debris flows) may occur as shown in Figure 3-27 and Figure 3-28, and a large amount of sediment may accumulate in the river channel. To address these issues, the following four basic policies for facilities development were established to mitigate the impact of both types of sediment movement.

【Basic Policies for Facility Development】

Basic Policy 1: At locations where debris flow overflow is particularly concerned (e.g., near Tanggul Curah Lengkong), the height of the training dike shall be raised to 3 m above the riverbed after pyroclastic flow deposition line. This is to ensure safety against debris flow inundation over the left bank.

As shown in Figure 3-27, the debris flow flooded on the left bank of Curah Lengkong River (near where the current Tanggul Curah Lengkong dike is located). As stated in Basic Policy 1 and 2, the sediment in the river channel will be excavated, but in case of insufficient excavation due to an inability to carry out emergency sediment excavation after pyroclastic flow deposition, the height of the training dike shall be 3 m higher than the riverbed after pyroclastic flow deposition, to secure the safety against debris flow inundation over the left bank (Figure 3-30).

The height of 3 m is determined by adding 1.7 m for debris flow depth and 1 m of freeboard (refer to Chapter 4 for debris flow depth details)

Basic Policy 2: An open-type sabo dam is constructed with existing dams (CD Kobokan 5, CD Pelintas Curah Lengkong 2) as sub-dams to develop the sediment capture effect at an early stage.

Two dams in the S2 area (CD Kobokan 5, CD Pelintas Curah Lengkong 2) are located near the valley exit where debris flows can be effectively captured. For these two sabo dams, a new open-type sabo dam shall be constructed upstream of the existing sabo dam. As a result, it is possible to develop a sediment capture effect in a short period of time. The existing dams shall be reconstructed and rehabilitated to be used as sub-dams.

【Sediment Management Policy】

Basic Policy 3: The river channel is excavated to the original riverbed level.

The S2 channel has a history of being buried with a large amount of sediment during the eruption (Figure 3-28 2) and 3)). Although erosion has progressed, a large amount of sediment is still deposited (Figure 3-28 4)). To maximize the river channel's capacity to retain pyroclastic flow deposits during future eruptions, sediment excavation shall be conducted down to the sediment management line, restoring the channel to its original bed elevation.

Basic Policy 4: Emergency sediment excavation is conducted immediately after pyroclastic flow deposition.

As shown in Figure 3-28 2), in past eruptions, pyroclastic flow deposits were later mobilized by rainfall as debris flows, resulting in channel overflow and flooding. In order to reduce the risk of inundation due to debris flows, emergency sediment excavation should be carried out promptly after pyroclastic flow deposition.

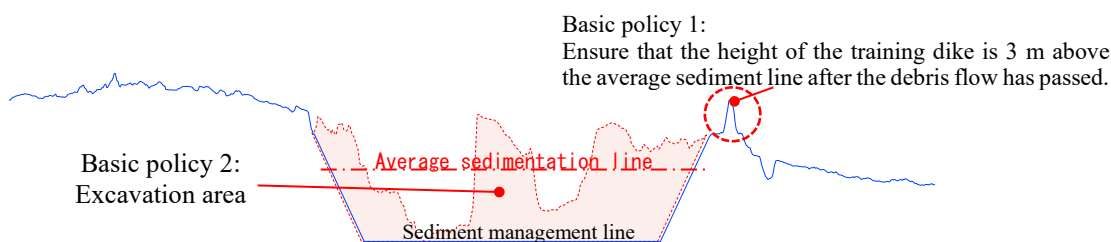


Figure 3-30 Basic policy supplementary diagram

3.6 Facility Plan for Midstream Section (S4 Area)

3.6.1 Disaster Mechanism

(1) Situation in the Midstream Section

During the 2021 eruption, pyroclastic flows reached the S4 area multiple times, depositing a massive amount of pyroclastic sediment. As of December 2021, pyroclastic flow deposits were accumulated at a height of more than 5 m above the height of the existing dike.



Figure 3-31 Condition of the midstream section (pyroclastic flow reached area)

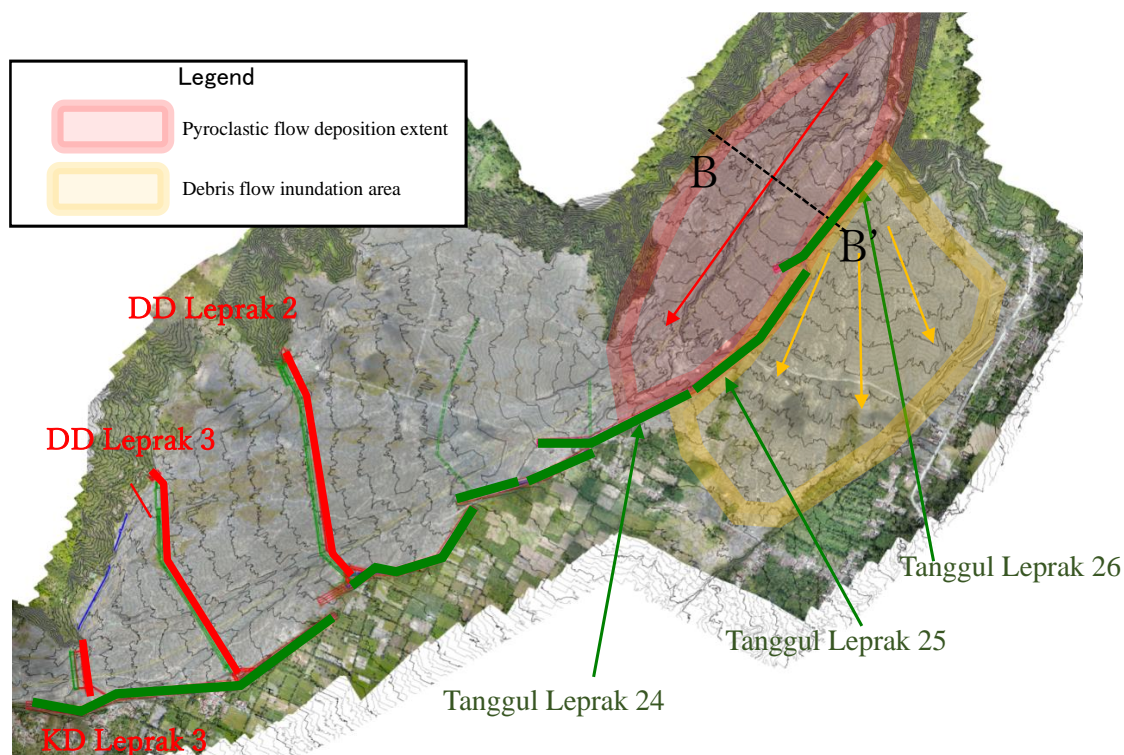
Immediately after the 2022 eruption, pyroclastic flows, mudflows, and debris flow deposits flow downstream, and sediment was deposited in the sand pocket. Sediment was mainly deposited in the center of the river channel, and the flow direction of the river channel moved left and right in the sand pocket. Consequently, localized bank erosion and irregular sediment accumulation occurred, changing positions within the sand pocket.



Figure 3-32 Condition of the midstream section (sand pocket section)

(2) Overview of the Affected Area

Pyroclastic flows, characterized by high-velocity powder-like flow, flowed down the valley and deposited across the entire area (red area in Figure 3-33). Subsequently, the pyroclastic flow in the upper part of the river was eroded by rainfall and flowed down as debris flows, and some of it overflowed and flooded in the left bank, near Tanggul Leprak 24, 25 and 26 (yellow area in Figure 3-33).



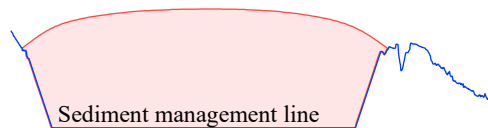
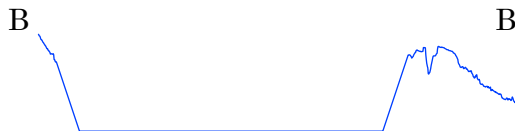
Source: Created by a survey team based on the results of the LiDAR Drone survey

Figure 3-33 Overview of the affected area in the S4 area

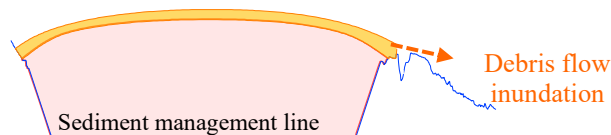
(3) Time Series of Sediment Movement Phenomena

The sediment movement phenomena along cross-section B-B', as shown in Figure 3-33, are summarized in Figure 3-34. The upstream section of the S4 area is the section where pyroclastic flows flowed down the river channel during the 2021 eruption. A large amount of unstable sediment from pyroclastic flows was deposited in the river channel in this section. It can be assumed that debris flow occurred due to rainfall under the circumstances where this sediment was accumulated, and the debris flow overtopped the raised river channel causing inundation.

1) Before the eruption



3) Debris flows and flooding due to rainfall



4) Current status (erosion in progress)

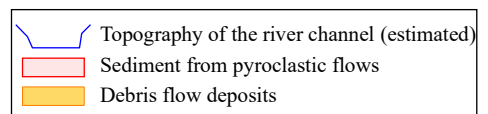
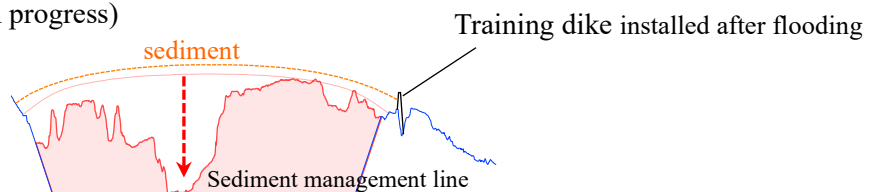


Figure 3-34 Time series of sediment movement phenomena in cross-section B-B'

3.6.2 Identification of Target Facilities

The selection of target facilities within the S4 area was conducted. The existing sabo facilities in the S4 area are summarized in Table 3-19. In the S4 area, there are five sabo dams (CD Leprak 2, DD Leprak 1, DD Leprak 2, DD Leprak 3, KD Leprak 3) and diversion dikes exist.

Since CD Leprak 2 and DD Leprak 1 are completely buried, it was decided to monitor them, while the other three sabo dams (DD Leprak 2, DD Leprak 3, KD Leprak 3) and training dikes were selected as target facilities for this project.

Table 3-19 S4 area list of existing facilities

Outline of Facility Layout					
Section	Package	No	Facility Type	Facility name	Evaluation
【Priority zone】 Debris flow inundation and deposition zone	S4	14	Sabo dam	CD Leprak 2	Under observation
		15	Sabo dam	DD Leprak 1	Under observation
		16	Sabo dam	DD Leprak 2	Target Facilities
		17	Sabo dam	DD Leprak 3	Target Facilities
		18	Sabo dam	KD Leprak 3	Target Facilities
		19	Training dike	Tanggul Leprak 26	Target Facilities
		20	Training dike	Tanggul Leprak 25	Target Facilities
		21	Training dike	Tanggul Leprak 24	Target Facilities
		22	Training dike	Tanggul Leprak 23	Target Facilities
		23	Training dike	Tanggul Leprak 22	Target Facilities
		24	Training dike	Tanggul Leprak II -D	Target Facilities
		25	Training dike	Tanggul Leprak XVII Kebondeli 2021	Target Facilities
26	Training dike	Emergency Dike	Target Facilities		



*YEC Jakarta Office

Figure 3-35 Facility layout of S4 area (flow diversion section)



Figure 3-36 Facility layout of S4 area (sand pocket section)

3.6.3 Facility Development and Sediment Management Policies for the S4 Area

Pyroclastic flows from the 2021 eruption reached the upstream section of the S4 area, where a large amount of pyroclastic flow was deposited in the river channel. Subsequent debris flows travel across the pyroclastic deposits, resulting in overflows and flooding on the low-elevation areas on the left bank.

The upstream section of S4 area is the fan crest of the vast Rejali alluvial fan. In preparation for the next eruption, debris flow shall be directed towards the western edge of the alluvial fan, thus it can prevent debris flow from flooding over the entire fan. Therefore, the training dikes in this section is the most important facility in the S4 area.

Meanwhile, the downstream section of S4 area has a flat topography and it is expected to capture a large amount of inflow sediment from upstream.

Since the concept of sediment capture differs from section to section even within the S4 area, the upstream section was designated as a “Flow Diversion Section” and the downstream section was designated as “Sand Pocket Section”. The position of each section is shown in Figure 3-37.

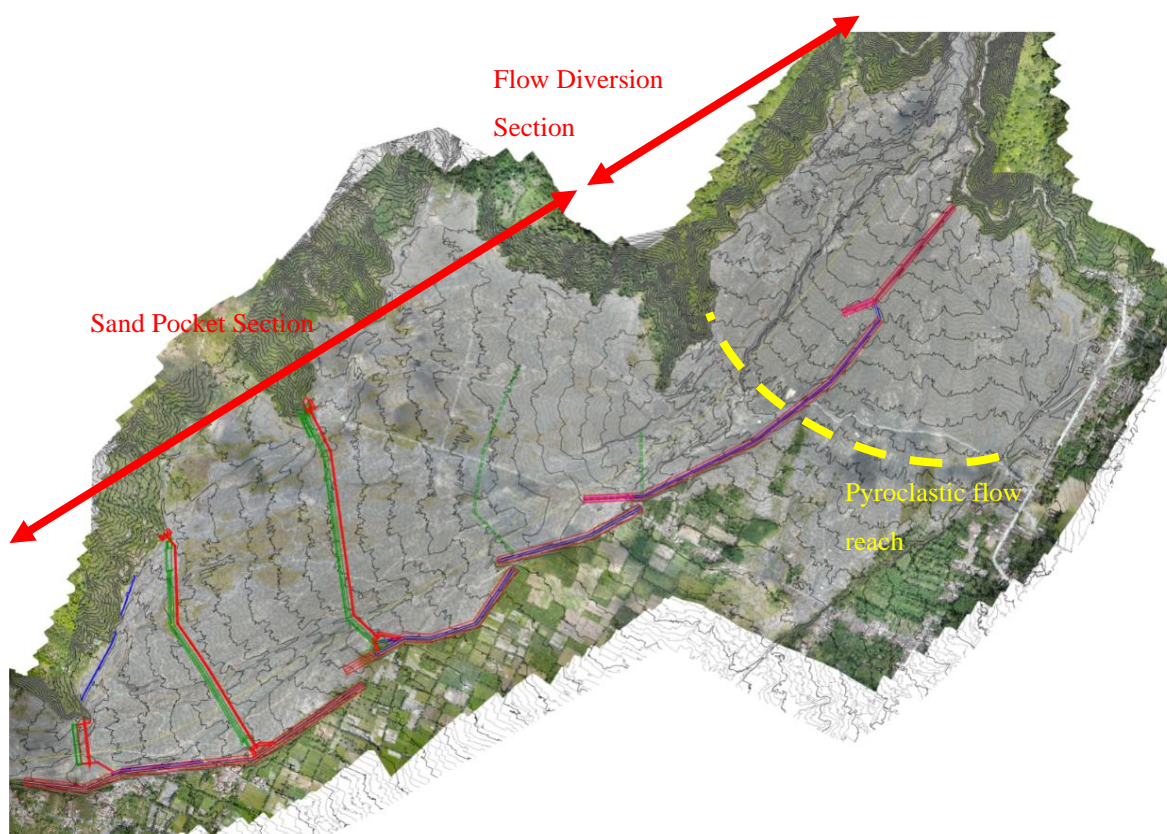


Figure 3-37 Location of sabo facilities in the S4 area

In the S4 area, two different types of sediment movement phenomena (pyroclastic flows and debris flows) occur as shown in Figure 3-33 and Figure 3-34, where a large amount of sediment may accumulate in the river channel. Therefore, the following four basic policies were established for facility development to mitigate these two sediment movement phenomena.

【Basic Policy for Facility Development】

Basic Policy 1: In areas where debris flow inundation is of particular concern (around Tanggul Leprak 24~26), the height of the training dike shall be raised to 3 m above the riverbed after pyroclastic flow deposition line. This is to ensure safety against debris flow inundation over the left bank.

As shown in Figure 3-33, the debris flow inundation occurred on the upper left bank of the S4 area near Tanggul Leprak 24~26. As stated in Basic Policy 1 and 2, the sediment in the river channel shall be excavated. In case of insufficient excavation due to an inability to carry out emergency sediment excavation after pyroclastic flow deposition, the height of the training dike shall be 3 m higher than the riverbed after pyroclastic flow deposition, to secure the safety against debris flow inundation over the left bank (Figure 3-38). The height of 3 m is determined by adding 1.7 m for debris flow depth and 1 m of freeboard. (See Chapter 4 for the details of the debris flow)

Basic Policy 2: The sediment capture effect is ensured by constructing new open-type sabo dams with three dams (KD Leprak 3, DD Leprak 3, DD Leprak 2) as sub-dam in the Sand Pocket Section.

The three dams in the Sand Pocket Section (KD Leprak 3, DD Leprak 3, DD Leprak 2) shall be newly constructed in the upstream of the existing sabo dams. This will enable establishment of sediment capture effect in a short period of time. The existing dams will be reconstructed and rehabilitated to be used as a sub-dam.

【Sediment Management Policy】

Basic Policy 3: The river channel is excavated down to the sediment management line of the existing facility.

The S4 channel has a history of being buried with a large amount of sediment during the eruption (Figure 3-34 2) and 3)). Although erosion has progressed, a large amount of sediment is still deposited ((Figure 3-34 4)). In the event of another eruption in the future, sediment excavation shall be carried out within the river channel (excavation down to the sediment management line) so that pyroclastic flow deposits can be stored in the river channel as much as possible.

Basic Policy 4: Emergency sediment excavation should be carried out promptly after pyroclastic flow deposition.

As shown in Figure 3-34 3), in past eruptions, debris flows flowed down after pyroclastic flow deposits and some of them flooded over the river channel. To reduce the risk of flooding due to debris flows, emergency sediment excavation should be carried out promptly after pyroclastic flow deposition.

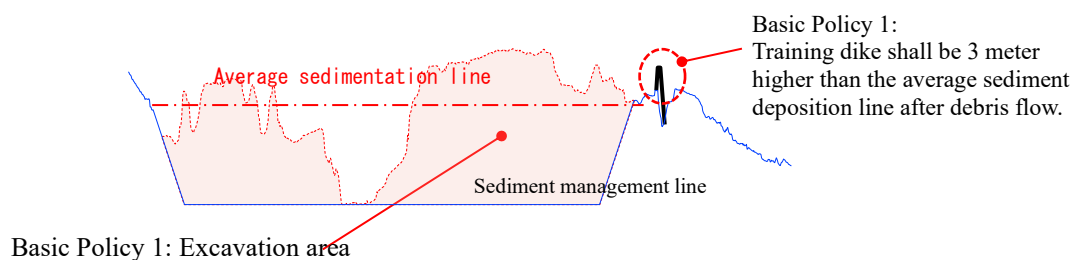


Figure 3-38 Basic policy supplementary diagram

3.7 Sediment Control Volume of Sabo Facilities After construction

The sediment control volume of sabo facilities at the upstream of the Rejali River design reference point is categorized into three stages: (1) immediately after construction (sediment control volume expected in the design), (2) current situation (sediment control volume considering the damage of facilities as of 2024), and (3) after the construction of the designed facility (sediment control volume with no sediment accumulation). The sediment control volume of sabo facilities of the Rejali River is presented in the table below.

Table 3-20 Sediment control volume of sabo facilities of the Rejali river

No	Facility name	Sediment control volume (m ³)			Reconstruction/ Rehabilitation / New	Remarks
		Immediately after facility construction	Current Situation	After the construction of designed facility		
1	CD Curah Lengkong 1	85,500	0	0	—	Shall not be rebuilt to remain the riverbed level low.
2	CD Pelintas Curah Lengkong 2	13,400	0	13,400	Reconstruction	
3	Check Dam Pelintas Summersari	9,600	9,600	0	—	Dam was buried and will not undergo rebuilding, so the sediment control volume is considered as 0m ³ .
4	CD Kobokan 7	634,800	634,800	634,800	Rehabilitation	
5	CD Kobokan 5	583,200	0	583,200	Reconstruction	
6	CD Kobokan 5A	78,000	0	0	-	Due to proximity to CD Kobokan 1, this facility will not be rebuilt.
7	CD Kobokan 1	218,000	0	384,400	Reconstruction	Shall be converted to an open-type dam
8	CD Kobokan 2	1,300	0	0	—	Due to proximity to CD Kobokan 1, this facility will not be rebuilt.
9	CD Kobokan 3	418,500	0	418,500	Reconstruction	
10	KD Leprak 1	33,400	0	0	—	Reconstruction is not planned to remain the riverbed level low.
11	KD Leprak 2	1,200	0	0	—	Shall not be rebuilt to remain the riverbed level low.
12	CD Leprak 2	49,000	49,000	73,500	Rehabilitation	Shall be converted to an open-type dam
13	DD Leprak 1	123,300	123,300	184,700	Rehabilitation	Shall be converted to an open-type dam
14	DD Leprak 2	168,000	0	252,000	Reconstruction	Shall be converted to an open-type dam
15	DD Leprak 3 (Sand Pocket)	167,200	0	251,200	Rehabilitation	Shall be converted to an open-type dam
16	KD Leprak 3	214,100	214,100	343,700	Rehabilitation	Shall be converted to an open-type dam
17	KD Pelintas Jugosari 1	0	0	0	—	Although it is listed as a sabo facility in PU's database, it is actually a non-sabo facility (bridge); thus, its effect is considered as 0m ³ .
18	DD Jugosari I	135,300	135,300	203,000	Rehabilitation	Shall be converted to an open-type dam
19	DD Jugosari 2	345,600	345,600	518,400	Rehabilitation	Shall be converted to an open-type dam
20	DD Jugosari 3 (Sand Pocket Jugosari)	124,300	124,300	186,500	Rehabilitation	Shall be converted to an open-type dam
21	KD Gondoroso	72,000	72,000	108,000	Rehabilitation	Shall be converted to an open-type dam
22	KD Pelintas Gondoroso	0	0	0	—	Although it is listed as a sabo facility in PU's database, it is actually a non-sabo facility (bridge); thus, its effect is considered 0.
Total		3,475,700	1,708,000	Reconstruction 1,651,500 Rehabilitation 2,503,800 Total 4,155,300		

* sabo facilities downstream from the planned facilities (7 facilities) are omitted here because the facility effect amount is 0.

3.8 Basic Design of the S2 Area

3.8.1 Current Status

The current status of CD Pelintas Curah Lengkong 2, CD Kobokan 5, and Tanggul Curah Lengkong is summarized below. The basic shape of the existing facility was based on existing drawings and any missing information was supplemented by on-site surveys.

CD Pelintas Curah Lengkong 2

The current state of CD Pelintas Curah Lengkong 2 is shown in Figure 3-39.

【Facility Functions】

- It is an open-type sabo dam (conduit type).
- It also served as a river-crossing structure, utilizing the crest of the dam body.

【Damage Status】

- While it is anchored to the exposed rock bed, the main body of the sabo dam is severely damaged due to significant erosion. The river-crossing function has been lost.
- The concrete material of the dam body remains intact and in good condition.

【Damage Causes】

- The damage is presumed due to abrasion caused by frequent debris flows containing large boulders.

【Structural Issues for Reconstruction】

- Abrasion countermeasures are required.
- Treatment of the contacting surfaces between the foundation bedrock and concrete is necessary.
- River-crossing function shall be incorporated into the sabo dam.
- The height of the dam shall be determined by taking into account the elevation difference between the upstream dike and the design sedimentation line.
- The conduit structure should be designed to withstand abrasion and impact loads.



*YEC Jakarta Office

Figure 3-39 Current status of CD Pelintas Curah Lengkong 2

CD Kobokan 5

The current state of CD Kobokan5 is shown in Figure 3-40.

【Facility Functions】

- Originally constructed as an open-type sabo dam, it is believed to have been converted into an closed-type dam during reconstruction. However, as built drawing of the reconstruction is unavailable.
- It is presumed that the dam had river-crossing function before the reconstruction.

【Damage Status】

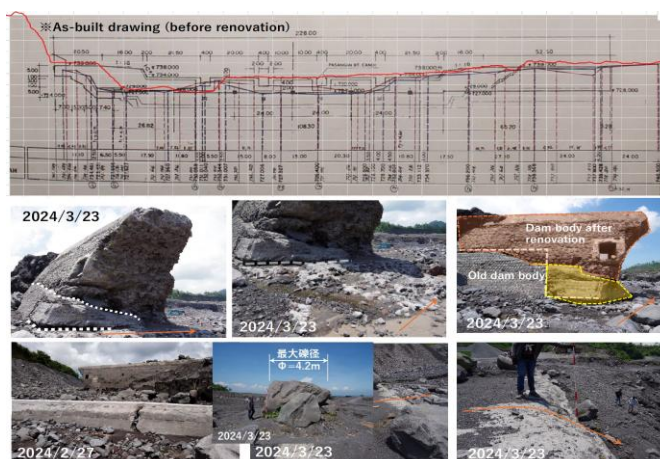
- The material of the original sabo dam is concrete, while masonry was used to heighten the structure for reconstruction. This leads to reduced adhesion strength at the material boundary and it is estimated to have caused damage due to debris flow impacts.
- Frequent debris flows have worsened the damage, and the main dam body has been washed away.
- The foundation of the original sabo dam body remains.
- The dam crest is made of a high-strength material, but it is damaged due to significant abrasion.
- Cracks have occurred due to the deformation on the sub-dams foundation. Significant abrasion is confirmed.

【Damage Causes】

- The damage is due to impacts and abrasion caused by frequent debris flows containing large boulders.
- Reduced strength due to poor adhesion between new and old materials is observed.

【Structural Issues for Reconstruction】

- Masonry is used for the reconstructed sections, which lacks of sufficient strength against debris flow loads.
- Protection works on the downstream riverbed is required to address channel degradation.
- Measures against impact and wear are necessary.
- Since debris flows might have overflowed over the right bank, either prevention structures for wing-overflow or overflow protection work must be implemented.

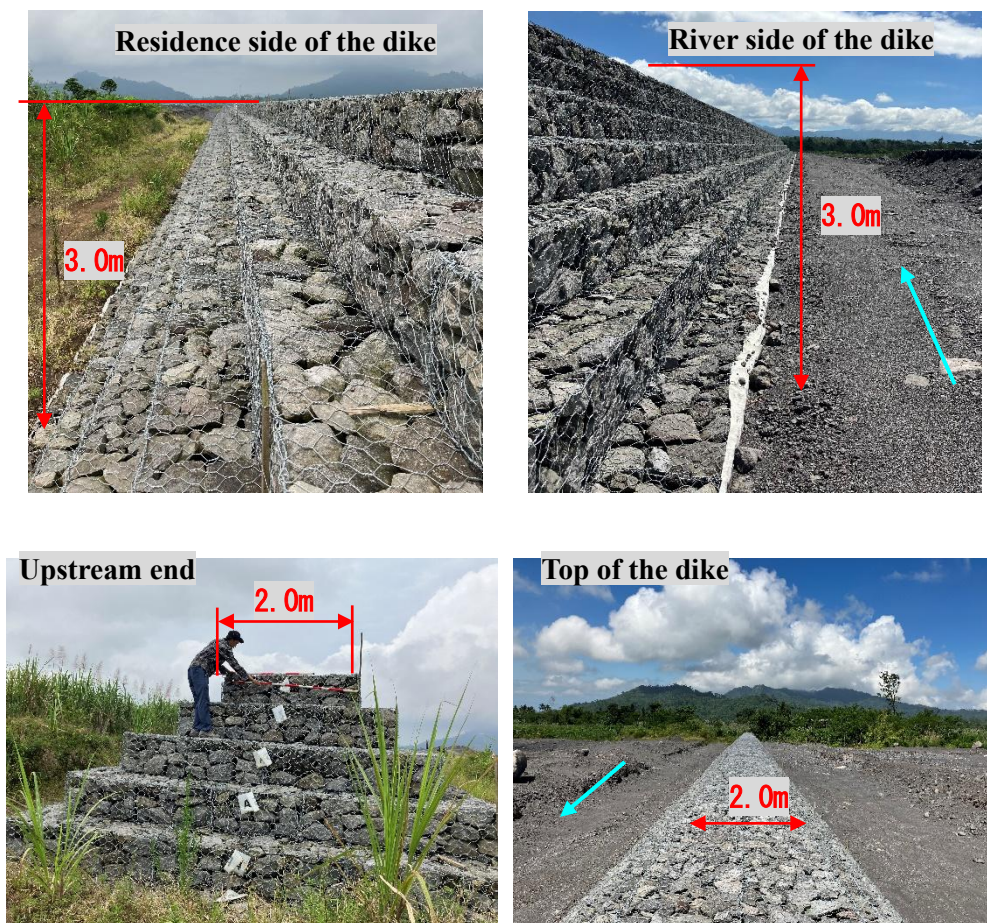


*YEC Jakarta Office

Figure 3-40 Current status of CD Kobokan 5

Tanggul Curah Lengkong

The current situation of Tanggul Curah Lengkong is shown in Figure 3-41. The training dike has been constructed in the section where the debris flow flooded. The dike was urgently constructed using gabion for the purpose of preventing another disaster.



*YEC Jakarta Office

Figure 3-41 Current status of Tanggul Curah Lengkong (May 2024)

The basic shape of the existing facility was estimated from past drawings and on-site surveys. The basic shape of Tanggul Curah Lengkong is shown in Figure 3-42.

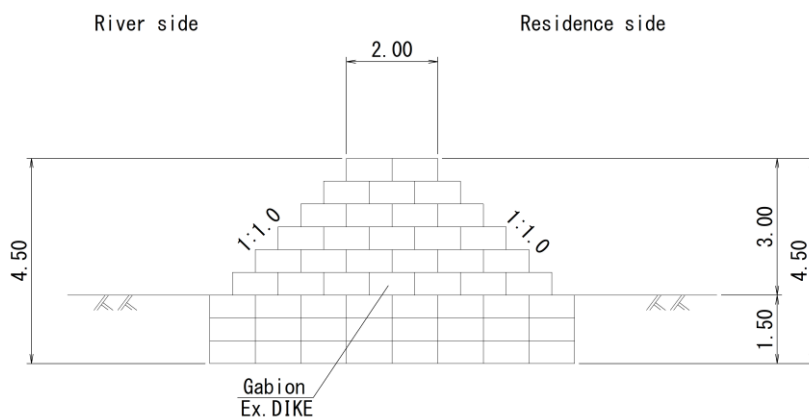


Figure 3-42 Existing structure of Tanggul Curah Lengkong

3.8.2 Basic Design of Sabo Dams

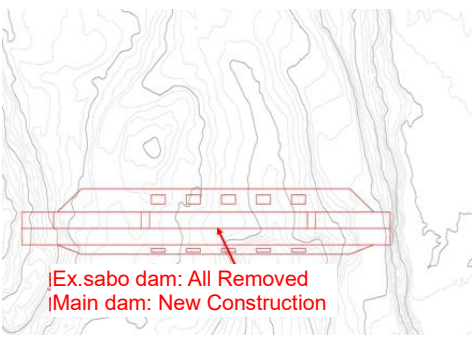
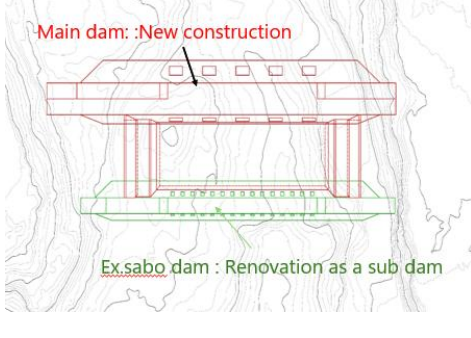
(1) Layout Policy

The layout policy of CD Pelintas Curah Lengkong 2 and CD Kobokan 5 was examined.

CD Pelintas Curah Lengkong 2

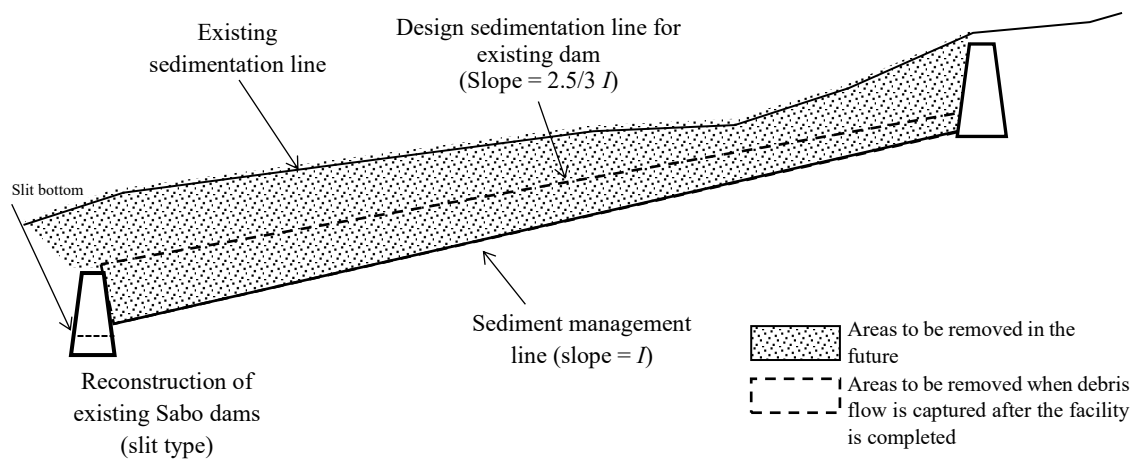
A comparative study was conducted on the layout policy of CD Pelintas Curah Lengkong 2. The layout comparison table is shown in Table 3-21. As a result, it was decided to adopt Option 2 where the existing sabo dam is used as a sub-dam and a new main dam is placed upstream. Option 2 is determined to be more economical as removal of existing structure is not required and excavation volume of sediment is less.

Table 3-21 CD Pelintas Curah Lengkong2 layout comparison study

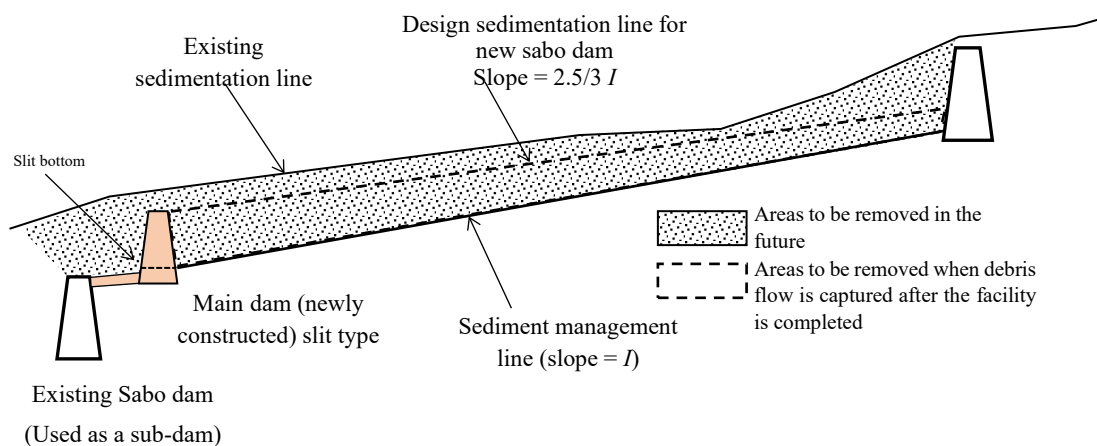
	Option 1 Renew the existing facility	Option 2 Build a new dam upstream of the existing facility
Overview Diagram		
Outline of the plan	Construct a new sabo dam at the same position as the existing sabo dam	Utilize the existing sabo dam as a sub-dam and construct the new main dam upstream of the existing sabo dam
Facility effect	Compared to Option 2, there is almost no difference ✓	There is almost no difference compared to Option 1 ✓
Economy	<ul style="list-style-type: none"> Removal of existing dams: all Installation of a new dam: same as Option 2 Excavation Volume: larger compared to Option 2 ¹⁾ 	<ul style="list-style-type: none"> Removal of existing dams: partial Installation of a new main dam: same as Option 1 Reuse existing facilities Excavation volume: less compared to Option 1. <p style="text-align: center;">✓</p>
Ancillary roads	Since the longitudinal slope of the ancillary road is 10% or more, there are risk about the safety of construction vehicles.	Since the longitudinal slope of the ancillary road is 10% or less, construction vehicles can pass safely. ✓
Evaluation	Rejected	<p style="text-align: center;">✓</p> <p style="text-align: center;">Adopted</p>

Note 1: Comparison of excavation volumes when converting the existing dam into a slit-type structure versus constructing a new slit-type dam.

The upper diagram in Figure 3-43 shows the excavation volume when the existing dam is converted into a slit-type structure, while the lower diagram illustrates the excavation volume when a new slit-type dam is constructed. The hatched areas in the longitudinal river profiles represent the excavation volumes for each case. It is evident that the excavation volume for the latter (new construction) is smaller than that for the former (conversion of the existing dam).



(Excavation volume for converting the existing sabo dam into a slit-type structure)



(Excavation volume when a new slit-type dam is constructed)

Figure 3-43 Comparison of excavation volumes between converting the existing dam into a slit-type structure and constructing a new slit-type dam

CD Kobokan 5

A comparative study was conducted on the Layout Policy of CD Kobokan 5. The layout comparison table is shown in Table 3-22. As a result of a comparison study, it was decided to adopt the Option 2 where the existing sabo dam is used as a sub-dam and a new main dam is placed upstream. Option 2 is determined to be more economical and selected as removal of existing dam is not required and excavation volume of the sediment is less.

Table 3-22 CD Kobokan5 Layout Comparison Study

	Option 1 Renew the existing facilities	Option 2 Build a new dam upstream of the existing facility
Overview diagram		
Outline of the plan	Construct a sabo dam at the same position as the existing sabo dam	Utilize the existing sabo dam as a sub dam and construct the new main dam upstream of the existing sabo dam
Facility effect	Compared to Option 2, there is almost no difference ✓	There is almost no difference compared to Option 1 ✓
Economy	<ul style="list-style-type: none"> • Removal of existing dams: all • Installation of a new dam: same as Option 2 • Excavation Volume: larger compared to Option 2²⁾ 	<ul style="list-style-type: none"> • Removal of existing dams: partial • Installation of a new main dam: same as Option 1 • Reuse existing facilities • Excavation Volume: less compared to Option 1²⁾ ✓
Ancillary roads	Since the longitudinal slope of the ancillary road is 10% or more, there is risks about the safety of construction vehicles.	Since the longitudinal slope of the ancillary road is 10% or less, construction vehicles can pass safely. ✓
Evaluation	Rejected	✓ Adopted

Note 2: The comparison of the amount of sediment excavation is the same as that of CD Pelintas Curah Lengkong 2 described above.

(2) Dam Material

The dam body material for CD Pelintas Curah Lengkong 2 and CD Kobokan 5 were evaluated. Options include concrete, masonry, and soil cement. Considering the high frequency of debris flows in this area, concrete was selected since it has higher strength.

(3) Dam Type

The dam types of CD Pelintas Curah Lengkong 2 and CD Kobokan 5 were examined (Figure 3-44). In the Review Master Plan (2024), the existing facilities are planned to be converted from closed-type to open-type to improve the sediment control effect. For this reason, in this study, an open-type sabo dam will be adopted for the newly constructed sabo dam.

Since the dam is planned to have a road function, it was decided to adopt a conduit type dam. The details regarding the incorporation of the road function will be discussed in the next section.

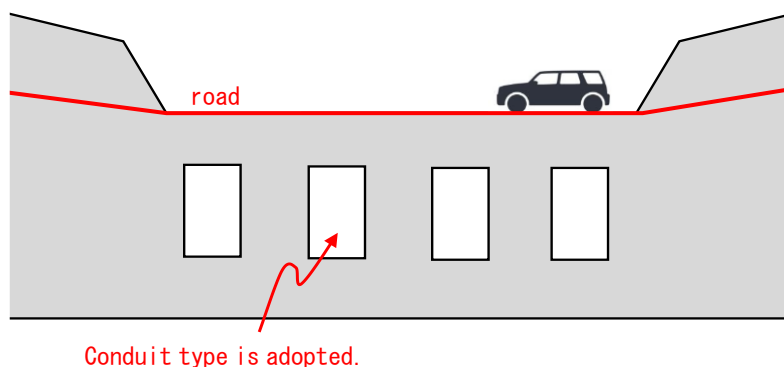


Figure 3-44 Front view of a conduit type sabo dam

(4) Dam Height

1) Dam height of CD Pelintas Curah Lengkong 2

The size of the dam of CD Pelintas Curah Lengkong 2 was examined. On the upstream left bank of the dam, there is a section where sediment has flooded. Currently, a dike (gabion) has been constructed as an emergency measure. The size of the CD Pelintas Curah Lengkong 2 is determined to ensure the elevation difference between the design sedimentation line and the training dike. It is also designed so that even in the event of pyroclastic flows of a similar scale to those of the 2021 and 2022 eruptions, debris flows will not overtop the training dike (Figure 3-45 and Figure 3-47).

The height of the new sabo dam was set so that the elevation difference between the planned sedimentation level and the top of the dike is greater than depth of the debris flow (1.7 m) + the freeboard (1 m).

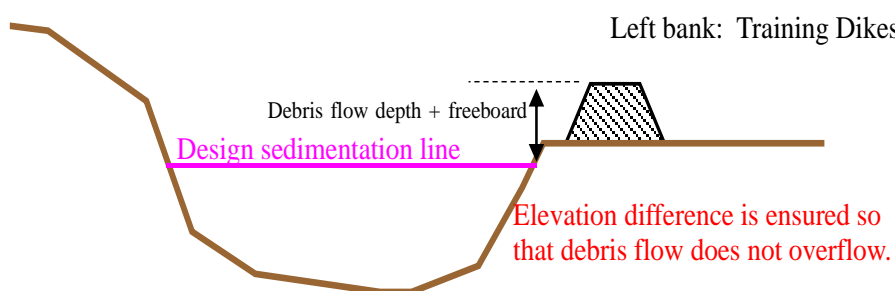


Figure 3-45 Consideration for determining dam height

2) Dam height of CD Kobokan 5

The size of the dam of CD Kobokan 5 was examined. Residential areas exist on the upstream right bank of the dam. The size of the CD Kobokan 5 is planned by ensuring the elevation difference between the design sedimentation line and the right bank. This ensures that even in the event of pyroclastic flows on the same scale as the 2021 and 2022 eruptions, debris flows will not overflow (Figure 3-46 and Figure 3-48).

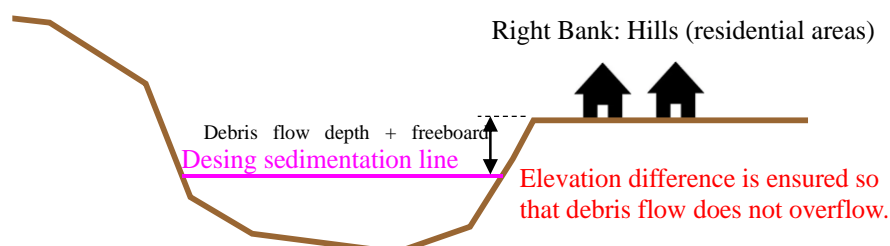


Figure 3-46 Consideration for Determining Dam height

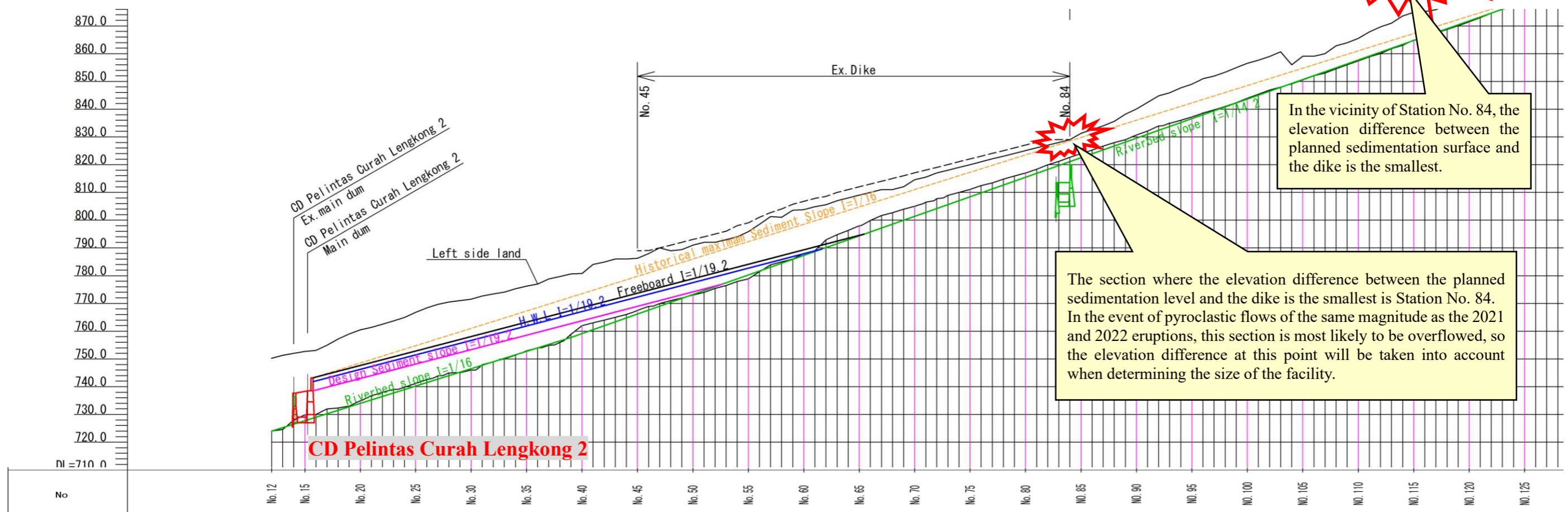
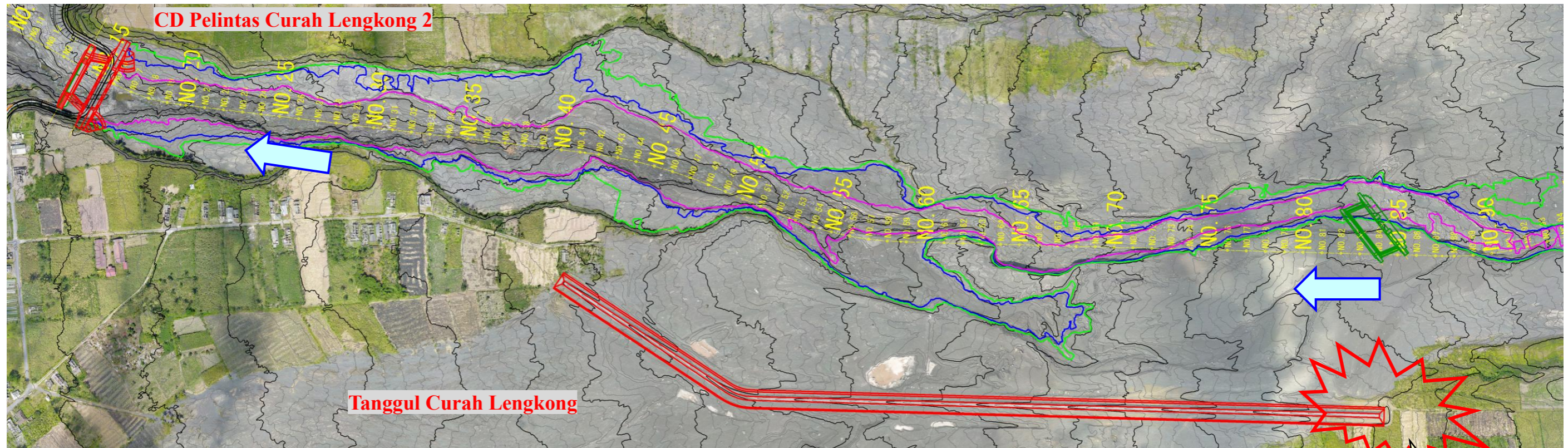


Figure 3-47 Key Considerations for Determining the Dam Size of CD Pelintas Curah Lengkong 2

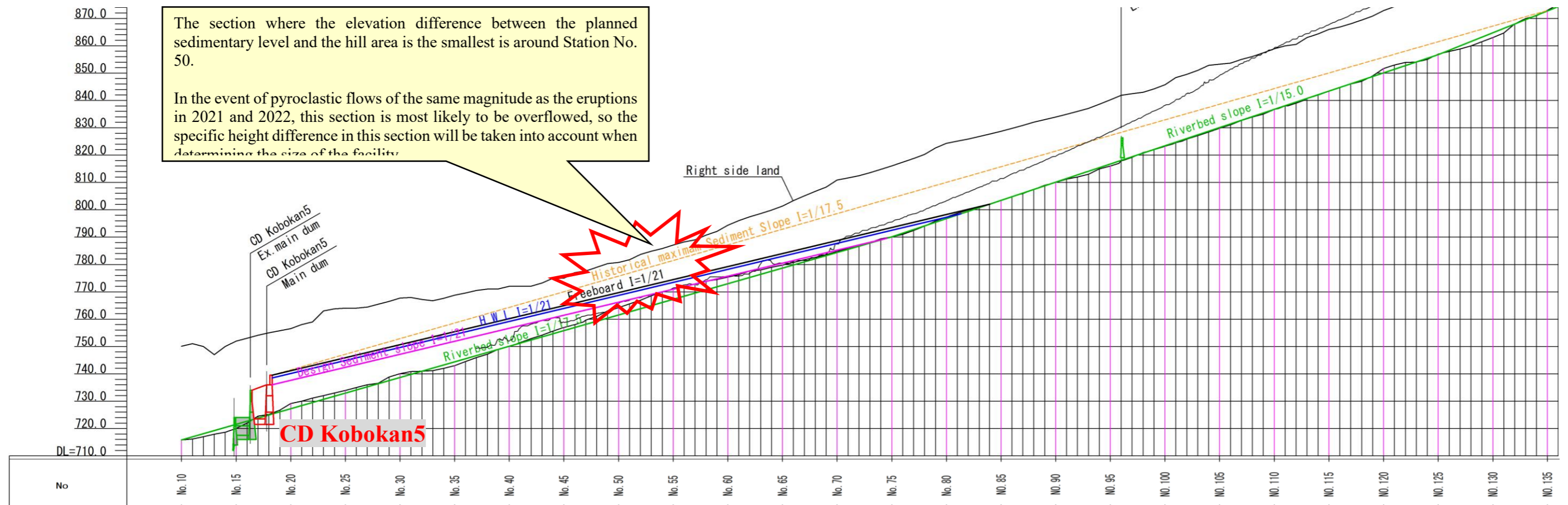
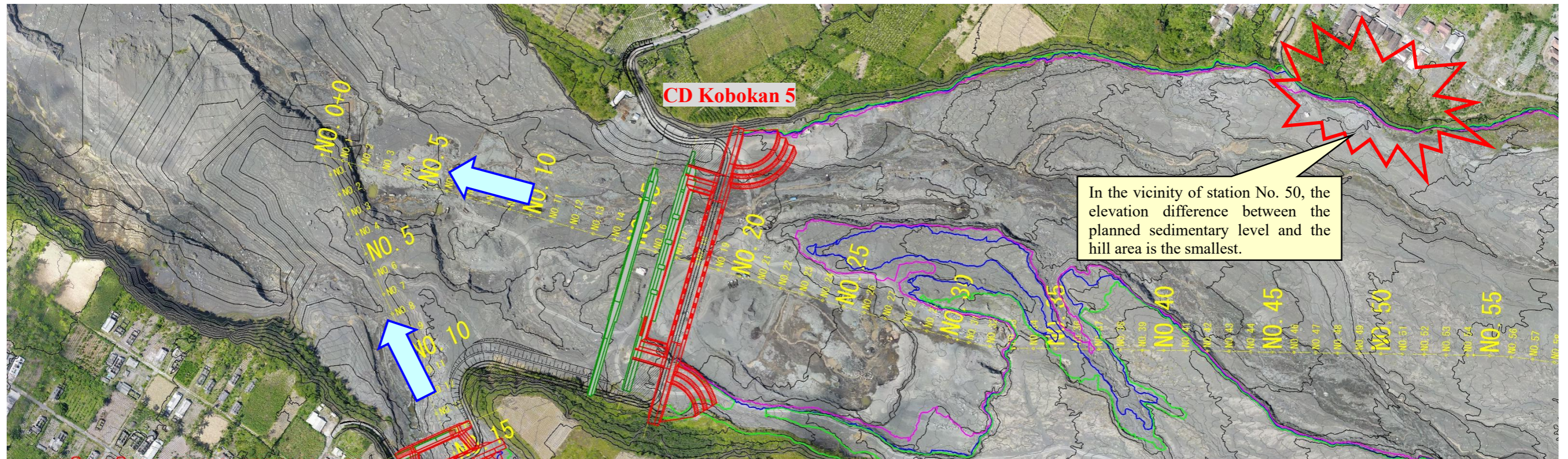


Figure 3-48 Key considerations for determining the dam size of CD Kobokan 5

(5) Countermeasures Against Boulder Impact

Large boulders are scattered within the river channel, and debris flows may transport these boulders downstream. If such boulders collide with the dam wings, they could potentially cause damage. To mitigate this risk, revetment shall be installed on the upstream side of the sabo dam to serve as protective barriers. These revetments will act as a buffer, preventing direct impacts on the wing walls, reducing the structural damage. The proposed countermeasure strategy is illustrated in Figure 3-49.

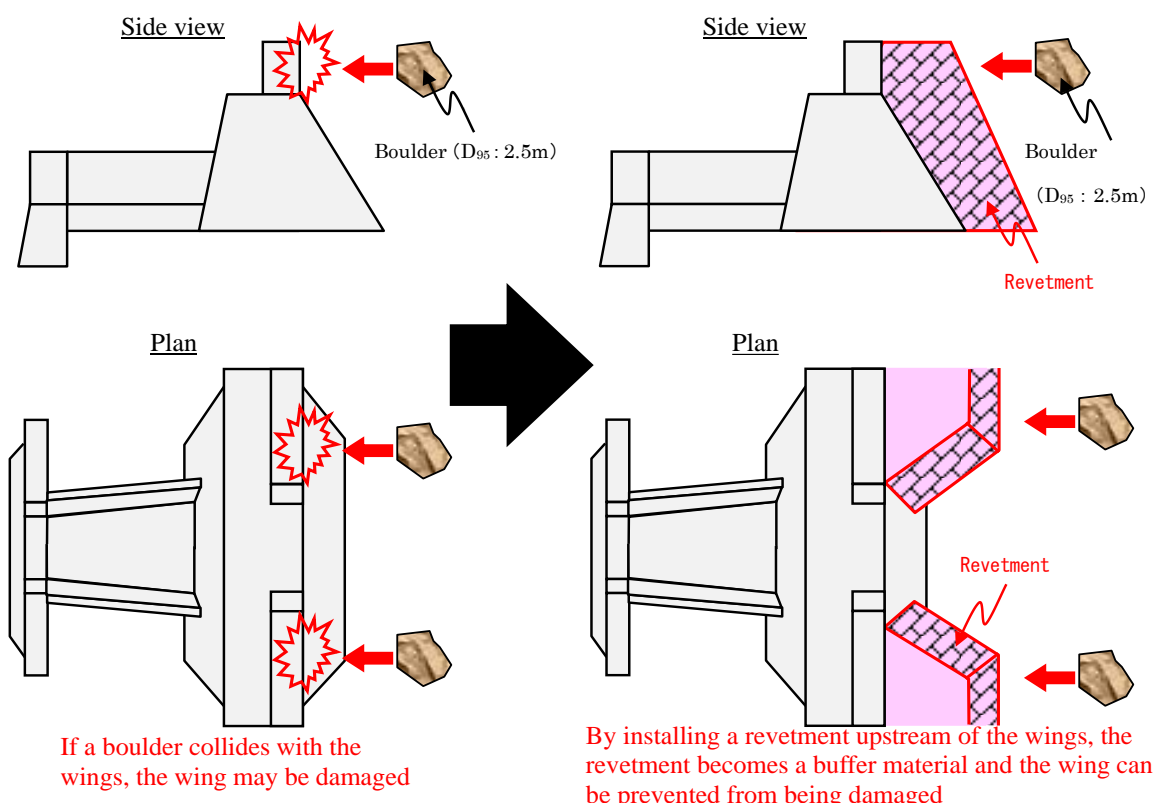


Figure 3-49 Countermeasures against boulder impacts

(6) Abrasion Countermeasures

To address abrasion, high-strength concrete with 50 cm thickness will be used, particularly for spillway crests and similar areas.

Since abrasion research specific to Indonesia is limited, this study refers to the findings from Japan's Sakurajima region, specifically in the Mochikizawa debris flow-prone area¹.

In Mochikizawa on Sakurajima, 107 debris flow occurrences were recorded over the past 25 years (4.28 occurrences per year) with the abrasion rate of a regular concrete ranging from a minimum of 10 mm to a maximum of 59 mm (average 29.25 mm). Assuming that the strength of high-strength concrete is 2.5 times that of regular concrete, the abrasion rate of high-strength concrete can be roughly considered as 1/2.5 of that of regular concrete². Assuming the frequency of debris flow is similar to that in Mochikizawa (4.28 times per year), the amount of wear on high-strength concrete to reach 50 cm would take approximately 21 years (minimum) to 43 years (average), based on the

¹ Mochikigawa No. 1 Sabo Dam Lava Steel 11th On-Site Investigation Report, Heisei 24 (2012)

² Measures Against Scouring and Abrasion of Dams in Debris Flow Areas, Proceedings of the 1997 Sabo Society Research Presentation

calculations in Table 3-23. This value may vary depending on the frequency of debris flow occurrences, but it is generally expected that resurfacing would be necessary after the indicated years. The high-strength concrete in Sakurajima has a design strength of 27 N/mm², with a maximum coarse aggregate size of 40 mm, a slump of 5 cm, air content of 4.5%, a maximum water-cement ratio of 55%, and a minimum cement content of 300 kg/m³.

Table 3-23 Estimation of concrete abrasion in Sakurajima, Mochikizawa

	Normal Concrete			High-Grade Concrete		
	Abrasion Rate (Minimum)	Abrasion Rate (Average)	Abrasion Rate (Maximum)	Abrasion Rate (Minimum)	Abrasion Rate (Average)	Abrasion Rate (Maximum)
Abrasion rate per year (mm/year)	10	29.25	59	4 (10/2.5)	11.7 (29.25/2.5)	23.6 (59/2.5)
Number of debris flows (times/year) (Actual value: 107 times/25 years = 4.28 times/year)	4.28 (107/25)					
Number of years until 50 cm (= 500 mm) abrasion, assuming that a debris flow occurs at the same frequency as above (4.28 times/year)	50.0 (500/10)	17.1 (500/29.25)	8.5 (500/59)	125.0 (500/4)	42.7 (500/11.7)	21.2 (500/23.6)

(7) Road Planning

Prior to the 2021 eruption, a road was built to cross the Curah Lengkong and Summersari rivers as a supplementary function to the existing sabo dam. Currently, the existing sabo dam has been damaged by the debris flow, and a simple road has been built in the river channel. For this reason, there is a possibility that the road will be severed during the next flooding. As a supplementary function of the proposed dam, the dam-crest is wide enough to allow vehicles to pass.

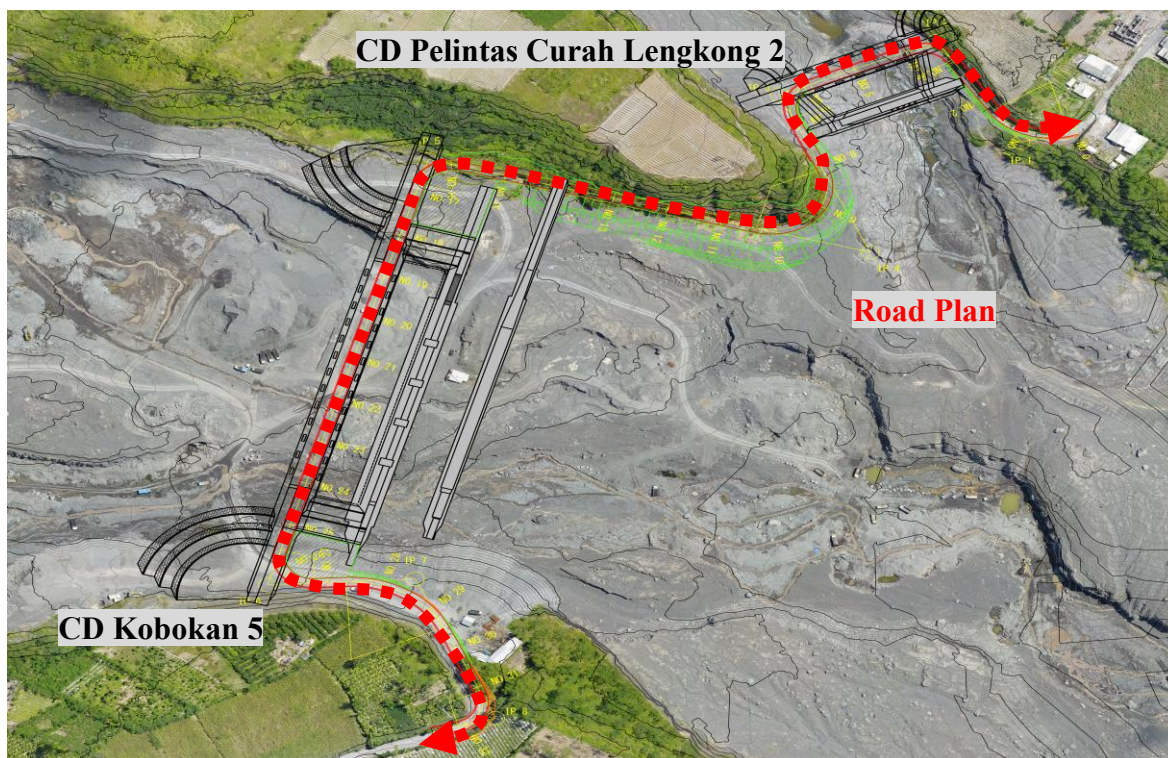


Figure 3-50 Design of road alignment

3.8.3 Basic design of the Dike

(1) Current Issues

The current issues of Tanggul Curah Lengkong are as follows.

- Issue 1: The existing dike is constructed with gabion, which raises risks about its durability.
- Issue 2: The current dike has a crest width of 2 meters, but according to Indonesia's design technical guidelines "Pd T-16-2004-A_Pencanaan Teknis Tanggul pada Sungai Lahar, P3", a crest width of 4 meters is required.
- Issue 3: In the event of another debris flow, the dike needs to be high enough to prevent the debris flow from overflowing.

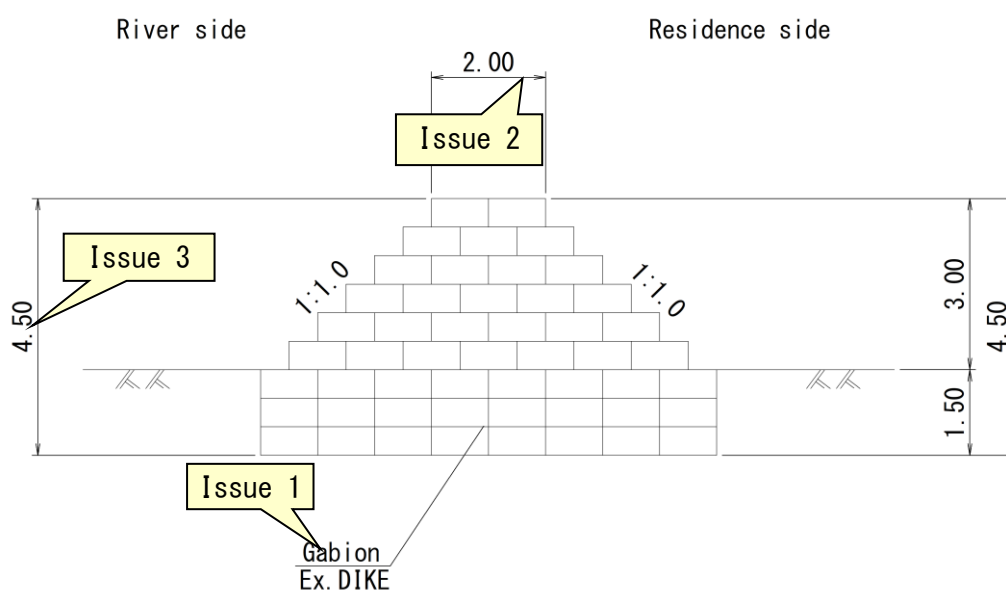


Figure 3-51 Current issues of Tanggul Curah Lengkong

(2) Reconstruction Policy

1) Dike Material

The plan is to continue to use the gabion, which are the materials for the existing dike. To secure a 4-meter-wide crest for the training dike, the material will be changed to masonry concrete (cyclop). The surface of the dike will be covered with concrete to improve its durability.

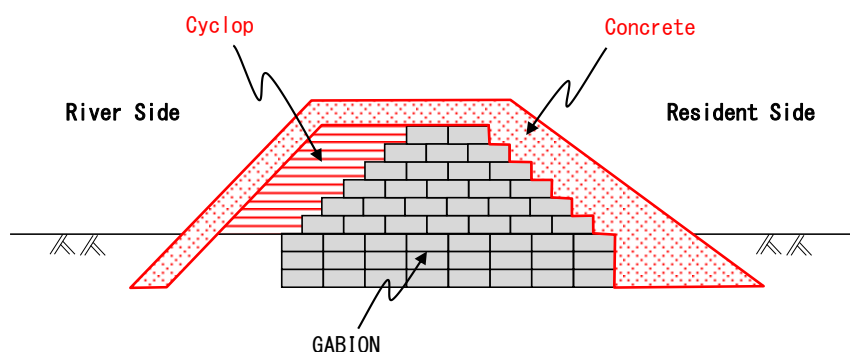


Figure 3-52 Material of Tanggul Curah Lengkong

2) Dike Height

The height of the training dike will be designed to accommodate the flow depth and the hydraulic jump height of debris flows, with an additional allowance for safety.

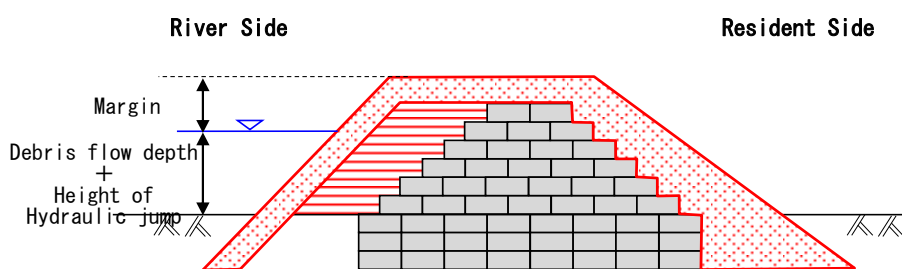


Figure 3-53 Training dike height of Tanggul Curah Lengkong

3) Measures Against Debris Flows

Mitigation measures were considered to prevent the debris flow from overtopping. If the slope on the inner side (resident side) of the training dike is too gentle, there is a possibility that the debris flow could run up the dike and overflow. Therefore, the slope on the inner side (resident side) of the dike will be designed to be steep, with the top section set to be vertical (Figure 3-54).

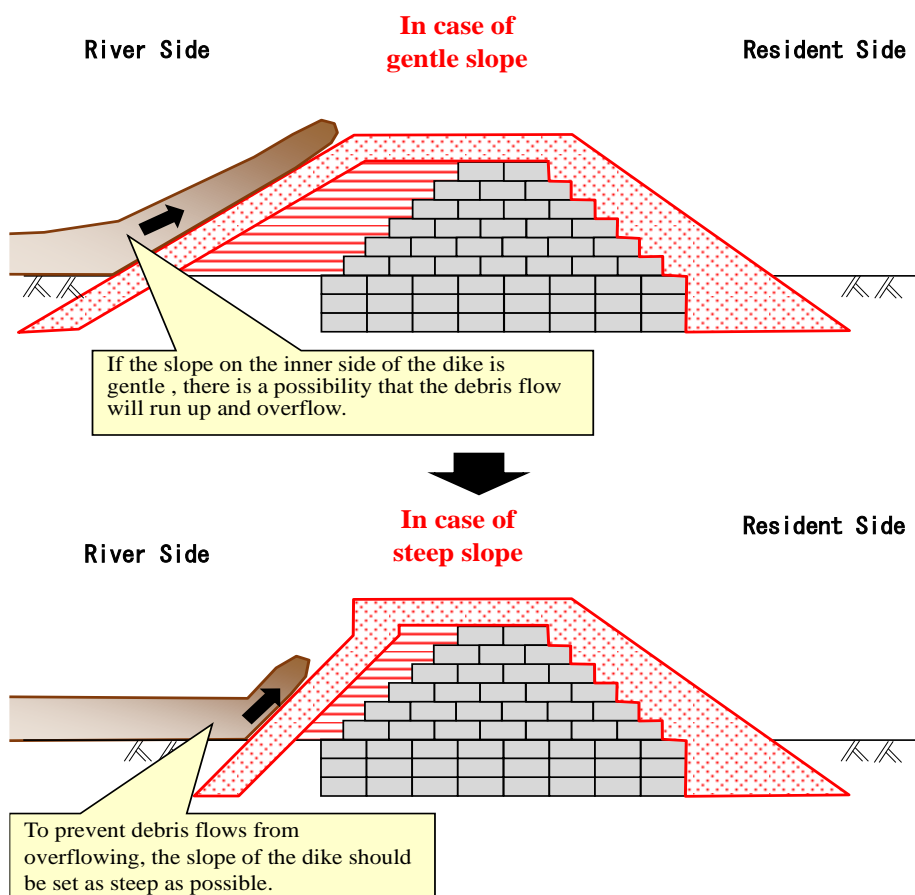


Figure 3-54 Slope of Tanggul Curah Lengkong

3.9 Basic Design of the S4 Area

3.9.1 Current Status

The current status of KD Leprak 3, DD Leprak 2, DD Leprak 3, and the training dikes is summarized below. The sabo dams (KD Leprak 3, DD Leprak 2, and DD Leprak 3) are buried under sediment and their condition cannot be confirmed. The shape of the existing structures was referenced from previous drawings, while missing information was supplemented with a site survey.

KD Leprak 3

The current state of KD Leprak 3 is shown in Figure 3-55.

【Facility Functions】 ※As built drawings of the renovation works are the only means of verification.

- Groundsills (closed-type)

【Damage Situation】

- Sediment has accumulated above the groundsill by approximately 1m, where the dam body is buried and cannot be seen.
- Abutments on the left and right banks are only partial damaged.

【Damage Cause】

- The dam body is buried and cannot be seen.
- If a local scouring occurs on the upstream side of the main dam (old dam body), there is a high possibility that major damage will occur in the current structure.
- The absence of a downstream riverbed protection work on the old dam body increases the risk of collapse due to erosion caused by the impact of falling water.
- The old dam body, which is made of soil embankment and gabions, is easily adaptable to changes in topography. However, it is less effective to maintain its functionality for sediment retaining.

【Structural Issues For Reconstruction】

- The structure of the old dam body needs to be strengthened.
- It is necessary to take into account the overflow over the sleeves and strengthen the downstream riverbed protection.
- It is necessary to take measures against abrasion over the crest of the dam body (overflow section).
- It is necessary to situate the dam so that it does not interfere with the bridge during construction.



Figure 3-55 Damage to the left bank of KD Leprak 3 (May 2024)

DD Leprak 2, DD Leprak 3

The current state of KD Leprak 2 is shown in Figure 3-56.

【Facility Functions】

- It is a closed-type sabo dam.

【Damage Situation】

- Sediment has accumulated above the dam body by about 1m, where the dam body is buried and cannot be seen.
- Due to the presence of a boulder on the top of the left wing, it is presumed that past debris flows have overflowed the left wing. The left abutment was partially eroded and the internal masonry is exposed. In addition, damage has progressed due to recent debris flows.

【Damage Causes】

- The main body of the sabo dam is severely damaged due to scouring on the riverbed foundation and the impact from frequent debris flows containing boulders.

【Structural Issues for Reconstruction】

- It is necessary to use high-strength concrete or other strong materials for the wings and abutments which are exposed to direct debris flow impact.
- Strengthening the downstream riverbed protection work presuming overtopping of the wings is required.
- Erosion protection measures for the dam crest (overflow section) are necessary.



Figure 3-56 Damage to the left wing of DD Leprak 2 (May 2024)

Training Dikes in the Flow Diversion Section

The current status of the existing dikes in the flow diversion section (Figure 3-37) is shown in Figure 3-57. The current status of these dikes (Tanggul Leprak 24, Tanggul Leprak 25, and Tanggul Leprak 26) are summarized below. In the section where the debris flow flooded, emergency dikes were constructed afterwards. These dikes were constructed using gabion as emergency measures to prevent another disaster.

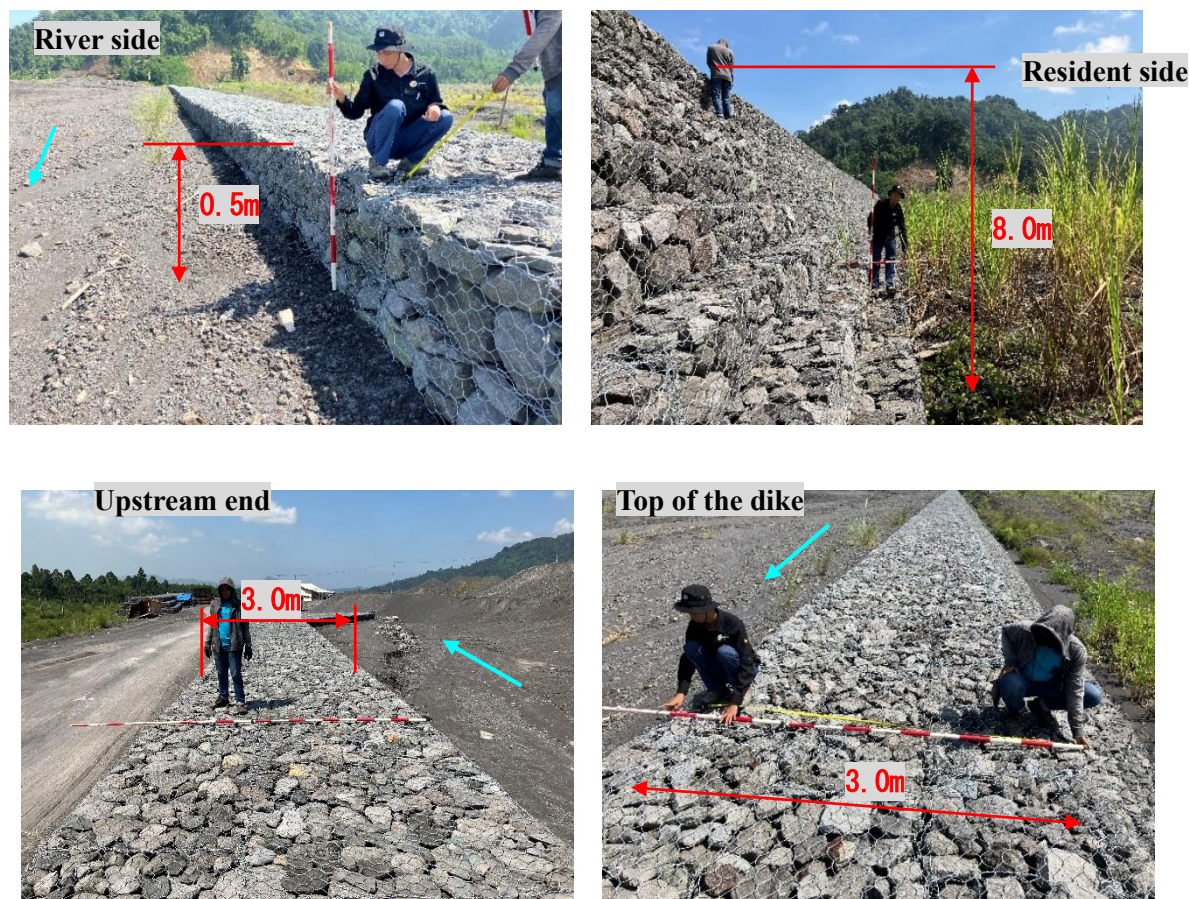


Figure 3-57 Current status of the training dikes (May 2024)

The basic shape of the dikes (Tanggul Leprak 24, Tanggul Leprak 25, and Tanggul Leprak 26) in the flow diversion section is shown in Figure 3-58.

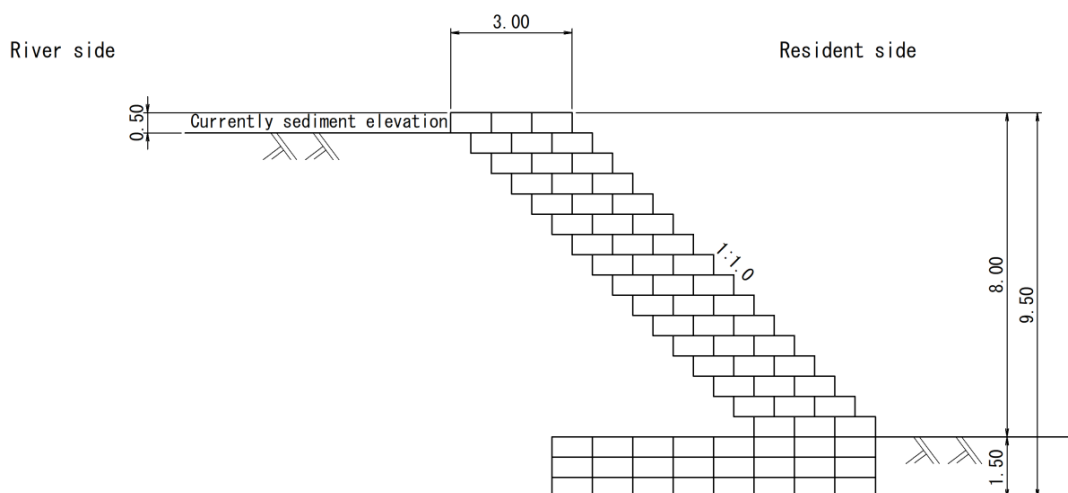


Figure 3-58 Existing dike at Tanggul Leprak 24, 25, and 26

Dike in the Sand Pocket Section

The current status of the existing dikes in the sand pocket section (Figure 3-37) is shown in Figure 3-59 ~ Figure 3-62. Current condition of these dikes (Tanggul Leprak 22, Tanggul Leprak 23, Tanggul Leprak II-D, Tanggul Leprak XVII Kebondeli 2021, Emergency Dike) is summarized below. The materials of these dikes are masonry or gabion.



Figure 3-59 Current Status of Tanggul Leprak 22 and Tanggul Leprak 23 (May 2024)



Figure 3-60 Current status of Tanggul Leprak II-D (May 2024)



Figure 3-61 Current status of Tanggul Leprak XVII Kebondeli 2021 (May 2024)



Figure 3-62 Current status of the Emergency Dike (May 2024)

The basic shape of the existing dikes in the Sand Pocket Section was estimated from the as built drawings and on-site surveys. The basic shape of the dikes (Tanggul Leprak 22, Tanggul Leprak 23, Tanggul Leprak II.-D, Tanggul Leprak XVII Kebondeli 2021, Emergency Dike) is presented in Figure 3-63 ~ Figure 3-67.

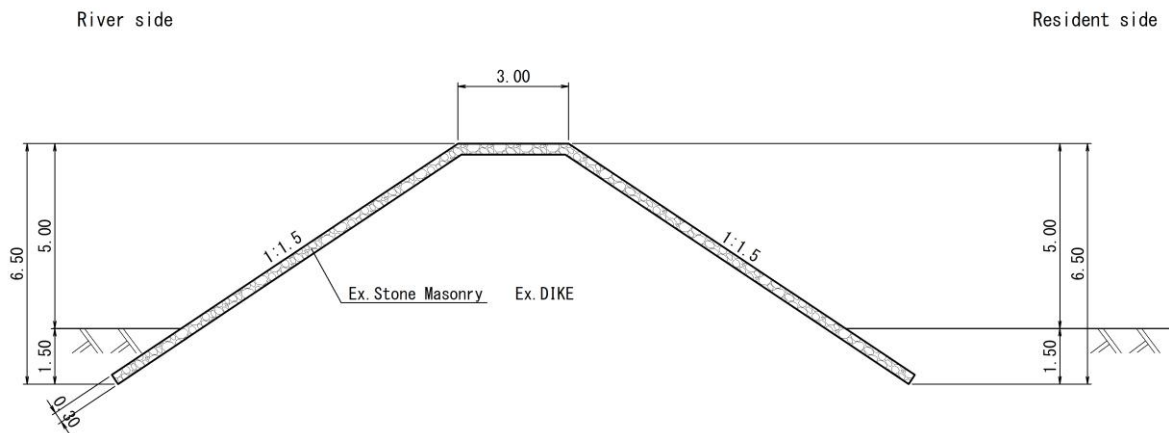


Figure 3-63 Existing dike at Tanggul Leprak 22

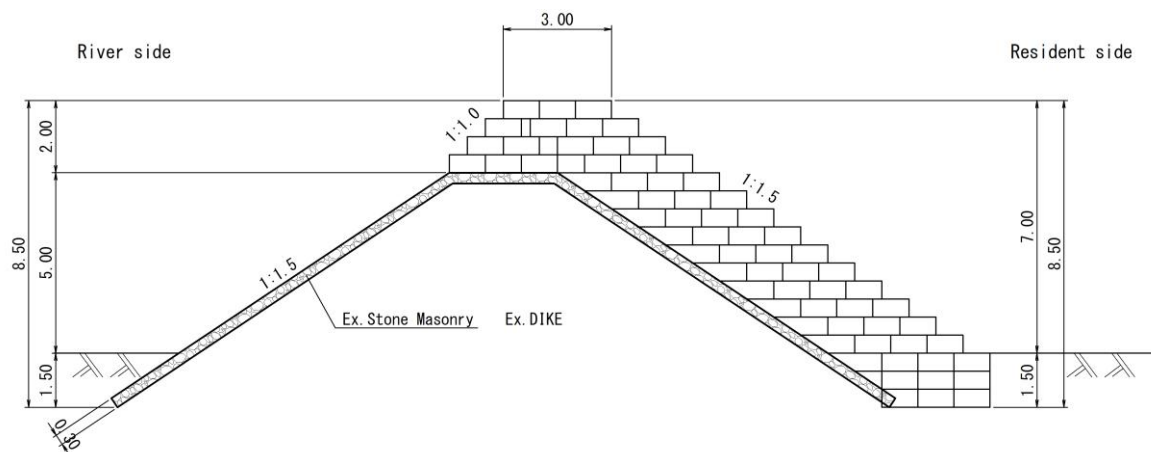


Figure 3-64 Existing dike at Tanggul Leprak 23

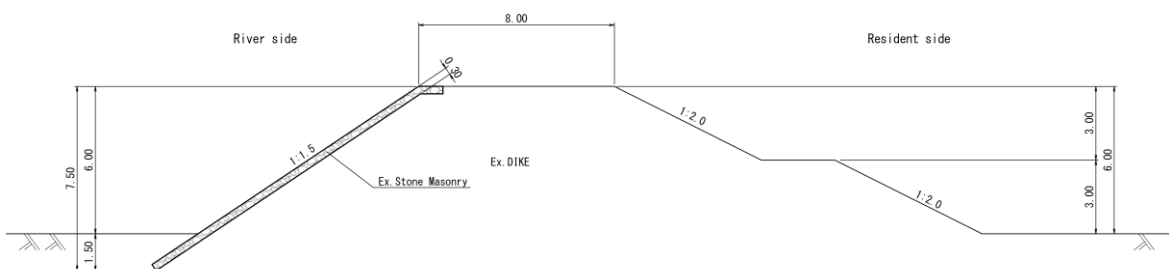


Figure 3-65 Existing dike Tanggul Leprak II-D

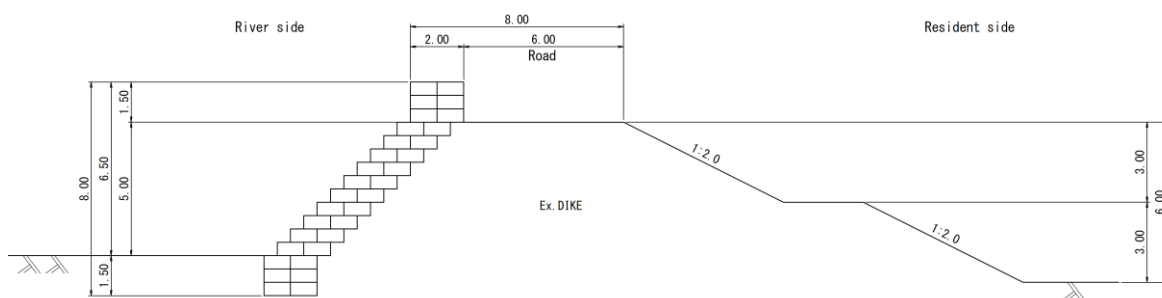


Figure 3-66 Existing dike at Tanggul Leprak XVII Kebondeli 2021

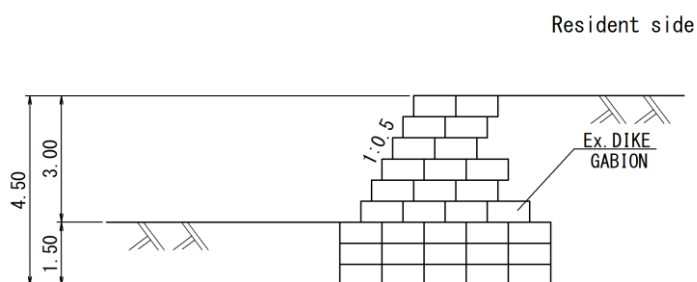


Figure 3-67 Existing dike at Emergency Dike

3.9.2 Basic Design of sabo Dam

(1) Layout Policy

The layout policy of KD Leprak 3, DD Leprak 2 and DD Leprak 3 is explained below.

KD Leprak3

A suspension bridge has been constructed at the location of KD Leprak 3. When reconstructing the sabo dam, interference with the bridge is unavoidable and the traffic must be shut down during construction. For this reason, a new dam is constructed upstream of the existing structure which will be used as a sub-dam. The image of layout plan of KD Leprak 3 is shown in Figure 3-68 and Figure 3-69, summarizing the above situation.

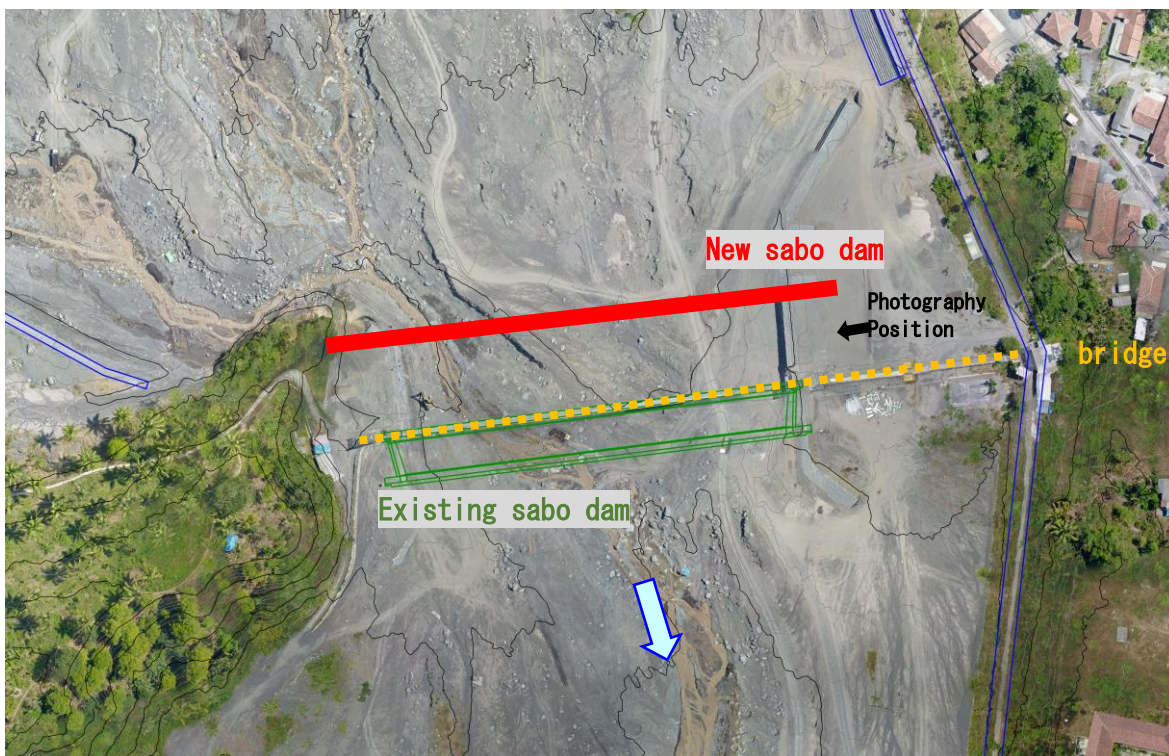


Figure 3-68 Layout plan of KD Leprak 3



Figure 3-69 Layout plan of KD Leprak 3 (view from left bank)

DD Leprak 2, DD Leprak 3

Regarding the location plan of DD Leprak 2 and DD Leprak 3, alternative plans were compared. The comparison is shown in Table 3-24. As a result, it was decided to adopt the Option 2 where the existing sabo dam would be used as a sub-dam and a new main dam would be placed upstream.

Table 3-24 DD Leprak 2 and DD Leprak 3 layout comparison study

	Option 1 Renovation of existing facilities	Option 2 New construction a sabo dam upstream of the existing facility
Outline of the plan	Construct a new sabo dam at the same position as the existing sabo dam	Construct a new sabo dam upstream of the existing sabo dam and utilize the existing sabo dam as a sub-dam
Facility effect	Compared to the Option 2, there is almost no difference ✓	There is little difference from Option 1 ✓
Economy	<ul style="list-style-type: none"> Removal of existing dams: all Construction of a new dam: same as Option 2 	<ul style="list-style-type: none"> Removal of existing dams: some parts Construction of a new main dam: same as Option 1 Reuse of existing facilities ✓
Evaluation	Rejected	✓ Adopted

(2) Dam Material

The materials for KD Leprak 3, DD Leprak 2, and DD Leprak 3 were studied. Concrete, masonry, and soil cement are compared as construction materials. Concrete, which has excellent strength, will be adopted, since these facilities are located in an area where debris flows occur frequently.

(3) Dam Type

The dam types of KD Leprak 3, DD Leprak 2, and DD Leprak 3 were examined (Figure 3-70). In the Review Master Plan (2024), existing facilities shall be renovated from closed-type to open-type to improve the sediment control effect. Therefore, in this study, the open-type will be adopted for the newly constructed sabo dams. Further, a slit type will be applied, since road functionality is not required.

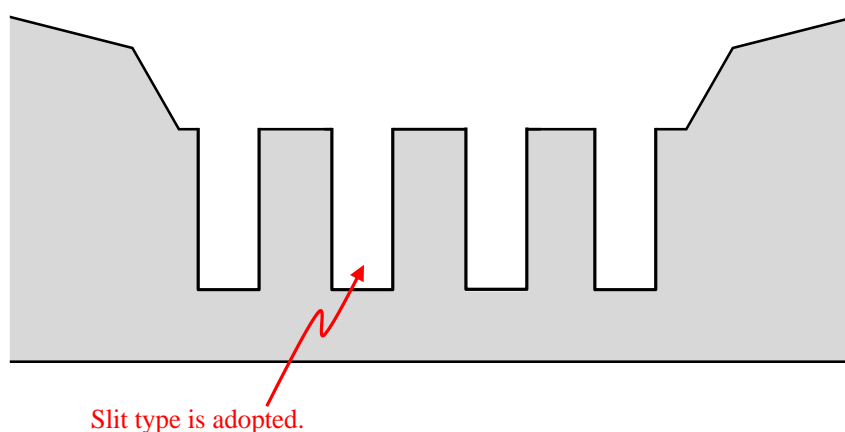


Figure 3-70 Front view of slit type dam

(4) Dam Height

The dimensions of KD Leprak 3, DD Leprak 2 and DD Leprak 3 are examined. On the upstream left bank of the dams, training dikes have been constructed. The dimensions of the KD Leprak 3, DD Leprak 2, and DD Leprak 3 dams are determined such that the elevation difference between the design sedimentation line and the dikes is ensured. It is designed so that debris flows will not overflow the dikes even in the events of the pyroclastic flow identical to those of the 2022 and 2022 eruptions, (Figure 3-45).

(5) Countermeasures Against Boulders Impact

The river channel is filled with boulders, and debris flows may transport these boulders. If the boulders collide with the wing section and slits, they may be damaged. Hence, the slit spacing is planned to be as wide as possible (Figure 3-71) and revetments will be installed on the upstream of the sabo dam (Figure 3-49). By installing revetments, it will act as a buffer to prevent the boulders from direct impact to the wings, thus helping minimize damages.

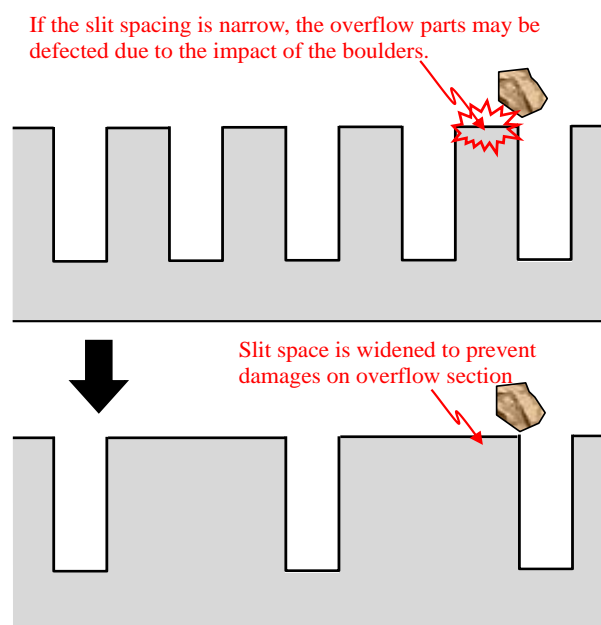


Figure 3-71 Mitigation Measures Against the Impact of Boulders (slit spacing measures)

(6) Abrasion Countermeasures

The countermeasure policy for the S4 area is the same as for the S2 area, as described above in “3.8.2 Basic Design of the sabo Dam”.

3.9.3 Basic Design of the Training Dikes

(1) Current Issues

The training dikes in the flow diversion section (Tanggul Leprak 24, Tanggul Leprak 25, Tanggul Leprak 26) and training dikes in the sand pocket section (Tanggul Leprak 22, Tanggul Leprak 23, Tanggul Leprak II.-D, Tanggul Leprak XVII Kebondeli 2021, Emergency Dike) are currently facing the following issues (Figure 3-72 and Figure 3-73).

- Issue 1 : The existing dikes are constructed using gabions and masonry. Since the gabion is the materials for emergency structures, there remain issues regarding the durability.
- Issue 2 : The current crest width of the dike is 3 m, while 4 m is required according to the Indonesian design technical guideline “Pd T-16-2004-A_Perencanaan Teknis Tanggul pada Sungai Lahar, P3”.
- Issue 3 : In the event of another disaster in the future, it is to be ensured that debris flows do not overtop the dike.

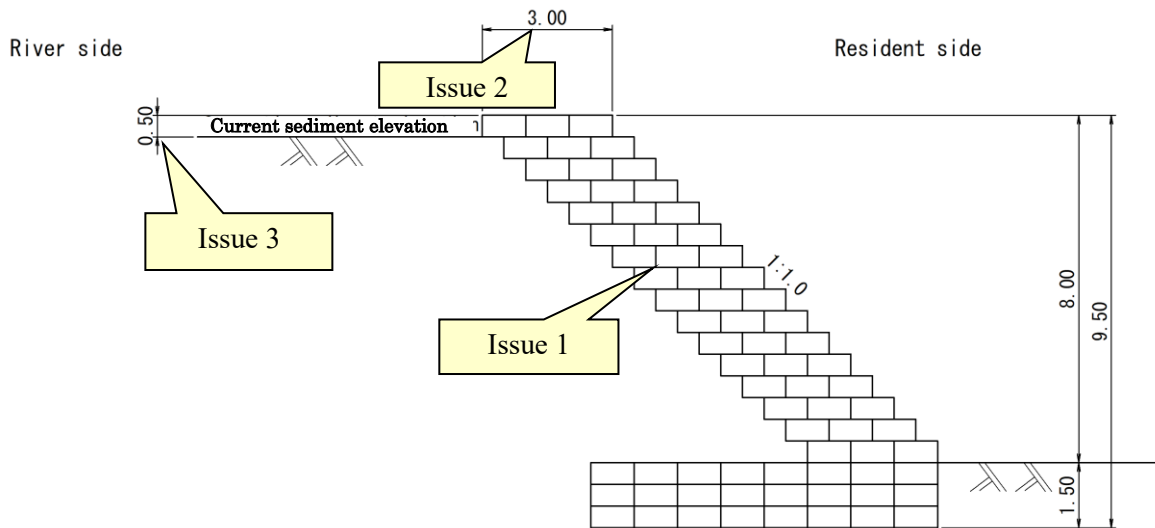


Figure 3-72 Current issues of training dikes in flow diversion section (Tanggul Leprak 24, 25, 26)

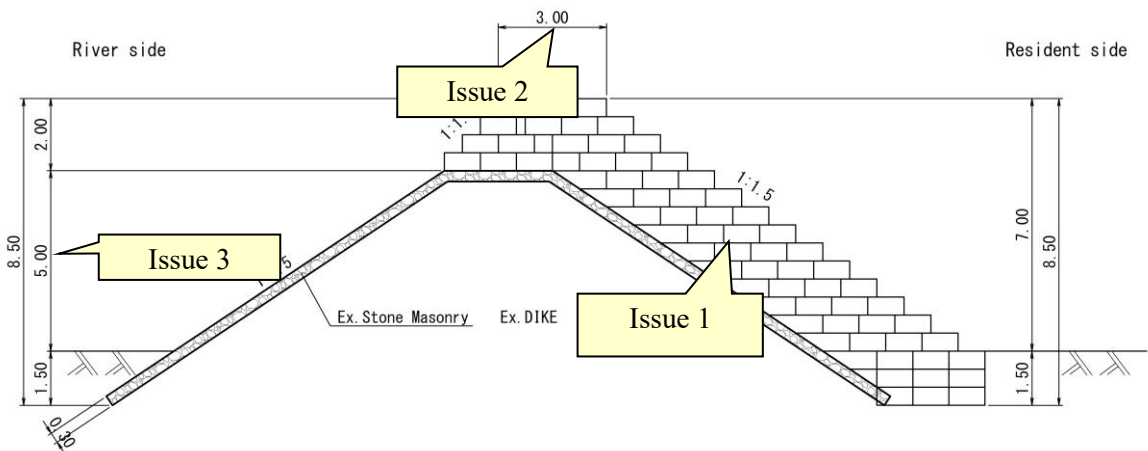


Figure 3-73 Current issues of training dikes in the sand pocket section (Tanggul Leprak 22, 23)

(2) Reconstruction Policy

1) Materials of training dikes

The materials of existing facilities are gabion and it will be utilized as is. To secure a width of 4 m at the crest of the dike, the material inside the dike will be masonry concrete (cyclop). Concrete will be applied to the surface of the training dike to enhance its durability (Figure 3-74).

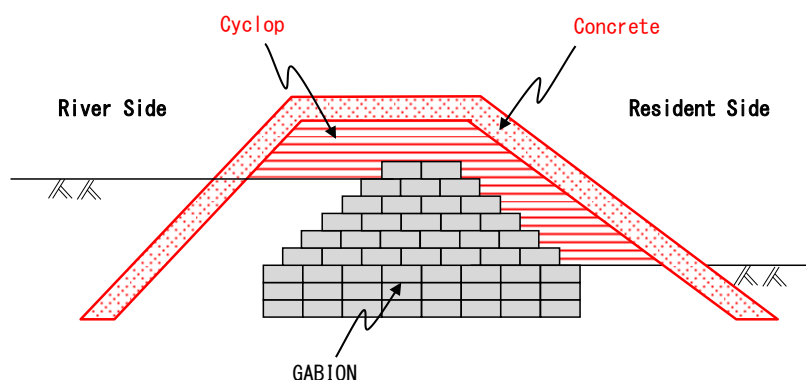


Figure 3-74 Training dike material (Tanggul Leprak 24, 25, 26)

2) Height of training dikes

The height of the training dike will be determined by adding the debris flow depth, the hydraulic jump height plus the freeboard (Figure 3-75), to ensure the safety against overflow.

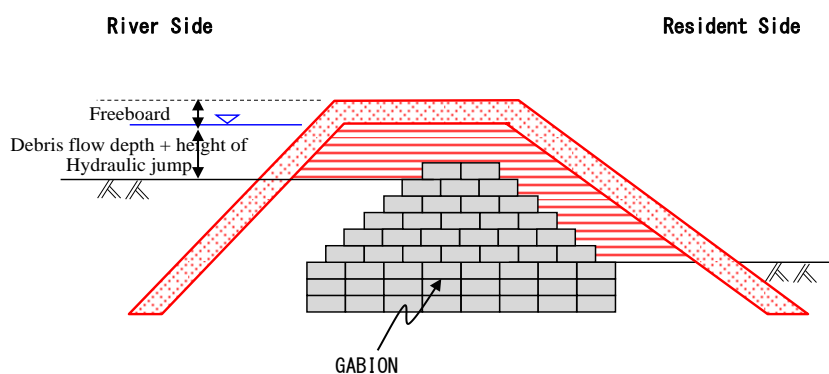


Figure 3-75 Height of the training dike (Tanggul Leprak 24, 25, 26)

3) Measures against debris flows

Mitigation measures to prevent debris flows from overflowing are discussed. If the slope of the dike on the inner side (resident side) is gentle, there is a risk that the debris flow will run up and overflow the dike. Thus, the slope of the dike on the river side shall be steep with the top section set vertical (Figure 3-54).

4) Basic shape of dike

If the existing material is gabion or masonry, the existing material will be utilized. If the crest width is 4 m, no additional measures will be applied to the surface of the river side of the dike. If the dike is made of gabion, concrete will be applied on its surface to improve the durability. As there is no significant damage to the Tanggul Leprak 22, the crest width will not be changed from the current 3m, and only underpinning work will be carried out.

Tanggul Leprak 24, 25, 26
Shape of existing

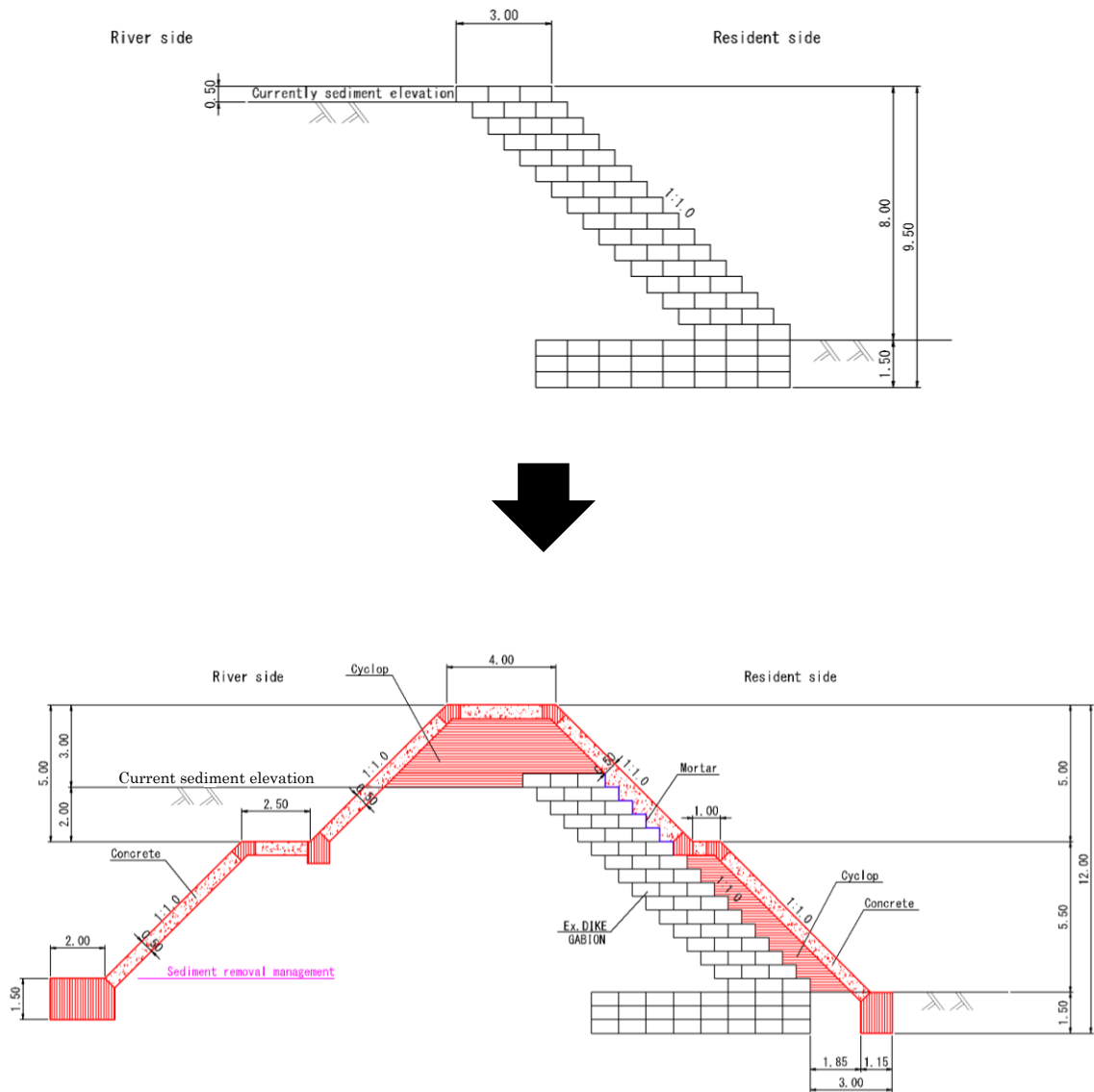


Figure 3-76 Basic shapes of Tanggul Leprak 24, 25, and 26

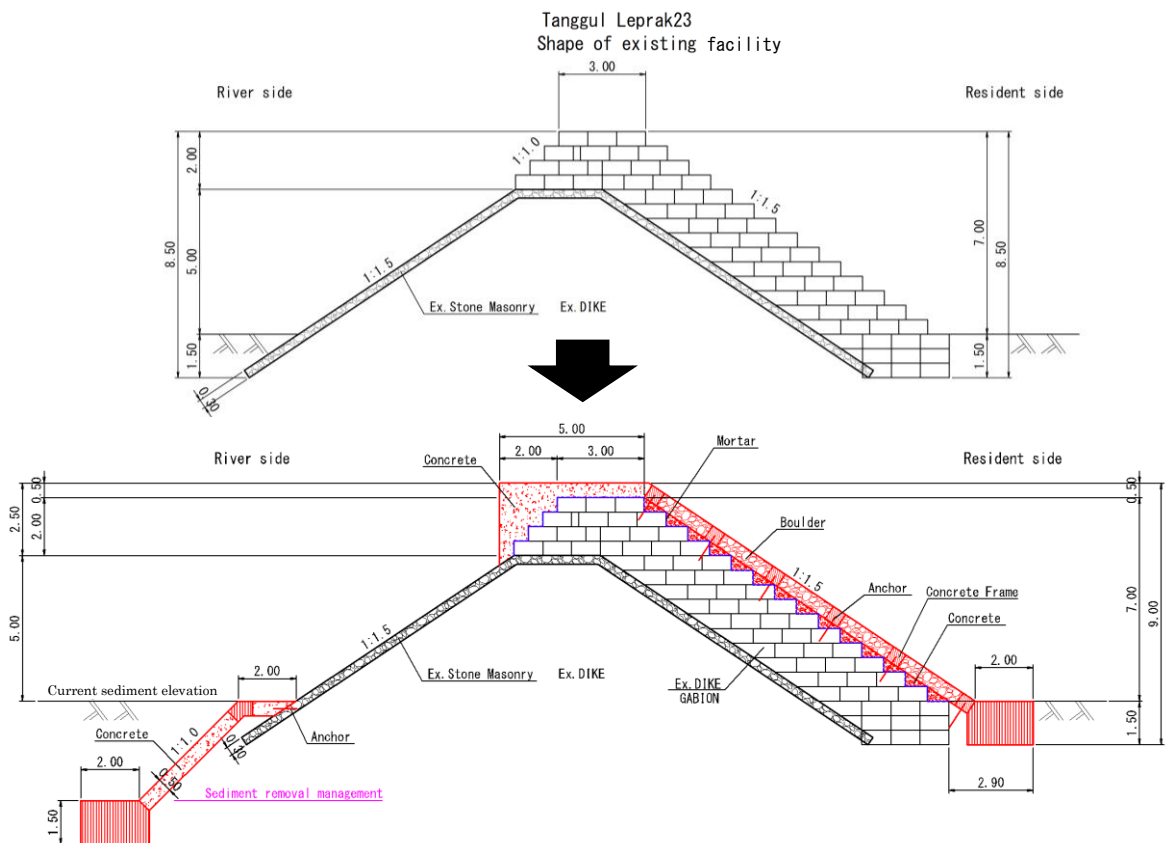


Figure 3-77 Basic shape of Tanggul Leprak 23

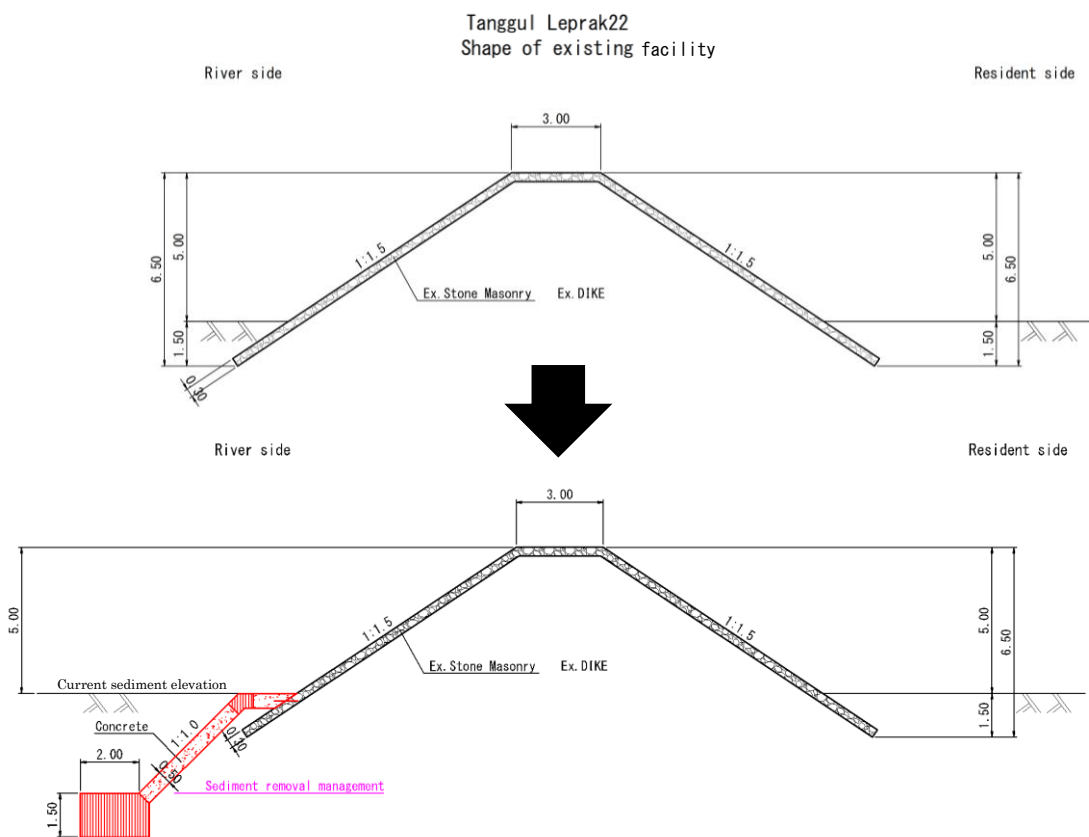


Figure 3-78 Basic shape of Tanggul Leprak 22

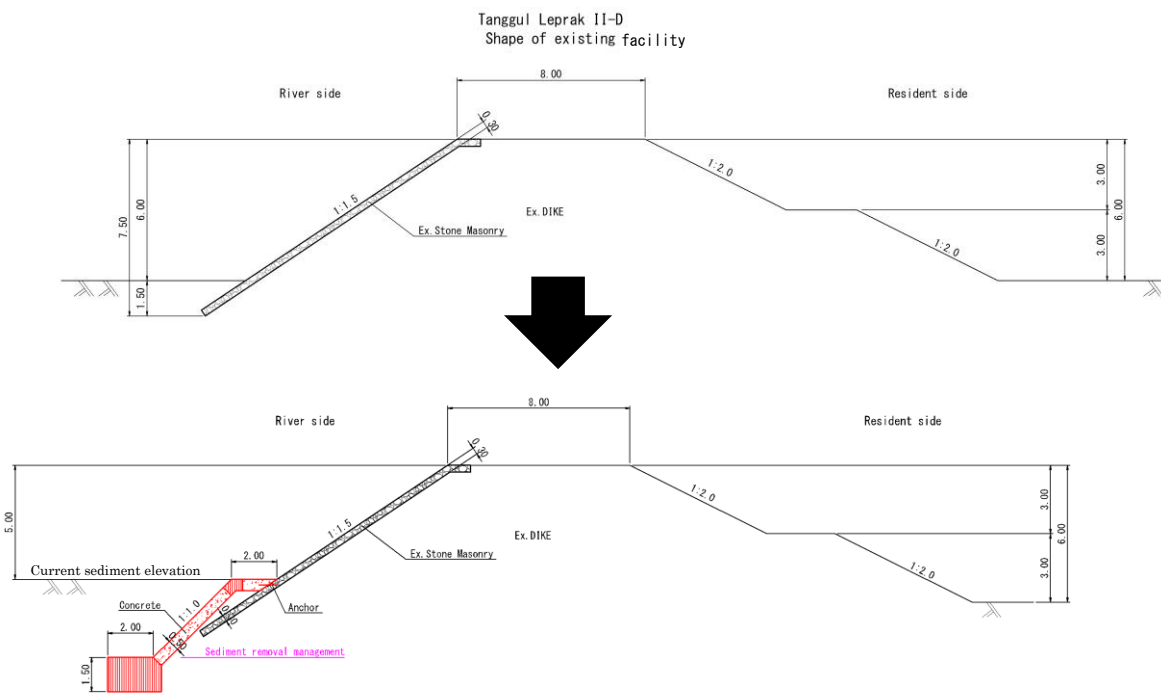


Figure 3-79 Basic shape of Tanggul Leprak II-D

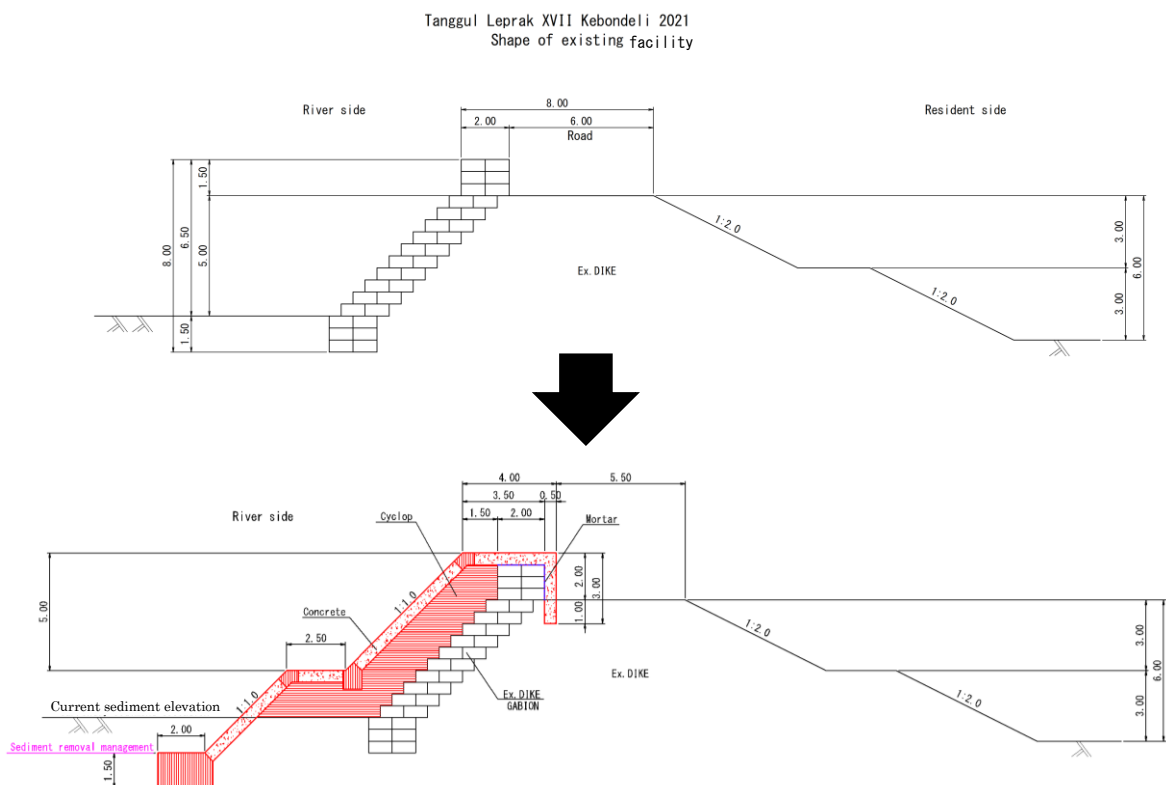


Figure 3-80 Basic shape of Tanggul Leprak XVII Kebondeli 2021

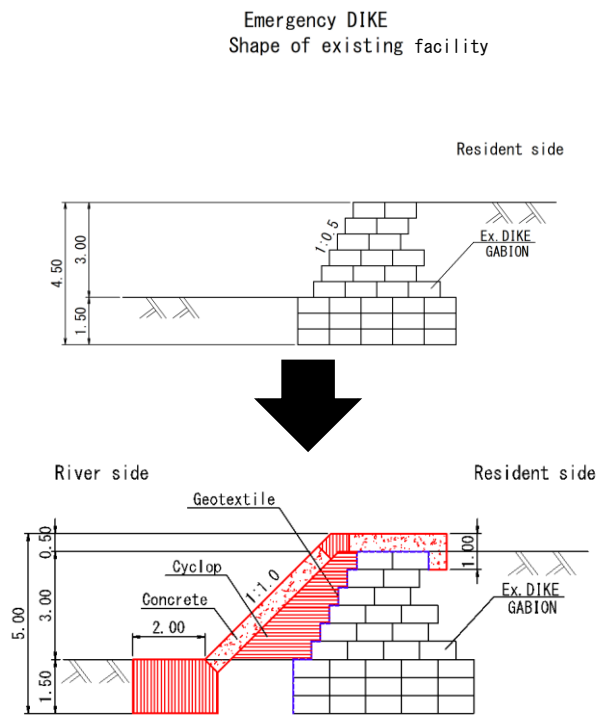


Figure 3-81 Basic shape of emergency dike

CHAPTER 4 PRELIMINARY DETAILED DESIGN

The calculations for the design of main dam (open-type) and the training dikes were performed, and drawings of facility design were prepared based on the calculation results.

4.1 Applicable Standards and Guidelines

Technical standards are reviewed periodically in response to major disasters and new research findings. The latest technical standard for the design of sabo dam in Indonesia is “SNI 2851-2021 Desain Sabo dam, 2021”, which was used as the primary standard in this project. However, for the aspects not addressed by this technical standard, older versions of Indonesians technical standards and guidelines, and Japanese technical standards were referenced to provide supplemental guidance.

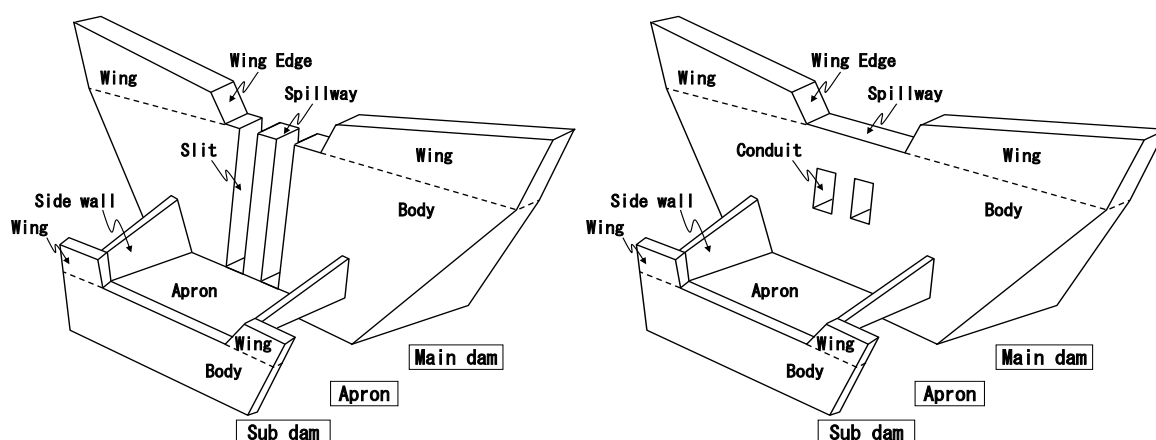
The design constants, geological constants, and other numerical values and formulas are primarily conformed with the standards outlined in Table 4-1. Furthermore, Indonesia’s standards were developed with reference to Japan's standards, since both countries share similar natural phenomena, particularly in relation to volcanos. Consequently, the sediment movement mechanism and physical constants used in both countries are consistent. The numerical values and their sources are cited throughout this report.

Table 4-1 List of complied standards

No	Document Title	Year of Publication	Publisher
1	SNI 2851-2021 <i>Sabo dam Design</i>	2021	National Standardization Agency, Indonesia
2	Revision of SNI 03-2851-1991 <i>Procedures for Technical Planning of Sediment Retaining Dams</i>	1991	National Standardization Agency, Indonesia
3	Pd T-12-2004-A <i>Technical Planning for River Bed Control Weirs</i>	2004	Department of Human Settlements and Regional Infrastructure, Indonesia
4	Pd T-16-2004-A <i>Technical Planning for Embankments on the Lahar River</i>	2004	Department of Settlements and Regional Infrastructure, Indonesia
5	Technical Guideline for Establishing Sabo Master Plan against Debris Flow and Driftwood	2016	National Institute for Land and Infrastructure Management
6	Technical Guidelines for Designing Sabo Facilities against Debris Flow and Driftwood	2016	National Institute for Land and Infrastructure Management

4.2 Components of Sabo Dam

The components of sabo facilities are presented in Figure 4-1 as follows. Regarding the type of sabo dam, as mentioned in “3.1.4 Layout Policy and Selection of sabo Facilities”, an open type was adopted.



Source : SNI 2851-2021 _Design Sabodam, P26

Figure 4-1 Names of components of open type sabo dams (left: slit type, right: conduit type)

4.3 Design Constants

The summary of the design constants used in the design process is compiled below.

4.3.1 Concrete Constants

The sabo dams are designed on the assumption that concrete will be used as the dam material. However, for the unit volume weight of concrete to be used in calculating the self-weight, the apparent unit volume weight after deducting the weight of the openings shall be used, since it is assumed that the structural type of all planned sabo dams will be of the open type. It is specified that the apparent unit volume weight shall be calculated by the following formula^{*1}. Based on the calculation results, the unit weight of the dam body in this project was calculated to be 20.0 kN/m³. The basis for calculating the apparent unit weight is detailed in Appendix 4-3-1.

$$\gamma_{rc} = \frac{W_{rc}}{V_c}$$

Where, γ_{rc} : apparent concrete unit weight (kN/m³)

W_{rc} : weight of dam blocks calculated as an open type structure for the open section (kN)

V_c : volume of dam blocks calculated assuming the open section as a closed structure (m³)

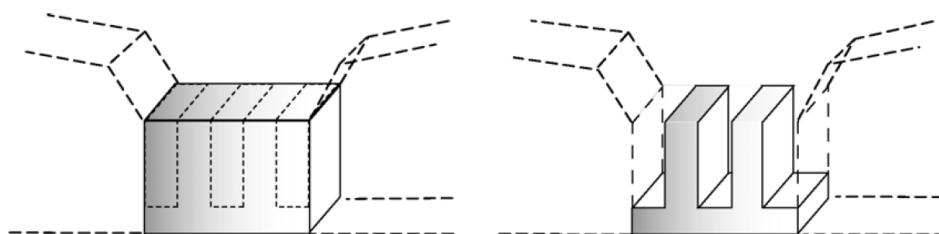


Figure 4-2 Dam body volume of spillway on the slit part

Table 4-2 Unit weight of dam body material

Material	Unit Weight
Concrete ^{*2}	22.6 kN/m ³ (2.3t/m ³)
Concrete for the target sabo facility	20.0 kN/m ³ (2.0 t/m ³)

Source: ^{*1} Technical Guidelines for Designing Sabo Facilities against Debris Flow and Driftwood, p. 23

^{*2} SNI 2851-2021 Sabo dam Design, p.36

4.3.2 Foundation Constants

It is specified that Table 4-3 shall be used for the constants of the foundation ground of sabo dams. Based on the results of the field survey and boring survey, the type of foundation ground was grasped and the constant of each sabo dam was determined.

Due to the results of the surveys, it was confirmed that there is no exposed rock on the riverbed except for CD Pelintas Curah Lengkong 2. Therefore, for CD Pelintas Curah Lengkong2, the foundation ground was evaluated as equivalent to "Soft Rock I" according to Indonesian standards. For other dams, the foundation grounds were evaluated as equivalent to "Gravel layer - Dense" of the standards. The results of the constants of foundation ground for each sabo dams are shown in Table 4-4.

Table 4-3 Determination of geotechnical constants^{*1}

Type of Foundation		Allowable Bearing Capacity (kN/m ²)	Shear Strength (kN/m ²)	Friction Coefficient
Rock	Hard Rock (A)	6,000	3,000	1.2
	Medium Hard Rock (B)	4,000	2,000	1.0

Type of Foundation	Allowable Bearing Capacity (kN/m ²)	Shear Strength (kN/m ²)	Friction Coefficient	
Soft Rock	Soft Rock (II)	2,000	1,000	0.8
	Soft Rock (I)	1,200	600	0.7
Boulders and Cobbles		—	0.7	
Gravel layer	Dense	600	—	0.6
	Loose	300	—	0.6
Sandy soil	Dense	300	—	0.6
	Loose	200	—	0.55
Clayey soil	Very hard	200	—	0.5
	Hard	100	—	0.45
	Medium	50	—	

Source: ※1 SNI 2851-2021_Sabo dam Design, P.33

※1 Pd T-12-2004-A_Perencanaan Teknis Bendung Pengendali Dasar Sungai, P.23

Table 4-4 Determination of geotechnical constants

Construction Package	Facility Name	Ground Type	Allowable Bearing Capacity (kN/m ²)	Shear Strength (kN/m ²)	Friction Coefficient
S2 Package	CD Kobokan 5	Gravel layer: Dense	600	-	0.6
	CD Pelintas Curah Lengkong 2	Soft Rock I	1,200	600	0.7
S4 Package	KD Leprak 3	Gravel layer: Dense	600	-	0.6
	DD Leprak 3	Gravel layer: Dense	600	-	0.6
	DD Leprak 2	Gravel layer: Dense	600	-	0.6

4.3.3 Design Loads

The constants for design loads were determined as described below.

(1) Unit Weight of Water

It is specified that the unit weight of water shall be approximately 11.77 kN/m³ for dams of less than 15 meters high, and approximately 9.81 kN/m³ for dams of 15 meters or higher. Since this study plans for dams of less than 15 meters high, a unit weight of water was determined to be 11.77 kN/m³ was selected.

Source : ※1 SNI 2851-2021_Sabo dam Design, p. 49

(2) Unit Weight of Sediment in Muddy Water

It is specified that the unit weight of sediment in muddy water shall be calculated using the formula ※1. For this study, the unit weight of sediment in muddy water was calculated to be 8.24 kN/m³.

$$\begin{aligned} \gamma_s &= C^* \times (\sigma - \rho) \times g / 1000 \\ &= 8.24 \text{ kN/m}^3 \end{aligned}$$

Where, γ_s : Unit weight of sediment in muddy water (kN/m³)
 C^* : Volume concentration of deposited sediment (0.6) ※2
 ρ : Density of water (1,200 kg/m³) ※3 (≐ 11.77kN/m³)
 σ : Density of gravel (2,600 kg/m³) ※3 (≐ 25.51kN/m³)
 g : Gravitational acceleration (9.81 m/s²)

Source: ※1 Commentary on technical guidelines for designing countermeasures against debris flows and driftwood, p.6

※2 SNI 2851-2021_Sabo dam Design, P.21, P.22, P.36, P.49

※3 SNI 2851-2021_Sabo dam Design, P. 21

(3) Unit Weight of Debris Flow

It is specified that the unit volume weight of a debris flow shall be calculated using the following formula.^{※1}

$$\gamma_d = \{ \sigma \times C_d + \rho \times (1 - C_d) \} \times g$$

- Where, γ_d : Unit weight of debris flow (kN/m³)
 C_d : Debris flow concentration ^{※2} (described later in Section 4.4.3 (1) 1)
 ρ : Density of water (1,200 kg/m³) ^{※2} (≈ 11.77 kN/m³)
 σ : Gravel density (2,600 kg/m³) ^{※2} (≈ 25.51 kN/m³)
 g : Gravitational acceleration (9.81 m/s²)

Source: ^{※1} SNI 2851-2021 _Sabo dam Design, p.43
^{※2} SNI 2851-2021 _Sabo dam Design, p.21

(4) Coefficient of Earth Pressure

It is specified that the earth pressure coefficient shall be generally between 0.3 and 0.4 ^{※1}. For this study, the coefficient was calculated to be 0.3 based on the following formula ^{※2}

$$C_e = \frac{1 - \sin \theta}{1 + \sin \theta} = \frac{1 - \sin 35^\circ}{1 + \sin 35^\circ} = 0.27 \approx 0.3$$

- where, C_e : Earth pressure coefficient
 θ : Internal friction angle (assumed for gravel and gravel-mixed sand = 35°) ^{※3}

Source: ^{※1} Revisi SNI 03-2851-1991 _Tata Cara Perencanaan Teknik Bendungan Penahan Sedimen, Page 28
^{※2} Collection of Sabo Design Formulas (Manual), P99
^{※3} SNI 2851-2021 _Sabo dam Design, P. 36

4.4 Spillway Design

The components in the design of spillways are as presented in Figure 4-3 as follows.

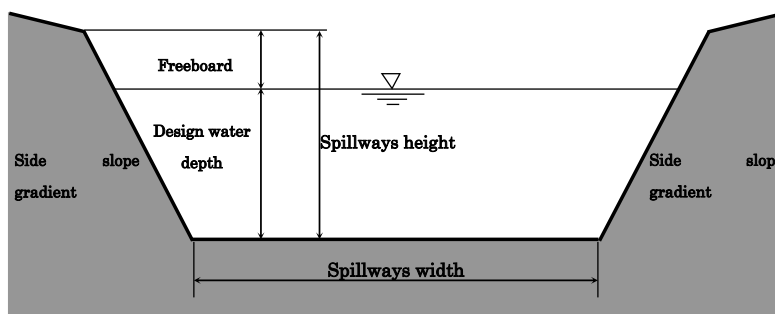


Figure 4-3 Overview of spillway

4.4.1 Spillway Width

It is specified that the spillway width shall be determined by considering the current riverbed width and the spillway width of existing sabo dams^{※1}. The spillway width for each facility was determined as shown in Table 4-5.

Table 4-5 Spillway width

Construction Package	Facility Name	Current Riverbed Width	Spillway Width of Existing sabo dam	Determined Spillways Width
S2 Package	CD Kobokan 5	Approx. 100-150 m	125 m	135 m
	CD Pelintas Curah Lengkong 2	Approx. 30-50 m	unknown	45 m
S4 Package	KD Leprak 3	Approx. 150 m	130 m	130 m
	DD Leprak 3	Approx. 800 m	781.14 m	795 m

Construction Package	Facility Name	Current Riverbed Width	Spillway Width of Existing sabo dam	Determined Spillways Width
	DD Leprak2	Approx. 800 m	799.95 m	816 m

Source : *1 SNI 2851-2021 _Sabo dam Design, p.5-7

4.4.2 Wing Edge Gradient

It is specified that the gradient of wing edge shall be 1:0.5 *1

Source : *1 SNI 2851-2021 _Sabo dam Design, p.38

4.4.3 Spillway Height

It is specified that the height of spillway shall be equal to the design water depth plus the freeboard height. *1

Source : *1 SNI 2851-2021 _Sabo dam Design, p.38

(1) Design Water Depth

It is specified that the design water depth shall be the largest value among the following 1 to 3 *1.

1. Value of the overflow depth for discharge considering sediment content
2. Value of the overflow depth for debris flow peak discharge
3. Value of the maximum gravel diameter

Source: *1 SNI 2851-2021 _Sabo dam Design, p.5-7

1) Overflow Depth for Discharge Considering Sediment Content

It is specified that the discharge considering sediment content shall be 1.5 times the discharge of water without sediment with a 1/100 probability. The peak discharge of water is as described in the Review Master Plan (2024) . The discharge considering sediment content at each dam location was calculated as shown in Table 4-6. The overflow depth for the discharge considering sediment content was calculated using the following formula. The calculation basis for the overflow depth for discharge considering sediment content is explained in the Appendix 4-3-1.

$$1.5 \times Q = \frac{2}{15} \times C \times \sqrt{2g} \times (3B_1 + 2B_2) \times D_h^{3/2}$$

Where, Q : Discharge of water without sediment (m³/s)
 C : Flow coefficient (0.60)
 g : Gravitational acceleration (9.81 m/s²)
 B_1 : Bottom width of the spillways (m)
 B_2 : Overflow water surface width (m)
 D_h : Overflow depth (m)

Table 4-6 Overflow depth for discharge considering sediment content

Construction package	Facility name	Discharge of water without sediment Q	Discharge considering sediment content $1.5 \times Q$	Overflow depth D_h
S2 Package	CD Kobokan 5	315.0 m ³ /s	472.5 m ³ /s	1.7 m
	CD Pelintas Curah Lengkong 2			3.3 m
S4 Package	KD Leprak 3	371.0 m ³ /s	556.5 m ³ /s	1.8 m
	DD Leprak 3			0.6 m
	DD Leprak 2			0.6 m

Source : *1 SNI 2851-2021 _Sabo dam Design, P. 22

*2 Commentary on technical guidelines for designing countermeasures against debris flows and driftwood, P. 8

*3 Review Master Plan 2024, Chapter 3, 3.1.1 Basic Conditions, Table 3-3 Flood Peak Discharge by Rational

Formula

※4 SNI 2851-2021 _Sabo dam Design, P.12

※5 Revisi SNI 03-2851-1991_ Tata Cara Perencanaan Teknik Bendungan Penahan Sedimen, P.10

2) Overflow Depth for Debris Flow Peak Discharge

It is specified that the peak discharge of debris flow in this study shall be calculated using the theoretical equation based on rainfall calculation methods). The peak flow of debris flow was calculated as follows:

Source: ※1 Guidelines for formulating basic erosion control plans (debris flow and driftwood countermeasures) p. 28

• Formula for debris flow concentration

It is specified that the debris flow concentration (C_d) shall be calculated using the following formula※2. The results of the calculation shows that the debris flow concentration (C_d) was less than or equal to 0.30. Since the debris flow concentration (C_d) is typically within 0.30 to 0.54※1, it was determined that the value of the debris flow concentration (C_d) in this study was 0.03.

$$C_d = \frac{\rho \times \tan \theta}{(\sigma - \rho) \times (\tan \phi - \tan \theta)}$$

$$C_d = 0.30 \sim 0.54$$

Where, C_d : Concentration of debris flow
 ρ : Density of water (1,200 kg/m³) ※2 (≐ 11.77kN/m³)
 θ : Riverbed gradient (°)
 σ : Gravel density (2,600 kg/m³) ※2 (≐ 25.51kN/m³)
 ϕ : Internal friction angle of the deposited soil (assuming that the deposited soil is gravel and sand with gravel, internal friction angle = 35°) ※3

Table 4-7 Debris flow concentration

Construction package	Facility name	Riverbed gradient I	Calculation results C_d	determined C_d
S2 Package	CD Kobokan 5	1/17.5 (3.27°)	0.08	0.30
	CD Pelintas Curah Lengkong 2	1/16.0 (3.57°)	0.08	
S4 Package	KD Leprak 3	1/33.3 (1.72°)	0.04	
	DD Leprak 3			
	DD Leprak 2			

Source: ※1 SNI 2851-2021 _Sabo dam Design, P. 21

※2 Guidelines for formulating basic erosion control plans (debris flow and driftwood countermeasures) Page 28

※3 SNI 2851-2021 _Sabo dam Design, P. 36

• Debris flow peak discharge

It is specified that the debris flow peak discharge Q_{sp} shall be calculated using the following formula ※1.

$$Q_{sp} = \frac{C^*}{C^* - C_d} \times Q_p$$

Where, Q_{sp} : Debris flow peak discharge (m³/s)

C^* : Volumetric sediment concentration of the deposited sediment (0.6)※2

C_d : Debris flow concentration
 Q_p : Target flow rate of fresh water ^{※3} (m³/s)

Table 4-8 Debris flow peak discharge

Construction package	Facility name	Debris flow concentration C_d	Discharge of water without sediment Q_p	Debris flow peak discharge Q_{sp}
S2 Package	CD Kobokan 5	0.30	315.0 m ³ /s	630.0 m ³ /s
	CD Pelintas Curah Lengkong 2			
S4 Package	KD Leprak 3		371.0 m ³ /s	742.0 m ³ /s
	DD Leprak 3			
	DD Leprak 2			

Source : ^{※1} SNI 2851-2021 _Sabo dam Design, P. 22

^{※2} SNI 2851-2021 _Sabo dam Design, P.21, P.22, P.36, P.49

^{※3} Review Master Plan 2024, Chapter 3, 3.1.1 Basic Conditions Table 3-3 Flood peak discharge according to rational formula

▪ **Determination of overflow depth for debris flow peak discharge**

It is specified that the overflow depth for the debris flow peak discharge shall be calculated using the following formula^{※1}. The basis for the calculation of the overflow depth for the debris flow peak discharge is detailed in the Appendix 4-3-1.

$$Q_{sp} = \frac{1}{n} \times D_d^{2/3} \times I^{1/2}$$

Where, Q_{sp} : Debris flow peak discharge (m³/s)

n : Roughness coefficient (front section: 0.1) ^{※1}

D_d : Overflow depth (m)

I : Riverbed gradient

Table 4-9 Determination of overflow depth for debris flow peak discharge

Construction package	Facility name	Riverbed gradient I	Peak debris flow rate Q_{sp}	Overflow depth D
S2 Package	CD Kobokan 5	1/17.5	630.0 m ³ /s	1.7 m
	CD Pelintas Curah Lengkong 2	1/16.0		2.8 m
S4 Package	KD Leprak 3	1/33.3	742.0 m ³ /s	2.1 m
	DD Leprak 3			0.7 m
	DD Leprak 2			0.7 m

Source : ^{※1} Guidelines for formulating basic erosion control plans (debris flow and driftwood countermeasures) P.30

3) Maximum Gravel Diameter

It is specified that the maximum gravel diameter shall be determined as the particle size corresponding to the 95th percentile of the cumulative distribution based on measurements of large gravel sizes located upstream and downstream of the sabo dam's planned site ^{※1}. The gravel size survey results are detailed in the Appendix 4-2. According to the survey results, the maximum gravel diameter D_{95} was calculated to be 2.5 meters.

Source : ^{※1} SNI 2851-2021 _Sabo dam Design, p. 5 to 6

4) Determination of Design Water Depth

The calculated overflow depths for each facility were organized, and the design water depth was determined as shown in Table 4-10.

Table 4-10 Determination of design water depth

Construction package	Facility name	Overflow depth		Maximum Gravel Diameter	Design water depth
		Discharge considering sediment content	Debris flow peak discharge		
S2 Package	CD Kobokan 5	1.7 m	1.7 m	2.5 m	2.5 m
	CD Pelintas Curah Lengkong 2	3.3 m	2.8 m		3.3 m
S4 Package	KD Leprak 3	1.8 m	2.1 m		2.5 m
	DD Leprak 3	0.6 m	0.7 m		2.5 m
	DD Leprak 2	0.6 m	0.7 m		2.5 m

(2) Freeboard

It is specified that the freeboard shall be determined by selecting the larger of the values between those calculated from the design discharge and the riverbed gradient.

1) Freeboard Corresponding to the Design Flow Rate

It is specified that the freeboard corresponding to the design discharge shall be as shown in Table 4-11. The design discharge used here is the discharge considering sediment content, which is 1.5 times the target flow rate for clear water (Table 4-6). The freeboard corresponding to the discharge of each dam is determined as shown in Table 4-12.

Table 4-11 Freeboard^{*1}

Design discharge	Freeboard
Less than 200 m ³ /s	0.6 m
200-500 m ³ /s	0.8 m
Greater than 500 m ³ /s	1.0 m

Source: ^{*1} SNI 2851-2021_Desain Sabodam, P.32

Table 4-12 Freeboard corresponding to the discharge

Construction package	Facility Name	Design Discharge	Freeboard (corresponding to the discharge)
S2 Package	CD Kobokan 5	472.5 m ³ /s	0.8 m
	CD Pelintas Curah Lengkong 2		0.8 m
S4 Package	KD Leprak 3	556.5 m ³ /s	1.0 m
	DD Leprak 3		1.0 m
	DD Leprak 2		1.0 m

2) Freeboard Corresponding to the Riverbed Gradient

It is specified that the freeboard height corresponding to the riverbed gradient shall be designed so that the ratio of the freeboard height to the design water depth does not fall below the values specified in Table 4-13. ^{*1}

Table 4-13 Minimum ratio of freeboard height to the design water depth by riverbed gradient^{*1}

Riverbed Gradient	(Freeboard height) / (Design Water Depth)
Greater than 1/10	0.5
1/10-1/30	0.4

Riverbed Gradient	(Freeboard height) / (Design Water Depth)
1/30-1/50	0.3
1/50-1/70	0.25

Source: ※¹ SNI 2851-2021 _Desain Sabodam, P.32

The comparison between the freeboard corresponding to the discharge (Table 4-12) and the freeboard corresponding to the riverbed gradient (Table 4-13) is presented in Table 4-14. The freeboard corresponding to the riverbed gradient was calculated by rounding up to the second decimal place.

Table 4-14 Freeboard for riverbed gradient

Construction Packages	Facility Name	Riverbed Gradient for Each Facility $I \times 2.5/3$	Minimum Ratio of Freeboard to Design Water Depth by Streambed Gradient (Table 4-13)	Freeboard Corresponding to the Discharge / Design Water Depth (Table 4-12) / (Table 4-10)	Assessment
S2 Package	CD Kobokan 5	1/21.0	0.4	$0.8/2.5 = 0.32$	NG
	CD Pelintas Curah Lengkong 2	1/19.2		$0.8/3.3 = 0.24$	NG
S4 Package	KD Leprak 3	1/40.0	0.3	$1.0/2.5 = 0.4$	OK
	DD Leprak 3			$1.0/2.5 = 0.4$	OK
	DD Leprak 2			$1.0/2.5 = 0.4$	OK

Source: ※¹ Explanation of design technical guidelines for landslides and driftwood projects, P.10

※² SNI 2851-2021 _Sabo dam Design, P. 32

3) Determination of Freeboard

It is specified that The freeboard shall be determined by comparing the freeboard corresponding to the discharge and the freeboard corresponding to the riverbed gradient, and the larger value was adopted. The freeboard for each dam was determined as shown in Table 4-15.

Table 4-15 Determination of freeboard

Construction Packages	Facility Name	Freeboard	Remarks
S2 Package	CD Kobokan 5	1.0 m	Minimum ratio of freeboard to design water depth by riverbed gradient
	CD Pelintas Curah Lengkong 2	1.4 m	Minimum ratio of freeboard to design water depth by riverbed gradient
S4 Package	KD Leprak 3	1.0 m	Freeboard corresponding to the discharge
	DD Leprak 3	1.0 m	Freeboard corresponding to the discharge
	DD Leprak 2	1.0 m	Freeboard corresponding to the discharge

(3) Determination of Spillway Height

The spillway height was determined by summing the design water depth and freeboard for each facility, as shown in Table 4-16.

Table 4-16 Determination of water flow height

Construction Packages	Facility Name	Design Water Depth h_3	Freeboard ΔH	Spillway Height H
S2 Package	CD Kobokan 5	2.5 m	1.0 m	3.5 m
	CD Pelintas Curah Lengkong 2	3.3 m	1.4 m	4.7 m
S4 Package	KD Leprak 3	2.5 m	1.0 m	3.5 m

Construction Packages	Facility Name	Design Water Depth h_3	Freeboard ΔH	Spillway Height H
	DD Leprak 3	2.5 m	1.0 m	3.5 m
	DD Leprak 2	2.5 m	1.0 m	3.5 m

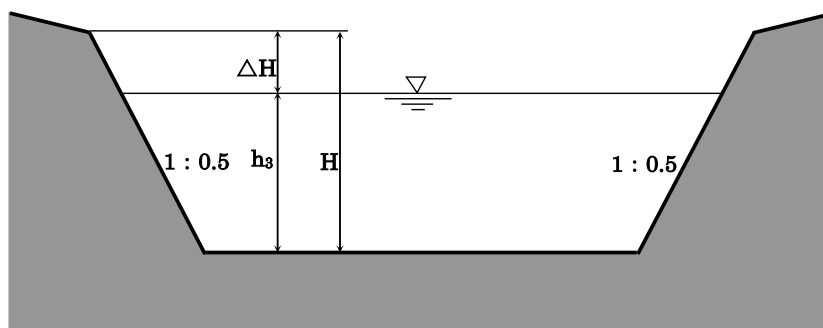


Figure 4-4 Overview diagram of Spillway

4.5 Sabo Dam Design

Based on the design conditions, the design of the main sabo dam for the planned sabo dam was carried out.

4.5.1 Main Dam Design

(1) Crest Width of the Overflow Section

It is specified that the crest width shall be determined considering factors such as the riverbed material near the dam site, the type of sediment being transported, and the design discharge. The crest width of the sabo dam must be wide enough to withstand the impact of transported sediment and to endure the friction of passing gravel through the spillway section. The width was determined as shown in Table 4-17.

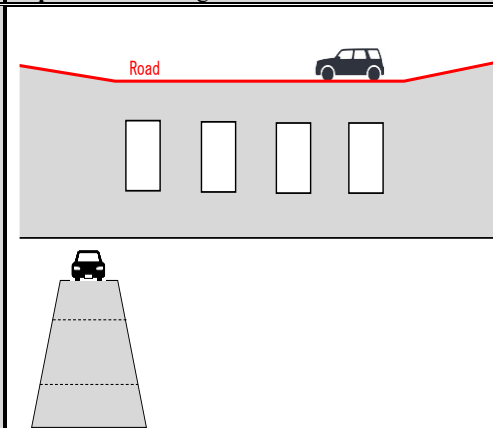
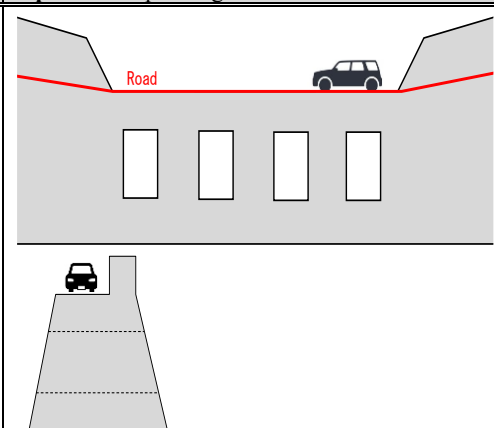
Table 4-17 Crest width of the overflow section^{※1}

Crest Width	1.5-2.5 m	3.0-4.0 m
Riverbed Materials	Sand and gravel	Cobbles to boulders
Sediment Transport Type	River sections with relatively little sediment transport or minimal debris flow	Debris flow zone

Source : ^{※1} SNI 2851-2021 _ Sabo dam Design, P.32

The riverbed material in both S2 area and S4 area is classified as “cobbles to boulders”, while the sediment transport type is “debris flow zone”. Therefore, the crest width was determined to be 3-4 meters as shown in Table 4-17. Furthermore, CD Kobokan 5 and CD Pelintas Curah Lengkong 2 in the S2 Package are planned to include road functions. Hence, a comparative review of the crest width for these two dams was conducted. As a result, Option 2 which includes both the crest width & road width and therefore is superior in safety, was adopted for CD Kobokan 5 and CD Pelintas Curah Lengkong 2 (Table 4-18).

Table 4-18 Crest width for CD Kobokan 5 and CD Pelintas Curah Lengkong 2

	Option 1: Utilizing the Crest as a Road	Option 2: Separating the Crest and Road
Overview Diagram		
Plan Overview	Utilize the crest as a road without a water flow section.	Separate the crest and road, and include a spillway section.
Safety	Dam Structure: The crest width is smaller compared to Option 2, making it difficult to ensure safety against external forces such as wear and damage. △	Dam Structure: The crest width is larger compared to Option 1, ensuring safety against external forces such as abrasion and damage. ○
	Overflow Area: Without a spillway, the overflow will be wide and the downstream erosion area will be larger. △	Overflow Area: With a spillway, the overflow area is narrow hence minimizing the downstream erosion. ○
Economic Efficiency	Main Dam: Smaller crest width provides economic advantages compared to Option 2. ○	Main Dam: Larger crest width results in lower economic efficiency compared to Option 1. △
	Downstream Riverbed Protection: Without a spillway, the downstream riverbed protection will be larger than Option 2, leading to less economic efficiency. △	Downstream Riverbed Protection: With a spillway, the downstream riverbed protection can be minimized, hence providing an economic advantage over Option 1. ○
Evaluation	△ Not Adopted	○ Adopted

The crest width of the existing sabo dams in the S2 area and S4 area is 4.0 meters and 3.0 meters, respectively. Therefore, the crest width of the planned dams will be the same as that of the existing sabo dams. The crest width for each facility is determined as shown in Table 4-19. Further, for CD Kobokan 5 and CD Pelintas Curah Lengkong 2, which will include road functions, the crest width has also been designed to accommodate the road width.

Table 4-19 Determination of crest width

Construction Package	Facility Name	Road Width	Crest Width	Total Crest Width
S2 Package	CD Kobokan 5	6.0 m	4.0 m	10.0 m
	CD Pelintas Curah Lengkong 2	6.0 m	4.0 m	10.0 m
S4 Package	KD Leprak 3	—	3.0 m	3.0 m
	DD Leprak 3	—	3.0 m	3.0 m
	DD Leprak 2	—	3.0 m	3.0 m

(2) Downstream Slope

To prevent abrasion from falling rocks in the overflow section and damage to the dam body due to direct impacts, the downstream slope of the dam is considered within the range of 1:0.2 to 1:0.0 (vertical) ^{*1}. However, the existing sabo dams in Mt. Semeru use a slope of 1:0.2. For a downstream gradient, 1:0.2^{*2} is generally adopted. In determining the upstream gradient for stability calculations, it is often economically advantageous to set the downstream gradient to 1:0.2. For this project, the same downstream slope as the existing dam will be adopted, selecting a slope of 1:0.2.

Table 4-20 Determination of downstream slope

Construction Package	Facility Name	Downstream Slope
S2 Package	CD Kobokan 5	1:0.2
	CD Pelintas Curah Lengkong 2	
S4 Package	KD Leprak 3	
	DD Leprak 3	
	DD Leprak 2	

Source : ^{*1} SNI 2851-2021 _Sabo dam Design, Page 6

^{*2}Technical Guidelines for Designing Sabo Facilities against Debris Flow and Driftwood

(3) Upstream Slope

The upstream slope of the dam body is determined based on the results of stability calculations. The details of the stability calculations are described in Section 4.5.3 Stability Calculations.

Table 4-21 Determination of upstream slope

Construction Package	Facility Name	Upstream Slope
S2 Package	CD Kobokan 5	1:0.2
	CD Pelintas Curah Lengkong 2	
S4 Package	KD Leprak 3	1:0.5
	DD Leprak 3	1:0.4
	DD Leprak 2	1:0.3

(4) Dam Body Material

The overflow section of the dam is expected to withstand not only normal flow but also flood flows and debris flows, which could lead to wear and damage from fine sediment and gravel. Therefore, the crest of the dam will be protected to prevent this. The crest of the dam shall be constructed using high-cement-content concrete (300kg/m³).

The dam body will be constructed using concrete (18-5-40BB), and coarse stone concrete (Cyclop) shall be used as the filling material. The coarse stone shall have an approximate diameter of 40 cm.

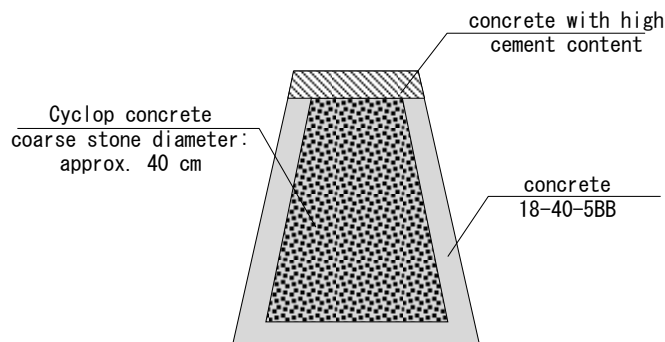


Figure 4-5 Embankment material (side view)

4.5.2 Foundation Design

It is specified that Table 4-22 shall be applied for the foundation depth of sabo dams. Based on the results of the field survey and boring survey, the geology of the foundation ground was grasped and the depth of foundation for each sabo dam was determined. From the results of the surveys, it was confirmed that there were no rocks exposed on the riverbed except for CD Pelintas Curah Lengkong2. For this reason, the foundation ground of CD Pelintas Curah Lengkong 2 was evaluated to be equivalent to soft rock, and the foundation was designed to have a depth of 2m from the deepest river bed level. For the other dams, the foundation was evaluated to be equivalent to earth, sand, gravel, and boulders, and therefore, the foundation depth of 3 m from the deepest river bed level was designed.

Table 4-22 Depth of foundation embedment

Dam structure \ Geology	Hard and medium hard rock	Soft rock	Soil, gravel, and boulders
Main sabo dm	1.0-1.5 m	1.5-2.0 m	2.5-3.0 m
Sub-dam and vertical wall	Equivalent to the main sabo dam		

4.5.3 Stability Calculation

It is specified the dam shall be met the following stability requirement under loading conditions during flood and debris flow:

- The resultant force line of the dam's weight and external forces must be within the central 1/3 of the base of the dam to ensure stability against overturning.
- The dam must be stable against sliding on the foundation.
- The allowable bearing capacity of the foundation must exceed the maximum stress caused by external loads.

Source : *1 SNI 2851-2021 _Sabo dam Design, Page 4

*2 Revisi SNI 03-2851-1991 _Tata Cara Perencanaan Teknik Bendungan Penahan Sedimen, Pages 9 to 10

(1) Design External Forces

It is specified the stability conditions and design external forces for the sabo dam shall be shown in Table 4-23 and Figure 4-6.

Table 4-23 Stability conditions and design external forces for the Sabo dam *1

Sabo Dam Heigh	Normal Conditions	During Debris Flow	During flood
Under 15 m		① Self-Weight ② Hydrostatic Pressure ③ Earth Pressure ④ Drag Force of Debris Flow	② Hydrostatic Pressure

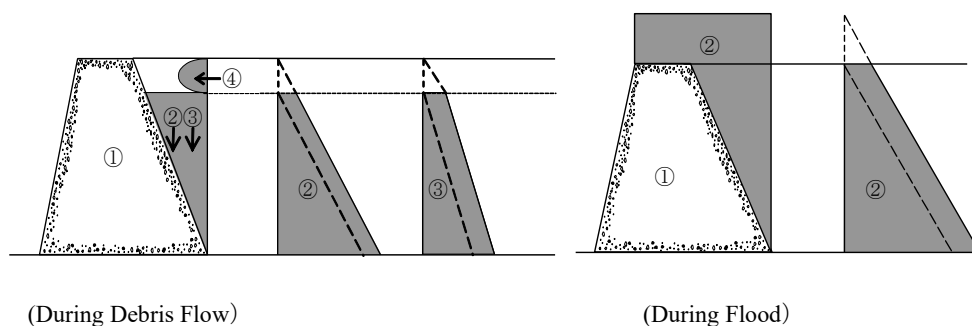


Figure 4-6 Design external forces for stability calculations of sabo dam *1

Source : *1 SNI 2851-2021 _Sabo dam Design, P.32

1) Self-Weight of the Dam

It is specified that the weight of the dam body shall be calculated using the following formula. The calculation of the dam body weight is detailed in the Appendix 4-3-1.

$$W = WC \times A$$

Where, W : Self-weight of dams per unit cross-sectional area (kN)
 A : The unit cross-sectional volume of the dam body (m³)
 WC : The unit weight of the dam body (kN/m³)

Source: ^{※1} SNI 2851-2021_Sabo dam Design, P.28, 34

^{※2} Revisi SNI 03-2851-1991_Tata Cara Perencanaan Teknik Bendungan Penahan Sedimen, P 26-28

2) Hydrostatic Pressure

It is specified that the hydrostatic pressure shall be calculated using the following formula. The water levels during flood events and debris flow events differ, as shown in Figure 4-7. The basis for calculating the hydrostatic pressure is provided in the Appendix 4-3-1.

$$P = W_o \times h_w$$

Where, P : Hydrostatic pressure at depth of h_w (kN/m³)
 W_o : Unit volume weight of muddy water (kN/m³)
 h_w : Depth of water (m)

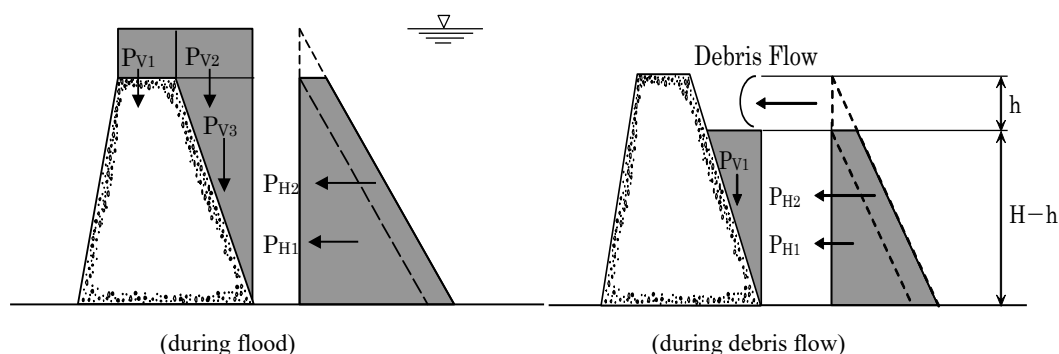


Figure 4-7 Hydrostatic pressure

Source: ^{※1} SNI 2851-2021_Sabo dam Design, P.28, 33~34

^{※2} Revisi SNI 03-2851-1991_Tata Cara Perencanaan Teknik Bendungan Penahan Sedimen, P.26~28

3) Earth Pressure

It is specified that the earth pressure shall be calculated using the following formula. The sediment height is obtained by subtracting the debris flow depth from the dam height, as shown in Figure 4-8. The basis for calculating sediment pressure is provided in the Appendix 4-3-1.

$$P_{eV} = W_{si} \times h_e$$

$$P_{eH} = C_e \times W_{si} \times h_e$$

Where, P_{eV} : Horizontal component of earth pressure (kN/m²)
 P_{eH} : Horizontal earth pressure (kN/m²)
 W_{si} : Unit weight of sediment in muddy water (kN/m³)
 h_e : Sediment height (m)
 C_e : Earth pressure coefficient

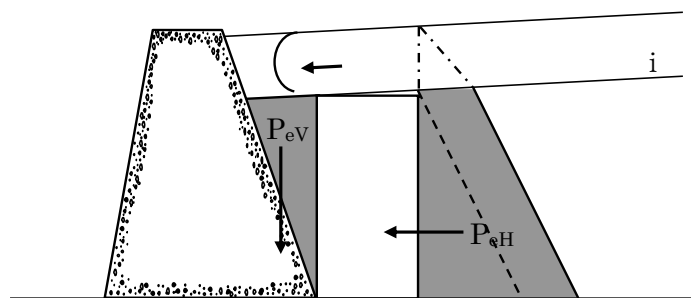


Figure 4-8 Sediment pressure

Source: ^{※1} SNI 2851-2021_Sabo dam Design, P.28, 33~34

4) Drag Force of Debris Flow

It is specified that the drag force of debris flow shall be calculated using the following formula. The basis for calculating the drag force of debris flow, debris flow velocity, and debris flow depth is detailed in Appendix 4-3-1.

$$F = \alpha \frac{\rho_d}{g} h U^2$$

- Where,
- F : Drag force of debris flow per unit width (kN/m)
 - U : Debris flow velocity (m/s)
 - h : Debris flow depth (m)
 - g : Gravitational acceleration (9.8 m/s²)
 - α : Coefficient (assumed to be 1.0)
 - ρ_d : Unit weight of the debris flow (kN/m³)
 $= (\sigma \times C_d + \rho (1 - C_d)) - \rho = 2.6 \times C_d + 1.2 (1 - C_d)$

The load due to drag force of debris flow is considered most dangerous against overturning and bearing capacity when the sediment accumulation space is nearly full, leaving only the depth of the debris flow as a space for impact. Therefore, the position of the debris flow force load is calculated by assuming that it acts at a height of $h/2$ from the crest elevation, as shown in Figure 4-9.

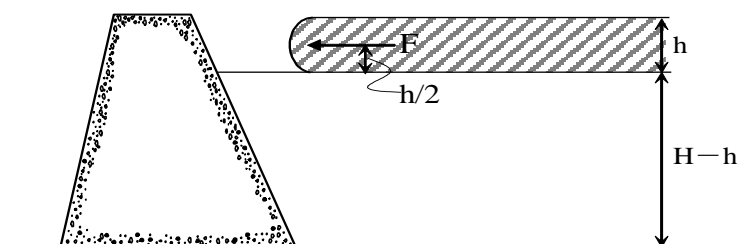


Figure 4-9 Drag force of debris flow^{※2}

It is specified that the velocity of the debris flow shall be calculated using the following equation:

$$h = \frac{Q_{sp}}{B \cdot U} = \left\{ \frac{n \cdot Q_{sp}}{B(\sin \theta)^{0.5}} \right\}^{3/5}$$

$$U = \frac{1}{n} h^{2/3} (\sin \theta)^{1/2}$$

- Where,
- h : Debris flow depth (m)
 - Q_{sp} : Peak discharge of debris flow (m³ /s)
 - B : Width of the debris flow (m)
 - U : Velocity of the debris flow (m/s)
 - n : Roughness coefficient (front section: 0.1)

θ : Riverbed slope ($^{\circ}$)

Source: ^{※1} SNI 2851-2021_Sabo dam Design, P.56

^{※2} SNI 2851-2021_Sabo dam Design, P.28, 33~34

^{※3} SNI 2851-2021_Sabo dam Design, P.15

(2) Stability Analysis

1) Stability Against Overturning

Resultant force consisting of a dam's self-weight and external forces must be within the central 1/3 of the dam to ensure stability against overturning. It is specified this stability condition shall be checked by following equation^{※1}.

$$X = \frac{M}{V}$$

$$e = X - \frac{1}{2}b_2 \leq \frac{1}{6}b_2$$

Where, X : Length to point of application of force in dam base (m)

M : Sum of the moments of the loads acting on the cross-section per unit width, measured from the upstream end of the dam body (kN/m³)

V : Total vertical force per unit width acting on the cross-section (kN/m)

b_2 : Base width of the dam (m)

e : Distance from the intersection of the resultant line of the loads to the center of the dam base (m)

Source: ^{※1} SNI 2851-2021_Sabo dam Design, P.15~17

^{※1} Revisi SNI 03-2851-1991_Tata Cara Perencanaan Teknik Bendungan Penahan Sedimen, P.9-10

2) Stability Against Sliding

It is specified the stability against sliding between the dam base and the foundation shall be confirmed using the following equation^{※1}.

$$N \leq \frac{f \times V}{H}$$

Where, N : Safety factor against sliding ($N = 1.2$ for gravel foundations, $N = 4.0$ for rock foundations)

f : Friction coefficient (refer to Table 4-3)

V : Total vertical force per unit width of the section (kN/m)

H : Total horizontal force per unit area of the section (kN/m)

Source: ^{※1} SNI 2851-2021_Sabo dam Design, P.15-17

^{※1} Revisi SNI 03-2851-1991_Tata Cara Perencanaan Teknik Bendungan Penahan Sedimen, P.9-10

3) Stability Against the Sinking of Foundation

Dam foundation must have sufficient strength to withstand the vertical load from the dam. Specifically, the allowable bearing capacity of the foundation must be greater than the maximum stress due to external loads. It is specified this stability condition shall be checked using the following equation^{※1}. Additionally, it is specified that stability against tensile stress shall be also calculated using this equation^{※1}.

$$\sigma_{\max} = \frac{V}{b_2} \cdot \left(1 + \frac{6e}{b_2}\right) < ga \quad \sigma_{\min} = \frac{V}{b_2} \cdot \left(1 - \frac{6e}{b_2}\right) > 0$$

Where, σ_{\max} : Maximum vertical stress at the dam base (kN/m²)

- σ_{min} : Minimum vertical stress at the dam base (kN/m²)
- V : Total vertical force per unit width of the section (kN/m)
- b_2 : Base width of the dam (m)
- e : Distance from the intersection point of the resultant force line and the dam base to the center of the base (m)
- ga : Allowable bearing capacity of the foundation soil (kN/m²)

Source: *¹ SNI 2851-2021_Sabo dam Design, P.15~17

(3) Results of Stability Calculation

The basis for the stability calculation is detailed in Appendix 4-3-1. The results confirms that the designed dam meets all necessary stability requirements as follows:

Table 4-24 Stability calculation results for CD Kobokan 5

	During Flood					
	Overflow Section Upstream Slope = 1:0.3	Stability against overturning	e	2.19	<	2.21
Stability against sliding		τ	1.25	>	1.2	OK
Maximum ground reaction force		σ_{max}	521.30	<	600	OK
Minimum ground reaction force		σ_{min}	2.10	>	0	OK
During Debris Flow						
Stability against overturning		e	1.47	<	2.21	OK
Stability against sliding		τ	1.37	>	1.2	OK
Maximum ground reaction force		σ_{max}	426.80	<	600	OK
Minimum ground reaction force	σ_{min}	85.40	>	0	OK	
During Flood						
Non-Overflow Section Upstream Slope = 1:0.2	Stability against overturning	e	1.01	<	2.43	OK
	Stability against sliding	τ	8.77	>	4.00	OK
	Maximum ground reaction force	σ_{max}	352.40	<	1,200	OK
	Minimum ground reaction force	σ_{min}	146.00	>	0.00	OK
	During Debris Flow					
	Stability against overturning	e	0.61	<	2.43	OK
	Stability against sliding	τ	9.21	>	4.00	OK
	Maximum ground reaction force	σ_{max}	318.90	<	1,200	OK
Minimum ground reaction force	σ_{min}	190.80	>	0.00	OK	

Table 4-25 Stability calculation results for CD Pelintas Curah Lengong 2

	During Flood					
	Overflow Section Upstream Slope = 1:0.3	Stability against overturning	e	1.72	<	1.96
Stability against sliding		τ	7.26	>	4.00	OK
Maximum ground reaction force		σ_{max}	422.70	<	1,200	OK
Minimum ground reaction force		σ_{min}	27.10	>	0.00	OK
During Debris Flow						
Stability against overturning		e	1.00	<	1.96	OK
Stability against sliding		τ	9.34	>	4.00	OK
Maximum ground reaction force		σ_{max}	310.50	<	1,200	OK
Minimum ground reaction force	σ_{min}	100.80	>	0.00	OK	

Non-Overflow Section Upstream Slope = 1:0.2	During Flood					
	Stability against overturning	e	1.01	<	2.43	OK
	Stability against sliding	τ	1.69	>	1.20	OK
	Maximum ground reaction force	σ_{max}	352.40	<	600	OK
	Minimum ground reaction force	σ_{min}	146.00	>	0.00	OK
	During Debris Flow					
	Stability against overturning	e	0.61	<	2.43	OK
	Stability against sliding	τ	1.81	>	1.20	OK
Maximum ground reaction force	σ_{max}	318.90	<	600	OK	
Minimum ground reaction force	σ_{min}	190.80	>	0.00	OK	

Table 4-26 Stability calculation results for KD Leprak 3

Overflow Section Upstream Slope 1:0.5	During Flood					
	Stability against overturning	e	1.09	<	1.32	OK
	Stability against sliding	τ	1.33	>	1.20	OK
	Maximum ground reaction force	σ_{max}	254.40	<	600	OK
	Minimum ground reaction force	σ_{min}	23.80	>	0.00	OK
	During Debris Flow					
	Stability against overturning	e	0.52	<	1.32	OK
	Stability against sliding	τ	1.77	>	1.20	OK
Maximum ground reaction force	σ_{max}	172.60	<	600	OK	
Minimum ground reaction force	σ_{min}	75.60	>	0.00	OK	
Non-Overflow Section Upstream Slope = 1:0.5	During Flood					
	Stability against overturning	e	1.31	<	1.32	OK
	Stability against sliding	τ	1.44	>	1.20	OK
	Maximum ground reaction force	σ_{max}	323.40	<	600	OK
	Minimum ground reaction force	σ_{min}	0.70	>	0.00	OK
	During Debris Flow					
	Stability against overturning	e	1.07	<	1.32	OK
	Stability against sliding	τ	1.41	>	1.20	OK
Maximum ground reaction force	σ_{max}	322.90	<	600	OK	
Minimum ground reaction force	σ_{min}	33.70	>	0.00	OK	

Table 4-27 Stability calculation results for DD Leprak 3

Overflow Section Upstream Slope = 1:0.4	During Flood					
	Stability against overturning	e	0.77	<	1.00	OK
	Stability against sliding	τ	1.33	>	1.20	OK
	Maximum ground reaction force	σ_{max}	193.10	<	600	OK
	Minimum ground reaction force	σ_{min}	25.60	>	0.00	OK
	During Debris Flow					
	Stability against overturning	e	0.35	<	1.00	OK
	Stability against sliding	τ	1.92	>	1.20	OK
Maximum ground reaction force	σ_{max}	120.40	<	600	OK	
Minimum ground reaction force	σ_{min}	58.10	>	0.00	OK	

Non-Overflow Section Upstream Slope = 1:0.4	During Flood					
	Stability against overturning	e	0.95	<	1.00	OK
	Stability against sliding	τ	1.57	>	1.20	OK
	Maximum ground reaction force	σ_{max}	281.80	<	600	OK
	Minimum ground reaction force	σ_{min}	7.60	>	0.00	OK
	During Debris Flow					
	Stability against overturning	e	0.83	<	1.00	OK
	Stability against sliding	τ	1.51	>	1.20	OK
	Maximum ground reaction force	σ_{max}	281.20	<	600	OK
	Minimum ground reaction force	σ_{min}	27.00	>	0.00	OK

Table 4-28 Stability calculation results for DD Leprak 2

Overflow Section Upstream Slope = 1:0.3	During Flood					
	Stability against overturning	e	0.82	<	0.92	OK
	Stability against sliding	τ	1.22	>	1.20	OK
	Maximum ground reaction force	σ_{max}	207.70	<	600	OK
	Minimum ground reaction force	σ_{min}	11.10	>	0.00	OK
	During Debris Flow					
	Stability against overturning	e	0.39	<	0.92	OK
	Stability against sliding	τ	1.76	>	1.20	OK
	Maximum ground reaction force	σ_{max}	126.80	<	600	OK
	Minimum ground reaction force	σ_{min}	51.10	>	0.00	OK
Non-Overflow Section Upstream Slope = 1:0.3	During Flood					
	Stability against overturning	e	0.81	<	0.92	OK
	Stability against sliding	τ	1.80	>	1.20	OK
	Maximum ground reaction force	σ_{max}	341.00	<	600	OK
	Minimum ground reaction force	σ_{min}	20.30	>	0.00	OK
	During Debris Flow					
	Stability against overturning	e	0.76	<	0.92	OK
	Stability against sliding	τ	1.70	>	1.20	OK
	Maximum ground reaction force	σ_{max}	343.70	<	600	OK
	Minimum ground reaction force	σ_{min}	33.10	>	0.00	OK

4.5.4 Type of the Opening Section

(1) Selection Policy for Opening Type

The proposed dam shall be an open-type sabo dam, designed to allow constant water flow through the openings. The opening type can be selected between slit type and conduit types. The slit type opening is prone to significant damage and wear due to collisions with boulders, as the piers (the concrete section between the slits) are vulnerable to this. Therefore, conduit type is preferred.

However, for the conduit type, a beam-shaped concrete section with an upper slab (at least 3-4 m in width) is required to integrate the left and right concrete sections at the top of the conduit. This will ensure the structural stability. If the dam height is restricted by topographic factors, making it impossible to provide an upper slab equal or greater than the top width, the slit type shall be used to maintain the required open space. As a result, it was determined to use a conduit type for the S2 area and a slit type for the S4 area.

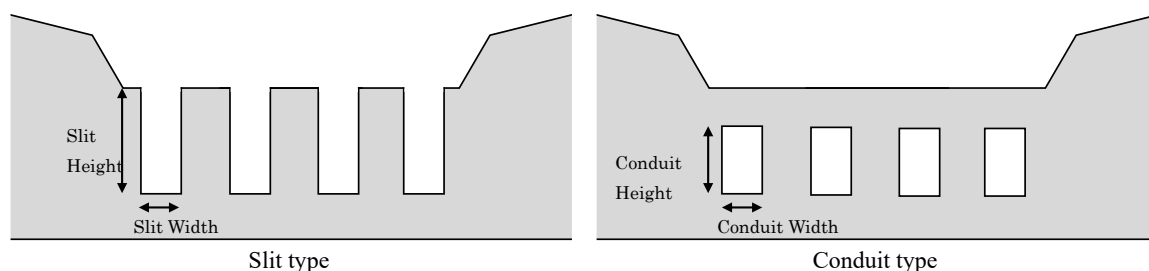


Figure 4-10 Type of the opening section

(2) Effective Height and Dam Height

The study on the dam height is described in “3.8 Basic Design of S2 Area” and “3.9 Basic Design of S4 Area”. Heights for sabo dams are generally determined in 0.5 m increments. The summary of the effective height from the crest of the opening section to the crest of the overflow section and the total dam height are presented in Table 4-29. As shown in Figure 4-11, the elevation of the crest of the dam opening section is planned to be higher than the elevation of the crest of the sub-dam or the sub-dam’s opening.

Table 4-29 Effective height and dam height

Construction Package	Facility name	Effective height	Dam height
S2 Package	CD Kobokan 5	10.0 m	14.5 m
	CD Pelintas Curah Lengkong 2	8.5 m	11.5 m
S4 Package	KD Leprak 3	4.0 m	7.0 m
	DD Leprak 3	2.0 m	5.0 m
	DD Leprak 2	2.0 m	5.0 m

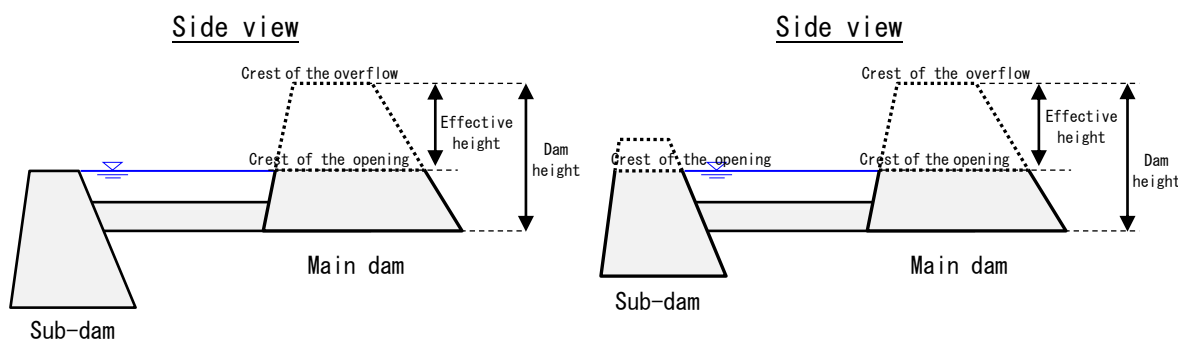


Figure 4-11 Outline of effective height and dam height

(3) Determination the Opening Height

In the S4 area, KD Leprak 3, DD Leprak 3, and DD Leprak 2 have small effective heights, making it difficult to install the upper slab of the beam-shaped concrete. Therefore, the slit type shall be adopted for these dams. The purpose of the upper slab of the beam-shaped concrete is to ensure a thickness that could withstand the impact of boulder. It shall be equal to or greater than the crest width, and 4m is planned.

Table 4-30 Opening height

Construction Package	Facility Name	Type	Width	Height
S2 Package	CD Kobokan 5	Conduit Type	3.0m	4.0m
	CD Pelintas Curah Lengkong 2			4.5m
S4 Package	KD Leprak 3	Slit Type	3.0m	4.0m
	DD Leprak 3			2.0m

Construction Package	Facility Name	Type	Width	Height
	DD Leprak 2			2.0m

Source: *¹ SNI 2851-2021_Sabo dam Design, P.12

(4) Determination of Opening Width

It is specified that the width of the opening shall be 1.5 times the maximum gravel diameter (D_{95})^{*1}. The maximum boulder diameter is 2.5 m (Table 4-10), so it becomes 3.75 m, which is 1.5 times of the diameter. As the width of the opening is increased, there is a risk that the earth and sand will flow out of the opening, making it more difficult to capture the debris flow. Therefore, the opening width is set to 3.0 m to capture the debris flow more easily.

(5) Opening Configuration

Openings are positioned in the overflow section, and it was confirmed whether the clear water flow rate could be discharged through the openings alone. The basis for calculating the discharge capacity of the openings is detailed in Appendix 4-3-1. If the number of openings in the proposed dam is set as shown in Table 4-31, it is confirmed that the discharge can pass through the openings alone.

For DD Leprak 2 and DD Leprak 3, the width of the overflow section is approximately 800 m and the river channel position is shifting within the sand pocket area. The results of the on-site survey show that the river at the relevant location flowed down to one side of either the left bank or the right bank. For this reason, assuming that discharge would flow along only one side, it was confirmed that discharge would be able to flow even through half the number of openings installed ($76/2 = 38$).

Table 4-31 Opening configuration

Construction Package	Facility name	Opening height	Water depth when flowing down the opening section	Number of placement
S2 area	CD Kobokan 5	6.0 m	2.7 m	14 locations
	CD Pelintas Curah Lengkong 2	4.5 m	4.2 m	7 locations
S4 area	KD Leprak 3	4.0 m	3.0 m	14 locations
	DD Leprak 3	2.0 m	1.6 m (38 locations)	76 locations
	DD Leprak 2	2.0 m	1.6 m (38 locations)	76 locations

4.5.5 Apron Design

(1) Apron Works

The design of the apron works for the planned sabo dam was carried out. The calculation basis for the thickness and length of the apron is detailed in the Appendix 4-3-1.

1) Thickness of Apron

The thickness of the apron is influenced by factors such as the quality of the water falling from the spillway section (whether it contains gravel or boulders), the presence or absence of a protection pool on top of the apron, and the foundation of the apron. It is specified that the thickness of apron shall be calculated using the formula shown below. In the proposed sabo dam, the existing dam will be used as a sub-dam, and a water cushion pool will be formed in front of the main dam. Therefore, the thickness of the apron was calculated assuming the case that there is a water cushion pool on a gravelly foundation. The calculation of the thickness of apron is detailed in the Appendix 4-3-1.

- For gravelly foundation with no protection pool:

$$t = 0.2 \times (0.6 h_1 + 3h_3 - 1.0)$$

In the case of calculating based on dam height (H), the above formula can be transformed into the following expression.^{※2}

$$t = \frac{0.2 \times (0.6H + 3h_3 - 1.0)}{1.12}$$

- In the case of gravelly soil with a protection pool:

$$t = 0.1 \times (0.6h_1 + 3h_3 - 1.0)$$

When calculating with respect to the dam height (H), the above formula can be transformed as follows.^{※2}

$$t = \frac{0.1 \times (0.6H + 3h_3 - 1.0)}{1.06}$$

Where, t : Thickness of the apron (m)
 H : Dam height (m)
 h_3 : Design water depth of the dam (m)
 h_1 : Effective drop (m) ($H-t$)

Table 4-32 Determined thickness of the apron

Construction package	Facility name	Apron thickness
S2 Package	CD Kobokan 5	2.0 m
	CD Pelintas Curah Lengkong 2	2.0 m
S4 Package	KD Leprak 3	2.0 m

Source : ^{※1} SNI 2851-2021 _Sabo dam Design, P.2

^{※2} Revisi SNI 03-2851-1991 _Tata Cara Perencanaan Teknik Bendungan Penahan Sedimen, P. 12

^{※3} Erosion control design formula collection p133

2) Apron Length

The riverbed immediately downstream of a sabo dam is at risk of being scoured by the energy of the falling water from the dam. Hence, it is crucial to secure the required length of the apron to prevent erosion. It is specified that sabo dams with a height of 15 m or less, the following empirical formula^{※1} shall be applied to determine the necessary apron length. The calculation of the Apron Length is detailed in the Appendix 4-3-1.

$$L = (1.5 \sim 2.0) \times (H_1 + h_3) \text{ (L is rounded up to the nearest 1.0 m)}$$

Where, L : Length of the apron (including the vertical wall crest) (m)
 H_1 : Effective height of the dam (dam height – apron thickness) (m)
 h_3 : Design water depth of the dam (m)

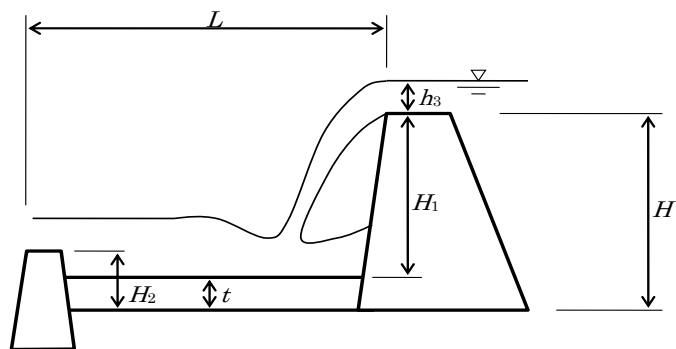


Figure 4-12 Positional relation between main dam and sub-dam

Source: ^{※1} SNI 2851-2021_Sabo dam Design, P.19

^{※1} Revisi SNI 03-2851-1991_Tata Cara Perencanaan Teknik Bendungan Penahan Sedimen, P.12

(2) Overlap Height

It is specified that the overlap height (H_2) between the main dam and the sub-dam shall be determined using an empirical formula ^{※1}. The calculation basis for the overlap height is provided in the Appendix 4-3-1.

$$H_2 = \left(\frac{1}{3} \sim \frac{1}{4} \right) \times H$$

Where, H_2 : The overlap height between the main dam and the sub-dam. (m)

H : Height of the main dam (m)

(Refer to Figure 4-10 for the positional relationship)

Source: ^{※1} SNI 2851-2021_Sabo dam Design, P.7

^{※1} Revisi SNI 03-2851-1991_Tata Cara Perencanaan Teknik Bendungan Penahan Sedimen, P.7

4.6 Training Dike Design

4.6.1 Slope of the Embankment

It is desirable that the slope of the training dike be as steep as possible in order to avoid the risk of overflow due to the debris flow climbing up the slope. Therefore, 1:1.0 is adopted for the dike gradient. However, It is specified that the stable slope of the embankment shall be 1:1.5^{※1}. For this reason, steps with width of 2.5 m are installed every 5m in height of the dike. The mean gradient of the dike slope including the steps is planned to be 1:1.5.

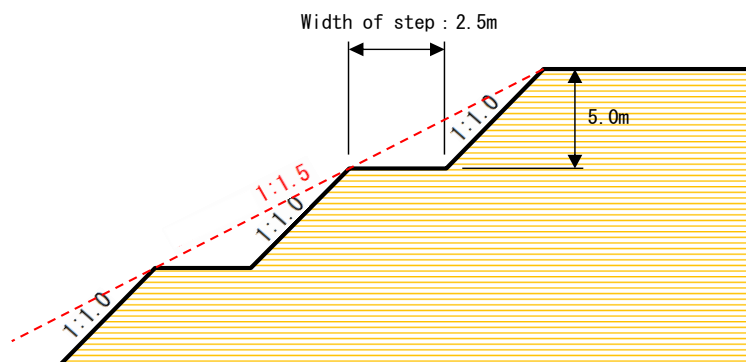


Figure 4-13 Schematic diagram of training dike slope

Source: ^{※1} Pd T-16-2004-A_Perencanaan Teknis Tanggul pada Sungai Lahar, P.15

4.6.2 Crest Width

The crest width of the training dike is standardized to be at least 4 meters to ensure proper compaction work and structural strength. Therefore, It is planned to secure a crest width of at least 4.0 meters.

Source : *¹ Pd T-16-2004-A_Perencanaan Teknis Tanggul pada Sungai Lahar, P3

4.6.3 Depth of Foundation Embedment

It is specified the foundation embedment for the training dikes shall be typically required to be at least 1.0 meters, as per standard practices*¹. However, existing dikes in Mt. Semeru area adopt a foundation embedment of 1.5 m (Figure 4-14). Since sand mining is carried out in the target area and considering possibility of excessive excavation due to sand mining, the foundation of dike is also planned to be embedded at 1.5m from the sediment management line.

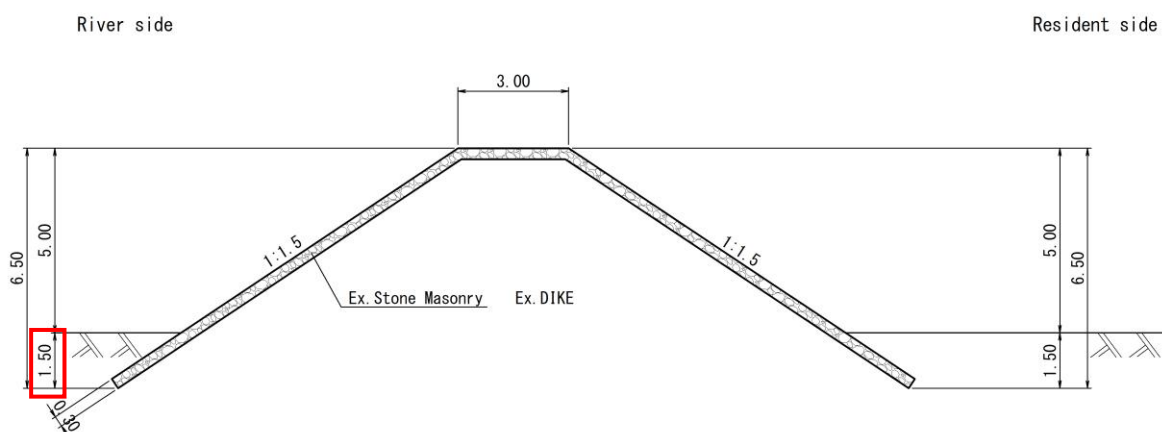


Figure 4-14 Embedment of existing training dike (example: Tanggul Leprak 22)

Source : *¹ Pd T-16-2004-A_Perencanaan Teknis Tanggul pada Sungai Lahar, P12

4.6.4 Training Dike Height

The alluvial fan in the volcanic area is still in the developing stage during volcanic activity, and the riverbeds in these areas are at high risk of being buried due to riverbed elevation increases. The water and debris in these areas tend to flow perpendicularly to the contour lines (along the steepest gradient) and radiating outward from the apex of the fan (the river channel), which causes the floods to spread laterally.

The function of the training dikes is to redirect this lateral flow back towards the center of the river channel. Therefore, the worst case scenario is assumed in the design. The height of the dike is determined by calculating the hydraulic jump to ensure that even if the debris flows strike the dike at right angles to the normal direction of the dike, the flow will not overtop the dike. This is different from river dike designed to handle parallel flows in river channels, as the function and methods for determining the necessary height differ for a training dike.

(1) Examination of Water Depth Considering the Height of Hydraulic Jump

It is specified that sabo dams with a height of 15 m or less, the following empirical formula*¹ shall be applied to determine the necessary apron length. The water depth considering the height of hydraulic jump (h_2) is calculated using the following formula*¹:

$$h_2 = \frac{-1 + \sqrt{1 + 8Fr^2}}{2} + h_1$$

$$Fr = \frac{U}{\sqrt{gh_1}}$$

Where, h_1 : Water depth during debris flow (m)
 h_2 : Water depth during debris flow plus hydraulic jump height (m)
 U : Velocity of debris flow (m/s)
 Fr : Froude number
 g : Gravitational acceleration (m/s²)

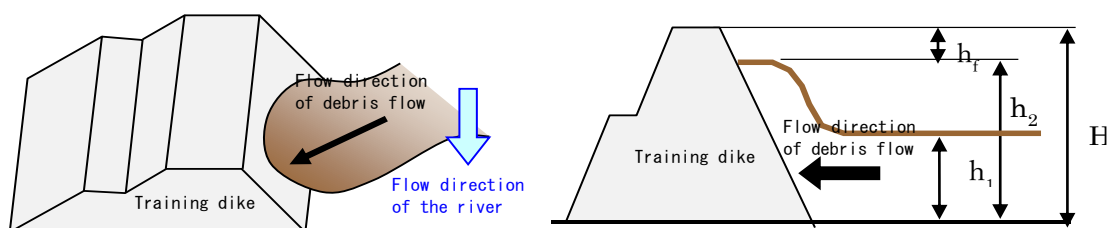


Figure 4-15 Hydraulic jump height (left: overhead view, right: cross-sectional view)

Source: ^{※1} Pd T-16-2004-A_Perencanaan Teknis Tanggul pada Sungai Lahar, P.7

(2) Examination of Training Dike Height

The height of the training dike is determined by adding a freeboard to the water depth considering the hydraulic jump height. The required freeboard is as specified in

Table 4-33. The basis for the calculation of the training dike height is detailed in the Appendix 4-3-2.

Table 4-33 List of freeboard heights^{※1}

Design Discharge (m ³ /s)	Freeboard Height (m)
Less than 200	0.6
200-500	0.8
500-2000	1.0

Source: ^{※1} Pd T-16-2004-A_Perencanaan Teknis Tanggul pada Sungai Lahar, P.15

4.7 Design Drawing Preparation

Based on the results of the previous section, design drawings have been created. The design drawings for each facility are as shown on the next page. The complete set of drawings is attached in Appendix 4-3-3.

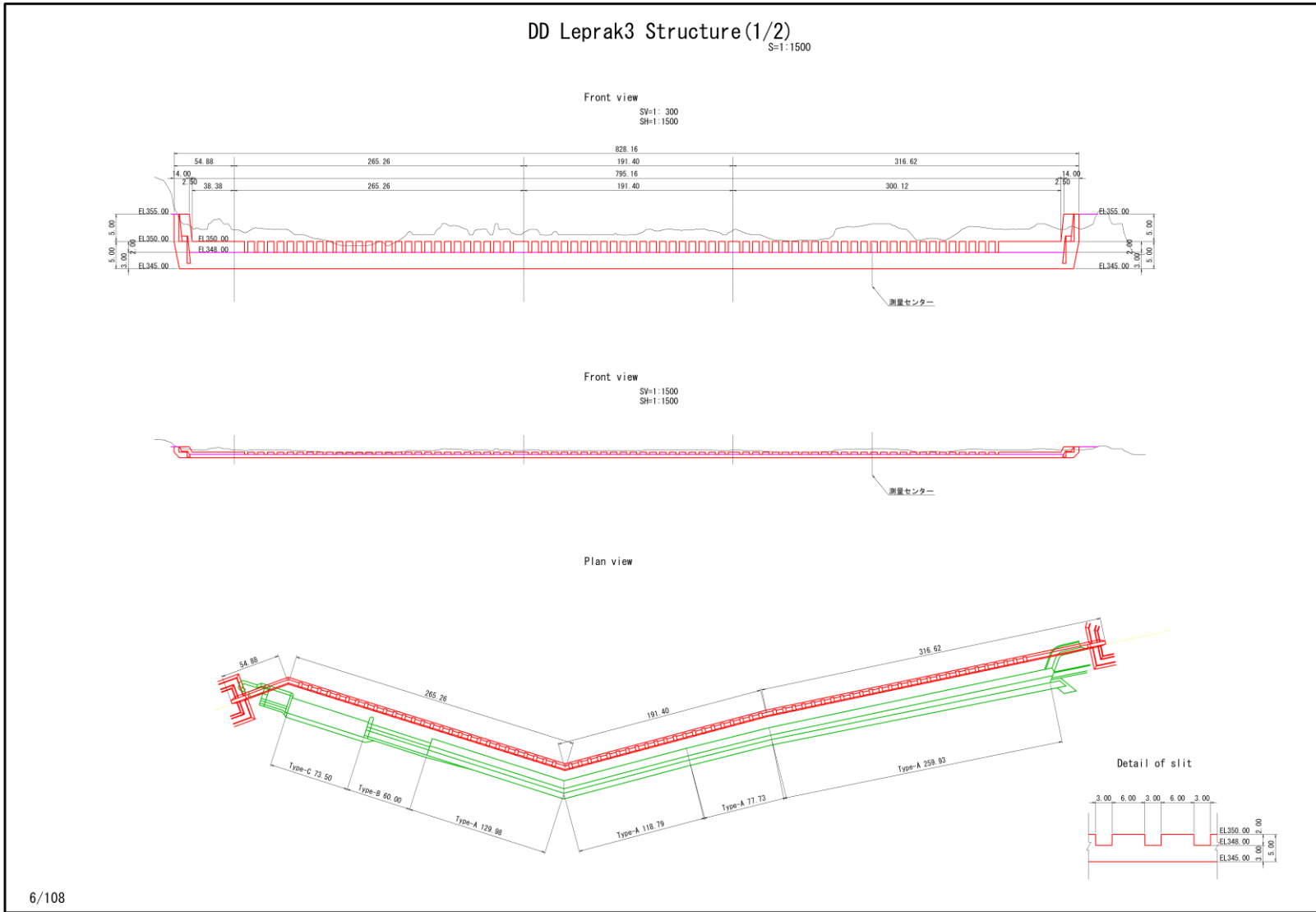


Figure 4-19 Drawings for DD Leprak 3

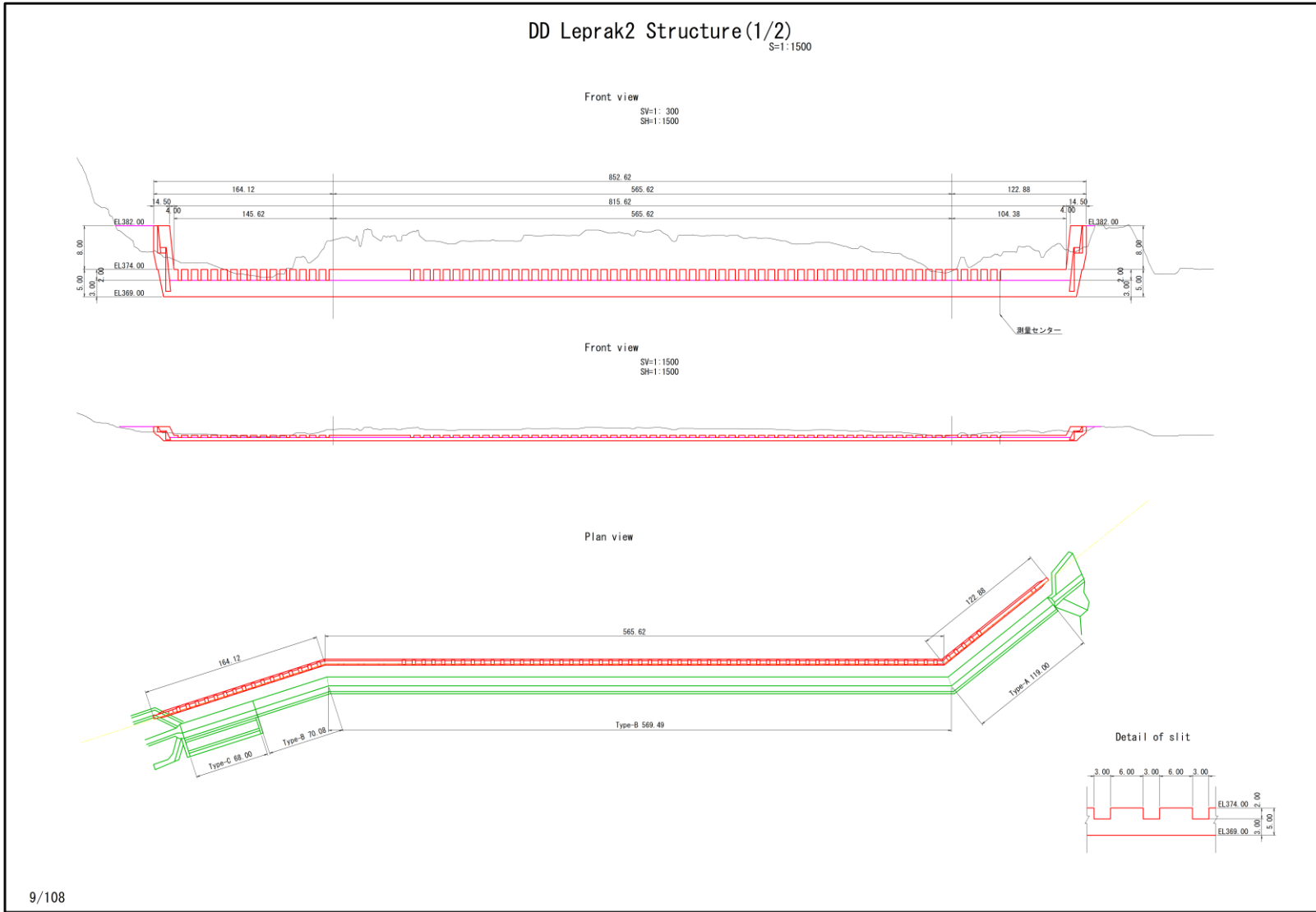


Figure 4-20 Drawings for DD Leprak 2

CHAPTER 5 CONSTRUCTION PLAN

5.1 Referenced Standards

The standards referenced in preparing the construction plan for this project are shown in Table 5-1.

The Indonesian standards include provisions on working capacity of heavy equipment and daily work volumes for schedule calculation (items 1 and 2 in Table 5-1), as well as standards for materials and testing methods (items 3 to 12 in Table 5-1). However, there are no specific guidelines or manuals regarding the construction methods for sabo dam facilities.

In contrast, Japanese standards such as the Technical Guideline for Establishing Sabo Master Plan against Debris Flow and Driftwood, and the Technical Guideline for Designing Sabo Facilities against Debris Flow and Driftwood, and their commentaries contain limited details on construction planning. However, based on aforementioned Technical Guidelines, the “Guidelines for Sabo Facility Design, Volume 7: Construction” published by the Chubu Regional Development Bureau of the Ministry of Land, Infrastructure, Transport and Tourism, includes essential basic construction plan items for sabo dam facilities.

The draft construction plan for this project was compiled with reference to these applicable standards, as detailed in Appendix 5-1.

Table 5-1 List of referenced standards

No	Document Title	Year of Publication	Publisher
1	Ministry of Public Works and Public Housing of the Republic of Indonesia Regulation No. 8 of 2023 on Guidelines for Preparing Cost Estimates for Construction Work in Public Works and Public Housing Sector	2023	<i>PUPR, Indonesia</i>
2	Circular Letter No. 73/SE/Dk/2023 on Procedures for Preparing Cost Estimates for Construction Work in Public Works and Public Housing Sector	2023	<i>PUPR, Indonesia</i>
3	SNI 03-3976-1995: Procedure for mixing and pouring concrete	1995	<i>Badan Standarisasi Nasional, Indonesia</i>
4	SNI 03-2400-1991 on General Planning Procedures for River Weirs	1991	<i>Badan Standarisasi Nasional, Indonesia</i>
5	SNI 03-1974-1990: Test method for compressive strength of concrete	1991	<i>Badan Standarisasi Nasional, Indonesia</i>
6	SNI 03-2492-1991: Sampling and testing method for core concrete	1991	<i>Badan Standarisasi Nasional, Indonesia</i>
7	SNI 03-1972-1990: Test method for concrete slump	1990	<i>Badan Standarisasi Nasional, Indonesia</i>
8	SNI 03-1743-1989: Heavy compaction test method for soil	1989	<i>Badan Standarisasi Nasional, Indonesia</i>
9	SNI 03-1966-1989: Test method for determining the plastic limit	1989	<i>Badan Standarisasi Nasional, Indonesia</i>
10	SNI 03-1967-1989: Test method for determining the liquid limit	1989	<i>Badan Standarisasi Nasional, Indonesia</i>
11	SNI 03-1968-1989: Sieve analysis test method for coarse aggregates	1989	<i>Badan Standarisasi Nasional, Indonesia</i>
12	SNI 03-1969-1989: Test method for dry density of soil	1989	<i>Badan Standarisasi Nasional, Indonesia</i>
13	Guidelines for Sabo Facility Design, Volume 7: Construction	2020	Chubu Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism

Source: Prepared by JICA Project Team

5.2 Construction Plan

5.2.1 Scope of Work

The main work to be carried out in this project is outlined in Table 5-2.

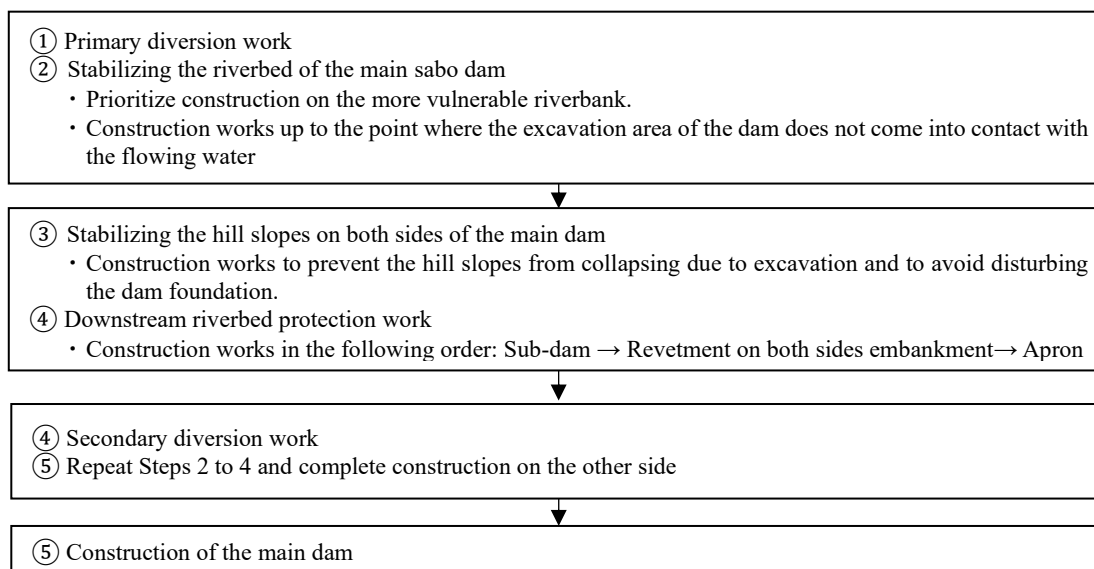
Table 5-2 Facilities and main work types

Area	Facility Name	Main Works Types
S2	<ul style="list-style-type: none"> – CD Kobokan 5 – CD Pelintas Curah Lengkong 2 – Tanggul Curah Lengkong 	<ol style="list-style-type: none"> 1. Preparation work <ul style="list-style-type: none"> • Equipment and material yard • Worker accommodation and management office setup • Mobilization and demobilization of heavy equipment • Temporary road 2. Sabo dam <ul style="list-style-type: none"> • Concrete work • Rubble concrete work (cyclopean concrete) • Reinforcing steel work, formwork work, scaffolding work • Diversion work (temporary cofferdam, sandbag work) 3. Diversion dike <ul style="list-style-type: none"> • Excavation work, embankment work • Concrete work • Geotextile work
S4	<ul style="list-style-type: none"> – Krib Hulu Leprak – Tanggul Leprak 22 – Tanggul Leprak 23 – Tanggul Leprak 24 – Tanggul Leprak 25 – Tanggul Leprak 26 – KD Leprak 3, – DD Leprak 2, – DD Leprak 3 – Tanggul Leprak XVII Kebondeli 2021 – Tanggul Emergency, – Tanggul Leprak II-D 	

Source: Prepared by JICA Project Team

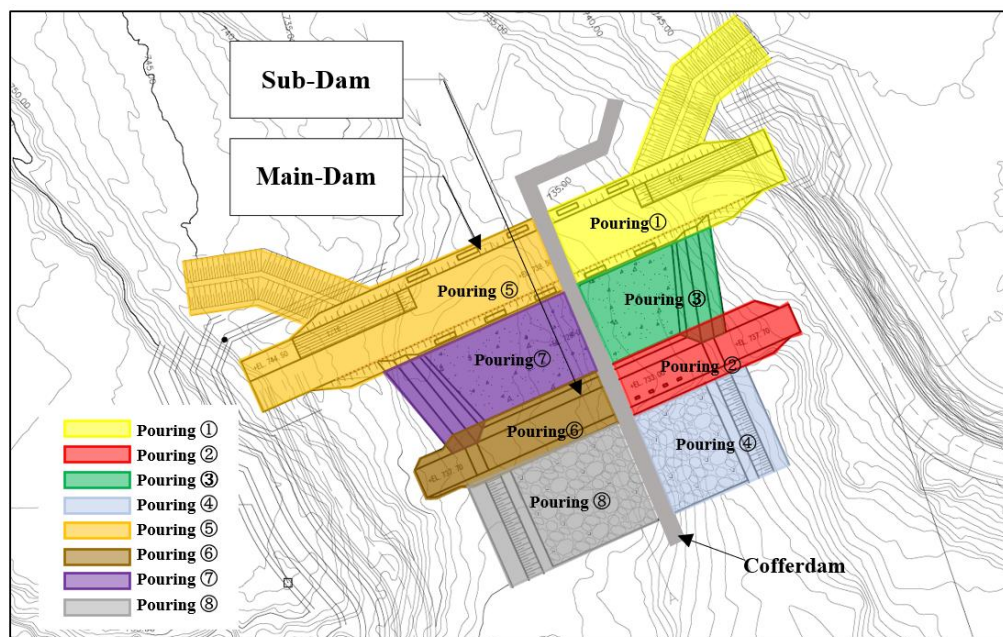
5.2.2 Construction Procedure of Sabo Dam

The construction sequence for sabo dam will follow the order shown in Figure 5-1 as the basic guideline. The starting side of the dam for concrete works is determined after a comprehensive assessment of factors such as access from the existing road, traffic flow from the equipment and material yard, temporary construction plans, and surrounding constraints. In this construction phase (S2 area and S4 area), access is available from the existing road on the left bank, and the equipment and material yard (proposed) are located on the same side. Therefore, to shorten the construction period and reduce costs, concrete works will begin from the left bank. Figure 5-2 illustrates the construction procedure for CD Pelintas Curah Lengkong 2 in the S2 area as an example.



Source: Prepared by JICA Project Team

Figure 5-1 Construction procedures of Sabo dam



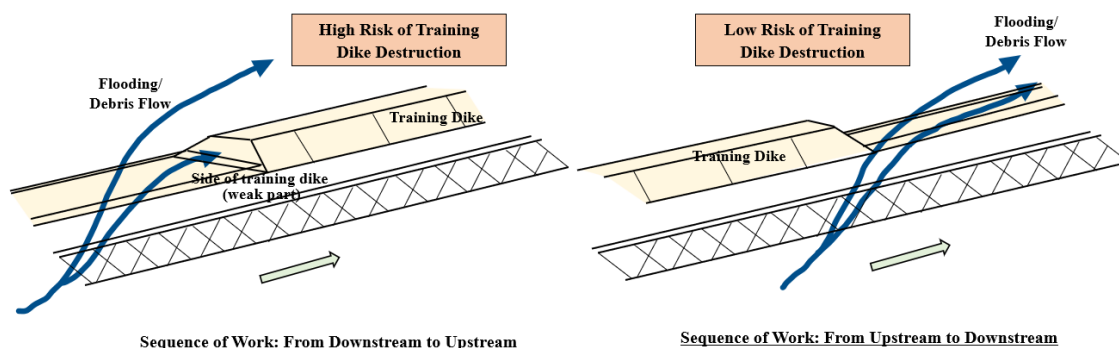
Source: Prepared by JICA Project Team

Figure 5-2 Concrete placement sequence for the Sabo dam (example of CD Pelintas Curah Lengkong 2)

5.2.3 Construction Procedure for Training Dikes

The construction of the training dike will primarily proceed from the upstream side, based on the following considerations:

- Ensuring safety during construction: The primary purpose of the training dike in this plan is to prevent the lateral spread of flooding from the alluvial fan top and upstream channels of the alluvial fan. Flooding on a developing alluvial fan is expected to spread radially from upstream rather than laterally from the channel. Therefore, construction from the fan top towards downstream ensures greater safety for the training dike during construction.
- Reducing the risk of training dike damage during flooding: Minimize direct impact of flooding on vulnerable sections (e.g., side slopes of the training dike) to reduce the risk of structural damage (Figure 5-3).
- Protection of the land behind the training dike: For the construction of the training dike the height of the embankment is gradually increased from upstream to downstream, thereby minimizing the risk of damage caused by flooding to the land behind the training dike caused.

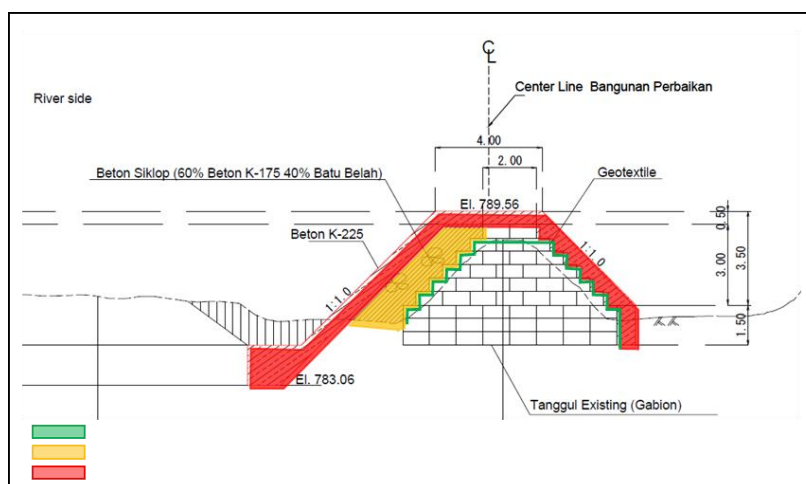


Source: Prepared by JICA Project Team

Figure 5-3 Comparison of training dike construction directions

The construction procedure for each cross-section of the training dike is shown in Figure 5-4. The excavation slope for ensuring safety during excavation shall be set within a range of 1:0.5 to 1:1 (reference values from Japanese construction planning standards i.e., gravelly and sandy soils: 1:0.5, volcanic ash: 1:0.5–1:0.7, highly collapsible natural slopes: 1:1.0). For excavation heights exceeding 5 meters, berms shall be installed to maintain slope stability (reduce scouring force caused by surface water).

The main construction work for this project involves raising and improving existing training dikes. To ensure secure adhesion between the existing training dike and new structures, measures such as rebar insertion and chipping should be thoroughly executed. Further, rainfall may disturb the water-cement ratio during concrete pouring which potentially affects the final quality. Rain protection measures such as preparing covers for the construction area should be prepared in advance.



Source: Prepared by JICA Project Team

Figure 5-4 Construction procedure for training dikes (example of Tanggul Curah Lengkong)

5.3 Plan for Temporary Works

5.3.1 Diversion Work

(1) Design Discharge for Temporary Works

The design discharge for temporary works is determined with the 2-year return period, considering the construction period and economic feasibility of the S2 and S4 areas (Table 5-3). The design discharge was set for each sabo dam with reference to the Review Master Plan (2024) for Mt. Semeru (Table 5-4).

Table 5-3 Design discharge for temporary works using rational formula

River Name	Reference Point	Probability flow rate (m ³ /sec)								
		2	3	5	10	20	30	50	100	
Rejali	Curah Lengkong	1	74	81	90	100	111	116	124	134
	Curah Kobokan	2	72	79	87	98	108	113	120	130
	Sumbersari	3	44	48	53	60	66	69	74	80
		4	174	191	212	237	261	275	292	315
		5	204	225	249	279	307	323	344	371
		6	312	344	380	425	468	493	525	567
	Rejali (tributary)	7	109	120	132	148	163	172	183	197
		8	388	428	473	530	584	615	653	706
		9	542	598	661	739	814	858	912	985

Source: Based on the “Review of Volcanic Debris Control Plan for Mt. Semeru (2024)” from the Data Collection Survey on Volcanic Disaster Reduction in East Java and Bali Islands in The Republic of Indonesia

Table 5-4 Design discharge for temporary works by facility

Area	Facility name	Temporary target flow rate (m ³ /s)
S2	CD Kobokan 5	116 m ³ /s (72m ³ /s+44m ³ /s)
	CD Pelintas Curah Lengkong 2	74 m ³ /s
S4	KD Leprak 3, DD Leprak 2, DD Leprak 3	204 m ³ /s

Source: Prepared by JICA Project Team

(2) River Flow Diversion Methods

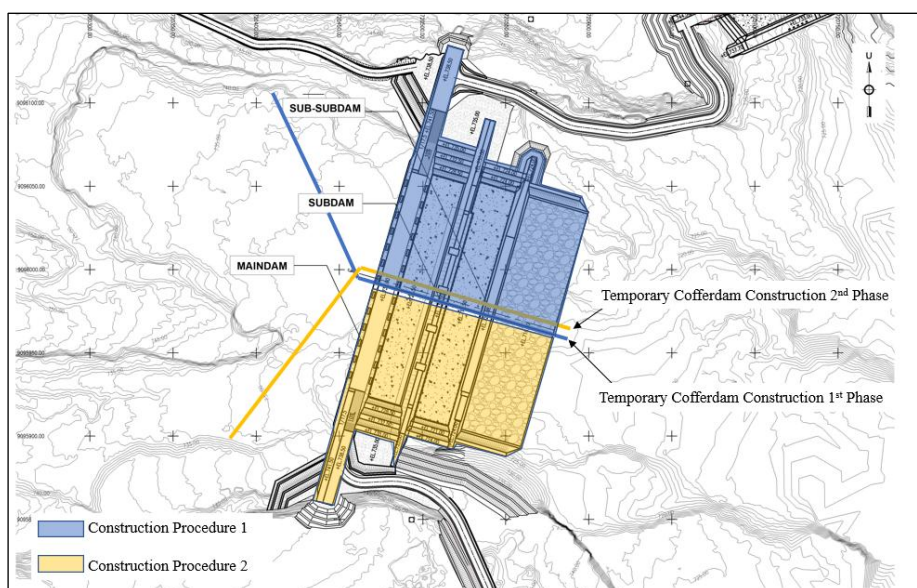
The river flow diversion methods in sabo dam construction can be classified into three.

- Temporary drainage tunnel
- Half-river channel closure
- Temporary open drainage channel

Table 5-5 shows the application conditions and characteristics of each method. For this project, a half-river channel closure method is assumed since the channel width is sufficient to ensure the design discharge for temporary works and to protect the construction area from debris flow inundation. An image of the diversion plan applying the half-river channel closure method is shown in Figure 5-5.

Table 5-5 Diversion methods and their characteristics

Method	Applicable conditions and features
Temporary drainage tunnel	1) becomes expensive as the design discharge increases. 2) has advantages if the river bends sharply for shortcut; can be constructed regardless of river width and riverbed sediment depth. 3) requires a long duration and high cost. 4) allows full dam body excavation and does not interfere construction works. 5) holds a risk of being buried, in the event of a debris flow.
Half-river channel closure	1) is suitable for long channel widths and large design discharge. 2) requires lower construction cost and shorter construction period. 3) requires short diversion work duration, but dam construction is divided into two parts, preventing full-scale execution. 4) protects the construction area from flooding and debris flow damage.
Temporary open drainage channel	1) is not suitable for large design discharge. 2) can be implemented in narrow rivers or when the riverbed sediment layer is deep. 3) requires lower construction cost and shorter construction period. 4) allows full dam body excavation. 5) holds a risk of being buried, in the event of a debris flow

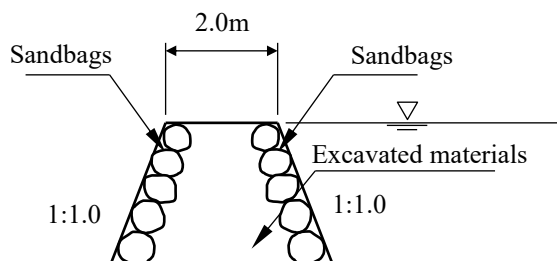


Source: Prepared by JICA Project Team

Figure 5-5 Half-river channel closure method (CD Kobokan 5 in the S2 area)

(3) Temporary Cofferddam

In the half-river channel closure method, a temporary cofferdam is installed to guide flooding and to handle normal flow (Figure 5-6). The minimum width of the crest of the cofferdam is 2 m with a structure based on embankment structure using locally available materials. The cofferdam work is an earth embankment, and no freeboard is set up for the cross-sectional height of the diversion channel.

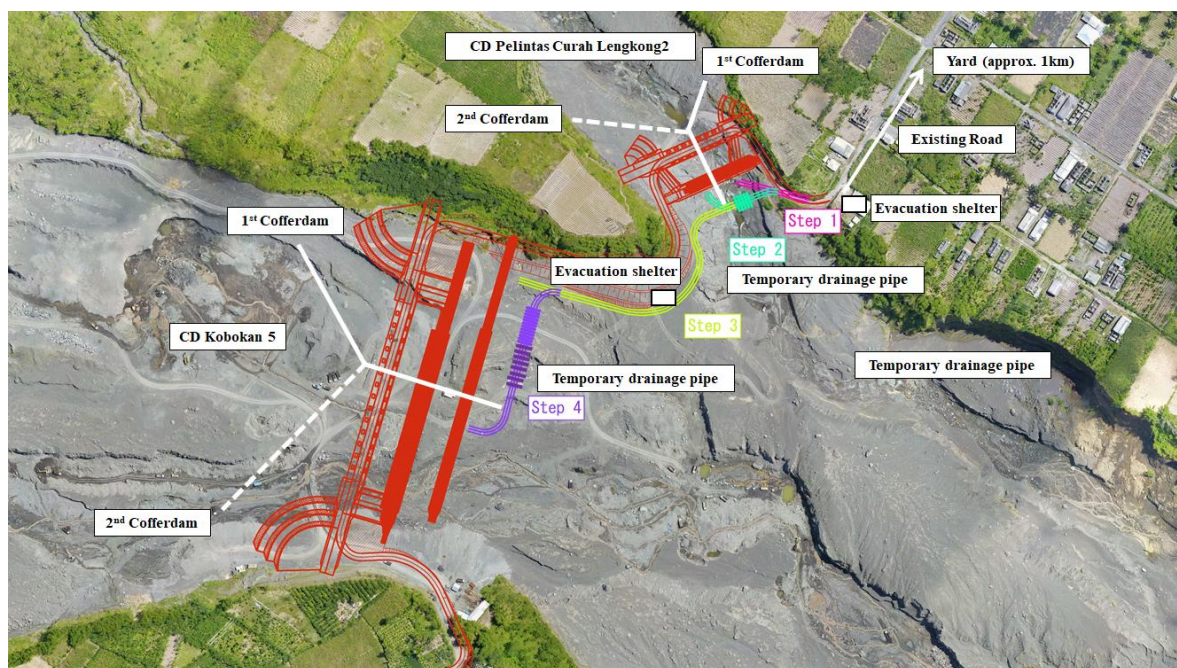


Source: Prepared by JICA Project Team, referring to the Ministry of Land, Infrastructure, Transport, and Tourism, Chubu Regional Development Bureau, Sabo Facility Design Guidelines, Volume 7, Construction, P. 7-2.

Figure 5-6 Cross-section of temporary cofferdam

5.3.2 Construction Roads

The roads required for this project can be classified into access roads for maintenance and construction roads for construction works. Existing roads or sabo dam with river crossing function will be used as access roads for maintenance, as outlined in “3.4.2 Sediment Management Policy, (2) Access Roads for Sediment Management”.



Source: Prepared by JICA Project Team

Figure 5-7 Construction road plan for the S2 area

When planning construction road, it is essential to modify the plans appropriately according to the progress and circumstances of the construction. The construction road for this project will be planned with the following considerations:

- Route setting according to construction progress: Routes will be established based on the construction stages, including temporary structures. These routes will be adjusted as necessary as the construction area expands and progresses through various phases.
- Efficiency: Routes will be designed to minimize transportation distances for materials and equipment, aiming to shorten construction time and reduce costs.
- Safety: Efforts will be made to avoid intersections with sand mining traffic routes to ensure the safety of workers and equipment. Additionally, the routes will take emergency evacuation paths into account in the event of an eruption, pyroclastic flow, or debris flow.

The Figure 5-7 illustrates an example of a construction road plan for the S2 area, taking the above considerations into account.

Regarding the specifications for construction roads (temporary roads), there are no specific regulations for construction roads under Indonesian standards. However, the heavy equipment assumed for this project is of the same standard as those in Japan. Therefore, the conditions for construction roads referring to the “Guidelines for Sabo Facility Design, Volume 7: Construction” page 7-4 to 7-9 published by the Chubu Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism, is summarized as follows:

- The standard width is 4.0 m (roadway 3.0 m + shoulder 0.5 m × 2), with consideration for installation of waiting/passing areas (roadway width at least 5.0 m and effective length 20 m at 500 m intervals).
- The curve radius shall be 15 m or more, and the maximum longitudinal gradient shall be 12%. The embankment slope shall be standardized at 1:1.5.
- The road surface shall be crushed stone paving or other better material, with a minimum thickness of 20 cm.
- The design speed shall be basically 30 km/h or 20 km/h.

5.4 Quality Control Plan

The contractor shall submit a construction plan to the consultant before starting the work, which describes the target values for strength and dimensions, test and inspection methods, and construction methods based on the design documents (specifications, drawings, etc.). The consultant shall check the submitted construction plan. In particular, the tests and inspections shall be in accordance with the project management plan, where the test methods, timing, frequency, and numerical targets for the standards of the tests/inspections shall be provided to ensure quality.

Quality control needs to be implemented through the following measures:

- Verification of contractor's construction drawings
- On-site inspection of steel bar reinforcement during construction
- On-site confirmation of the construction progress, construction methods, etc.
- Confirmation of compaction and concrete strength test results
- Review or attendance of equipment test results/factory inspection results
- Review of construction drawings and actual on-site progress
- Reviewing as-built drawings

The main items that require quality control are as follows

- Concrete work
- Reinforcement and formwork work
- Earthwork
- Pavement work

Major items for quality test management for concrete work are listed in Table 5-6, while the items for earthwork and pavement work are shown in Table 5-7.

Table 5-6 Quality control items for concrete work (draft)

Control Item		Test Method	Test Frequency	
Material	Cement	Quality certificate, chemical and physical test results	Per material	
	Water	Component test results	Per material	
	Admixture	Quality certificate, composition analysis table	Per material	
	Fine Aggregate	Oven-dried specific gravity		At every material change
		Grain size distribution, coarse grain ratio		
		Clay lumps and fine particles ratio		
Coarse Aggregate	Oven-dried specific gravity		At every material change	
	Grain size distribution (mixed)			
Mixing Test		Compressive strength test (specimen cube)	For every mix	
During Pouring	Slump (Concrete)		For each pour	
	Air content			
	Temperature			
Strength		Compressive strength test (7 days, 28 days)	As per specified frequency	

Source: Prepared by JICA Project Team, referring to the SNI 03-1972-1990: Test method for concrete slump; SNI 03-1974-1990: Test method for compressive strength of concrete; SNI 03-2492-1991: Sampling and testing method for core concrete; and SNI 03-2834-1992: Procedure for normal concrete mix design.

Table 5-7 Proposed quality control items for earthwork and pavement work

Control Item		Test Method	Test Frequency
Embankment Work	Construction	Density test (compaction)	At specified frequency
Road Works	Mixing Materials	Liquid limit, plasticity index	For each mixture
		Particle size distribution (mixture)	
		Aggregate strength test	
		Aggregate density test	
		Maximum dry density (compaction test)	
	Construction	Density test (compaction rate)	At specified frequency

Source: Prepared by JICA Project Team, referring to the SNI 03-1743-1989: Heavy compaction test method for soil; SNI 03-1966-1989: Test method for determining the plastic limit; SNI 03-1967-1989: Test method for determining the liquid limit; SNI 03-1968-1989: Sieve analysis test method for coarse aggregates; and SNI 03-1969-1989: Test method for dry density of soil.

5.5 Equipment and Material Procurement Plan

Based on the results of the on-site survey, major materials (such as cement, aggregates, wood, etc.) used in this project are produced domestically in Indonesia. Locally produced and imported reinforcing bars are available in the local market and can be procured domestically. Therefore, the procurement classification for major materials is planned based on the following guidelines and is shown in the table below:

- Procure locally produced materials as much as possible.
- Procure imported products if they are regularly distributed in the market of Indonesia.
- Materials that are difficult to procure locally shall be procured from Japan or a third country. Suppliers shall be determined with consideration given to price, quality, duration for delivery, etc.

Table 5-8 shows the procurement classification of major construction materials.

Table 5-8 Procurement classification of major construction materials

Material Name	Local Procurement	Procurement from Japan	Procurement from Third Countries
(1) Material			
Cement	○		
Aggregate	○		
Reinforcing steel bars	○		
Plywood (formwork material)	○		
Fuel	○		
Purchase soil	○		
Piles	○		
Geotextile	○		
Scaffolding and support materials	○		
Large sandbags	○		
(2) Equipment			
Temporary materials	○		
Submersible pumps	○		
Concrete plant	○		

Source: Prepared by JICA Project Team

Table 5-9 Procurement classification of major construction equipment

Machine Name	Specifications	Rent/Purchase	Local	Japan	Third Country
Dump truck	5.0 m ³	Rental	○		
Backhoe hydraulic breaker	135-150 HP	Rental	○		
Truck mixer	8 m ³	Rental	○		
Backhoe	Piled: 0.8m ³ (Stacked 0.6m ³)	Rental	○		
Wheel loader	1 – 1.6 m ³	Rental	○		
Concrete pump truck	90~110m ³ /h	Rental	○		
Tamper	4.7 HP	Rental	○		
Concrete plant	60 m ³ /hour	Rental			
Vibratory roller	0.8 – 1.1 ton	Rental	○		
Diesel generator	Output: 45kVA	Rental	○		
Rough terrain crane	Hydraulic telescopic boom type: 15-ton lift	Rental	○		
Submersible pump	10 L/s	Rental	○		

Source: Prepared by JICA Project Team

5.6 Safety Measures

The potential hazards and safety measures for sabo facility construction in volcanic areas are shown in Table 5-10.

Table 5-10 Potential hazards and safety measures in this project

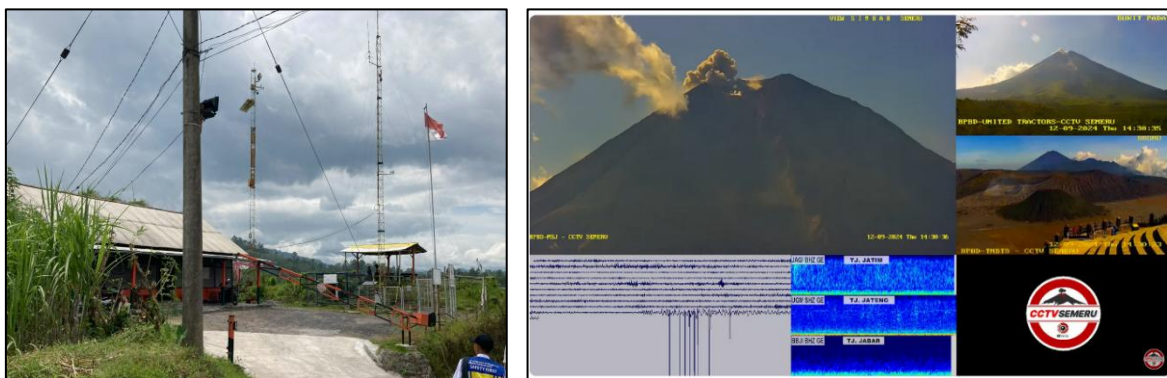
Hazards		Safety Measures
Volcanic activity hazards	<ul style="list-style-type: none"> Eruptions of Semeru volcano, lava flows, volcanic earthquakes Emission of volcanic ash and volcanic gases during eruptions 	<ul style="list-style-type: none"> Responding to unforeseen circumstances is of utmost importance. Assuming the occurrence of natural disasters such as volcanic eruptions and debris flow, response policies shall be established taking into consideration the following items. <ul style="list-style-type: none"> Information gathering Emergency evacuation Establishment of an emergency communication system Response procedures in the event of an emergency
Hazards due to	<ul style="list-style-type: none"> The Mt. Semeru region 	<ul style="list-style-type: none"> If severe weather such as heavy rain or flooding is

Hazards		Safety Measures
weather conditions	<p>experienced high intensity of rainfall, posing risks of heavy rain and flooding.</p> <ul style="list-style-type: none"> • Sudden changes in wind speed or strong winds may affect operational stability. 	<p>expected to create hazardous conditions, operations must be promptly halted.</p> <ul style="list-style-type: none"> • In case of a sudden change in weather conditions that may lead to adverse weather, the site supervisor shall temporarily suspend work and evacuate workers to a safe location.
Geological hazards	<ul style="list-style-type: none"> • The river channel designated as the construction area is highly unstable, posing risks of slope failures and landslides. 	<ul style="list-style-type: none"> • Earthwork activities shall be conducted under the supervision of the site supervisor, following the established procedures and methods. Workers must perform tasks in accordance with the supervisor's instructions. • Excavated soil must not be placed near the edge/wing of the excavation slope. If temporary placement is unavoidable, measures must be taken to prevent slope collapse or the falling of materials into the excavation area. • If weather conditions such as wind, rain, or surface water flow into the excavation area cause slope failure, the slope should be protected using tarps or safety nets. • The site supervisor must evacuate workers to a safe location if there is a risk of slope failure or ground collapse.
Hazards related to heavy equipment and material handling	<ul style="list-style-type: none"> • Risk of entrapment, entanglement, or falls involving heavy equipment or materials. 	<ul style="list-style-type: none"> • Ensure that the installation and operational areas for construction machinery and equipment are always level and properly compacted, and verify the bearing capacity of the ground. Implement anti-tipping measures when necessary. • Prohibit simultaneous upper and lower-level operations (e.g., working on elevated structures while others work below). Do not allow anyone to stand under suspended loads. • When handling, inspecting, or maintaining construction machinery and equipment, turn off the power source to prevent accidents such as entrapment or entanglement of workers.
Hazards associated with work at height (Locations with a height difference of 2 m or more)	<ul style="list-style-type: none"> • Risk of falling or tripping 	<ul style="list-style-type: none"> • Scaffolding shall be set up in work areas with height of >2 m above the ground. If the scaffolding cannot be set up due to unavoidable circumstances, workers shall use protective equipment to prevent falls, such as safety belts and roping (rope safety device). In places where safety belts, etc. are used, equipment for attaching safety belts, etc. shall be installed. • To prevent construction vehicles or machinery from falling into excavation areas, install wheel chocks or similar devices in appropriate locations.

Source: Prepared by JICA Project Team

The above hazards shall be thoroughly considered and safety measures shall be implemented during the construction of the sabo facilities. In particular, hazards associated with volcanic activity pose a significant risk of serious accidents. Therefore, it is essential to rigorously examine and establish measures to address these risks.

Among the safety measures under consideration, tools shown in Figure 5-8 and other means should be utilized to collect information and monitor volcanic activity. This will enable continuous assessment of eruption and flooding risks. Furthermore, establishing a robust system for emergency evacuation instructions is indispensable for ensuring proper information sharing and prompt guidance.



Volcanic monitoring facilities

Live streaming of Mt. Semeru

Figure 5-8 BNPB (National Disaster Management Agency) facilities and activities in the S2 area

In preparation for emergency situations such as unexpected accidents, the following considerations shall be considered in the emergency response policy:

- Prioritize human life above all else.
- Establish a robust emergency contact system.
- Establish emergency response procedures.
- Set up protocols for first aid response.
- Ensure a thorough reporting of accidents and injuries.

The safety plan prepared by the contractor shall thoroughly address the above hazards. It also must comply with the Indonesian Ministry of Public Works and Housing (PUPR) Construction Safety Management System (SMKK) guidelines (Regulation No. 21/PRT/M/2019) and refer to the JICA Safety Standard Specifications (JSSS), as necessary.

5.7 Construction Schedule Plan

(1) Calculation of Annual Operating Days

The number of annual operating days (working days) is calculated by considering the following:

$$A = B - (C + D + E - F) = 365 - (52 + 22 + 58 - 12) = 245 \text{ days}$$

A = Annual operating days

B = Total days in a year = 365 days

C = Number of Sundays in a year = $365 / 7 = 52$ days

D = Number of public holidays in a year = approximately 22 days

E = Number of average rainy days in a year = 58 days

F = Number of days where public holidays and rainy days overlap = $E \div B \times (C + D) = 58 \div 365 \times 74 = 12$ days

Therefore, the non-operating factor is calculated as: $365 \text{ days} \div 245 \text{ days} = 1.49 \approx 1.5$

The working days are calculated by multiplying the operation days (derived from man-hours, etc.) by the non-operating factor.

(2) Working Hours

The working hours for the project are set as daytime operations, consisting of five days a week with eight hours of actual work each day, totaling no more than 40 hours per week.

(3) Project Schedule Calculation

The entire project is divided into S2 area (3 facilities) and S4 area (14 facilities). The construction schedule for each area is shown in Figure 5-9 and Figure 5-10. The period from the start to completion for both the S2 and S4 areas is expected to be 24 months (2 years).

The calculation of work capacity of construction machinery and daily construction volume is based on the Ministerial Decree of Public Works and Housing (PUPR) No. 8/2023 Guidelines for Preparing Cost Estimates for Construction Work and PUPR Circular Letter No. 73/SE/Dk/2023.

Item	Duration (Day)	YEAR - 1												YEAR - 2											
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
PRELIMINARY WORK	60	█	█	█	█																				
CURAH LENGKONG DIKE	180			█	█	█	█	█	█	█	█	█	█	█											
CD PELINTAS CURAH LENGKONG 2 WORKS	255									█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	
CD KOBOKAN 5	330																								

Source: Prepared by JICA Project Team

Figure 5-9 Construction schedule for S2 area

Item	Duration (Day)	YEAR - 1												YEAR - 2											
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
PRELIMINARY WORK	60	█	█	█	█																				
LEPRAK UPSTREAM TRAINING DIKE	105			█	█	█	█	█	█	█	█	█	█												
LEPRAK 26 DIKE	150					█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	
LEPRAK 25 DIKE	150									█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	
LEPRAK 24 DIKE	150																								
LEPRAK 23 DIKE	150																								
LEPRAK 22 DIKE	90																								
LEPRAK II-D DIKE	60			█	█	█	█	█	█	█	█	█	█												
DISPERSION DAM LEPRAK 2	180					█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	
LEPRAK XVII KEBONDELI 2021 DIKE	150																								
DISPERSION DAM LEPRAK 3	150																								
CONSOLIDATION DAM LEPRAK 3	90																								
EMERGENCY DIKE	120																								

Source: Prepared by the Survey Team

Figure 5-10 Construction schedule for S4 area

5.8 Items to be Noted in Construction

The following points should be taken into account during the implementation of construction works:

- (1) Adherence to labor standards

The employer shall comply with Indonesian labor laws when hiring workers, as well as respect appropriate working conditions and customs associated with the employment, prevent disputes with workers, and ensure safety related to occupational accidents.

(2) Safety measures during construction

In this project, ensuring construction safety during high-water periods through rainy seasons is the top priority. Pre-identifying evacuation actions and locations, establishing an emergency communication system, and thoroughly collecting information with BNPB's local volcano monitoring facilities or by setting up monitoring cameras / rain gauge equipment, are essential.

Further, this project assumes the use of existing roads, where ensuring the safety for existing traffic including sand mining vehicles is necessary. Therefore, safety personnel shall be stationed upstream and downstream or before and after construction sections during working hours. If necessary, barriers and other safety measures shall be implemented. During nighttime operations, safety lights and illumination facilities shall be installed.

(3) Environmental preservation during construction

Considering the impact on the surrounding environment, waste materials and surplus soil from the demolition of existing structures shall be disposed to designated sites. In addition, measures for dust, turbid water, etc. generated during construction shall be prepared.

(4) Emphasis on concrete quality control

The quality of the concrete will have a large impact on the lifespan of the concrete structures planned in this project. To construct high-quality concrete with minimal cracks, the quality control shall be a priority during the construction on materials such as aggregates, sand, water, cement, and forms, specification of the mixing plant, regulations for concrete transport, and pouring / curing.

CHAPTER 6 CONSTRUCTION ESTIMATION COST

6.1 Material Unit Price and Construction Unit Price

The unit prices and rates used for construction cost estimation are based on the unit prices specific to the target regions (Lumajang Regency and East Java Province). The unit price information referenced for this estimation is presented in Table 6-1.

Table 6-1 List of referenced unit price information

No	Document Name	Publication Year
1	Harga Satuan Bahan dan Upah Pembangunan Bidang SDA Dinas PUPR Kabupaten Lumajang Tahun 2024 <i>(Unit Prices for Materials and Development Wages for Water Resources Management by the PUPR for Lumajang Regency 2024)</i>	2023
2	Peraturan Gubernur Jawa Timur No. 35 Tahun 2023 Tentang Standar Biaya Umum Tahun 2024 <i>(East Java Governor Regulation No. 35 Year 2023 on General Cost Standards for 2024)</i>	2023
3	Jurnal Harga Satuan Bahan Bangunan Konstruksi Indonesia Edisi 43 Tahun 2024 untuk Kota Malang <i>(Indonesian Construction Material Unit Price Journal, 43rd Edition, 2024, Malang City)</i>	2024
4	Vendor Estimates	2024

Source: JICA Project Team

Furthermore, the unit prices per work unit (unit price table) were calculated based on the PUPR guidelines. The cost estimation standards referenced are listed in Table 6-2. For detailed unit price tables, refer to Appendix 6-2.

Table 6-2 List of referenced cost estimation standards

No	Document Name	Publication Year
1	Peraturan Menteri Pekerjaan Umum dan Perumahan Rakyat Republik Indonesia Nomor 8 Tahun 2023 tentang Pedoman Penyusunan Perkiraan Biaya Pekerjaan Konstruksi Bidang Pekerjaan Umum dan Perumahan Rakyat <i>(Ministry of PUPR Regulation No. 8 Year 2023 on Guidelines for Preparing Construction Work Cost Estimates for Public Works and Housing)</i>	2023
2	Surat Edaran Nomor 73/SE/Dk/2023 tentang Tata Cara Penyusunan Perkiraan Biaya Pekerjaan Konstruksi Bidang Pekerjaan Umum dan Perumahan Rakyat <i>(Circular Letter No. 73/SE/Dk/2023 on Procedures for Preparing Construction Work Cost Estimates for Public Works and Housing)</i>	2023

Source: JICA Project Team

6.2 Overview of Construction Costs

The approximate construction costs required for this project are 2.30 billion Japanese Yen for S2 area and 2.74 billion Japanese Yen for S4 area. Table 6-3 shows the estimation conditions, and Table 6-4 to Table 6-7 provide the results of the construction cost estimation. For detailed breakdowns of the estimation results, refer to Appendix 6-2.

Table 6-3 Estimation conditions

Estimation Date	June 2024
Exchange Rate	JPY 1 = IDR 104.24 <i>(Based on the average rate from Bank Indonesia between March and May 2024)</i>
Construction Period	As indicated in the implementation schedule in “Section 5.7 Project Plan”

Source: JICA Project Team

Table 6-4 Estimation results

NO.	Item	Amount (Rp.)	Amount (Yen) ※reference	Ratio (%)
I	Preparation Work	1,536,358,000	14,738,661	0.64
II	Safety Management	1,805,747,000	17,322,976	0.75
III	CURAH LENGKONG DIKE WORKS	28,906,820,513	277,310,251	12.03
IV	CD PELINTAS CURAH LENGKONG 2 WORKS	27,343,402,705	262,311,998	11.38
V	CD KOBOKAN 5 WORKS	180,617,921,176	1,732,712,214	75.19
S2 Construction Cost		240,210,249,393	2,304,396,099	100.00

NO.	Item	Amount (Rp.)	Amount (Yen) ※reference	Ratio (%)
I	Preparation Work	1,830,158,000	17,557,157	0.64
II	Safety Management	1,874,927,000	17,986,637	0.66
III	LEPRAK UPPER DIVERSION DIKE	13,419,939,844	128,740,789	4.71
IV	LEPRAK 26 DIKE	39,411,503,961	378,084,267	13.82
V	LEPRAK 25 DIKE	30,721,494,766	294,718,868	10.77
VI	LEPRAK 24 DIKE	28,766,028,846	275,959,601	10.09
VII	LEPRAK 23 DIKE	27,235,354,049	261,275,461	9.55
VIII	KD LEPRAK 3 WORKS	16,702,611,171	160,232,264	5.86
IX	PEKERJAAN TANGGUL LEPRAK XVII KEBONDELI 2021	27,819,383,564	266,878,200	9.76
X	LEPRAK 22 DIKE	17,551,997,903	168,380,640	6.16
XI	LEPRAK II-D DIKE	15,756,346,579	151,154,514	5.53
XII	EMERGENCY DIKE	7,559,452,243	72,519,688	2.65
XIII	DD LEPRAK 2	29,838,675,459	286,249,765	10.46
XIV	DD LEPRAK 3	26,659,624,880	255,752,349	9.35
S4 Construction Cost		285,147,498,265	2,735,490,198	100.00

S2 and S4 Construction Cost		525,357,747,659	5,039,886,298	
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Source: JICA Project Team

Table 6-5 Construction cost for S2 area facilities

NO.	Work Item	單位	數量	單價 (Rp.)	金額 (Rp.)	合計 (Rp.)
I	PREPARATION WORK					1,536,358,000
1	Mobilization and Demobilization of Construction Equipment	Ls	1.00	826,000,000	826,000,000	
2	Project Facilities (Board of Directors)	Ls	1.00	710,358,000	710,358,000	
II	IMPLEMENTATION OF CONSTRUCTION SAFETY MANAGEMENT SYSTEM (SMKK)					1,805,747,000
1	Implementation of Construction Safety Management System (SMKK)	Ls	1.00	1,805,747,000	1,805,747,000	
III	CURAH LENGKONG DIKE WORKS					28,906,820,513
A	EARTHWORKS					802,987,122
1	Installation of bowplank (guide boards)	m'	1,800.00	63,330	113,994,000	
2	Marking out the trace of the new infrastructure on site and placing 1-meter long wooden stakes (5/7 lumber)	m2	17,922.39	20,740	371,710,369	
3	Cross-sectional excavation profile	m	261.00	26,120	6,817,320	
4	Mechanical Sand Excavation (excavated material is dumped nearby)	m3	36,785.08	8,440	310,466,033	
B	CONCRETE WORK					28,103,832,791
1	Concrete Making and Casting f'c = 10 Mpa (K 125) Mechanical Transported radius 2000 m	m3	380.00	986,860	375,006,800	
2	Geotextile, Medium thickness (s-400 to < 800 gr), Manual	m2	15,300.00	38,590	590,427,000	
3	1 m2 Regular Formwork for Concrete Walls with Multiflex 12 mm or 18 mm	m2	5,814.00	95,770	558,806,780	
4	Cyclops Concrete 60% Concrete f'c 15 Mpa; 40% Split Stone	m3	8,560.45	828,710	7,094,130,520	
5	Dismantle 1 m2 of Formwork and Scaffolding in the Normal Way (and Clear Debris) for Non Expose	m2	5,814.00	4,460	25,930,440	
6	1 m2 Exposed Concrete Wall Formwork with 18 mm Multiflex	m2	19,969.00	143,250	2,860,559,250	
7	1 m2 Scaffolding / Supporting Formwork Rafters 5/7 for Concrete Walls Tm 2.50 m	m2	25,783.00	96,260	2,481,871,580	
8	Concrete Making and Casting f'c = 20 Mpa (K 225) Mechanically Transported radius 2000 m	m3	12,599.85	1,109,990	13,985,707,502	
9	Carefully dismantle 1 m2 of Formwork and Scaffolding	m2	19,969.00	6,680	133,392,920	
IV	CD PELINTAS CURAH LENGKONG 2 WORKS					27,343,402,705
A	RIVER WATERING & DEWATERING WORK					37,829,860
1	Backfill Sand (Material from Excavation, Mechanically)	m3	43.50	16,360	711,660	
2	1 Piece of Sand Geogab Size 145 x 240 cm	Unit	70.00	468,500	32,795,000	
3	Hourly operation of a 5 KW diesel water pump with a maximum suction head of 3 m and a maximum discharge head of 10 m (capacity 10 L/s at a suction head of 1 m and a discharge head of 10 m)	Hour	70.00	61,760	4,323,200	
B	DEMOLITION WORKS					48,384,000
1	Demolition with RDB: Loading of Demolition Results (Rock f > 25 cm) and Transport, (mechanically, transported to the disposal area with a distance of up to 500 m)	m3	900.00	53,760	48,384,000	
C	EARTHWORKS					1,748,608,777
1	Installation of bowplank (guide boards)	m'	384.17	63,330	24,329,549	
2	Marking out the trace of the new infrastructure on site and placing 1-meter long wooden stakes (5/7 lumber)	m2	9,910.27	20,740	205,539,062	
3	Cross-sectional excavation profile	m	434.00	26,120	11,336,080	
4	Mechanical Sand Excavation (transported to disposal area, distance 0 m to 500 m)	m3	72,596.47	19,520	1,417,083,028	
5	Mechanical Sand Excavation (excavated material is dumped nearby)	m3	8,062.27	8,440	68,079,353	
6	Backfill Sand (Material from Excavation, Mechanically)	m3	1,359.52	16,360	22,241,704	
D	CONCRETE WORK					23,740,650,153
1	1 m2 Regular Formwork for Concrete Walls with Multiflex 12 mm or 18 mm	m2	5,807.82	95,770	556,214,999	
2	Cyclops Concrete 60% Concrete f'c 15 Mpa; 40% Split Stone, with Concrete Pump (CP)	m3	12,507.18	842,630	10,538,927,544	
3	Dismantle 1 m2 of Formwork and Scaffolding in the Normal Way (and Clear Debris) for Non Expose	m2	5,807.82	4,460	25,902,881	
4	1 kg Slab reinforcement for B/TP or B/TS diameter > 12 mm Semi-Mechanical method	Kg	44,459.74	15,100	671,342,074	
5	1 m2 Exposed Concrete Wall Formwork with 18 mm Multiflex	m2	6,599.37	143,250	945,359,390	
6	1 m2 Scaffolding / Supporting Formwork Rafters 5/7 for Concrete Walls Tm 2.50 m	m2	12,407.19	96,260	1,194,315,944	
7	Concrete Making and Casting f'c = 30 Mpa (K 350) Mechanically Transported within a radius of 2000 m with a Concrete	m3	4,313.48	1,289,590	5,562,621,963	
8	Construction Joint Filler	m3	42.06	81,370	3,422,702	
9	Concrete Making and Casting f'c = 20 Mpa (K 225) Mechanically Transported within a radius of 2000 m with a Concrete	m3	3,222.44	1,302,880	4,198,458,881	
10	Carefully dismantle 1 m2 of Formwork and Scaffolding	m2	6,599.37	6,680	44,083,775	
E	MAINTENANCE WORK & FINISHING					970,462,416
1	Irregular Riprap, Less Dense-Many Cavities, Height Difference 0-1 m & Mechanical Tidying	m3	2,909.06	333,600	970,462,416	
F	OTHER WORKS					24,531,080
1	Weep Hole	m	553.00	44,360	24,531,080	
G	PELINTAS CURAH LENGKONG, L = 95.00 m					772,936,420
1	Mechanical Sand Excavation (excavated material is dumped nearby)	m3	3,090.04	8,440	26,079,917	
2	Backfill Sand (Material from Excavation, Mechanically)	m3	371.74	16,360	6,081,666	
3	1 m2 Exposed Formwork for Concrete Floor Slabs with Multiflex 18 mm (TP), JaTm 0.60 m	m2	114.00	127,830	14,572,620	
4	Dowel Bar	Unit	304.00	58,960	17,923,840	
5	1 m2 Concrete Floor Formwork Scaffolding with 5/7 cm Rafters 4.00 m high, JaTm 0.60 m	m2	114.00	117,400	13,383,600	
6	Concrete Making and Casting f'c = 20 Mpa (K 225) Mechanically Transported radius 2000 m	m3	475.00	1,109,990	527,245,250	
7	Carefully dismantle 1 m2 of Formwork and Scaffolding	m2	114.00	6,680	761,520	
8	Construction Joint Sealant	m3	1.19	81,370	96,827	
9	Box Culvert 100 x 100 x 120 cm	Unit	18.00	4,519,670	81,354,060	
10	U-Ditch 50 x 60 x 120 cm	Unit	80.00	982,920	78,633,600	
11	Guidepost	Unit	47.00	144,760	6,803,720	
V	CD KOBOKAN 5 WORKS					180,617,921,176
A	RIVER WATERING & DEWATERING WORK					956,364,475
1	Installation of bowplank (guide boards)	m'	795.63	63,330	50,399,814	
2	Marking out the trace of the new infrastructure on site and placing 1-meter long wooden stakes (5/7 lumber)	m2	27,839.96	20,740	577,400,841	
3	Cross-sectional excavation profile	m	1,713.00	26,120	44,743,560	
4	Backfill Sand (Material from Excavation, Mechanically)	m3	4,176.00	16,360	68,319,360	
5	1 Piece of Sand Geogab Size 145 x 240 cm	Unit	400.00	468,500	187,400,000	
6	Hourly operation of a 5 KW diesel water pump with a maximum suction head of 3 m and a maximum discharge head of 10 m (capacity 10 L/s at a suction head of 1 m and a discharge head of 10 m)	Hour	455.00	61,760	28,100,800	
B	DEMOLITION WORKS					155,620,330
1	Demolition with RDB: Loading of Demolition Results (Rock f > 25 cm) and Transport, (mechanically, transported to the disposal area with a distance of up to 500 m)	m3	2,894.72	53,760	155,620,330	
C	EARTHWORKS					5,380,643,590
4	Mechanical Sand Excavation (transported to disposal area, distance 0 m to 500 m)	m3	245,460.98	19,520	4,791,398,338	
5	Mechanical Sand Excavation (excavated material is dumped nearby)	m3	27,273.44	8,440	230,187,853	
6	Backfill Sand (Material from Excavation, Mechanically)	m3	21,947.27	16,360	359,057,399	
D	CONCRETE WORK					166,177,329,786
1	1 m2 Regular Formwork for Concrete Walls with Multiflex 12 mm or 18 mm	m2	17,172.96	95,770	1,644,653,948	
2	Cyclops Concrete 60% Concrete f'c 15 Mpa; 40% Split Stone, with Concrete Pump (CP)	m3	106,647.96	842,630	89,864,772,077	
3	Dismantle 1 m2 of Formwork and Scaffolding in the Normal Way (and Clear Debris) for Non Expose	m2	17,172.96	4,460	76,591,382	
4	1 kg Slab reinforcement for B/TP or B/TS diameter > 12 mm Semi-Mechanical method	Kg	155,195.04	15,100	2,343,445,104	
5	1 m2 Exposed Concrete Wall Formwork with 18 mm Multiflex	m2	26,124.90	143,250	3,742,391,681	
6	1 m2 Scaffolding / Supporting Formwork Rafters 5/7 for Concrete Walls Tm 2.50 m	m2	43,297.85	96,260	4,167,851,407	
7	Concrete Making and Casting f'c = 30 Mpa (K 350) Mechanically Transported within a radius of 2000 m with a Concrete	m3	32,746.75	1,289,590	42,229,883,371	
8	Construction Joint Filler	m3	134.86	81,370	10,973,622	
9	Concrete Making and Casting f'c = 20 Mpa (K 225) Mechanically Transported within a radius of 2000 m with a Concrete	m3	18,828.00	1,302,880	21,922,252,874	
10	Carefully dismantle 1 m2 of Formwork and Scaffolding	m2	26,124.90	6,680	174,514,321	
E	MAINTENANCE WORK & FINISHING					775,080,180
1	Irregular Riprap, Less Dense-Many Cavities, Height Difference 0-1 m & Mechanical Tidying	m3	2,323.38	333,600	775,080,180	
F	OTHER WORKS					58,067,240
1	Weep Hole	m	1,309.00	44,360	58,067,240	
G	CURAH LENGKONG TO KOBOKAN 5, L = 230.00 m					951,890,310
1	Mechanical Sand Excavation (excavated material is dumped nearby)	m3	20,531.14	8,440	173,282,801	
2	Backfill Sand (Material from Excavation, Mechanically)	m3	2,482.24	16,360	40,609,365	
3	Box Culvert 100 x 100 x 120 cm	Pcs	35.00	4,519,670	158,188,450	
4	U-Ditch 50 x 60 x 120 cm	Pcs	200.00	982,920	196,584,000	
5	Guidepost	Pcs	115.00	144,760	16,647,400	
6	Cyclops Concrete 60% Concrete f'c 15 Mpa; 40% Split Stone	m3	384.24	828,710	318,423,530	
7	1 m2 Exposed Concrete Wall Formwork with 18 mm Multiflex	m2	195.60	143,250	28,019,700	
8	1 m2 Scaffolding / Supporting Formwork Rafters 5/7 for Concrete Walls Tm 2.50 m	m2	195.60	96,260	18,828,456	
9	Carefully dismantle 1 m2 of Formwork and Scaffolding	m2	195.60	6,680	1,306,808	
H	KOBOKAN 5, L = 175.00 m					6,162,925,265
1	Mechanical Sand Excavation (excavated material is dumped nearby)	m3	2,866.69	8,440	24,194,868	
2	Backfill Sand (Material from Excavation, Mechanically)	m3	8,193.75	16,360	134,049,750	
3	1 m2 Exposed Formwork for Concrete Floor Slabs with Multiflex 18 mm (TP), JaTm 0.60 m	m2	210.00	127,830	26,844,300	
4	Dowel Bar	Unit	560.00	58,960	33,017,600	
5	1 m2 Concrete Floor Formwork Scaffolding with 5/7 cm Rafters 4.00 m high, JaTm 0.60 m	m2	210.00	117,400	24,654,000	
6	Concrete Making and Casting f'c = 20 Mpa (K 225) Mechanically Transported radius 2000 m	m3	875.00	1,109,990	971,241,250	
7	Carefully dismantle 1 m2 of Formwork and Scaffolding	m2	3,279.27	6,680	21,905,524	
8	Construction Joint Sealant	m3	2.19	81,370	177,997	
9	Box Culvert 100 x 100 x 120 cm	Unit	13.00	4,519,670	58,755,710	
10	U-Ditch 50 x 60 x 120 cm	Unit	145.00	982,920	142,523,400	
11	Guidepost	Unit	87.00	144,760	12,594,120	
12	Cyclops Concrete 60% Concrete f'c 15 Mpa; 40% Split Stone	m3	4,800.05	828,710	3,977,845,889	
13	1 m2 Exposed Concrete Wall Formwork with 18 mm Multiflex	m2	3,069.27	143,250	439,672,928	
14	1 m2 Scaffolding / Supporting Formwork Rafters 5/7 for Concrete Walls Tm 2.50 m	m2	3,069.27	96,260	295,447,930	
Total						240,210,249,393

Source: JICA Project Team

Table 6-6 Construction cost for S4 area facilities (1/2)

NO.	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE (Rp)	TOTAL (Rp)	SUB TOTAL (Rp.)
I	PREPARATION WORKS					1,830,158,000
1	Mobilization and Demobilization of Construction Equipment	Ls	1.00	1,124,000,000	1,124,000,000	
2	Project Facilities (Board of Directors)	Ls	1.00	706,158,000	706,158,000	
II	IMPLEMENTATION OF CONSTRUCTION SAFETY MANAGEMENT SYSTEM (SMKK)					1,874,927,000
1	Implementation of Construction Safety Management System (SMKK)	Ls	1.00	1,874,927,000	1,874,927,000	
III	DIKE LEPRAK UPPER DIVERSION					13,419,939,844
A	EARTHWORKS					180,754,708
1	Bowplank Installation	m'	260.00	63,330	16,465,800	
2	Stake Out Trace of New Infrastructure & Wooden Stakes (Raft 5/7) Length 1 m	m2	5,460.00	20,740	113,240,400	
3	Excavation Cross Profile	m	218.40	26,120	5,704,608	
4	Mechanical Sand Excavation (excavated material is dumped nearby)	m3	5,372.50	8,440	45,343,900	
B	CONCRETE WORK					13,239,185,136
1	1 m2 Regular Formwork for Concrete Walls with Multiflex 12 mm or 18 mm	m2	3,079.13	95,770	294,888,376	
2	Dismantle 1 m2 of Formwork and Scaffolding in the Normal Way (and Clear Debris) for Non Expose	m2	3,079.13	4,460	13,732,924	
3	Cyclops Concrete 60% Concrete fc' 15 Mpa: 40% Stone	m3	9,435.29	828,710	7,819,122,491	
4	1 m2 Exposed Concrete Wall Formwork with 18 mm Multiflex	m2	3,858.86	143,250	552,781,695	
5	1 m2 Scaffolding / Supporting Formwork Rafter 5/7 for Concrete Walls Tm 2.50 m	m2	6,937.99	96,260	667,851,014	
6	Carefully dismantle 1 m2 of Formwork and Scaffolding	m2	3,858.86	6,680	25,777,185	
7	Concrete Making and Casting fc' = 20 Mpa (K 225) Mechanical Transported radius 2000 m	m3	3,481.80	1,109,990	3,864,757,632	
8	Construction Joint Filler	m3	3.37	81,370	273,820	
IV	DIKE LEPRAK 26					39,411,503,961
A	EARTHWORKS					2,590,472,406
1	Bowplank Installation	m'	1,200.00	63,330	75,996,000	
2	Stake Out Trace of New Infrastructure & Wooden Stakes (Raft 5/7) Length 1 m	m2	26,307.77	20,740	545,623,150	
3	Excavation Cross Profile	m	916.80	26,120	23,946,816	
4	Mechanical Sand Excavation (excavated material is dumped nearby)	m3	230,439.15	8,440	1,944,906,440	
B	CONCRETE WORK					36,821,031,554
1	1 m2 Regular Formwork for Concrete Walls with Multiflex 12 mm or 18 mm	m2	7,349.50	95,770	703,861,615	
2	Dismantle 1 m2 of Formwork and Scaffolding in the Normal Way (and Clear Debris) for Non Expose	m2	7,349.50	4,460	32,778,770	
3	Cyclops Concrete 60% Concrete fc' 15 Mpa: 40% Stone	m3	9,395.16	828,710	7,785,860,972	
4	1 m2 Exposed Concrete Wall Formwork with 18 mm Multiflex	m2	24,327.28	143,250	3,484,882,144	
5	1 m2 Scaffolding / Supporting Formwork Rafter 5/7 for Concrete Walls Tm 2.50 m	m2	31,676.78	96,260	3,049,206,362	
6	Carefully dismantle 1 m2 of Formwork and Scaffolding	m2	24,327.28	6,680	162,506,197	
7	Concrete Making and Casting fc' = 20 Mpa (K 225) Mechanical Transported radius 2000 m	m3	19,075.48	1,109,990	21,173,586,495	
8	Geotextile, Medium thickness (> 400 to < 800 gr), Manual	m2	11,100.00	38,590	428,349,000	
V	DIKE LEPRAK 25					30,721,494,766
A	EARTHWORKS					1,389,604,224
1	Bowplank Installation	m'	996.58	63,330	63,113,411	
2	Stake Out Trace of New Infrastructure & Wooden Stakes (Raft 5/7) Length 1 m	m2	19,030.50	20,740	394,692,570	
3	Excavation Cross Profile	m	676.64	26,120	17,673,837	
4	Mechanical Sand Excavation (excavated material is dumped nearby)	m3	108,308.58	8,440	914,124,406	
B	CONCRETE WORK					29,331,890,541
1	1 m2 Regular Formwork for Concrete Walls with Multiflex 12 mm or 18 mm	m2	3,637.50	95,770	348,363,375	
2	Dismantle 1 m2 of Formwork and Scaffolding in the Normal Way (and Clear Debris) for Non Expose	m2	3,637.50	4,460	16,223,250	
3	Cyclops Concrete 60% Concrete fc' 15 Mpa: 40% Stone	m3	9,388.90	828,710	7,780,673,247	
4	1 m2 Exposed Concrete Wall Formwork with 18 mm Multiflex	m2	18,655.50	143,250	2,672,400,375	
5	1 m2 Scaffolding / Supporting Formwork Rafter 5/7 for Concrete Walls Tm 2.50 m	m2	22,293.00	96,260	2,145,924,180	
6	Carefully dismantle 1 m2 of Formwork and Scaffolding	m2	18,655.50	6,680	124,618,740	
7	Concrete Making and Casting fc' = 20 Mpa (K 225) Mechanical Transported radius 2000 m	m3	14,432.62	1,109,990	16,020,058,324	
8	Geotextile, Medium thickness (> 400 to < 800 gr), Manual	m2	5,795.00	38,590	223,629,050	
VI	DIKE LEPRAK 24					28,766,028,846
A	EARTHWORKS					1,146,437,947
1	Bowplank Installation	m'	945.40	63,330	59,872,182	
2	Stake Out Trace of New Infrastructure & Wooden Stakes (Raft 5/7) Length 1 m	m2	16,002.00	20,740	331,881,480	
3	Excavation Cross Profile	m	708.90	26,120	18,516,468	
4	Mechanical Sand Excavation (excavated material is dumped nearby)	m3	87,223.68	8,440	736,167,817	
B	CONCRETE WORK					27,619,590,899
1	1 m2 Regular Formwork for Concrete Walls with Multiflex 12 mm or 18 mm	m2	7,199.74	95,770	689,519,339	
2	Dismantle 1 m2 of Formwork and Scaffolding in the Normal Way (and Clear Debris) for Non Expose	m2	7,199.74	4,460	32,110,852	
3	Cyclops Concrete 60% Concrete fc' 15 Mpa: 40% Stone	m3	9,993.40	828,710	8,281,628,442	
4	1 m2 Exposed Concrete Wall Formwork with 18 mm Multiflex	m2	15,948.00	143,250	2,284,551,000	
5	1 m2 Scaffolding / Supporting Formwork Rafter 5/7 for Concrete Walls Tm 2.50 m	m2	23,147.74	96,260	2,228,201,693	
6	Carefully dismantle 1 m2 of Formwork and Scaffolding	m2	15,948.00	6,680	106,532,640	
7	Concrete Making and Casting fc' = 20 Mpa (K 225) Mechanical Transported radius 2000 m	m3	12,336.72	1,109,990	13,693,633,058	
8	Geotextile, Medium thickness (> 400 to < 800 gr), Manual	m2	7,862.50	38,590	303,413,875	
VII	DIKE LEPRAK 23					27,235,354,049
A	EARTHWORKS					841,379,868
1	Bowplank Installation	m'	650.00	63,330	41,164,500	
2	Stake Out Trace of New Infrastructure & Wooden Stakes (Raft 5/7) Length 1 m	m2	11,900.00	20,740	246,806,000	
3	Excavation Cross Profile	m	529.10	26,120	13,820,092	
4	Mechanical Sand Excavation (excavated material is dumped nearby)	m3	61,579.05	8,440	519,727,214	
5	Backfill Sand (Material from Excavation, Mechanically)	m3	1,214.06	16,360	19,862,063	
B	CONCRETE WORK					26,393,974,181
1	1 m2 Regular Formwork for Concrete Walls with Multiflex 12 mm or 18 mm	m2	3,121.60	95,770	298,955,287	
2	Dismantle 1 m2 of Formwork and Scaffolding in the Normal Way (and Clear Debris) for Non Expose	m2	3,121.60	4,460	13,922,320	
3	Cyclops Concrete 60% Concrete fc' 15 Mpa: 40% Stone	m3	11,154.98	828,710	9,244,239,332	
4	1 m2 Exposed Concrete Wall Formwork with 18 mm Multiflex	m2	9,815.25	143,250	1,406,034,563	
5	1 m2 Scaffolding / Supporting Formwork Rafter 5/7 for Concrete Walls Tm 2.50 m	m2	12,936.85	96,260	1,245,300,834	
6	Carefully dismantle 1 m2 of Formwork and Scaffolding	m2	9,815.25	6,680	65,565,870	
7	Concrete Making and Casting fc' = 20 Mpa (K 225) Mechanical Transported radius 2000 m	m3	9,113.29	1,109,990	10,115,662,876	
8	Construction Joint Filler	m3	7.70	81,370	626,800	
9	1 kg Slab reinforcement for B/T or B/Ts diameter > 12 mm Semi-Mechanical method	Kg	198,532.18	15,100	2,997,835,901	
10	1 kg Anchor Bolt	kg	36,134.41	23,030	832,175,398	
11	Geotextile, Medium thickness (> 400 to < 800 gr), Manual		4,500.00	38,590	173,655,000	

Source: JICA Project Team

CHAPTER 7 OVERVIEW OF ENVIRONMENTAL AND SOCIAL CONSIDERATIONS ACTIVITIES

7.1 Update of Existing Environmental Assessment Reports

7.1.1 Types and Determination Process of Environmental Assessment Reports in Indonesia

The key legal frameworks governing environmental and social considerations in Indonesia are as follows:

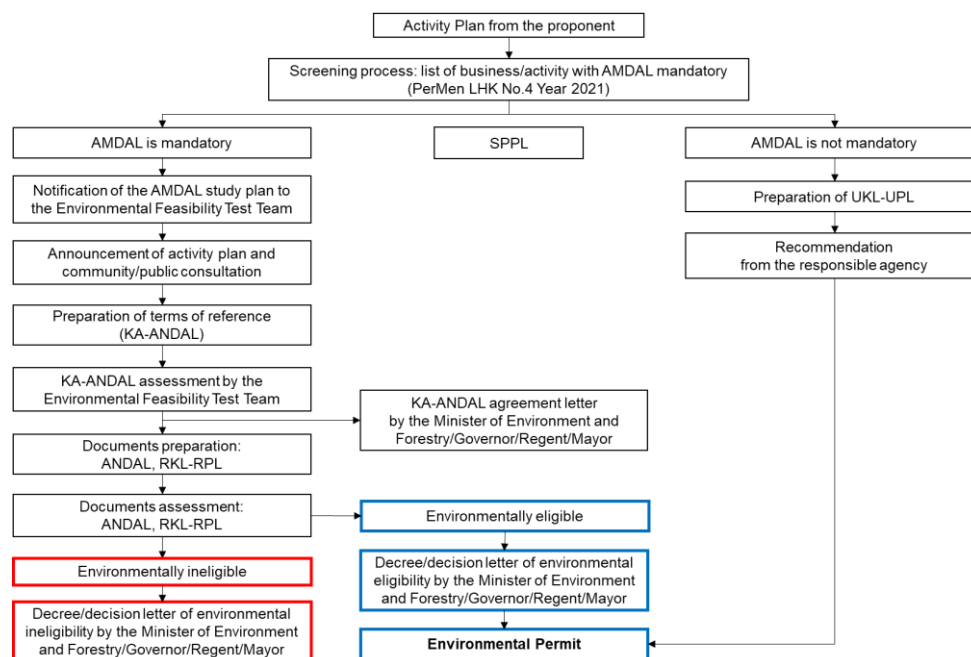
[Environmental Regulations]

- Environmental Protection and Management Law (Law No. 32 of 2009)
- Implementation of Environmental Protection and Management (Government Regulation No. 22 of 2021)
- Types of Project Plans/Activities Subject to Environmental Impact Assessment (Regulation of the Minister of Environment and Forestry No. 4 of 2021)
- Implementation of Spatial Planning (Government Regulation No. 21 of 2021)

Indonesia regulation administers three types of environmental assessment reports required to obtain environmental approval and a prerequisite for construction permits. The processes vary depending on the degree of risk associated with the relevant project activities:

1. AMDAL (Environmental Impact Assessment): requires an Environmental Impact Assessment (EIA) review process.
2. UKL-UPL (Environmental Management and Monitoring Program): requires a review process for the Environmental Management and Monitoring Plan.
3. SPPL (Statement of Environmental Management and Monitoring Commitment): requires submission of an Environmental Management Plan.

The Ministry of Environment and Forestry or the Environmental Agency at the provincial, regency, or municipal level determines whether AMDAL is required, based on the nature and scale of the project (as stipulated in Minister of Environment and Forestry Regulation No. 4 of 2021). The assessment flow is outlined below.



Source: JICA Project Team

Figure 7-1 Environmental assessment process flow in Indonesia

7.1.2 Status of Existing Environmental Assessment Report Preparation

The project content and scale requirements related to this project as set out in Minister of Environment and Forestry Regulation No. 4 of 2021 are as follows:

Table 7-1 Scale requirements for project activities by type of environmental document

Countermeasures	AMDAL	UKL-UPL	SPPL
River normalization (small cities or rural areas)	a. length \geq 15 km; or b. volume \geq 500,000 m ³	a. 15 km > length \geq 1 km; or b. 500,000 m ³ > volume \geq 50,000 m ³	a. length < 1 km; or b. volume < 50,000 m ³

During the emergency response works following the 2021 eruption, it was determined that the required environmental assessment reports for S2 and S4 targeted in this project, based on the criteria in Table 7-1, would be UKL-UPL. The reports were prepared in accordance with the basic framework outlined in Government Regulation No. 22 of 2021 (refer to Table 7-2) and submitted by the Lumajang Regency Public Works and Spatial Planning Office (DPUTR) to the Lumajang Regency Environmental Office (DLH). Based on these reports, environmental approvals were obtained on March 16, 2023, and May 24, 2023.

Table 7-2 Basic structure of UKL-UPL

Item	Details
A. Person in charge/institution information	
B. Project plan/activity description	<ul style="list-style-type: none"> • Project name • Project location and map • Project size • Compatibility with existing spatial plans • Technical approvals (environmental standards) related to the project/activity • Components of the project that may have an environmental impact
C. Environmental impacts and approaches to environmental management, as well as environmental management and monitoring standards	<ul style="list-style-type: none"> • Environmental impacts caused by project plan/activities (sources of impact, types of impact, magnitude of impact). • Environmental management standards (management criteria, management locations, management period). • Environmental monitoring standards (monitoring criteria, monitoring locations, monitoring period). • Environmental management and monitoring agencies.
D. Statement	<ul style="list-style-type: none"> • A signed statement from the person responsible for the project plan/activity implementing UKL-UPL.
E. References	<ul style="list-style-type: none"> • Books, journals, articles, publications, and research reports on the sources of data and information used in the preparation of the UKL-UPL.
F. Appendix	<p>Attach the following data and information as necessary:</p> <ul style="list-style-type: none"> • Technical approval of the project plan/activity, compliance with environmental quality standards and toxic and hazardous materials (B3) waste management, and traffic impact analysis published by the authorized agency. • Formal proof that the location plan for the project plan/activity has been completed in accordance with the applicable spatial planning, in the form of a confirmation letter or recommendation. • Other detailed information on the physical activity plan that is considered necessary. • Maps describing the locations of environmental management and environmental monitoring. • Other data and information that is considered necessary.

7.1.3 Update of Environmental Approvals

Article 89 of Government Regulation No. 22 of 2021 stipulates the need for modifications to environmental approvals in response to changes in project plans or activities. Accordingly, it was deemed necessary to update the previously obtained environmental approval based on the preliminary detailed design results (draft).

Following discussions with DLH of Lumajang Regency, the regulatory body for environmental approvals, it was agreed to update the existing UKL-UPL as part of the process to secure revised environmental approval. The steps for updating the approval, carried out according to the workflow is presented in Figure 7-2.

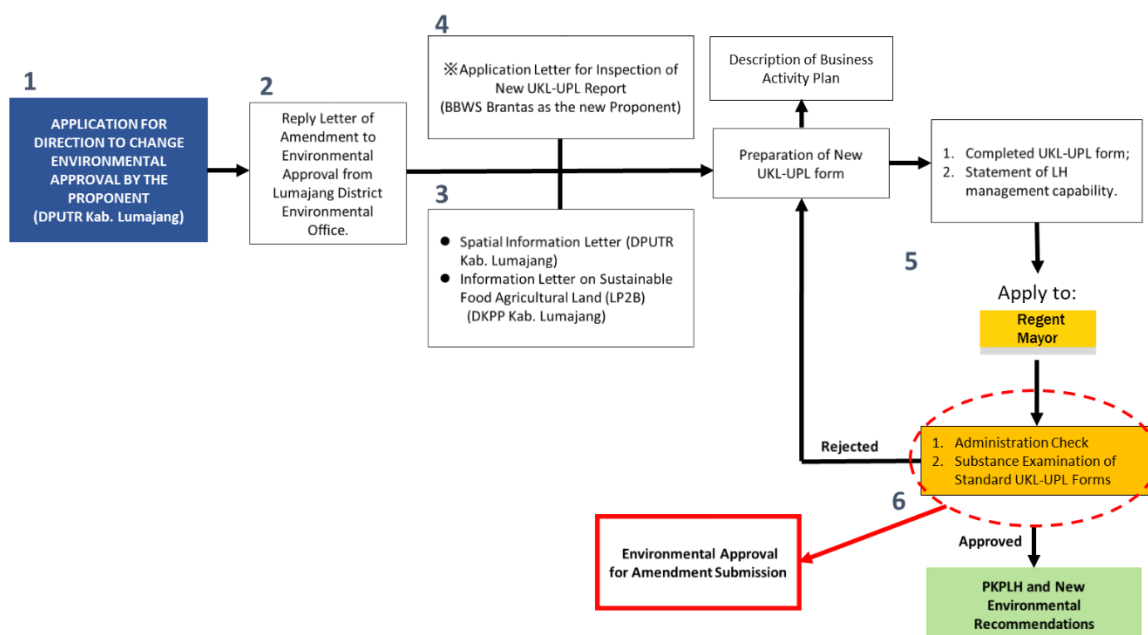


Figure 7-2 Environmental survey report revision workflow

1. DPUTR of Lumajang Regency requests modification of the environmental approval.
2. DLH of Lumajang Regency approves the modification request.
3. Notification regarding spatial planning changes is submitted to DLH, and notification regarding sustainable agricultural land is sent to the Food Security and Agriculture Agency (DKPP).
4. A request is submitted to change the implementing agency from DPUTR to BBWS Brantas.
5. The revised UKL-UPL is prepared and submitted to the Governor of Lumajang Regency.
6. The revised UKL-UPL forms the basis for approving the modification of environmental approval.

7.1.4 Key Updates to the Environmental Assessment Report

The original UKL-UPL application divided the project, including the targeted facilities, into three packages. For the updated report, a comparative analysis was conducted between the plans in the original UKL-UPL and the preliminary detailed design results (draft) for each package.

The type of environmental assessment report required for sabo facility plans depends on excavation volumes and facility length. The comparison confirmed that all three packages remained within the UKL-UPL criteria—river length in the construction area under 15 km and excavation volumes under 500,000 m³—as outlined in Table 7-1. Therefore, no additional EIA was required, and the content of the existing UKL-UPL was updated accordingly.

Table 7-3 Comparison of existing plans and preliminary detailed design results (draft)

Pk. No.	No	Facility	Volume (m ³)		Length (m)	
			Before	After	Before	After
3	S2-1	CD Kobokan 5	248,822.00	254,640.63		
		CD Kobokan 5a	156,195.00	156,195.00		
		CD Kobokan 1	45,600.00	45,600.00		
		CD Kobokan 3	41,250.00	41,250.00		
		Total	491,867.00	497,685.63	± 1,369	± 1,369
1		CD Curah Lengkong 1	108,675.00	108,675.00		
	S2-2	CD Pelintas Curah Lengkong 2	1,260.00	30,032.75		
	S2-3	Tanggul Curah Lengkong	27,300.00	80,662.74		
		Total	137,235.00	219,370.49	± 1,600	± 1,600
4	S4-1	Krib Hulu Leprak	30,720.00	2,146.95		
		Tanggul Leprak 22	-	16,343.60		
		Tanggul Leprak 23	-	4,810.00		
		Tanggul Leprak 24	32,640.00	20,052.00		
		Tanggul Leprak 25		23,532.75		
		Tanggul Leprak 26		35,391.25		
		Tanggul Leprak XVII Kebondeli 2021	-	34,460.88		
		Tanggul Leprak II-D	-	28,043.38		
	Total	63,360.00	164,780.81			
	S4-2	Krib Beton Sumberwuluh	15,790.00	15,898.13		
	S4-3	KD Leprak 3	216,000.00	61,237.16		
		DD Leprak 2		91,167.00		
		DD Leprak 3		155,792.00		
		Tanggul Emergency		524.64		
		Sub Total	216,000.00	308,720.80		
		Total	295,150.00	489,399.74	± 2,282	± 3,885
				<500,000.00		<15,000

7.2 Updates in line with JICA Guidelines for Environmental and Social Considerations

7.2.1 Anticipated Negative Impacts During Construction

Based on the JICA Guidelines for Environmental and Social Considerations (January 2022) (hereafter, JICA Guidelines), the scope of impacts under review was confirmed and the UKL-UPL was updated. The specific measures and monitoring items related to environmental and social considerations are stated according to "C. Environmental Impact and Environmental Management Initiatives, and Environmental Management and Monitoring Standards" in Table 7-2, and summarized at the end of the chapter as "Matrix of Environmental Management and Monitoring Standards". This matrix was checked against the scopes of impacts to be assessed in JICA Guidelines to confirm the specific measures and monitoring contents. Furthermore, in consultation with BBWS Brantas and the DLH of Lumajang Regency, the missing items were added and the missing parts were updated. The main aspects that were missing in the existing UKL-UPL were as follows

- (1) Specificity of the measures to be described in the environmental management standards
- (2) Feasibility of monitoring (method of implementation, frequency, location)
- (3) Social environmental issues such as land use, impact on existing social infrastructure and gender.

(4) Establishment of a grievance redress mechanism

The update was carried out based on the deficiencies identified, and the main points (1) and (2) were incorporated into the updated content. Table 7-4 shows an excerpt and summary of the main parts of the updated version of the “Matrix of Environmental Management and Environmental Monitoring Standards” according to the categories of the scopes to be assessed. In the table, the parts that have been significantly added to or updated from the existing UKL-UPL are indicated in bold blue.

On the other hand, as shown in Table 7-2, the UKL-UPL has a prescribed form. The form focuses on the environmental impact of construction, and the form was already certainly decided, so it was difficult to comprehensively incorporate the missing scope. Therefore, the missing items that could not be included in the UKL-UPL documents listed in (3) and (4) are summarized in 7.3 as recommendations for environmental and social considerations that should be taken into account in future project implementation.

Table 7-4 Matrix of environmental management and monitoring standards (extracted and summarized from UKL-UPL)

Category	Item	Environmental Management Standards (Countermeasures)	Environmental Monitoring Standards			Related Agencies
			Activity	Location	Period	
Pollution Control/ Natural Environment	Wastes (Domestic Solid Wastes)	<ul style="list-style-type: none"> • Provide trash bins and carry out routine transportation a maximum of once every 3 (three) days to the nearest waste management or the temporary landfill (TPS). • Put up a warning to throw away trash in the places provided. • Carrying out waste management in accordance with related laws and regulations. 	<p><u>Data Collection Method</u> Direct observation of the presence of solid waste that arises .</p> <p><u>Data Analysis Method</u> Carry out qualitative analysis by comparing conditions before and during construction.</p>	In the project area, basecamp, director's kit and around the activity location	Every day during the construction period	<p><u>Implementing Agency</u> *BBWS Brantas <u>Supervisor Agency</u> Lumajang Regency DLH Aparat Musupika <u>Report Receiving Agency</u> Lumajang Regency DLH</p>
	Wastes (Construction Wastes)	<ul style="list-style-type: none"> • Arrange the place/warehouse for building materials to avoid damage to building materials. • Scrap waste (mechanical work residue in the form of metal) is placed in a scrap metal collection area and, in coordination with external parties, is recycled or reused. • Prepare a temporary storage area for residual materials and construction waste, and consolidate construction waste in the temporary storage area before transporting it off-site. • Reduce construction waste by preventing material damage through proper and protected storage of construction materials. • Reuse residual material according to the material specifications required to reduce the amount of residual material in the disposal area. 	<p><u>Data Collection Method</u> Create a data inventory that recorded the amount of construction waste generated by contractors each day.</p> <p><u>Data Analysis Method</u> Evaluate the performance of construction waste management by comparing the amount of construction waste generated (stored) and managed. (utilized, transported outside the project site)</p>	Temporary storage location for construction waste in the project site area	During construction phase	<p><u>Implementing Agency</u> *BBWS Brantas <u>Supervisor Agency</u> Lumajang Regency DLH Aparat Musupika <u>Report Receiving Agency</u> Lumajang Regency DLH</p>
	Air Pollution	<ul style="list-style-type: none"> • Close the bodies of material transport vehicles properly to prevent particles and dust from flying up along the road to the work site. • Regularly water down the roads used by material transport vehicles that may cause dust to fly up, and soak materials that are not damaged by water before cutting. • Workers should wear masks. • Do not leave materials and materials piled up for too long at the planned activity site. • Clean the vehicle body and tires if materials or materials that may be covered in dust or mud are left. • Clean the road if materials are scattered on the road. 	<p><u>Data Collection Method</u> Conduct atmospheric testing at the field.</p> <p><u>Data Analysis Method</u> Comparing test results with the national standards.</p>	8 points in the project area and its surroundings (Supiturang Village, Pronojiwo District)	During the construction phase, routinely every 6 months and incidentally if there are complaints from the public	<p><u>Implementing Agency</u> *BBWS Brantas <u>Supervisor Agency</u> Lumajang Regency DLH Aparat Musupika <u>Report Receiving Agency</u> Lumajang Regency DLH</p>

Category	Item	Environmental Management Standards (Countermeasures)	Environmental Monitoring Standards			Related Agencies
			Activity	Location	Period	
Pollution Control/ Natural Environment	Noise	<ul style="list-style-type: none"> • Build a barrier or wall around the planned activity location. • Arrange the equipment and material transportation schedule so that it is not carried out during break times. • Carry out regular maintenance on heavy equipment. • Do not work at night (work 08.00-17.00 WIT). 	<u>Data Collection Method</u> Direct measurement in the field with a sound level meter <u>Data Analysis Method</u> Comparing test results with the national standards	8 points in the project area and its surroundings (Supiturang Village, Pronojiwo District)	Daily during construction/ Routinely every 6 months and when there are complaints from the public	<u>Implementing Agency</u> *BBWS Brantas <u>Supervisor Agency</u> Lumajang Regency DLH <u>Aparat Musupika Report Receiving Agency</u> Lumajang Regency DLH
	Vibration	<ul style="list-style-type: none"> • Conduct construction activities during the day. • Follow the SOP for construction work. • Prepare the SOP for compensation if there is proven damage to surrounding buildings due to construction activities. 	<u>Data Collection Method</u> Conduct vibration test in an accredited Laboratory. <u>Data Analysis Method</u> Compare laboratory test data with applicable quality standards.	Project footprint	During construction and when there are complaints from the public	<u>Implementing Agency</u> *BBWS Brantas <u>Supervisor Agency</u> Lumajang Regency DLH <u>Aparat Musupika Report Receiving Agency</u> Lumajang Regency DLH
	Water Use (Domestic water)	<ul style="list-style-type: none"> • Provide appropriate toilet facilities for workers. • Regular cleaning of toilets by cleaning staff • Suction fecal sludge from toilets through cooperation with third parties who have competence in this field • Create warning signs, provide education and prohibitions to workers so that while at the construction site they always maintain cleanliness and do not pollute the river. 	<u>Data Collection Method</u> Direct observation, water quality testing if water pollution is suspected. <u>Data Analysis Method</u> Carry out qualitative analysis by comparing conditions before and during construction.	In the project area, basecamp, director's kit and around the activity location	Routinely every 6 months during construction and when there are complaints from the public	<u>Implementing Agency</u> *BBWS Brantas <u>Supervisor Agency</u> Lumajang Regency DLH <u>Aparat Musupika Report Receiving Agency</u> Lumajang Regency DLH
Social Environment	Local Employment and Livelihood	<u>Employment and dismissal of construction workers (50 people assumed)</u> <ul style="list-style-type: none"> • When recruiting workers, give priority to the local community according to the necessary qualifications. • Pay wages according to at least the provincial minimum wage (UMK), in accordance with expertise and applicable standards. • Coordinate the process of recruiting and dismissing workers with government officials and the Labor Office • Workers will be enrolled in national health insurance (JKN). • Provide vocational training in preparation for dismissal at the end of the project. 	<u>Data Collection Method</u> Conduct dialogue/interviews with employees and the surrounding community regarding recruitment activities. <u>Data Analysis Method</u> Record the results of the collected opinions Analyze the results of comparing application conditions, treatment, etc. in the recruitment process.	The scope of social boundaries around the activity location	During the recruitment process/ Once at the time of layoff	<u>Implementing Agency</u> *BBWS Brantas <u>Supervisor Agency</u> Lumajang Rgency Labor Office <u>Aparat Musupika Report Receiving Agency</u> Lumajang Regency Labor Office
	Utilization of	<u>Negative concerns for land lease (pre-construction</u>	<u>Data Collection Method</u>	The scope of	When land	<u>Implementing Agency</u>

Category	Item	Environmental Management Standards (Countermeasures)	Environmental Monitoring Standards			Related Agencies
			Activity	Location	Period	
	land and local resources	<u>phase)</u> <ul style="list-style-type: none"> • Conduct socialization and coordination with the Community, local sub-district village officials, Sand Mining Owners and DLH. • Open Access for the community who want to provide suggestions, opinions and responses in the UKL-UPL Process. 	Gather opinions from stakeholders Gather necessary licenses and registration information <u>Data Analysis Method</u> Record and organize the results of the collected opinions Evaluating whether the necessary licenses and registrations are in place for the implementation of the project	social boundaries around the activity location	rental activities are carried out	*BBWS Brantas <u>Supervisor Agency</u> Lumajang Rgency DLH Aparat Musupika <u>Report Receiving Agency</u> Lumajang Rgency DLH
	Local Conflicts of Interest	<u>Conflict of interest between those hired and those not hired by the project</u> <ul style="list-style-type: none"> • The recruitment process is carried out transparently and in accordance with applicable procedures. • Coordinating with local sub-district officials and the Labor Office in the process of recruiting workers 	<u>Data Collection Method</u> Record the number of local workers involved in the activities Observation of the labor recruitment process <u>Data Analysis Method</u> Record the results of the collected opinions Analyze the results of comparing application conditions, treatment, etc. in the recruitment process	The scope of social boundaries around the activity location	During the recruitment process	<u>Implementing Agency</u> *BBWS Brantas <u>Supervisor Agency</u> Lumajang Rgency Labor Office Aparat Musupika <u>Report Receiving Agency</u> Lumajang Rgency Labor Office
	Existing social infrastructures and services	<u>Traffic congestion caused by construction vehicles</u> <ul style="list-style-type: none"> • Provide adequate space for vehicles to enter and exit. • Move equipment and materials during off-peak hours (at night). • Park equipment and vehicles appropriately in accordance with regulations to avoid using the road body. • Install traffic signs to ensure smooth movement. • Prohibit parking on the side of the road. • Assign personnel wearing personal protective equipment (PPE) to direct traffic at the entrance and exit of the work area and at road intersections. • Drivers should pay attention to the tires of their vehicles, especially when entering and leaving the 	<u>Data Collection Method</u> Direct observation <u>Data Analysis Method</u> Carry out qualitative analysis by comparing conditions before and during construction.	On the route taken and at the exit and entrance to the activity location	Every day during vehicle mobilization	<u>Implementing Agency</u> *BBWS Brantas <u>Supervisor Agency</u> Lumajang Rgency Transportation Office Aparat Musupika <u>Report Receiving Agency</u> Lumajang Rgency Transportation Office

Category	Item	Environmental Management Standards (Countermeasures)	Environmental Monitoring Standards			Related Agencies
			Activity	Location	Period	
		<p>work area, to ensure that they are not contaminated with mud. If mud or dirt is attached to the tires before leaving the site, install a water drain trap and clean the tires.</p> <ul style="list-style-type: none"> Drivers of material and equipment transport vehicles must always comply with posted signs and take care not to transport loads that exceed the current road capacity. Use vehicles that have passed a roadworthiness test and do not exceed the maximum load capacity of 8 tons. 				
	Working conditions (Occupational safety and Health)	<p><u>Accident</u></p> <ul style="list-style-type: none"> Work according to Procedure/SOP. Report immediately if you find something unsafe. Use Personal Protective Equipment (PPE) when working. Carry out evacuation procedures according to SOP in the event of a natural disaster 	<p><u>Data Collection Method</u> Visual observation, recording of work accidents</p> <p><u>Data Analysis Method</u> Compare monitoring results with applicable SOPs</p>	Construction work area	Every day during construction work	<p><u>Implementing Agency</u> *BBWS Brantas</p> <p><u>Supervisor Agency</u> Lumajang Regency DLH</p> <p><u>Aparat Musupika</u> <u>Report Receiving Agency</u> Lumajang Regency DLH</p>

*The implementing organization is referred to as BBWS Brantas, the contractor is scheduled to implement.

Blue bold: Additions and updates to the existing UKL-UPL

7.2.2 Confirmation of Land and Acquisition and Involuntary Resettlement

The project primarily involves rehabilitation and reconstruction of existing facilities along the rivers, thus no new land acquisition is required. For S4-1 (Tanggul Leprak 22–26), a 3-meter widening of the existing facility will ensure necessary gradients, but after inquiring with BBWS Brantas about this point, it was confirmed that it is not necessary to acquire new land.

All project sites are public land along rivers, with no residential areas affected, ensuring that no relocation of residents is required.

7.2.3 Comparison of JICA Guidelines and UKL-UPL and Bridging Measures

As a summary, the contents of the JICA Guidelines and the updated UKL-UPL were compared, and the gaps between the two and the countermeasures to fill them are shown in Table 7-5.

Table 7-5 Comparison of JICA Guidelines and UKL-UPL, and bridging measures

Target	JICA Guidelines	Contents of UKL-UPL	Comparison of JICA Guidelines and UKL-UPL, Bridging Measures
Basic Principles	<ul style="list-style-type: none"> ➤ Environmental and social impacts caused by projects must be assessed and examined at the earliest possible planning stage. Alternatives or mitigation measures must be examined, in order to avoid such impacts as much as possible, and to minimize, reduce or mitigate them when such avoidance is impossible. The result of the examinations must be reflected into the project plan. (Appendix 1. 1. 1) 	<p>“Chapter 3: Matrix of environmental management and monitoring standards” describes the anticipated environmental impact before, during and after construction, as well as specific mitigation measures. No alternative plans are described.</p>	<p>As there is no requirement to include alternative proposals in the UKL-UPL format, there is no description, but in 3.3.2, the circumstances of the asset distribution, riverbed conditions, disaster history, etc. for each of the S1 to S4 packages are compared, and the circumstances in which S2 and S4 were selected are described.</p>
Examination of Measures	<ul style="list-style-type: none"> ➤ Multiple alternatives must be examined in order to avoid or minimize adverse impacts by the project and to choose better project options in terms of environmental and social considerations. (Appendix 1. 2. 1) 	<p>None stated.</p>	<p>As there is no requirement to include alternative proposals in the UKL-UPL format, there is no description, but in 3.3.2, the circumstances of the asset distribution, riverbed conditions, disaster history, etc. for each of the S1 to S4 packages are compared, and the circumstances in which S2 and S4 were selected are described.</p>
Scope of Impacts to Be Assessed	<ul style="list-style-type: none"> ➤ The impacts to be assessed with regard to environmental and social considerations include impacts on human health and safety, as well as on the natural environment, that are transmitted through air, water, soil, waste, accidents, water use, climate change, biodiversity, and ecosystem services, including trans-boundary or global scale impacts. These also include social considerations such as: Migration of population including involuntary resettlement, local economy such as employment and livelihood, utilization of land and local 	<p>“Chapter 3: Matrix of environmental management and monitoring standards” includes information on the impacts on human health and safety, the natural environment, and social considerations.</p>	<p>Table 7-4 shows a comparison between the items related to this project within the scope of impacts to be assessed and the items listed in the UKL-UPL, and the items considered to be lacking are summarized in 7.3 as recommendations.</p>

Target	JICA Guidelines	Contents of UKL-UPL	Comparison of JICA Guidelines and UKL-UPL, Bridging Measures
	resources, social institutions such as social capital and local decision-making institutions, existing social infrastructures and services, vulnerable social groups such as poor peoples and indigenous peoples, equality of benefits and losses and equality in the development process, gender, children's rights, cultural heritage, local conflicts of interest, infectious diseases such as HIV/AIDS, and working conditions including occupational safety. (Appendix 1. 3. 1)		
Compliance with Laws, Standards, and Plans	➤ Projects must comply with the laws, ordinances, and standards related to environmental and social considerations established by host country governments, including local governments. Projects must also conform to the environmental and social consideration policies and plans of the host country governments. (Appendix 1.4.1)	“Chapter 1, 1.1 Background” states that UKL-UPL was selected in accordance with Government Regulation No. 22 of 2021 (Environmental Protection and Environmental Management).	In accordance with government regulations, UKL-UPL was selected as the required environmental document, and approval was obtained from the DLH in accordance with the prescribed procedures.
Social Acceptability	➤ Projects must be adequately coordinated so that they are accepted in a socially appropriate manner for the countries and areas where the projects are planned. (Appendix 1.5.1)	In the environmental management standards in “Chapter 3: Matrix of environmental management and monitoring standards”, there is a mention on “socialization and coordination with various stakeholders”.	There is a description of stakeholder dialogue in the UKL-UPL. There are recommendations regarding stakeholder consultation with relevant organizations and local communities in 7.3 (2) and (3).
Monitoring	<ul style="list-style-type: none"> ➤ During the project implementation, project proponents monitor whether any unforeseeable situations occur, and the performance and effectiveness of the planned mitigation measures. Project proponents take appropriate measures based on the results of such monitoring. ➤ In cases where sufficient monitoring is deemed essential for appropriate environmental and social considerations, such as projects for which mitigation measures should be implemented while monitoring their effectiveness, Project proponents must ensure that the project plans include feasible monitoring plans. (Appendix 1.10.1, 2) ➤ Appropriate plans and systems for measures, such as monitoring plans and environmental management plans, must be prepared. The costs of implementing such plans and systems, and the financial methods 	“Chapter 3: Matrix of environmental management and monitoring standards” includes the environmental management plan (countermeasures) and monitoring plan for each affected item.	The environmental management plan (countermeasures) and monitoring plan for each affected item in the UKL-UPL include a description of the implementing and supervisor organizations. The monitoring for leased land and monitoring standards for pollution control are described as recommendations in 7.3 (1). Although there is no specific mention of costs, it has been confirmed that the costs for monitoring are borne by the contractors in charge of the actual monitoring.

Target	JICA Guidelines	Contents of UKL-UPL	Comparison of JICA Guidelines and UKL-UPL, Bridging Measures
	to fund such costs, must be determined. (Appendix 1.2.2)		
Grievance Redress Mechanism	➤ A mechanism for handling concerns and grievances from people and communities affected by the project's environmental and social impacts must be in place. (Appendix 1.11.1)	The environmental management standards of "Chapter 3: Matrix of environmental management and monitoring standards" includes "open access for the community who want to provide suggestions, opinions and responses".	There is a description of the establishment of a grievance redress mechanism in UKL-UPL. The specific method of establishment is described as a recommendation in 7.3 (4).
Climate Change	➤ For projects that are expected to generate more than a certain amount of greenhouse gas emissions, the total amount of greenhouse gas emissions will be estimated and disclosed before the project implementation. (Appendix 1.6.1)	None stated.	Not applicable because large-scale greenhouse gas emissions are not expected.
Biodiversity	➤ Projects must not involve significant conversion or significant degradation of critical habitats or critical forests. (Appendix 1.7.1)	None stated.	Not applicable because significant conversion or significant degradation of critical habitats or critical forests is not expected.
Involuntary Resettlement and Loss of Livelihood	➤ Involuntary resettlement and loss of means of livelihood are to be avoided when feasible by exploring all viable alternatives. (Appendix 1.8.1)	None stated.	Not applicable because involuntary resettlement and loss of livelihood are not expected.
Indigenous Peoples	➤ Any adverse impacts that a project may have on indigenous peoples are to be avoided when feasible by exploring all viable alternatives. (Appendix 1.9.1)	None stated.	Not applicable because indigenous peoples are not confirmed to be living in the project area.

7.3 Recommendations for Environmental and Social Considerations

Following the submitted updated UKL-UPL, the environmental approval necessary for a construction permit was obtained on December 10, 2024. With regard to the scope that could not be included in the update of the UKL-UPL, which already has a fixed format, the following have been compiled as recommendations for environmental and social considerations to be taken into account for ongoing project development. An information session on environmental and social considerations was held in December 20, 2024 to share the results of these recommendations.

(1) Monitoring Temporary Land Renting during Construction

This project is considering renting approximately 2.5 hectares of land for each of S2 and S4 each as a place to manufacture concrete and standby areas for heavy equipment during construction. The Engineering Estimate (EE) includes rental costs calculated based on the unit price set by PU. In addition, it is expected that a total of approximately 54,100 m² of private land will be temporarily leased to secure a construction work site along the river.

These are only temporary measures during construction and will not affect environmental approvals, but the contractor will need to conduct environmental monitoring every six months in accordance with the monitoring frequency specified in the UKL-UPL to ensure appropriate management. In addition, a plan should be made in advance to ensure that the land can be promptly restored to its original state after construction is completed and returned to the landowner.

The specific monitoring items will be in accordance with the items listed in the pollution control/natural environment category in Table 7-4. For items that actually require field inspection and testing, the relevant Indonesian regulations shall be followed. The standard values for each regulation are shown in Table 7-5.

Table 7-6 Monitoring Test Items/Standard Values

Item	Monitoring Test Items/Standard Values	Reference Regulations and Standards
Air Pollution	NO ₂ : 200 µg/m ³ SO ₂ : 150 µg/m ³ Ox: 100 µg/m ³ CO: 10000 µg/m ³ , Pb: 2 µg/m ³ , dust (TSP): 230 µg/m ³	Implementation of Environmental Protection and Management (Government Regulation No. 22 of 2021)
Noise	< 70 dB (A)	Noise Level Standards (Minister of Environment Regulation No. 48 of 1996)
Vibration	f 4hz <2 mm/sec, f 5hz >7.5 mm/sec, f 6.3hz <7 hz, f 8hz <6 hz, f 10hz <6 hz, f 12.5hz < 4.86 hz, f 16hz <4 hz, f 20hz <3.8 hz, f 25hz <3.2 hz, f 31.5hz <3 hz, f 40hz <2 hz, f 50hz <1 hz	Vibration Level Standards (Minister of Environment Regulation No. 49 of 1996)
Water Quality (waste water)	pH: 6-9 BOD: 30 mg/L COD: 100 mg/L TSS: 30 mg/L Oil and Fat: 5 mg/L Ammonia: 10 mg/L Total Coliform: 3000/100mL	Household Wastewater Quality Standards (Minister of Environment and Forestry Regulation P.68/MENLHK/SETJEN/KUM.1/8/2016)

(2) Strategy to Minimize Soil Excavation and Its Implementation

Although the expected excavated soil volume for this project is expected to be within the UKL-UPL standard range, there is a possibility that excavating soil and sand close to existing sabo facilities such as sabo dams and diversion dikes, could affect the stability of the foundations of these existing facilities. In order to minimize such impacts, BBWS Brantas plans to promote proper excavation work by the Energy and Mineral Resources Agency of East Java Province (ESDM East Java) and local sand miners to reduce the overall excavation volume.

A stakeholder meeting was held with the ESDM East Java, which is in charge of monitoring mining companies licensed by the Ministry of Energy and Mineral Resources, the Water Resources Agency of East Java (SDA), which is in charge of technical support, and BBWS Brantas. This meeting aimed to explain the details of this project plan to the relevant agencies and seek their understanding and cooperation in setting the minimum distance from existing facilities for sand mining and the range in which excavation is possible, and their agreement was obtained. Further, ESDM East Java organized a follow-up meeting with seven sand mining companies. The invited companies are those whose sand mining permits overlap with the project areas (S2 and S4 areas). The project overview was presented and focus group discussions with miners. Joint on-site surveys are planned to take place. It is necessary to request the sand mining companies to respect the minimum distance from existing facilities and the range of excavation that can be carried out.

BBWS should develop a detailed reduction strategy that specified the excavation range and excavation depth limits, based on a comprehensive evaluation of the changes in river boundaries and the condition of buried structures due to the eruption. This strategy should be shared with relevant agencies. In addition, they should call for cooperation and conduct monitoring of sand mining companies operating in the target area through the ESDM East Java.

Currently, sand mining is permitted around buried structures, but there is a need to establish a system that ensures immediate notification to BBWS Brantas if any structures are discovered during the mining process.

Furthermore, in order to regulate illegal miners who do not have the necessary permits, it is necessary to take measures against illegal miners such as by holding broader stakeholder meetings.

(3) Consideration Regarding Utilization of Access Roads Adjacent to Residential Areas

The roads adjacent to residential area is planned to be utilized as construction access roads, and permission for its use during construction has already been obtained from the local government. However, since these roads are also used by local residents and sand mining companies, it is necessary to obtain the understanding of these stakeholders before utilizing the roads.

A meeting with stakeholders, including the local community, is scheduled to take place after the contractor for the project is selected. However, as the bidding process is currently on hold for administrative reasons, the meeting has not yet been held. Nevertheless, discussions should be held as soon as possible after preparations are complete, involving the stakeholders, local government, related agencies (such as ESDM and the Regional Development Planning Agency (BAPPEDA)), local community, and sand mining companies.

Further, although environmental standards and monitoring criteria address issues such as waste, noise, air pollution, and other issues, specific plans should be developed to minimize the impact on the daily lives of local residents. This plan should be implemented in collaboration with the community, ensuring their agreement and cooperation.

(4) Establishment of a Grievance Redress Mechanism

At the outset of the project, it is necessary to establish a mechanism for handling complaints from people and community affected by the environmental and social impacts of the project. Specifically, it is necessary to establish a dedicated grievance mechanism at the project site and in the local community so that local residents can directly submit complaints, and a hotline to receive complaints by phone or online so that anonymous reports can also be made.

BBWS Brantas currently has a grievance redressal mechanism for all projects under its jurisdiction in the form of WhatsApp, website and SMS, and disseminates information through its official SNS. In addition to these general grievance redress points, a dedicated grievance redress point and hotline should be established at the project office for this project. The contents should be announced on project posters around the work site, etc., to facilitate access by affected people and surrounding communities. Although the establishment of such a focal point is conventionally considered to be the role of the contractor, it is recommended that it be clearly specified as a specific activity in the contract with the contractor to ensure its establishment, if possible.

(5) Gender-Inclusive Construction Planning

In Indonesia, there are many female engineers, surveyors, and other professionals, including those working in government agencies. However, the number of female workers in civil engineering and construction projects tends to be less. To address this during construction work, efforts should be made to tackle wage disparities, provide separate toilets / rest areas for men and women, ensure privacy / safety, and create a work environment where everyone can feel comfortable and secure.

Furthermore, given the anticipated influx of workers from outside the area during the project implementation, comprehensive measures should be taken to prevent women in the local community and female construction workers from potential risks such as sexual violence or other forms of harm. To prevent these issues, strict site safety management should be implemented at the construction site,

along with gender equality and human rights education. All construction workers should receive training on gender-based violence, sexual exploitation and abuse, and harassment to ensure a safe and respectful work environment.

