Case Study

JENEBERANG RIVER BASIN,
SOUTH SULAWESI , INDONESIA

1. **RIVER BASIN**
2. **CALDERA OF MT. BAWAKARAENG**
3. **SEDIMENT CONTROL PLAN**
4. **BILI-BILI DAM**
5. **PROBLEMS OF DOWNSTREAM AREA OF BILI-BILI DAM**

1. RIVER BASIN

The Jeneberang River System, which has a catchments area of 762.01 km^2, originates at caldera slope of the Mt. Bawakaraeng. Five (5) major sub-basins :

1. Bili-Bili Dam Basin : 384.40 km^{2,}
2. Salo Malino : 85.89 km^2,
3. Salo Kausisi : 37.50 km^2,
4. Jene Rakikang (42.2 km^2),
5. Binanga Jajang : 22,7 km^2,

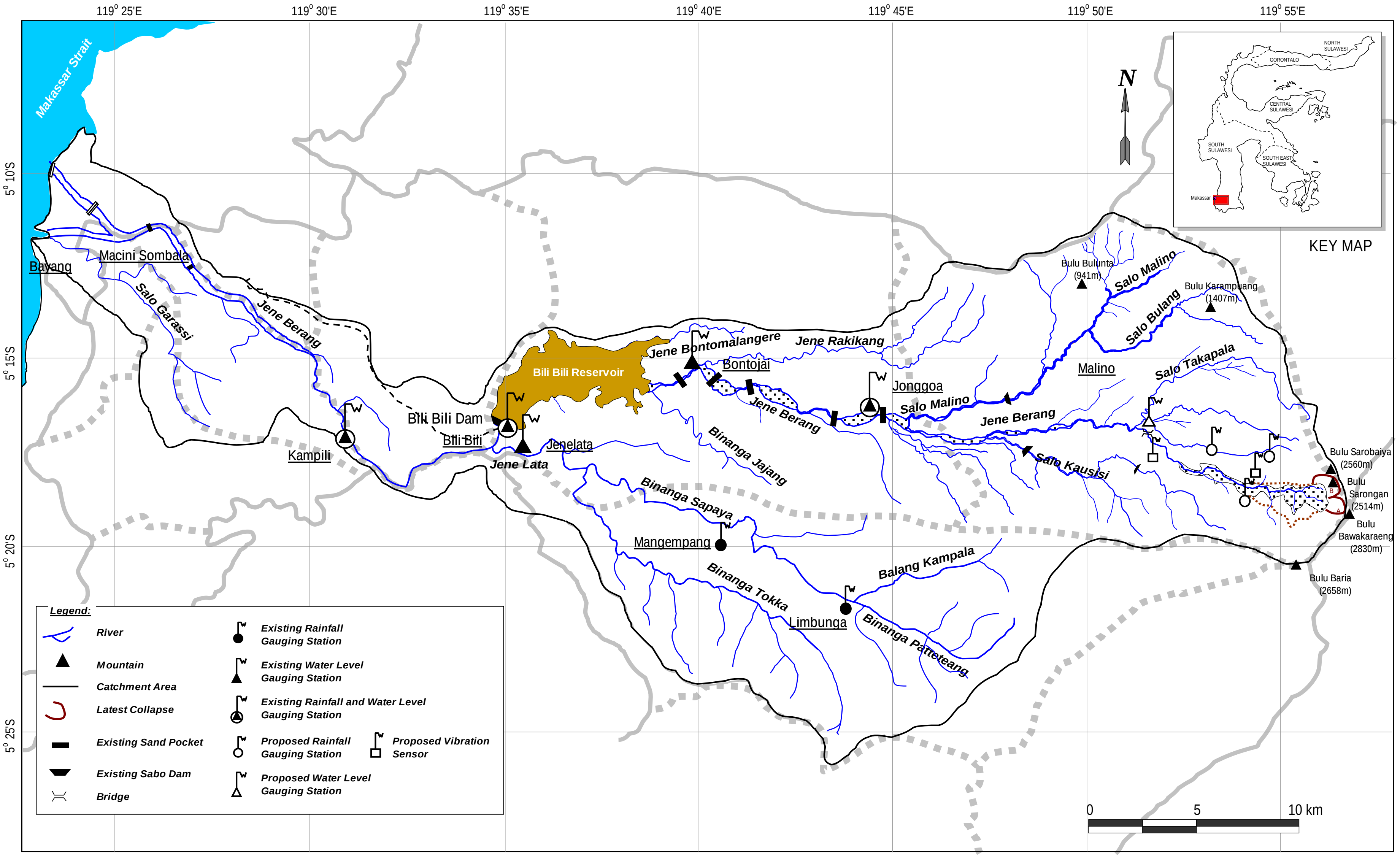
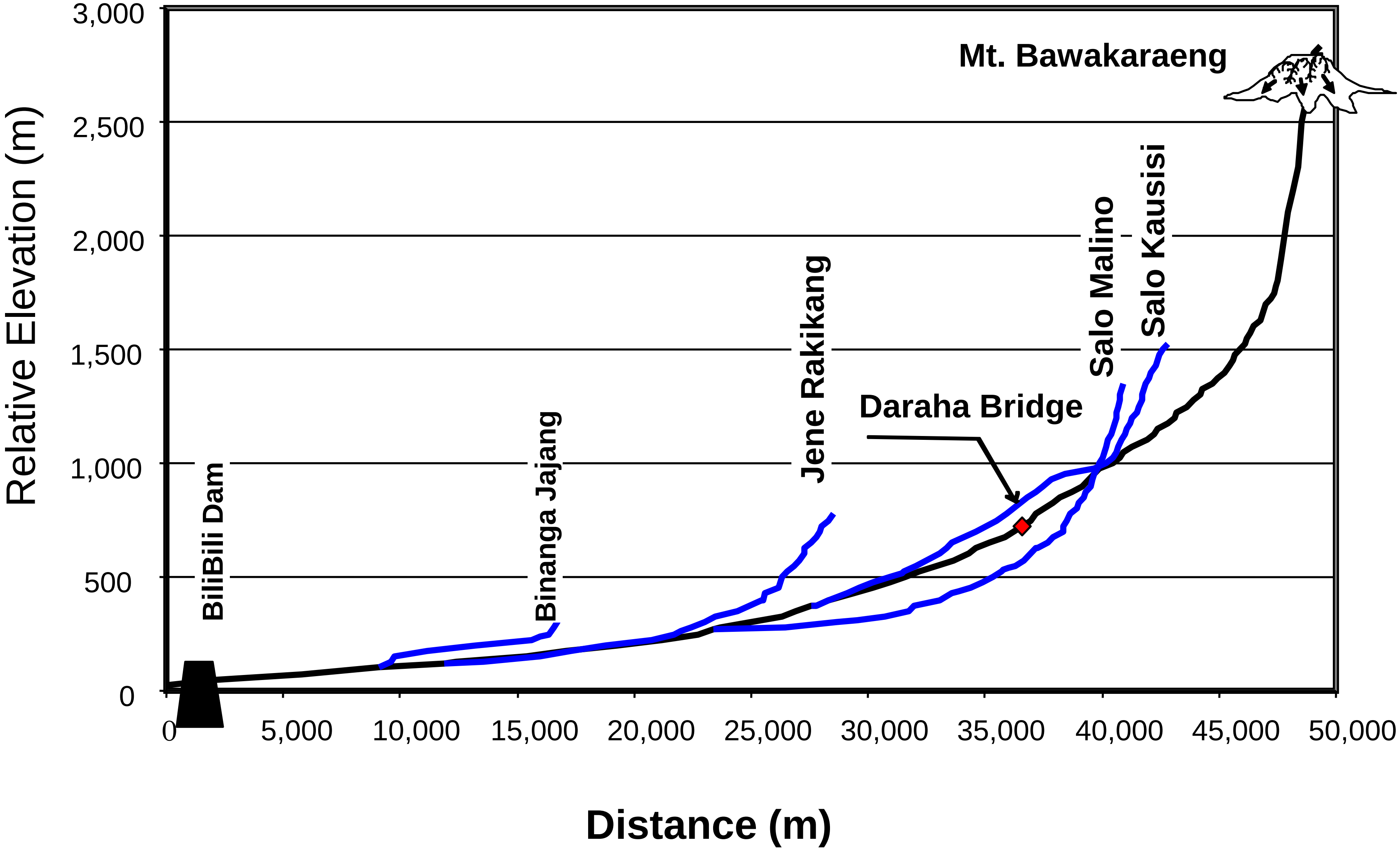

119° 25'E
119° 30'E
119° 35'E
119° 40'E
119° 45'E
119° 50'E
119° 55'E
5° 10'S
5° 15'S
5° 20'S
5° 25'S
Makassar Strait
N
KEY MAP
NORTH SULAWESI
GORONTALO
CENTRAL SULAWESI
SOUTH SULAWESI
SOUTH EAST SULAWESI
Makassar
Bayang
Macini Sombala
Salo Garassi
Jene Berang
Kampili
Bili Bili Dam
Bili-Bili
Bili Bili Reservoir
Jenelata
Jene Lata
Jene Bontomalangere
Bontojai
Jene Rakikang
Jene Berang
Binanga Jajang
Binanga Sapaya
Mangempang
Binanga Tokka
Limbunga
Binanga Patteteang
Balang Kampala
Jonggoa
Salo Malino
Jene Berang
Salo Kausisi
Malino
Salo Takapala
Salo Malino
Salo Bulang
Bulu Bulunta (941m)
Bulu Karampuang (1407m)
Bulu Sarobaiya (2560m)
Bulu Sarongan (2514m)
Bulu Bawakaraeng (2830m)
Bulu Baria (2658m)
B
A
0
5
10 km
Legend:
River
Mountain
Catchment Area
Latest Collapse
Existing Sand Pocket
Existing Sabo Dam
Bridge
Existing Rainfall Gauging Station
Existing Water Level Gauging Station
Existing Rainfall and Water Level Gauging Station
Proposed Rainfall Gauging Station
Proposed Vibration Sensor
Proposed Water Level Gauging Station

Figure 1.

Figure 1.


Mt. Bawakaraeng
Salo Malino
Salo Kausisi
Jene Rakikang
Daraha Bridge
Binanga Jajang
BiliBili Dam
Relative Elevation (m)
3,000
2,500
2,000
1,500
1,000
500
0
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
50,000
Distance (m)

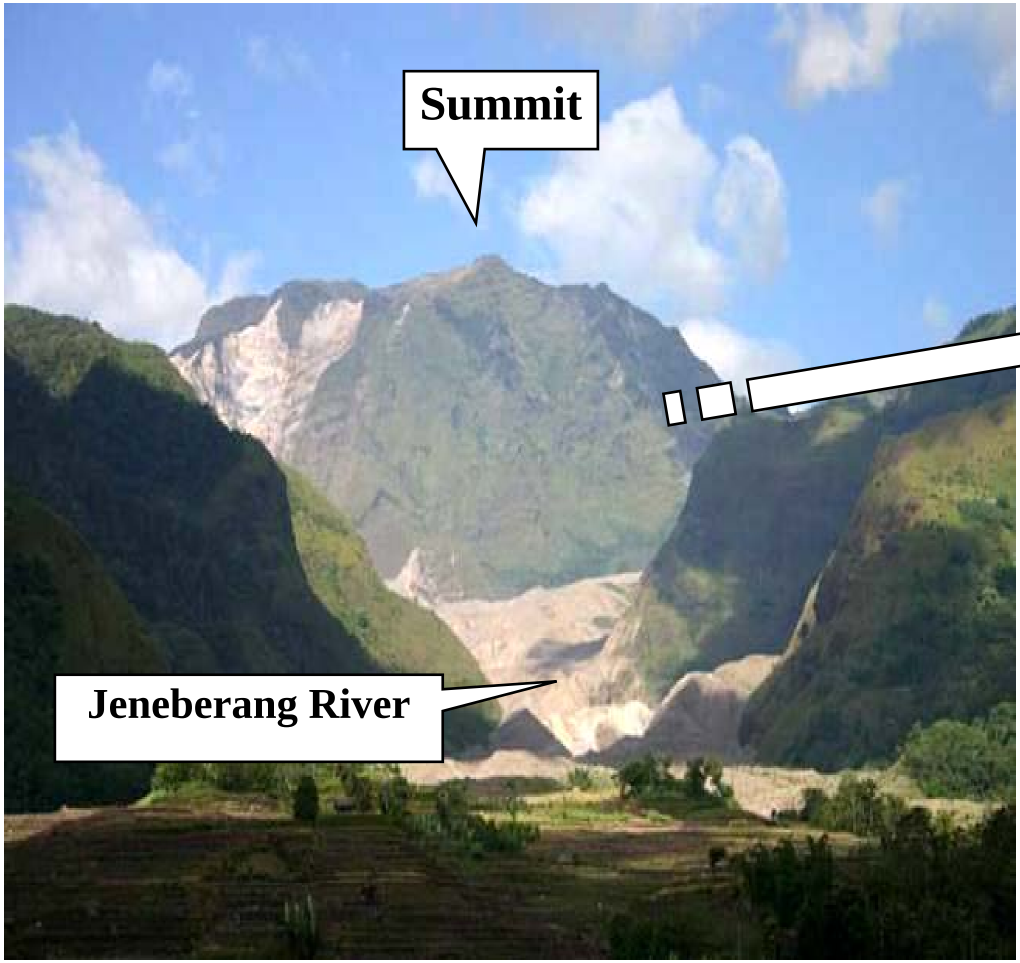
2. CALDERA OF MT. BAWAKARAENG

2.1. Natural Condition.

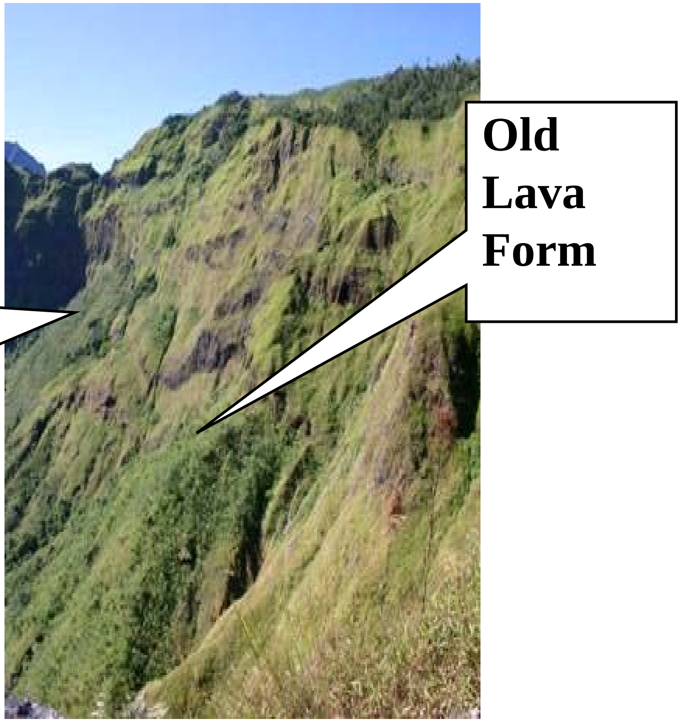
Elevation: 2,830 m

Mt. Bawakaraeng, whose name literally means “Mouth of King”, shows large caldera formation.

Existing Caldera is surrounded by Mountain ranges of Lompobatang and Bawakaraeng ranging from Elev. 1,800 m to 2,200m. The caldera is in process of expansion at present.

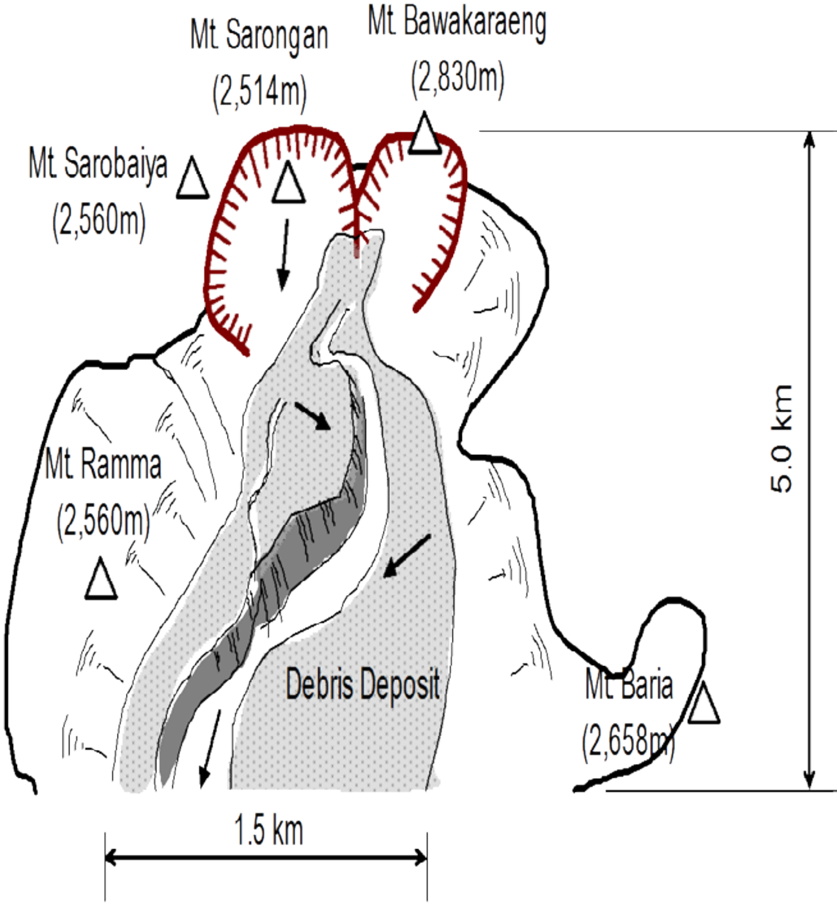


Mt. Bawakaraeng
(Elev.2,830m)



Mt. Bawakaraeng
Caldera Wall

Lompobatang-Bawakaraeng Caldera
(as of July, 2005)

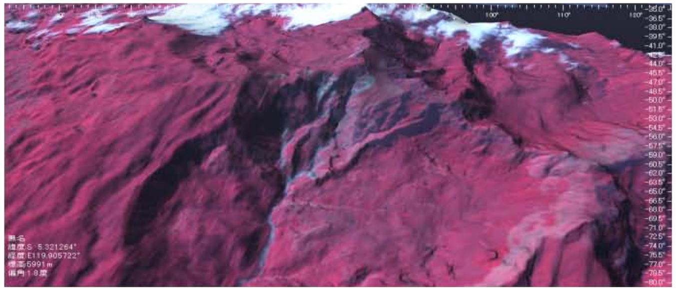


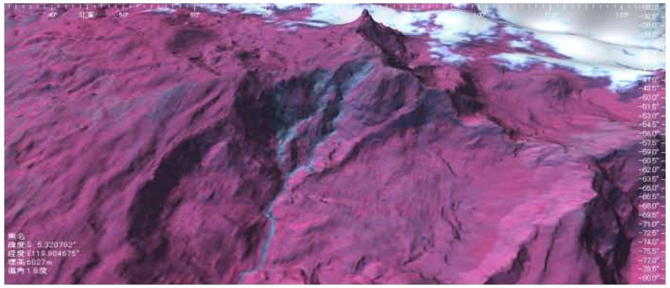
2.2. Occurrence of Caldera Collapse

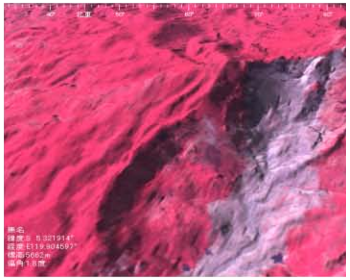
A gigantic caldera-wall collapse occurred on March 26, 2004, at the northeast of caldera of Mt. Bawakaraeng (hereinafter the Collapse). The volume of collapsed mass is estimated at 200 to 300 million m^3. The caldera-wall collapse brought tremendous damage to the area, accounting for 32 people death and missing, 635 cows losing, many houses, elementary school and about 1,500 ha of agricultural land buried. Total damage was estimated at about Rp. 22 billion.

ASTER (07 Jul. 2001) **ASTER (25 Mar. 2004)** **ASTER (07 Sep. 2006)**

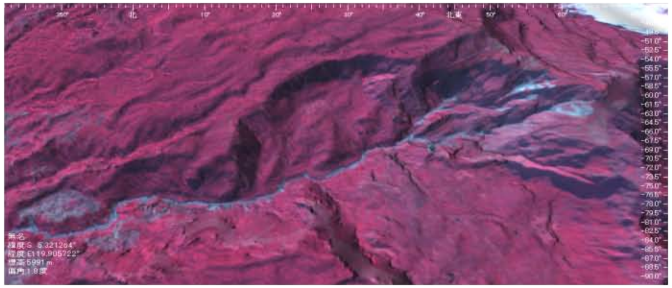
Bird View at about EL. 6000m

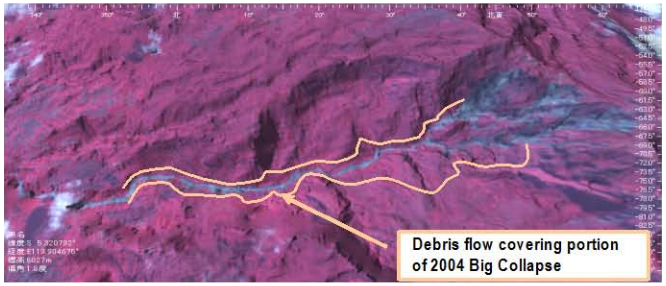


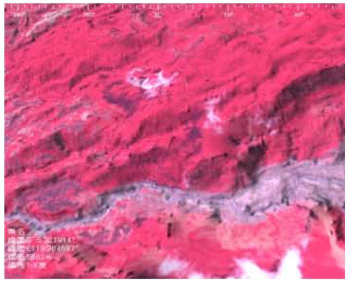




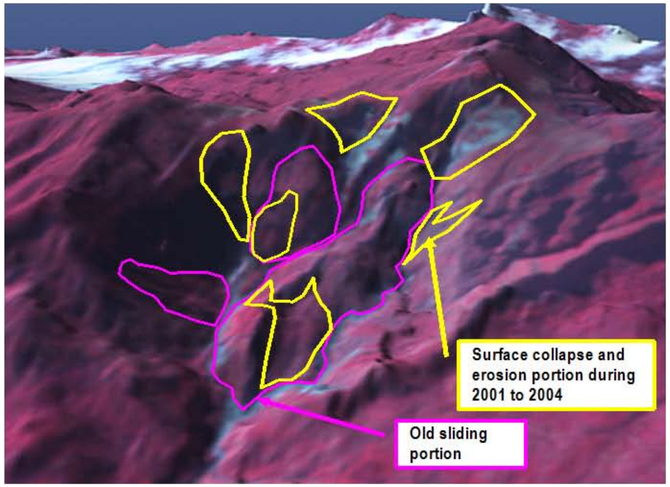
Bird View along river at about EL. 6000m

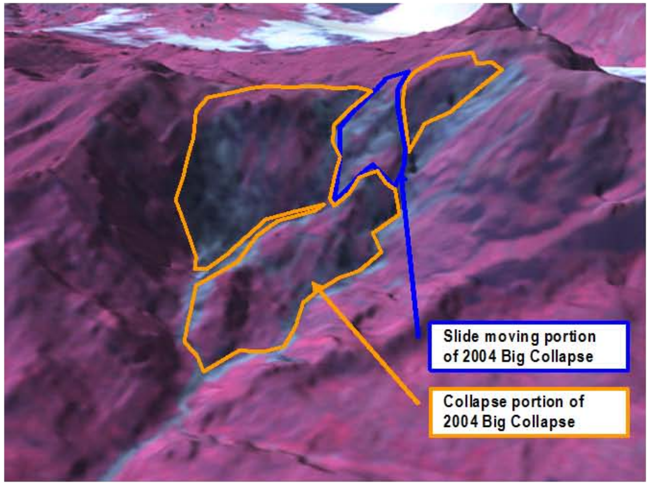


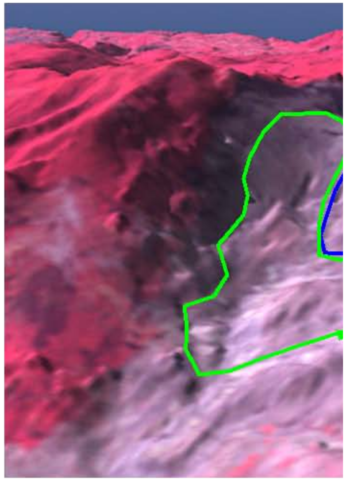




Comparison of Collapse Condition



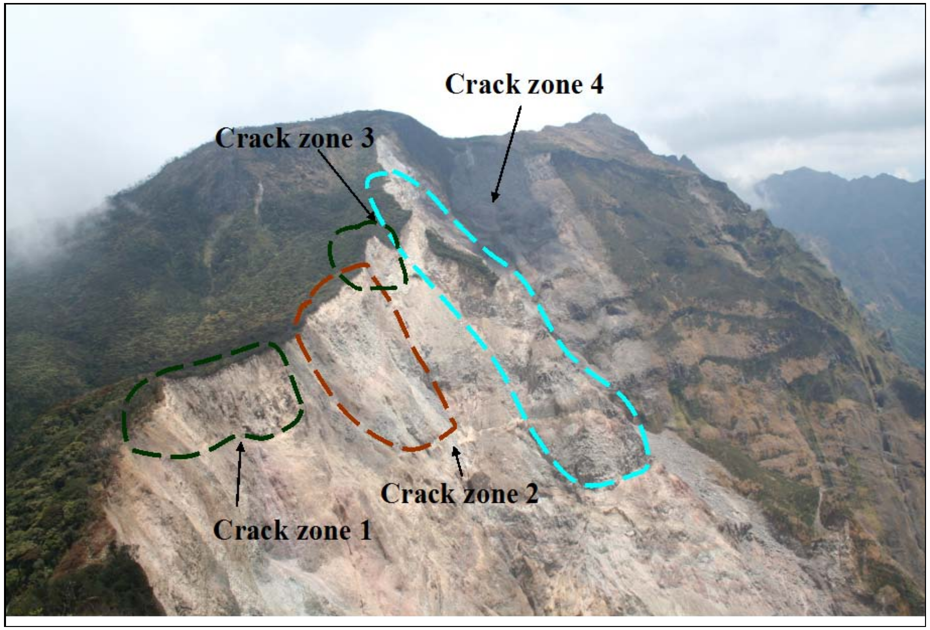




2.3. Monitoring of Cracks

There are many cracks observed and start setting observation points at each zone by installation of wooden pegs as shown in picture below. Pompengan-Jeneberang RBO has installed such observation point totally 32 locations (EL.2600-2650m).

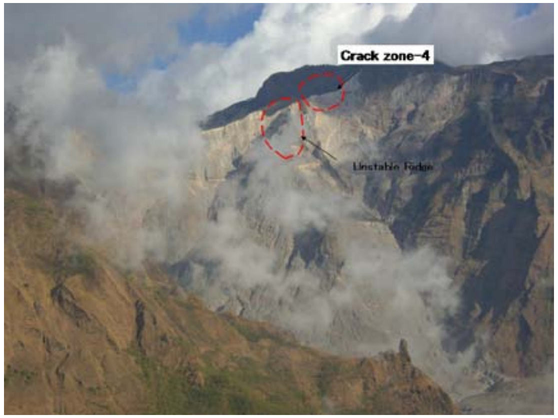
Each displacement of crack will be observed at least once in three months as well as rainfall data by using automatic rainfall gauging instrument install by the Pompengan-Jeneberang RBO.



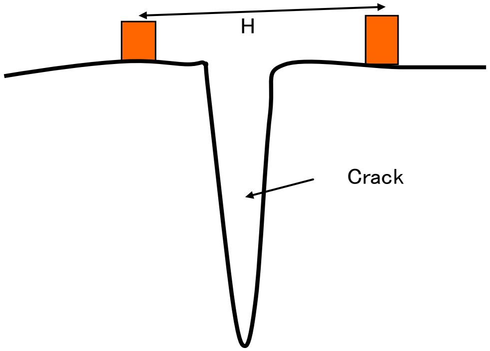
Zone 1,2 and 3

Locations of monitoring piles for opening of cracks

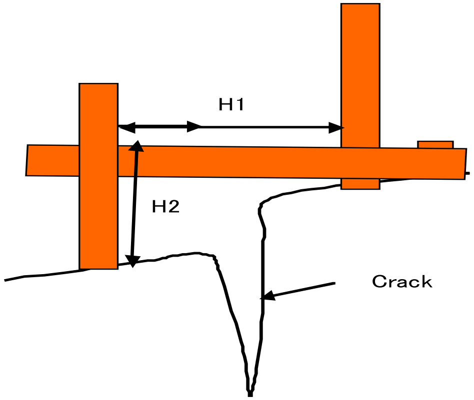
For monitoring of open crack, measurement pile and board bar are installed and change of intervals between piles and boards are measured. And condition of collapsed wall is observed by watching and taking photos from the fixed points.



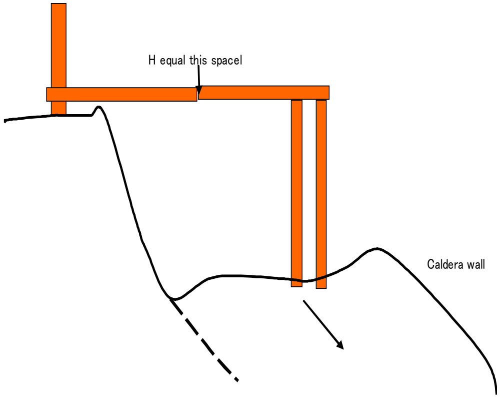
Zone 4



Installation for small open crack Applied for open crack with width of less than 20 cm



Installation for crack which may move horizontally and vertically
Applied for open crack with width of 20 cm and more



Installation for crack which has sliding condition
Applied for crack 2-4 only

2.4. Potential Collapse of Caldera Ridge Wall

To grasp of the Caldera wall slope condition and stability in detail, slope units are divided into three (3) groups, 10 units in the North Caldera, 10 units in the East Caldera and 10 units in the South Caldera. In each slope unit, slope inventory record has prepared. The total unstable volume of the whole caldera wall slope is estimated to be 145,068,000 m^3. In east caldera wall is estimated with 111,073,000 m^3.

Level of possibility Collapace

- **Level I,** estimated volume is 20,102,500m^{3,} In east Caldera, and partly in the east side of the North Caldera.
- **Level II** ,estimated volume is 24,646,000 m^{3}.
- **Level III,** estimated volume is 27,819,500 m^{3}
- **Expansion Portion,** which indicates possible maximum collapse extent at present condition, is estimated to be 72,500,000m^{3} in volume.

3. Sediment Control Plan

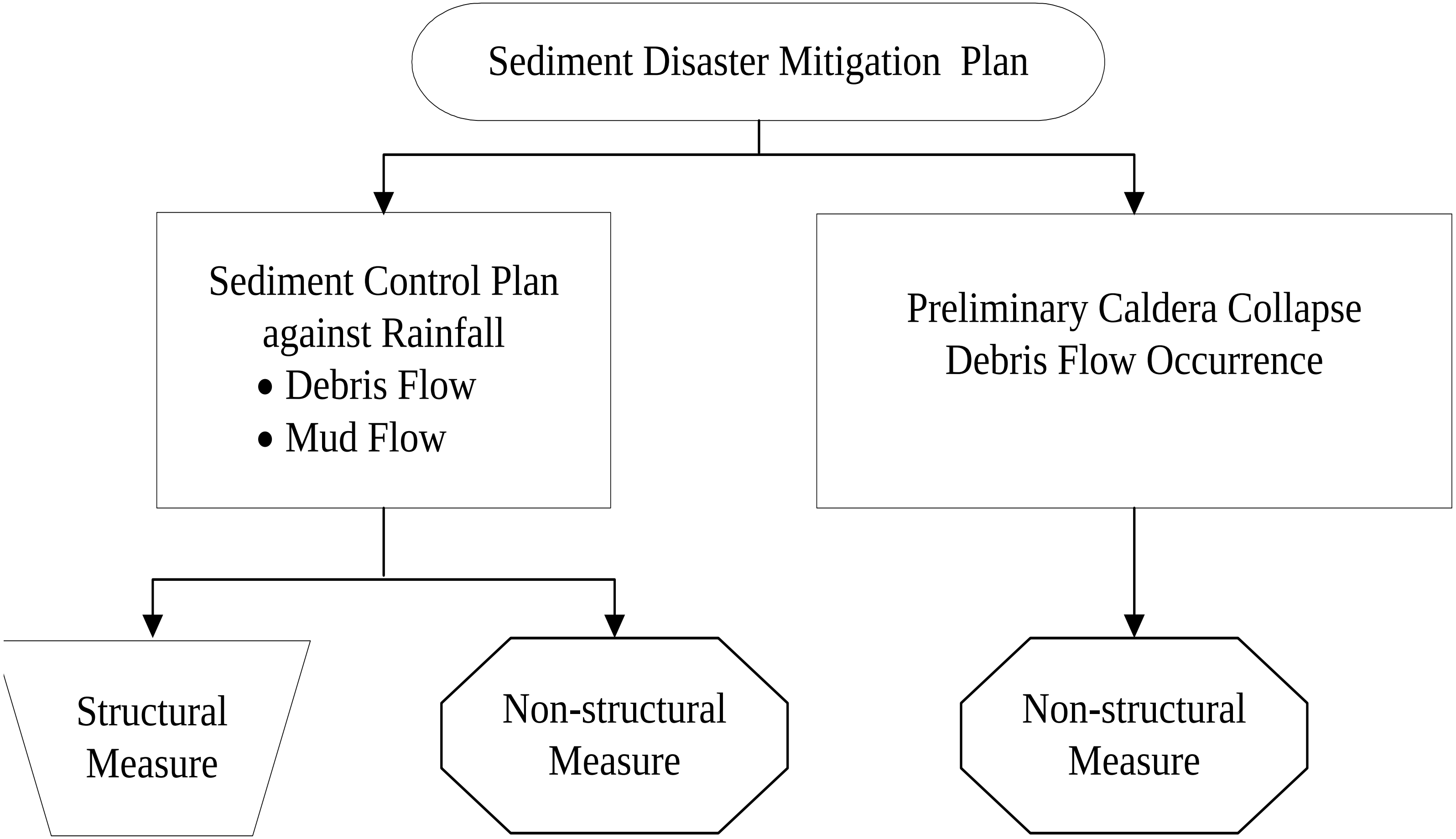
3.1. Formulation of Sediment Disaster Mitigation Plan

1) caldera wall collapse (as preliminary sediment movement),
2) debris flow,
3) mud flow, and
4) gully erosion and surface erosion.

Among these phenomena, there are two types of considerable sediment disasters, namely:

1) Sediment disasters directly caused by preliminary (future collapse) and secondary collapse,
2) Sediment disasters caused by rainfall such as debris flow, mud flow, gully/river bank erosion

Sediment disaster mitigation plan should be formulated against both the sediment disasters, and will be formulated in combination with structural measures and non-structural measures.



Sediment Disaster Mitigation Plan

Sediment Control Plan against Rainfall

- Debris Flow
- Mud Flow

Preliminary Caldera Collapse Debris Flow Occurrence

Structural Measure

Non-structural Measure

Non-structural Measure

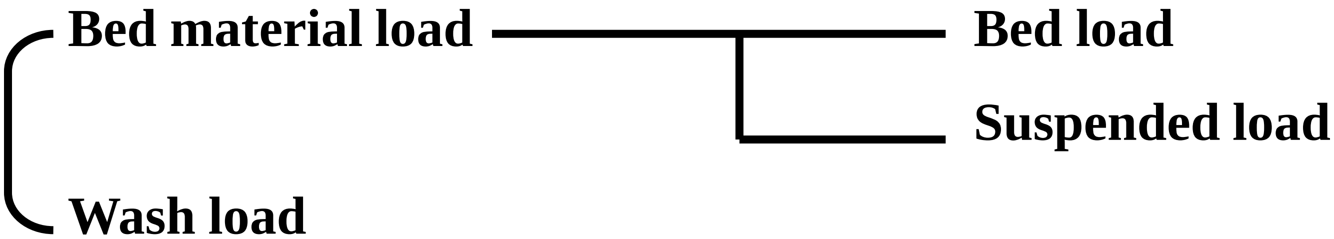
Both the structural and non-structural measures have to cooperate demonstrating each characterized measures to attain sediment disaster mitigation in the Jeneberang River Basin.

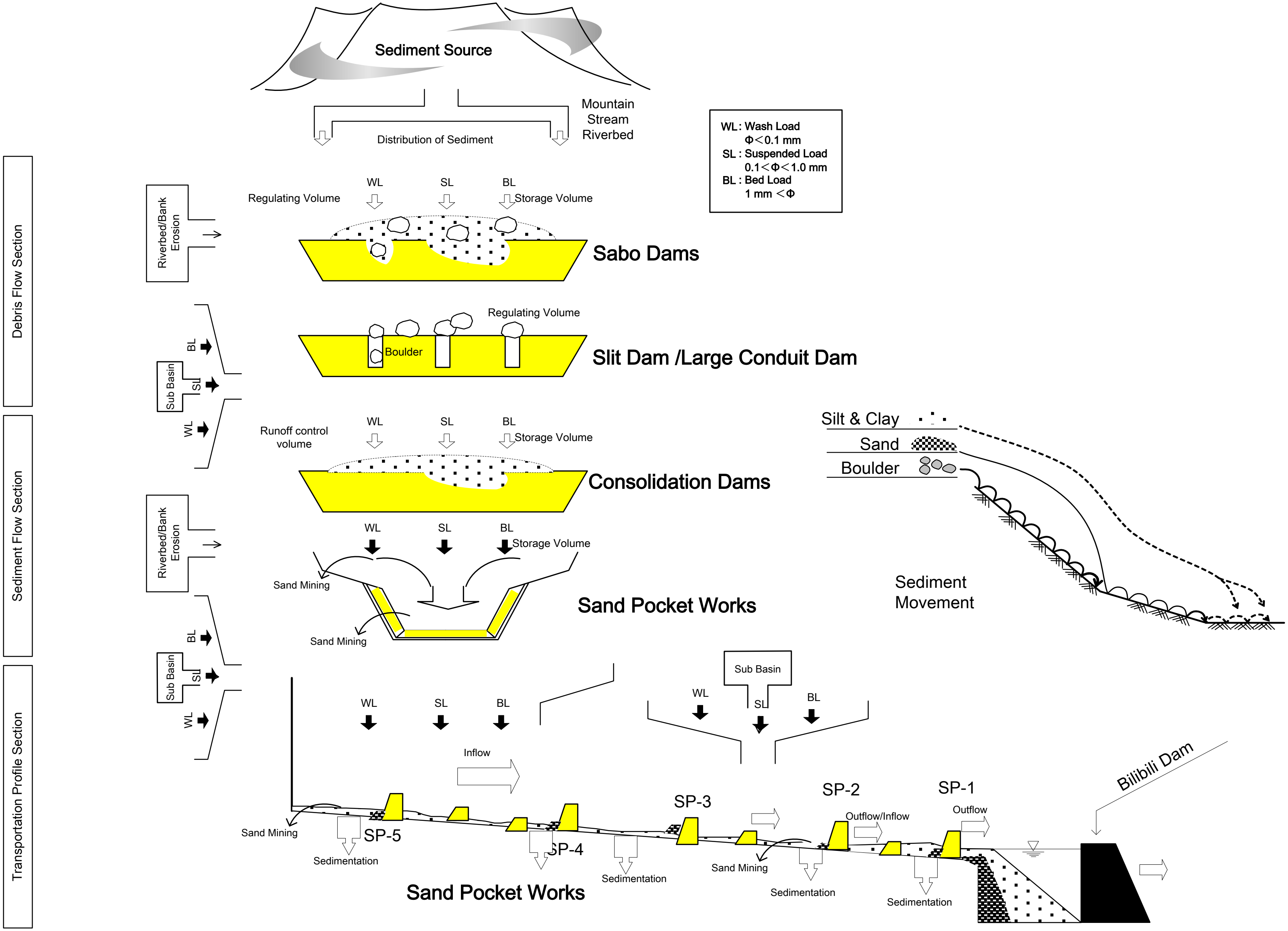
3.2 Target Sediment Amounts to be controlled

The amount of sediment deposit in the main river of Jeneberang was estimated at over 230 million m^3 (JICA estimation in 2006) and 40 % of them still remained in caldera area. The unstable sediment in the caldera is estimated with 90 million m3 as of July 2008. Therefore, 61% of the total sediment deposit has already flowed into the downstream reaches. It volume is estimated based on the topographic survey result with 140 million m^3.

3.3. Concepts of Sediment Transportation System by Structure Measure

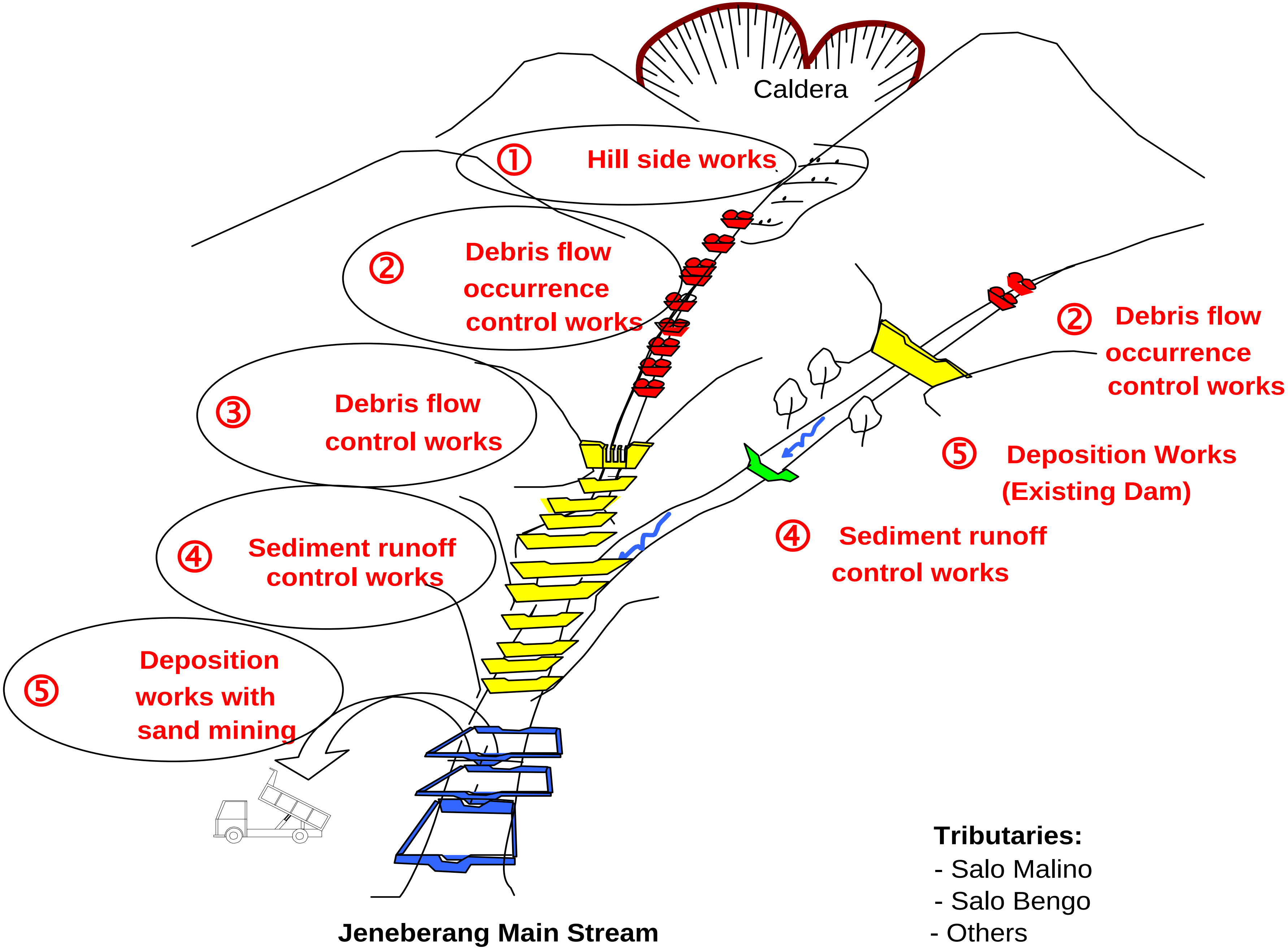
It is necessary to analysis sediment transportation system in the basin. It is the way to formulate a sabo facility plan in the Jeneberang River Basin. In general, sediment transportation loads is classified as:



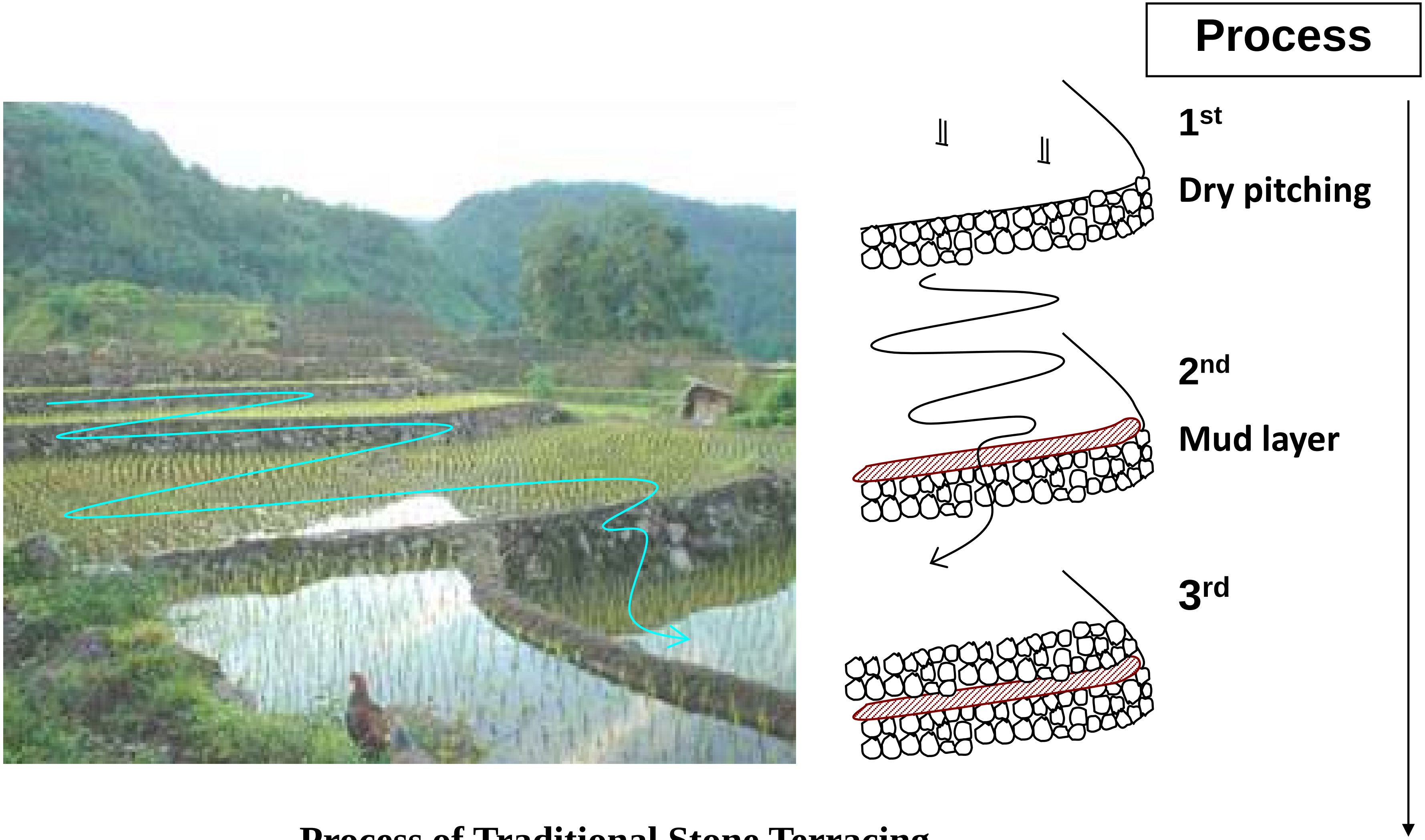

Sediment Source
Mountain Stream Riverbed
Distribution of Sediment
WL : Wash Load
Φ<0.1 mm
SL : Suspended Load
0.1<Φ<1.0 mm
BL : Bed Load
1 mm <Φ
Debris Flow Section
Sediment Flow Section
Transportation Profile Section
Riverbed/Bank Erosion
Regulating Volume
WL
SL
BL
Storage Volume
Sabo Dams
Sub Basin
Regulating Volume
Boulder
Slit Dam /Large Conduit Dam
Runoff control volume
Consolidation Dams
Riverbed/Bank Erosion
Storage Volume
Sand Mining
Sand Mining
Sand Pocket Works
Silt & Clay
Sand
Boulder
Sediment Movement
Sub Basin
Inflow
Sand Mining
Sedimentation
SP-5
SP-4
SP-3
SP-2
SP-1
Outflow/Inflow
Outflow
Sedimentation
Sand Mining
Sedimentation
Sedimentation
Bilibili Dam
Sand Pocket Works

3.4 Layout of Sediment Control Works

Based on tentative target sediment amount to be controlled and to be transported at present and future topographic conditions along the river courses, the propose facility layout plan as illustrated in Figure below, which can be classified into six (6) sediment control works, to reduce the debris flow occurrence, to stabilize the riverbed, to regulate the debris flow deposit, to control debris flow direction and to reduce the inflow sediment to Bili-Bili reservoir.


Caldera
① Hill side works
② Debris flow occurrence control works
③ Debris flow control works
④ Sediment runoff control works
⑤ Deposition works with sand mining
② Debris flow occurrence control works
⑤ Deposition Works (Existing Dam)
④ Sediment runoff control works
Tributaries:
- Salo Malino
- Salo Bengo
- Others
Jeneberang Main Stream

1) Hillside Works and Surface erosion control work .



Process

1st

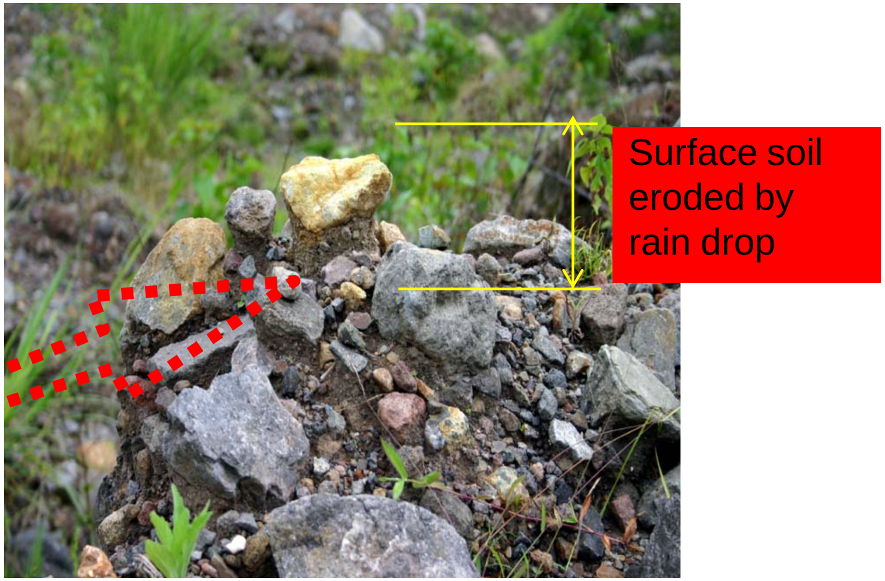
Dry pitching

2nd

Mud layer

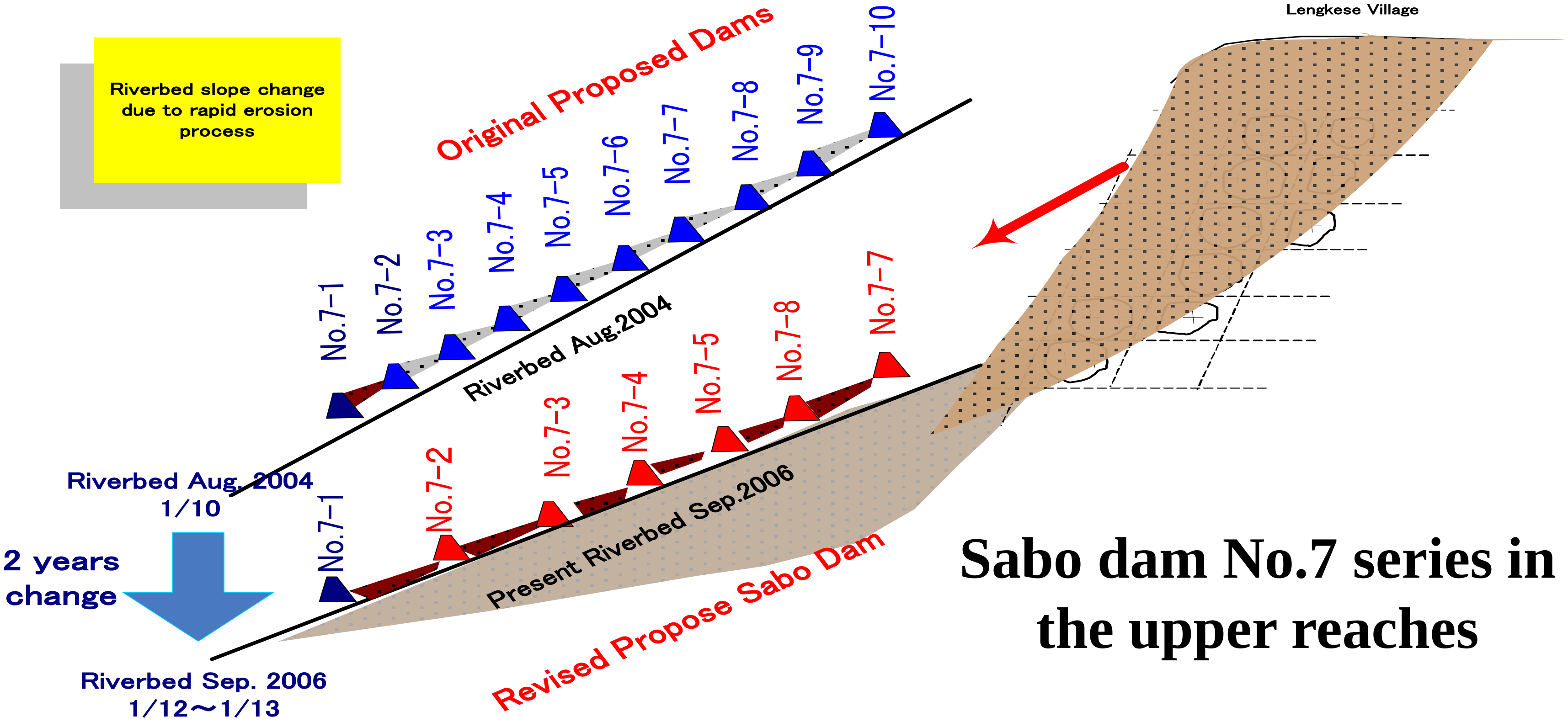
3rd

Process of Traditional Stone Terracing

	
Outlet of Caldera: Surface erosion control work site: dense plantation is required. EL.1000-1500m	**EL 1,500m**: Surface erosion by rain drop on the deposit of caldera: rain drop has accurate surface erosion process. 2 -3 cm depth surface erosion during half hour rainfall observed

2) **Debris flow occurrence control works**

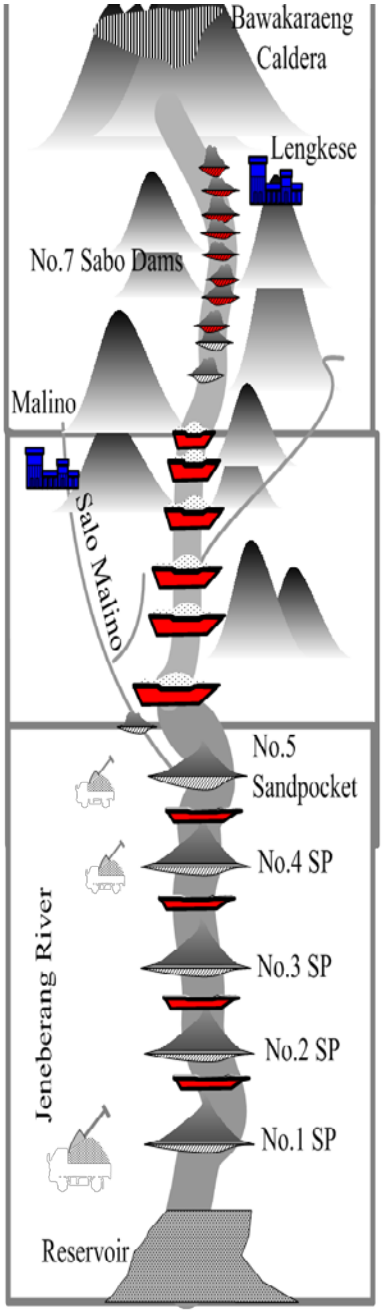
shall be proposed with series of sabo dams at the exit of a valley, and debris flow direction control works with sabo dams.



Sabo dam No.7 series in the upper reaches

3) Debris flow control works, and Sediment runoff control works shall be proposed in combination with Sabo dams and consolidation dams to restrain unstable riverbed and riverbank profile with present riverbed level, to control debris flow direction, and to accumulate runoff sediment deposit at river section from Daraha Bridge section to upper reach section of sand pocket No.5 dam.

4) Sediment deposition works and Flow Direction Control Works which stock the large amount of gravel and sand material with sand pocket facilities.



Location /Proposed Sabo Facility	**Recommended Sabo Facility /Structure Type**
(1) Upper Reach **Debris Flow Occurrence Control works** **Series of Sabo dams (it is necessary to consider the number of sabo dams /type of sabo dams based on the results of movement of sediment from caldera)**	● **Combination type of INSEM and concrete type** ● **CSG and ISM type of soil cement was applied to shorten construction Period**
(2) Middle Reach **(Debris Flow Control Works, Sediment Runoff Control Work)** **Series of Sabo dams (1 Open type dam, and 5 closed type dam)** **Series of Consolidation dams with Irrigation intake facility (2 consolidation with crossing road, and 4 consolidation dams)**	● **Combination type of INSEM and concrete type** ● **Combination of Masonry and concrete type**
(3) Sand Pocket Area **(Sediment Deposit Area)** **Rehabilitation of 5 existing sand pocket dams** **A series of dispersion dams with irrigation intake facility would be considered**	● **Existing sand pocket dams will be utilized as either sub-dam body or base body of new main dams** ● **Combination of Masonry and concrete type**
Sediment Disposal work by machinery excavation at the edge of reservoir	● **Machinery excavation both by mining activities and Government at the edge of Reservoir**

Lay Out of Sabo Plans

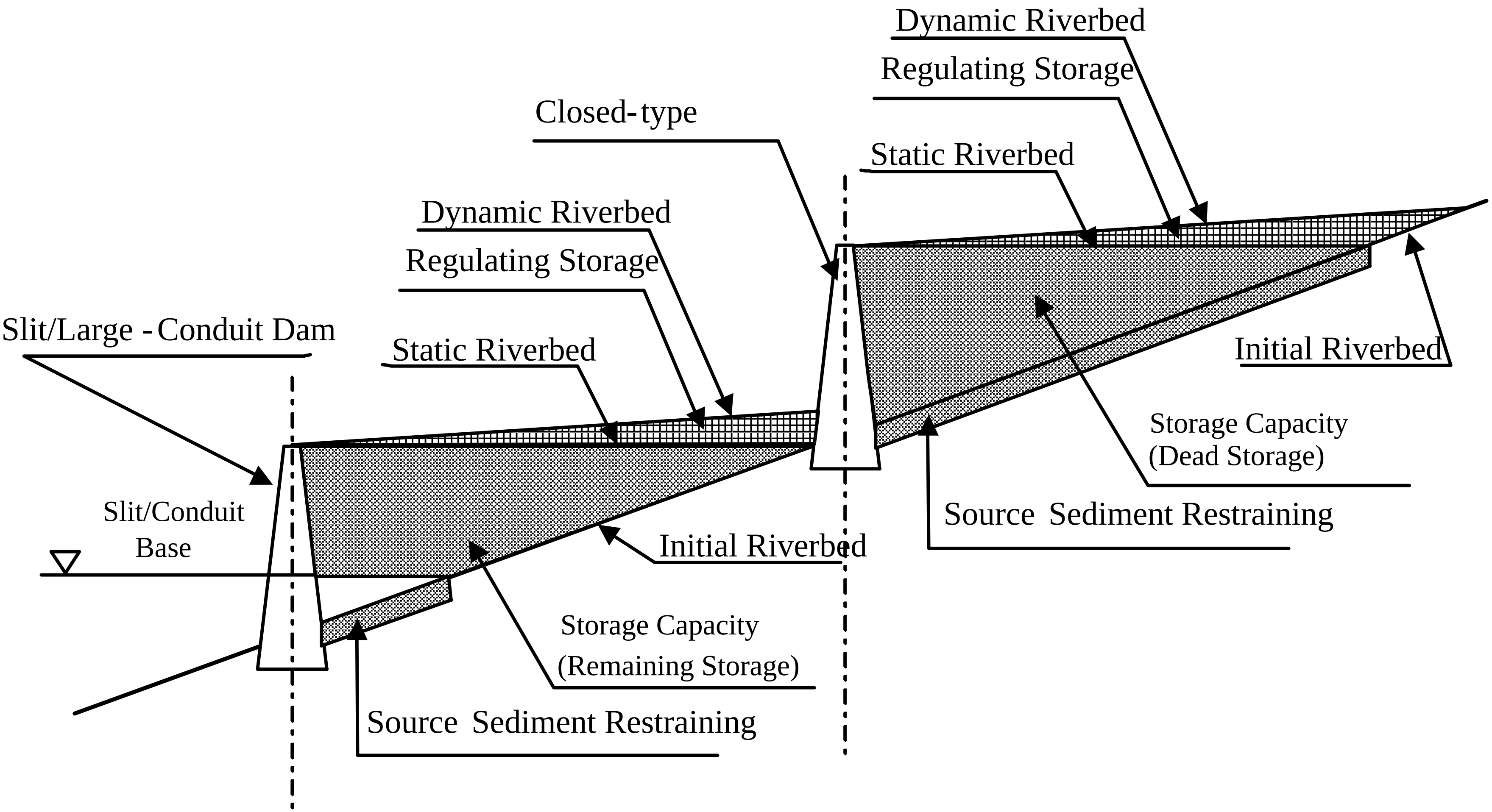
3.6. Sediment Control Effect by Proposed Sabo Facilities

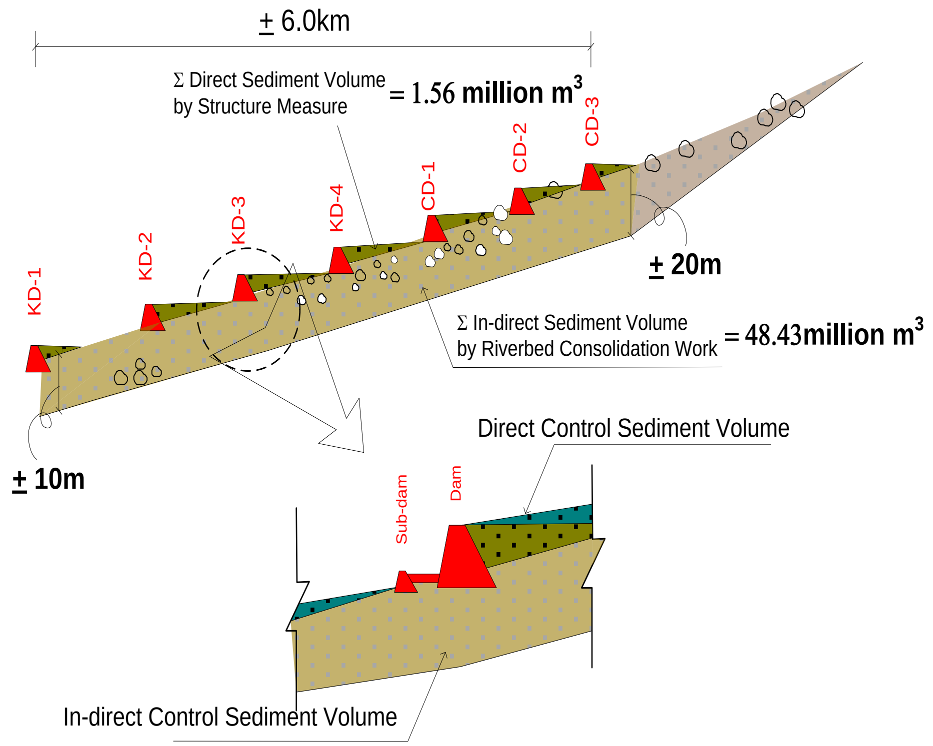
The sediment control facilities has constructed on present riverbed between upper to middle reaches which already piled up with sediment deposits in order to fix present riverbed deposit. The facilities will be functioned as fixation of riverbed which means;

- to reduce secondary sediment movement from present sediment deposits,
- to reduce lateral erosion of sediment deposits
- to control riverbank erosion during flooding time
- to stock and regulate the debris flow deposit from upper stream
- to guide sediment flow/sediment flow direction

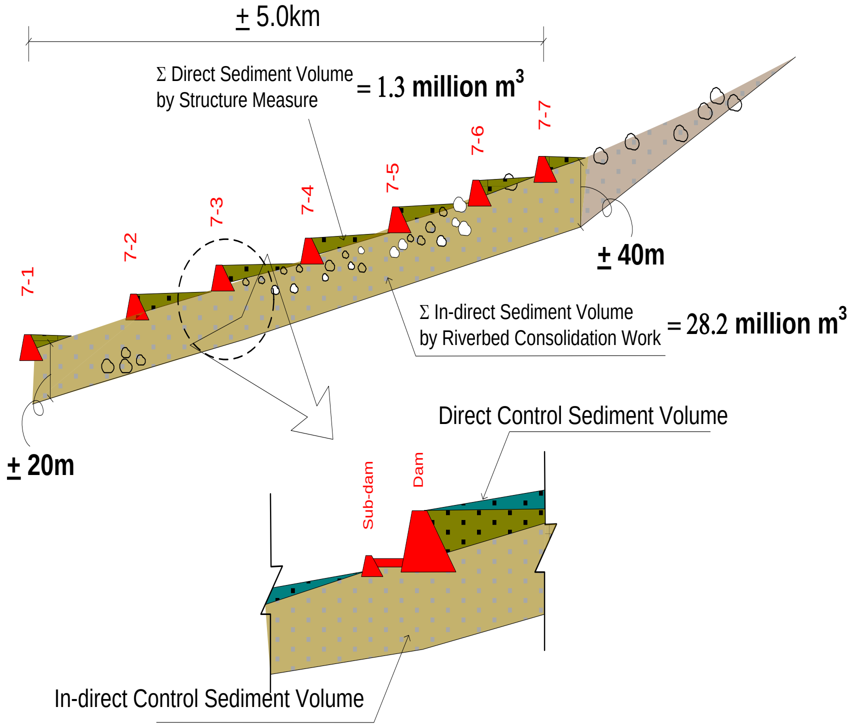
Open-type Dam
(Blockage-type Dam)

Closed-type Dam
(Normal Dam)





Middle Reach



Upper Reach

Estimated sediment control volumes of the above proposed facilities are summarized in table below

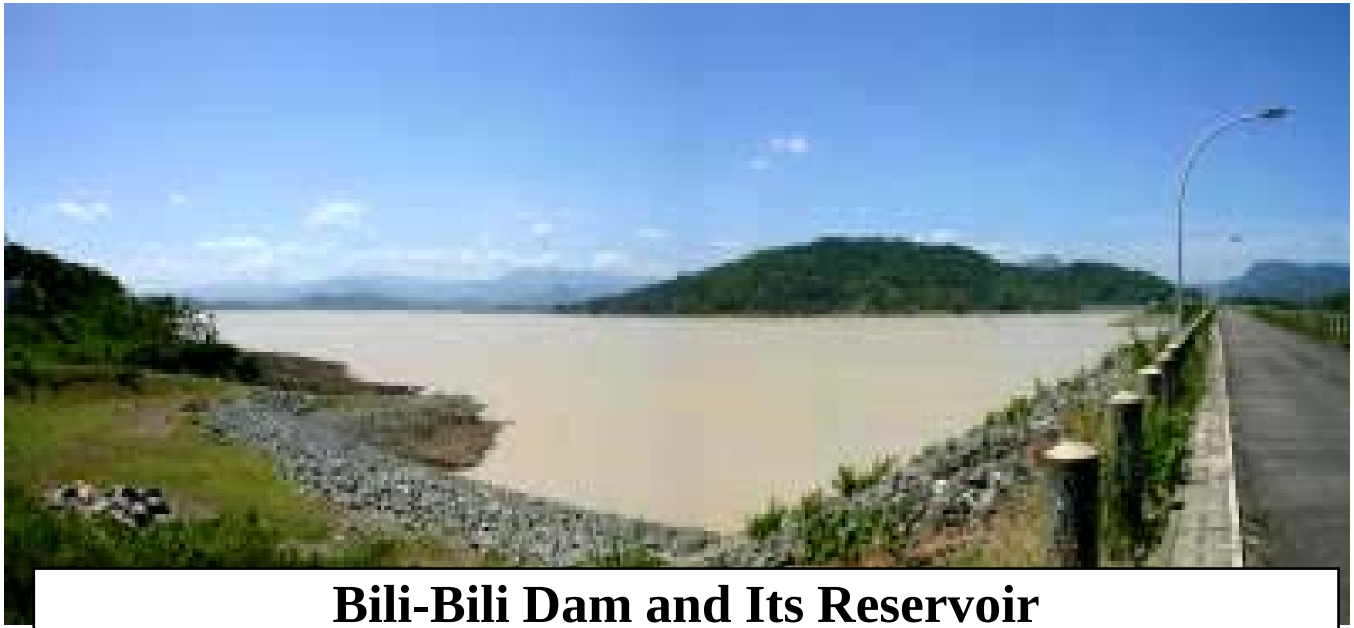
(Million m^3)

Location	**Direct Control Sediment Volume**	**In-direct Control Sediment Volume**	**Total Direct and Indirect Control Sediment Volume**
(1) Upper Reach	**1.300**	**28.200**	**29.500**
(2) Middle Reach	**1.560**	**48.430**	**49.990**
Total	**2.860**	**76.630**	**79.490**

3.7. Implementation of Works

Since the caldera wall collapsed on March 2004, the Government of Indonesia cooperating with Government of Japan had made efforts to cope the above sediment problem in Jeneberang River both structural measures and non-structural measures as shown on figures below.

4. Bili-Bili Dam



Bili-Bili Dam and Its Reservoir

Dam type :	Rock-fill dam
Main Dam height :	73 m
Main Dam Crest length :	750 m
Main Dam Crest width :	10 m
Main Dam Body volume :	2.76 million m^3
Catchment area :	384.4 km^2
Left Wing Dam height :	42 m
Left Wing Dam Crest length :	646 m
Left Wing Crest width :	10 m
	1.47 million m^3

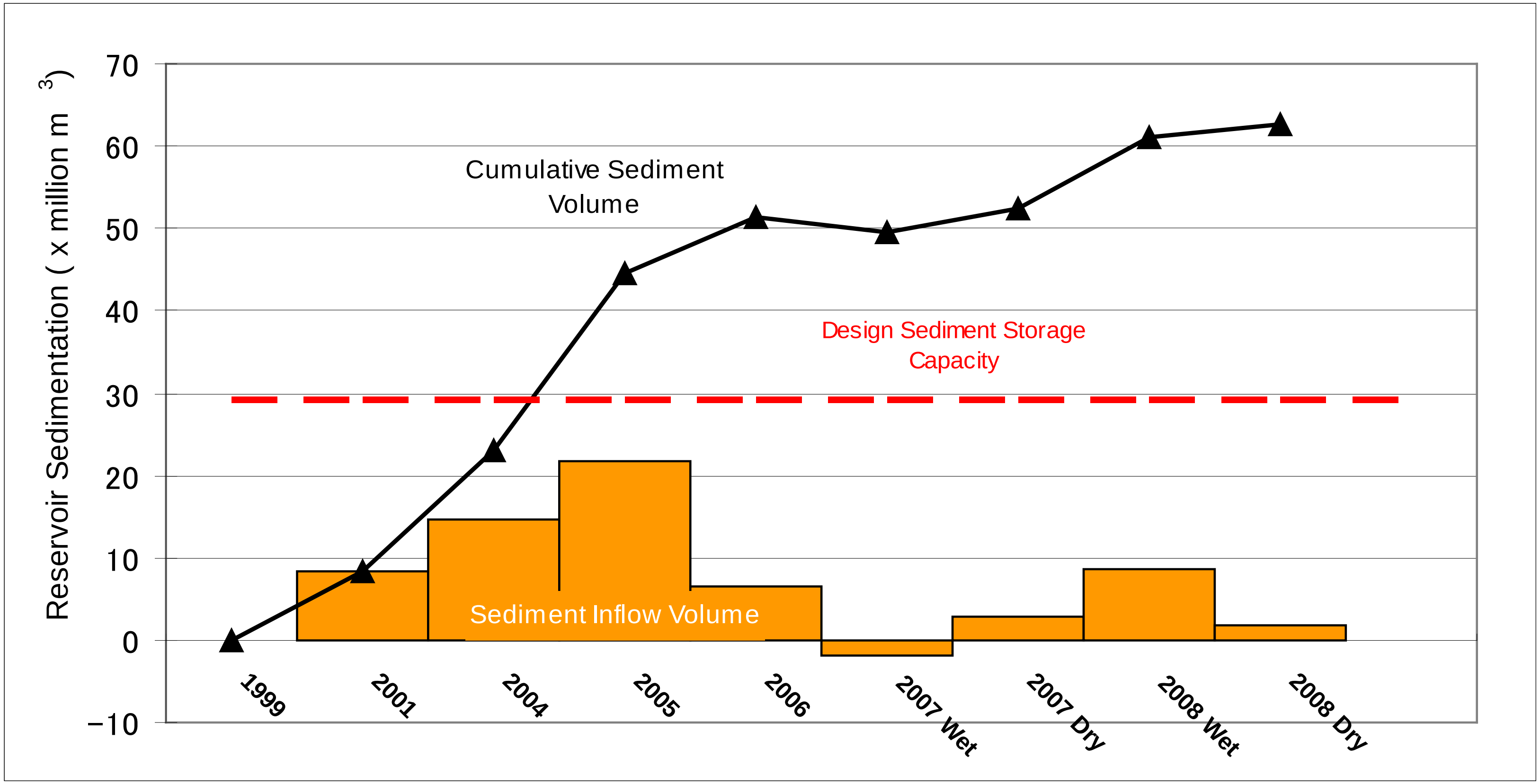
Gross storage volume :	375 million m^3
Effective storage volume :	346 million m^3
Sediment Capacity :	29 million m^3
Water Utilization Capacity :	305 million m^3
Design Flood Water Level :	EL.103.0 m
Normal Water Level :	EL. 99.5 m
Low Water Level :	EL.65.0 m
Irrigation area (total):	25,000 ha
Raw Water transmission capacity:	3.3 m^3/s

- Three (3) irrigation systems are named as Bili-Bili, Bissua and Kampili, Net total irrigation service areas 23,663 ha.
- Municipal and industrial water supply
  - PDAM Makassar
  - PDAM Gowa
  - Sugar factory in Takalar Regency (PT. Perkebunan Nusantara IV (Persero)
- Hydro Power 18 MW

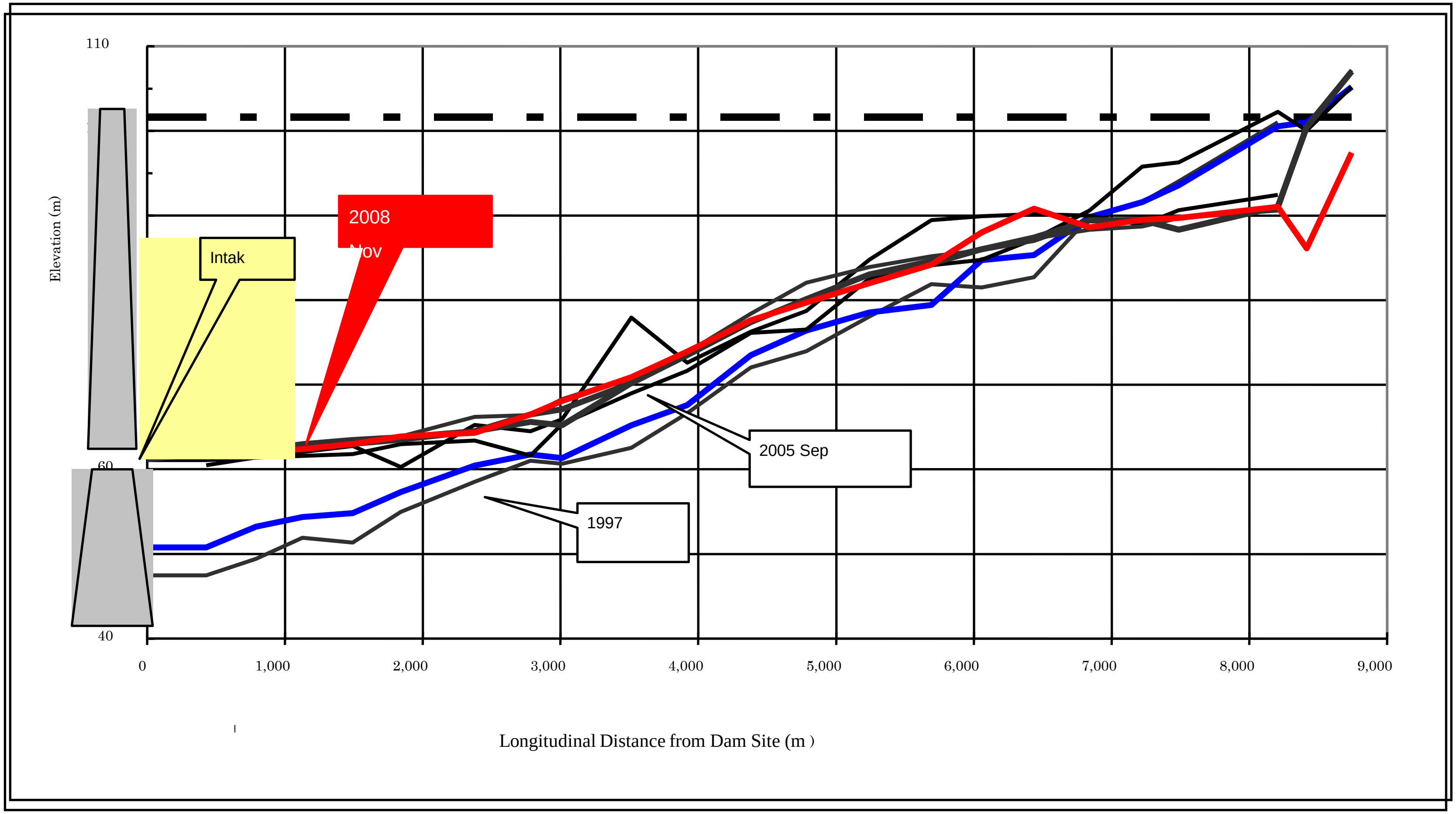
PDAM Makassar owns water treatment plants with clean water production capacity of 2,340 liter/sec in total and takes 1,250 liter/sec from the Jeneberang River, or about 53 % of the total water production, while water source of PDAM Gowa totally depends on the water flow of the Jeneberang River Basin

4.1. Reservoir Sedimentation

The cumulative reservoir sedimentation curve since 1997shown on following figures and cumulative sedimentation volume had reached 62,744,000 m^3 as of November 2008.

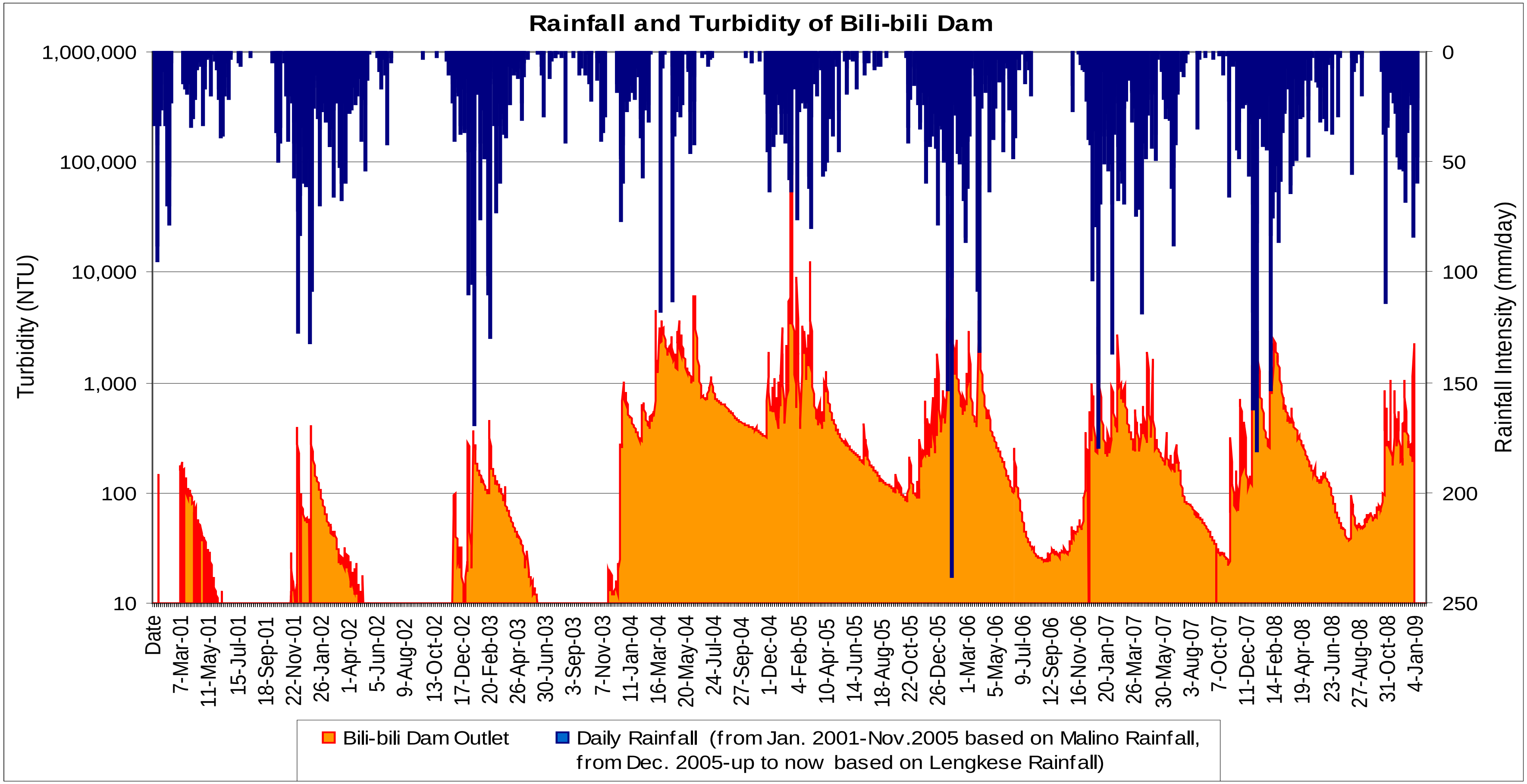


The annual variation of sedimentation profile of Bili-Bili Reservoir based on lowest riverbed elevation of results of bathymetric survey result is shown on Figure below.



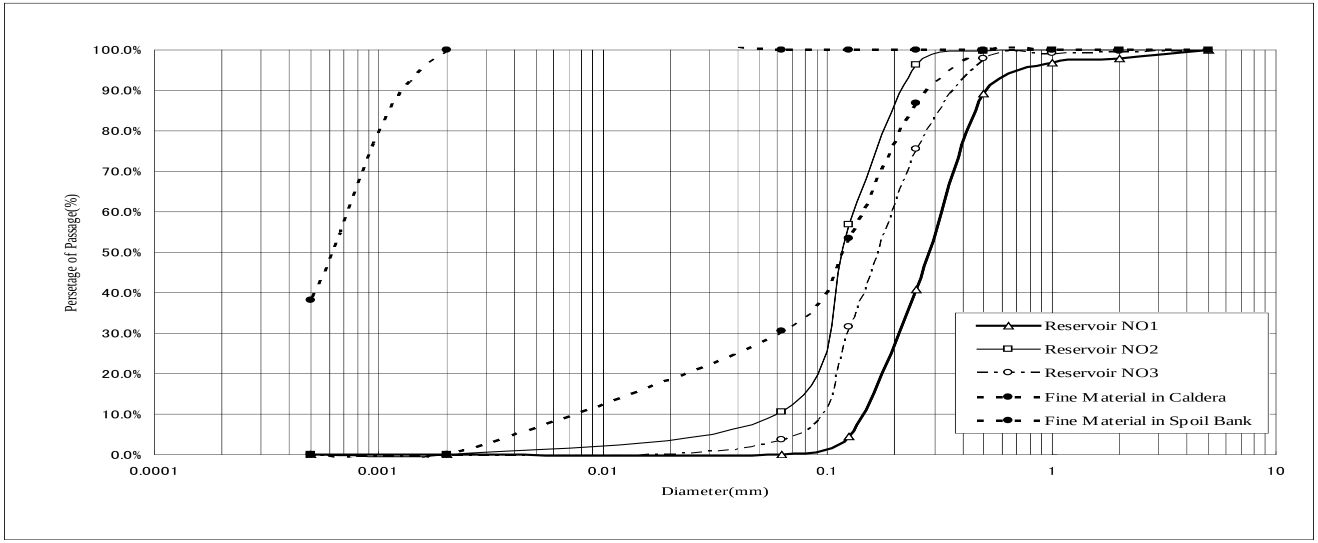
4.2. Turbidity of Bili-Bili Reservoir

The following graph shows raw water turbidity records before and after the collapse. High turbidity rates occurred during the rainy season in the month of December and January. The maximum turbidity rate declined to 33,000 NTU in 2006 and about 4,000 NTU in 2007.



4.3. Characteristics of Reservoir Sediment Deposition

The investigation of sedimentation in reservoir edge in the state of reservoir water level at EL. 83.29 m was conducted on October 12, 2006 and the following characteristics are founded.

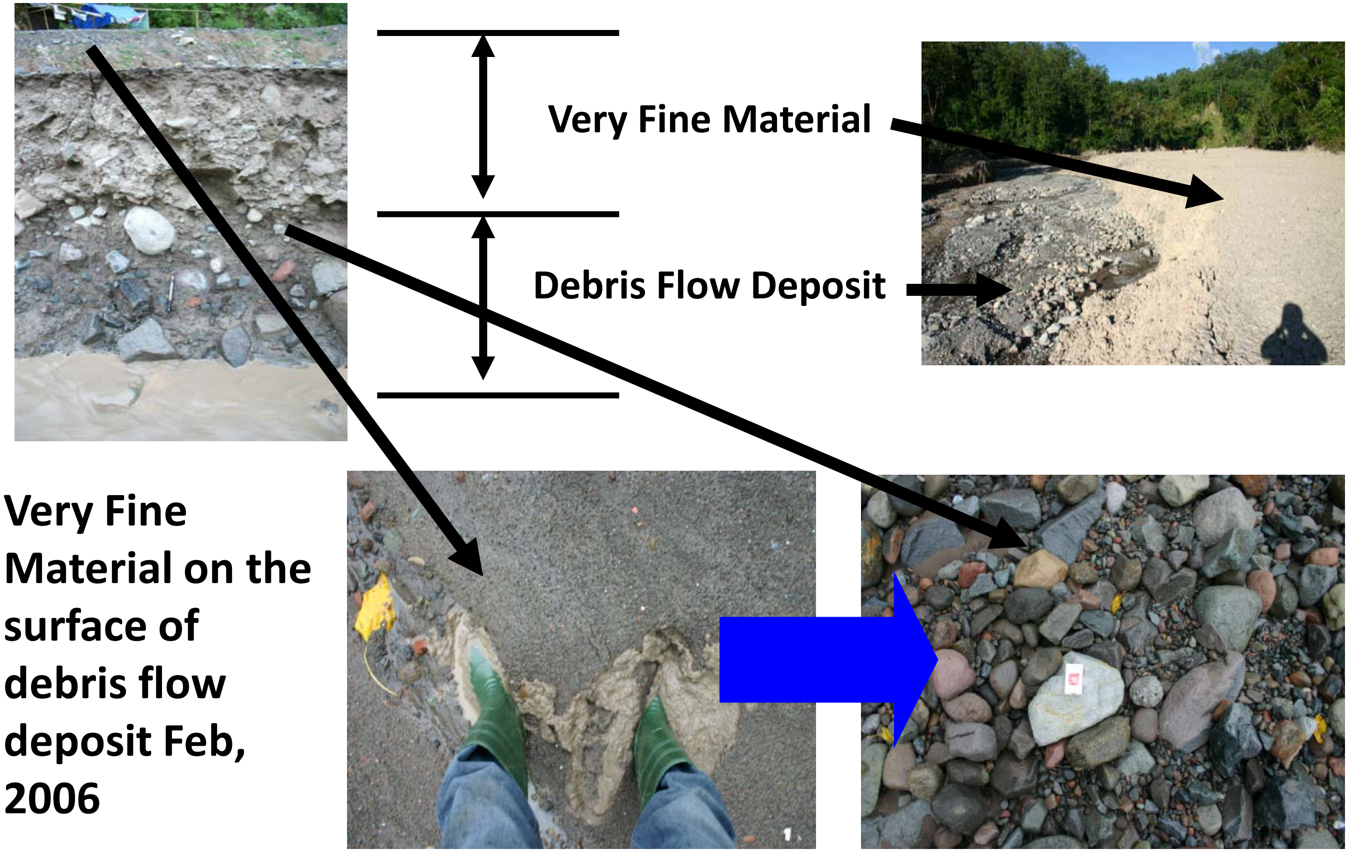


As shown in grain distribution of reservoir deposit, content of sediment size is mainly 1mm>φ> 0.075mm (fine sand) and φ< 0.075mm (silt) is less 10 % and classified as bed load material.

4.4. Cause of Reservoir Turbidity

Serious muddy water occurred from 2004 and significant reduce at present. The cause of muddy water is originated from very fine soil particle which covered on the sediment deposit in the caldera area. Field investigation made on October 2006 found the very fine soil exists at temporary spoil bank in right reservoir edge. The grain distribution is smaller than 0.075mm that classified as wash load materials. This material is same soil which accumulated on the sediment surface in December 2004.

These fine materials on the surface of debris flow materials which causes to high turbidity observed several time in the caldera area and upper reach of Daraha bridge site.



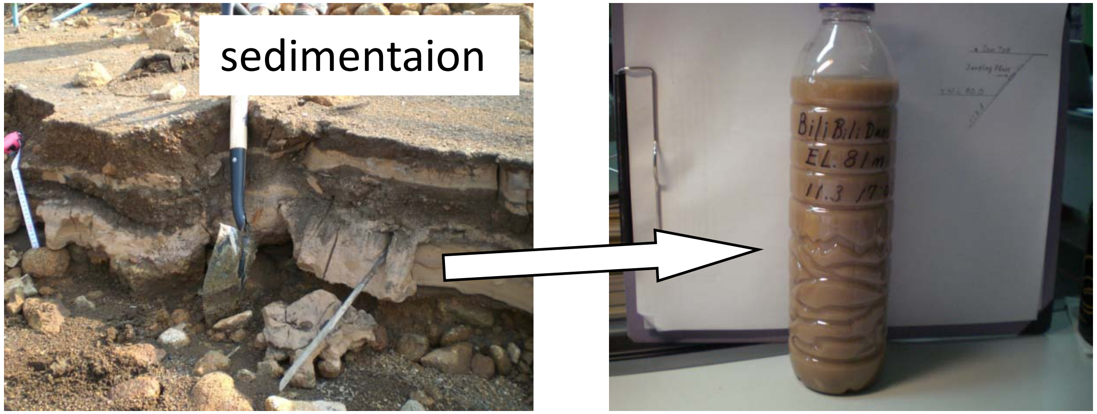
Very Fine Material

Debris Flow Deposit

Large-Scale of Sediment Flow Occured (July 2005, Dry Season)

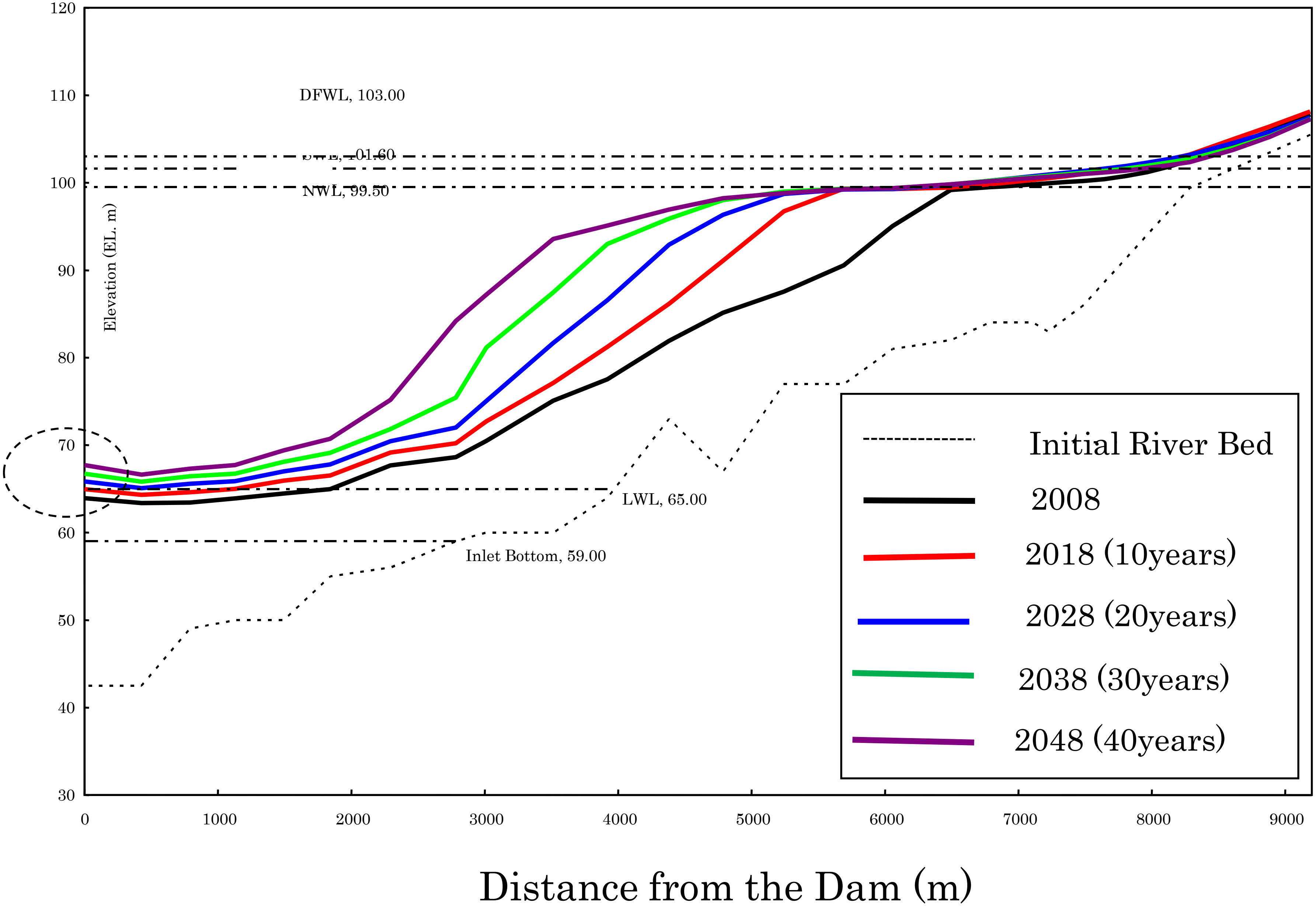
Very Fine Material on the surface of debris flow deposit Feb, 2006

Appereance of sand gravel materials after washed away (Mar, 2—0)



Very fine material at inlet structure of Bili-Bili Dam (el.82 m, November 3, 2006)

4.5. Prediction of Future Reservoir Sedimentation



	Cumulative Sedimentation Volume (10^{3}m^2)	Percentage of Sediment Volume in the Gross Storage Capacity	Cumulative Sedimentation in the Water Utilization Capacity (10^{3}m^2)	Percentage of Sediment Volume in the Water Utilization Capacity	Cumulative in the Flood Control Capacity (10^{3}m^2)	Percentage of Sediment Volume in the Flood Control Capacity
2008	60,959	16%	57,215	19%	1,373	3%
2018 (10 years)	98,394	26%	93,000	30%	2,939	7%
2028 (20 years)	126,105	34%	119,825	39%	3,936	10%
2038 (30 years)	148,623	40%	142,943	47%	3,675	9%
2048 (40 years)	168,981	45%	163,778	54%	3,329	8%

Note: Gross Storage Capacity = 375,000,000 m^3; Water Utilization Capacity = 305,000,000 m^3;

4.6 Reservoir Sediment Management Plan

The measures of Bili-Bili reservoir sediment management might be specified the following stages.

1st stage: Occurrence of caldera collapse

2nd stage: Reduce sediment inflow to reservoir

Reduction of sediment transportation volume, fine sediment trapping facilities, excess sediment removal both by structural sabo dam watershed improvement by planting conservation work,

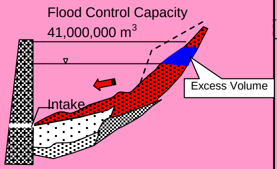
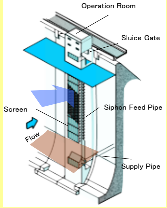
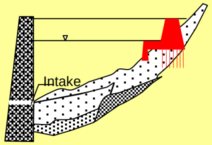
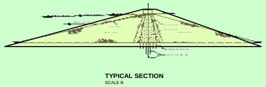
3rd Stage: Increase reservoir sedimentation volume and keep dam function. Decrease reservoir capacity in 2048 become 50 % , Maintenance dredging work surrounding intake

4th Stage: Recovering reservoir capacity and function

Dry excavation, Construct giant sediment trap at the edge of reservoir, Selectable intake facility

5th Stage: Alternative dam construction at Jenelata

Table 5. Overall Countermeasure for Sedimentation

	Countermeasure work	Main Works	Picture / Image of Facility	2008	2009	2010	2011	2012	2013	2014	2015
				1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
1	**<u>IP 524 Urgent Disaster Reduction Project</u>** for reduction of sediment outflow from Caldera and Upper River Section	**Debris flow mitigation work** in upper reaches (structural measure and non-structural measure)	-	On-Going Urgent Sediment Control Project							
		Sediment removal work at edge of reservoir (Recoving of flood control function)		On-Going Urgent Sediment Control Project			Continued sediment removal work by GOI				
2	**<u>IP 524 Most Urgent Maintenance Dredging Work</u>** for avoiding possible inlet blockade by sediment inflow	**Maintenance dredging** surrounding intake screen during dry season (mean depth: 20-30m)					Dredging period : Rainy Season (6months)				
3	**<u>Urgent Measures</u>** to sustain original dam functions	**Improvement of Intake facility**		F/S Study					Installation of selective intake		
		Installation of Giant Sediment Trap							Installation of Giant Sediment Trap		
4	**<u>Long Term Measure</u>** (Recommendation)	**Provision of New Dam in Jenelata River (Jenelata Dam)** Reservoir Capacity: 140 million m3, Dam Height 48.0 m					Detail Examination of Multi-Purpose Dam (F/S. DD.CS)				

5. PROBLEMS OF DOWNSTREAM AREA OF BILI-BILI DAM

1. Illegal buildings and high trees hamper water flow (reducing wet area of river section);
2. Solid and liquid waste disposal causes water quality deterioration;
3. Safety of residents who reside in the river area;

4 Excessive sand mining may cause river bed degradation.

Figure 26. Man-Made Break and Natural Damage of River Dike

- Flood risk to residents
- Reduction of River Flow Capacity

THANK YOU

Figure 27. Garbage Dumping Into River Body

Garbage may lead to river degradation and water quality deterioration

Garbage may lead to river degradation and water quality deterioration

Garbage may lead to river degradation and water quality deterioration

Building ruins may decrease river channel capacity for accomodating flood water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