THE REPUBLIC OF INDONESIA
DIRECTORATE GENERAL OF
WATER RESOURCES
MINISTRY OF PUBLIC WORKS AND HOUSING

THE REPUBLIC OF INDONESIA

THE PROJECT FOR ASSESSING AND INTEGRATING CLIMATE CHANGE IMPACTS INTO THE WATER RESOURCES MANAGEMENT PLANS FOR BRANTAS AND MUSI RIVER BASINS

（Water Resources Management Plan）

FINAL REPORT

VOLUME-III
SUPPORTING REPORT & HANDBOOK
(2/2)

December 2019

JAPAN INTERNATIONAL COOPERATION AGENCY

NIPPON KOEI CO., LTD.
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THE UNIVERSITY OF TOKYO

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THE PROJECT
FOR
ASSESSING AND INTEGRATING CLIMATE CHANGE IMPACTS INTO THE WATER RESOURCES MANAGEMENT PLANS
FOR
BRANTAS AND MUSI RIVER BASINS
(Water Resources Management Plan)

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Brantas River Basin

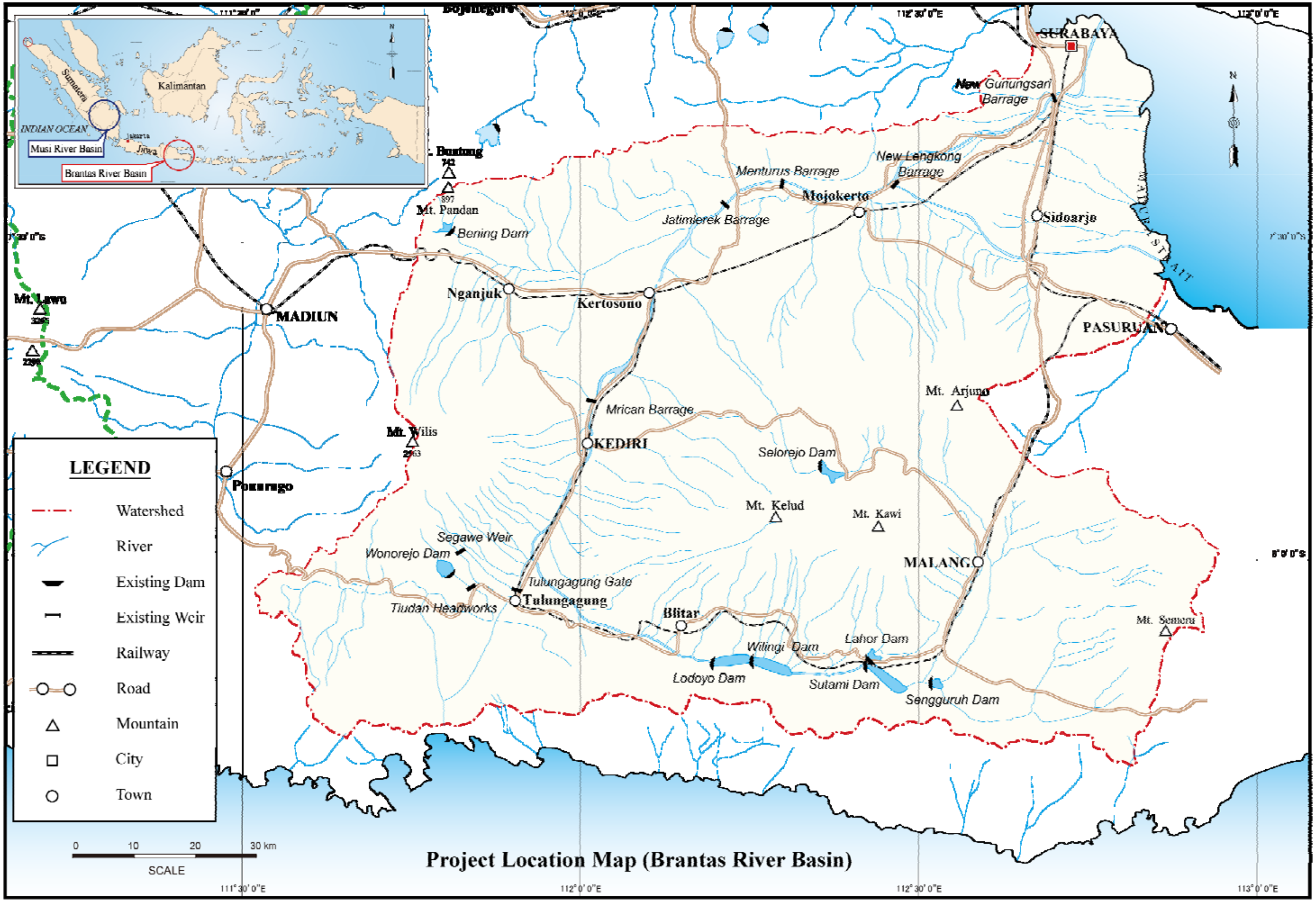
Cost Estimate: August 2017 Price

Exchange Rate: USD 1.0 = IDR 13,341.82 = JPY 109.84

Musi River Basin

Cost Estimate: March 2019 Price

Exchange Rate: USD 1.0 = IDR 14,230.00 = JPY 111.10



Project Location Map (Brantas River Basin)

Project Location Map (Musi River Basin)

Abbreviations and Glossaries

	Indonesia	English
AMDAL	Analisis Mengenai Dampak Lingkungan	Environmental Impact Assessment
APBN	Anggaran Pendapatan dan Belanja Negara	National Budget
BAKOSURTANAL	Badan Koordinasi Survei dan Pemetaan Nasional	National Coordination Agency for Surveys and Mapping
BAPPEDA	Badan Perencanaan Pembangunan Daerah	Regional Planning Agency
BAU		Business As Usual
BBWS	Balai Besar Wilayah Sungai	Large River Basin Organization
BCM	-	Business Continuity Management
BCP	-	Business Continuity Plan
BCR	-	Benefit Cost Ratio
BIG	Badan Informasi Geospasial	Geospatial Information Agency
BKSDA	Balai Konservasi Sumber Daya Air	Water Resources Conservation Center
BLHD	Badan Linkungan Hidup Daerah	Regional Living Environment Agency
BMKG	Bandan Metorologi, Klimatologi, dan Geofisika	Meteorological, Climatological, and Geophysical Agency
BNPB	Badan Nasional Penanggulangan Bencana	National Disaster Management Agency
BOD		Bio-chemical Oxygen Demand
BPBD	Badan Penanggulangan Bencana Daerah	Regional Agency for Disaster Management
BPDASHL	Balai Pengelolaan Daerah Aliran Sungai dan Hutan Lindung	Brantas-Sampean Watershed and Protected Forest Management Organization
BPPW	Balai Prasarana Permukiman Wilayah	Regional Settlement Infrastructure Agency
BPS	Badan Pusat Stasistik	Central Bureau of Statistics
BRG	Badan Restorasi Gambut	Peatland Restoration Agency
COD	-	Chemical Oxygen Demand
DANIDA	-	Ministry of Foreign Affairs of Denmark
D/D	-	Detailed Design
DEM		Digital Elevation Model
DGWR	Direktorate Jenderal Sumber Daya Air	Directorate General of Water Resources
DISHUT	Dinas Kehutanan	Department of Forestry
DGWR	Direktorat Jenderal Sumber Daya Air	Directorate General of Water Resources
DLH	Dinas Lingkungan Hidup	Department of Environmental
DNPI	Dewan Nasional Perubahan Iklim	National Council on Climate Change
DO	-	Dissolved Oxygen
DRR	-	Disaster Risk Reduction
DPRKPCK	Dinas Perumahan Rakyat, Kawasan Permukiman dan Cipta Karya	Department of Public Housing, Settlement and Cipta Karya
EC	-	Electric Conductivity
EIA	Analisis Mengenai Dampak Lingkungan	Environmental Impact Assessment
EIRR		Economic Internal Rate of Return
ESDM	Kementerian Energi dan Sumber Daya Mineral	Ministry of Energy and Mineral Resources
EWS	Sistem Peringatan Eini	Early Warning System

	Indonesia	English
F/S	-	Feasibility Study
FFWS	Sistem Peramalan dan Peringatan Banjir	Flood Forecasting and Warning System
FPL	-	Flood Protection Level
FSL		Full Supply Level
FY	-	Fiscal Year
GCM		Global Climate Model
GDP	-	Gross Domestic Product
GOI	-	Government of Indonesia
GOJ	-	Government of Japan
GRDP		Gross Regional Domestic Product
GSM	-	Global System for Mobile communications
HDSS	-	Hydrometeorological Decision Support System
HydroSHEDS	-	Hydrological data and maps based on SHuttle Elevation Derivatives at multiple Scales
IEE	-	Initial Environmental Evaluation
IMS	Izin Mendinikan Bangnan	Building construction permit
iRIC	-	International River Interface Cooperative
IWRM	Pengelolaan Sumber Daya Air Terpadu	Integrated Water Resources management
JATIM	Jawa Timur	East Java
JBIC	-	Japan Bank for International Cooperation
JICA	-	Japan International Cooperation Agency
KLHK	Kementerian Lingkungan Hidup dan Kehutanan	Ministry of Environment and Forestry
KP	Kriteria Perencanaan	Design Criteria for Irrigation Networks
KPH	Kesatuan Pemangkuan Hutan	Forest management unit
KPHP	Kesatuan Pengelolaan Hutan Produksi	Production Forest Management Unit
LARAP	-	Land Acquisition and Resettlement Action Plan
LIBOR	-	London Interbank Offered Rate
LWL	-	Low Water Level
MSBL	Musi-Sugihan-Banyuasin-Lemaure	Musi-Sugihan-Banyuasin-Lemau
MDG’s	-	Millenium Development Goal
MH	Musim Hujan	Rainy season
MLIT	-	Ministry of Land, Infrastructure and Transportation and Tourism
MK	Musim Kemarau	Dry season
MOL		Minimum Operation Level
M/P	-	Master Plan
MPL	-	Micro Pulse Lidar
MPWH	Pekerjaan Umum dan Perumahan Rakyat	Public Works and Public Housing
MPWPH	Kementerian Pekerjaan Umum dan Perumahan Rakyat	Ministry of Public Works and Housing

	Indonesia	English
MSA	-	Multiple Scenario Approach
NGO	-	Non-Governmental organization
NPV	-	Net Present Value
NRW	-	Non-Revenue Water
O&M	-	Operation & Maintenance
ODA	-	Official Development Assistance
OKI	Ogan Komering Ilir	-
OKU	Ogan Komering Ulu	-
P2AT	Proyek Pengembangan Air Tanah	Groundwater Development Project
PCO	-	Point of Cost Optimum
PDAM	Perusahaan Daerah Air Minum	Indonesian Regional Water Utility Company
PJT-I	Perum Jasa Tirta I	Jasa Tirta I Public Corporation
PKL	-	Develop Local Activity Centers
PKN	-	National Activity Center
PKW	-	Regional Activity Center
PLN	Perusahaan Listrik Negara	State Electric Company
POLA	Rencana Strategis Manajemen Sumber Daya Air	Water Resources Management Strategic Plan
PP	Peraturan Pemerintah	Government regulation
PR4	-	Progress Report-4
PSDA	Pengelolaan Samer Daya Air	Water Resources Management
RAD-GRK	-	Regional Action Plan on Greenhouse Gas
RENCANA	Rencana Penerapan Manajemen Sumber Daya Air	Water Resources Management Implementation Plan
RO	-	Reverse Osmosis
RPJM	Rencana Pembangunan Jangka Menegah	Mid-term Development Plan
RPJMD	Rencana Pembangunan Jangka Menegah Daerah	Medium Term Development Plan of Region
RPJP	Rencana Pembangunan Jangka Panjang	Long-term Development Plan
RTH	Ruang Terbuka Hijau	Green open space
RTRW	Rencana Tata Ruang Wilayah	Spatial Plan
RUPTL	Rencana Usaha Penyediaan Tenaga Listrik	Electricity Supply Business Plan
RWL	-	Reservoir Water Level
SEA	-	Strategic Environmental Assessment
SHM	-	Stakeholder Meetings
SHVP	Surabaya Haven Vaste Peil	Surabaya Harbor Flood Level
SID	-	Study Investigation Design
SNI	Standar National Indonesia	Indonesian National Standard
SPPL	-	-
SRI	-	System Rice Intensification
SSBSAP	-	South Sumatra Biodiversity Strategy and Action Plan

	Indonesia	English
TKPSDA	Tim Koordinasi Pengelolaan Sumber Daya Air	Water Resources Management Coordination Team
TOT	-	Training of Trainers
TPA	-	Development of regional Ultimate Waste Management System
TRGD	Tim Restorasi Gambut Daerah	Peat Restoration Team
UNISDR	-	United Nations International Strategy for Disaster Reduction
UPL-UKL	Upaya Pemantauan Lingkungan Hidup dan Upaya Pengelolaan Lingkungan Hidup	Environmental Management and Monitoring Plan
USLE	-	Universal Soil Loss Equation
VAT		Value Added Tax
WEB-DHM	-	Water Energy Budget-based Distributed Hydrological Model
WREFR & CIP	-	Water Resources Existing Facilities Rehabilitation & Capacity Improvement Project
WUA	-	Water Users Association

Supporting Report G

RIVER FACILITIES MANAGEMENT

The Republic of Indonesia

THE PROJECT
FOR
ASSESSING AND INTEGRATING CLIMATE CHANGE IMPACTS INTO
THE WATER RESOURCES MANAGEMENT PLANS FOR
BRANTAS AND MUSI RIVER BASINS
(WATER RESOURCES MANAGEMENT PLAN)

FINAL REPORT

Supporting Report G : RIVER FACILITIES MANAGEMENT (Brantas River Basin)

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PART 2 MUSI RIVER BASIN

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CHAPTER G1 GENERAL

G1.1 Tasks for River Facilities Management

"River Facilities" are composed with dam, weir, dike and other related facilities except for bridges across the river in this Project. Main tasks of the "River Facilities Management" in this Project are following six (6) items:

i) Collection and Analysis of Existing Data and Information
ii) Assessment of Effectiveness of Existing River Facilities to Assess Climate Change Impact in 2050
iii) Study for Optimal Operation of River Facilities to Mitigate Flood and Drought Risks
iv) Study for Other Adaptation and Mitigation Measures
v) Capacity Development for the Staff of the Government of Indonesian
vi) Preparation, Explanation and Discussion of Each Report

G1.2 Outline of Assignment for River Facilities Management

The field surveys for "River Faculties Management" were conducted 10 times in total in the course of the Project. Outline of the field works for the River Facilities Management is described below:

(1) 1st Field Work (2013.09.13 - 2013.10.13)

Data collection in Brantas and Musi River Basins;

(2) 2nd Field Work (2014.06.05 - 2014.06.29)

Site inspections in Brantas and Musi River Basins, and analysis collected data, held 1st workshop for River Facility Management, Preparation of Progress Report (1);

(3) 3rd Field Work (2015.08.17 - 2015.08.21)

Presentation for water resource management at Seminar in Jakarta;

(4) 4th Field Work (2016.01.25 - 2016.02.17)

Study for existing reservoir sedimentation in Brantas River, Preparation of Interim Report;

(5) 5th Field Work (2016.08.22 - 2016.09.20)

Study for future reservoir sedimentation and resilience (optimal dam operation) in Brantas River, Preparation of Progress Report (2);

(6) 6th Field Work (2016.12.05 - 2016.12.23)

Updated water balance study based on updated POLA in Brantas River (update of existing and future reservoir sedimentation data, update study for reservoir operation and collection of data/information of new dams), Preparation of Progress Report (2);

(7) 7th Field Work (2017.06.04 - 2017.06.21)

Study for adaptation measures in Brantas River, Preparation of Draft Final Report;

2nd Workshop for River Facility Management

(8) 8th Field Work (2017.08.31 - 2017.09.13)

Study and quantity calculation for adaptation measures in Brantas River, Flood routing for Selorejo Dam and Wonorejo Dam, Preparation of Draft Final Report;

(9) 9th Field Work (2018.06.27 - 2018.07.28)

Study for resilience and adaptation measures in Musi River.

(10) 10th Field Work (2019.04.23 - 2019.05.01)

Study for resilience and adaptation measures in Musi River, and preparation of Progress Report (5) for Musi River.

CHAPTER G2 COLLECTION OF DATA AND INFORMATION FOR RIVER FACILITY MANAGEMENT

G2.1 Data Collection for Brantas River Basin

The list of data collection for Brantas River Basin is presented in Table G 2.1.1.

Table G 2.1.1 List of Data Collection for Brantas River Basin

Category	Contents of Source Data	Organization Provided Data
Existing Dams	Leaflets of Existing Dams Operation Manual	PJT1
Previous Master Plan	M/P Brantas River (1st) 1961 M/P Brantas River (2nd) 1974 M/P Brantas River (3rd) 1986 M/P Brantas River (4th) Oct. 1998	JICA
POLA/RENCANA	REVIEW POLA 2015 Rancangan Rencana Pengelolaan Sumber Daya Air Wilayah Sungai Brantas (2013-2032)	BBWS Brantas
Reports for Proposed Dams	F/S for Ganteng Multipurpose Dam (Oct.2012)	BBWS Brantas
	D/D for Tugu Dam (Dec.2010)	BBWS Brantas
	F/S for Bendungan Serbagunan Beng (Jun.2003)	BBWS Brantas
	F/S for Bendungun Kedungwarak Dam (2005)	BBWS Brantas
	B/D for Bendungun Semantok (May 2013)	BBWS Brantas
	Review D/D for Lesti III Dam project (1994) Review Design including Model Test for Lesti III(Apr, 2014)	BBWS Brantas
	Report for Kesamben hydropower development project, (1982)	BBWS Brantas
	F/S for Beng Multipurpose Dam Work (2003)	BBWS Brantas
Reservoir Sedimentation	WREFER-CIP (2006) Sediment Roadmap in 2015-2019	BBWS Brantas PJT1

Source: JICA Project Team 2

G2.2 Musi River Basin

The list of data collection for Musi River Basin is presented in Table G 2.2.2.

Table G 2.2.2 List of Data Collection for Musi River Basin

Category	Contents of Source Data	Organization Provided Data
Previous Master Plan	"The Study on Comprehensive Water Management of Musi River Basin" (2003)	JICA
POLA/RENCANA	POLA (2014) RENCANA	BBWS SumateraVIII
Urban flood control in Palembang City	JICA SAPROF (2009) D/D for Palembang Sub-Project (2012) Implementation plan (JICA Loan IP-551)	BBWS SumateraVIII
PLTA Musi	Operation rule of PLTA. Text is PowerPoint style Sediment monitoring report(2015)	PLTA Musi
Komering Headwork	Rule operation of intake weir	Head of Regency Ogan Komering Ulu (OKU) Timur
Lakitan Headwork	Presentation of Lakitan weir plan and progress report (show in power point style)	

Category	Contents of Source Data	Organization Provided Data
Revetment (bank protection)	Location map and detail design	BBWS Sumatera VIII
Irrigation development project in swamp areas	Final report, summary report, supporting final report, thematic map	BBWS Sumatera VIII
Randu Canal	Discussion Materials Draft of Preliminary Report (May 28, 2014)	BBWS Sumatera VIII
Reports for Proposed Dams	Pre-F/S Proposed Mauradua/Komering 1&2 Dams, Ranau regulating dam (1982)	JICA
	F/S for Proposed Komering Dam(2013)	BBWS Sumatera VIII
	F/S for Proposed Saka Dam (2013)	BBWS Sumatera VIII
	Pre F/S for Proposed Padang Bindu/Tanjung Pura/Buluh Dams(2013)	BBWS Sumatera VIII

Source: JICA Project Team 2

PART 1 BRANTAS RIVER BASIN

CHAPTER G3 PRESENT CONDITION OF EXISTING RIVER FACILITIES IN BRANTAS RIVER BASIN

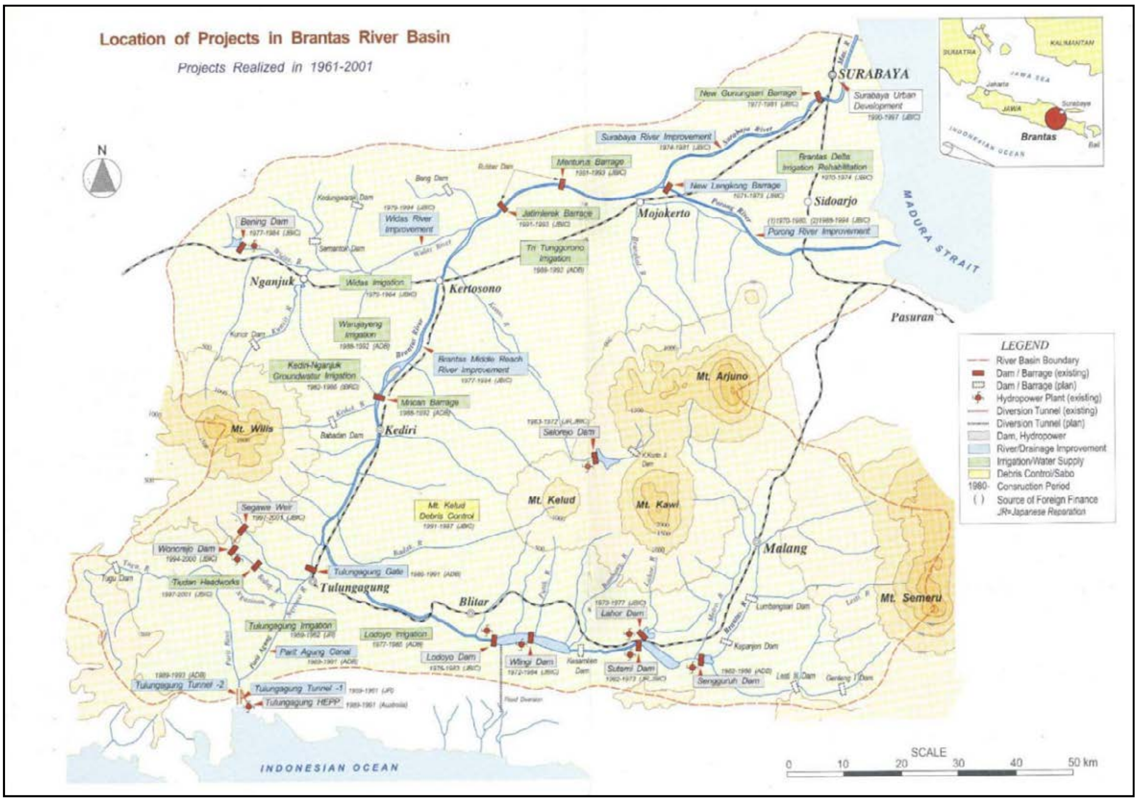
G3.1 Existing Dams and Reservoirs

Collection of basic information/data of the river facilities in Brantas River Basin were conducted through site inspection and interview survey to relevant staff of BBWS. Main objectives of the site inspection were to check present conditions and issues of the existing river facility management. Objective structures are existing dam, reservoir, intake weir, hydro power plant, outlet channel, pump station, rubber gate in the and upper Brantas River, and intake weir, water quality management facilities in Surabaya River. Basic dimension of the major existing dams, barrages and power plants are summarized in Table G 3.1.1.

Table G 3.1.1 Major Existing Barrage, Dam and Hydropower Plant in Brantas River Basin

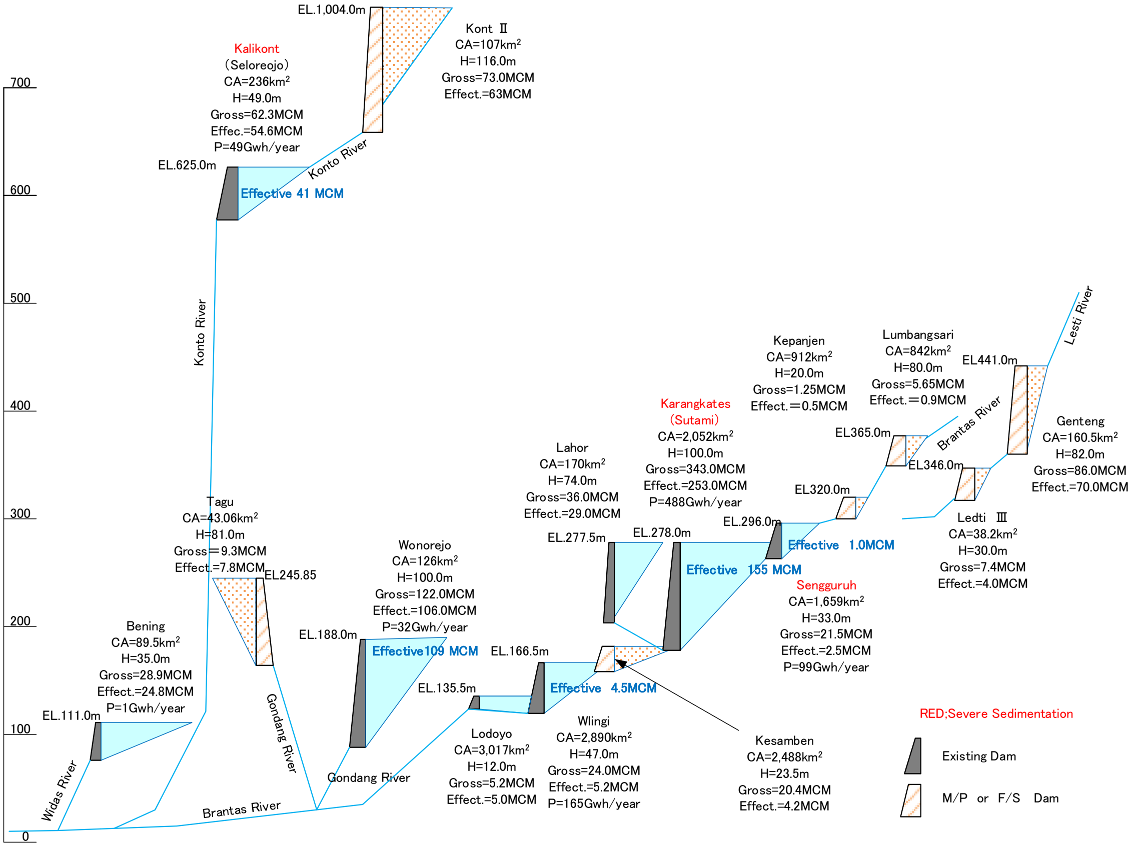
River Facility	Technical Feature
(1) Weir	
Waru-Turi Barrage (Mrican Barrage)	Longitudinal length=74.5m, L=159.8m, 9nos. spillway gates, 4nos. sluiceway gates
Jatimlerek Rubber Dam	H=1.85m, L=150m, 6nos. rubber gates
Menturus Rubber Dam	H=2.1m, L=150m, 6nos. rubber gates
New Lengkong Barrage	Longitudinal length==30.5m, L=150.8m, 8nos. spillway gates
Gunug Sari Barrage	H=6.0m, L=77.2m
(2) Dam	
Senggurh Dam	Rock Fill Dam, H=34m,L=378m, PS, Sediment Control
Sutami Dam	Rock Fill Dam, H=100m, L=823.5m, IR, DM, PS, FC
Lahor Dam	Rock Fill Dam, H=74m,L=443m, FC, DM, PS, IR
Wlingi Dam	Rock Fill Dam, H=47m, L=717m, FC, DM, IR
Lodyo Dam	H=12m, Afterbay for Wlingi Dam, PS
Wonorejo Dam	Rock Fill Dam, H=100m,L=545m,FC, DM, PS
Selorejo Dam	Zone Fill Dam, H=49m,L=450m, FC, DM, PS, IR
Bening Dam	Uniform Earth Fill Dam, H=36m,L=640m, FC, IR, PS
(3) Hydro Power Plant	
Selorejo P/S	Installed Capacity4.8MW, Power Generation 29.82 x10^6 kWh(2013)
Karangkates P/S	Installed Capacity105.0MW, Power Generation 560.22 x10^6 kWh(2013)
Wlingi P/S	Installed Capacity54.0MW, Power Generation 184.79 x10^6 kWh(2013)
Lodyo P/S	Installed Capacity4.5MW, Power Generation 38.04 x10^6 kWh(2013)
Bening P/S	Installed Capacity0.7MW, Power Generation none(2013)
Senggurh P/S	Installed Capacity28.8MW, Power Generation 90.23 x10^6 kWh(2013)
Tulungagung P/S	Installed Capacity36.0MW, Power Generation 181.99 x10^6 kWh(2013)
Wonorejo P/S	Installed Capacity6.5MW, Power Generation 28.02 x10^6 kWh(2013)
Mendalan P/S	Installed Capacity24.0MW, Power Generation 80.31 x10^6 kWh(2013)
Siman P/S	Installed Capacity10.8MW, Power Generation 67.87 x10^6 kWh(2013)

FC: Flood Control, IR: Irrigation Water Supply, DM: Domestic Water Supply, Hydro Power Generation
Source: PJT 1 Pamphlet,* PJT-I Annual Report, 2013



Source: JICA Project Team 2

Figure G 3.1.1 Location Map of River Facilities in Brantas River Basin



Source: JICA Project Team 2

Figure G 3.1.2 Schematic Profile of Main Dams in Brantas River Basin

G3.2 Sedimentation in Each Dam

G3.2.1 Reservoir Storage Volume Survey

PJT-1 has conducted bathymetry survey for each dam reservoir in the year shown in Table G 3.2.1. Reservoir capacity volume of each dam of the year is assessed based on the results of the bathymetry survey.

Table G 3.2.1 Year of Reservoir Capacity Volume Survey in Each Dam

No.	Name of Dam	Year of Reservoir Capacity Volume Survey
1	Sengguruh	1993, 1996, 1997, 2001, 2002, 2003, 2008, 2012, 2014
2	Sutami	1973, 1977, 1982, 1987, 1989, 1992, 1994, 1995, 1997, 1999, 2002, 2003, 2004, 2006, 2007, 2009, 2011, 2014
3	Wlingi	1995, 2001, 2004, 2006, 2007, 2008, 2009, 2011, 2013
4	Lodoyo	1996, 1999, 2003, 2007, 2008, 2009, 2011, 2013
5	Wonorejo	2004, 2005, 2008, 2011
6	Selorejo	1993, 1997, 1999, 2003, 2006, 2009, 2011, 2013, 2014
7	Lahor	1994, 1995, 1999, 2002, 2011, 2014
8	Bening	2004, 2007, 2011, 2012

Source: JICA Project Team 2

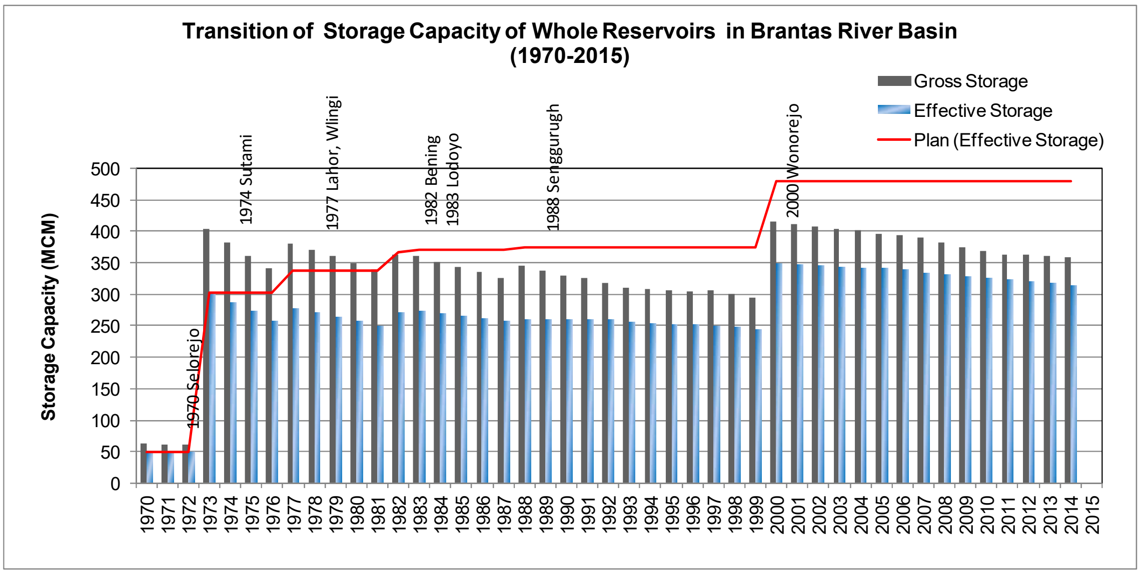
G3.2.2 Transition of Reservoir Storage Volume

In addition to the bathymetry data, reservoir storage volume from 2007 to 2014 is assessed as described in the RENCANA (2015 Review). The original source of the bathymetry data ad been requested to PJT-1 for collection, but so far the data has not been provided to Team 2.

Based on these data, transition of storage capacity of each dam reservoir from 1970 to 2014 is analyzed. Figure G 3.2.1 and Table G 3.2.2 show the transition of gross storage capacity of whole reservoirs, and Figure G 3.2.2 show transition of flood storage capacity. For each dam, the transition of the gross storage is presented in Figure G 3.2.3.

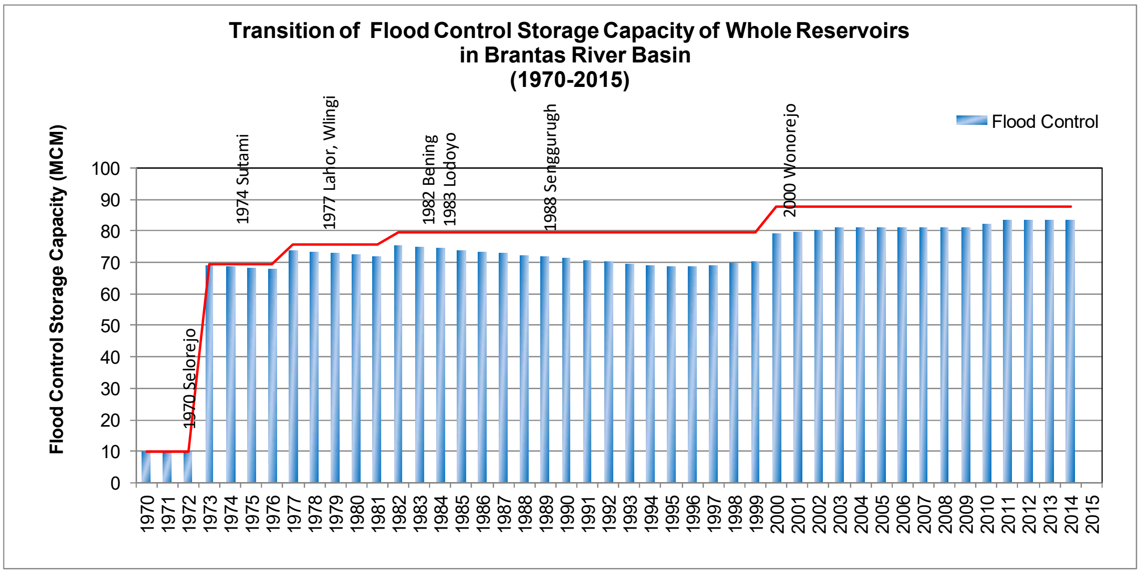
These figures and table indicate that;

- Since 1970, the reservoir storage capacity has been increased with dam constructions in the basin,
- As of 2015, total effective storage capacity is around 318 MCM,
- Effective storage capacity volume is being lost year by year due to sedimentation of reservoir. Recently dredging and sediment flushing are being conducted to remove sediment deposits in the reservoirs. By these effects, rate of sedimentation in the reservoirs is mitigated, and
- Flood control storage capacity is not significantly lost. In some parts, increase of the flood control capacity is observed. These are considered due to less accuracy of bathymetry survey, or erosion of river bank in surrounding area of reservoir and effect of sediment removal activities.



Source: PJT 1, WREFER&CIP, RENCANA (2015 Draft Review)

Figure G 3.2.1 Transition of Gross and Effective Storage Capacity of Whole Reservoirs in Brantas River Basin from 1970 to 2014



Source: PJT 1, WREFER&CIP, RENCANA (2015 Draft Review)

Figure G 3.2.2 Transition of Flood Control Storage Capacity of Whole Reservoirs in Brantas River Basin from 1970 to 2014

Table G 3.2.2 Transition of Gross Storage Capacity of Each Dam Reservoir in Brantas River Basin

Unit: Million m3

	Sengguruh	Sutami	Lahor	Wilingi	Lodoyo	Selorejo	Wonorejo	Bening	Total
Original	21.50	343.00	36.11	24.0	5.2	62.3	122.0	32.9	647.01
1970						62.30			62.30
1971						61.72			61.72
1972						61.13			61.13
1973		343.00				60.55			403.55
1974		322.67				59.96			382.63
1975		302.34				59.38			361.72
1976		282.01				58.80			340.81
1977		261.68	36.11	24.00		58.21			380.00
1978		253.60	35.93	22.86		57.63			370.02
1979		245.52	35.75	21.73		57.04			360.05
1980		237.45	35.57	20.59		56.46			350.07
1981		229.37	35.39	19.46		55.88			340.09
1982		221.29	35.21	18.32		55.29		32.90	363.01
1983		215.51	35.03	17.03	5.20	54.71		32.71	360.19
1984		209.74	34.85	15.73	4.98	54.13		32.51	351.94
1985		203.96	34.67	14.44	4.77	53.54		32.32	343.70
1986		198.19	34.49	12.79	4.55	52.96		32.12	335.10
1987		192.41	34.31	11.15	4.34	52.37		31.93	326.51
1988	21.50	192.40	34.13	9.50	4.12	51.79		31.74	345.18
1989	18.27	192.39	33.95	7.05	3.91	51.21		31.54	338.31
1990	15.04	191.58	33.77	4.60	3.69	50.62		31.35	330.66
1991	11.82	190.78	33.59	4.77	3.41	50.04		31.15	325.55
1992	8.59	189.97	33.41	2.51	3.12	49.45		30.96	318.01
1993	5.36	188.12	33.23	1.98	2.84	48.87		30.77	311.17
1994	4.71	186.27	33.05	3.38	2.68	48.56		30.57	309.22
1995	4.06	184.59	32.43	4.79	2.51	48.24		30.38	307.00
1996	3.41	184.01	32.19	5.54	2.35	47.93		30.18	305.61
1997	5.35	183.42	31.96	5.23	2.30	47.61		29.99	305.85
1998	4.89	181.94	31.72	4.91	2.26	45.16		29.79	300.67
1999	4.44	180.45	31.48	4.60	2.21	42.70		29.60	295.48
2000	3.98	178.97	31.24	4.28	2.17	43.03	122.00	29.41	415.07
2001	3.52	177.48	31.01	3.97	2.12	43.36	119.08	29.21	409.75
2002	3.20	176.00	30.77	4.12	2.08	43.68	116.16	29.02	405.02
2003	2.32	174.57	30.58	4.26	2.03	44.01	113.24	28.82	399.83
2004	2.12	173.70	30.38	4.41	2.15	43.65	110.32	28.63	395.36
2005	1.91	172.84	30.19	4.41	2.26	42.54	116.53	27.41	398.10
2006	1.71	171.97	30.00	4.00	2.38	42.92	114.25	26.19	393.41
2007	1.50	171.10	29.80	4.41	2.50	41.82	111.96	24.97	388.07
2008	1.30	168.30	29.61	4.42	2.78	40.71	109.68	25.55	382.35
2009	1.21	165.50	29.42	4.42	2.73	39.61	108.87	26.13	377.88
2010	1.13	161.34	29.22	4.42	2.69	38.86	108.05	26.70	372.41
2011	1.04	157.17	29.03	4.42	2.64	38.11	107.24	25.72	365.37
2012	1.14	157.63	29.04	4.64	2.68	37.34	107.24	27.86	367.57
2013	1.17	158.10	29.04	4.85	2.72	36.57	107.24	27.86	367.55
2014	1.19	158.56	29.05	4.85	2.72	34.82	107.24	27.86	366.29
2015		187.37							

☐ WREFR&CIP 2005

☐ RENCANA (Draft)

▨ Additional Data collected in this Project

Data in Italic Interporated data

Source: PJT 1, WREFER&CIP, RENCANA (2015 Draft Review)

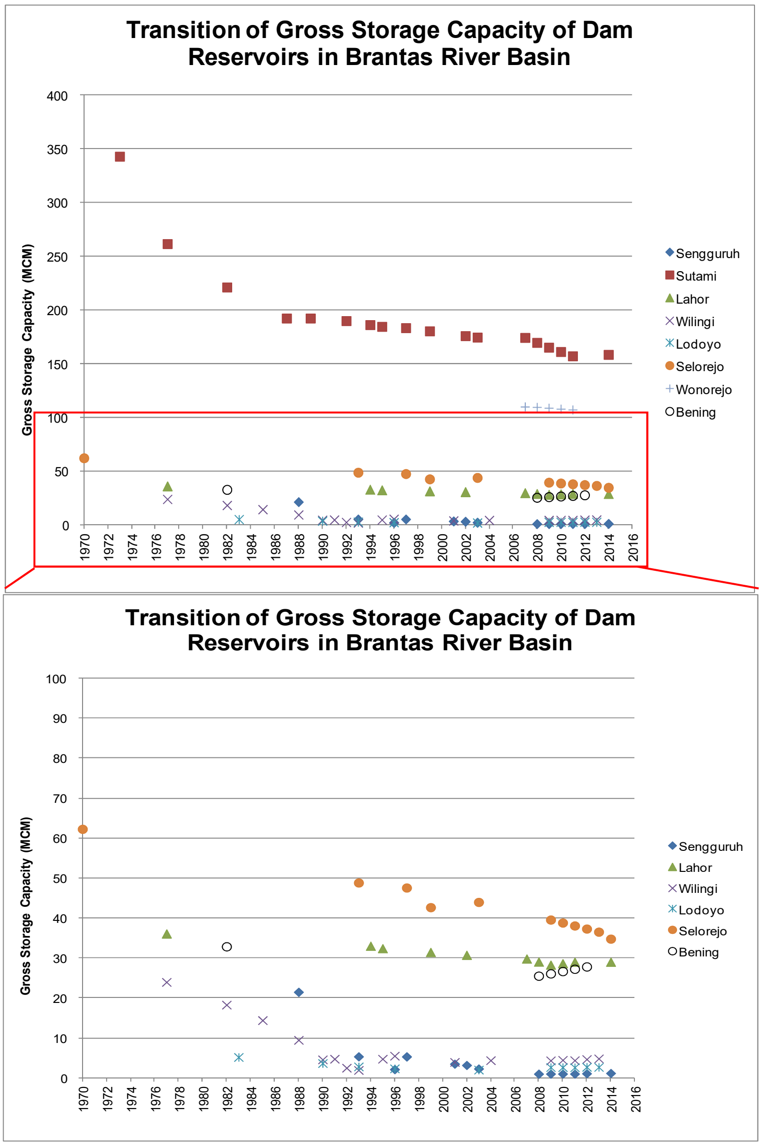
Table G 3.2.3 Transition of Effective Storage Capacity of Each Dam Reservoir in Brantas River Basin

Unit: Million m3

	Sengguruh	Sutami	Lahor	Wilingi	Lodoyo	Selorejo	Wonorejo	Bening	Total
Original	2.50	253.00	29.43	5.2	5.0	50.1	106.0	28.4	479.63
1970						50.10			50.10
1971						49.86			49.86
1972						49.62			49.62
1973		253.00				49.38			302.38
1974		238.37				49.14			287.51
1975		223.74				48.90			272.64
1976		209.11				48.66			257.77
1977		194.48	29.43	5.20		48.42			277.53
1978		189.02	29.26	4.16		48.18			270.63
1979		183.57	29.09	3.12		47.94			263.72
1980		178.11	28.92	2.08		47.70			256.81
1981		172.66	28.75	1.04		47.46			249.91
1982		167.20	28.58			47.23		28.40	271.40
1983		164.33	28.41	0.00	5.00	46.99		28.28	273.01
1984		161.47	28.24	0.00	4.81	46.75		28.16	269.43
1985		158.60	28.07		4.63	46.51		28.04	265.84
1986		155.74	27.89	0.00	4.44	46.27		27.93	262.26
1987		152.87	27.72	0.00	4.25	46.03		27.81	258.68
1988	2.50	152.75	27.55		4.06	45.79		27.69	260.34
1989	2.24	152.63	27.38	0.00	3.88	45.55		27.57	259.25
1990	1.98	153.13	27.21		3.69	45.31		27.45	258.78
1991	1.73	153.63	27.04	2.34	3.41	45.07		27.33	260.55
1992	1.47	154.13	26.87	1.09	3.12	44.83		27.21	258.73
1993	1.21	152.63	26.70	1.21	2.84	44.59		27.10	256.28
1994	1.22	151.13	26.53	1.34	2.68	44.56		26.98	254.43
1995	1.23	149.15	26.26	1.46	2.51	44.53		26.86	252.00
1996	1.24	148.49	26.06	1.73	2.35	44.49		26.74	251.09
1997	1.20	147.82	25.86	1.81	2.28	44.46		26.62	250.04
1998	1.17	147.46	25.65	1.88	2.21	42.21		26.50	247.08
1999	1.15	147.09	25.45	1.96	2.14	39.96		26.38	244.13
2000	1.12	146.54	25.39	2.03	2.07	40.35	106.00	26.26	349.76
2001	1.09	145.98	25.34	2.11	2.00	40.74	104.26	26.15	347.66
2002	1.13	145.43	25.28	2.08	1.93	41.12	102.52	26.03	345.51
2003	1.04	145.20	25.22	2.04	1.86	41.51	100.77	25.91	343.55
2004	1.00	144.31	25.15	2.01	1.91	41.27	99.03	25.79	340.48
2005	0.97	143.42	25.09	2.01	1.96	41.03	102.81	24.83	342.12
2006	0.93	142.54	25.03	2.02	2.01	40.79	101.54	23.86	338.72
2007	0.90	141.65	24.96	2.02	2.06	39.74	100.27	22.90	334.50
2008	0.86	140.76	24.90	2.03	2.12	38.68	99.00	22.68	331.02
2009	0.82	139.87	24.83	2.03	2.17	37.63	98.36	22.46	328.18
2010	0.79	138.98	24.77	2.04	2.22	37.02	97.73	22.24	325.78
2011	0.75	138.10	24.71	2.04	2.27	36.41	97.09	22.02	323.38
2012	0.72	137.21	24.64	2.04	2.32	35.38	96.45	21.80	320.57
2013	0.68	136.32	24.58	2.05	2.37	34.35	95.82	21.58	317.75
2014	0.64	135.43	24.52	2.05	2.42	33.32	95.18	21.36	314.93
2015									

☐	WREFR&CIP 2005
☐	RENCANA (Draft)
xxx	Interporated data
▨	Additional Data

Source: PJT 1, WREFER&CIP, RENCANA (2015 Draft Review)



Source: PJT 1, WREFER&CIP, RENCANA (2015 Draft Review)

Figure G 3.2.3 Transition of Gross Storage Capacity of Each Dam Reservoir in Brantas River Basin

Table G 3.2.4 Change of Storage Capacity of Each Dam Reservoir in Brantas River Basin

No.	Name of Dam	Year	Storage Volume (mil. m3)		
			Gross	Effective	Dead
1	Sengguruh	1988	21.50	2.50	19.00
		2014	1.19	0.64	0.55
		Latest / Original (%)	5.5	25.6	2.9

No.	Name of Dam	Year	Storage Volume (mil. m3)		
			Gross	Effective	Dead
2	Sutami	1972	343.00	253.00	90.00
		2014	158.56	135.43	23.13
		Latest / Original (%)	46.2	53.5	25.7

No.	Name of Dam	Completion Year	Storage Volume (mil. m3)		
			Gross	Effective	Dead
3	Lahor	1977	36.10	29.40	6.70
		2014	29.05	24.52	4.53
		Latest / Original (%)	80.5	83.4	67.6

No.	Name of Dam	Completion Year	Storage Volume (mil. m3)		
			Gross	Effective	Dead
4	Wlingi	1977	24.00	5.20	18.80
		2013	4.85	2.05	2.80
		Latest / Original (%)	20.2	39.4	14.9

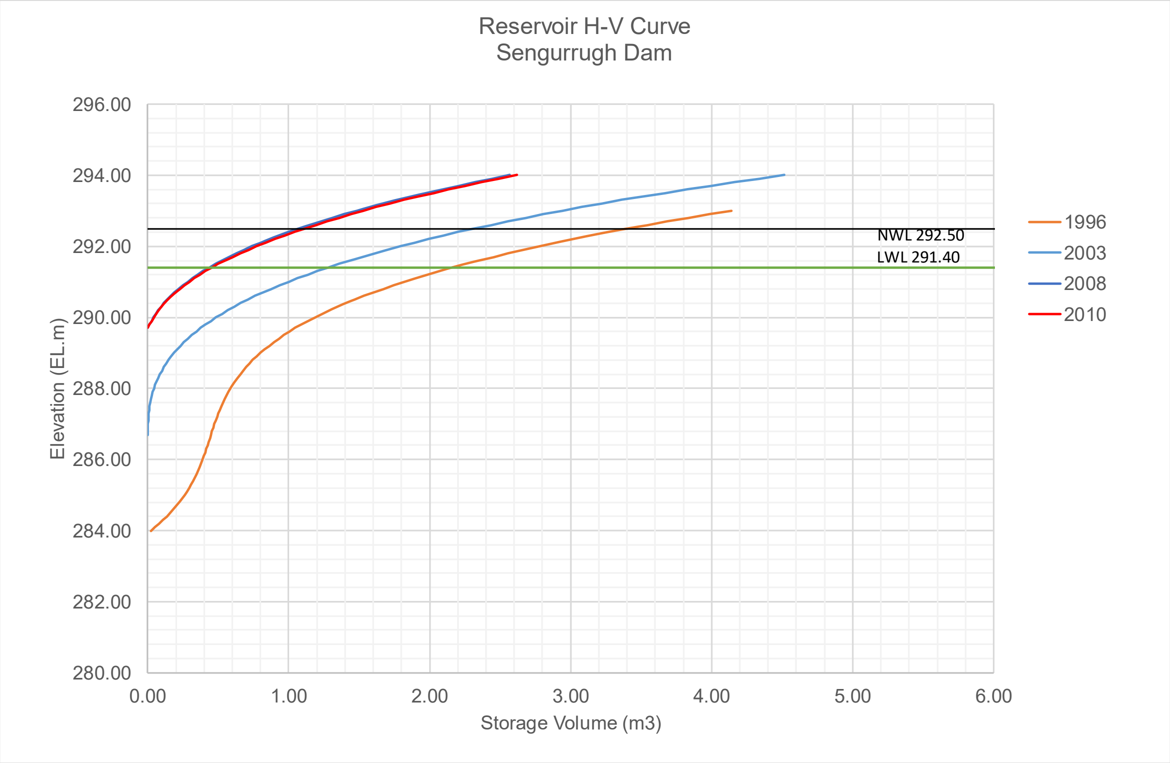
No.	Name of Dam	Completion Year	Storage Volume (mil. m3)		
			Gross	Effective	Dead
5	Lodoyo	1980	5.80	4.20	1.60
		2013	2.72	2.37	0.35
		Latest / Original (%)	46.9	56.4	21.9

No.	Name of Dam	Completion Year	Storage Volume (mil. m3)		
			Gross	Effective	Dead
6	Serolejo	1970	62.30	50.10	12.20
		2014	34.82	33.32	1.50
		Latest / Original (%)	55.9	66.5	12.3

No.	Name of Dam	Completion Year	Storage Volume (mil. m3)		
			Gross	Effective	Dead
7	Bening	1981	32.90	28.40	4.50
		2012	27.86	21.80	6.06
		Latest / Original (%)	84.7	76.8	134.7

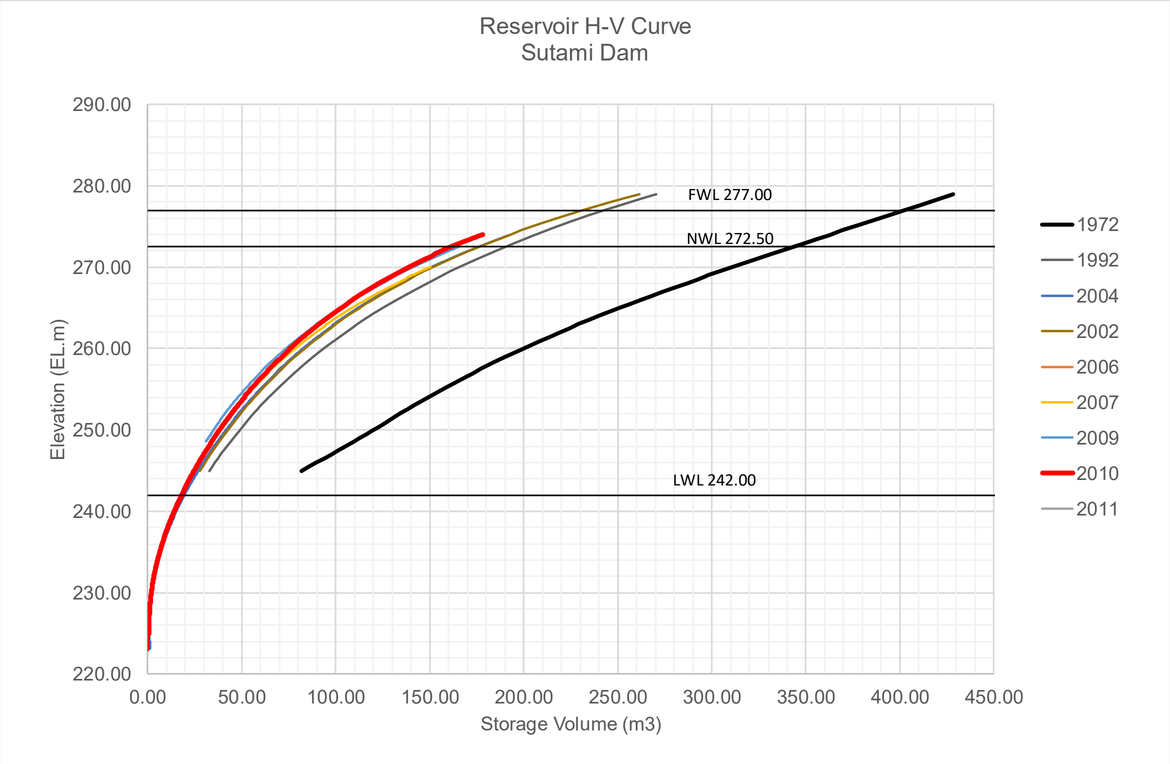
No.	Name of Dam	Completion Year	Storage Volume (mil. m3)		
			Gross	Effective	Dead
8	Wonorejo	2001	122.00	106.00	16.00
		2011	107.24	97.09	10.15
		Latest / Original (%)	87.9	91.6	63.4

Source: PJT 1, WREFER&CIP, RENCANA (2015 Draft Review)



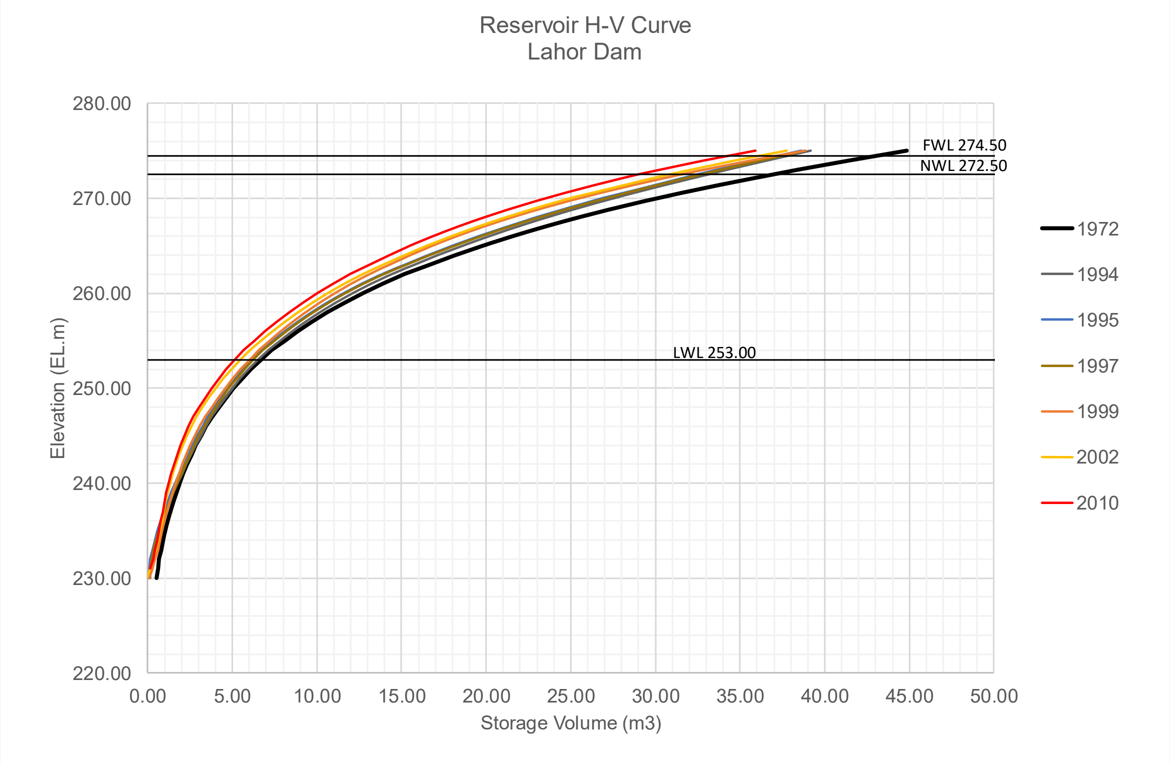
Source: JICA Project Team 2

Figure G 3.2.4 HV Curve in Senggurh Dam



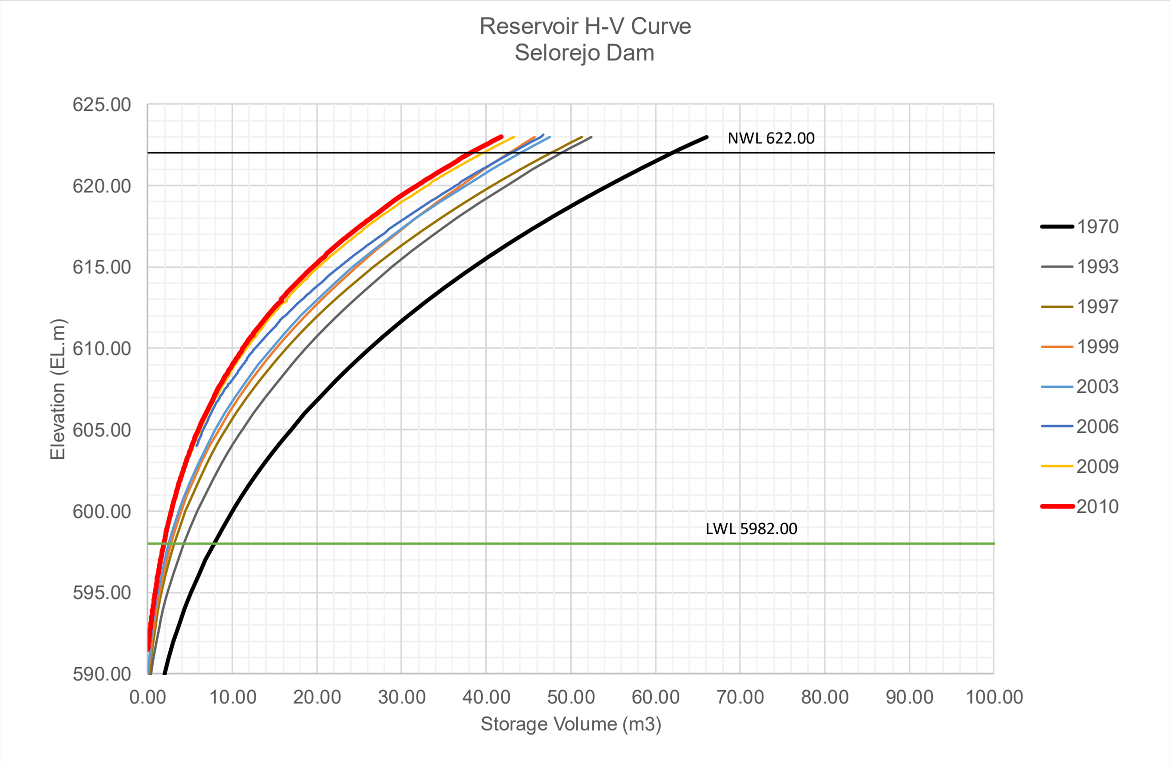
Source: JICA Project Team 2

Figure G 3.2.5 HV Curve in Sutami Dam



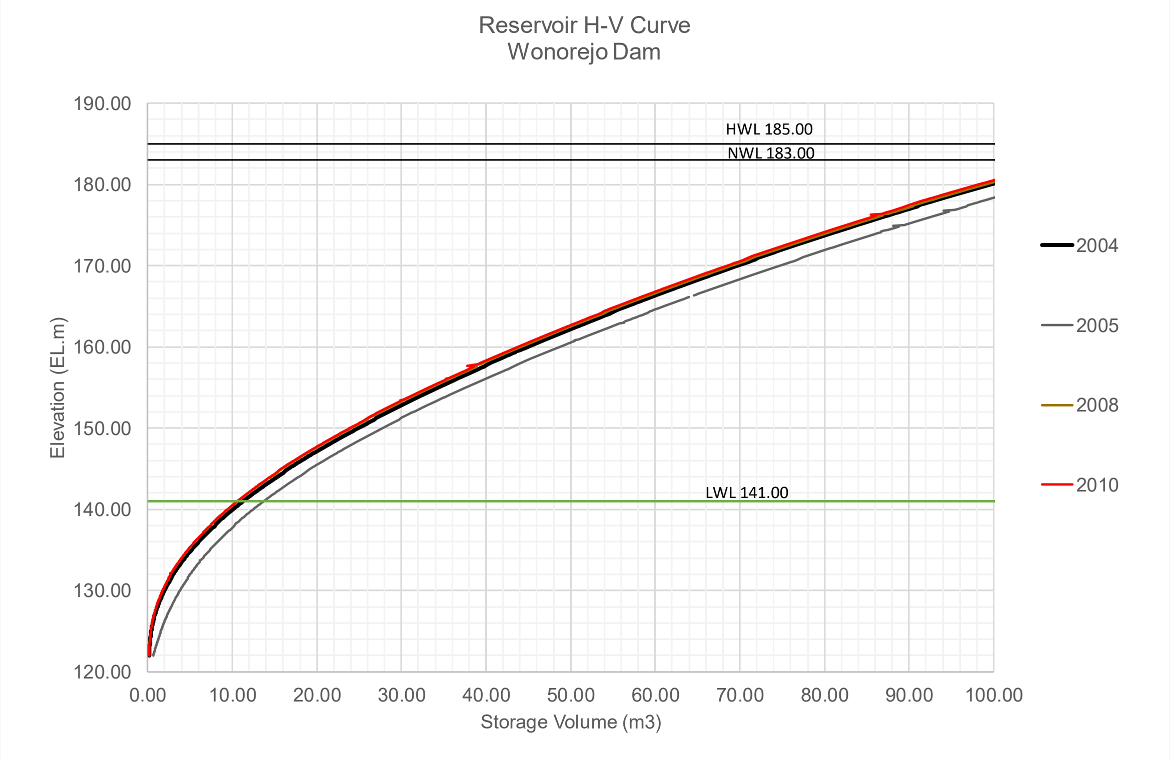
Source: JICA Project Team 2

Figure G 3.2.6 HV Curve in Lahor Dam



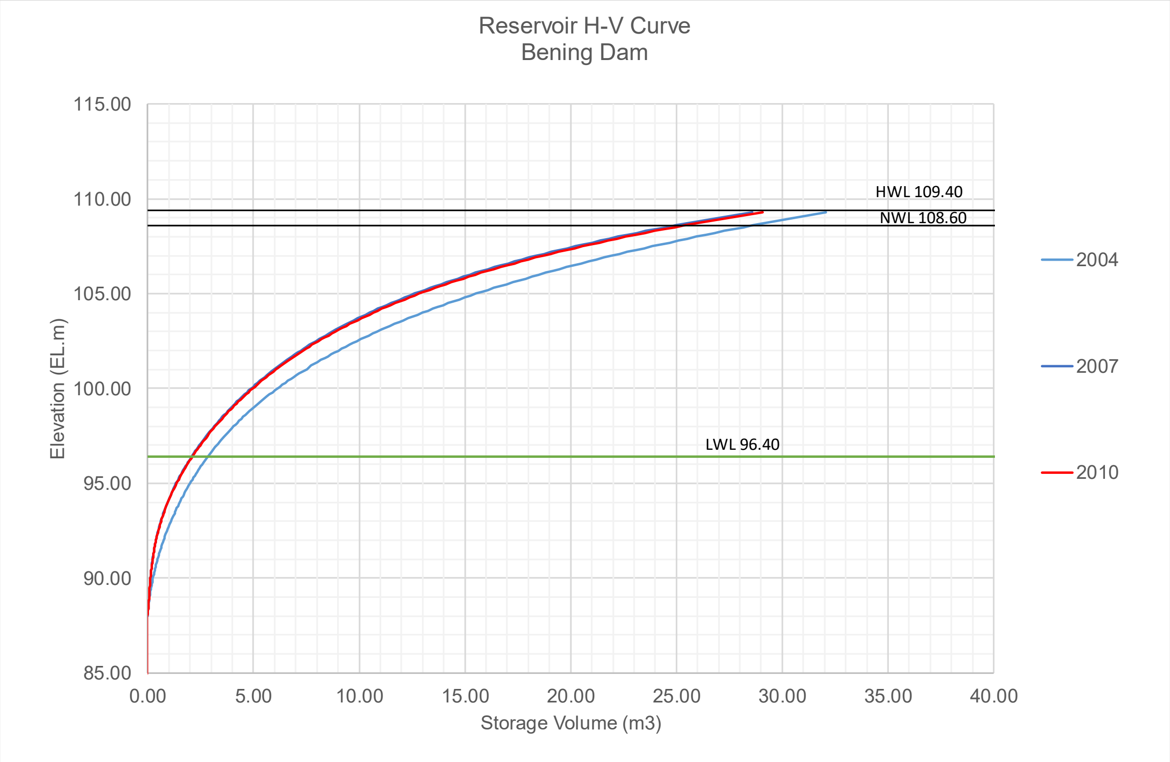
Source: JICA Project Team 2

Figure G 3.2.7 HV Curve in Selorejo Dam



Source: JICA Project Team 2

Figure G 3.2.8 HV Curve in Wonorejo Dam



Source: JICA Project Team 2

Figure G 3.2.9 HV Curve in Bening Dam

G3.2.3 Dredging and Sediment Flushing

PJT-1 has conducted dredging of sediment deposits in Senggurh, Sutami, Wlingi, Lodoyo, and Selorejo Reservoirs. Beside of the dredging, sediment flushing is also conducted in Wlingi and Lodoyo Reservoirs. Table G 3.2.5 and Table G 3.2.6 show the dredging and sediment flushing volume in each Dam, respectively.

In the WREFER & CIP, trial test of sediment flushing in Wlingi and Lodoyo dams was conducted in May 2004. In this test, topographic survey was carried out before and after flushing, while several indices of water quality in the river stretch between the downstream of the dam to the New Lengkong Dam were monitored before, during and after flushing. Test results indicated sediment removal volume in 1-2 days were 219,000 m^3 in Wlingi and 106,000 m^3 in Lodoyo, respectively, and turbidity water with change of water color was observed up to the New Lengkong Dam.

Table G 3.2.5 Dredging Volume in Each Dam Reservoir

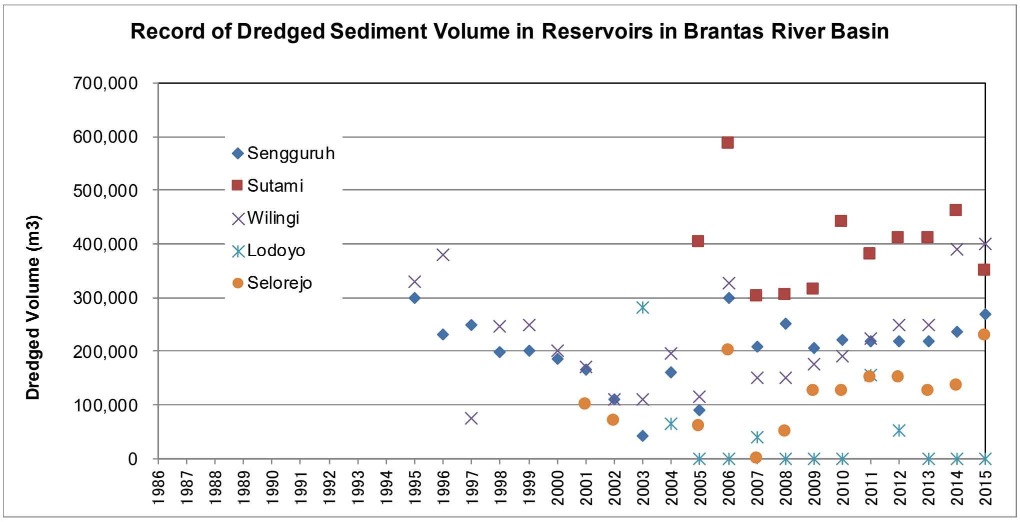
	Sutami	Lahor	Wilingi	Lodoyo	Selorejo	Wonorejo	Bening	Total
1988								
1989								0
1990								0
1991								0
1992								0
1993								0
1994								0
1995	300,000		330,157					630,157
1996	232,265		379,000					611,265
1997	250,000		75,000					325,000
1998	198,000		247,000					445,000
1999	200,000		250,000					450,000
2000	187,070		201,159					388,229
2001	165,510		170,940		101,100			437,550
2002	110,083		110,769		70,044			290,896
2003	42,900		110,633	282,398				435,931
2004	160,565		196,421	65,386				422,372
2005	90,920	401,390	0	115,500	0	60,000	0	0	667,810
2006	300,420	587,270	0	326,260	0	200,000	0	0	1,413,950
2007	207,800	300,750	0	150,630	41,140	0	0	0	700,320
2008	251,470	303,910	0	150,100	0	50,100	0	0	755,580
2009	207,270	315,450	0	175,630	0	125,980	0	0	824,330
2010	220,100	439,690	0	191,710	0	125,000	0	0	976,500
2011	220,000	380,000	0	225,000	155,320	150,000	0	0	1,130,320
2012	220,000	410,000	0	250,000	51,360	150,000	0	0	1,081,360
2013	220,000	410,000	0	250,000	0	125,000	0	0	1,005,000
2014	237,000	460,000	0	390,000	0	135,000	0	0	1,222,000
2015	270,000	350,000	0	400,000	0	230,000	0	0	1,250,000
Total	4,291,373	4,358,460		4,695,909	595,604	1,522,224			15,463,570

☐ Sediment Management Road Map (2015-2019)

▨ Data from PJT-1 (Jan. 2017)

🟦 Including the dreding by National Fund

Source: PJT 1, WREFER&CIP, RENCANA (2015 Draft Review)



Source: JICA Project Team 2

Figure G 3.2.10 Dredging Volume in Each Dam Reservoir

Table G 3.2.6 Sediment Flushing Volume in Each Dam Reservoir

Flushing Implementation		Flushed Sediment Volume (m^3)	
Year	Time	Wlingi dam reservoir	Lodoyo dam reservoir
1990	4	1,900,000	no data
1992	1	215,000	no data
1993	1	189,000	no data
1999	1	479,900	65,200
2000	1	363,600	276,300
2001	2	715,000	52,300
February 2004	1	679,000	769,000
May 2004	1	219,000	106,000
2005	no data	935,500	245,200
2006	no data	356,600	146,400
2007	no data	459,200	268,000
2008	no data	395,500	145,200
2009	no data	145,500	64,400
2010	no data	561,200	232,600
2011	no data	351,600	0
2012	no data	0	0
2013	no data	269,500	0
2014	no data	0	0
2015	no data	0	0
Total Volume (m^3)		8,235,100	2,370,600
Max Volume (m^3)		935,500	769,000
Min Volume (m^3)		-	52,300
Average Volume (m^3)		433,426	148,163

Source : PJT-I Malang

G3.2.4 Sediment Inflow into Reservoirs

Sediment balance in the reservoir is shown in the equation below:

$$\Delta \mathrm{V} = \mathrm{S_{in}} - \mathrm{S_{out}} - \mathrm{V_{dredge}} - \mathrm{V_{flush}}$$

Where,

$\Delta \mathrm{V}$: Variation of reservoir storage (m^3)

$\mathrm{S_{in}}$: Sediment inflow into reservoir (m^3)

$\mathrm{S_{out}}$: Sediment outflow into reservoir (m^3)

$\mathrm{V_{dredge}}$: Dredging volume (m^3)

$\mathrm{V_{flush}}$: Sediment flushing volume (m^3)

As shown in the equation, sediment inflow into the reservoir can be estimated from the variation of the reservoir storage capacity, and volume of dredging and volume of sediment flushing in case sediment outflow volume is identified. Actually, it is difficult to measure the sediment outflow volume physically. Hence, in order to estimate $\mathrm{S_{out}}$, “trapping efficiency ($\mathrm{E_t}$)” which is a relation between $\mathrm{S_{in}}$ and $\mathrm{S_{out}}$ is used. For computation of Et, the Brune’s middle curve formula is applied as an empirical one adopting a parameter of the reservoir rotation ratio (C/I).

$$\mathrm{E_t} = \frac{\mathrm{S_{in}} - \mathrm{S_{out}}}{\mathrm{S_{in}}} = \frac{\left({}^{\mathrm{C}}\!/_{\mathrm{I}}\right)}{\left\{0.012 + 1.02\left({}^{\mathrm{C}}\!/_{\mathrm{I}}\right)\right\}}$$

Where,

C/I: Rotation ratio

C: Gross Storage Capacity (m^3)

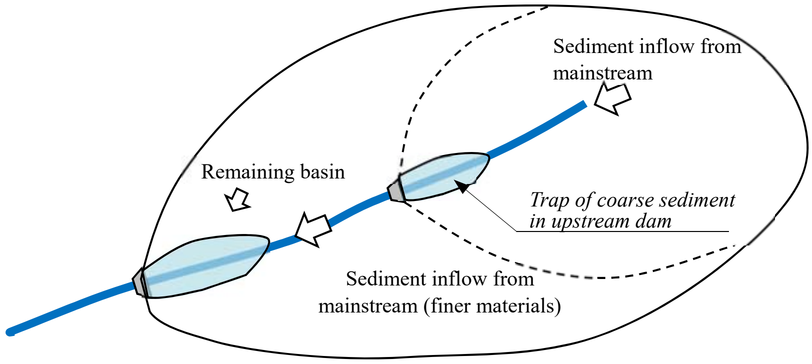
I: Annual Volume of Water Inflow into Reservoir (m^3)

Based on the above equations, sediment inflow is estimated as below:

<Equation of sediment inflow for Senggurh, Lahor, Selorejo, Wonorejo and Bening Dam Reservoirs>

$$\mathrm{S_{in}} = \frac{\Delta \mathrm{V} + \mathrm{V_{dredge}} + \mathrm{V_{flush}}}{\mathrm{E_t}}$$

The above equation can be adopted if there is no dam in the upstream stretch. In case there is another dam in the upstream stretch, such as Sutami, Wlingi, Lodoyo Dams, majority of the composition of sediment inflow into the reservoir would be fine materials because coarser materials are trapped in the upstream dam before entering into the reservoir as shown in figure below. Thereby the trapping efficiency of such dams tends to be decrease.



Source: JICA Project Team 2

Figure G 3.2.11 Schematic Image of Sediment Inflow into Reservoir in Case of with A Dam in Upstream Area

So far there is no theoretical equation describing this phenomenon. In this study, referring to the previous similar study reports, trapping efficiency of such dam is estimated multiplying a reduction factor of α with Et as shown in the following equation. The reduction factor of α can be estimated through the calibration based on the actual records of reservoir sedimentation.

< Equation of sediment inflow from main stream in case of with a Dam in upstream area>

$$E_{t\_dam} = \alpha \cdot E_t = \frac{S_{in\_dam} - S_{out\_dam}}{S_{in\_dam}} \qquad (\alpha<1)$$

Where,

S_{in_dam}: Sediment inflow from river channel into the reservoir in case there is an upper dam

S_{out_dam}: Sediment outflow from reservoir h in case there is an upper dam

Because of the above characteristics, sediment inflow of these dams should be estimated separately, i.e. from mainstream and from remaining basin. The equation of the sediment balance of these dams is summarized as below.

< Equation of sediment inflow in case of with a Dam in upstream area> $S_{in\_rem} + \alpha \cdot S_{in\_dam} = \frac{\Delta V + V_{dredge} + V_{flush}}{E_t}$

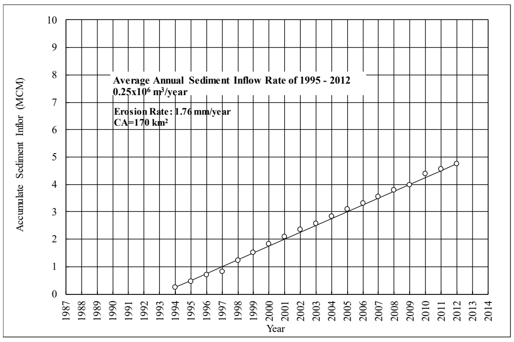
The result of estimation of annual sediment inflow in each dam reservoir is presented in Table G 3.2.7 and Figure G 3.2.11.

Table G 3.2.7 Annual Sediment Inflow Volume in Each Dam Reservoir

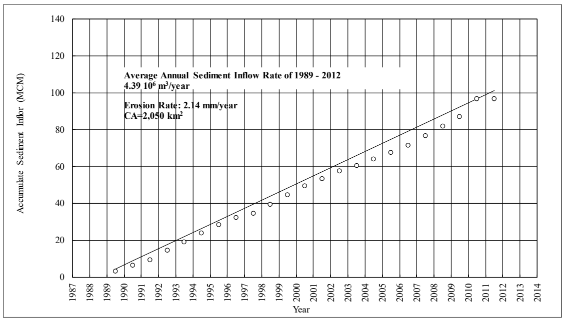
Unit: Million m^3

	Sengguruh	Sutami	Lahor	Wilingi	Lodoyo	Selorejo	Wonorejo	Bening
1988	4.96							
1989	4.95	3.17						
1990	4.95	3.31						
1991	4.13	2.66						0.21
1992	6.64	5.32						0.29
1993	5.75	4.59				0.97		0.31
1994	5.72	4.67	0.24			0.78		0.28
1995	5.56	4.63	0.23	4.17		0.73		0.22
1996	4.72	3.93	0.24	3.64	3.49	0.55		0.21
1997	2.78	2.10	0.12	1.95	1.80	0.74		0.16
1998	5.49	5.03	0.40	4.92	4.87	0.83		0.21
1999	5.63	5.23	0.28	4.69	4.54	0.86		0.24
2000	5.22	4.89	0.30	4.50	4.28	0.73	0.79	0.25
2001	3.89	3.62	0.28	3.52	3.32	0.64	0.73	0.21
2002	4.58	4.42	0.25	4.05	3.83	0.52	0.72	0.18
2003	2.91	2.73	0.22	2.70	2.50	0.52	0.43	0.15
2004	3.58	3.50	0.26	3.31	3.09	0.48	0.27	0.15
2005	3.56	3.58	0.26	3.37	3.12	0.57	0.31	0.14
2006	4.02	4.04	0.23	3.64	3.33	0.51	0.40	0.16
2007	5.19	5.19	0.25	4.60	4.32	0.71	0.44	0.15
2008	5.11	5.16	0.23	4.48	4.20	0.63	0.48	0.20
2009	5.18	5.22	0.19	4.34	3.98	1.08	0.38	0.18
2010	9.34	9.70	0.43	8.82	8.56	0.73	0.64	0.31
2011			0.16		0.18	0.73	0.65	
2012			0.17					
2013								
2014								
2015								
Average	4.95	4.39	0.25	4.17	3.71	0.70	0.52	0.21

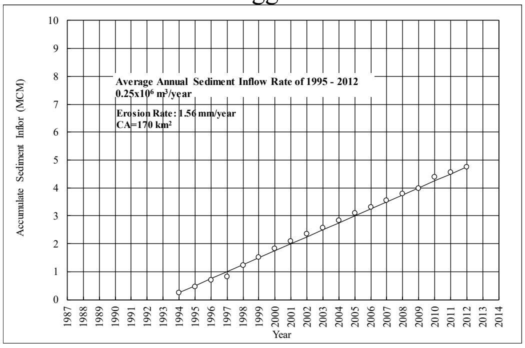
Source: JICA Project Team 2



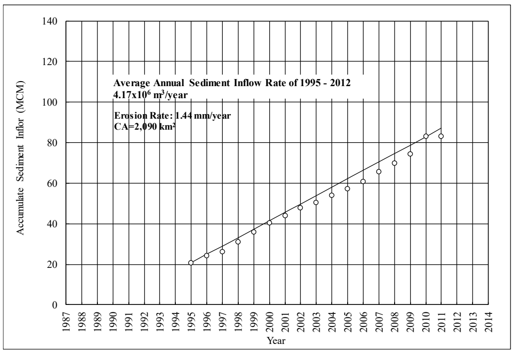
Senggurh



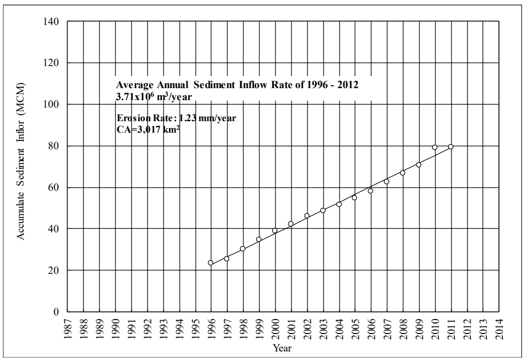
Sutami



Lahor



Wlingi



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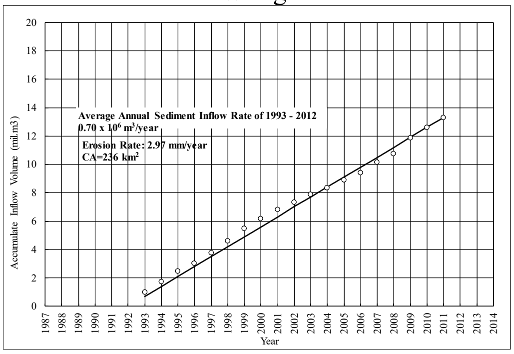
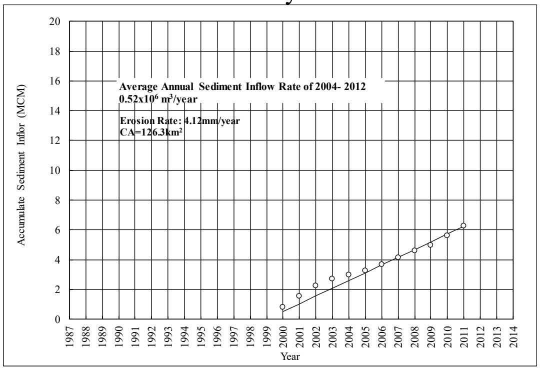
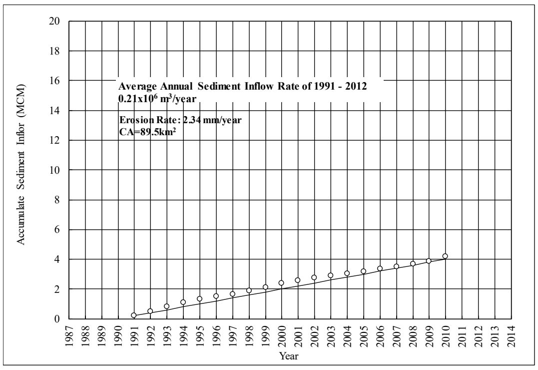


Selorejo



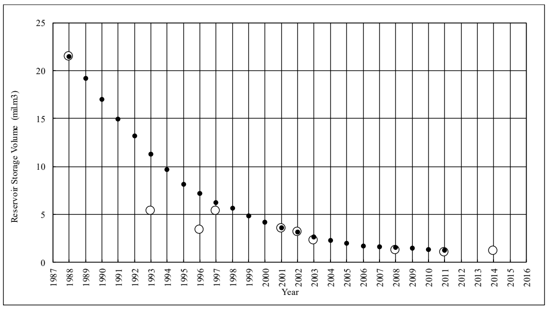
Wonorejo



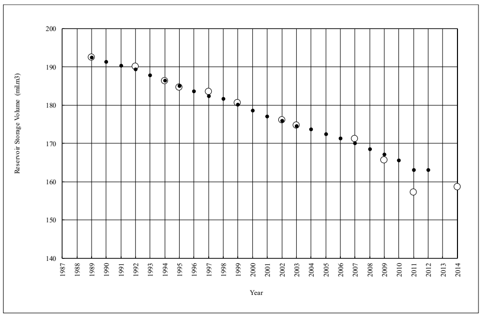
Bening

Source: JICA Project Team 2

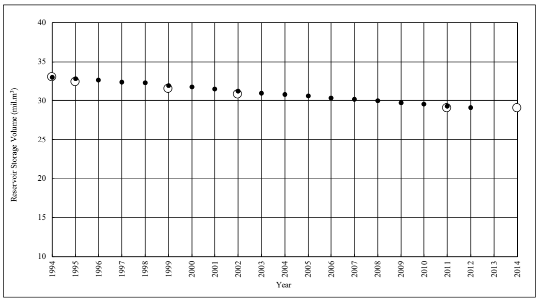
Figure G 3.2.12 Accumulated Sediment Inflow Volume in Each Dam Reservoir



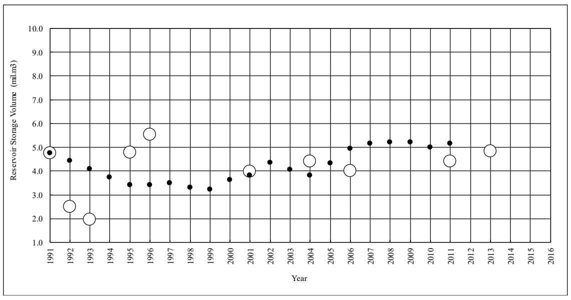
Senggurh



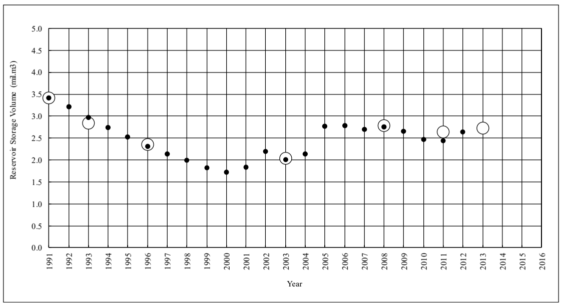
Sutami



Lahor



Wlingi



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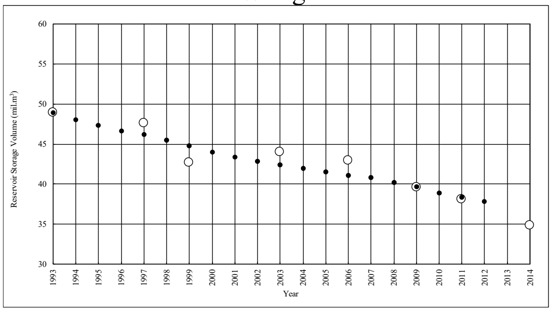
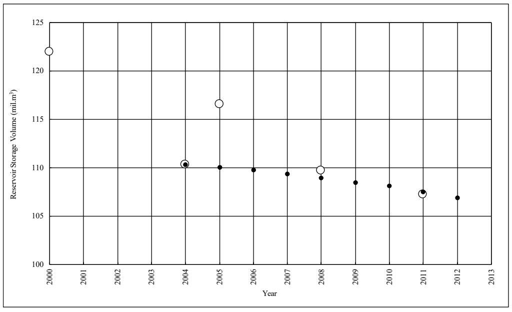
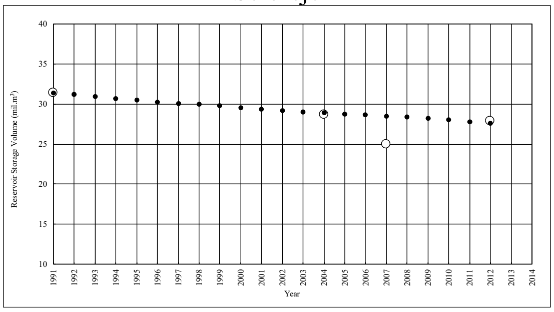


Selorejo



Wonorejo



Bening

Source: JICA Project Team 2

Figure G 3.2.13 Change of Reservoir Storage Volume in Each Dam Reservoir

G3.2.5 Summary of Current Status of Reservoir Sedimentation

Dam reservoir storage capacity of each dam as of 2014 is estimated based on the result of calibration with actual result of reservoir sedimentation and sediment balance as shown in Table G 3.2.8 below.

Table G 3.2.8 Dam Reservoir Storage Capacity as of 2014

Unit: Million m^3

Dam	Gross Storage*	Sediment Storage	Effective Storage	Flood Control Storage
Senggurh Dam	1.19	0.55	0.64	-
Sutami Dam	158.56	23.13	135.43	55.96
Lahor Dam	29.05	4.53	24.52	5.51
Wlingi Dam	4.85	2.80	2.05	-
Lodoyo Dam	2.72	0.30	2.42	-
Selorejo Dam	34.82	1.50	33.32	10.86
Wonorejo Dam	107.24	12.06	95.18	7.42
Bening Dam	27.86	6.50	21.36	3.63

*"Gross Storage" is defined as sediment storage plus effective storage.

Source: JICA Project Team 2

Basic information associated with the reservoir sedimentation of each dam, such as annual inflow discharge, annual sediment inflow, annual sediment outflow, annual sediment trapped volume and annual sediment released volume is summarized in Table G 3.2.9 below.

Table G 3.2.9 Basic Information associated with Reservoir Sedimentation

Item		Unit	Sungguruh	Sutami	Lahor	Wlingi	Lodoyo	Selorejo	Wonorejo	Bening
Catchment Area	Main stream	km^2	1,659	1,659	170	2,050	2,890	236	126	90
	Remaining Basin	km^2	-	221	-	840	127	-	-	-
	Total	**km^2**	**1,659**	**2,050**	**170**	**2,890**	**3,017**	**236**	**126**	**90**
Annual Inflow Discharge	from Main River	MCM	2,002	2,002	347	2,466	3,277	336	147	335
	from Remaining Basin	MCM	-	464	-	975	322	-	-	-
	Total	**MCM**	**2,002**	**2,466**	**347**	**3,440**	**3,599**	**336**	**147**	**335**
Annual Sediment Inflow Discharge	from Main River	MCM	4.95	3.99	0.25	3.15	3.58	0.70	0.52	0.20
	from Remaining Basin	MCM	-	0.40	-	1.00	0.20	-	-	-
	Total	**MCM**	**4.95**	**4.39**	**0.25**	**4.15**	**3.78**	**0.70**	**0.52**	**0.20**
Annual Sediment Outflow Discharge		MCM	3.94	3.06	0.04	3.75	3.58	0.07	0.23	0.03
Annual Sediment Trapped Volume	from Main River	MCM	1.01	1.00	0.21	0.30	0.19	0.63	0.29	0.17
	from Remaining Basin	MCM	-	0.34	-	0.10	0.01	-	-	-
	Total	**MCM**	**1.01**	**1.33**	**0.21**	**0.39**	**0.20**	**0.63**	**0.29**	**0.17**
Annual Sediment Release Volume	Annual Dredging Volume	MCM	0.00	0.15	0.00	0.18	0.03	0.06	0.00	0.00
	Annual Flushing Volume	MCM	-	-	-	0.24	0.13	-	-	-
	Total	**MCM**	**0.00**	**0.15**	**0.00**	**0.42**	**0.16**	**0.06**	**0.00**	**0.00**

Source: JICA Project Team 2

An average erosion rate in the dam river basin is estimated dividing the annual sediment inflow volume by the dam catchment area. The estimated average erosion rate of each dam is presented in Table G 3.2.10.

Table G 3.2.10 Average Erosion Rate in Each Dam River Basin

Dam	Annual Sediment Inflow ($10^6 m^3$)	Catchment Area (km^2)	Average Erosion Rate (mm)
Senggurh	4.95	1659.0	2.98
Sutami	4.39	2050.0	2.14
Lahor	0.25	160.0	1.56
Wlingi	4.17	2890.0	1.44
Lodyo	3.71	3017.0	1.23
Selorejo	0.70	236.0	2.97
Wonorejo	0.52	126.3	4.12
Bening	0.21	89.5	2.34

Source: JICA Project Team 2

G3.3 Operation and Maintenance of River Facilities

G3.3.1 Operation and Maintenance Manuals

Operation and maintenance manuals for river facilities in the Brantas River Basin are prepared by PJT-1. The list of the manuals is presented as below.

Main contents of the Operation and Maintenance Manual are generally composed of following items:

1. General

location, construction, function, technical data

2. Operation and Maintenance

Operation of dam reservoir and hydro-mechanical works

Maintenance of civil structures and hydro-mechanical works

Table G 3.3.1 List of Operation and Maintenance Manual for River Facilities in Brantas River Basin

No	List of OM Manual	Published Year
1	Operation and Maintenance Manual for NEW GUNUNGSARI BARAGE	Mar. 2000
2	Operation and Maintenance Manual for JATIMLEREK RUBBER GATE	Aug. 1998
3	Operation and Maintenance Manual for MENTURUS RUBBER GATE	Jun. 1998
4	Operation and Maintenance Manual for SEDAYU LAWAS RUBBER GATE	Aug. 2012
5	Operation and Maintenance Manual for NEW LENGKONG BARRAGE	Sep. 2007
6	Operation and Maintenance Manual for MRICAN BARRAGE	Mar. 2010
7	Operation and Maintenance Manual for SEGAWE BARRAGE	Jan. 2006
8	Operation and Maintenance Manual for BENING DAM	Jan. 2007
9	Operation and Maintenance Manual for LAHOR DAM	Oct. 2007
10	Operation and Maintenance Manual for LODOYO DAM	Oct. 2002
11	Operation and Maintenance Manual for SELOREJO DAM	Sep. 2007
12	Operation and Maintenance Manual for SENGGURUH DAM	Sep. 2007
13	Operation and Maintenance Manual for SUTAMI DAM	Jul. 2007
14	Operation and Maintenance Manual for TIUDAN DAM	Mar. 2006
15	Operation and Maintenance Manual for WLINGI DAM	Jan. 2007
16	Operation and Maintenance Manual for WONOREJO DAM	Mar. 2006
17	Operation and Maintenance Manual for JAGIR GATE	Aug. 2009
18	Operation and Maintenance Manual for GUBENG GATE	
19	Operation and Maintenance Manual for BENDO GATE	Jun. 2009
20	Operation and Maintenance Manual for TULUNGAGUNG GATE and PUMP	Apr. 2010

No	List of OM Manual	Published Year
21	Operation and Maintenance Manual for MLIRIP GATE	Sep. 2007
22	Operation and Maintenance Manual for TEROWONGAN TULUNGAGUNG SELATAN GATE	Jun. 2014
23	Operation and Maintenance Manual for PORONG RIVER	Feb. 2006
24	Operation and Maintenance Manual for WONOKROMO	

Source: JICA Project Team 2

G3.3.2 Operation Data

Operation data of the river facilities are also recorded by PJT-1. The operation data for water level reservoir inflow, reservoir outflow and irrigation intake discharge of the dams and gates (basically daily data) from 2003 to 2012 are collected in the course of the Project.

G3.3.3 Data of Spillout from Dam (by water balance simulation)

Spillout discharge from the dam is one of the most important indices to evaluate degree of water resource development in the basin at present as well as potential of water resources in the future. However, no data of spillout discharge from each dam were provided during the Project.

Therefore, spillout data is referred to the result of the water balance simulation conduced in the Project. The simulated spillout discharge from the dam in case of 2050 future climate change conditions under middle scenario is presented in the following table.

Table G 3.3.2 Simulated Spillout Discharge from Each Dam in Case of 2050 Climate Change Conditions (Medium Scenario) unit: 1,000 m^3

Year	Sutami/Lahor	Wonorejo	Selorejo	Beninig
1992	256,652	0	45,075	26,095
1993	445,154	556	69,720	35,919
1994	37,246	0	11,105	2,824
1995	132,010	0	21,718	23,222
1996	225,789	0	39,519	41,997
1997	194,622	0	42,064	23,776
1998	569,621	204	104,947	41,509
1999	327,223	0	74,374	25,376
2000	520,990	521	74,506	59,685
2001	70,263	0	16,432	30,919
2002	399,765	0	46,313	30,842
2003	115,433	0	18,535	23,825
2004	85,583	0	15,098	18,354
2005	712,258	0	75,982	48,085
2006	249,639	0	33,737	33,068
2007	175,355	0	22,975	19,603
2008	143,414	0	17,927	23,776
2009	380,561	0	40,844	28,398
2010	33,512	0	7,847	14,728
Average	**267,110**	**67**	**40,985**	**29,053**
Min	**33,512**	**0**	**7,847**	**2,824**
Max	**712,258**	**556**	**104,947**	**59,685**

Source: JICA Project Team 2

CHAPTER G4 PROPOSED RIVER FACILITIES IN WATER RESOURCES MANAGEMENT PLAN (POLA, RENCANA) IN BRANTAS RIVER BASIN

G4.1 Water Resource Development Plan

In the course of the study, data and information related to proposed river facilities in the Brantas River basin have been collected and reviewed. The data sources are as below:

- POLA 2010
- RENCANA 2013 (draft)
- Review POLA 2015(draft)

G4.1.1 POLA 2010

In POLA 2010, there were 13 proposed dams for the water resources development plan in the Brantas River basin.

Table G 4.1.1 Proposed Dams in Brantas River Basin in POLA 2010

No	Dam Reservoir	Short term (2006-2010)	Medium term (2011-2020)	Long term (2021-2030)
1	Genteng I Reservoir	Study, pre-design, D/D	Implementation	
2	Tugu Reservoir	Study, pre-design, D/D	Implementation	
3	Beng Reservoir	Study, pre-design, D/D	Implementation	
4	Kedungwarak Reservoir	Study, pre-design, D/D	Implementation	
5	Ketandan Reservoir		Study, pre-design, D/D	Implementation
6	Semantok Reservoir		Study, pre-design, D/D	Implementation
7	Kuncir Reservoir	Study, pre-design, D/D	Implementation	
8	Babadan Reservoir		Study, pre-design, D/D	Implementation
9	Lesti III Reservoir	Design Details	Study, pre-design, D/D	
10	Kepanjen Reservoir		Study, pre-design, D/D	Implementation
11	Lumbang Sari Reservoir		Study, pre-design, D/D	Implementation
12	Kesamben Reservoir	Study, pre-design	D/D	Implementation
13	Konto II Reservoir		Study, pre-design, D/D	Implementation

Source：POLA(2010)

G4.1.2 RENCANA 2013 (draft)

In RENCANA 2013 (draft), there were 10 proposed dams presented in the figure of water resources development plan. Comparing with the POLA 2010, six (6) proposed dams (Bagong, Kampak, Nglemi, Sumber Agung, Kembangan, Kali Lanang) were newly added.

G4.1.3 REVIEW POLA 2015(draft)

The concept of water resources development until 2030 in Review POLA 2015 (Draft) has been revised from POLA 2010. The list of dam structures is changed, and the list of ponds, development plan of ponds and long storage structures are added to Review POLA 2015 (Draft).

In REVIEW POLA 2015 (draft), there were 23 proposed dams listed up with their location, storage capacity and function. Comparing with the RENCANA 2013 (draft), 10 proposed dams were newly added.

G4.1.4 List of Proposed Dams in Water Resource Development Plan

Consequently, there are 29 proposed dams in total in the Brantas River Basin based on the above plans. The list of the proposed dams is presented in Table G 4.1.2.

Table G 4.1.2 List of Proposed Dams in Past and Current Water Resources Plans

No.	Name	MP 1998	POLA 2010[*1]	RENCANA 2013[*2]	REVIEW POLA (2015)
1	Genteng I Dam	o	Scenario 1,2	L	o
2	Tugu Dam	o	Scenario 1-2	S	o
3	Beng Dam	o	Scenario 1,2,3	-	o
4	Kedungwarak Dam	o	Scenario 1,2,3	L	o
5	Ketandan Dam	o	Scenario 1	-	o
6	Semantok Dam	o	Scenario 1	S	o
7	Kuncir Dam	o	Scenario 1,2	-	o
8	Babadan Dam	o	Scenario 1	-	o
9	Lesti III Dam	o	Scenario 1,2,3	-	o
10	Kepanjen Dam	o	Scenario 1	-	o
11	Lumbang Sari Dam	o	Scenario 1	-	o
12	Kesamben Dam	o	Scenario 1,2,3	-	o
13	Konto II Dam	o	Scenario 1	-	o
14	Bagong Dam	-	-	S	-
15	Kampak Dam	-	-	M	-
16	Nglemi Dam	-	-	M	-
17	Sumber Agung Dam	-	-	M	-
18	Kembangan	-	-	M	-
19	Kali Lanang	-	-	L	-
20	Krangkates IV&V	-	-	-	o
21	Marmoyo Dam	-	-	-	o
22	Brangkal – Plandaan Dam	-	-	-	o
23	Kembar Dam Jenesgelaran – Jurangbang	-	-	-	o
24	Kopen Dam	-	-	-	o
25	Jarak Dam	-	-	-	o
26	Gembrong Dam	-	-	-	o
27	Jatijejer Dam	-	-	-	o
28	Jinggring Dam	-	-	-	o
29	Sabo Dinoyo Dam	-	-	-	o
	Number of Proposed Dams	13	13	10	23

*1 Scenario 1- Strong Economic Condition, Scenario 2- Normal Economic Condition, Scenario 3- Weak Economic Condition

*2 S: Short Term, M: Medium Term: L: Long Term

Source：JICA Project Team 2

G4.2 Proposed Dams

G4.2.1 Proposed Dams until 2030

In Review POLA 2015 (Draft), there are five (5) dams to be constructed in the Brantas River basin until 2030, which are:

By Year 2020: Tugu Dam, Lesti III Dam,

By Year 2025: Bagong Dam, Semantok Dam, and

By Year 2030: Beng Dam.

The locations of the above five (5) proposed dams are shown in Figure G 4.2.1. The present status of the five (5) dams is updated through an interview survey with BBWS Brantas as shown in Table G 4.2.1.

Table G 4.2.1 Status of Proposed Dams in Brantas River Basin

No.	Name of Dam	River /Location	Effective Storage Volume (Mil. m^3)	Purpose	Updated information based on interview with BBWS Brantas
2	Tugu	Keser River Kab. Trenggalek	7.8	FC, IR, WS	One of 3 priority dams in BBWS Brantas. The construction works is on-going and will be completed after 2017. Since there are geotechnical problems in the construction site, review on design of spillway is being undertaken. There are some land acquisition problems.
3	Beng	Beng River	147.0	IR, HP,WS	F/S of Beng Multipurpose Dam Work was conducted in 2003. Social issues are arisen at present.
6	Semantok	Semantok River Kab.Nganjuk	8.3	FC, IR, HP	One of 3 priority dams in BBWS Brantas. SID was conducted in May 2013. The design has been almost finished. The project continues the construction phase. Regarding the dam location, two alternatives of upstream and downstream sites are being discussed with Local Government.
9	Lesti III	Lesti River Kab. Malang	7.4	IR, HP, SC	D/D review and additional geological investigation were made in 2014. AMDAL(Environmental Impact Assessment) was finished. Budget allocation is being await. Land acquisition of the project is to be started soon.
14	Bagong	Bagong River Kab. Trenggalek	13.5	FC, IR	One of 3 priority dams in BBWS Brantas. SID was conducted in April 2014. Design certification was issued. Land acquisition as started in 2015. The construction works will be started in 2017/2018. There is budget problem. After "Balai Bendungan" conducted direct surveys of dams, they discovered a crack in the cliff backrest. Because of this, the budget plan 2017 is necessary for corrections. Additional studies of geology as well as additional investigations quarry location area will be required and is likely to require additional EIA study for quarry new area.

Note: WS: Urban water supply, IR: Irrigation, FC: Flood control, HP: Hydropower, SC: Sediment control

Source: JICA Project Team 2

G4.2.2 Status of Other Proposed Dams

The latest information for the proposed dams and river facilities are collected as presented in Table G 4.2.2 below:

Table G 4.2.2 Present Status of Proposed Dam in Brantas River Basin as of December 2016

No.	Name	Updated information based on the interview to BBWS as of December 2016
1	Genteng I Dam	The Study has not yet completed. The implementation is postponed after 2017 because of tight budget and government policy is given to irrigation.
2	Tugu Dam	See Table G4.2.1 above.
3	Beng Dam	See Table G4.2.1 above.
4	Kedungwarak Dam	Social issues are arisen and the project is almost canceled. Same as last time.
5	Ketandan Dam	Social issues are arisen and the project is almost canceled.
6	Semantok Dam	See Table G4.2.1 above.
7	Kuncir Dam	The study was finished in 2015. The construction of weirs was completed.
8	Babadan Dam	Only a small dam was constructed in 2007. Rehabilitation study of the dam is being undertaken.
9	Lesti III Dam	See Table G4.2.1 above.
10	Kepanjen Dam	no information
11	Lumbang Sari Dam	no information
12	Kesamben Dam	PJT-1/PLN have a plan to construct a weir for power supply.
13	Konto II Dam	Construction works of small consolidation dam was started in 2016. There are series of facilities for sediment control.
14	Bagong Dam	See Table G4.2.1 above.
15	Kampak Dam	F/S is being undertaken by local consultant. Final Report will be provided within 2016. People in Brenggolo Sub Village, Bogoran Village, Kampak District Sub District, Trenggalek Regency at June 2016 had demonstrations rejecting the establishment Kampak Dam. Approximately 106 households were affected, restless because until now the plan is not socialized in detail, regarding the area to be affected as well as the relocation process. Residents are asked to fill out questionnaires related to the development plan. The contents of the questionnaire also lead to land acquisition, whereas the study for the construction of the dam is still in the feasibility study stage. At SID, there are 3 alternative locations. BCR (Benefit Cost Ratio) was declared unfit because of an error calculation of the impact of flooding, so it is necessary to re-calculation. (BCR for flood control <1)
16	Nglemi Dam	F/S will be conducted in 2020's
17	Sbr Agung Dam	F/S will be conducted in 2020's
18	Kembangan	Plan for study in 2016 if fund is available. Design is prepared by local government (Trenggalek Regency), and design proposes a small dam (they called EMBUNG) for irrigation.
19	Kali Lanang	Plan for study in 2016 if fund is available
20	Krangkates IV&V	Plan for additional hydroelectric power generation.
21	Marmoyo Dam	Only a leaflet is available. The plan is for a small dam (H=6m, V=96,000m^3) for irrigation and domestic water.
22	Brangkal – Plandaan Dam	No information
23	Kembar Dam Jenesgelaran – Jurangbang	No information
24	Kopen Dam	No information
25	Jarak Dam	No information
26	Gembrong Dam	Study Investigation Design (SID) was already finish at 2010. The plan is for a small dam (H=14m, V=144,000m^3) for irrigation, domestic and industrial water supply.

No.	Name	Updated information based on the interview to BBWS as of December 2016
27	Jatijejer Dam	No information
28	Jinggring Dam	Study Investigation Design (SID) was already finish at 2016. Initially it was planned to build a large dam but canceled. The present plan is for a small dam (H=15m, V=71,000m^3) for irrigation water supply. In the SID, the design covers another dam site of Janging Dam adjacent to the Jinggring Dam. The present plan of Janging Dam is also for a small dam (H=15m, V=31,000m^3) for irrigation water supply.
29	Sabo Dinoyo Dam	No information

Source: JICA Project Team 2

Site inspection for major proposed dams, i.e. Lesti III, Genteng I, Kont II, Tugu, Babadan and Semantok Dams was carried out in September, 2016. The main finding is shown in Table G 4.2.3.

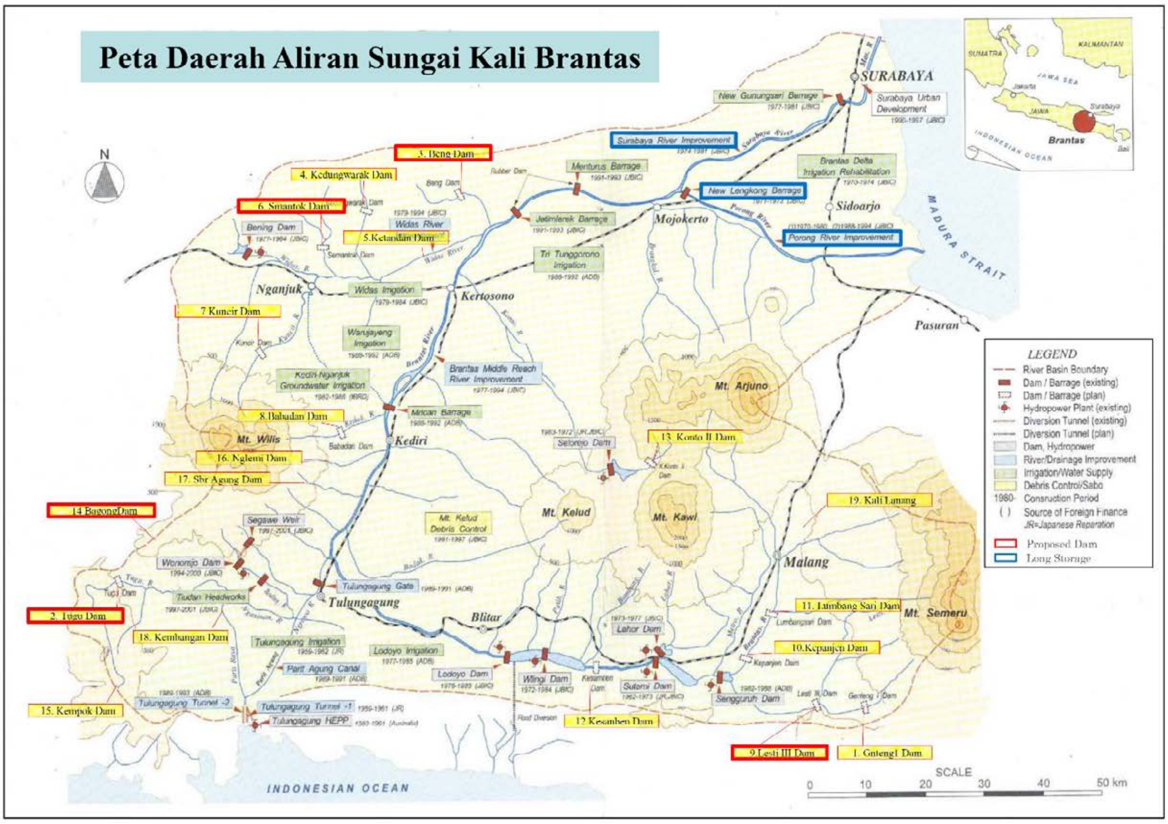
Table G 4.2.3 Result of Site Inspections for Major Proposed Dams

No.	Name	Main Findings of Site Inspection*1
1	Genteng I Dam	・ F/S was already done in 2002. The proposed dam is a large dam with 82 m in height. It is necessary to construct saddle dams, a large area of land acquisition, resettlements and replacement of primary roads. ・ At the time of the inspection, the number of affected houses is increased due to development of proposed reservoir area because it has passed 14 years since the completion of F/S.
2	Tugu Dam	・ The construction works is on-going, as of Sept 3, 2016 progress construction ± 53.8 %. ・ At the time of the inspection, excavation works of dam is almost finished, and the foundation works has been started. Geotechnical problems are arisen because the dam site is located in the land sliding areas. Many large cracks are found on the shotcrete covering the slopes of abutment at both left and right sides. BBWS-BS is currently undertaking the study for countermeasures.
6	Semantok Dam	・ There are two(2) alternative dam sites. BBWS had proposed the alternative 2 (more upstream than alternative 1), but it was rejected by the local government. At present, the local government proposes the construction of the alternative-1. ・ At the time of the inspection for the alternative-1, it was confirmed necessity for land acquisition and resettlement of around 200 houses. The dam type is a kind of structure having functions of dike embankment and retarding basin. As per information of the chief of village, local residents do not object for the project implementation.
8	Babadan Dam	・ The plan of the dam was prepared in MP1985. It was planned as trans basin scheme. At present, BBWS has no information for the dam. ・ At the time of the inspection, it was confirmed that land use is mainly for agriculture and few people living in the proposed site. Because the site is hilly area, the dam type will be similar as the Benin Dam.
9	Lesti III Dam	・ D/D was completed in 2014. The dam is designed as a gated dam with a height of around 30 m considering mitigation of social impacts. ・ The dam site seemed to be a good for construction from the viewpoints of access and topography. Since sediment yield from the basin is large, sediment management system shall be necessary.
13	Konto II Dam	・ The plan of the dam was prepared in MP1985.MP. ・ At present, construction of small dams is proposed in the upstream of Selorejo Dam to control sediment inflow.

*1: Number is referred to Table 3.2.3.

*2 Site Visit Sep. 8-10, 2011

Source：JICA Project Team 2



Source: JICA Project Team 2

Figure G 4.2.1 Location Map of Proposed Dams and Long Storage Structures in Brantas River Basin

G4.3 Proposed Ponds

Information about the planned locations of new ponds are unavailable in Review POLA 2015 (Draft). However, the local governments of regencies have carried out new pond constructions. Even though the number of new pond constructions is planned to be two (2)/year per regency, the actual number of new ponds has been decided based on the annual budget by the local governments. Table G4.3.1 shows the list of ponds.

Table G 4.3.1 List of Existing and Planned Storage Structures until 2030

No.	Name	Status	Storage Volume (mil. m^3)
1	Bening/ Widas	Existing	0.5
2	Margumulyo	Existing	0.5
3	Ngrobyong	Existing	0.5
4	Sentul	Existing	0.5
5	Sideorejo	Existing	0.5
6	Gondang	Existing	0.5
7	Grogol	Existing	0.5
8	Grojogan	Existing	0.5
9	Karangjati	Existing	0.5
10	Kepuhrejo (Sumber kepuh)	Existing	0.5
11	Kradean/ Mandenan	Existing	0.5
12	Mangunan	Existing	0.5
13	Pelabuhan	Existing	0.5
14	Sempal	Existing	0.5

15	Grogol	Existing	0.5
16	Joho (Kecamatan Semen)	Existing	0.5
17	Joho (Kecamatan Tarokan)	Existing	0.5
18	Lamong	Existing	0.5
19	Sumber Songo	Existing	0.5
20	Siman (Reservoir)	Existing	0.5
21	Pakel	Existing	0.5
22	Babadan	Existing	0.5
23	Bureng	Existing	0.5
24	Gedangan Kulon	Existing	0.5
25	Kutukan	Existing	0.5
26	Kidal Bang	Existing	0.5
27	Lowokjati	Existing	0.5
28	Malangsuko	Existing	0.5
29	Pringgo	Existing	0.5
30	Segaran	Existing	0.5
31	Sukondo	Existing	0.5
32	Sumber Jambe	Existing	0.5
33	Sukun	Existing	0.5
34	Song-song	Existing	0.5
35	Watudakon	Existing	0.5
36	Bayu Blandong	Existing	0.5
37	Majorejo	Existing	0.5
38	Majodadi	Existing	0.5
39	Mojowarno	Existing	0.5
40	Segaran	Existing	0.5
41	Kedung Sengon	Existing	0.5
42	Kulal Secang	Existing	0.5
43	Logawe	Existing	0.5
44	Manggarejo	Existing	0.5
45	Nghuyu/ Tempuran	Existing	0.5
46	Ngomben	Existing	0.5
47	Oro-oro Ombo	Existing	0.5
48	Peming	Existing	0.5
49	Poh Salak	Existing	0.5
50	Sawahan	Existing	0.5
51	Sumber Agung	Existing	0.5
52	Sumber Kepuh	Existing	0.5
53	Sumber Soko	Existing	0.5
54	Sumber Sono	Existing	0.5
55	Mbji Maron	Existing	0.5
56	Ngemplak	Existing	0.5
57	Ngepeh	Existing	0.5
58	Nglentreng	Existing	0.5
59	Panggul	Existing	0.5
60	Prmbon	Existing	0.5
61	Pule	Existing	0.5
62	Suruh	Existing	0.5
63	Tegaren	Existing	0.5
64	Wakelan	Existing	0.5
65	Watulimo	Existing	0.5
66	Winong/ winong sawahan	Existing	0.5
67	Blendis	Existing	0.5
68	Branjang	Existing	0.5
69	Cerobong/ Uvala Demuk	Existing	0.5
70	Cerobong/ Uvala Desa Banyuurip	Existing	0.5
71	Cerbong/ Uvala Pannggungwuri	Existing	0.5
72	Cerobong/ Uvala Tenggarejo I	Existing	0.5

73	Cerobong/ Uvala Tenggarejo II	Existing	0.5
74	Kates	Existing	0.5
75	Perung Kidul	Existing	0.5
76	Punjul	Existing	0.5
77	Winong/ Uvala Desa Winong	Existing	0.5

Source: Review POLA 2015 (Draft)

G4.4 Proposed Long Storage Structures

In Review POLA 2015 (Draft), there are three (3) long storage structures to be constructed in the Brantas River basin until 2020. The locations of these long storages are shown in Figure G 4.2.1.

However, a study report is available only for a Kali Mati long storage structure. The remaining two (2) structures have not been studied yet. The storage volumes of the two (2) long storages are roughly estimated in this Project.

The storage volumes of proposed long storage structures are assessed in Table G 4.4.1.

Table G 4.4.1 Assessment Results of Storage Volumes of Long storage Structures Proposed in Review POLA 2015 (Draft)

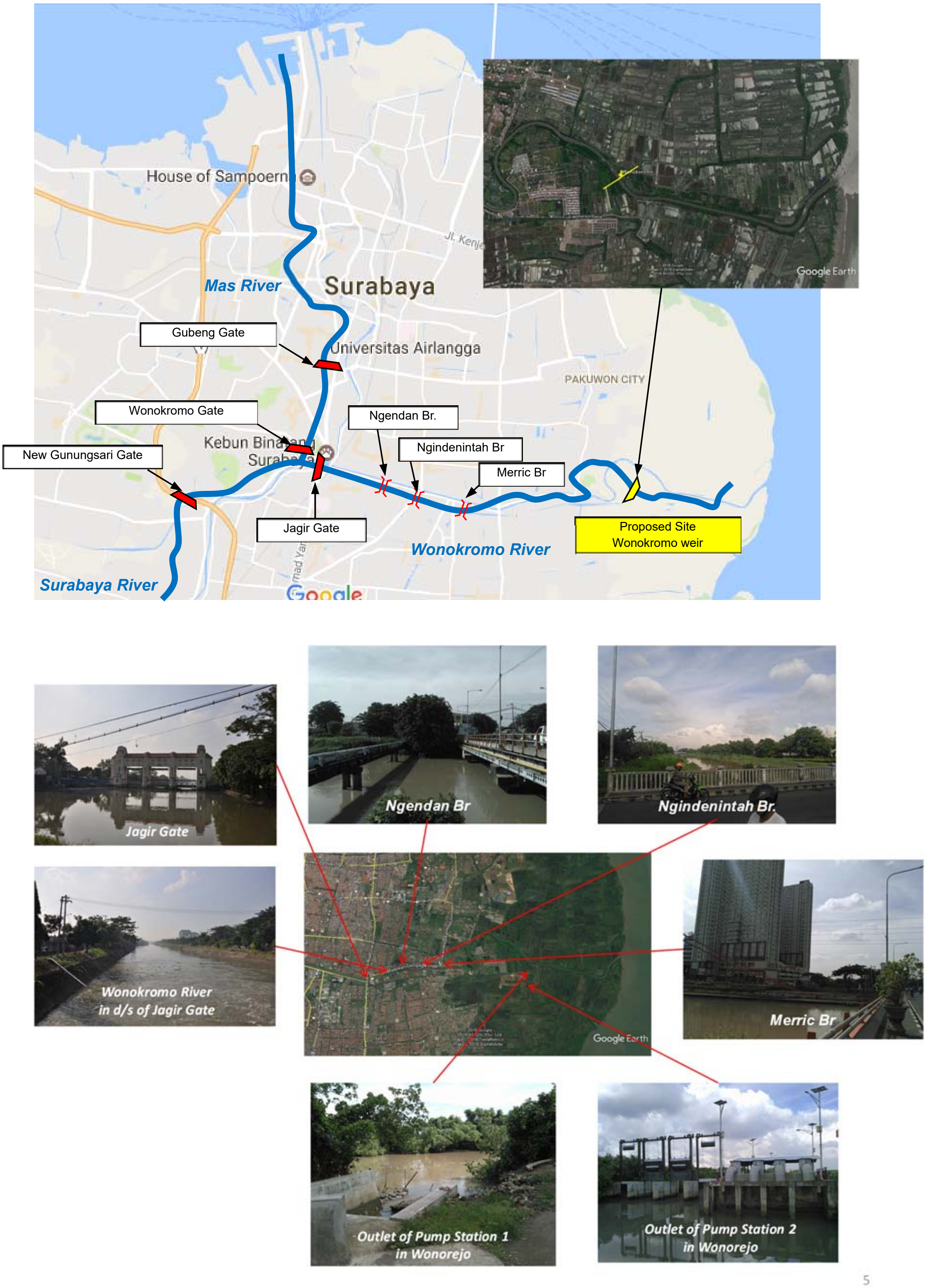
No.	Name of Long Storage	Possible Storage Volume	NWL	LWL	Design Bed Level	Design Dike Level
		(m^3)	(El.m)	(El.m)	(El.m)	(El.m)
1	Wonokuromo	309,000	3.10	2.60	-	4.10
2	Porong	2,410,000	7.40	3.10	2.10	8.90
3	Kali Mati					
3-1	Long storage1	553,300			10.20	15.94
3-2	Long storage2	597,200			9.70	15.15
3-3	Long storage3	504,300				13.14
	Total of Kali Mati	1,654,800				

Note: *1 refer to 3.2.3 (3) 1) Wonokuromo Long Storage

Source: For data of Kali Mati long storage, BBWS Brantas. For Porong and Wonokromo long storages, JICA Project Team 2

(1) Wonokuromo Long Storage

BBWS Brantas considers constructing the Wonokuromo long storage at about 10.6 km downstream from Jagir Gate. Location of the Wonokuromo long storage is shown in Figure G 4.4.1. The concept of the Wonokuromo long storage creates a fresh water reservoir along the Wonokuromo River by construction of a barrage with new gate that will work as a tidal barrage.



Source: JICA Project Team 2

Figure G 4.4.1 Location and Present Site Conditions of Wonokuromo Long Storage

Design water levels shall be considered from the function of the Wonokuromo barrage. One is a full supply water level that is decided from the topographical condition and river condition. The other is a low water level that is decided from the tidal water level. Tidal water level at Surabaya Harbor from 2006 to 2015 provided from STASIUN METEOROLOGI MARITIM is shown in Table G 4.4.2. The tide data is based on hourly data with accuracy of 10 cm.

Table G 4.4.2 Tidal Water Level at Surabaya Harbor from 2006 to 2015

Unit: cm (SVHP)

Data		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	For 10 years
Tidal Water Level	Maximum	150	150	160	150	150	160	150	150	150	110	160
	Minimum	-170	-170	-170	-170	-160	-170	-170	-180	-160	-170	-180

Note: Vertical reference of elevation is Surabaya Harbor Vertical Plate (SVHP).
Source: STASIUN METEOROLOGI MARITIM

The design high tide level (HTL) is applied at EL.1.6 m (SVHP) as the maximum tidal water level for the past 10 years.

Setting of low water level (LWL) is decided from i) sea water level rising, ii) difference of specific density between sea water and river water to protect from sea water intrusion into the long storage and iii) allowance. Target of sea water rising is set at 2100 year from life of the barrage structure. Sea water rising is assumed at 5mm/year from the recent climate change studies. Height of sea water rising is as follows;

HR = 5mm/year x (2100-2010) +(allowance) =0.45m +(allowance,0.05m)=0.5m

The water head difference due to difference of specific density between sea water and river water (dS) is designed at 0.50m as below:

$$\begin{aligned} dS &= (\rho s-\rho w)/\ \rho w \times H+ \alpha \\ &= (1.035-1.000)/1.000 \times 5.6+ \alpha \\ &= 0.496\text{m} \fallingdotseq 0.50\text{m} \end{aligned}$$

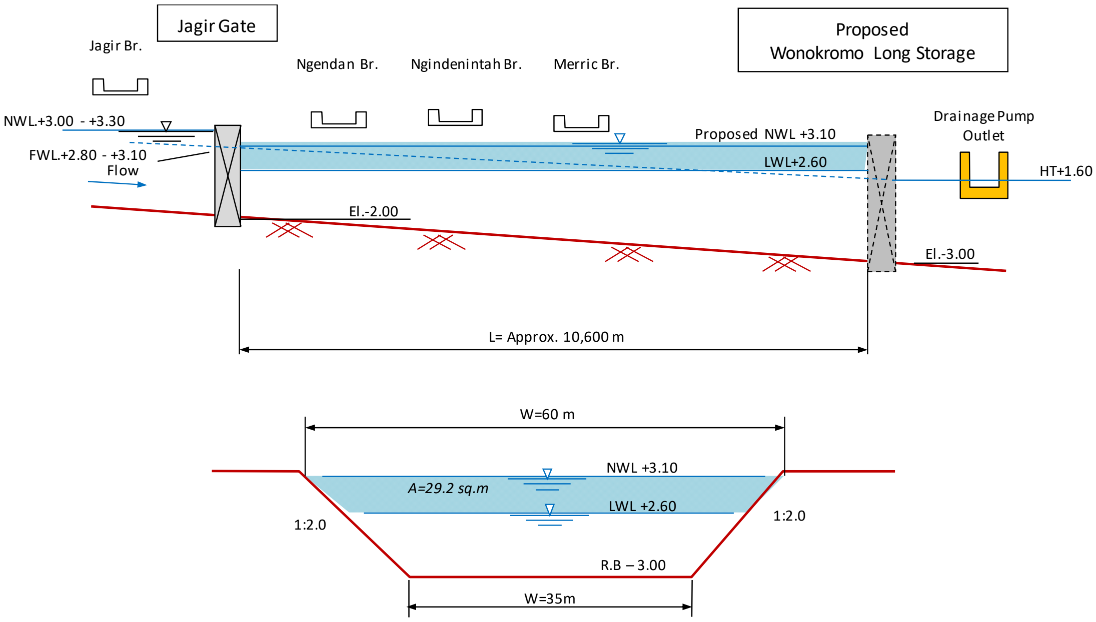
where;

ρs: specific density of sea water (1.035g/cm^3),
ρw : specific density of water (1.000g/cm^3) ,
H: design water depth between design bed level and HT plus sea level rising(5.6m),
α: allowance for tide level fluctuations (0.30m)

Low water level (LWL) is set from following formula;

LWL = HTL + HR + dS =EL.1.6m + 0.5m + 0.5m =EL.2.6m (SHVP)

There are no river cross sections at upstream of the Wonokuromo long storage. The storage volume is estimated from Google Earth and site inspection result. The storage volume of the Wonokuromo long storage is 309,000 m3. Even though the estimated volume is smaller than one of Review POLA 2015 (Draft) (2 million m^3), the estimated one is applied in the Project but the economic viability of the Wonokuromo long storage is not studied in the Project.



FWL: Full supply Water Level, NWL: Normal Water Level, LWL: Low Water Level
Source: JICA Project Team 2

Figure G 4.4.2 Estimation of Storage Volume of Wonokuromo Long Storage

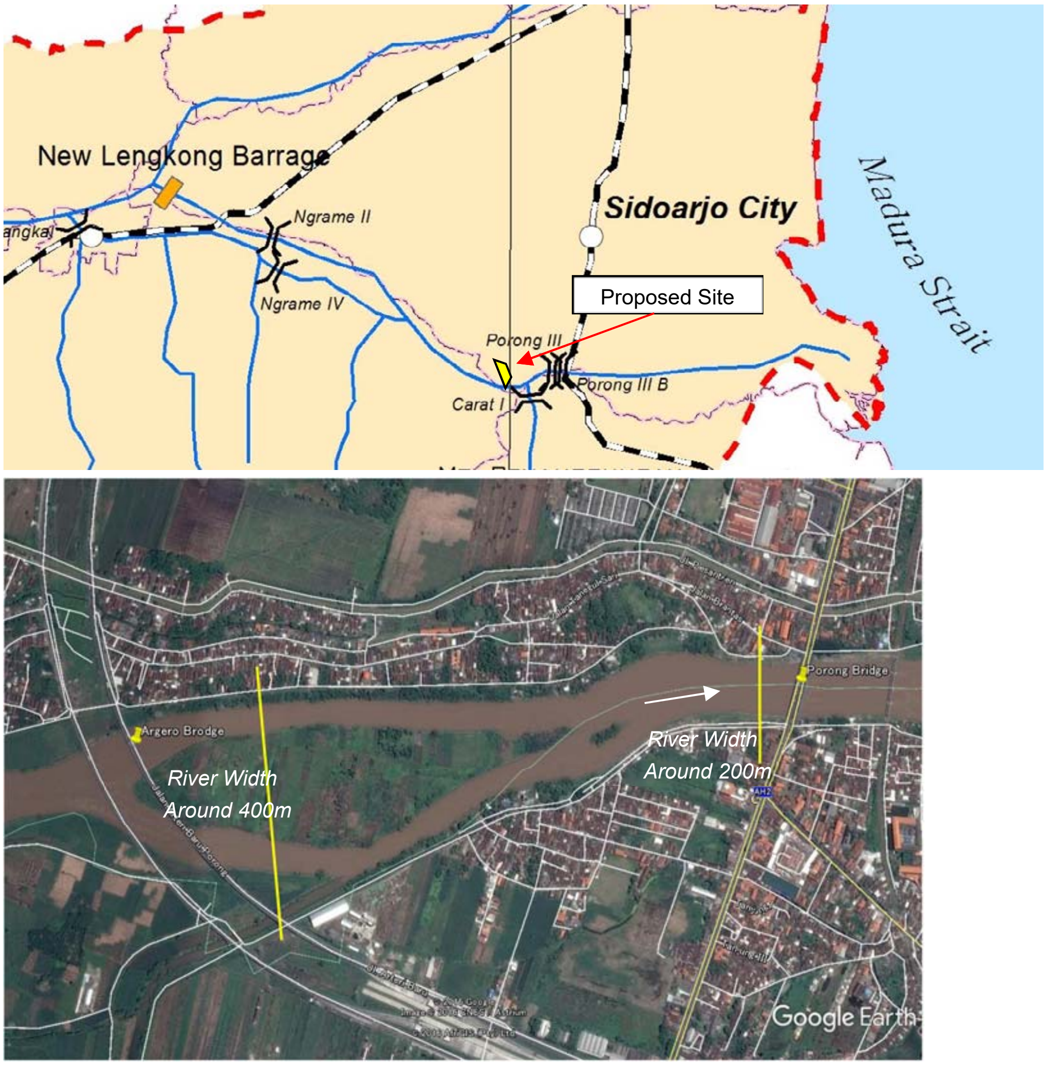
At the time of study and design of the Wonokuromo long storage, following points shall be noted:

- There are three (3) existing bridges in the storage area of the proposed long storage. A required clearance above back water level of the barrage shall be secured.
- Survey for the existing bank level and river cross section is necessary to determine the design bank level so as not to overflow by back water of the barrage.
- Study for impact to the existing pumping station (owned by DINAS PU) located nearby the proposed barrage.
- Assessment of necessity of resettlement of informal settlers along the left bank upstream of the barrage.
- Study for sea water intrusion

(2) Kali Porong Long Storage

Two alternative sites are planned as shown in Figure G 4.4.3.

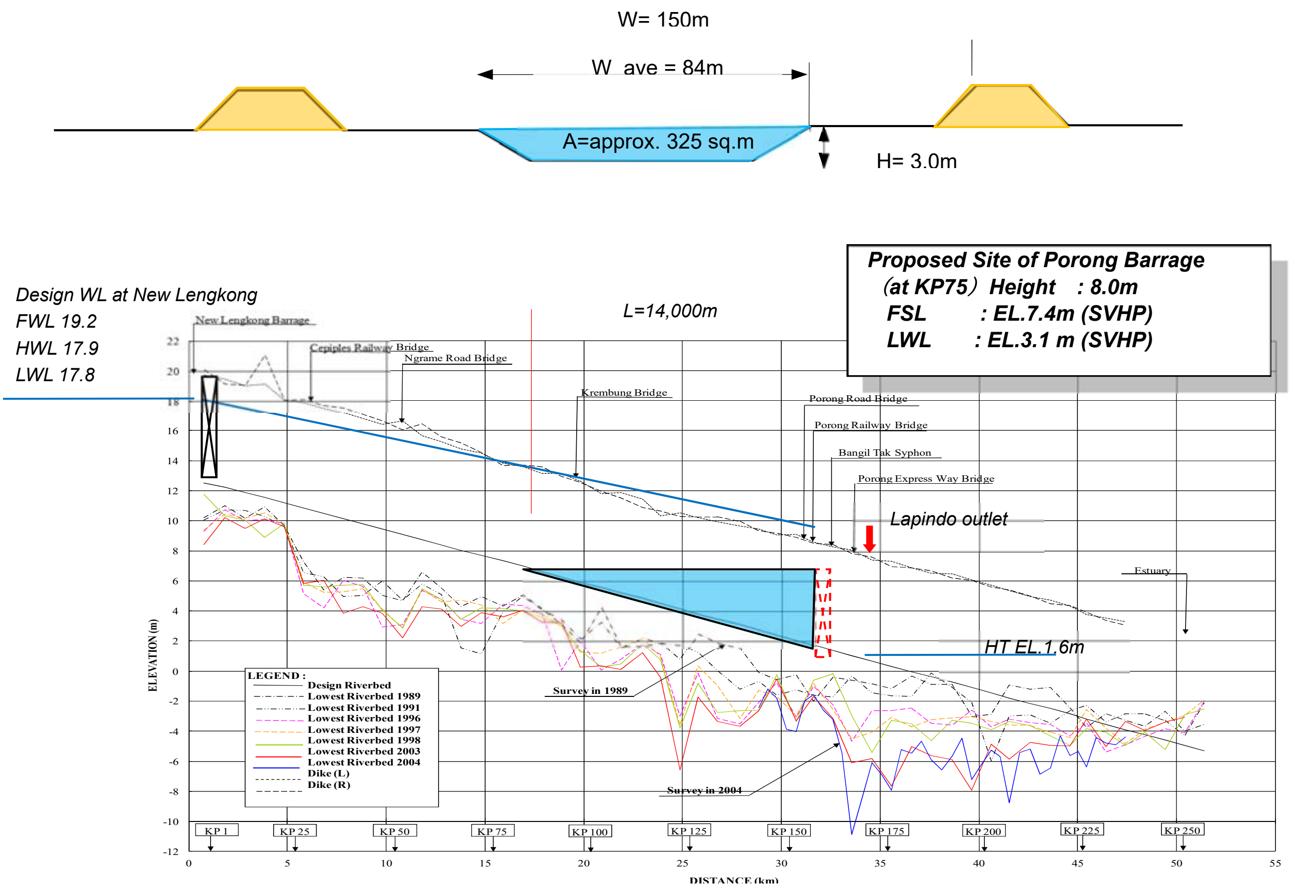
Related document of Kali Porong long storage is available only location map of two alternatives of the weir site in the upstream of the Porong Bridge. In the upstream site, river width is as 400 m because the river flow is split due to existence of a large sand bar in the middle of the channel. In the downstream site, the split flow is joined again and river width becomes narrow as 200 m. In the Project, downstream site is tentatively selected considering the advantage of shorter barrage length. It is also noted that downstream of the Porong Bridge is not appropriate for the new weir site because it would be affected by the existing outlet of the Lapindo mudflow. When BBWS Brantas studies and designs a barrage, barrage location shall be selected from topographical, geological, economical, environmental and social points of view.



Source: JICA Project Team 2

Figure G 4.4.3 Location of Alternative Site of Kali Porong Long Storage

Storage volume is decided from relation of water level and topographical condition. Figure G 4.4.4 shows the river longitudinal profile at the proposed Kali Porong Long Storage. The barrage site is affected from saline water since the existing river bed level is lower than the tide level. Therefore, LWL shall be set above the high tidal water level of 1.6m. In addition, taking into account the future sediment depositions in the river channel after construction of the barrage, LWL is set at the design riverbed level plus 1.0 m. FSL is decided from upstream topographical condition and existing bank level. LWL and FSL is set at EL. 3.1 m (SVHP) and EL. 7.4 m (SVHP), respectively. The storage length is 14.0 km upstream from the weir site and average cross section area is 325 m^2 as shown in Figure G 4.4.4 referring to the existing cross section survey data in 2004. The storage volume of the Porong long storage is estimated at 2,410,000 m^3.



Source: JICA Project Team 2

Figure G 4.4.4 Estimation of Storage Volume of Kali Porong Long Storage

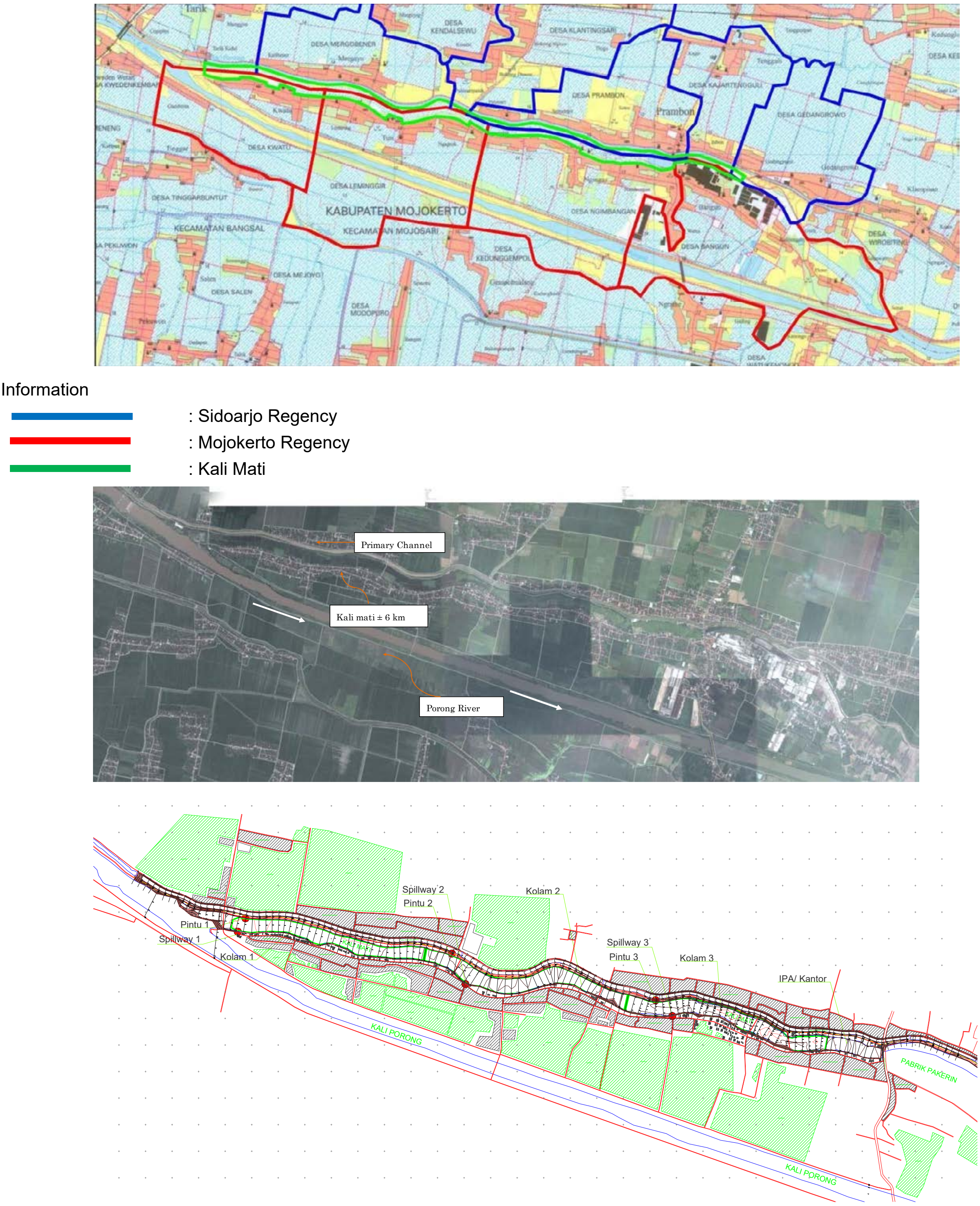
At the time of study and design of the Porong long storage, following points shall be noted:

- The weir site shall be selected based on the detailed study for topographical, geological, economical, environmental and social points of view.
- The Porong River is already improved as a compound river section with high water channel and dike embankment. Hydraulic impacts of back water by the construction of the Porong long storage shall be carefully studied considering the elevations of existing highwater channel bed and dike level.
- At present, there are some sections where the dike elevation is lower than the design high water level of 50-year flood. If existing dike can be heightened, the proposed weir height of the long storage is raised to increase its storage capacity.

(3) Kali Mati Long Storage

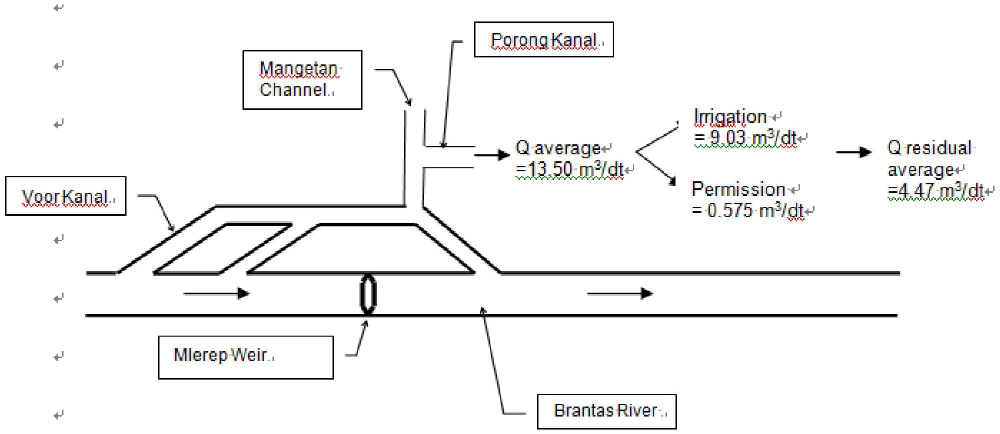
In 2013, SID Long storage Kali Mati for Raw Water was conducted. The construction of the long storage is aiming at supplying fresh water to Sidoarjo Regency. The location of the Kali Mati Long Storage is presented in Figure G 4.4.5 below: The weir site is located in Desa Margobener/Klantingsasari/Prambon/Kajar tengguli/Gedangrowo in Sidoarjo and Desa Kwatu/ Leminggil/Ngimbangan/Bangun in Mojokerto.

Water use allocation scheme is presented in the figure below. Average water use for the long storage is planned at 4.47 m^3/s ranging from 1.79 m^3/s to 7.03 m^3/s.



Source: BBWS Brantas

Figure G 4.4.5 Location of Construction Site of Kali Mati Long Storage



Source: BBWS Brantas

Figure G 4.4.6 Water Use Allocation Scheme of Kali Mati Long Storage

The Kali Mati long storage is 5 km long in total. The storage area is divided into three (3) sections as presented in Table G 4.4.3 below. Bed elevation of each storage is designed at least 1 m above the riverbed level of the Porong River and lower than the bed level of the Porong canal. The width of each storage varies based on the site conditions. The average width is approx.100m.

Table G 4.4.3 Basic Dimension of Kali Mati Long Storage

Section	Long Storage 1:	Long Storage 2	Long Storage 3
Length	1,550m	1,650m	1,550m
Design bed level	+10.20m	+9.70m	+9.20m
Design water level	+14.74m	+13.95m	+13.14m
Design dike level	+15.94m	+15.15m	+14.34m
H ave	4.14 m	3.60m	2.95 m
Area	133,500 m^2	166,000 m^2	170,900 m^2
Storage volume	553,300 m^3	597,200 m^3	504,300 m^3

- Intake gate and spillway

Section	Long storage 1:	Long storage 2	Long storage 3
Intake	3 nos. 1.35 mW x 2.6mH	3 nos. 1.35 mW x 2.6mH	3 nos. 1.35 mW x 1.0mH
Spillway			
Design discharge	2.5 m^3/s	5.0 m^3/s	7.5 m^3/s
Crest width	3.0 m	3.0 m	7.0 m
Crest elevation	+14.74 m	+13.95 m	+13.14 m
FWL	+15.26 m	+14.474m	+m

Source: BBWS Brantas

At the time of study and design of the Kali Mati long storage, following points shall be noted:

- The Kali Mati long storage will be constructed by excavation of the old river channel. The perimeter dike of the long storage is necessary to be constructed.
- The upstream land of the proposed long storage is used as paddy field at present. If water level of the long storage is high, return flow from the paddy would not be drained properly. Drainage system and layout of drainage facilities from the paddy and the long storages shall be studied and designed.
- In the long storage, sediment will be deposited as same as in a dam reservoir. Study for volume of sedimentation and removal of sedimentation shall be necessary.

CHAPTER G5 ASSESSMENT OF CLIMATE CHANGE INPACTS ON FUTURE STORAGE RESERVOIR VOLUME IN 2050

G5.1 Estimation of Future Storage Reservoir Volume

As for the dam reservoirs, decrease in the effective storage capacities due to sedimentation is one of the big issues in the Brantas River basin. It is anticipated that sediment yield will further increase due to more intensive rainfall by climate change. The sediment yield mechanism is studied based on available data such as sedimentation records, land use, rainfall records, etc., and future sediment yields in the target year 2050 under climate change is estimated.

G5.1.1 Estimation of Future Sediment Inflow into Reservoirs

Increase of future sediment yield due to more intensive rainfall by climate change is estimated by following three (3) methodologies.

(a) USLE (United Soil Loss Equation)

(b) Equation of Suspended Load

(c) Assessment of erodible rainfall amount

(1) USLE (United Soil Loss Equation)

As mentioned in Section G3.2, the specific discharge of sediment and the surface erosion ratio are 2,752 (m^3/km^2/year) and 2.75 (mm/year) respectively in the present climate.

The change of the sediment discharge in the future climate is studied by the following formula (USLE: Universal Soil Loss Equation) which is applied about soil erosion.

USLE is shown as follows;

$$A = R \cdot K \cdot LS \cdot P \cdot C \text{ (t/ha/year)}$$

where,

A：amount of average annual soil loss
R：rainfall and runoff factor
K：soil erodibility factor
LS：slope length-gradient factor
P：support practice factor
C：crop/vegetation and management factor

R is represented as follows;

$$R = (E \times I_{60}) / 100$$

E is defined to be the amount of the rainfall energy of a series of rainfall.

$$E = (210 + 89 \mathrm{Log} I) \times r$$

where,

I：maximum hourly rainfall in a series of rainfall (cm/hour)
r：total amount of a continuous rainfall (cm)

Also, a continuous rainfall is defined as the rainfall with its duration more than 6 hours.

On the other hand, the maximum hourly rainfall in a series of rainfall (I) in the Brantas basin is calculated as follow;

- Upper Brantas : 38.1% of the daily rainfall
- South Mt.Kelud : 47.2% of the daily rainfall
- North West Brantas : 49.8% of the daily rainfall
- North Brantas : 52.0% of the daily rainfall

Where, I (the maximum hourly rainfall in a series of rainfall) was set 50% of a daily rainfall to avoid complexity of calculation and to take a general trend. Table G 5.1.1 shows R (rainfall and runoff factor) ratio between 2050 and 2000 for the whole Brantas Basin (136 model basins) and the target basins (6 dams). The ratio in the Brantas Basin is expected an average increase of 21%. On the other hand, that of the target dam basins is expected an average increase of 15% (Table G 5.1.1).

Table G 5.1.1 Rainfall and Runoff Ratio

Scenario	Whole Basin	Average of 6 Dams*	adopted
Low (2050/2000)	1.19	1.09	1.10
Medium (2050/2000)	1.12	1.12	1.15
High (2050/2000)	1.33	1.24	1.25
Average	1.21	1.15	
*: Senggurh, Karangkates, Wlingi, Lodoyo, Selorejo, Wonorejo			

Source: JICA Project Team 2

(2) Equation of Suspended Load

At first, annual average discharge of the present and the future climate conditions both for whole basin and the target dam basin is estimated based on the hydrological analysis result as shown in Table G 5.1.2.

Table G 5.1.2 Annual Average Discharge of the Present and the Future Climate

Scenario		-	Annual Average Discharge(m^3/s)	
			Whole Basin	6 Dams Basin
Present [1)]		a	61.43	28.47
Future [2)]	Low	b	61.88	27.18
	Medium	c	51.50	24.39
	High	d	53.69	23.98
Ratio (Future/Present)	Low	b/a	1.01	0.95
	Medium	c/a	0.84	0.86
	High	d/a	0.87	0.84

1): 1991.1.1- 2010.12.31 2): 2046.1.1- 2065.12.31

Source: JICA Project Team 2

Next, the sediment yield of suspended load is studied as follows.

The sediment yield of suspended load is shown by the following formula.

$Qs = k \times Q^n$

Where,

Qs : Suspended sediment (ton/ hour)

Q : Discharge (m^3/s)

k, n: constant

In the Wlingi Dam Basin, the sediment discharge of suspended load was surveyed before. According to the result, the regression equation is as shown in Table G5.1.3.

Table G 5.1.3 Regression Equation

River Name	Regression equation	k	n
Lekso	$Qs = k \times Q^n$	0.06	2.60
Ganggangan		22	2.53
Jari		2	2.59
Putih		15	2.82

Source: Recommendation Report on Countermeasures Against Sediment Inflow to Wlingi Reservoir (1990)

A ratio of the present climate to the future climate in the Brantas basin was calculated by the following formula.

$r = \sum Qsf / \sum Qsp = \sum k \times Q^n f / \sum k \times Q^n p = \sum Q^n f / \sum Q^n p$

where,

the subscript “f” and “p” are as follows;

f : future climate

p : present climate

In the calculation, constant “k” and “n” are respectively assumed as k=1, n= 2.50 to take a rough trend.

The result of calculation for annual average sediment yield is shown in Table G 5.1.4.

While Low and Upper scenario show an increasing trend, Medium scenario shows a decreasing trend. An increasing rate which is shown in Table G5.1.2 is thought to be excessive.

Table G 5.1.4 Annual Average Sediment Yield of the Present Climate to the Future Climate

	Case		Annual Sediment Yield	
			Whole Basin (billion ton/yr.)	Dam Basin (million ton/yr)
Present*1	Average	a	2.5	412.0
Future*2	High	b	4.5	566.3
	Medium	c	2.6	378.3
	Low	d	5.3	715.5
Ration(Future/Present)		b/a	1.76	1.37
		c/a	1.01	0.92
		d/a	2.06	1.74

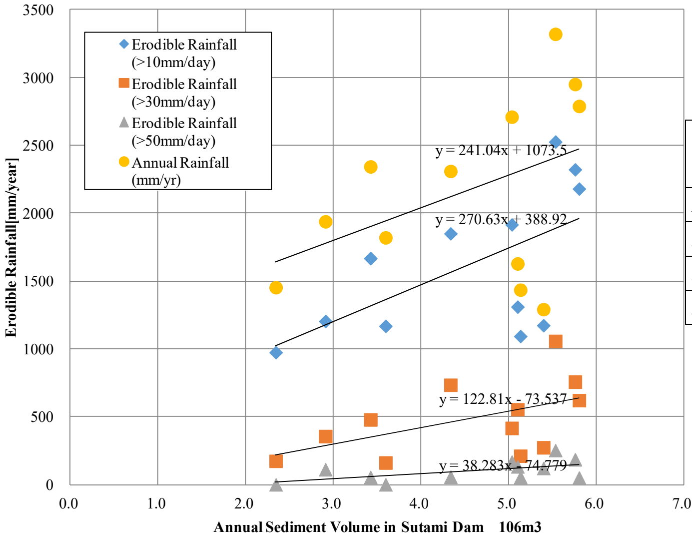
1): 1991.1.1- 2010.12.31 2): 2046.1.1- 2065.12.31

Source: JICA Project Team 2

(3) Assessment of erodible rainfall amount

It is known that sediment yield (surface soil erosion) is increased with increase of rainfall amount in the basin. In addition, in case the rainfall amount is increased beyond a critical value, the progress of sediment yield is accelerated. The critical value is called erodible rainfall (Re).

In order to examine the tendency of erodible rainfall in the Brantas River basin, five cases of Re=0, 10, 30, 50 and 100 mm/day are assumed, and the relation between the annual reservoir sediment inflow and annual rainfall amount beyond each erodible rainfall is assessed adopting existing reservoir sedimentation data and rainfall data in the Sutami Dam reservoir basin. The results are shown in Figure G 5.1.1.



Cases	Correlation with Annaul Sediment Inflow
Annual Rainfall (Re>0mm/day)	0.42
Annual Rainfall (Re>10mm/day)	0.60
Annual Rainfall (Re>30mm/day)	0.53
Annual Rainfall (Re>50mm/day)	0.59

Source: JICA Project Team 2

Figure G 5.1.1 Relation between Annual Sediment Inflow and Erodible Rainfall in Sutami Dam

As shown in the result, correlation is not so high for all cases but the case of Re=10mm/day shows the highest correlation with the reservoir sediment inflow among the above cases.

Adopting this case, the annual rainfall beyong the erodible rainfall of 10mm/day are estimated for present conditions (average from 1991 to 2010) and future climate change condition of each scenario. The results of Sutami, Selorejo, Wonorejo and Bening Dam basins and whole Brantas River basin are shown in Table G 5.1.5 below:

Table G 5.1.5 Relation between Annual Sediment Inflow and Erodible Rainfall in Sutami Dam

Item		Present	Future Climate Change Senario (2050)		
		1991-2010	Lower	Middle	Upper
Sutami	(mm/year)	1984	1788	1895	1870
	Ratio	-	0.90	0.96	0.94
Selorejo	(mm/year)	2236	2289	2208	2187
	Ratio	-	1.02	0.99	0.98
Wonorejo	(mm/year)	1777	1462	1561	1626
	Ratio	-	0.82	0.88	0.91
Bening	(mm/year)	2074	1963	1861	2210
	Ratio	-	0.95	0.90	1.07
Whole Basin	(mm/year)	1703	1735	1642	1792
	Ratio	-	1.02	0.96	1.05

Source: JICA Project Team 2

Comparison of three methods is presented in Table G 5.1.6 below:

Table G 5.1.6 Result of Estimation of Increase Rate in Future Sediment Yield

Method	Increase rate of Future sediment yield to the present condition (α)		
	Future Climate Change Scenario (2050)		
	Low	Medium	High
(a) USLE	1.10	1.15	1.25
(a) Suspended Load*	1.74	0.92	1.37
(b) Erodible Rainfall (R>10mm/day)	1.02	0.96	1.05
Adopted	1.10	1.15	1.25

Note: *Recommendation Report on Countermeasures against Sediment Inflow to Wlingi Reservoir, 1990

Source: JICA Project Team 2

As a conclusion in this study, increase rate of the future annual sediment inflow derived from the assessment result by the USLE in the dam basins is adopted taking into the conservative value for the study of future water use in the basin. The estimation adopting the suspended load relation is considered as reference because the value was estimated based on the tributaries of the Wlingi River basin only and a smaller number of plotting od sediment rating curve.

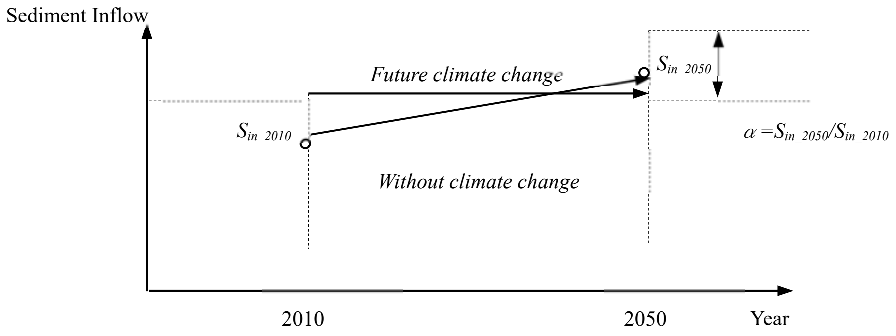
G5.1.2 Estimation of Future Storage Reservoir Volume

The simulation case for estimation of the future dam reservoir sedimentation in each climate change scenario is summarized in Table G 5.1.7.

Table G 5.1.7 Simulation Case for Estimation of Future Dam Reservoir Sedimentation

Item	Present Climate	Future Climate Change Scenario (2050)		
		Lower	Medium	Upper
Annual Dam Inflow	Past average	Result of WEB-DHM run-off analysis		
Annual Dam Sediment Inflow	Past average	Increase by 1.10 time of present sediment inflow(α=1.10)	Increase by 1.15 time of present sediment inflow(α=1.15)	Increase by 1.25 time of present sediment inflow(α=125)

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure G 5.1.2 Estimation of Future Dam Reservoir Sediment Inflow

Adopting the above predicted annual sediment inflow, future storage reservoir volume in the target year of 2050 is estimated. Approach and condition of the estimations is shown below:

- The annual change of storage volume of each dam reservoir is simulated considering the sediment balance and sediment trapping ratio as described in Section G 4.2.4.
- Initial conditions of reservoir storage volume are set at year 2014 in which the latest calibrated data is available.
- Annual dam inflow discharges both for present and future climate change conditions were estimated by the WEB-DHM run-off analysis by the JICA Project Team 1. The result shows that the annual dam inflow discharge in case of the future climate change condition is as almost same as or minor decrease from that of the present condition. In this study, therefore, future annual dam inflow discharge from 2014 to 2050 is assumed to be constant as that of present condition.
- Annual sediment inflow in the future is adopted taking into account the increase rate as shown in Figure G 5.1.2.
- The sediment removal volume of each reservoir in the future are estimated referring to the latest sediment removal/deriding plan provided by PJT-1 as Table G 5.1.8 below.

Table G 5.1.8 Plan for Sediment Removal in Dam Reservoir in Brantas River Basin in 2016

Dam	Dredging (m^3)	Flushing (m^3)
Senggurh Dam	270,000	-
Sutami Dam	375,000	-
Lahor Dam	-	**
Wlingi Dam	370,000	**
Lodoyo Dam	-	-
Selorejo Dam	280,000	-
Wonorejo Dam	-	-
Bening Dam	-	-

Note: ** No annual plan for flushing in 2016.
Source: Result of Interview to PJT 1 on March 16, 2016

Dam reservoir storage curve (HV-curve) under NWL in the target year of 2050 is created assuming a similarity of the curve with the latest bathymetry survey, and to fit to the predicted effective and dead storage volume. As for the HV-curve above NWL in the flood control zone, it is considered that almost no sediment will be deposited in this zone, therefore, the curve is assumed as same as that of the latest survey.

The predicted gross storage volume of dam reservoirs in the Brantas River basin in 2030 and the target year of 2050 are presented in Table G 5.1.9 below:

Table G 5.1.9 Prediction of Gross Storage Volumes of Dam Reservoirs in 2030

Dam	Gross Storage under Present Climate	Future Climate Change Scenario (2050) unit: Million m^3		
		Low	Medium	High
Senggurh Dam	1.38	1.35	1.34	1.32
Sutami Dam	140.80	140.73	140.70	140.63
Lahor Dam	25.64	25.59	25.57	25.53
Wlingi Dam	4.36	4.35	4.34	4.32
Lodoyo Dam	0.67	0.67	0.67	0.67
Selorejo Dam	29.52	29.40	29.34	29.21
Wonorejo Dam	97.71	97.57	97.50	97.35
Bening Dam	24.81	24.77	24.75	24.70

Source: JICA Project Team 2

Table G 5.1.10 Prediction of Gross Storage Volumes of Dam Reservoirs in 2050

Dam	Gross Storage under Present Climate	Future Climate Scenario (2050) unit: Million m^3		
		Low	Medium	High
Senggurh Dam	1.39	1.31	1.28	1.21
Sutami Dam	119.37	119.03	118.86	118.50
Lahor Dam	21.46	21.24	21.13	20.89
Wlingi Dam	4.20	4.15	4.13	4.07
Lodoyo Dam	0.12	0.12	0.12	0.12
Selorejo Dam	23.18	22.57	22.25	21.60
Wonorejo Dam	87.71	87.08	86.75	86.08
Bening Dam	1.39	1.31	1.28	1.21

Source: JICA Project Team 2

G5.2 Estimation of Future Flood Control Storage

The location where reservoir sedimentation is accumulated is in the effective storage space of the reservoir under FSL. The impact of reservoir sedimentation to the flood control space above FSL is smaller than that in the effective storage. This phenomenon is shown on the actual change of the flood control capacity as mentioned in Section G2.5.

In this study, the flood control capacity of each dam in future is assumed to be same as that in 2012.

CHAPTER G6 ASSESSMENT OF CLIMATE CHANGE IMPACTS ON RIVER FACILIY MANAGEMENT IN 2050

G6.1 General

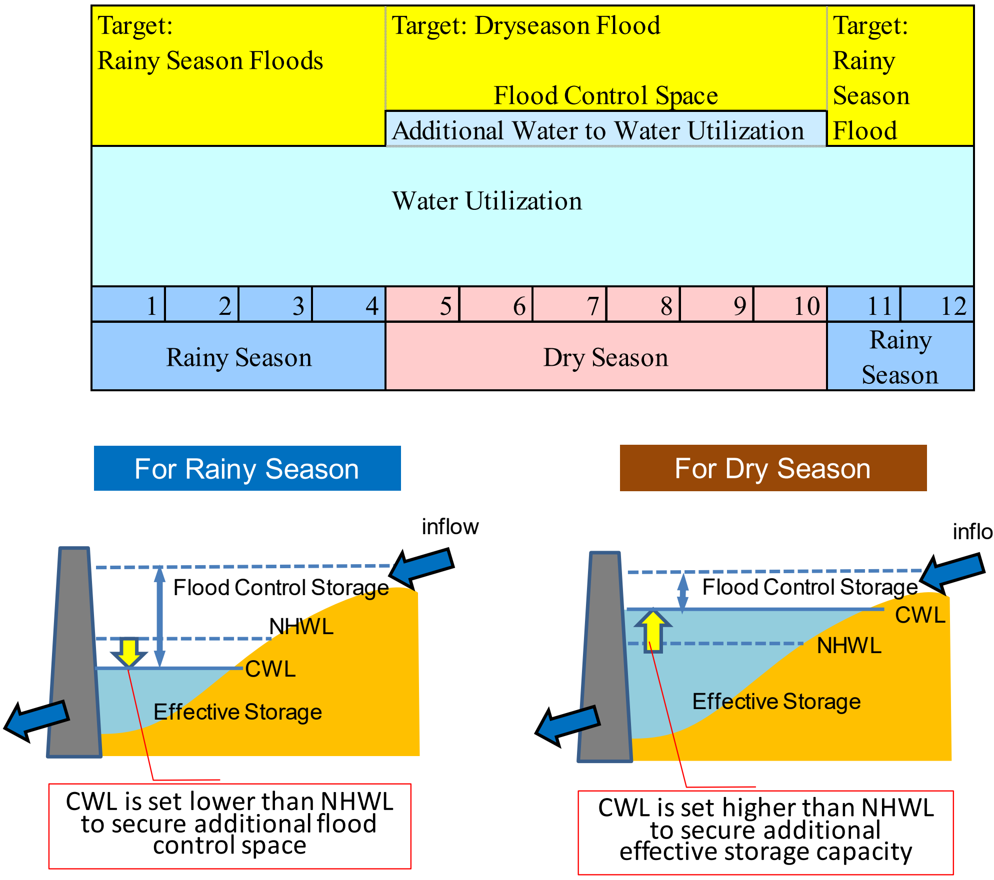
In this Chapter, a study for reservoir operation of the Sutami Dam is conducted for resilience measure. As for adaptation measure, construction of new dams and heightening of the Sutami Dam is studied as below.

G6.2 Measures of Resilience by River Facility Management

G6.2.1 Introduction of Control Water Level to Sutami Reservoir Operation for Resilience

(1) Concept of Control Water Level Method

A control water level method has been already applied to the Wonogiri Dam in Indonesia. This method is aiming at control allocation of reservoir storage capacity by season, for flood control and for water use. This method uses two full supply levels as shown in Figure G 6.2.1, which are for the rainy and dry seasons.



Source: JICA Project Team 2

Figure G 6.2.1 Conceptual Illustration of Control Water Level Method

G6.2.2 Control Water Level for Rainy Season

(1) Climate Change Impact for Flood Control in Sutami Dam

Flood inflow into the dam reservoir is predicted to increase due to climate change.

On the other hand, the impact of reservoir sedimentation to the flood control zone above NWL is minimal comparing with than that in effective storage because the location where reservoir sedimentation is generally accumulated is in the effective storage zone of the reservoir under NWL This phenomenon is shown on the actual change of flood control capacity as mentioned in the previous Section G2.1. In this study, the flood control capacity of each dam in future is assumed to be same as that in 2012.

The impact of climate change on flood control in use of an existing dam is studied at the Sutami Dam which has the biggest flood control capacity in the Brantas River basin.

(2) Present Design Flood Control Operation

The flood control operation of the Sutami Dam has been studied and determined in "Report on the Revision of Design of the Karangkates Dam, August 1965" (hereinafter called "the 1965 Study"). Two kinds of design hydrographs were prepared, one for the design flood and another for the abnormal flood, to simulate flood routing in the reservoir. The design values of spillway discharge, flood water level and dam crest elevation are determined as presented in Table G 6.2.1. The simulation result of flood routing in the case of the design flood is shown in Figure G 6.2.2.

Table G 6.2.1 Designed Flood Control Operation of Sutami Dam

Items		**Design Flood**	**Abnormal Flood**
Inflow	Peak Discharge	3,000 m^3/s	4,200 m^3/s
	Average return period	1/200	1/1000
Initial Water Level	-	WL 272.500 m	WL 272.500 m
Outflow under Case A*	Discharge	1,060 m^3/s	1,580 m^3/s
	RWL	WL 275.500 m	WL 276.630 m
Outflow under Case B*	Discharge	920 m^3/s	1,400 m^3/s
	RWL	WL 276.150 m	WL 277.230 m
Designed Value	Spillway Design	1,600 m^3/s	
	Flood WL	FWL 277.000 m	
	Dam Crest	EL. 279.000 m	

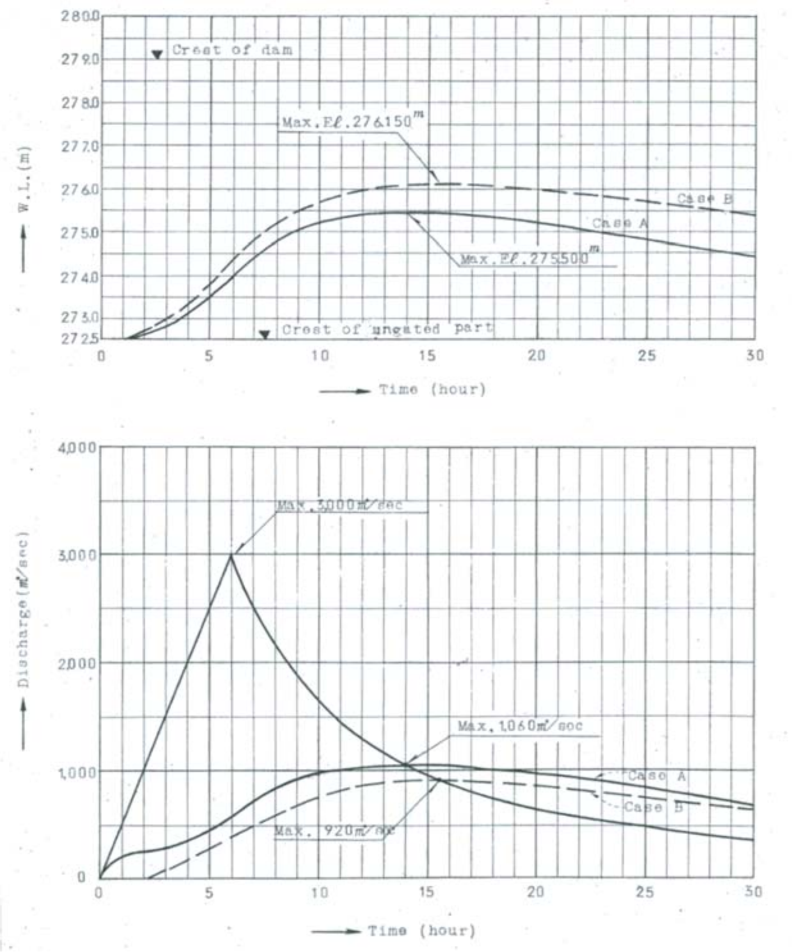
Note: * Case A : with spillway gate operation, Case B: without spillway gate operation
Source: 1965 Study Report

(3) Simulation of Flood Control Operation in 2050

Flood control operation for the Sutami Dam under future climate change in the target year of 2050 is simulated adopting the same manner with Case A (with spillway gate operation) of the original design. For the flood hydrographs in the future climate change scenario, the original design hydrographs are enlarged as shown in Figure G 6.2.3 taking into account the increase rate of probable rainfall obtained from the analysis of the climate change study undertaken by Team 1. Simulation cases and conditions are summarized in Table G6.2.2.

(4) Simulation Results of Flood Control Operation in 2050

The results of simulation are presented in Figure G 6.2.4 and summarized in Table G 6.2.3.



Source: 1965 Study Report

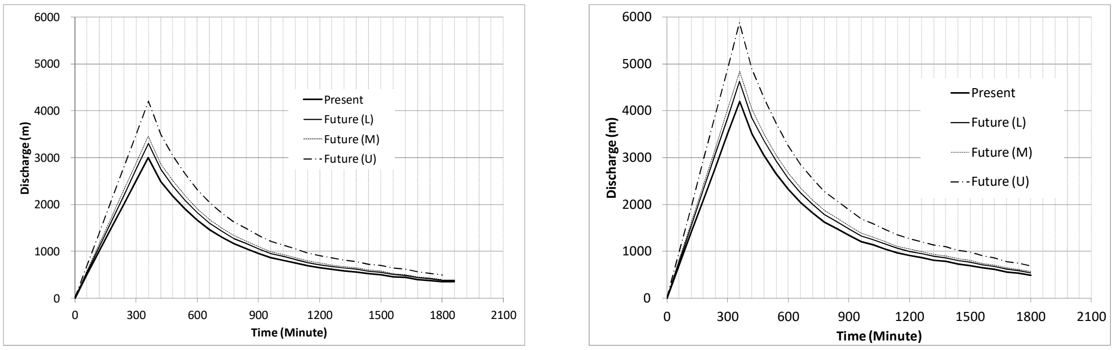
Figure G 6.2.2 Flood Routing of Sutami Dam for Design Flood with Peak Discharge of 3,000 m^3/s

Table G 6.2.2 Cases for Simulation of Flood Control Operation of Sutami Dam in 2050

Cases		Design Flood	Abnormal Flood	Dam HV-Curve
(1) Original Design (1972)		3,000 m^3/s	4,200 m^3/s	1972 data
(2) Present condition(2014)		3,000 m^3/s	4,200 m^3/s	2014data
(3) Future condition (2050)				
i) Under Present climate		3,000 m^3/s	4,200 m^3/s	2050data (P)*
Under Future Climate Change Scenario	ii) Low	3,300 m^3/s	4,620 m^3/s	2050data (L)*
	iii) Medium	3,450m^3/s	4,830 m^3/s	2050data (M)*
	iv) High	4,200 m^3/s	5,880 m^3/s	2050data (U)*

Note: * Dam HV-Curve above NWL in Flood Control Storage is assumed to be constructed since 2014.

Source: JICA Project Team 2



Design Flood

Abnormal Flood

Source: JICA Project Team 2

Figure G 6.2.3 Flood Hydrographs in Future Climate Change Scenario in 2050

Table G 6.2.3 Simulation Results of Flood Control Operation in 2050

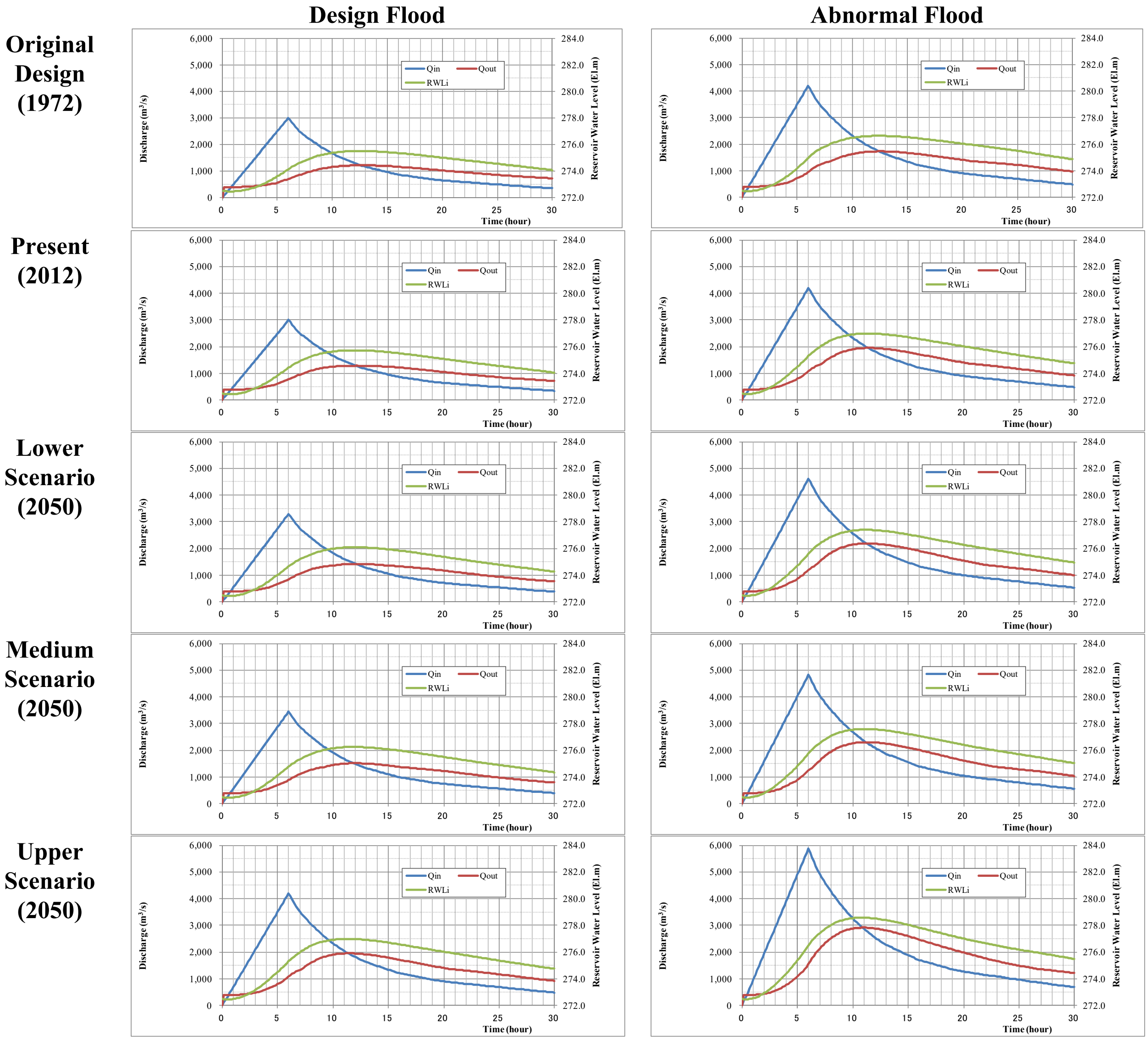
< Design Flood>

Cases		Maximum Reservoir Water Level		Dam Outflow Discharge	
		Value (El.m)	Difference (m)	Value (m^3/s)	Difference(m^3/s)
(1) Original Design (1972)		275.50		1,060	
(2) Present condition(2012)		275.74	+ 0.24	1,291	+ 231
(3) Future condition (2050)					
i) Under Present climate		Same as (2)	Same as (2)	Same as (2)	Same as (2)
Under Future Climate Change Scenario	ii) Low	276.09	+ 0.59	1,428	+ 368
	iii) Medium	276.25	+ 0.75	1,517	+ 457
	iv) High	277.00	+ 1.50	1,955	+ 895

< Abnormal Flood>

Cases		Maximum Reservoir Water Level		Dam Outflow Discharge	
		Value (El.m)	Difference (m)	Value (El.m)	Difference(m^3/s)
(1) Original Design (1972)		276.63	-	1,580	-
(2) Present condition(2012)		277.00	+ 0.37	1,955	+ 375
(3) Future condition (2050)					
i) Under Present climate		Same as (2)	Same as (2)	Same as (2)	Same as (2)
Under Future Climate Change Scenario	ii) Low	277.40	+ 0.77	2,189	+ 609
	iii) Medium	277.60	+ 0.97	2,308	+ 728
	iv) High	278.58	+ 1.95	2,919	+ 1,339

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure G 6.2.4 Simulation Results of Flood Control Operation at Sutami Dam

- Comparing with the designed values, the increments of maximum reservoir water levels in the future conditions range from +0.59 m to +1.50 m for the design flood, and from +0.77 m to +1.95 m for the abnormal flood.
- The increments of maximum spillway discharges in the future conditions range from +368 m^3/s to +895 m^3/s for the design flood and from +609 m^3/s to +1,335 m^3/s for the abnormal flood.
- In the most extreme case of the abnormal flood with the high scenario, the maximum reservoir water level would reach up to 278.58 m which is only 0.42 m lower than the dam crest elevation.

As shown in the above, the flood risk of overtopping of the dam is increasing in the Sutami dam due to climate change. Any countermeasures shall be applied before the situation will be critical.

(5) Setting control water level for the Sutami dam in 2050

When the abnormal flood water level is kept to original design (EL. 276.63m), two options are considered from above simulation.

- Case1: Control water level method (Lowering normal water level during rainy season)
- Case2: Increasing outflow discharge from spillway

In Case1, some rehabilitation of spillway is required discharging water below crest elevation of spillway. In Case 2, inundation risk at downstream of the Sutami dam is increased comparing with Case1 and construction of dike along mainstream is required. Therefore, this project studies the Case1. Simulation conditions are as follows;

- Design flood condition: Reservoir water level is less than EL. 275.50m and maximum outflow from spillway is smaller than 1,060m^3/s
- Abnormal flood condition: Reservoir water level is less than EL. 276.63m and maximum outflow from spillway is smaller than 1,580m^3/s

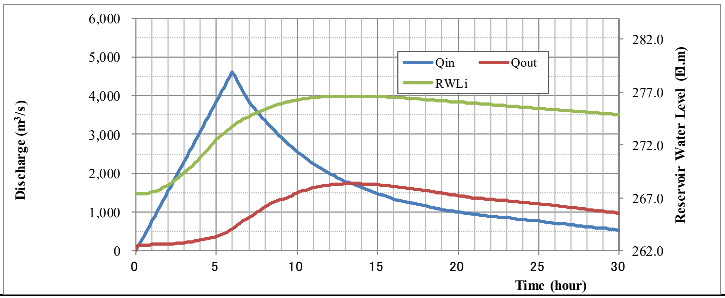
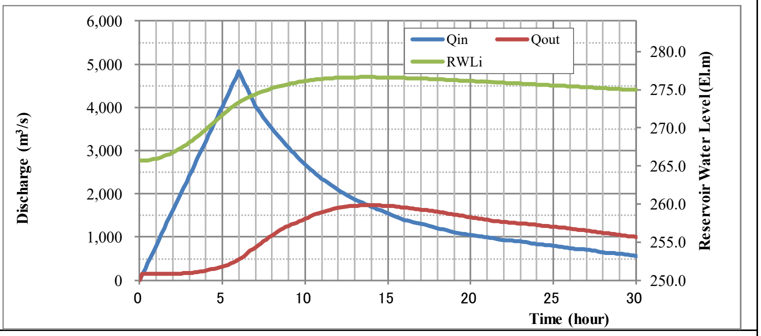
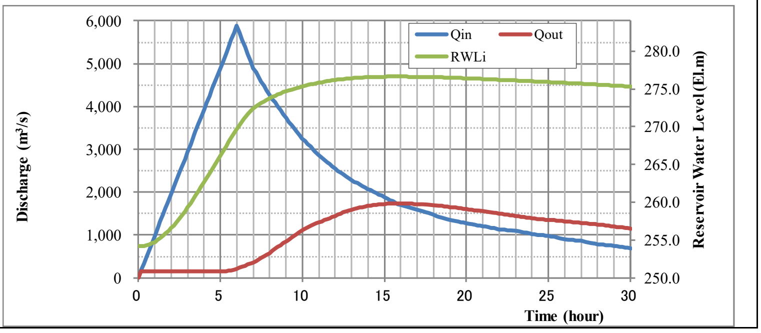
The simulation results are shown in Table G 6.2.4. To cope with the future increase of flood inflow discharge, it will be needed to adopt control water level in rainy season so that required flood control volume can be secured in the future.

Table G 6.2.4 Result of Reservoir Operation for Control Water Level

Scenario	Design Flood		Abnormal Flood	
	Full Supply Level (EL.m)	Flood Water Level (EL.m)	Full Supply Level (EL.m)	Abnormal Flood Water Level (EL.m)
Original	272.50	275.50	272.50	276.63
Low	269.40		267.35	
Medium	268.30		265.70	
High	261.40		254.20	

Source: JICA project Team 2

Full supply level during rainy season in medium scenario shall be set at EL. 265.70m.

Low		
Medium		
High		

Source: JICA Project Team 2

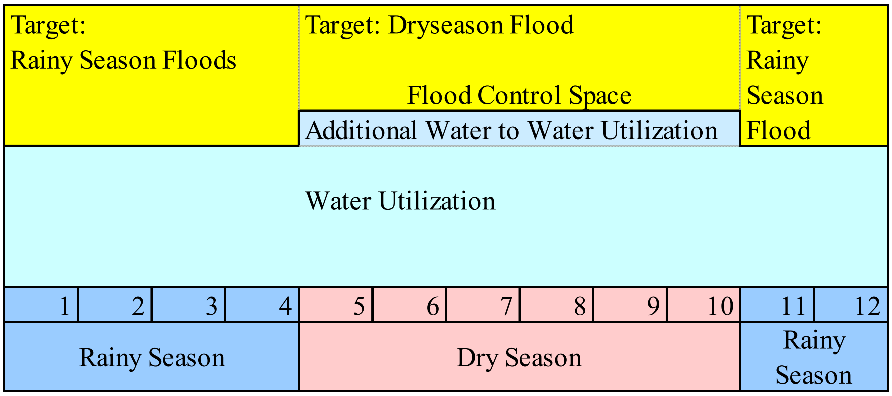
Figure G 6.2.5 Result of Reservoir Operation for Control Water Level

G6.2.3 Control Water Level for Dry Season

(1) Concept of Control Water Level for Dry Season

The Wonogiri dam in Solo River applies the control water level for dry season due to the characteristics of the climate condition in Java Island. This method applies two kinds of the full supply level in the rainy season and the dry season as shown in figure below.

It is considered reasonable to adopt the control water level for dry season to the dams in Brantas River Basin.



Target: Rainy Season Floods

Target: Dryseason Flood

Flood Control Space

Additional Water to Water Utilization

Target: Rainy Season Flood

Water Utilization

1	2	3	4	5	6	7	8	9	10	11	12
Rainy Season				Dry Season						Rainy Season	

Source: JICA Project Team 2

Figure G 6.2.6 Conceptual Illustration of Control Water Level Method

(2) Control Water Level

Hydrograph of design flood in dry season is adjusted from the design flood in rainy season as below:

(a) Magnitude of design flood volume in rainy season and dry season: 0.4

(b) Flood water level : EL. 275.5 m

(c) Maximum outflow: 1,060 m^3/s

(d) Reservoir volume : H-V curve (2050 year)

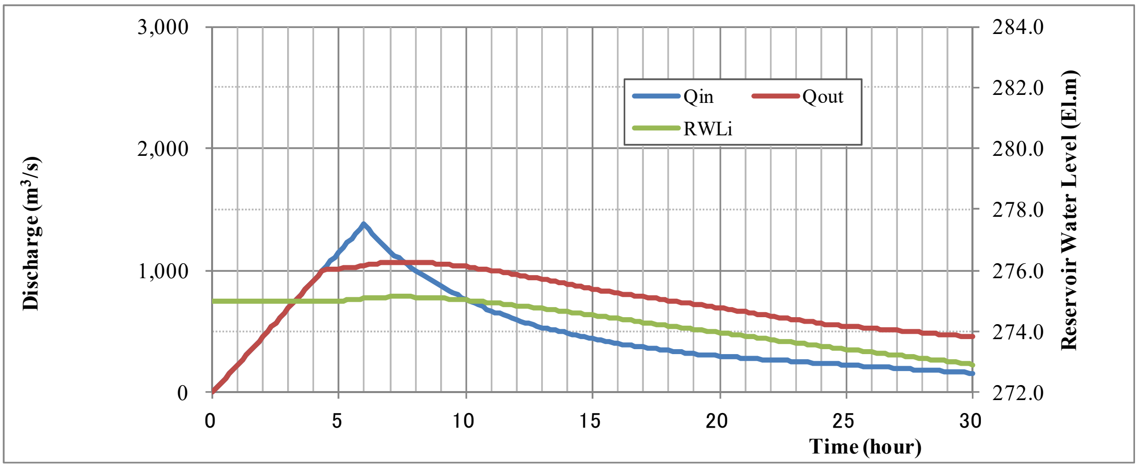
(e) Design flood in rainy season: 3,450 m^3/s (Table G6.2.2)

Table G 6.2.5 and Figure G 6.2.7 show the result of flood routine in dry season.

Table G 6.2.5 Comparison of Control Water Levels in Dry Season

Case	CWL (EL.m)	Peak Inflow (m^3/s)	Max. RWL (EL.m)	Max. Outflow (m^3/s)
0	272.50	1,380	273.76	630
1	273.00		274.01	700
2	274.00		274.49	831
3	274.900		275.07	1,041
4	275.00		275.14	1,070
Original	FSL 272.50	3,450	FWL 275.500	1,060

Note: CWL; Control Water Level, RWL; Reservoir Water Level, FSL; Full Supply Level, FWL; Flood Water Level
Source: JICA Project Team 2



Source: JICA Project Team 2

Figure G 6.2.7 Result of Flood Routing in Dry Season (Case 3 in Table G 6.2.6)

The full supply level in dry season can be raised from WL. 272.50m to WL. 274.90m based on the above routing results.

G6.2.4 Use for the Storage between Minimum Operation Level and Low Water Level in Sutami dam for Resilience

Sutami Dam and Selorejo Dam have set Minimum Operation Water Level (MOL) to optimize the power generation operation. In the past actual operation records, the reservoir level was not lowered to LWL, and the reservoir storage capacity below MOL is not used.

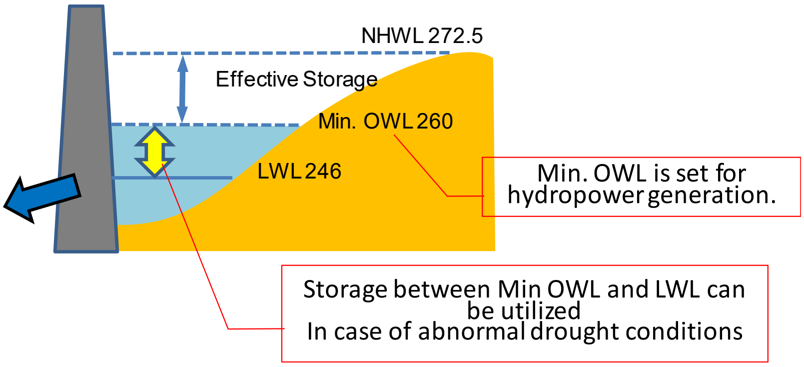
Changing the operation and utilizing the water storage capacity between MOL and LWL can be considered as a resilience plan.

As shown in table below, the water storage capacity between MOL and LWL of the Sutami is 47.8 MCM in 2012 and that of Selorejo dams is 12.2 MCM in 2010.

Table G 6.2.6 Storage Capacity Between MOL and LWL

Item		Sutami Dam		Selorejo	
		Original	2012	Original	2010
Reservoir WL (El.m)	NHWL	272.5		622.0	
	MOL	246.0		598.0	
	LWL	260.0		612.0	
Reservoir Storage (MCM)	NWHL-LWL	253.00	131.88	50.10	36.97
	FSL-MOL	109.80	84.08	24.31	24.73
	MOL– LWL	**143.20**	**47.80**	**25.79**	**12.24.**

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure G 6.2.8 Storage Capacity Between MOL and LWL in Sutami Dam

G6.3 Adaptation Measures by River Facility Management

G6.3.1 Increasing Store Water by New Dam

(1) Priority of Proposed Dams

As mentioned in Chapter G3, there are 29 proposed dams which were able to be confirmed through the data collection in the course of the Project.

These dams are classified into three (3) categories as below:

1) Category A

At present, the Government of Indonesia identifies 65 priority dams which are prioritized for implementation as a National Strategic Projects. Among of these dams, three (3) dams of Tugu Dam, Semantok Dam, Bagon Dam are identified in the Brantas River Basin.

In addition, as mentioned in the above there are five (5) dams to be constructed in the Brantas River basin until 2030 in Review POLA 2015 (Draft), which are:

By Year 2020:	Tugu Dam, Lesti III Dam,
By Year 2025:	Bagong Dam, Semantok Dam, and
By Year 2030:	Beng Dam.

The above five dams are considered as the first prioritized dams in the Brantas River Basin.

2) Category B

The dams to be classified in the Category B are the ones that have detailed plan and information based on the previous master plans, feasibility studies and detailed designs.

3) Category C

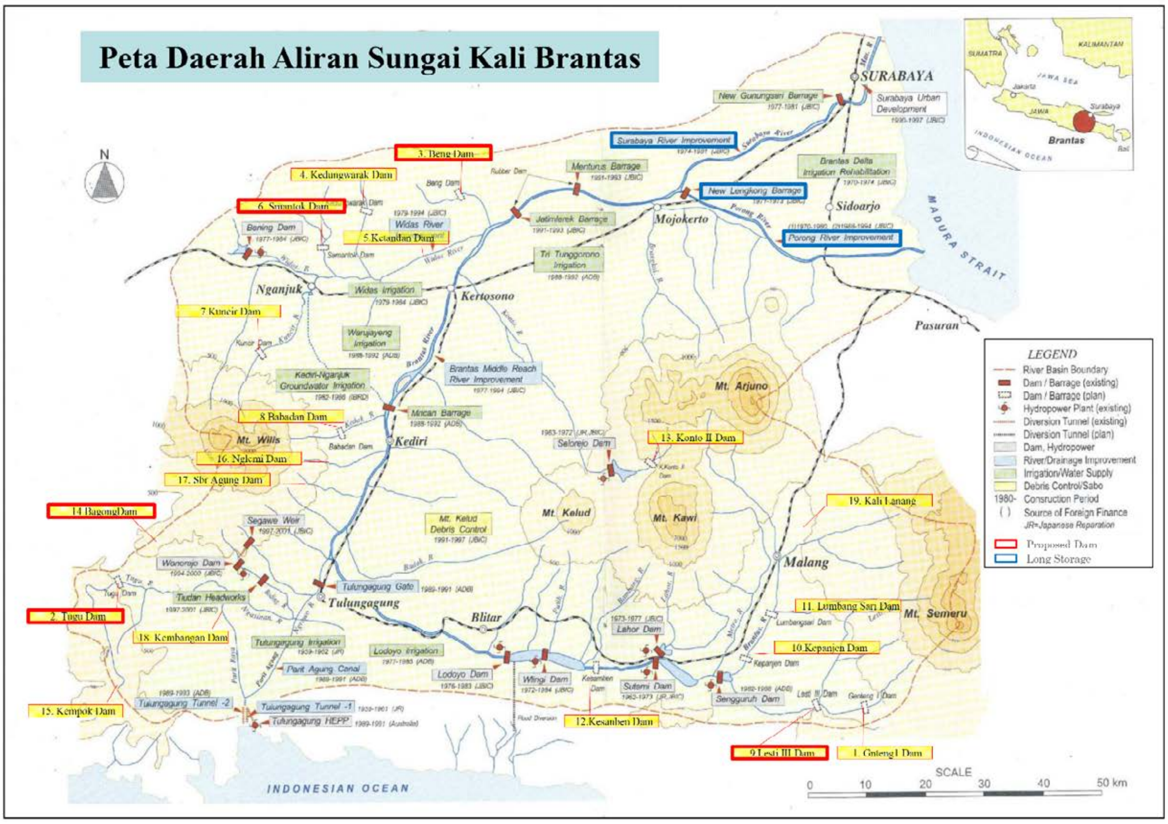
The dams to be classified in the third class are the ones that have no or very few detail information.

Based on the above criteria, 29 proposed dams are classified as shown in Table G 6.3.1 below:

Table G 6.3.1 Priority of Proposed Dams in Brantas River Basin

Priority	Dam
Category A (Strategic Projects listed in REVIEW POLA 2015)	Tugu Dam
	Beng Dam
	Semantok Dam
	Lesti III Dam
	Bagong Dam
Category B (Projects that are completed study and design)	Genteng Dam
	Kedungwarak Dam
	Ketandan Dam
	Kuncir Dam
	Babadan Dam
	Kepanjen Dam
	Lumbang Sari Dam
	Kesamben Dam
	Konto II Dam
	Kampak Dam
Category C	Nglemi Dam
	Sbr Agung Dam
	Kembangan
	Kali Lanang
	Krangkates IV&V
	Marmoyo Dam
	Brangkal – Plandaan Dam
	Kembar Dam,Jenesgelaran – Jurangbang
	Kopen Dam
	Jarak Dam
	Gembrong Dam
	Jatijejer Dam
	Jinggring Dam
	Sabo Dinoyo Dam

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure G 6.3.1 Location Map of Proposed Dams and Long Storage Structures in Brantas River Basin

(1) Effects of Proposed Dams in This Study

For the proposed dams of Category A and B, basic information of dam location, purpose, dam type and basic dimension, and reservoir storage capacity is presented in Table G 6.3.2.

These proposed dams are taken into consideration of the other climate change adaptation measures against droughts by increasing store water.

Table G 6.3.2 Type and Basic Dimension of Proposed Dams

No	Name	River Basin/ River	Purpose	Dam			Reservoir Capacity (Million m^3)		
				Type	Length (m)	Height (m)	Gross	Effective	Dead
1	Genteng I Dam	Lesti River Basin/ Genteng River	F, I, SC	R	441.0	84.0	82.0	76.1	5.9
2	Tugu Dam	Ngrowo River Basin/ Keser River	F, I, U	R	245.9	81.0	9.3	7.8	1.6
3	Beng Dam	Beng River	I, P,U	R	70.0	32.0	121.6	88.1	33.5
4	Kedungwarak Dam	Widas River Basin/ Kedungwarak River	I, P,U	R	164.3	25.3	13.6	9.0	4.6
5	Ketandan Dam	Widas River Basin/ Ketandan River	I	R	128.5	33.5	6.1	4.9	1.2
6	Semantok Dam	Widas River Basin/ Semantok River	F, I, P	R	92.5	38.5	22.4	18.3	4.1
7	Kuncir Dam	Widas River Basin/ Kuncir River	F, I, P, U	R	450.5	100	30.5	22.5	8.0
8	Babadan Dam	Bendokrosok	F, P, U	R	179	80	100.0	84.0	16.0
9	Lesti III Dam	Lesti River Basin/ Lesti River	I, P, SC	R	346	30	7.4	4.0	3.4
10	Kepanjen Dam	Brantas River	P, SC	E	320	20	1.3	0.5	0.8

No	Name	River Basin/ River	Purpose	Dam			Reservoir Capacity (Million m^3)		
				Type	Length (m)	Height (m)	Gross	Effective	Dead
11	Lumbang Sari Dam	Brantas River	P, SC	E	378	28	5.7	0.9	4.8
12	Kesamben Dam	Brantas River	P, U	GW	171	11.5	6.6	6.2	0.4
13	Konto II Dam	Konto River	F, P, SC	R	1004	120	73.0	63.0	10.0
14	Bagong Dam	Bagong River		R	330	81.79	17.4	-	-
15	Kampak	Tugu River	F, U	R	316	70	6.20	5.67	0.53

Note: WS: Urban water supply, IR: Irrigation, FC: Flood control, HP: Hydropower, SC: Sediment control
Source: The Latest Reports/Documents collected in the Study

G6.3.2 Heightening of Sutami Dam

(1) Function of Dam Heightening

The reservoir storage volume to be developed by the proposed dam heightening can be utilized for i) water use, ii) flood control, or iii) both purposes by introducing the control water level. It will be necessary to carry out a detailed study in order to determine this. In this preliminary study, it is assumed that dam heightening is aiming at developing the water use storage taking into account more urgent requirements and benefits in the Brantas Basin.

(2) Preliminary Study for Dam Heightening

The study for the dam heightening is target for the Sutami Dam which has the largest storage capacity in the Brantas River Basin. Since the Sutami Dam reservoir is directly connecting with the Lahr Dam reservoir through a connecting channel, following three (3) cases are considered:

1) Sutami Dam heightening
2) Lahor Dam heightening
3) Heightening of both dams

The increased volume by 1 m heightening of each case is roughly estimated based on the H-V curve as shown in the table. In this study, case 1) Sutami Dam heightening is adopted considering the larger increased volume by heightening.

Table G 6.3.3 Increase of Storage Volume by Dam Heightening

Item	Sutami Dam	Lahor Dam
Flood Water Level(FWL)	EL.277.0 m	EL. 275.7 m
Reservoir Area（at FWL）	19 km^2 (at EL.277)	4.0 km^2
Reservoir Area （at EL.280m）	21 km^2 (at EL.280)	5.0 km^2 (at EL.280)
Increase of Storage Volume by 1m heightening	20MCM/m	5MCM/m

Source: JICA Project Team 2

(3) Height of Dam Heightening

Topography of the Sutami Dam site shows that ground elevation in surrounding area of the left dam abutment is around EL.280.0 m. Referring to the topographic maps of the scale of 1:50,000, the number of bridges and villages to be affected by the proposed dam heightening are roughly counted as shown in the table below.

Figure below shows present conditions of land use, house, and existing structures (road, railway, bridge) in surrounding area of Sutami Dam

Source: Google Earth

Figure G 6.3.2 Satellite Image of Surrounding Area of Sutami Dam

Table G 6.3.4 Affected Bridges and Villages by Dam Heightening

Case	Case1	Case 2
Dam Heightening	（+2.5m）	（+15.0m）
	NWHL=EL275	NWHL=EL287.5
The number of affected bridges	14	22(4)
The number of affected villages	0	23 (5)

*1 This study is conducted for two cases referring to available contour lines (EL.275.0, EL.287.5) in the existing topographic map of 1:50:000

*2 The value in parenthesis shows the data of Lahor Dam

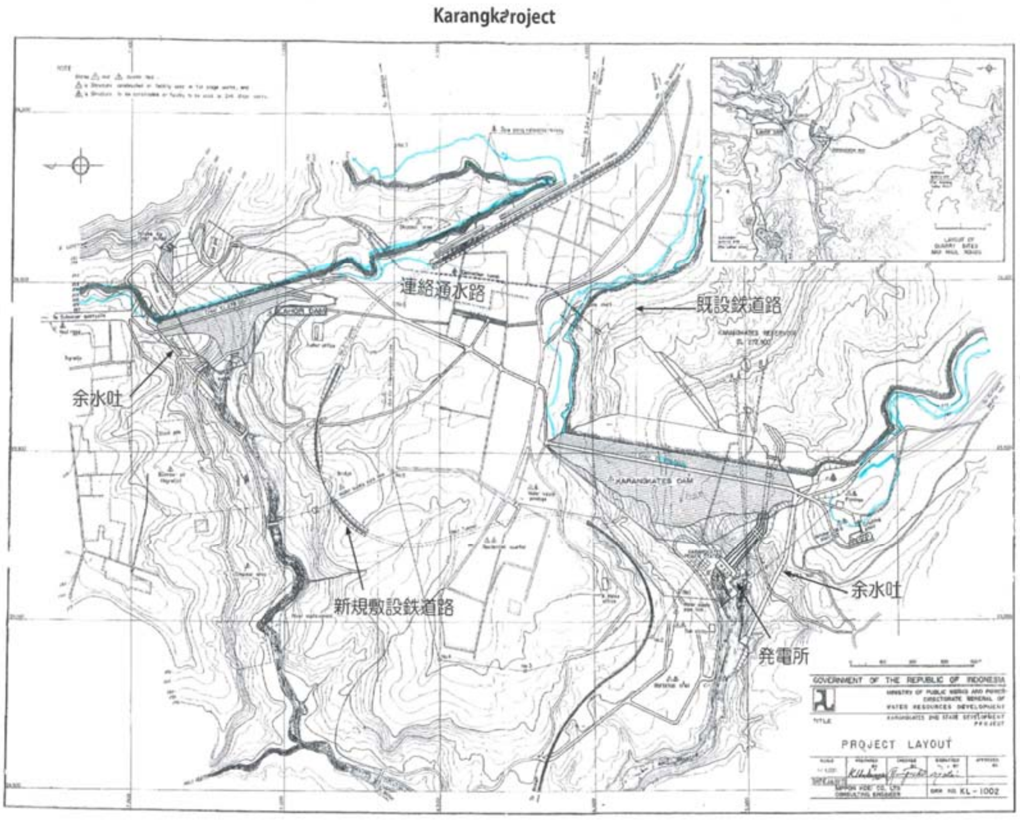
Source: JICA Project Team 2

If it is assumed the reservoir area of El.287.5m (Case 2), there are a lot of existing bridges and villages to be relocated in connection with the dam heightening. On the other hand, as shown in the Case 1: a small scale of dam heightening, the social impact can be mitigated. In addition, in the previous geological study report pointed out that there is a pervious sandy layer at the right dam abutment in the area with elevation of around 278.0 m.

Taking into consideration above, dam heightening by 5 m adopted in this study to mitigate the social impact and technical condition. In this proposal, the NHWL is raised from EL.272.7 m to EL.277.5, and dam crest elevation is raised from EL.279.0 m to EL.284. 0m.

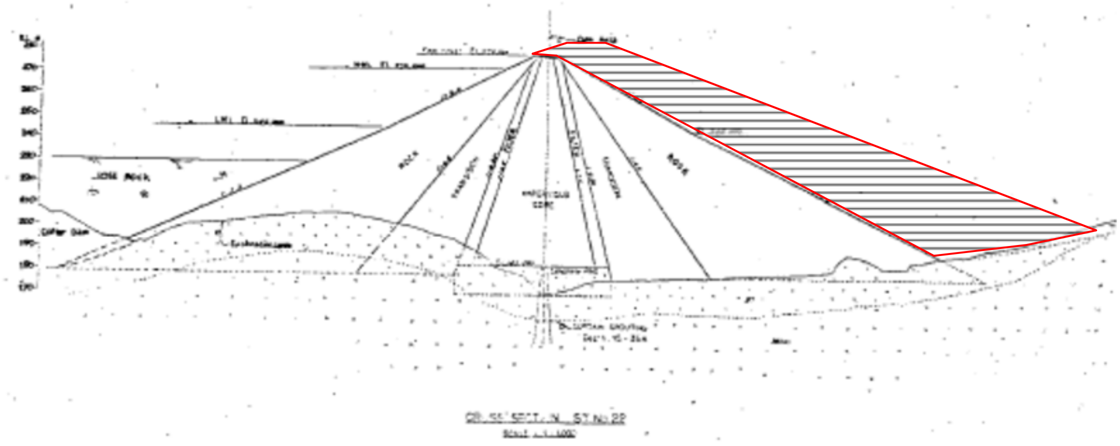
(4) Layout of Dam Heightening

Layout plan of the dam heightening is presented in figures below.



Source: JICA Project Team 2

Figure G 6.3.3　　Layout `Plan of Sutami Dam



Source: JICA Project Team 2

Figure G 6.3.4　　Typical Cross Section of Dam Heightening of Sutami Dam

Table G 6.3.5 Preliminary Designed Dimension of Dam Heightening of Sutami Dam

Item	Dimension	Remarks
Height of Dam Heightening	5.0 m	
Downstream slope of the heightening	1 : 2.6	Ref. design of Murayamasita reservoir in Japan
Embankment Volume	1,198,000 m^3	Preliminary estimate
Required Facility	New Spillway	L=460m
	Improvement Existing Spillway	1 LS
	Gate at connecting channel	1 no.
	Saddle Dam	L=1,000m, H=3m

Source: JICA Project Team 2

PART 2 MUSI RIVER BASIN

CHAPTER G7 PRESENT CONDITIONS OF EXISTING RIVER FACILITIES IN MUSI RIVER BASIN

G7.1 Barrage, Dam and Hydropower Plant

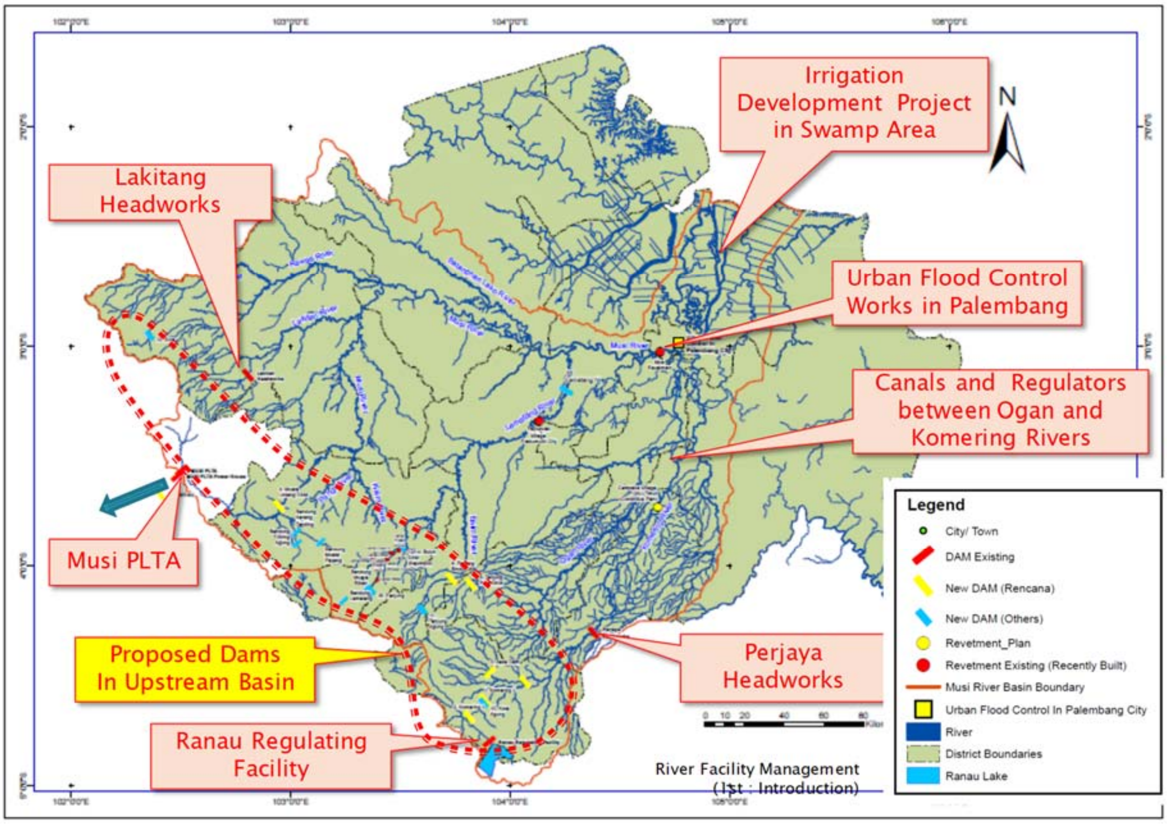
Data collection of the river facilities in the Musi River basin was conducted through site inspection and interview survey to relevant staff of BBWS. Basic information and operation and maintenance of these facilities were examined. Basic dimension of the major existing dams, headworks and hydropower plants are summarized in Table G 7.1.1.

From the view point of the existing river facility management, the main points that should be considered in the water balance analysis are; i) Inter-basin transfer scheme from Musi HP, ii) Water supply system from the Ranau Lake to Komering Irrigation System, and iii) Operation of regulators and their canals between Komering River and Ogan River.

Table G 7.1.1 Major Headworks, Dam and Hydropower Plant in Musi River Basin

River Facility	Technical Feature	Construction Year
(1) Headworks		
Perjaya Headworks	End sill height=2-3m, L=215.5m, gated weir, with 7 nos. spillway gates, 3nos. sluiceway gates, 59,148ha	1996
Lakitang Headworks	H=7.66m, L=80m, fixed weir with 4 nos. sluiceway gates, 9,667ha	1997
Lintang Kiri Headworks	H=4.0m, L=40.0m, fixed weir with 3 nos. sluiceway gates, 3,037ha	2011
Lintang Kanan Headworks (Siring Agung) (Karang Tanding)	H=1.0m, L=31.0m, fixed weir with sluiceway gates,1,293ha H=1.5m, L=24.0m, fixed weir with sluiceway gates1,761ha	1997
Lematang Headworks	H=2.0m, L=30.0m, fixed weir with 2 nos. sluiceway gates, 3,000ha	On-going construction
(2) Dam/Reservoir		
Ranau Lake	Reservoir area: 125 km^2, Storage volume: 190 MCM for irrigation water supply.	-
Ranau Regulating Facility	H=7.0m, L=144.0m, gated weir with 6 nos. regulating gates and emergency spillway	1996
(3) Hydro Power Plant		
Musi PLTA	Installed Capacity: 21.0MW, Power Generation 1,834GWh/year	2006
Ranau Niagla PLTMH	Installed Capacity: 2 x 850 kW,	2015

Source: JICA Project Team 2



Source: Prepared by JICA Project Team 2 based on data/information of BBWS

Figure G 7.1.1 Location Map of Major Headworks, Dam and Hydropower Plant in Musi River Basin

G7.2 Existing River Bank Protection Works

River bank erosion is one of most serious flood problems in the Musi River basin. How to protect the residential houses and infrastructures along erodible riverbank in the middle and upstream basin becomes main issue on the flood risk management.

River bank erosion is one of most serious flood problems in the Musi River basin. How to protect the residential houses and infrastructures along erodible riverbank in the middle and upstream basin becomes main issue on the flood risk management.

As per information from BBWS, it is pointed out that serious bank erosion is occurred in Sekayu City in Banuyasin Regency. The national road along the Musi River is suffering from the active bank erosion which have already reached to beside the road by around 2-3 meters. At present, rehabilitation on the damaged river bank protection works in two sections in Selayu are being conducted by BBWS and Bina Marga, respectively. The reasons of the damaged are i) progressing local scouring due to water colliding front located at an outer curve of meandering river and ii) massive sand mining activities nearby river channel.

Source: JICA Project Team 2

March 2018

July 2018

Source: JICA Project Team 2

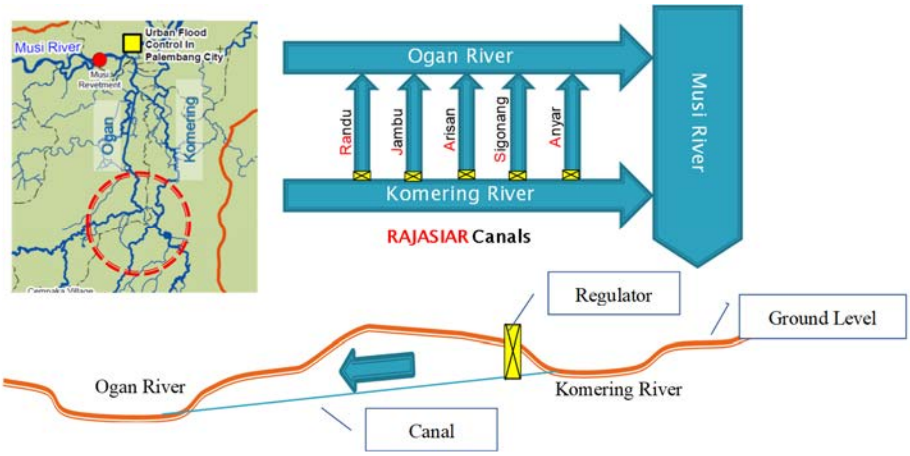
Figure G 7.2.1 Location Map and Site Photo of River Bank Erosion at Sekayu

G7.3 Existing Regulators

Between Komering and Ogan Rivers, there are five (5) connecting canals (RAJASIAR Canals) and regulators. The canals were constructed in Dutch Era aiming at a flood diversion from Komering to Ogan so as to mitigate flood damage in the lower Komering River. However, riverbed degradation and bank erosion in the canals became worse due to straight and steep alignment of the canals. Thereby drought in lower Komering River became problem because water had been diverted from Komerring to Ogan even in dry season. To cope with this, regulators were constructed at inlet of each canal. The main functions of the regulators are shown below;

- In rainy season: Flood diversion from Komering River to Ogan River
- In dry season: Discharge control to secure water supply in downstream of Komering

For the Randu Canal, the regulator had been repeatedly damaged by floods. In 2014, the regulator with closure dike in Randu Canal have just rehabilitated.



Source: JICA Project Team 2

Figure G 7.3.1 Schematic Image of RAJASIAR Canals

Source: JICA Project Team 2

Figure G 7.3.2 Regulator in Randu Canal in Komering River

Source: JICA Project Team 2

Figure G 7.3.3 Regulators in Segonang Canal and Anyar Canar in Komering River

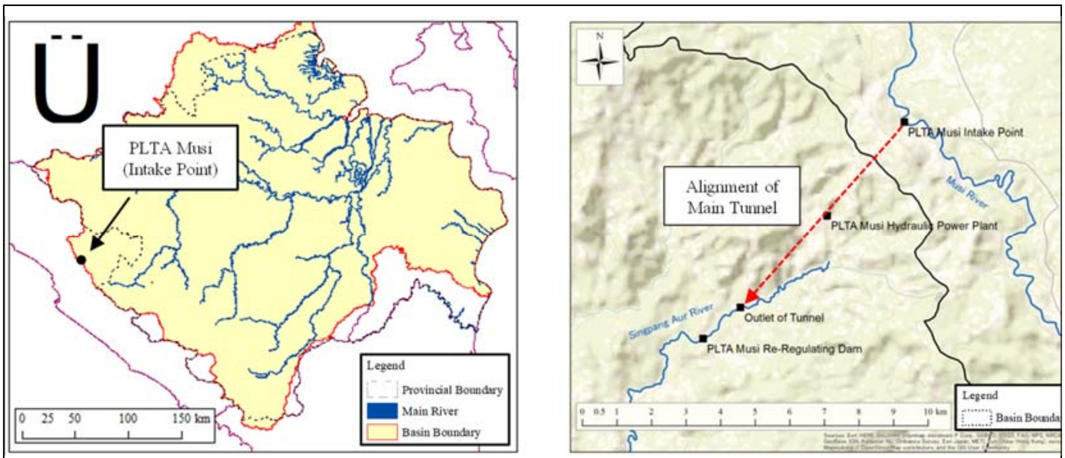
In addition, there is one more canal connecting the Ogan and Komering Rivers. It is the Haji Canal which is likely to cause floods over urban areas nearby.

G7.4 MUSI PLTA

G7.4.1 Project Area

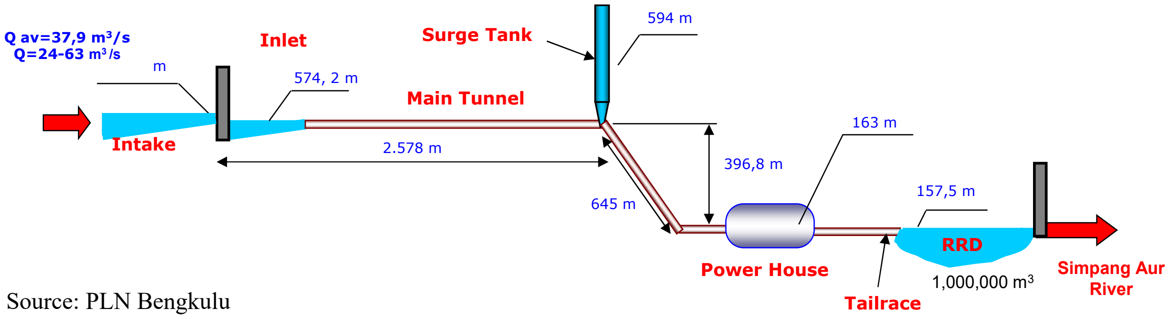
The Musi Hydroelectric Power Project site is located in the central part of Bengkulu Province in Sumatera and the intake dam site is about 30 km northeast of Bengkulu City, the capital of the Province. The Project involves the inter-basin transfer of water from the Musi river in Kepahiang Regency to the Simpangaur river in North Bengkulu Regency. The project area is adjacent to the Curup-Kepahiang road, which is a part of the national highway connecting Bengkulu to Palembang.

The construction works for the Project were commenced in 1994 and completed in 2006.



Source: JICA Project Team 2

Figure G 7.4.1 Location and Layout of PLTA Musi



Source: PLN Bengkulu

Figure G 7.4.2 Schematic Diagram of PLTA Musi

- Operation Year : 2006
- Installed Capacity : 210 MW (3 Units)
- Total annul energy : 1.834 GWh
- Plant discharge : 62.0 m3/s
- Maintenance flow to Musi River : 1.1 m3/s

Source: JICA Project Team 2

Figure G 7.4.3 Facilities of PLTA Musi

G7.4.2 Project Features

The Project formulated as a run-of-river type hydroelectric power development scheme. Installed capacity of the Project is 210 MW and annual energy output is expected at 1,140 GWh harnessing gross water head of 404 m by diverting water of 62.0 m^3/sec from the Musi river to the Simpangaur river in adjacent watershed through a 7.5 km long waterway and an underground powerhouse. The principal features of the Project are given below.

(1) Hydrology of the Musi river at the intake dam site

Catchment area	:	587 km^2
Mean annual rainfall	:	3,100 mm
Annual average runoff	:	42.3 m^3/sec
95% dependable discharge	:	17.4 m^3/sec
200-yr flood	:	780 m^3/sec
Catchment area	:	587 km^2

(2) Operation features of the Project

Reservoir water level	:	F.S.L. El. 579.100 m
M.O.L. El. 578.000 m Tail water level at tailrace		
Chamber	:	T.W.L. El. 174.700 m(for Q = 62.0 m^3/sec, 3 units operation)
Gross head	:	404.4 m
Net head	:	396.4 m
Mean discharge for power generation	:	38.4 m^3/sec
95% dependable firm discharge for power generation	:	15.5 m^3/sec
Plant discharge	:	62.0 m^3/sec(for 3 units operation)
Duty discharge from intake dam to the Musi river	:	1.1 m^3/sec
Installed capacity	:	210 MW (= 70 MW x 3 units)
Power generation, peak	:	210 MW
Annual energy, primary	:	467 GWh
secondary	:	673 GWh
total		1,140 GWh

(3) Major structural features of the Project

1) Reservoir

Reservoir surface area	:	1.14 k m^2
Storage capacity gross	:	2.23 million m^3
effective	:	1.00 million m^3

2) Intake Dam

Type	:	Gated concrete weir
Pier crest	:	El. 580.500 m
Weir crest	:	El. 572.500 m
Flap gate	:	10.0 m wide x 3 nos.
Sluiceway	:	10.0 m wide x 7.0 m high x 3 nos.
Upper scouring gate	:	6.0 m wide x 7.0 m high x 2 nos.
Lower scouring gate	:	6.0 m wide x 1.5 m high x 2 nos.

3) Intake

Width	:	10.2 m wide x 2 nos.
Sill elevation	:	El. 574.200 m
Intake gate	:	8.2 m wide x 5.3 m high x 2 nos.
Trashracks	:	10.2 m wide x 6.5 m high x 2 nos.

4) Reregulating reservoir

Catchment area	:	30 k m^2
Annual average runoff	:	2.2 m^3/sec
Reservoir surface area	:	0.27 k m^2
Storage capacity, gross		1.05 million m^3
effective	:	1.00 million m^3

5) Reregulating Dam

Type	:	Concrete gated weir
Height	:	16.0 m
Width	:	23.0 m
Pier crest	:	El. 159.000 m
Weir crest	:	El. 147.000 m
HWL.	:	El. 157.500 m
Reregulating gate	:	6.0 m wide x 10.8 m high x 1 no. 6.0 m wide x 6.0 m high x 2 nos.

G7.5 Ranau Regulating Facility

G7.5.1 Project Area

The Ranau Regulating Facility (RRF) is located at the outlet of the Ranau Lake for storing water and regulating the outflows from the lake so as to meet the downstream water demands including the maintenance flow for the lower reach of Komering River.

G7.5.2 Project Features

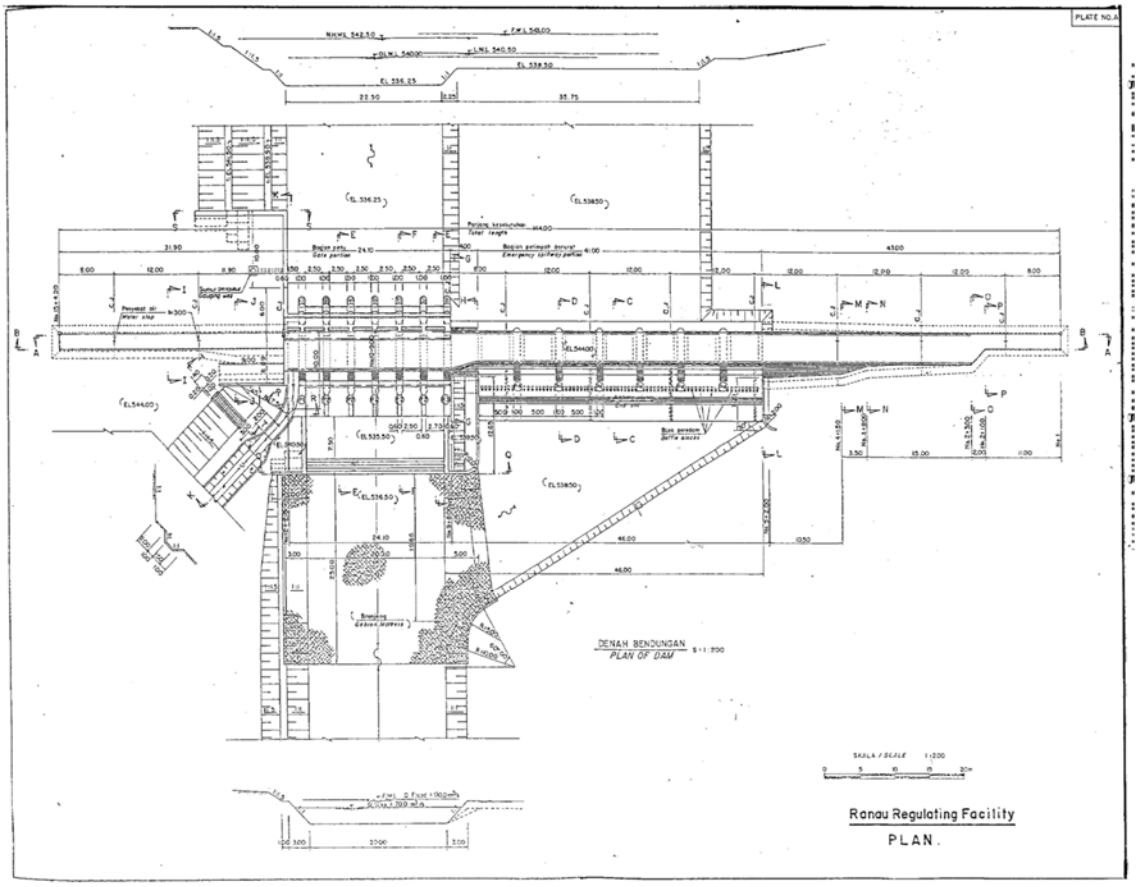
The Facility is a concrete-made structure consisting of six outlet gates to control the released amount of water and an overflow type spillway. An intake gate is erected at the right side of the structure to supply irrigation water for the agricultural land of about 420 ha in Ranau village. In order to measure the released discharges to the Komering River, a broad-crested weir is provided at 80 m downstream from the spillway.

The RRF spillway-crest elevation is El. 537.00. The normal high water level (NHWL) designed for the spillway has been revised to be at EL. 541.70; and the normal low water level (NLWL), at EL 540.20. There is an effective storage capacity of 190 MCM available between the NHWL and the NLWL for irrigation purpose for the KIP.

The designed flood water level for the spillway is set at EL. 543.00, corresponding to a design flood with daily rainfall of 1,000-year recurrence probability.

1.Design Regulating Discharge Max.	93 m^3/sec at WL 541.70 Min. 50 m^3/sec at WL 540.20
2.Design Water Level	
- Design Flood Water Level (F.W.L)	El. 543.00 m
- Design Water Level at Lake Ranau (N.H.W.L)	El. 541.70 m
- Low Water Level (L.W.L)	El. 540.20 m
3.Type of Facility	Concrete Dam
4.Height of Dam	

- Elevation of Dam Crest	El. 544.00 m:
- Elevation of Dam Foundation	El. 537.00 m
- Total Height of Dam	7.00 m
5. Length of Dam	
- Gate Portion	24.10 m
- Emergency Spillway Portion	41.00 m
- Non overflow Portion (Total Length)	144.00 m
(middle)	4.00 m
(left)	43.00 m
(right)	31.90 m
6.Gate Sill Elevation	
- Regulating Gat	El. 537.00 m
- Intake Gate for Local Use of Water	El. 539.50 m
7. Gate Size (W x H)	
- Regulating Gate	2.5 m x 1.6 m x 6 Nos.
- Intake Gate for Local Use of Water	1.5 m x 1.0 m x 1 No.
8. Stilling Basin	
- Floor Elevation	El. 535.50 m
- Length of Basin	15.00 m
- Height of End-sill	1.00 m
9. Emergency Spillway	
(a) Top Elevation	El. 542.50 m
(b) Length of Emergency Spillway	5.00 m x 7 Nos.
(c) Stilling Basin	
- Floor Elevation	El. 538.50 m
- Length of Basin	3.00 m
- Height of End-sill	0.30 m
10. Driving Channel	
(a) Length of Channel	
- Upper	2.23 km
- Lower	0.87 km
(b) Base Width	
- Upper (double section)	61 m and 17.5 m
- Lower	20 m
(c) Type of Channel	Trapezoidal Section



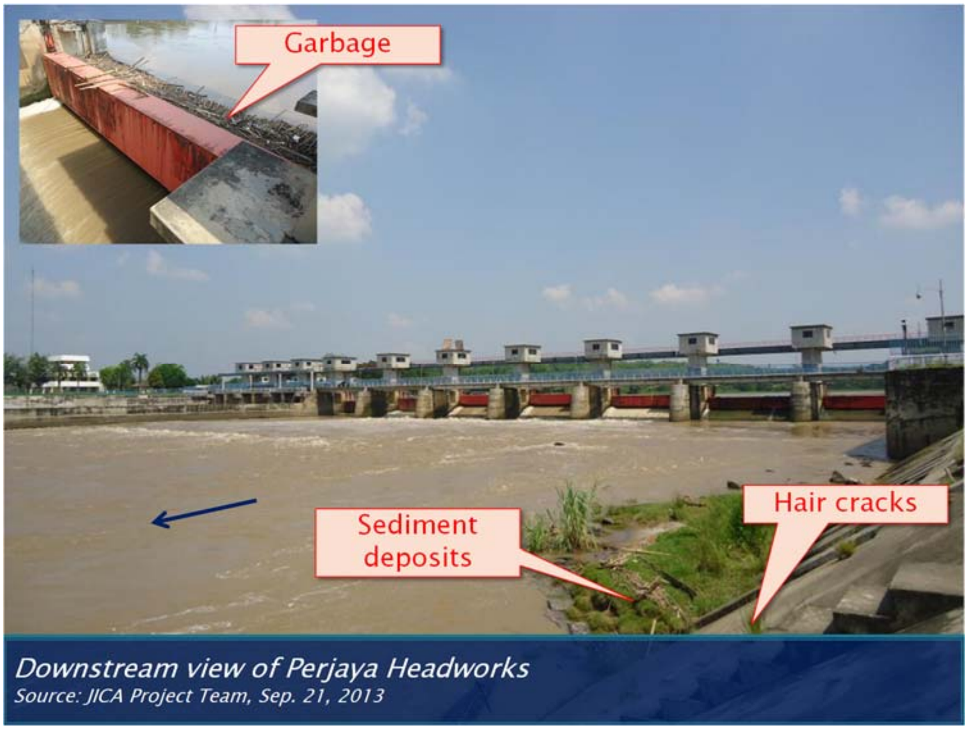
Source: Operation and Maintenance Manual of Komering Irrigation Project

Figure G 7.5.1 Location and Layout of PLTA Musi

G7.6 Perjaya Headworks

G7.6.1 Project Area

The Komering irrigation system consists of the Komering Main Canal complemented with the secondaries and sub-secondaries to convey the Komering River water drawn at the Perjaya Headworks, from the intake, through the canals and further down to the turnouts (TOs) of respective tertiary units (TUs). Besides, there are the Ranau Regulating Facility (RRF) on the Ranau Lake, the major water source of KMIS in dry seasons, which is about 120 km far upstream from the Perjaya Headworks; and two water level gauging stations on the Komering River at Damarpura and Pracak villages. They are taken as the complementary facilities of KMIS.



Downstream view of Perjaya Headworks
Source: JICA Project Team, Sep. 21, 2013

Source: JICA Project Team 2

Figure G 7.6.1 Photo of Perjaya Headworks

G7.6.2 Project Features

The Perjaya Headworks consists of a diversion weir equipped with seven flood discharge gates, three upper and lower sluices, one fish ladder and one intake structure of five slide gate leaves complemented with five settling basins and Parshall flumes. A power generation plant and a control house for the headworks gate operation are also provided.

(1) Diversion Weir

(a) Design Flood	2,200 m3/sec
(b) Design High Water Level	EL. 81.00
(c) Total Length of Weir	215.5 m
(d) Gate Size (W x H) and Number	
- Flood Weir Portion FG1 ~ FG5	20.0 m x 2.9 m x 5 Nos.
- FG6 & FG7	20.0 m x 3.9 m x 2 Nos.
- Scouring Sluice Portion SG1 ~ SG3	12.5 m x 4.2 m x 3 Nos.
- Under Sluice Portion UG1 ~ UG3	12.5 m x 2.0 m x 3 Nos.

(2) Stilling Basin

(a) Flood Weir Portion	
- Length of Basin : FG1 ~ FG3	330 m
FG4 ~ FG7	40 m
- Height of End Sill FG1 ~ FG3	2 m
FG4 ~ FG7	3 m
(b) Scouring Sluice Portion	
- Length of Basin	50 m
- Height of End Sill	3 m

(3) Fish Ladder

- Length	75.5 m
- Slope	1 :11.7

(4) Intake

- Design WL : EL. 79.70
- Maximum Intake Capacity : 101 m3/sec
- Design Intake Capacity : 91.68 m3/sec
- Intake Width : 49.5 m

(5) Settling Basin

(a) Design Discharge 16 m3/sec/bay

(b) Nos. of Basin 5 Nos.

- Width 45 m
- Length 140 m
- Height 2.9 ~ 4.3 m

(c) Driving Channel

Upper Driving Channel - Width : .50 m
- Length : 115 m
- Height : 9 m
- Type : Concrete, U-Type

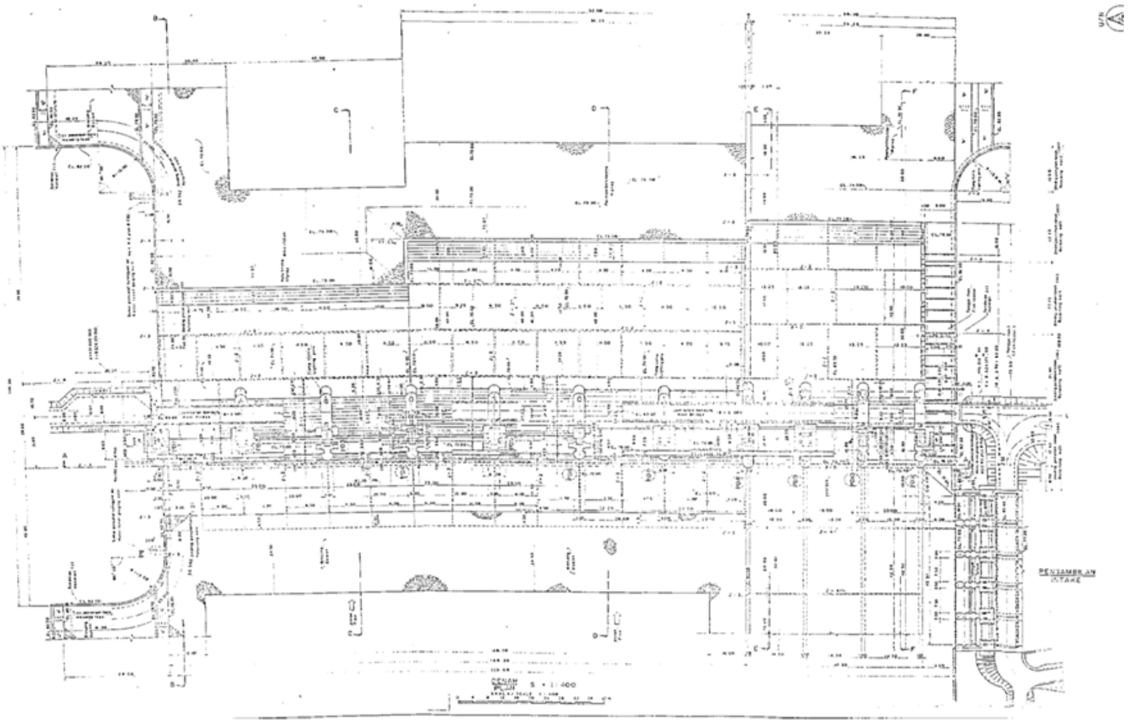
Lower Driving Channel - Width : 4 m
- Length : 60 m
- Height : 4 m
- Type : Concrete Lining Trapezoidal Section 1 : 1.5

(d) Sand Flush Gate : 3.0 x 0.8 x 10 nos. x 5 bays

(6) Control House Yard

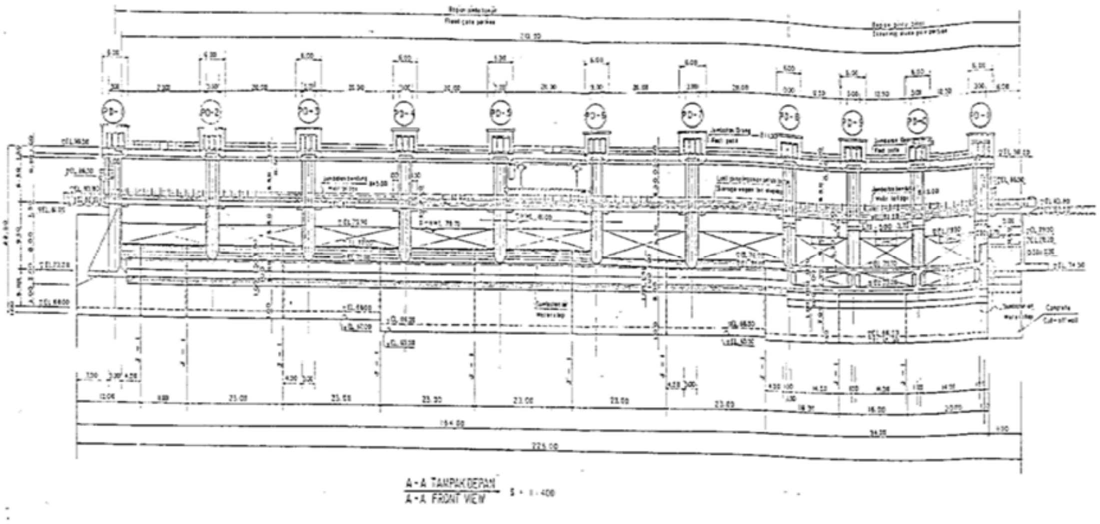
(a) Control House : 638 m2 in 4 Stairs

(b) Diesel Generator House : 16 x 10.5 m



Source: Operation and Maintenance Manual of Komering Irrigation Project

Figure G 7.6.2 Plan of Perjaya Headworks

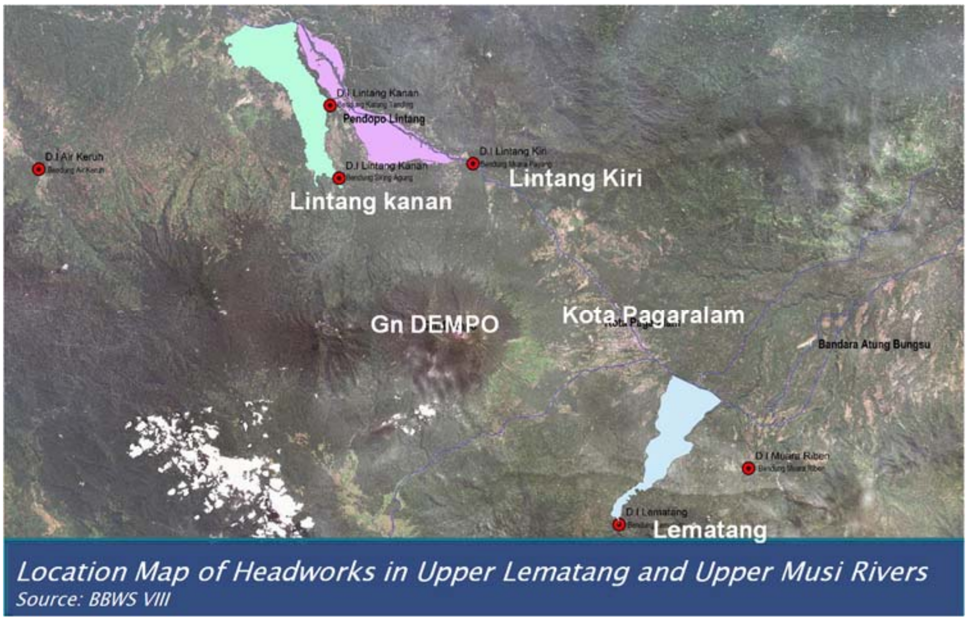


Source: Operation and Maintenance Manual of Komering Irrigation Project

Figure G 7.6.3 Cross Section of Perjaya Headworks

G7.7 Other Intake Facilities

There are one (1) headwork in Lakitan River and three (3) headworks in Lematang River Basin, i.e. i) Lematang, ii) Lintang Kanan, and iii) Lintang Kiri headworks as shown in the location map below:



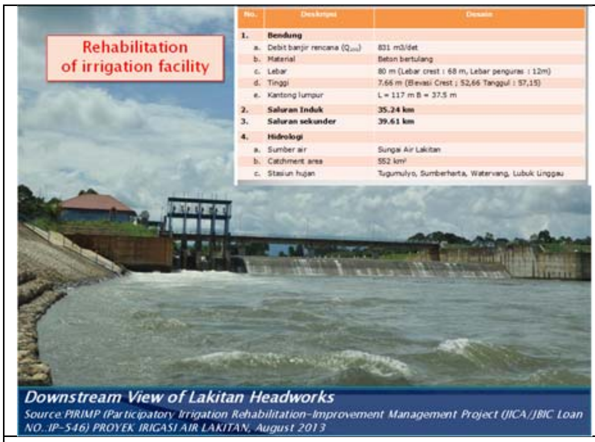
Source: JICA Project Team 2

Figure G 7.7.1 Location Maps of Headworks in Upper Lematang and Upper Musi Rivers

Table G 7.7.1 Technical Feature of Headworks in Upper Lematang and Upper Musi Rivers

River Facility	Technical Feature	Const. Year
(1) Headworks		
Perjaya Headworks	End sill height=2-3m, L=215.5m, gated weir, with 7 nos. spillway gates, 3nos. sluiceway gates, 59,148ha	1996
Lakitang Headworks	H=7.66m, L=80m, fixed weir with 4 nos. sluiceway gates, 9,667ha	1997
Lintang Kiri Headworks	H=4.0m, L=40.0m, fixed weir with 3 nos. sluiceway gates, 3,037ha	2011
Lintang Kanan Headworks (Siring Agung) (Karang Tanding)	H=1.0m, L=31.0m, fixed weir with sluiceway gates,1,293ha H=1.5m, L=24.0m, fixed weir with sluiceway gates1,761ha	1997
Lematang Headworks	H=2.0m, L=30.0m, fixed weir with 2 nos. sluiceway gates, 3,000ha	On-going construction

Source: JICA Project Team 2



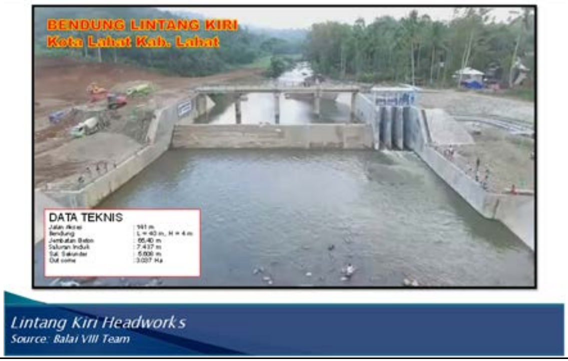
No.	Deskripsi	Desain
1.	**Bendung**	
a.	Debit banjir rencana (Q_{100})	831 m3/det
b.	Material	Beton bertulang
c.	Lebar	80 m (Lebar crest : 68 m, Lebar penguras : 12m)
d.	Tinggi	7.66 m (Elevasi Crest : 52,66 Tanggul : 57,15)
e.	Kantong lumpur	L = 117 m B = 37.5 m
2.	**Saluran Induk**	**35.24 km**
3.	**Saluran sekunder**	**39.61 km**
4.	**Hidrologi**	
a.	Sumber air	Sungai Air Lakitan
b.	Catchment area	552 km²
c.	Stasiun hujan	Tugumulyo, Sumberharta, Watervang, Lubuk Linggau

Downstream View of Lakitan Headworks
Source: PIRIMP (Participatory Irrigation Rehabilitation-Improvement Management Project (JICA/JBIC Loan NO.:IP-546) PROYEK IRIGASI AIR LAKITAN, August 2013

LAKITANG Headworks

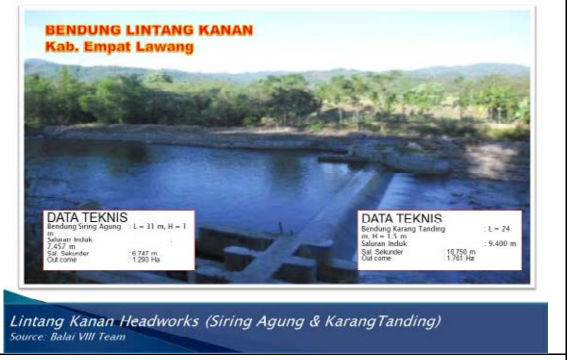
Lematang Headworks
Source: Balai VIII Team

BENDUNG LEMATANG
Kota Pagar Alam



Lintang Kiri Headworks
Source: Balai VIII Team

BENDUNG LINTANG KIRI
Kota Lahat Kab. Lahat



Lintang Kanan Headworks (Siring Agung & KarangTanding)
Source: Balai VIII Team

BENDUNG LINTANG KANAN
Kab. Empat Lawang

Source: JICA Project Team 2, BBWS VIII

Figure G 7.7.2 Photos of Headworks in Upper Lematang and Upper Musi Rivers

CHAPTER G8 PROPOSED RIVER FACILITIES IN WATER RESOUCES MANAGEMENT PLAN (POLA, RENCANA) IN MUSI RIVER BASIN

G8.1 Proposed Plan in RENCANA

In RENCANA (Year 2017), the proposed plan for construction of eight (8) dams is presented to meet the needs of both domestic or irrigation water. The investment schedule of these dams is divided into four periods (5 years) as below:

Table G 8.1.1 Proposed Plan of Construction of Dam in POLA/RENCAN in Musi River Basin

2016-2021	2022-2026	2027-2031	2032-2036
1. Komering 2 (2021) 2. Komering 1 (2021)	3. Muara Lingtang (2026) 4. Saka (2026) 5. Tanjung Pura (2026)	6. Muara Dua (2031)	7. Padan Bindu (2036)

No.	Name of Dam	River	Completion Year	Potential Discharge (m^3/s)	Total Storage (MCM)/ Dam Height	Present Status
1	Komering II (Tiga Dihaji Dam)	Komering	By 2021	+5.5	105.8 (H=121.5m)	Pre F/S in 1982. DD,LARAP, AMDAL were completed. At present bidding of construction/
2	Komering I	Komering	By 2021	+5.0	938 (H=50-70m)	Pre F/S in 1982.
3	Saka	Komering/ Saka	By 2026	+5.5	43.2 (H=74.8m)	F/S in 2015, D/D in 2016
4	Muara Lintang	Musi	By 2026	+5.0	21,633 (H=150m)	RENCANA. No study
5	Tanjung Pura	Enim	By 2026 By 2031	+3.0 +5.0	766 (H=160m)	Pre FS2015
6	Muara Dua	Komering	By 2031	+9.0	139 (H=40-50m)	Pre F/S in 1982. At present, BBWS decided to cancel the dam construction due to social issue.
7	Padang Bendu	Enim	By 2036	+10.0	938 (H=50-70m)	Pre FS2015

Source: Water Resources Management Plan Musi-Sugihan-Banyuasin, Lemau River Basins (Year 2017), Figure 3-2 Water Balance of High Economic Scenario p.32, Figure 5-2 Balance of Water Fulfillment in MSBL RB

The following information was provided for the proposed dams by BBWS;

- For the Muara Lintang Dam, only data/information on the POLA/RENCANA is available, but no study/investigation is conducted yet.
- For the Padang Bindu Dam and the Tanjung Pura Dam, the study was conducted in 2015. The study report was provided to JPT.
- For the Muara Dua Dam, it is included as one of potential dam sites in the POLA/RENCANA. However, based on the result of protest movement by local residents, the Balai VIII decided to cancel the dam construction. It is confirmed between Balai VIII and JPT that the Muara Dua Dam is not considered for the future water balance study to be carried out in this Project.

G8.2 Proposed Dams in Other Sources

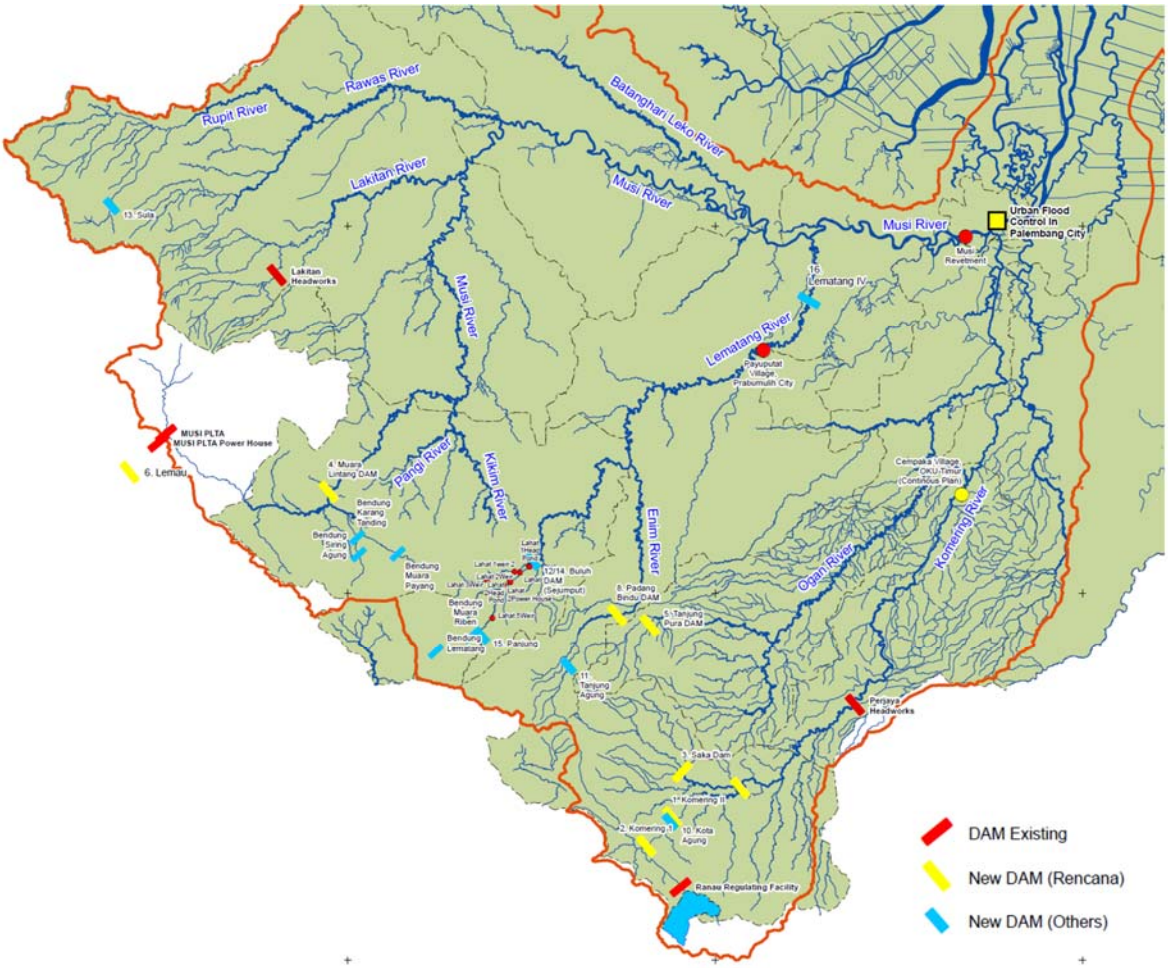
In addition to the RENCANA, data and information of proposed river facilities in the Musi River Basin were collected from following three (3) sources. The name, location, dimension and function are summarized in Table G 8.2.1.

01: Blue Book: Documen Rancangan Rencana Pengelolaarn Sumber Daya Air Wilayah Sungai MSBL (27 March 2013), p.137-143

02: A List of "Potential of Dam and Hydropower" source BBWS Sumatra VIII (2011)

03: A list of Economic Feasibility of Reservoir SDA

As per collected data and documents from the interview survey to BBWS, HV-curve for some proposed dams are prepared using the GIS.



Source: Prepared by JICA Project Team 2 referring to RENCANA(2016) and others

Figure G 8.2.1 Location Map of Proposed Dams in Musi River Basin

Table G 8.2.1 List of Proposed Dams in Musi River Basin

No.	Name	Main Function				Location	River	Source[3)]						Proposed Development Stage in RENCANA	Present Status	Remarks
		Flood Control	Irrigation	Hydropower Generation	Domestic and Industrial Water			00	01	02	03	04	05		Stage	
1	Komering 2（Tiga Dihaji)		o	o	o	Ds. Sekabumi Pauh Kec. Tiga Dihaji Kab. OKU Selatan	Komering WS /Komering River	o	o	x	o	o	o	2021	D/D: completed F/S: completed in Apr. 2013	Renamed from Komering 2 to Tigadihaji
2	Komering 1		o	o		Ds. Sekabumi Pauh Kec. Tiga Dihaji Kab. OKU Selatan	Komering WS /Komering River	o	o	x	o	o	o	2023	FS1982	
3	Saka		o			Ds. Sekabumi Pauh Kec. Tiga Dihaji Kab. OKU Selatan	Komering WS /Saka River?	o	x	x	x	x	x	2025	F/S: completed in Apr. 2013	
4	Muara Lintang		o	o		Ds. Sekabumi Pauh Kec. Tiga Dihaji Kab. OKU Selatan	Musi WS /Musi River	o	o	o	o	o	x	2027	no study/investigation is conducted yet.	
5	Tajung Pura		o	o	o	OKU /Muara Jaya	Ogan WS /Ogan River	o	o	o	o	o	x	2028	Pre-F/S: completed in 2015	
6	Lemau		o			Ds. Sekabumi Pauh Kec. Tiga Dihaji Kab. OKU Selatan	Lamau River	o	x	x	x	o	x	2030	no information	Out of Musi River Basin
7	Muara Dua		o	o		Ds. Sekabumi Pauh Kec. Tiga Dihaji Kab. OKU Selatan	Komering WS /Selabung River	o	o	o	o	o	o	2032	no information	BBWS already decided to cannel the dam construction. It is assessed as "not feasible" due to high risk of backwater. Proposed Dam Site is already occupied with houses, so it would be very difficult to implement
8	Padang Bindu		o	o	o	Muara Enim /Tanjung Agung	Enim WS /Enim River	o	o	o	o	o	x	2033	Pre-F/S: completed in 2015	
Proposed Dams in Other Source																
9	Baru		o	o		OKU Selatan	Komering River	x	o	o	o	x	x	no information		(same as Komering 1 in Pre FS 1982 & FS2013)
10	Kota Agung		o	o		OKU Selatan	Komering WS /Selabung River	x	o	o	o	x	x	no information		(same as Komering 2 Pre FS 1982 & FS2013)
11	Tanjung Agung		no info	o			Enim WS /Musi River?	x	o	o	x	x	x	no information		
12	Sejumput		o	o		Lahat /Pulau Pinang	Lematang WS /Lematang River	x	o	o	o	x	x	no information		(same as 14 Buluh Dam)
13	Sula		o	o		Musi Rawas /Rawas Ulu	Rawas WS /Rupit River	x	o	o	o	o	x	(2013-2032)		
14	Buluh		o	o	o	Lahat /Pagar Gunung	Enim WS /Musi River?	x	x	o	x	o	x	(2013-2032)	Pre-F/S: completed in 2015	
15	Panjung		no info	o		Lahat /Kota Agung	Lematang WS /Lahat River	x	x	o	x	x	x	no information		
16	Lematang IV		o	o		Lahat /Kota Agung	Lematang WS /Lematang River	x	x	o	x	o	x	(2013-2027)		(Lematan Headworks is on-going construction)
Existings Dams																
17	Musi 1 HEPP		-	o		Rejang Lebong /Padang U Tanding	Musi WS /Musi River	x	x	o	x	x	x	already constructed		
18	Ranau (pre-F/S 1982)		o	o		OKU Selatan	Komering WS /Komering River	-	-	-	-	-	o	-	Pre-Fs: completed in 1982	

Note: 1) Proposed location of Baru Dam in RENCANA is same as that of Komering 1 Dam in Pre-FS 1982 and FS2013
2) Proposed location of Kota Agung Dam in RENCANA is same as that of Komering 2 Dam in Pre-FS 1982 and FS2013
3) o: available, x: not available

Source:
00: RENCANA 2016
01: Blue Book (confirmed by Mr.Katayama). Documen Rancangan Rencana Pengelolaarn Sumber Daya Air Wilayah Sungai MSBL (27 March 2013), p.137-143
02: A List o f"Potential of Dam and Hydropower" source BBWS Sumatera VIII (2011) (collected by Mr.Katayama)
03: A list of Economic Feasibility of Reservoir SDA (collected by Mr.Katayama)
04: Documen Rancangan Rencana Pengelolaarn Sumber Daya Air Wilayah Sungai MSBL (27 March 2013), Figure 4.3 - 4.7, p.134-136
05:_Komering PreFS1982

G8.3 Study for Effective and Sediment Storage Volume of Proposed Dam

In some of the new dam plans, there is no dam water level-capacity curve or capacity allocation but only information about dam location and dam height. For these dams, dam water level-capacity curves were created from the available topographic data.

As a result of the water balance calculation, it was confirmed that there are four basins where the water shortage will occur in the future: the Komering River, the Lematang River, the Lakitan River, and the Klingi River. Among them, there are several new dam plans in the Lematang River basin. However, since the degree of study level was low, basic specifications such as dam height and dam capacity were uncertain. As a climate change impact adaptation measure, preliminary study was conducted to set up the basic specifications of these dam. The results for following three (3) dams are presented in table below:

- Tanjung Agung Dam
- Panjung Dam
- Buluh Dam (renamed to Lematang Dam. Location is almost same as Sejumput Dam)

Table G 8.3.1 List of Selected Proposed Dams in Musi River Basin

Basic Dimension	Tanjung Agung	Panjung	Buluh
Foundation Elevation	EL.940m	EL.700m	EL.200m
Crest Elevation	EL.1070m	EL.870m	EL.273m
Dam Height	130m	170m	73.0m
Catchment Area	226 km^2	220 km^2	391km^2
NWL	EL.1060 m	EL.860 m	EL.269.0 m
LWL	EL.1,022 m	EL.780 m	EL.252.0m
Sediment Storage	20.3MCM	26.2MCM	32.0MCM
Effective Storage	43.0MCM	106.1MCM	29.8MCM
Development Plan	Maximum	Maximum	Pre F/S2013

Source: JICA Project Team 2

CHAPTER G9 OPTIMIZATION OF EXISTING WATER RESOURCES MANAGEMENT FACILITIES FOR MITIGATION OF CLIMATE CHANGE INPACTS ON FLOODS

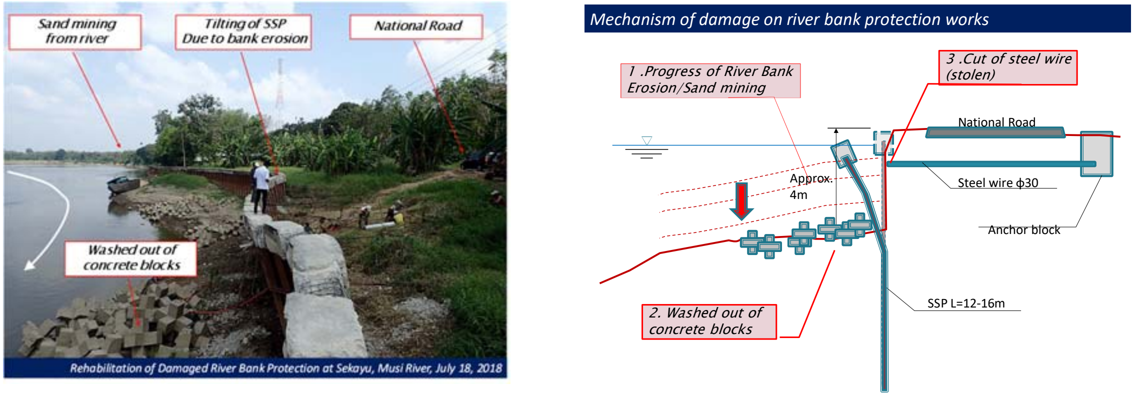
G9.1 River Bank Protection Works

As mentioned in Chapter G7, river bank erosion is one of most serious flood problems in the Musi River basin. How to protect the residential houses and infrastructures along erodible riverbank in the middle and upstream basin becomes main issue on the flood risk management.

The mechanism of the damage on existing river bank protection in Sekayu City in Kabupaten Banyuasin and basic approach to propose durable countermeasures were studied and discussed with the staff of BBWS.

For optimization of exiting river bank protection works for mitigation of the climate change impact in the Musi River, following points are recommended to be implemented by BBWS-S8:

- Preparation of inventory of river bank erosion
- Study (survey, geological investigation, river morphology, riverbed material survey)
- Risk assessment of river bank erosion
- Selection of priority area for improvements of river bank protection works
- Preparation of design standard and guideline
- Control and regulate of quarry in the river channel and its monitoring



Source: JICA Project Team 2

Figure G 9.1.1 Photo and Mechanism of River Bank Erosion at Sekayu

G9.2 Connecting Channels between Komering and Organ Rivers

As mentioned in Chapter G7, there are five (5) connecting canals (RAJASIAR Canals) and regulators between Komering and Ogan Rivers. The main functions of the regulators are i) flood diversion from Komering River to Ogan River in rainy season, and ii) discharge control to secure water supply in downstream of Komering in dry season.

For optimization of exiting regulators for mitigation of the climate change impact, following points should be noted in term of the facility management of the regulator:

- It is important to make/update plan and design of regulators considering the climate change impacts to control discharge and sediment load properly in lower Komering and Ogan Rivers
- There is an existing plan showing discharge distribution, but it shall be reviewed in detail and updated through topographic survey and river survey (cross -longitudinal section), hydrological analysis, sediment balance study.
- It is recommended to study the necessity of forecasting system of river flow conditions and formulating related organizations by monitoring and recording river information, such as water levels, discharges, sediment loads and riverbed materials, and hydro-meteorological data.
- It is necessary to prepare operation and maintenance manual of the regulators based on the updated plan.
- In addition, improvement of river bank protection and maintenance dredging in the canals would be necessary to secure the safety of the regulator and canals