CONCLUSIONS AND RECOMMENDATIONS OF THE STUDY

A. AUTHORITY

This Final Report was prepared in accordance with the Scope of Works for the Study on Countermeasures for Sedimentation in the Wonogiri Multipurpose Dam Reservoir agreed between the Japan International Cooperation Agency (JICA) and the Directorate General of Water Resources (DGWR), Ministry of Public Works, the Republic of Indonesia on March 9, 2004.

B. OBJECTIVES OF THE STUDY

The objectives of the Study are to:

i) Formulate a master plan for sustainable countermeasures for sedimentation problems in the Wonogiri multipurpose dam reservoir,

ii) Conduct a feasibility study of the selected priority project(s), and

iii) Transfer technology to counterpart personnel in the course of the Study.

The goals of the Study after achievement of the above objectives are to:

i) Implement the project to be proposed under the Study to secure the long-term ability of the reservoir to supply water for irrigation and hydropower generation, and

ii) Provide solutions and technical approaches for reservoir sedimentation problems which are increasing concern in Indonesia.

C. CONCLUSIONS

It may be concluded from both the Master Plan Study and Feasibility Study that:

i) The Wonogiri multipurpose dam completed in 1981 is the sole large reservoir on the Bengawan Solo River. The Wonogiri dam has contributed much to social welfare in the basin and has greatly benefited the country in terms of both regional and national economic developments.

ii) The Wonogiri reservoir has been suffering from sediment deposits and garbage at the intake that provides water for power generation and irrigation water supply. The Keduang River that enters the reservoir just upstream of the dam is the primary cause of the current sediment-related problems. The sediment and garbage from the Keduang River have deposited massive quantities of sediment in the forebay adjacent to the dam. The reservoir sedimentation survey in 2006 showed sediment deposition depth of approximately 20 m in maximum in the forebay. It was predicted that in the near future the forebay area would be completely filled with sediment deposits due to continuing sediment inflow from the Keduang River. Establishment of sustainable sediment management system in the reservoir has become crucial.

iii) The main source of the sediment was identified as the soil erosion from the cultivated upland fields and settlement areas within the Wonogiri dam watershed. The volume of annual soil erosion is estimated at around 93% of the annual sediment inflow into the reservoir (annual average 3.2 million m^3 in 1993-2004). Such high soil erosion rate might be caused as a consequence of the poor land management and agricultural

development that local farmers had to adopt, due to poverty and the large farming population, in the topographically critical areas on steeper mountain slopes. Out of sub-watersheds, the Keduang watershed produces the highest soil loss.

iv) Urgent countermeasures (the Project) were proposed in the Master Plan. The Project aims at securing the proper function of the intake with provision of combination of structural and non-structural measures to cope with the sediment inflow into the reservoir from the Keduang River. The watershed conservation in the Keduang sub-watershed as the non-structural measure will mitigate sediment yield, thereby reducing the sediment inflow from its watershed. The sediment storage reservoir as the structural measure will release the sediment inflow from the Keduang River to the downstream reach through the new spillway; thereby the sedimentation at the intake will be drastically decreased.

v) Most of the sediment and garbage inflow from the Keduang River will be completely retained in the sediment storage reservoir. The existing intake will become completely relieved from the current sediment-related issues. The retained sediment and garbage in the sediment storage reservoir will be easily released from the new spillway.

vi) Implementation of the watershed conservation will be carried out by means of community-based management, preventing soil erosion as well as encouraging the local farmers to increase farm income and thereby to improve the quality of life by improving their current land use practices. This comprehensive approach for the watershed conservation will much contribute to poverty alleviation providing stabilization of the farmers' economic situation.

vii) The Project is technically sound and economically feasible, showing high economic viability with an EIRR 16.4%. The Project will make sustainable operation of the Wonogiri reservoir possible and contribute to stabilization of the livelihood of people in the local communities as well as improvement of social welfare from the national economic points of view.

D. RECOMMENDATIONS

Recommendations from both the Master Plan Study and Feasibility Study are summarized below:

i) The Wonogiri dam is one of the lifelines of the national infrastructures. The economic value of the Wonogiri dam for water storage is undoubtedly very high. As stipulated in the Scope of Works, it was agreed between DGWR and JICA that the goals of the Study is to implement the proposed countermeasures to secure the long-term ability of the Wonogiri reservoir. Because of the urgent needs to cope with the sediment inflow, the Project should be implemented as early as possible to keep the intake functioning properly.

ii) In the highly populated Java Island, the reservoir is a precious water source that would be very difficult to replace when once it is completely filled with sediments. From a realistic view points, it would be difficult to develop a new reservoir. It is strongly recommended that technical approaches and solutions provided under the Study should be applied to solve similar sedimentation problems in the existing reservoirs in Indonesia.

THE STUDY ON
COUNTERMEASURES FOR SEDIMENTATION
IN
THE WONOGIRI MULTIPURPOSE DAM RESERVOIR
IN
THE REPUBLIC OF INDONESIA

FINAL REPORT

VOLUME- I EXECUTIVE SUMMARY

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Abbreviation (1/3)

Abbreviation	Indonesian	English
ADB	Bank Pembangunan Asia	Asian Development Bank
AMDAL	Analisis Mengenai Dampak Lingkungan	Environmental Impact Analysis
APBD	Anggaran Pendapatan dan Belanja Daerah	Provincial Government Development Budget (Provincial Budget)
APBN	Anggaran Pendapatan dan Belanja Negara	Central Government Development Budget (National Budget)
BAKOSURTANAL	Badan Koordinasi Survey dan Pemetaan Nasional	National Coordination Agency for Surveys and Mapping
Balai PSDA	Balai Pengelolaan Sumber Daya Air	Regional Office of Water Resources Management
Balai PDAS	Balai Pengelolaan Daerah Aliran Sungai	Regional Office of Watershed Management
BAPEDAL	Badan Pengendalian Dampak Lingkungan	Environmental Impact Management Agency
BAPEDALDA	Badan Pengendalian Dampak Lingkungan Daerah Propinsi	Provincial Office of Environmental Impact Management Agency
BAPEEDA	Badan Perencanaan Pembangunan DaerahTingkat I	Regional Development Planning Agency of Province
BAPPENAS	Badan Perencanaan Pembangunan Nasional	National Development Planning Agency
BB	BB	Brachiaria Brizantha
BBI	Balai Benih Induk	Seed Production enter
BBLH	Biro Bina Lingkungan Hidup	Bureau of Environmental Guidance
B-C	-	Net Present Value
BD	-	Brachiaria Decumbens
BIMAS	Bimbingan Masal	Mass Guideline for Agricultural Divelopment
BKPH	Bagian Kesatuan Pemangkuan Hutan	Forest Administration Sub-unit
BMG	Badan Meteorologi dan Geofisika	Meteorological and Geophysical Agency
BOD	-	Biochemical Oxygen Demand
BP2TPDAS	Balai Penelitian dan Pengembangan Teknologi Pengolohan Daerah Aliran Sungai	Watershed Management Technology Centera, Ministry of Forestry
BPDAS Solo	Balai Pengeloloan Daerah Aliran Sungai Solo	Solo River Management Office of Ministry of Forestry
BPKH	Balai Pemantapan Kawasan Hutan	Forest Area Consolidation Bureau
BPPHH	Balai Pengendalian Peredaran Hasil Hutan	Forestation Result of Agricultural Extension Office
BPS	Biro Pusat Statistik	Central Bureau of Statistics
BPTP Terpadu	Balai Pengkajian Teknologi Pertanion	Integrated Agricultural Technology Assessment Center
BPTPH	Balai Proteksi Tanaman Pangan dan Hortikultura	Provincial Plant Protection Center
Cd		Cadmium
CDMP	-	Comprehensive Developmant and Management Plan Study for Bengawan Solo River Basin under Lower Solo River Improvement Project
COD	Kebutuhan Oksigen untuk proses kimia	Chemical Oxygen Demand
Cr	Khrom	Chromium
Cu	-	Copper
CWL	Tinggi Muka Air Kendali	Control Water Level
DAS	Daerah Aliran Sungai	Watershed, Catchment
DEM	-	Digital Elevation Method
DEPDAGRI	Departemen Dalam Negeri	Ministry of Home Affairs
DEPHUT	Departemen Kehutanan	Ministry of Forestry
DEPKES	Departemen Kesehatan	Ministry of Health
DEPTAN	Departemen Pertanian	Ministry of Agriculture
DFWL	Tingi Muka Air Banjir Rencana	Design Flood Water Level
DG	Direktorat Jendral	Directorate General
DGLWM	Direktorat Jendral Pengelolaan Lahan dan Air	Directorate General for Land and Water Management
DGWR	Direktorat Jenderal Sumber Daya Air	Directorate General of Water Resources
DHF	-	Dengue Hemorrhagic Fever
Dinas LHKP	Dinas Lingkungan Hidup, Kehutanan dan Pertambangan	Environment, Forestry and Mining Services of kabupaten Wonogiri
DIP	Daftar Isian Proyek	Approved Project Budget
DIPERTA	Dinas Pertanian Tanaman Pangan Daerah Propinsi Jawa	Provincial Agricultural Service of Central Java
DO	Oksigen Terlarut	Dissolved Oxygen
DPRD	Dewan Perwakilan Rakyat Daerah	Regional House of Representatives
DPU	Departemen Pekerjaan Umum	Ministry of Public Works
EFWL	Tinggi Muka Air Banjir Ekstra	Extra Flood Water Level
EIA	Analisis Dampak Lingkungan	Environmental Impact Assessment
EIRR	-	Economic Internal Rate of Return
EU	Uni Eropa	European Union
FAO	Badan Pangan Dunia	United Nations Development Programme /Food and Agriculture Organization
FORDA	Litbang Departemen Kehutanan	Forestry Research & Development Agency
GDP	-	Gross Domestic Product
GIS	Sistem Informasi Geografis	Geological Information System
GMU	Universitas Gadjah Mada	Gadjah Mada University

Abbreviation (2/3)

Abbreviation	Indonesian	English
GNKPA	Gerakan Nasional Kemitraan Penyelamatan Air	National Movement of the Partnership for Water Preservation
GNP	Pendapatan Nasional	Gross National Product
GOI	Pemerintah Indonesia	Government of Indonesia
GOJ	Pemerintah Jepang	Government of Japan
GPS	Sistem Posisi Global	Global Position System
GRDP	Produk Domestik Regional Bruto	Gross Regional Domestic Product
GERHAN	Gerakan Nasional Rehabilitasi Hutan dan Lahan	National Movement for Forest & Land Rehabilitation
H-A	-	Relation between reservoir water level and reservoir surface area
H-V	-	Relation between reservoir water level and reservoir capacity volume
HKTI	Himpunan Kerukunan Tani Indonesia	Farmer's Association
HPI	Indek Kemiskinan	Human Poverty Index
IBRD (WB)	Bank Dunia	International Bank of Reconstruction and Development (Work Bank)
IEE	Pengkajian Pendahuluan Lingkungan	Initial Environmental Examination
IPAIR	Iuran Pelayanan Irigasi	Irrigation Service Fee
IPEDA	Iuran Pen Bangunan Daerah	Village Land Tax, Provincial Development Tax
ISPA	Infeksi Saluran Pernafasan Atas	Upper Respiratory Nasopharynx
JAMALI	Sistem Interkoneksi Jawa-Madura-Bali	Java-Madura-Bali power generation system
JBIC	-	Japan Bank of International Cooperation
JICA	-	Japan International Cooperation Agency
JIS	Standar Industri Jepang	Japanese Industrial Standards
JPY, Yen	Yen	Japanese Yen
K2TA	Kelompok Konservasi Tanah dan Air	Soil and Water Conservation Farmer Group
KBD	Kebun Bibit Desa	Seeding Garden Village
KCI	-	Polassium Chloride
KESBANLINMAS	Badan Kesatuan Bangsa dan Perlingdungan Masyarakat	National Unity and Society Protection Board
KIMPRASWIL	Departemen Pemukiman dan Prasarana Wilayah	Ministry of Housing and Regional Infrastructure
KPH	Kesatuan Pemangkuan Hutan	Forest Administration Unit
KT	Kelompok Tani	Farmers' Group at Village Level
KUD	Koperasi Unit Desa	Village Cooperative Unit
LHKP Wonogiri	Lingkungan Hidup, Kehutanan dan Pertambangan	Forestry Sub-services of Wonogiri Human Environment, Forestry and Mining Services Office
LKMD	Lembaga Ketahanan Masyarakat Desa	Village Social Activities Group, Village Welfare Institution
LPTP	NGO (Lembaga Pengembangan Teknologi Perdesaan)	-
LSM	Lembaga Swadaya Masarahkat	Nongovernmental Organization (NGO)
LWL	Tinggi Muka Air Rendah	Low Water Level
M&E	Pemantauan dan Evaluasi	Monitoring and Evaluation
MOU	Nota Kesepahaman	Memorandum of Understanding
MT I	Musim Tanam I	Cropping Season I
MT II	Musim Tanam II	Cropping Season II
MT III	Musim Tanam III	Cropping Season III
NGO	Lembaga Swadaya Masyarakat	Non Governmental Organization
NHWL	Tinggi Muka Air Normal	Normal High Water Level
NO2	Nitrit	Nitrogen Dioxide
NO3	Nitrat	Nitrogen Trioxide
NTU	-	Nephelometric Turbidity Unit
O&M, O/M	Operasi dan Pemeliharaan	Operation and Maintenance
Otonomi daerah	Otonomi Daerah	-
OECF	-	Overseas Economic Cooperation Fund
OTCA	Lembaga Kerjasama Teknis Luar Negei	Overseas Technical Cooperation Agency
P4K	Pembinaan Peningkatan Pendapatan Petani-Nelayan Kecil	Farmer Groups of Small-Scale Farmers
Pb	-	Lead
PBS	Proyek Bengawan Solo	Bengawan Solo River Basin Development Project
P2AT	Proyek Pengembangan Air Tanah	Groundwater Development Project
P3A, HIPPA	Perkumpulan Petani Pemakai Air, Himpunan Petani	Water User's Association (WUA)
PABBS	Proyek Penyediaan Air Baku Bengawan Solo	Bengawan Solo River Water Supply Project
PBS	Proyek Bengawan Solo	Bengawan Solo River Basin Development Office
PCM	Pertemuan Konsultasi Masyarakat	Public Consaltaiton Meeting
PDAM	Perusahaan Daerah Air Minum	Regional Drinking Water Supply Company
PDAS	Pengelolaan Daerah Aliran sungai	Watershed Management
PDRB	Produk Domestik Regional Bruto	Product Domestic Regional Brutto
Perum	Perusahaan Umum	Public Corporation

Abbreviation (3/3)

Abbreviation	Indonesian	English
PERSEPSI	NGO (Perhimpunan untuk Studi dan Pengembangan Ekonomi dan Sosial)	-
pH	Nilai Keasaman	pH value
PHBM	Pengololaan Hutan Bersama Masyarakat	Community Participated Forest Management
PJP	Pembangunan Jangka Panjang	Twenty-Five Year Long Term Development Plan
PIPWS Bengawan	Proyek Induk Pengembangan Wilayah Sungai Bengawan	Bengawan Solo River Basin Development Office
PJT	Perum Jasa Tirta	Public Water Service Corporation
PKL	Penyuluh Kuhutanan Lapangan	Field Forestry Extension Worker
PKSDABS	Proyek Pengembangan Konservasi Sumber Daya Air Bengawan Solo	Bengawan Solo River Water Resources Conservation Development Project
PLTA Wonogiri	Pusat Listrik Tenaga Air Wonogiri	Wonogiri Power Station
PMF	Banjir Maksimum yang mungkin terjadi	Probable Maximum Flood
PO4	-	Phosphoric Tetroxide
PPL	Penyuluh Pertanian Lapangan	Field Extension Workers
ppm	Seper juta	parts per million
PPTPA	Penitia Pelaksana Tata Pengaturan Air	River Basin Water Resources Management Committee
PRA	Analisa Partisipatori Pedesaan	Participatory Rural Appraisal
PROPENAS	Program Pembangunan National	Five-Year National Development Program
PSAPBBS	Proyek Pengelolaan Sumber Air dan Pengendalian Banjir Bengawan Solo	Bengawan Solo River Water Resources Management and Flood Control Project
PSDA	Pekerjaan Umum Sumber Daya Air	Water Resource Management
PT CMA	PT Citra Mandala Agritrans	-
PTPA	Panitia Tata Pengaturan Air	-
PU	Pekerjaan Umum	Ministry of Public Works
REI	-	Rain Erosivity Index
RENSTRA	Rencana Strategis	Strategic Plan
REPEDA	Rancangan Peraturan Daerah	Annual Plan
Rp.	Rupiah	Indonesian Rupiah
RPH	Resort Pemangkuan Hutan	Field Unit of KPH
RTL	Rencana Tindak Lanjut	Field Technical Planning in Upper Solo Watershed Protection Project in Wonogiri Watershed
RTT	Rencana Teknis Tahunan	Yearly Technical Planning in Upper Solo Watershed Protection Project in Wonogiri Watershed
RUTRK-RDTRK	Rencana Umum/Detail tata Ruang Kota	General City Site Plan, Detailed City Site Plan
RWL	Muka Air Waduk	Reservoir Water Level
SBRLKT	Sub Balai Rehabilitasi Lahan dan Konservasi Tanah	Sub Unit for Land Rehabilitation and Soil Conservation
SCF	Faktor Konversi Standar	Standard Conversion Factor
SDR	Nisbah Pengantaran Sedimen	Sediment Delivery Ratio
SEA	Penilaian Lingkungan Strategis	Strategic Environmental Assessment
SFC	Perum Perhutani	State Forest Corporation
SHFD	Debit banjir tertinggi standar	Standard Highest Flood Discharge
SI	-	Stress Index
SS	Padatan Tersuspensi	Suspended Solid
SWOT	Kekuatan, Kelemahan, Kesempatan, Ancaman	Strength, Weakness, Opportunity, Threat
TDS	Total Padatan Terlarut	Total Dissolved Solid
TIU	Unit Pelaksana Teknis	Technical Implementation Unit
TOR	Kerangka Acuan Kerja	Terms of Reference
TSS	Total Padatan Tersuspensi	Total Suspended Solid
UKL	Upaya Kelola Lingkungan	Environmental Management Efforts
UNDP/FAO	Badan Pangan Dunia	United Nations Development Programme /Food and Agriculture Organization
UPL	Upaya Pemantau Lingkungan	Environmental Monitoring Efforts
UPR	Unit Pembenihan Rakyat	Community Nursery Unit
UPTD	Unit Pelaksana Teknis Daerah	Local Technical Implementation Unit
US$, USD	Dollar Amerika	US dollar
USAID	-	US Agency for International Development
USLE	Persamaan Kehilangan Tanah Umum	Universal Soil Loss Equation
VAP	Rencana Kerja Desa	Village Action Plan
WC3	Komite Koordinasi Konservasi DAS	Watershed Conservation Coordinating Committee
WKPP	Wilayah Kerja Penyuluhan Pertanian	Working Area of Agricultural Extension
WM	Pengelolaan Daerah Aliran sungai (DAS)	Watershed Management
WRM	Pengelolaan Sumber Daya Air (SDA)	Water Resource Management
Zn	Seng	Zinc

Part I : Master Plan Study

1 INTRODUCTION

1.1 Background of the Study

The Wonogiri multipurpose dam is the only large dam on the mainstream of the Bengawan Solo River, which is the largest river in the Java with a catchment area of around 16,100 km^2 and a length of about 600 km. Since impoundment of the Wonogiri reservoir on December 29, 1980, the Wonogiri dam has much contributed to social welfare in the basin and has greatly benefited the country in both regional and national economic development.

The Wonogiri reservoir has been filled with sediments. Poor land use of its watershed and intensive farming of annual crops using poor practices on the highly erosive and steep-sloped uplands as well as highly populated and intensely farmed areas are the main causes of the sedimentation of the Wonogiri reservoir. It could be said that, without any countermeasure to the sedimentation problem, the Wonogiri reservoir would, in the near future, lose its functions for water supply and flood control because of decrease of the storage capacity. In particular, sediment deposits at and around the intake structure have seriously affected its performance. In order to recover the storage capacity of the reservoir, fundamental permanent countermeasures should be established and implemented.

View of the Wonogiri Dam

1.2 Objectives of the Study

The objectives of the Study are to:

i) Formulate a master plan for sustainable countermeasures for sedimentation problems in the Wonogiri Multipurpose Dam Reservoir,

ii) Conduct a feasibility study of the selected priority project(s), and

iii) Transfer technology to counterpart personnel in the course of the Study.

The goals after achievement of the above objectives are to:

i) Implement the project to be proposed under the Study to secure the long-term ability of the reservoir to supply water for irrigation and hydropower generation, and

ii) Provide solutions and technical approaches for reservoir sedimentation problems which are increasing concern in Indonesia.

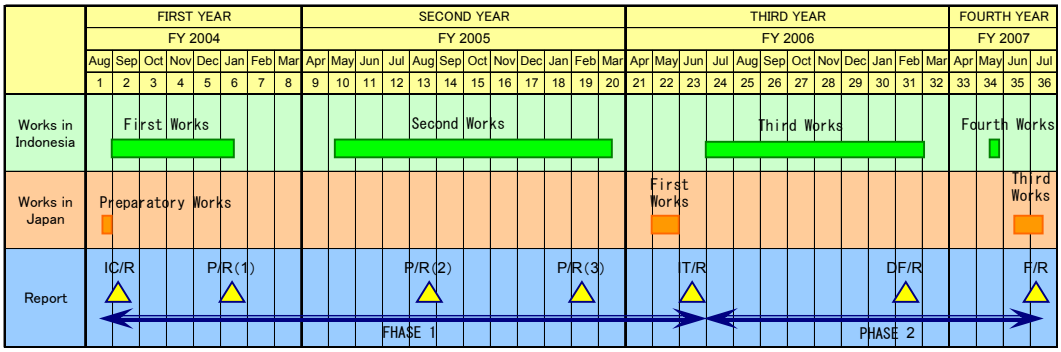
1.3 Study Area

The Study Area covers i) the entire catchment of the Wonogiri dam (reservoir area of 90 km^2 and remaining catchment area of 1,260 km^2), and ii) downstream reaches of the

Bengawan Solo River from the Wonogiri dam to the confluence with the Madiun River.

1.4 Scope and Schedule of the Study

The Study was carried out in accordance with the Scope of Works which was agreed between DGWR and JICA Preparatory Study Team on March 2004. The Study was divided into two phases, namely Phase I: Formulation of Master Plan and Phase II: Feasibility Study on the Selected Priority Project(s). The Study was scheduled to be carried out over 36 months starting in August 2004 and ending in July 2007.



Source: JICA Study Team

Figure 1 Overall Schedule of the Study

1.5 Study Organization

The Directorate General of Water Resources (DGWR) of the Ministry of Public Works at national level and the Bengawan Solo River Basin Development Project（PBS）at the site level act as the counterpart agencies. The Steering Committee and Technical Working Groups have been organized, composed of central and regional government agencies concerned with the Study.

2 PRESENT CONDITION OF THE STUDY AREA

2.1 Socio-Economic Condition

(1) Development Plans

The second Twenty-Five Year Long Term Development Plan (PJP II 1994－2019) and the second Five-Year National Development Program (PROPENAS 2005-2009) have been implemented by the Indonesian Government. The target during 5 years in 2005-2009 includes average economic growth rate of 7.6% by 2009. Kabupaten Wonogiri follows the regional development plan (RENSTRA 2006-2010). It includes some projects related to soil conservation by relevant agencies. This plan translates into the annual plan (REPEDA).

(2) Population

The population as of 2004 was 1,007 thousand in the Wonogiri watershed area of kabupaten Wonogiri and 3,632 thousand in the Wonogiri irrigated area of kabupaten Karanganyar, Sukoharjo, Klaten, and Sragen in Central Java Province. The population density as of 2004 was 553 person per km^2 in the Wonogiri watershed, which was the least densely populated area in Central Java Province.

(3) Economic Performance

Overall growth is positive and rising, although below Indonesia's long-term average. The

GDP per capita was estimated at Rp.7,946,000 in 2005. The government is projecting 6.6% average growth between years 2005-2009. The year-to-year inflation was at 17.03%; the core inflation (excluding volatile prices, such as food, and regulated prices, such as utility rates) was 9.68% in January 2006.

(4) Economic Structure in the Wonogiri Dam Watershed

The Wonogiri dam watershed area is still heavily dependant on agriculture, both in terms of GRDP (50% share) and employment (65% of labor force). The average of gross annual farm income was Rp.7.6 million in the Wonogiri irrigated area in 2002 and about Rp.5 million, including Rp.2.2 million from on-farm activities, in the Wonogiri dam watershed area in 2003. More than 246 thousand people or about 25% of the total population had desperate income of less than Rp.102,900 per month in 2002 in the Wonogiri dam watershed. In the downstream area of the Wonogiri dam, no large floods have occurred since completion of the dam. The Wonogiri dam has contributed to the stabilization of people's livelihood as well as social welfare. The Wonogiri dam has also provided the benefit for the Wonogiri irrigation area by means of increase of paddy production. At present, the Wonogiri dam watershed area is lagging behind the downstream area, of the Wonogiri dam, although not benefiting from the dam excluding electric power supply. It is strongly expected that the watershed conservation plan to be formulated by the current Study would focus on the increase of agricultural productivity and income.

Unemployment is still one of the main socioeconomic problems in the Wonogiri watershed area. According to BAPPEDA Wonogiri, the number of unemployed people in kabupaten Wonogiri is increasing every year and there were 14,345 unemployed in 1997 and 57,380 in 2000. The lack of employment opportunities in kabupaten Wonogiri is the cause of the extensive out-migration from the area.

2.2 Topography and Geology

(1) Topography

The Bengawan Solo River is the largest river in Java with a catchment area of around 16,100 km^2 and a length of about 600 km. The Bengawan Solo originates on southwest slope of G. Rahtawu in Tertiary Volcanic mountainous area and flows westward along the series of mountains. The Solo River generally takes a northward direction, receiving the Alang River, Temon River, Tirtomoyo River and Keduang River immediately upstream of the Wonogiri dam. Downstream of the Wonogiri dam, the Solo River clockwise around Mt. Lawu and flows eastward to Ngawi City after running through the alluvial plains of Surakarta City and Sragen City. After the confluence with the Madiun River, the Solo River flows northward to Cepu City before changing direction to the east-northeast and pouring into the Jawa Sea, about 30 km to the northwest of Surabaya City.

(2) Geology

The Study Area is located in the southwestern foothill of Mt. Lawu and situated around the boundary between Solo Zone and Southern Mountains Zone. These geomorphic zones of Java form belts extending in an east to west direction that extends further eastwards to Bali Island.

The Wonogiri dam and Reservoir area is underlain by volcanic breccia, tuff breccia, tuffaceous sandstone, calcareous sand and limestone of Miocene age belonging to the Southern Mountains Zone. Quaternary volcanic products of Solo Zone are distributed on the right bank of the Wonogiri dam and the Keduang River.

2.3 Meteorology and Hydrology

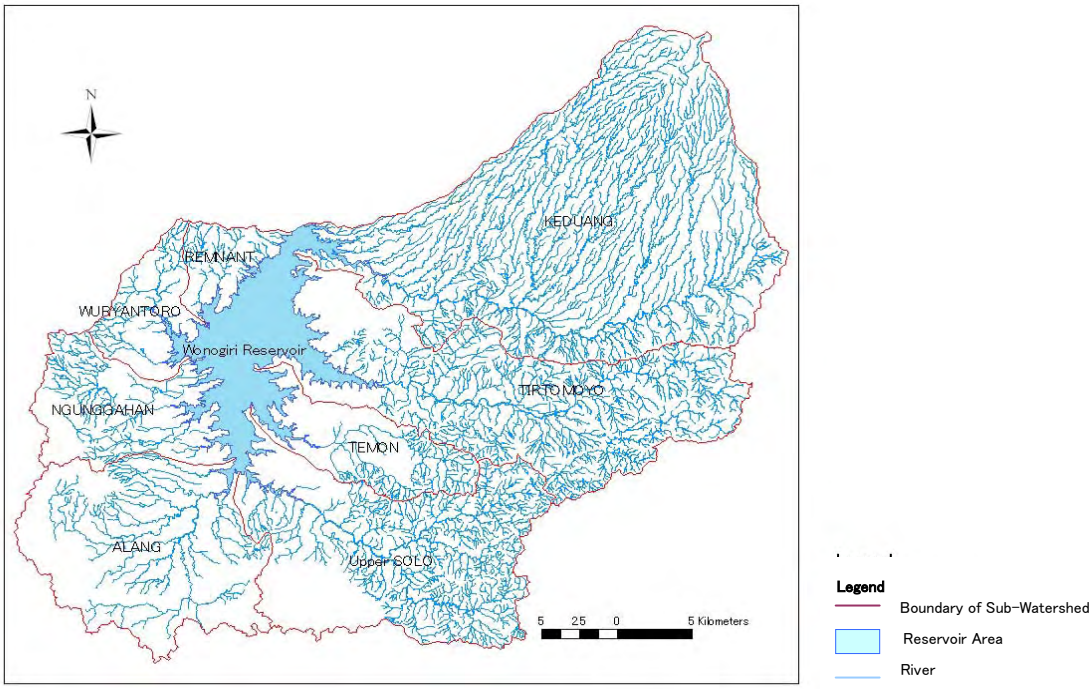
(1) Basin Rainfall

Mean annual rainfall of the Wonogiri catchment is around 1,990 mm based on the data at 36 stations between 1975 and 2005. Annual mean daily evaporation rate at the Wonogiri dam site is 5.3 mm/day. Evaporation in the dry season of July to November is relatively higher than that in the wet season of December to June.

(2) Inflow into the Wonogiri Reservoir

Hourly reservoir inflows from five major tributaries in 1993-2005 were estimated based on the reservoir operating records and simulated hourly discharges.

The Wonogiri reservoir experienced large-scale floods with peak discharges exceeding 2,000 m^3/s. One such large-scale flood occurred immediately after completion in 1980 and the largest flood peak discharge was recorded at 2,880 m^3/s on February 5, 1988, followed by the 1985 flood of 2,720 m^3/s.



Source: JICA Study Team

Figure 2 Watershed of Wonogiri Dam Catchment Area

Table 1 Estimated Mean Monthly Dam Inflow from 5 Major Tributaries and Remnant Area (Nov. 1993 – Jun. 2005)

(Unit: 10^6 m^3)

Tributary	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Annual
Keduang	22.9	38.7	50.0	81.1	82.6	44.6	10.7	7.5	5.0	2.2	3.2	5.9	354.3
Tirtomoyo	11.6	26.7	29.9	49.0	48.5	26.9	6.3	4.4	3.4	0.6	0.3	2.8	210.4
Temon	2.2	5.0	6.7	10.3	9.7	5.1	1.1	0.8	0.5	0.0	0.1	0.5	41.9
Solo	8.1	17.7	22.2	36.0	34.9	16.4	3.8	3.0	2.0	0.2	0.3	1.8	146.4
Alang	7.8	15.2	18.7	27.4	30.0	12.3	3.0	2.4	1.0	0.1	0.2	1.7	119.8
Remnant Area	7.0	13.6	16.5	25.5	25.0	13.7	3.5	2.5	1.7	0.4	0.6	1.8	111.7
Whole Basin	**59.6**	**116.9**	**144.1**	**229.3**	**230.6**	**119.0**	**28.3**	**20.5**	**13.6**	**3.6**	**4.7**	**14.3**	**984.4**

Note: Based on the hydrological data from November 1993 to June 2006.
Source: JICA Study Team

2.4 Soils and Land Use

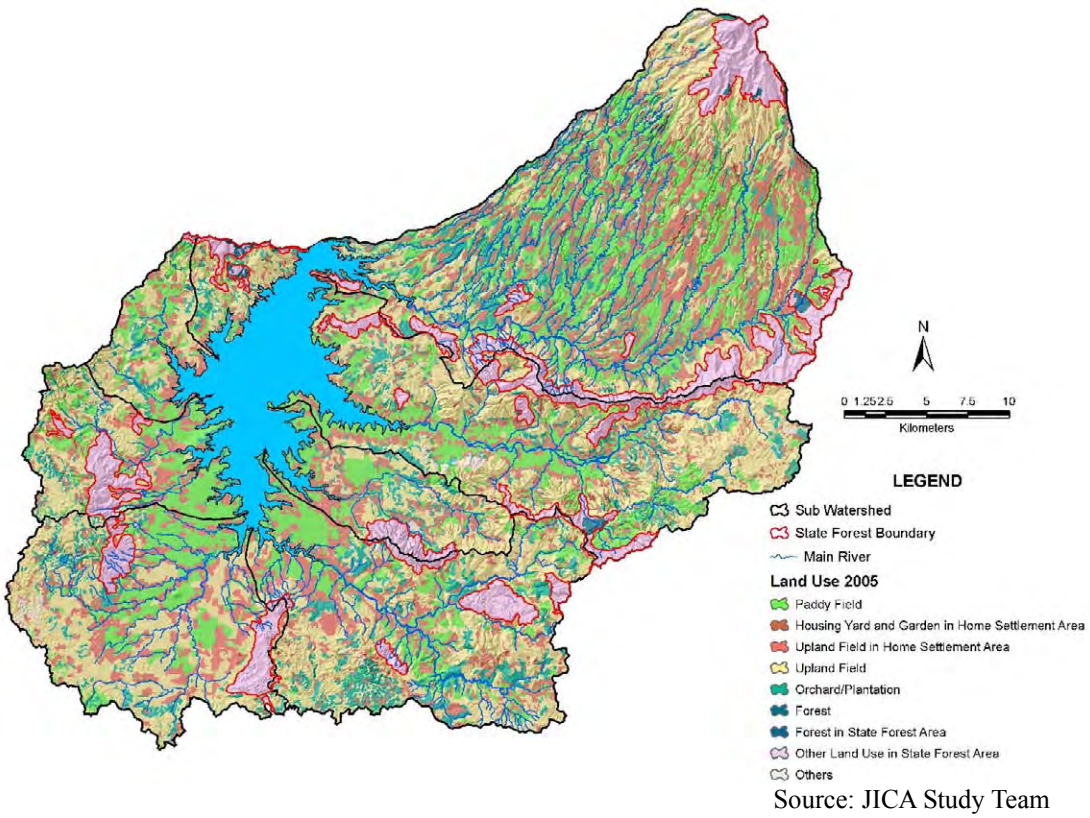
(1) Soils

The soils distributed in the Wonogiri watershed are classified into four soil types of Mediteran (42% of the whole area), Litosol (25%), Latosol (12%) and Grumusol (21%). All of these soils are fine textured (clay to silty clay) and their soil fertility is generally poor, being susceptible to water erosion. Among them, Mediteran and Latosol are categorized as highly fragile to surface soil erosion.

(2) Land Use

Low-lying flat lands in the Wonogiri dam watershed have been widely developed for paddy cultivation. Upland fields with an elevation of 200-1,000 m have been also developed for agricultural uses. Major portion of hilly areas has been cultivated almost up to the ridge of hilly areas. Under the current Study, the current land use was confirmed through the field survey and the topographical maps by BAKOSURTANAL as well as the interpretation of spot satellite images in 2003. The current land use in the Wonogiri dam watershed is shown in Figure 3 and summarized in Table 2.

As shown in this table, it was appeared that as of 2003 about 90% of the watershed comprises paddy field, home settlement area, upland field and orchard/plantations. Forests cover less than 1% of the dam watershed. Since the completion of Wonogiri dam in 1981, forest areas have been drastically decreased and upland fields have been increased. It is considered that such changes of land uses in the dam watershed might be one of main causes for the drastic increase of soil erosions within the dam watershed.



Source: JICA Study Team

Figure 3 Land Use Map in the Wonogiri Watershed

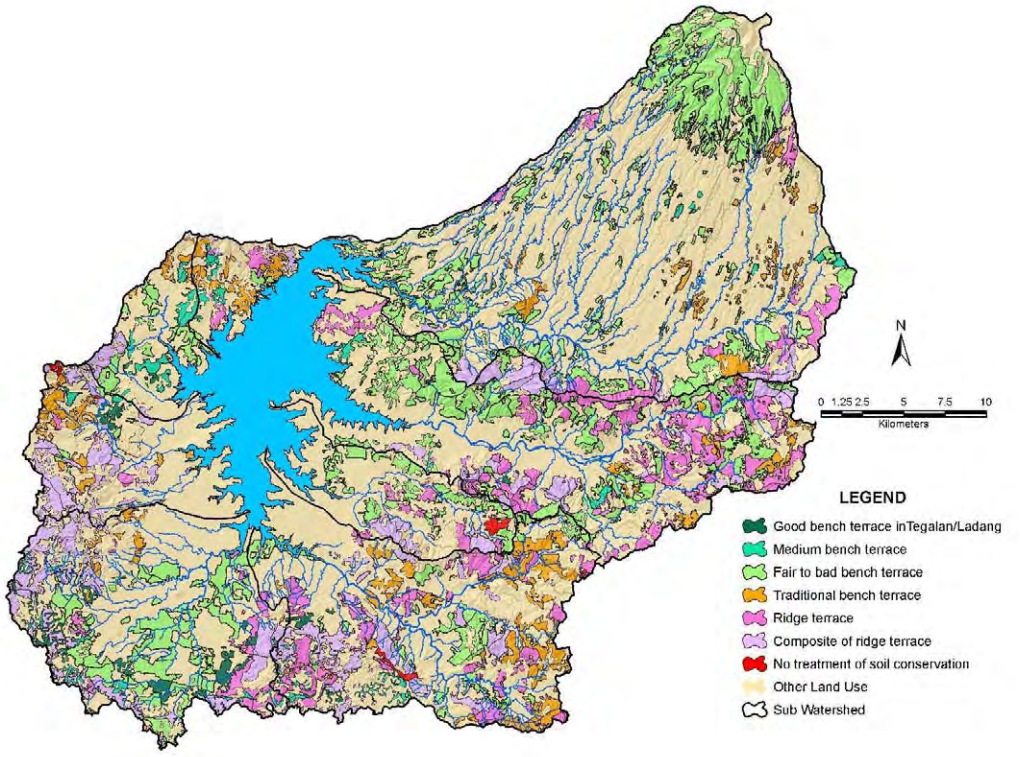
Table 2 Present Land Use of Wonogiri Watershed

Land use	Area (ha)	Ratio (%)
(1) Paddy field	30,495	24.5
(2) Home Settlement Area	26,764	21.6
- Housing yard and garden	*7,289*	*5.9*
- Upland in settlement area	*19,475*	*15.7*
(3) Upland field	39,761	32.0
(4) Orchard/ Plantation	12,867	10.3
(5) Forest	281	0.2
(6) State forest	12,779	10.3
- Forest	*385*	*0.3*
- Other land use (areas covered with young trees reforested and upland crops in State forest)	*12,394*	*10.0*
(7) Others (lakes, roads, rivers and other use)	1,384	1.1
Total	**124,331**	**100.0**

Source: Results of JICA field survey and interpretation of Satellite image (2003), and topographical maps of BAKOSURTANAL

(3) Terrace Conditions

The terrace conditions in the Wonogiri watershed is broadly classified into five terrace types of bench terrace (48%), traditional terrace (11%), ridge terrace (19%), no-terrace (21%) and composite (1%) (land of composite condition of ridge terrace and no-terrace). Most of the terraces are categorized into poorly maintained or not maintained. The improvement of such terraces will be essential for the conservation of the Wonogiri watershed.



Source : JICA Study Team

Figure 4 Terrace Condition in Uplands in the Wonogiri Watershed

2.5 Agriculture

The agriculture sector is the largest economic sector in Wonogiri and contributed 52% of the GRDP in 2002. The crop sub-sector is a leading sub-sector accounting for about 85% of the sector GRDP. The crop sub-sector is characterized by paddy field (wet land farming) food crops and upland (dry land farming) food, horticulture and estate crops. Wet land farming is practiced in paddy fields covering low-lying areas and in rice terraces constructed on sloping land. The dry land farming is extensively practiced in terraced fields constructed on moderate to steep sloping land. The primary crop in the wet land is paddy (wet land rice), while in upland, diversified seasonal crops and perennial crops are produced.

2.6 Watershed Management

Community based forestry development is ongoing under GERHAN (National Movement for Forest and Land Rehabilitation) program. GERHAN has been planned for the period of 5 years from 2003 to 2007 with the national overall target areas of 3 million ha in 372 kabupaten/cities. The Wonogiri dam watershed is one of the main targets of the national project for watershed conservation. The national budget under GERHAN allocated for the Wonogiri was Rp.8,950 million in 2003 and Rp.11,283 million in 2004. These programs were applied to about 11,000 ha of the people's forest in 2004.

3. CURRENT STATUS OF WONOGIRI RESERVOIR SEDIMENTATION

3.1 Wonogiri Multipurpose Dam

(1) Principal Feature of Wonogiri Multipurpose Dam

The principal features of the Wonogiri dam and reservoir are summarized in Table 3 below, and the allocated storage capacities and water levels thereof are also shown in Figure 5.

(2) Operation of Wonogiri Reservoir

1) Reservoir Operation

Mean annual inflow volume into the Wonogiri reservoir was approximately 1.23 billion m^3 in 1983-2005, and mean annual water release from the spillway (spill-out) was around 18% of the total outflow volume or 210 million m^3. Mean monthly inflow is the highest in February at 110.8 m^3/s (268 million m^3), and in August becomes at its lowest at 2.3 m^3/s (6 million m^3).

2) Flood Control

For flood control, the reservoir water level is controlled not to exceed the Control Water Level (El.135.3 m) during the flood season to eliminate the possibility of the PMF overtopping the dam crest. The reservoir provides 220 million m^3 of flood control capacity to regulate the standard highest flood discharge with peak discharge of 4,000 m^3/s to the regular outflow of 400 m^3/s.

3) Wonogiri Irrigation System

Water supply to the Wonogiri irrigation system was commenced immediately after completion of the Wonogiri Irrigation Project in 1986. Irrigation water is taken from the Colo intake weir located about 13 km downstream of the Wonogiri dam. At present, the irrigation area has been extended from 24,000 ha in the original plan to 29,330 ha where triple or double crop farming is being practiced. Mean monthly

discharges at the Colo weir in 1986-2005 ranged from 22 to 30 m^3/s in the dry season.

4) Power Generation at Wonogiri Hydropower Station

The powerhouse is located just downstream of the Wonogiri dam. It accommodates the generating equipment with an installed capacity of 12.4 MW to generate annual energy of 55,000 MWh. The maximum discharge for power generation is 75 m^3/s.

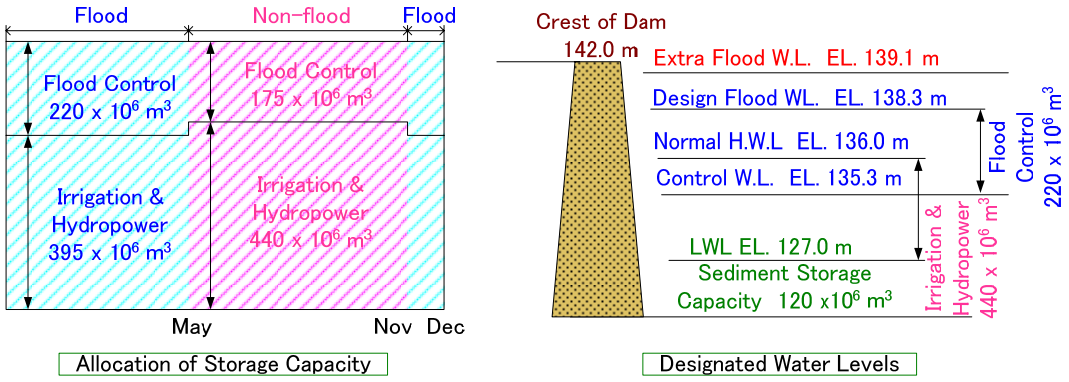
Table 3 Principal Features of Wonogiri Multipurpose Dam and Reservoir

Dam type	Rockfilll	Normal High Water Level	EL. 136.0 m
Dam height	40 m	Design Flood Water Level	EL. 138.3 m
Crest length	830 m	Extra Flood Water Level	EL. 139.1 m
Embankment volume	1,223,300 m^3	Spillway (Radial gate)	7.5 m x 7.8 m x 4 nos.
Catchment area	1,350 km^2	Crest height of dam	EL. 142.0 m
Reservoir area	90 km^2	Flood inflow discharge (around 60-year flood)	4,000 m^3/s
Gross storage capacity	735 x 10^6 m^3	Flood outflow discharge	400 m^3/s
Active storage capacity	615 x 10^6 m^3	Design flood discharge (100-year flood)	5,100 m^3/s
Flood control storage capacity	220 x 10^6 m^3	PMF	9,600 m^3/s
Irrigation & hydro power storage capacity	440 x 10^6 m^3	Installed capacity	12.4 MW
Sediment storage capacity	120 x 10^6 m^3	Design head	20.4 m
Sediment deposit level	EL. 127.0 m	Max. discharge	75 m^3/s
Control water level during flood season	EL. 135.3 m	Annual energy output	50,000 MWh

Source: PBS

(3) Garbage Problems at Intake

Considerable quantity of garbage washes into the intake forebay area at the beginning of the wet season. Partial blockage of the power intake by garbage occurs. The garbage consists of the vegetative residue of cassava, maize, etc. and the household wastes (vinyl, plastic, etc.). It is confirmed that all of the garbage comes from the Keduang River. For approximately 20 days in every wet season, the intake trash racks are blocked by the garbage causing an abrupt increase of the hydraulic head loss at the intake. When the loss abruptly becomes 1.5 m, the turbine should be shut down. The trash racks are cleaned by divers. As the channel of Keduang River is formed over the sediment deposits in front of the dam (see the photo attached at the beginning of this report), garbage from the Keduang River is likely to be conveyed near the intake at the beginning of the wet season.



Source: PBS

Figure 5 Allocation of Storage Capacity and Water Levels of Wonogiri Dam

3.2 Current Status of the Wonogiri Reservoir Sedimentation

(1) Previous Monitoring Studies on the Wonogiri Reservoir Sedimentation

A number of studies to evaluate the reservoir sedimentation have been carried out. Sedimentation rates estimated by the previous studies were 15.6 million m^3/year in 1980-1988 and 18.5 million m^3/year in 1981-1993, etc. The Study has concluded that accuracy of estimation by the previous studies was low.

(2) Current Status of the Wonogiri Reservoir Sedimentation

An echo sounding survey with GPS was conducted for the Wonogiri reservoir over two periods from October to November 2004 (before entering the wet season) and June to July 2005 (after the wet season) to clarify current status of the sedimentation as well as the incremental sediment deposit in the wet season in 2004/2005. Based on the results of the above reservoir survey as well as topographical maps before construction of the dam, contour mapping of the reservoir bed was carried out for the years of 1980 (before construction of the dam), 2004 and 2005. Then elevation-area-capacity relationships for the Wonogiri reservoir were estimated by using the DEM (10 x 10 m meshes totally around 900,000 meshes).

By using the above survey results and the contour mappings of the reservoir in 1980 and 1993, the capacity loss for each storage zone from 1980 to 2005 is summarized below.

Table 4 Loss of Capacity of Wonogiri Reservoir by Storage Zone between 1980 and 2005

Reservoir Zone	Reservoir Capacity (10^6 m^3)		Capacity Lost due to Sedimentation	
	1980	2005	Value (10^6 m^3)	of Original (%)
Flood Control Storage (El. 135.3 – 138.3 m)	232	230	2	0.9
Water Use Storage (El. 127.0 – 136.0 m)	433	375	58	13.4
Dead Storage (below El. 127.0 m)	114	58	56	49.1

Note: Reservoir capacity in 1980 was re-estimated based on the DEM. As shown in Figure 5, the flood control storage capacity overlaps the water use storage capacity in the range of EL. 135.3 m – EL. 136.0 m.
Source: JICA Study Team

i) As of 2005, total reservoir storage capacity is approximately 114 million m^3 or 16% of the original gross capacity of 735 million m^3 was lost due to sedimentation. The average annual rate of reservoir capacity loss is therefore around 0.64%/year (=16%/25 years).

ii) In the sediment storage zone, a volume of 56 million m^3 in total or 49.1% of the

original capacity has been lost.

iii) The effective storage zone has been reduced from 433 to 375 million m^3. The volume lost is 58 million m^3 or equivalent to 13.4% of the original gross capacity. The current effective capacity is round 86.6% of the original capacity.

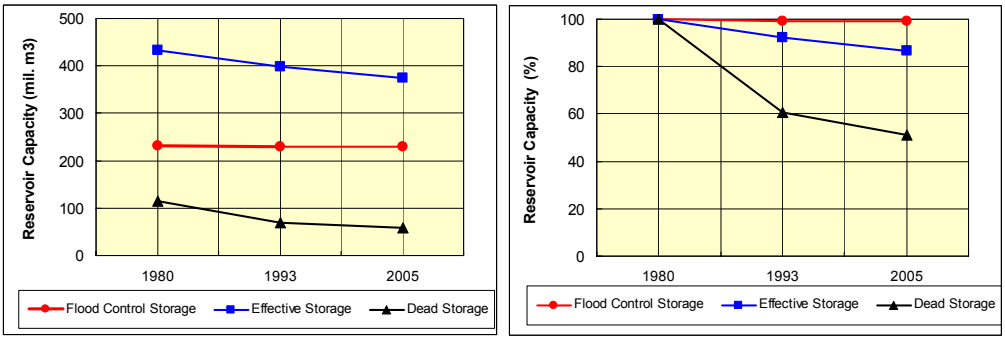
iv) There is almost no change in the flood control storage zone, because the loss of capacity is only 0.9% of the original capacity. At moment, dam safety against PMF is secured under the current reservoir condition (this is secured under the observance of the reservoir operation rule).

(3) Historical Change of Reservoir Sedimentation

The historical change of reservoir capacity in each storage zone is illustrated in Figure 6. The past reservoir survey result in 1993 was re-evaluated based on the new contour mapping. The elevation-area-capacity relationships in 1980, 1993 and 2005 are shown in Figure 7. The average annual sedimentation rates are around 5.7 million m^3/year in 1981-1993 and 4.5 million m^3/year in 1981-2005. The sedimentation rate after 1993 has become remarkably smaller. The sedimentation volume in the wet season in 2004/2005 that was surveyed under the Study was around 2.3 million m^3. The major reason for such remarkable increase of average annual sedimentation rate after 1993 might be:

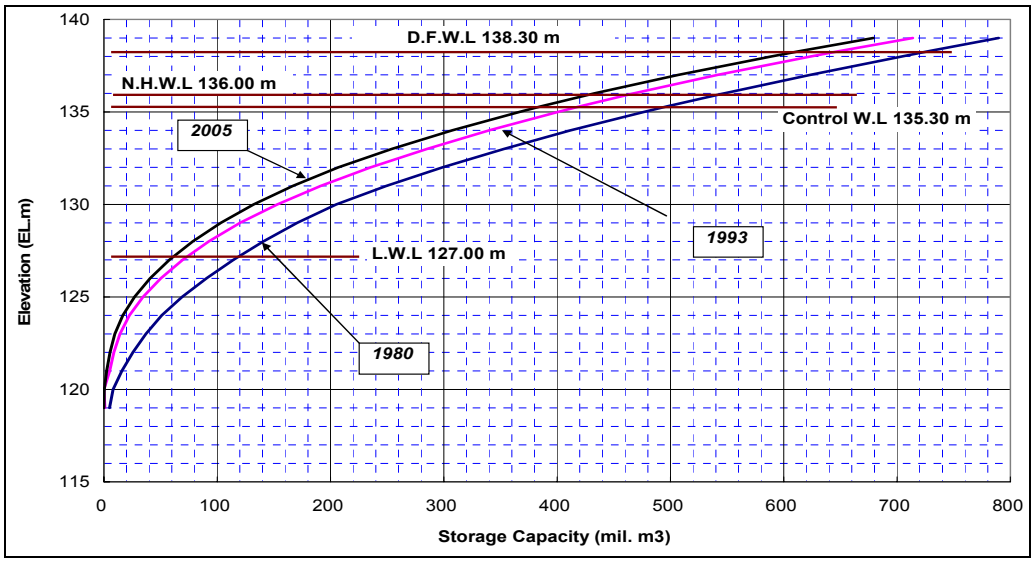
i) Many large floods that convey large sediment into the reservoir had occurred in 1980s after the completion of Wonogiri dam, and

ii) Reduced soil erosions due to the effects of the watershed conservation project in the Wonogiri dam catchment by IBRD in 1989-1994.



Source: JICA Study Team

Figure 6 Change of Wonogiri Reservoir Capacity by Storage Zone between 1980 and 2005



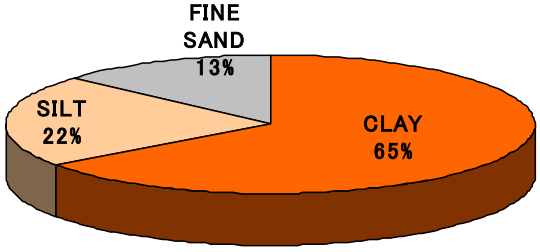
Source: JICA Study Team

Figure 7 Wonogiri Reservoir Elevation-Capacity Curves in 1980, 1993 and 2005

3.3 Geotechnical Conditions of the Wonogiri Reservoir

Core drilling was performed at 12 points in the Wonogiri reservoir in 2004. They confirmed that the sediment deposited in the Wonogiri reservoir consists of very fine grained materials (wash load) making up 87% of total volume as presented in the Figure 8 below.

The average bulk dry density of undisturbed samples taken from three (3) layers of 0.2-0.4 m, 0.6-0.8 m and 1.5-1.7 m in depth was 1.063 kg/m^3 corresponding to the void ratio of 59%. The average bulk wet density was 1.639 kg/m^3. Most of the samples were classified as CH in consistency.



Source: JICA Study Team

Figure 8 Percentage of Sediments Composition in the Wonogiri Reservoir

3.4 Monitoring on Sedimentation in front of Intake

The intake structure has been seriously affected by sediment inflowing from the Keduang River. PBS has been periodically monitoring sediment levels in front of the intake. It appears that opening space between the sediment level and the top of the intake was about 3.3 m in July 2005, while total opening space is 11.0 m. Sediment levels were stable for the dry season. Sediment level rose by 2.1 m for the wet season from October 2004 to July 2005.

4. EROSION SOURCES AND SEDIMENT YIELDS FROM WONOGIRI WATERSHED

4.1 Erosion Sources of Sediment Deposits in the Wonogiri Reservoir

Erosion sources for the sediment deposits in the Wonogiri reservoir were identified according to the visible erosion sites in the Wonogiri catchment; i) soil erosion of land surface, ii) gully erosion, iii) landslide (slope failure), iv) riverbank erosion, and v) slope erosion of the roadside.

4.2 Sediment Yield from Erosions of Gully and Landslide

The field investigation identified in total 71 locations of gully erosion and 25 landslide sites over the catchment. Gullies are intensively developing on the mountain slope areas of the Keduang River. The largest gully observed in this watershed is 5 - 8 m high, 15 - 20 m wide and 200 m long. Relatively large landslides were identified in the Tirtomoyo River. Landslide high potential zones are probably restricted in the area subject to hydrothermal alteration due to volcanic intrusions.

Sediment yields into the Wonogiri reservoir were estimated at around 52,000 m^3/year from gullies and 10,000 m^3/year from landslide.

4.3 Sediment Yield from Erosions of Riverbank and Roadside Slope

Progressing bank erosions occur mainly at; i) meandering stretch in the main stream, ii) confluence points of small tributaries, and iii) downstream banks of river structures such as bridges and irrigation intakes. Most active bank erosion is progressing in the Alang River and relatively small in the other basins.

The roadside slope erosions are distributed throughout the entire basin, especially on the steeper slope in the excavated section.

The total length of the existing riverbank and roadside slope erosions over the catchment were 25,860 m and 36,500 m respectively. Erosion volumes were derived from the field erosion rates by BP2TPDAS (Watershed Management Technology Center of Surakarta, Ministry of Forestry) in 1995. Sediment yield from riverbanks was estimated as 88,940 m^3/year applying an erosion rate of 3.44 m^3/m, and for roadside slope erosion, 7,300 m^3 applying a rate of 0.20 m^3/m.

4.4 Sediment Yield from Soil Erosion of Land Surface

Surface soil erosions from cultivated land are intensive over the catchment. Soil erosions are estimated by using the Universal Soil Loss Equation (USLE), which is the method most widely used to predict long-term rates of rill erosion from farm units of different management practices.

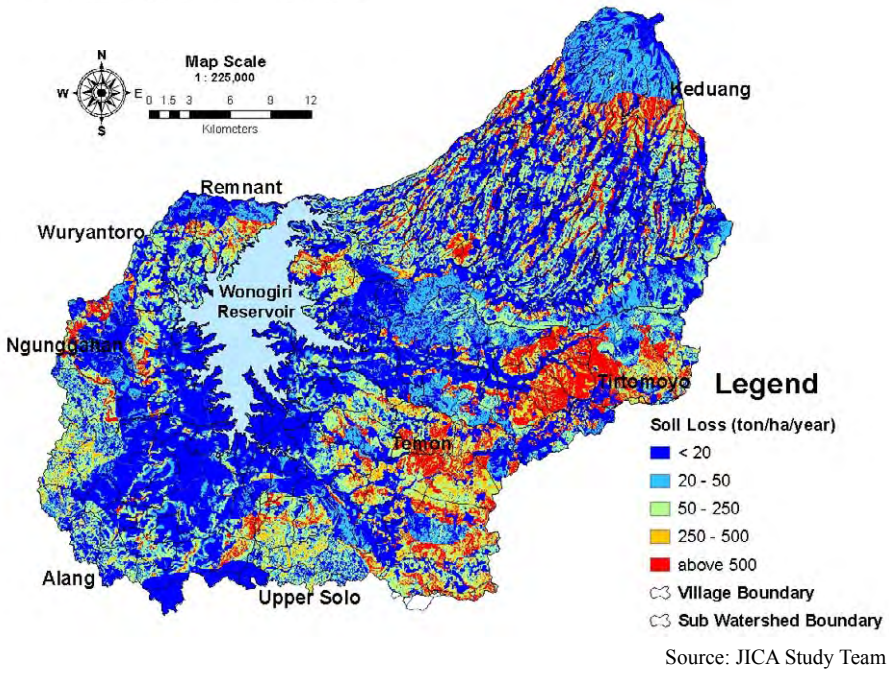
The USLE is an empirical multiple-regression-type equation which incorporates the parameters that influence erosion, and is expressed by the following equation:

$$A=R \cdot K \cdot L \cdot S \cdot C \cdot P$$

where, A: Average annual soil loss
R: Rainfall erosivity factor
K: Soil erodibility factor
L: Slope length factor
S: Slope steepness factor
C: Crop management factor

P: Support practice factor

Annual average soil loss was estimated at about 17.3 million tons/year or 139 tons/year/ha. Annual average soil loss/ha in the Wonogiri dam watershed is shown in the following Figure 9.



Source: JICA Study Team

Figure 9 Annual Average Soil Loss per Hectare in Wonogiri Watershed

4.5 Annual Sediment Yield to Wonogiri Reservoir

(1) Sediment Delivery Ratio

Most of the eroded sediment from a distant source will have numerous opportunities for re-deposition before the watershed outlet. The ratio between the erosion rate and sediment yield is the "sediment delivery ratio (SDR)".

Under the Study, the SDR for soil erosion from the land surface was extrapolated by using the measured sedimentation volume in the Wonogiri reservoir, which was directly surveyed in the Study. SDRs for each main tributary are summarized in the table below.

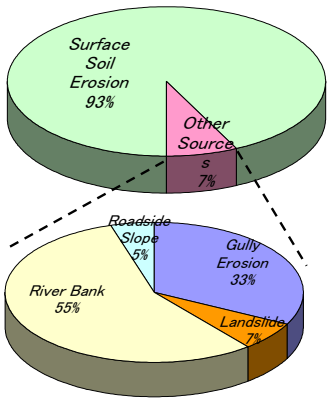


Figure 10 Source of Sediment Deposits in Wonogiri Reservoir

Table 5 Sediment Delivery Ratios in the Wonogiri Dam Watershed

Sub River System	Kuduang	Tirtomoyo	Temon	Upper Solo	Alang	Total
SDR (%)	23.6	10.4	6.7	16.5	32.9	18.1

Source : JICA Study Team

(2) Annual Sediment Yield from Erosions of Gully, Landslides, Riverbank and Roadside Slope

Average annual sediment yield into the Wonogiri reservoir in 1993-2004 was 3.18 million m^3. The dominant erosion source was soil erosion from the surface of the land. Its volume was 93% of the total, while sediment yields from other sources was only 7%. Under the

Study, the bulk density of source materials is assumed to be 1.6 ton /m^3 with a void ratio of 40%.

Table 6 Annual Sediment Yield into the Wonogiri Reservoir Classified by Source and River

(Unit : m^3/year)

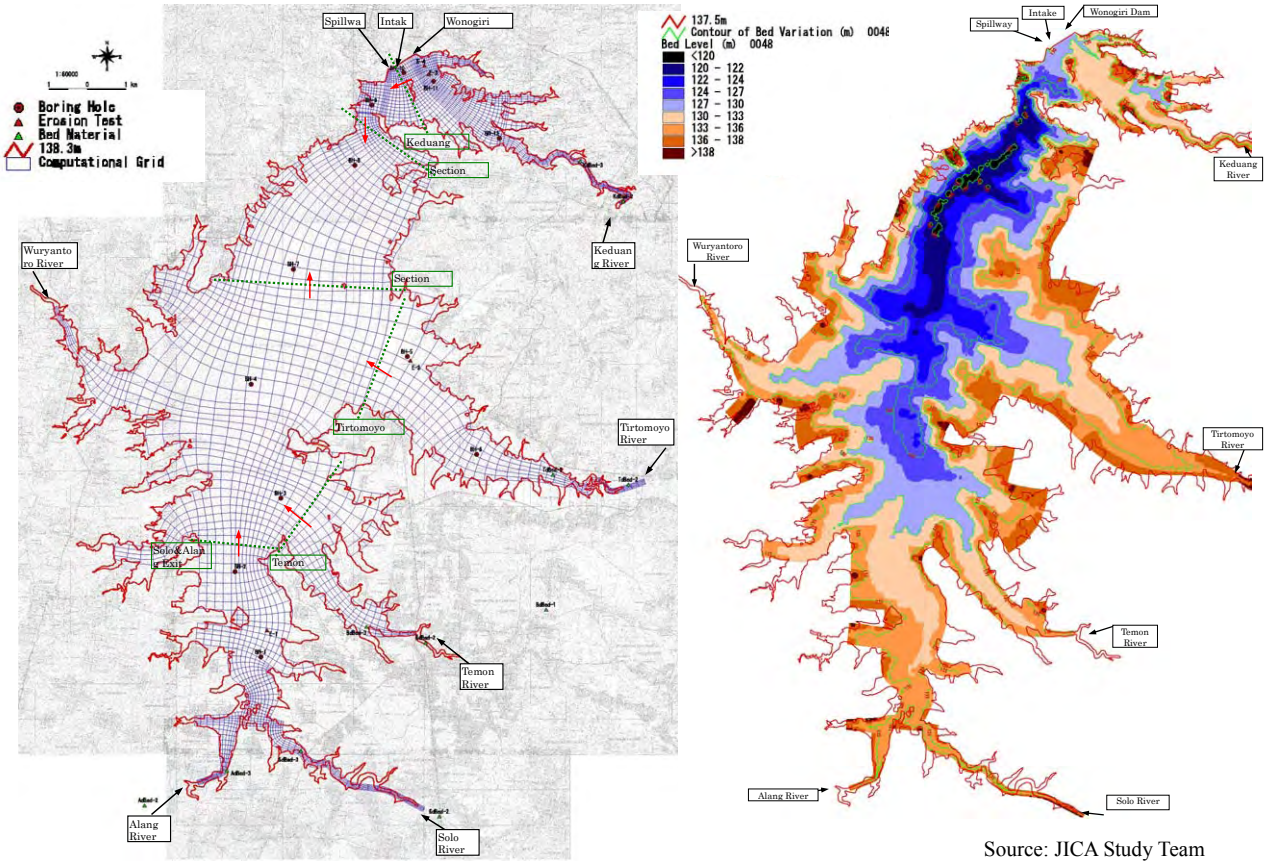
River System	Gully Erosion	Landslide	Riverbank	Roadside Slope	Surface Soil Erosion	Total
Kuduang	67,880	2,930	9,780	3,690	1,134,300	1,218,580
Tirtomoyo	90	11,730	19,760	2,480	469,700	503,760
Temon	30	0	11,350	600	61,000	72,980
Upper Solo	220	440	11,040	1,990	591,300	604,990
Alang	7,330	0	66,620	730	326,600	401,280
Others	0	0	11,850	1,170	363,900	376,920
Total	75,550	15,100	130,400	10,660	2,946,800	3,178,510

Source: JICA Study Team

5. RESERVOIR SEDIMENTATION ANALYSIS

5.1 Reservoir Sedimentation Analysis Model

A depth-integrated two-dimensional numerical model, NKhydro2D sediment transport model was employed to analyze the flow condition and potential for sedimentation in the Wonogiri reservoir. The model is based on a boundary-fitted and numerically generated orthogonal curvilinear coordinate system. The total number of grids was about 3,700 and the grid size was about 3 - 330 m The finer grids were set in area of the inflow river and near the Wonogiri dam, while coarser grids were set in center of the reservoir.



Source: JICA Study Team

Figure 11 Computational Mesh (left) and Bed Level Contour in the Reservoir (measured in October 2004, Contour Unit: m)

5.2 Reservoir Sedimentation Analysis in 2004/2005

The simulation model was calibrated by two field data surveys, before and after the wet season of 2004-2005. The results of calibration showed that estimate of sediment inflow and its allocation to the rivers during the rainy season of 2004-2005 was reasonable, and NKhydro2D model could be employed to simulate sedimentation in the Wonogiri reservoir. The following are conclusions:

i) The flow velocity in river area was fast during flood, while that in the center of the reservoir was very much slow. There was almost no sediment exchange between the Keduang area and the upstream area.

ii) Most sedimentation occurred in the river area (mouth) and the sedimentation reduced gradually towards the center of the reservoir. Sedimentation in the river area was about 0.1 - 0.3 m, while that in the center of the reservoir was less than 0.02 m.

iii) While the reservoir water level is lower at the beginning of the wet season, counter flow to the center occurred when the Keduang River was in flood. SS concentration in river area during floods was higher and the muddy current was inversely transported into the center of the reservoir from the Keduang River.

iv) The computed sediment release through the intake was about 141,000 m^3, consisting almost solely of clay.

v) On the basis of sediment from the Keduang River, the trap ratio of clay by the reservoir was 74-76%, although silt and the coarser sediments were almost all trapped.

5.3 Verification of the Reservoir Sedimentation during 1993-2004

By applying the sediment rating curve obtained by field observation in 2004-2005 to that in 1993-2004, sedimentation in the reservoir during 1993-2004 can also be simulated by the model. The variation of reservoir bed in 1993-2004 is summarized below.

i) In the Solo River, sedimentation progressed gradually to the center of the reservoir from the river area. The fore-set bed had reached the Temon River area with sedimentation of about 2 m.

ii) In center of the reservoir, the sedimentation depth was about 0.1~0.3 m.

iii) In the Keduang area, the sedimentation was more severe and the maximum depth of sedimentation was about 4 m.

iv) The fore-set bed invaded as far as the center of reservoir from the Keduang River and the sedimentation near the intake was about 2 m.

5.4 Sediment Balance in the Wonogiri Reservoir

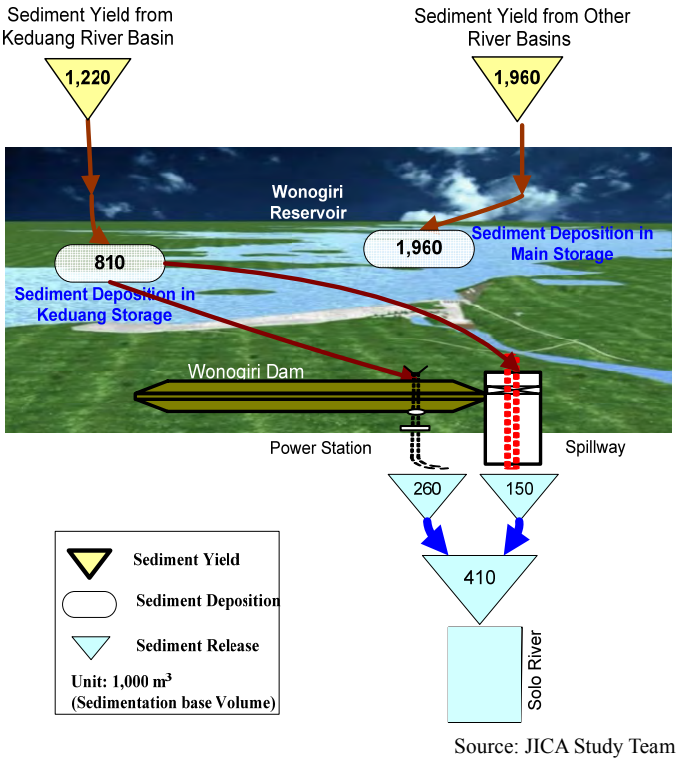
From the combined analysis results for 1993-2004 and for 2004-2005, the sediment inflow, sedimentation in the Wonogiri reservoir and sediment release (outflow) from the reservoir in the past 12 years (1993-2005) are estimated below:

i) In the past 12 years (1993~2005), the annual average of sediment inflow into the Wonogiri reservoir was 3.2 million m^3/year, in which the sediment inflow from Keduang River was 1.2 million m^3/year (about 38% of the total).

ii) The annual average of sediment release (outflow) was 0.4 million m^3/year, in which 0.15 million m^3 was via the spillway and 0.26 million m^3 via the intake of the power plant.

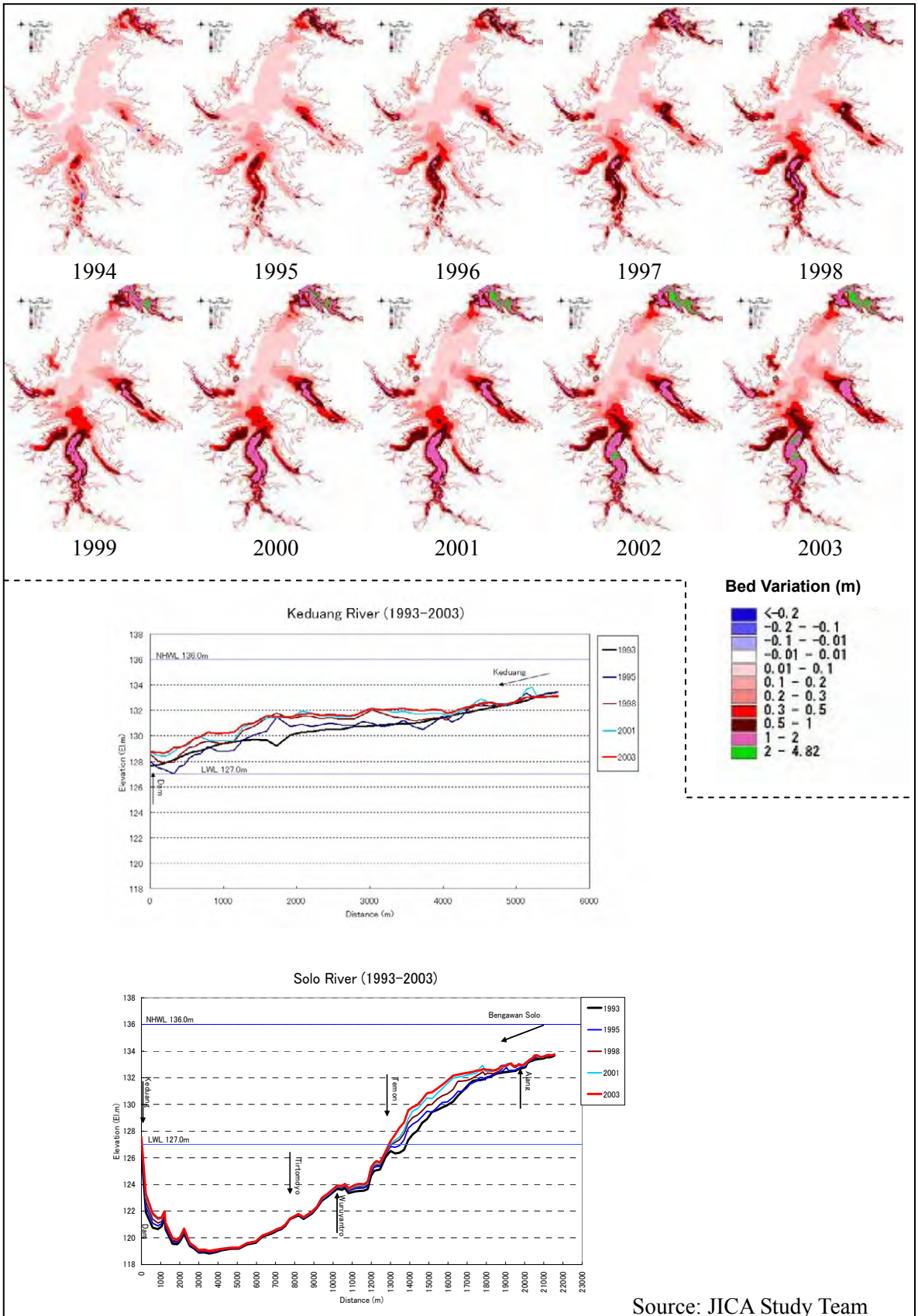
iii) Therefore, the annual average of sedimentation in the Wonogiri reservoir was 2.8 million m^3/year, and the sediment trap ratio of the reservoir was about 87%.

The current annual average sediment yield and sediment balance in the whole Wonogiri reservoir for 1993-2005 is worked out as shown in Figure12 below



Source: JICA Study Team

Figure 12 Current Annual Sediment Balance in Wonogiri Reservoir



Source: JICA Study Team

Figure 13 Reservoir Bed Variation and Longitudinal Profile of Deepest Bed in Keduang River and Solo River in 1993-2003

6. VERIFICATION TEST OF HYDRO-SUCTION DREDGING SYSTEM

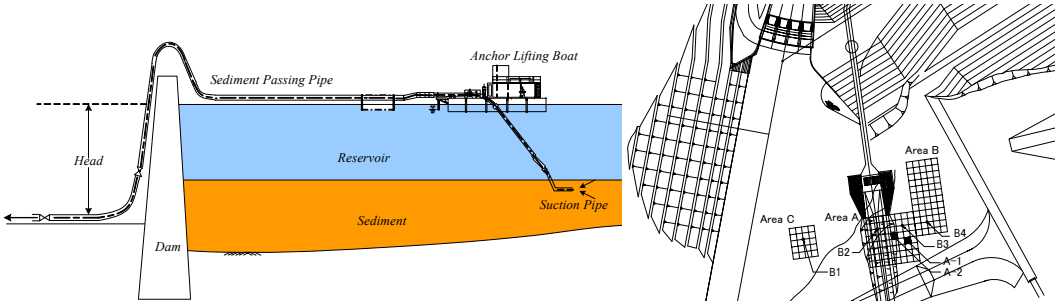
6.1 Overview of Verification Test

A verification test of the hydro-suction dredging system was carried out in front of the intake from September 12th to October 31, 2005. The objectives of the test were as follows:

i) To confirm whether the hydro-suction system is applicable to the sediment materials, which contain vegetative debris and garbage in the Wonogiri reservoir,

ii) To collect and analyze the basic operational data related to the hydro-suction system, and

iii) To examine and develop the hydro-suction system, which can be operated at low cost through energy saving.



Source: JICA Study Team

Figure 14 Schematic Profile of Hydro-Suction System

6.2 Pre-test

The performance of three (3) types of excavators was examined in the pre-test. As a result, side rotary excavator is expected to attain a high volumetric sediment concentration, because it could be adapted to changes in the topography of the reservoir bed and also comparatively small trash, consisting of vegetative debris such as bush and bamboo on the reservoir bed could be eliminated easily using the function of reversing the rotor blades for trash. The volumetric sediment concentration was measured to be 3.66 - 8.48% for side rotary.

6.3 Final Test

The test using side rotary excavator was carried out for sixteen different conditions of changing depth and flow rate. The density of sediment in the pipeline was proportion to the flow velocity. When a flow rate in the sediment passing pipe was around 12 m^3/min, density and volumetric sediment concentration conveyed by the system were approximately 1.09 g/cm^3 and 13%, respectively. Though a tendency for consolidation was found in the result of the core drilling, there were no serious problems that made the dredging difficult. The verification test confirmed that the hydro-suction system using side rotary can be applied to dredging of sediments in front of the intake at the Wonogiri dam.

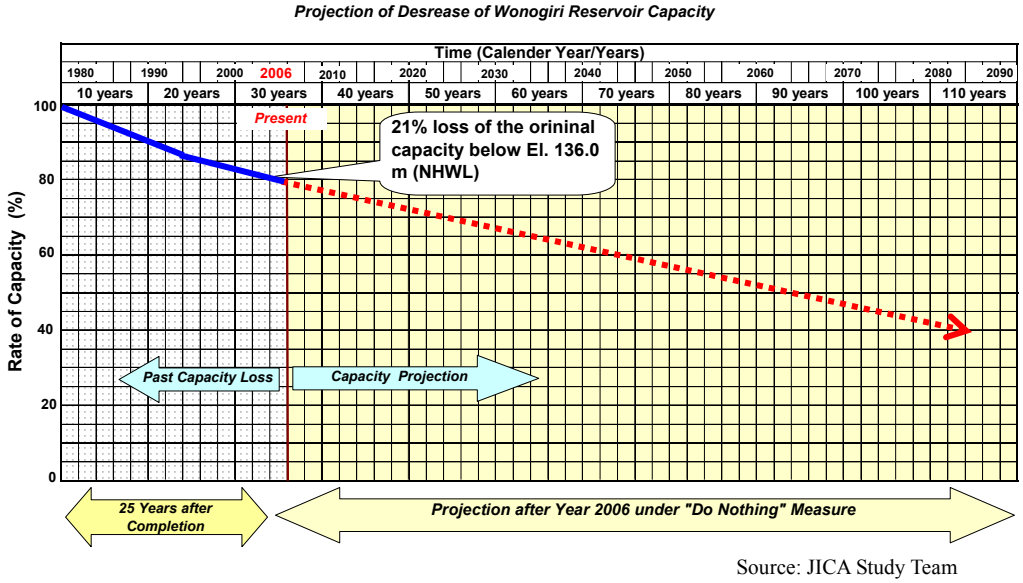
7. BASIC STRATEGY FOR MASTER PLAN FORMULATION

7.1 Projection of Wonogiri Reservoir Sedimentation

The current annual average sediment balance in the Wonogiri reservoir in the period of 1993-2005 is worked out as shown in Figure12. With a simple focus on the rate of

reservoir capacity loss, the future status of the Wonogiri reservoir was projected for the case where no reservoir sediment management measures are put in place from now on. In this projection, it was assumed based on the sediment balance above that the continuing sedimentation occurs only in both the water use and sediment storage capacity zones. The annual sediment deposition rates are assumed at 50% for each zone based on the actual sedimentation volume after the completion of Wonogiri dam. The projection result is shown in Figure 15 below.

By the year 2051, the Wonogiri reservoir will have lost around 28% of its water use capacity and will have completely lost its sediment storage capacity. The reservoir will have lost about 62% of the water use capacity by around the year 2105. The half of the effective capacity below NHWL will be lost by around the year 2062.



Source: JICA Study Team

Figure 15 Simplified Projection of Decrease in Wonogiri Reservoir Capacity

7.2 Goals of Master Plan

Considering the results of basic studies mentioned above, the goals of the master plan were set up as follows:

i) The Wonogiri dam should continue to contribute to stabilization of people's livelihood as well as improvement of social welfare at least the next 100 years. This goal will be only achieved by protecting and maintaining the expected function of the Wonogiri reservoir in terms of flood control, irrigation water, domestic and industrial water supply and hydropower generation.

ii) The Wonogiri reservoir has to be safe whatever happens in the future. This goal will be realized by careful observance of reservoir operation rule. The Wonogiri reservoir should be operated properly and safely in the occurrence of floods of any magnitude.

iii) Sustainable management of the Wonogiri reservoir will be achieved through the linkage with management and conservation of the Wonogiri watershed. The Wonogiri watershed has to be managed and conserved in harmony with improvements in the quality of life of farmers within its watershed.

7.3 Basic Strategy for Master Plan Formulation

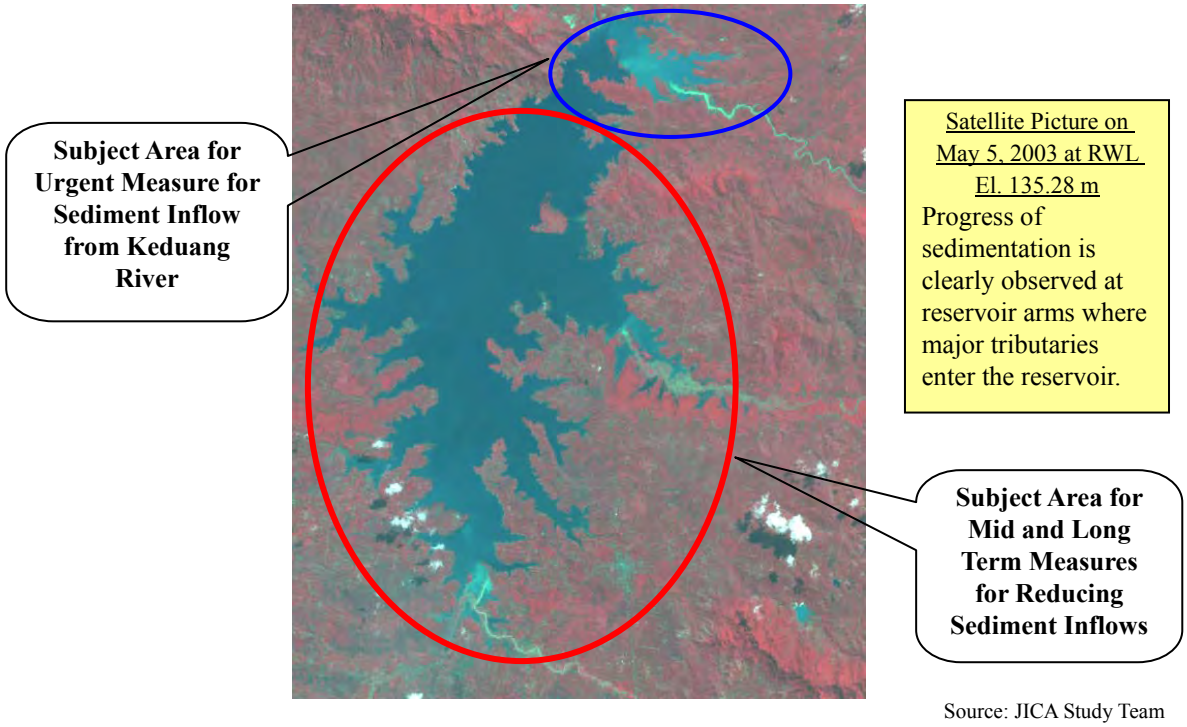
To achieve the goals, basic strategy for formulating the master plan was set up:

i) It was determined that he target design sediment deposition in the reservoir should be

less than the rate of 1.2 million m^3/year adopted in the original design in 1978.

ii) Top priority should be placed on measures to protect the intake structure. Countermeasure for handling sediment and garbage inflow from the Keduang River will be the most urgent measure.

iii) It will be a long time before the sediment inflows from other tributaries cause serious impacts on the intake. It is considered to be practical to adopt a watershed conservation policy to reduce the sediment yield rate therein as mid-term measure.



Source: JICA Study Team

Figure 16 Priority Areas of Master Plan

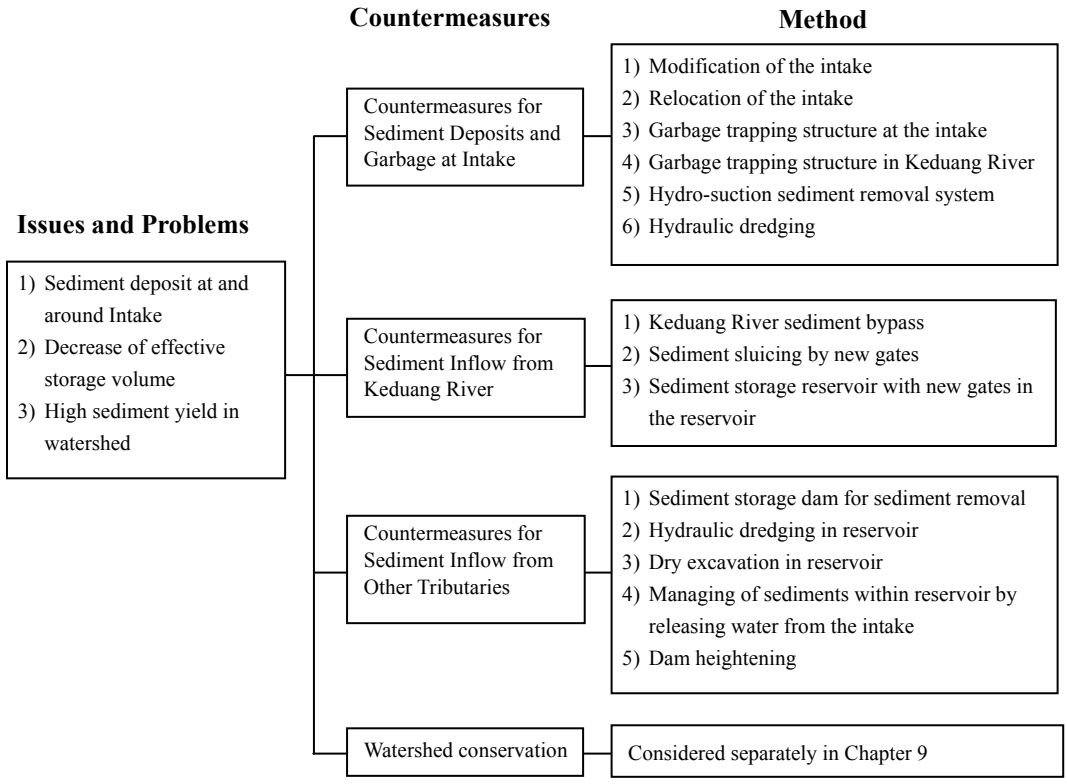
iv) Complete restoration of the reservoir will require huge expenditure and acquisition of vast spoil bank areas. Due to constraints, the most practical way is to reduce sediment inflow into the reservoir through watershed conservation to an extent that extends the reservoir lifespan.

v) The Wonogiri reservoir has been operated to raise the original NHWL by around 1 m from 1991 to store additional water of around 75 million m^3 to meet the strong water demands of the downstream water users. The current reservoir operation practice was assessed to be unsafe in view of the dam safety. Although the observance of the original operation rule will lead to reduction of the current water supply capacity, all the stakeholders have to recognize that the dam safety is of the utmost importance. Technical evaluations and preliminary design of alternative structural measures should be conducted under full observance of the current reservoir operation rule.

8. TECHNICAL EVALUATION ON STRUCTURAL SEDIMENT MANAGEMENT ALTERNATIVES

8.1 Conceivable Structural Alternatives

Conceivable structural alternative countermeasures were worked out for; i) sediment deposits and garbage at the intake, ii) sediment inflow from the Keduang River, and iii) sediment inflow from other tributaries.



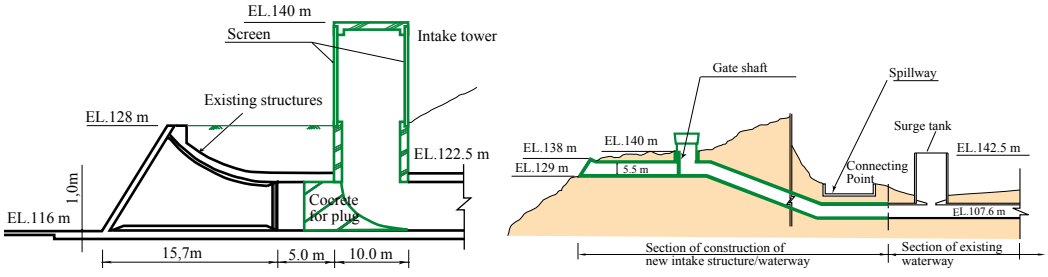
Source: JICA Study Team

Figure 17 Conceivable Structural Alternatives for Wonogiri Reservoir Sedimentation Issues

8.2 Countermeasures for Sediment Deposits and Garbage at Intake

(1) Modification and Relocation of Intake

Modification and relocation of the intake are inferior to other alternatives because irrigation water supply would be suspended during construction, construction cost is higher, and the sedimentation problem would not be completely solved. These alternatives would not provide a sustainable solution for the sedimentation problems in the Wonogiri reservoir.

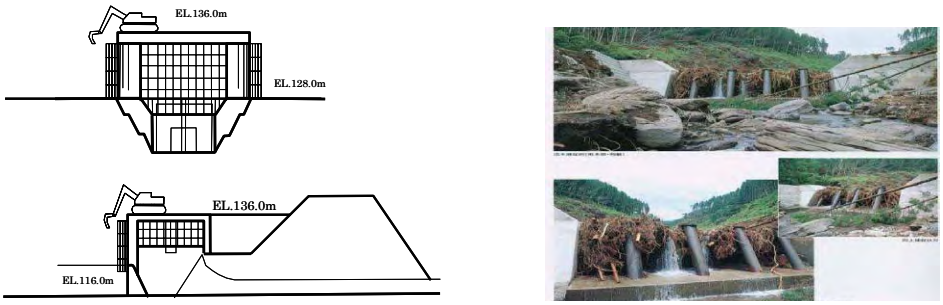


Source: JICA Study Team

Figure 18 Illustration of Modification(left) and Relocation(right) of Intake

(2) Garbage Trapping Structures at Intake and in the Keduang River

Garbage trapping structures either in the Keduang River or on the existing intake might prevent garbage from entering the existing intake. These alternatives would effectively solve the current garbage-related issues at the intake. However, sediment issues at the intake could not be solved by these alternative measures. In view of sustainable management of the Wonogiri reservoir function, garbage trapping structures might be applicable as supplemental components with the permanent countermeasure.

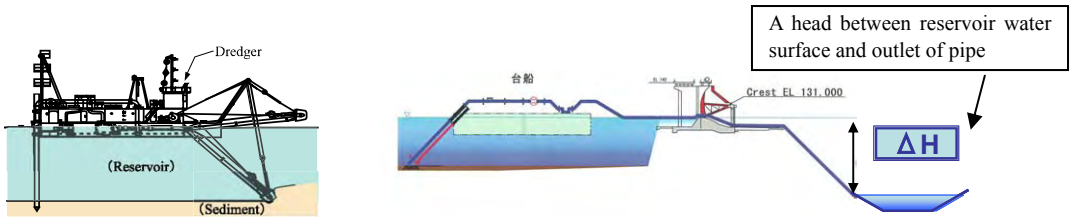


Source: JICA Study Team

Figure 19 Illustration of Garbage Trapping Structures at Intake(left)/ in the Keduang River(right)

(3) Hydraulic Dredging and Hydro-suction Sediment Removal System

Hydraulic dredging is the most reliable measures to remove sediments and garbage at intake, though their O&M cost is relatively high. On the other hand, the hydro-suction sediment removal system verified under the Study requires less O&M cost, although it depends on the reservoir water level in view of a required water head. These dredging methods might be recommendable as periodic maintenance dredging after the implementation of structural countermeasures as well as watershed conservation, because of a possibility of extraordinary sediment inflow due to extreme floods.



Source: JICA Study Team

Figure 20 Illustration of Hydraulic Dredging(left)/Hydro-suction Sediment Removal System(right)

(4) Technical Evaluation of Alternatives for Sediment Deposits and Garbage at Intake

The construction costs of alternatives were estimated as presented in the Table 7 below. Applicability and environmental and social impact were assessed as summarized in the attached Table 8. In conclusion, none of the alternative provides a sustainable solution to the sediment and garbage issues at the intake. Hydraulic dredging and hydro-suction sediment removal system might become a supplemental component of the permanent countermeasure.

Table 7 Construction Cost of Alternatives for Sediment Deposits and Garbage at Intake

Alternative	Construction Cost	Evaluation
1) Modification of intake	$3,160,000	not sustainable solution
2) Relocation of intake	$8,800,000	not sustainable solution
3) Garbage trapping structure at intake	$3,670,000	solution for garbage-related issues.
4) Garbage trapping structure in the Keduang River	$1,370,000	solution for garbage-related issues.
5) Dredging by hydro-suction method	$2,875,000	supplemental component
6) Hydraulic dredging	$4,456,700	supplemental component

Source: JICA Study Team

8.3 Countermeasures for Sediment Inflow from Keduang River

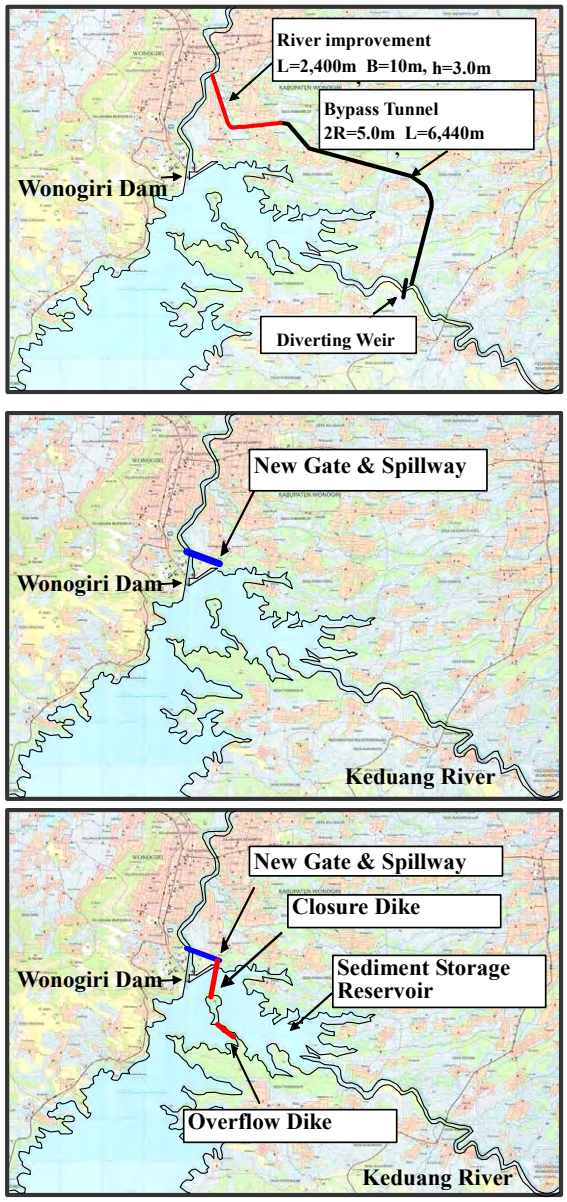
(1) Keduang River Sediment Bypass

Sediment bypassing is a method in which part of the incoming sediment-laden flood inflow from the Keduang River is diverted into a bypass tunnel to the downstream of the Wonogiri dam. It is noted that due to flat topographic condition, the discharge capacity of bypass tunnel becomes relatively small (50 m^3/sec at maximum). Thus the flood inflow from the Keduang River with high sediment concentration cannot be fully diverted. Modification of the intake or maintenance dredging at the intake will be also necessary to achieve sustainable operation of the reservoir.

(2) Sediment Sluicing with New Gates

With this method, the incoming sediment-laden flood flows from the Keduang River to the downstream reaches of Wonogiri dam through new gates before deposition in the reservoir. The new gates will be on the right abutment of the dam.

This method requires modification of the current reservoir operation rule due to the need to release massive amounts of water and to lower the water level near sediment deposit in front of the dam. There is a risk that the reservoir water level would not reach the NHWL at the end of wet season when so much water is used for sluicing.



Source: JICA Study Team

Figure 21 General Layout of Alternatives for Sediment Inflow from Keduang River

(3) Sediment Storage Reservoir with New Gates in the Wonogiri Reservoir

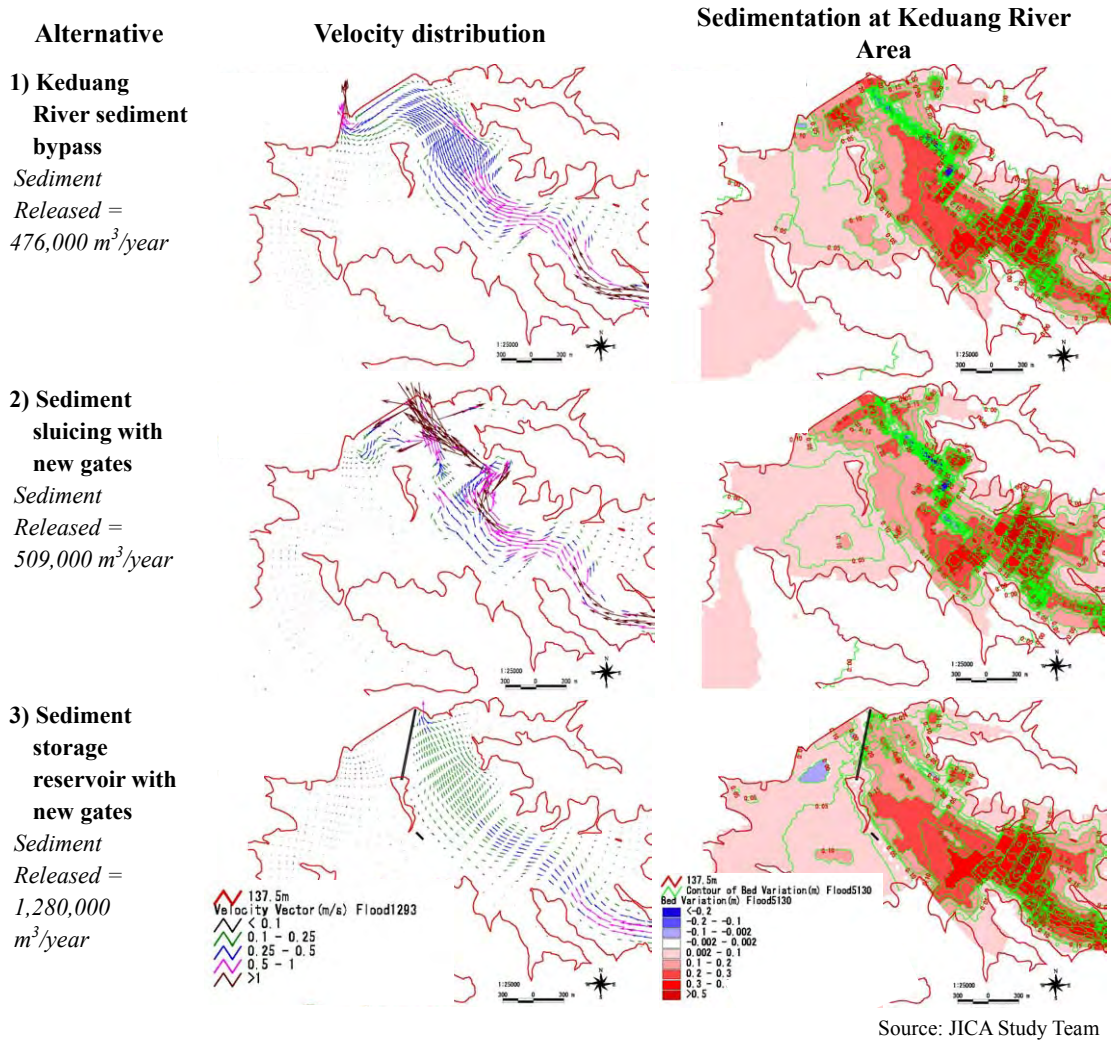
The structural difference between the sediment sluicing with new gates and a sediment storage reservoir is simply the construction of both closure and overflow dikes in the reservoir. The technical merit of the sediment storage reservoir system is that because of the closure dyke, the reservoir water level of the Wonogiri main reservoir would be secured even when sediment is being released by opening the new gates. All of the system components will be constructed within the Wonogiri dam area without relocation of local people.

Sediment releasing from the sediment storage reservoir would not be practiced every year. So far, excess water has been released through the existing spillway. When the excess water is released from the Wonogiri reservoir, the new gates would be opened instead of

the existing spillway gates.

(4) Technical Evaluation on Volume of Sediment Released

Technical effects on mitigation of sedimentation in reservoir were evaluated by the calibrated reservoir sedimentation analysis model as shown in figure below:



Source: JICA Study Team

Figure 22 Simulation Results of Countermeasures for Sediment Inflow from Keduang River

(5) Technical Evaluation of Alternatives for Sediment Inflow from Keduang River

The construction costs and the unit costs for sediment releasing were estimated as the Table 9 below. The results of overall evaluation of the three alternatives are summarized in Table 10. In conclusion, the sediment storage reservoir was selected as recommended countermeasure based on fundamental consideration and technical factors as follows:

i) Almost all of the garbage inflow from the Keduang River would be completely retained within the sediment storage reservoir.

ii) The majority of the sediment inflow from the Keduang River would be deposited within the sediment storage reservoir. Although small parts of the sediment inflow would enter the Wonogiri main reservoir through the overflow dike, sedimentation at the intake would be drastically decreased.

iii) Sediment deposits in the sediment storage reservoir could be released, whenever

necessary, without using the stored water in the Wonogiri main reservoir. The sediment storage reservoir can be operated independently from the Wonogiri main reservoir.

Table 9 Evaluation Results of Alternatives for Sediment Inflow from Keduang River

Alternative	Construction Cost	Unit Cost and	Released Sediment
1) Keduang River sediment bypass	$82,940,000	$10.7/m^3	476,000 m^3/year
2)Sediment sluicing with new gates	$35,630,000	$4.7/m^3	509,000 m^3/year
3) Sediment storage reservoir with new gates	$47,090,000	$3.8/m^3	1,280,000 m^3/year

Note: Released sediment volume is estimated from the reservoir sedimentation simulation analysis applying the inflow of hydrological wet year 1998/99. Unit cost for sediment releasing is estimated based on the construction cost and required O&M cost for 50 years. A total gate width of 30.0 m (=B7.5 m x 4 nos.) is applied in this evaluation.
Source: JICA Study Team

8.4 Countermeasures for Sediment Inflow from Other Tributaries

(1) Sediment Storage Dam for Sediment Removal, Hydraulic Dredging in Reservoir and Dry Excavation in Reservoir

If the sediment deposits can not be released, conceivable way would be to mechanically remove the sediment deposits in reservoir. However because of the limited space for spoil on the bank area near the reservoir, it is unrealistic to dispose of the sediment deposits from the reservoir as well as the trapped sediment deposits from the sediment storage dams.

(2) Managing of Sediments within Reservoir by Releasing Water from Intake

By use of the maximum intake discharge (around 70 m^3/s) for power generation, previously deposited sediments are moved toward the dead zone of the reservoir, thereby maintaining or increasing the effective capacity of the reservoir.

The disadvantage of this method is that a significant amount of water must be released through power generation, and there is a risk that the reservoir water level can not reach the NHWL. This might cause a water deficit for irrigation in downstream area and impact on paddy fields in the case of inappropriate water release. It might initiate unrest or conflict with local people.

(3) Dam Heightening

In this method, the dam crest is raised to secure the effective storage capacity. The dam heightening would be the option to adopt in the future when the storage capacity of the reservoir decreased substantially. The Steering Committee, on August 22 2005, concluded dam heightening could not recommended.

(4) Technical Evaluation of Alternatives for Sediment Inflow from Other Tributaries

The results of the overall evaluation of five alternatives for sediment inflow from other tributaries are summarized in the attached Table 11. In conclusion, no economical and sustainable solution would be provided by any of the structural alternatives. The most practical and sustainable measure is to reduce sediment yield as much as possible from the Wonogiri catchment by means of watershed conservation. Watershed conservation works would be superior to the structural alternatives.

9. PLANNING FOR WATERSHED CONSERVATION AND MANAGEMENT

9.1 Basic Concepts and Approaches

Around 93% of the annual average sediment yield into the Wonogiri reservoir comes from the surface of the lands (agricultural lands). The soil loss from off-farm lands such as landslide, riverside soil erosion and gullies is very small. The main erosion sources are uplands. Soil erosion control for the uplands in the settlement area is the most urgent objectives. The local people in the Wonogiri dam watershed understand that crop yields are seriously affected by degradation of soil fertility due to soil erosion and are keenly interested in soil conservation. The results of the survey made it clear that increase of the agricultural incomes of local farmers is essential. In order to solve such urgent objectives, it is necessary that watershed conservation should be promoted by considering the approaches from the view points of; i) water/soil conservation, ii) agricultural issues, and iii) socio-institution.

As soil textures in the watershed are very fine, it is not expected that soil erosion control by construction of large scaled Sabo dams would be economical or functional. So these structures will not be included in this Study. Instead, (1) Installation of improved bench terraces, which function very effective for soil erosion control as shown by the results of soil erosion tests carried out in the Wonogiri watershed, will be introduced. (2) In addition, soil conservation will be made by reinforcement of terrace risers and lips by covering with grasses. (3) Agro-forestry development will be promoted for soil erosion control, improvement for agricultural productivity and transfer of agricultural productivity improvement and agricultural income sources to future generations. (4) Soil conservation based on introduction improved technology on water/soil conservation, appropriate cropping patters, crop yield and soil management should be made. (5) Furthermore, prevention of soil erosion from the fringe of the settlement area will be made by hedge row and construction of side ditches.

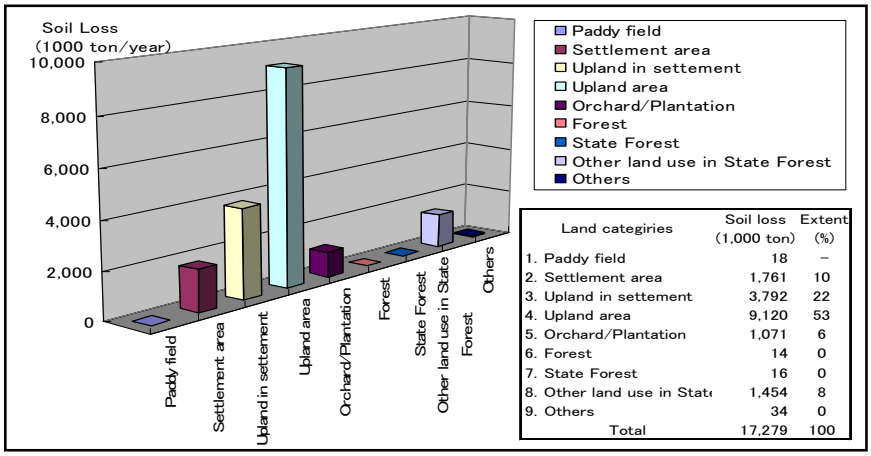
Most of the past watershed projects in the Wonogiri dam watershed were conducted by introducing a top-down system, but it is said that these projects did not produce the benefit expected. Therefore, (1) A community based bottom-up system will be basically adopted in this plan. It will be planned that local people can participate from the planning stage, through to monitoring stage after implementation. So in the initial stage it will be very important to obtain the support of the local community. (2) It is also very important to guarantee the transparency of all the project activities including capital for smooth implementation project. For this purpose an implementation committee should be instituted. (3) Considering the low benefit from agriculture improvement in the short term of the project, proper incentives for the beneficiaries should be introduced. Materials and farm inputs necessary for the project should be entirely subsidized. About 20-75% of the labor charge for construction should be subsidized.

9.2 Formulation of Watershed Conservation Plan

(1) Soil Erosion Sources and Subject Areas for Watershed Conservation

The total annual average soil loss from the Wonogiri watershed is estimated at about 17.3 million tons, mainly consisting of i) 9.1million tons or 53% of total soil loss from uplands, ii) 3.8 million tons or 22% from uplands in the settlement area, iii) 1.8million tons or 10% from settlement areas, and iv) 1.5million tons or 8% from the State Forest. These four main soil erosion sources cover over 90% of the total soil loss from the Wonogiri dam watershed as shown in Figure 23.

On the other hand, soil loss from other land use categories of i) paddy field, ii) orchard/plantation area under tree/tree crops cover (people's forest, orchard, estate crops area), and iii) others are estimated to be limited to an acceptable scale. The state forest lands are managed by the State Forest Corporation and reforestation programs are now ongoing.



Land categiries	Soil loss (1,000 ton)	Extent (%)
1. Paddy field	18	–
2. Settlement area	1,761	10
3. Upland in settement	3,792	22
4. Upland area	9,120	53
5. Orchard/Plantation	1,071	6
6. Forest	14	0
7. State Forest	16	0
8. Other land use in State	1,454	8
9. Others	34	0
Total	17,279	100

Source: JICA Study Team

Figure 23 Annual Average Soil Loss of Lands Classified by Land Use in Wonogiri Dam Watershed

It may be concluded from the above results that uplands, uplands in the settlement area and settlement areas should be considered as subject areas for watershed conservation. The total subject areas amount to 66,600 ha or 54% of the whole Wonogiri dam watershed as summarized below. The area extents of i) uplands, ii) uplands in settlement area and iii) settlement area are estimated from the present land use at about 39,800 ha or 32 %, 19,500 ha or 16% and 7,300 ha or 6% of the watershed area, respectively.

Table 12 Subject Areas for Watershed Conservation

Subject Area	Remarks
Uplands	Occupy about 1/3 of the watershed area from low lying area to steep sloping area
Uplands in Settlement areas	Mainly used for annual crop production with limited vegetative cover of perennial crops or trees
Settlement areas	Housing yard and home garden covered with perennial crops/trees

Source: JICA Study Team

(2) Classification of Subject Areas and Target Areas

1) Classification of Subject Areas

Classification criteria of subject areas is shown in Table 13. The factors of USLE that could be managed or mitigated through watershed conservation measures are P factor (land conservation factor) and C factor (vegetative/cultivation factor). Accordingly, the subject areas have been classified into sub-units (land units) in order to facilitate formulation of conservation plan on the basis of land use condition, slope steepness and terrace type and conditions as follows:

The processes for the classification of subject areas into land units for watershed conservation are illustrated in the Figure 24.

Based on the classification criteria for subject area, coding of land unit in a subject area is made as shown in Table 14. The subject areas were classified into 35 land units in total based on 'Coding of Land Units' for watershed conservation. The total area of each land

units is summarized as shown in Table 15.

2) Target Areas for Watershed Conservation Project

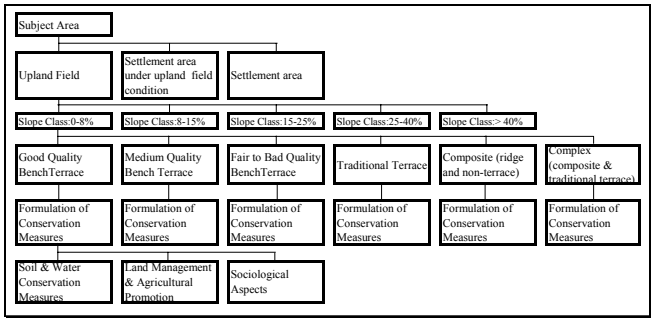
The target areas for the Wonogiri watershed conservation project were selected from the subject areas mentioned above based on the following considerations.

- Annual average soil loss and annual average soil loss/ha for the Wonogiri watershed are calculated for each of the 35 land units based on a polygon (20 m x 20 m).
- Based on the above calculation, soil loss and soil loss/ha for each village within the Wonogiri watershed was calculated. Then village that cover more than 100 ha, and have over 50 tons/ha of annual soil loss from the village area, were screened first. For each of the villages screened above, the annual average soil loss was calculated for the three kinds of the land use area of; i) uplands, ii) uplands in the settlement area and, iii) settlement areas. Secondly, villages with a total annual average soil loss per ha of more than 50 ton/ha/year, from the three kinds of land use, were screened.
- The target areas for the Wonogiri Conservation Project is an area of about 34,400 ha, which contains 180 villages as shown in Table 16.

Table 13 Classification Criteria of Subject Area

Factor	*Classification Criteria*	*Code*
Land Use	Upland	U
	Pekarangan 1/	P
	Housing Yard 2/	H
Slope	0 - 8%	S1
	8 - 15 %	S2
	15 - 25 %	S3
	25 - 40 %	S4
	40 %	S5
Terrace Type & Condition	Bench Terraced Land	
	- Good quality bench terrace	T1
	- Medium quality bench terrace	T2
	- Fair to bad quality bench terrace	T3
	Traditional Terrace Land	T4
	Composite (mix of ridge & non-terrace)	T5
	Complex (traditional terrace and composite	T6

1/: Upland in settlement area 2/: Housing yard in settlement area
Source: JICA Study Team



Source: JICA Study Team

Figure 24 Classification of Subject Areas into Land Units for Formulation of Conservation Measures

(3) Proposed Watershed Conservation Projects

The proposed basic watershed conservation measures consist of; i) soil conservation by physical and vegetative measures, ii) seasonal crop and agro-forestry developments and, iii) support programs for promoting the watershed conservation project. The basis for the formulation of watershed conservation applied, in the present proposed watershed conservation plan, for individual land units being classified by slope classes and current terrace type and condition are briefly discussed in the following:

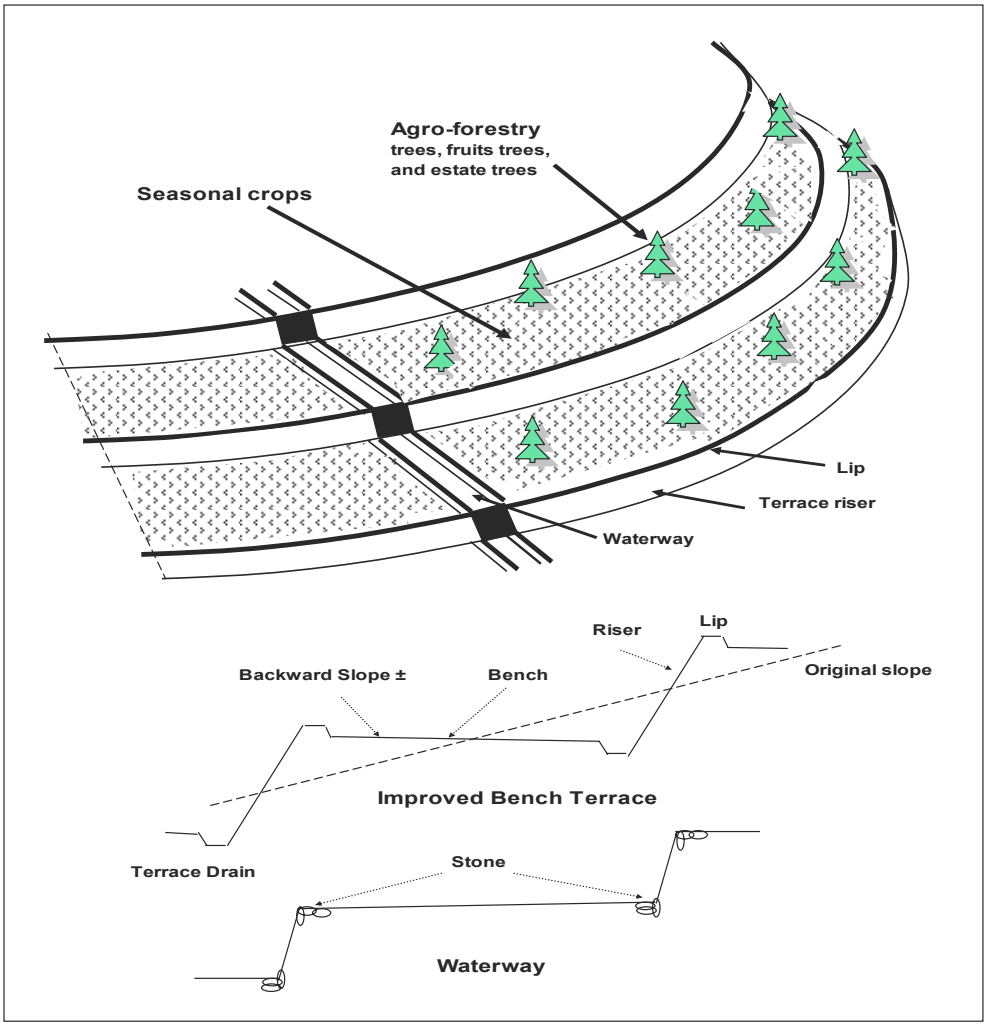
1) Soil Conservation Measures of Physical and Vegetative Measure.

It is considered that watershed conservation should minimize the cost of soil conservation measures and the project works could be easily carried out by the beneficiaries of the project. The proposed soil conservation measures are shown in Table 17. The standard design and image of the improved bench terrace are illustrated in the Figure 25 below.

Table 17 Proposed Terrace Improvement Works

Measures	Components
Physical Measures	Bench Terrace Improvement/Construction Works Improvement of waterway and drop structures Improvement of side ditch in the settlement area
Vegetative Measures	Lip stabilization Riser stabilization Hedge row at fringe of housing yard

Source: JICA Study Team



Source: JICA Study Team

Figure 25 Image of Improved Bench Terrace

Taking into consideration practical aspects of project development such as condition of access to sites, difficulties of terrace construction due to deep roots of big trees, very steep topography, uncertainty of farmer's intention of terracing, existing condition of hedge row, side ditches and so forth, rate of implementation of terracing works will be planned to be 100% of the uplands with less than 25% in steepness, 80% with 25-40% in steepness and 60% with over 40% in steepness.

An assessment has been made vegetative measures used in the past with the aim of incorporating past experience into the formulation of the present study. The criteria applied for the assessment include: i) degree of plant cover, ii) speed or easiness of establishment of vegetation, iii) economic use or value, and iv) field performances. The basic vegetative measures and agro-forestry development directed at bench terraces

and vegetative measures to mitigate soil erosion in housing yards are summarized in Table 18 below

Table 18 Basic Vegetative and Agro-forestry Measures in Improved Bench Terrace

Target Place/ Vegetative Measures	Vegetation	Kinds/Species
Terrace Lip - Lip Stabilization	Grass	Elephant Grass, *Panicum muticum,* King Grass
	Shrub	Lamtoro, *Glyricideae speium, Flemingia congesta Roxb etc.*
Terrace Riser - Riser Stabilization	Grass	BB (*Brachiaria brizantha*), BD (*Brachiaria decumbens*), Local creeping grasses
Terrace Bench - Agro-forestry Development	Tree crops/trees	Fruits, estate crops, trees
Housing Yard[1]/	Shrub	*Flemingia congesta Roxb etc.*

[1]/: Housing yard in home settlement, Source: JICA Study Team

2) Agricultural Promotion measures

Agricultural measures are formulated and summarized in Table 19 below. Improved farming methods for seasonal crops will be introduced and be disseminated to farmers/farmer groups through the strengthening of participatory agricultural extension activities.

Table 19 Proposed Agricultural Promotion Measures

Subject	Measures
Land Management for Soil & Water Conservation	Farm land improvement
	Land use modification/conversion
Agro-forestry Promotion	Promotion of agro-forestry development
Crop Sub-sector Measures	Improvement of cropping system and technology development

Source: JICA Study Team

Agro-forestry is considered as a soil and water conservation and agricultural promotion measure and it is envisaged that it will be introduced over the entire farm land area according to slope steepness to increase farm income and to mitigate the farm labor shortage problem, which is likely in the near future, in the watershed area. The introduction rate of agro-forestry crops development is 5% of the total upland, with less than 8% in steepness, 12.5% with 8-15% in steepness, 25% with 15-25% in steepness, 37.5% with 25-49 % in steepness and 50% with over 40%.

3) Support Program for Promoting Watershed Conservation Projects

For strengthening support for those farmers in executing watershed conservation, technical and financial support programs for the implementation of watershed conservation have been formulated. For promoting watershed conservation projects, there are three types of supporting programs consisting of:

i) Support Programs for Soil and Water Conservation Project

The proposed soil and water conservation measures have direct and immediate effect on soil conservation and support programs for practitioner farmers should be accommodated as components of development works to ensure the direct and immediate benefits of the measures. The proposed support programs include; i) Empowerment of beneficiary farmers and farmer groups and ii) Support programs for operation/implementation of conservation measures. In addition, the empowerment of field staff providing technical guidance and support to farmers and

farmer groups is an essential initial and periodic step required for the efficient and successful implementation of the measures.

ii) Support Programs for Land Management and Agricultural Promotion

The support programs are formulated aiming at strengthening of extension activities for land management & agricultural promotion and consist of; i) Technology development program, ii) Demonstration program, iii) Establishment of pilot demonstration field of tree crops and trees, iv) Farmer and farmer group training program, v) Palawija seed production program, vi) Livestock promotion program and, vii) Strengthening of logistic support for extension activities.

iii) Support Programs for Community Development

The support programs are formulated aiming at empowerment of village people and organization. The support programs provide various support for; i) Village assessment based on the PRA, ii) Formulation of draft village action plan, iii) Establishment of implementation committee, iv) Guidance and support of village grant fund and, v) Education program on watershed conservation.

(4) Project Works

The project works for the Wonogiri Watershed Conservation Project are shown in Table 20. The project works will be performed by introduction of farmer's participation system. Works such as cutting /filling, excavation, masonry and vegetation planting will be shared by the Government and beneficiary farmers in the project. All the materials necessary for the project such as farm inputs and construction materials will be purchased by the Government.

Table 20 Project Works for Watershed Conservation

item	(unit)	Total Project Work	item	(unit)	Total Project Work
		(1,000)			(1,000)
1. Land preparation			**2. Side diches (for housing yard)**		
1) Terracing			1) Side ditch		
(1) Cutting and filling	m^3	22,224	(1) Stone material	m^3	37
2) Waterway and drop			(2) Excavation work	m^3	53
(1) stone material	m^3	164	(3) Masonry work	m^3	33
(2) Excavation work	m^3	191	2) Headgerow		
(3) Masonry work	m^3	149	(1) Shrub, for hedger row	nr.	8,346
3) Lip and rizer, planting			(2) planting work, hedge row	m^2	1,043
(1) Seedling, grass for lip	nr.	304,731	**3. Agro-forestry and annual crops**		
(2) Seedling, shrub for lip	nr.	18,284	1) Agro-forestry and annual crops	Ls	
(3) Seedling, grass, for rizer	nr.	432,330	**4. Support program**		
(4) Planting work, for lip	m	91,420	1) Support programs	Ls	
(5) Planting work, for rizer	m^2	86,466			

Source: JICA Study Team

(5) Reduction of Annual Soil Loss

The annual average sediment inflow due to the surface soil erosion from the agricultural lands in the entire Wonogiri dam watershed is 2.95 million m3/year (see Table 6). Annual soil loss in the "without project condition" and "with project condition" has been calculated by USLE as summarized in Tables 21 and 22. As seen, the annual average soil loss was estimated at 1.61 million m^3/year in the "with project condition". Around 55% of the total annual average soil loss at present is trapped or reduced after implementation of the watershed conservation project.

Table 21 Estimated Reductions of Annual Soil Loss Production and Sediment Inflow

River Basin	Present Condition		After Implementation		Reduction	
	Sediment Inflow	Soil Loss	Sediment Inflow	Soil Loss	Sediment Inflow	Soil Loss
	(1,000 m^3/yr)	(1,000 ton/yr)	(1,000 m^3/yr)	(1,000 ton/yr)	(1,000 m^3/yr)	(1,000 ton/yr)
Kuduang	1,134	5,112	718	3,237	416	1,875
Tirtomoyo	470	4,786	229	2,331	241	2,455
Temon	61	974	29	457	32	517
Upper Solo	591	3,808	297	1,914	294	1,894
Alang	327	1,057	159	516	167	541
Ugunggahan	183	777	75	317	109	460
Wuryantoro	85	360	61	260	24	100
Remnant	96	405	40	170	55	235
Total	**2,947**	**17,279**	**1,609**	**9,202**	**1,338**	**8,077**

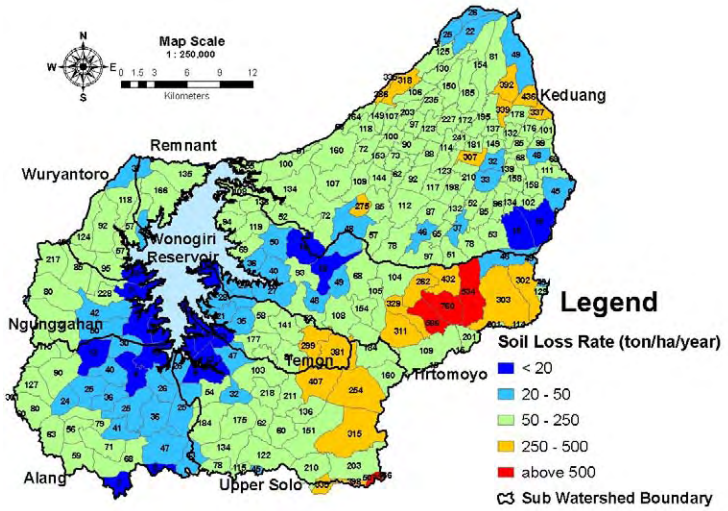
Note; i) Sediment inflow is estimated by the following formula: Sediment Inflow (m3) = Soil Loss (ton) x Sediment Delivery Ratio / Bulk Dry Density of Sediment (=1.064 ton/m3)
ii) Sediment inflow is the annual average sediment inflow due to the surface soil erosion.
Source: JICA Study Team

Table 22 Reduction of Annual Average Soil Loss in Sub-basin

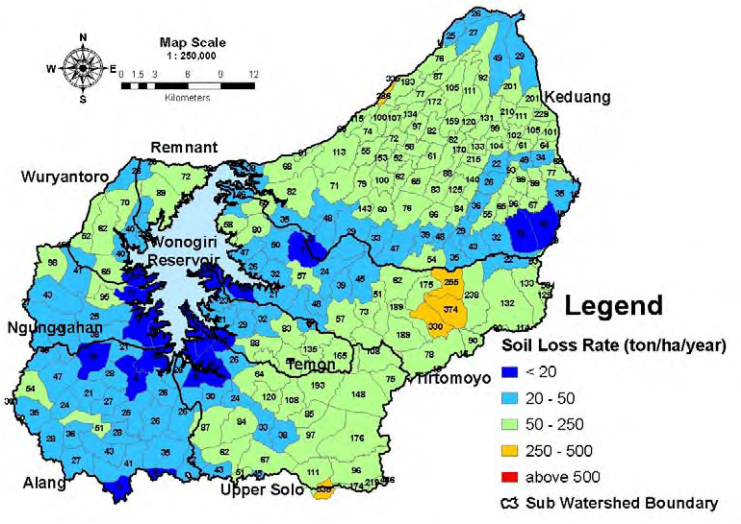
Sub-basin	Annual Average Soil Loss (1,000 ton)		Reduction of Annual Average Soil Loss (1,000 tons)
	Present condition	After implementation	
(1) Kuduang	5,112	3,237	1,875
(2) Tirtomoyo	4,786	2,331	2,455
(3) Temon	974	457	517
(4) Upper Solo	3,808	1,914	1,894
(5) Alang	1,057	516	541
(6) Ngunggahan	777	317	460
(7) Wuryantoro	360	260	100
(8) Remnant	405	170	235
Total	**17,279**	**9,202**	**8,077**

Remarks: *:This annual average soil loss is estimated under the land use condition in state forest area that 90% of the other land use in the state forest land will be reforested and 10% is assumed to be lost during the growing period due to pest/diseases and other reasons. Source: JICA Study Team

Before Implementation



After Implementation



Source: JICA Study Team

Figure 26 Comparison of Annual Soil Loss per Hectare of Village

10. INITIAL ENVIRONMENTAL EXAMINATION (IEE)

The IEE as well as the review of the draft scoping were carried out for the area covering; i) the entire catchment of the Wonogiri dam and ii) downstream reaches of the Bengawan Solo River from the Wonogiri dam to the confluence with the Madiun River. The IEE covers three environmental components; i) physical environment, ii) Natural environment and iii) socio-economic environment. The IEE concluded that the project components of master plan would not cause any significant adverse impacts, although there are minor negative impacts that can be mitigated by appropriate management. Because of the nature and scale of the project components, they are not subject to environmental assessment by Environmental Impact Assessment (AMDAL) in Indonesia.

It may be judged that the project components should fall into Category B[1] according to the JICA Guideline for Environmental and Social Considerations.

11. FORMULATION OF MASTER PLAN

11.1 Urgent Plan: Countermeasures for Garbage and Sediment Inflow from Keduang River

The design annual sediment balance of the Wonogiri reservoir for the urgent plan is shown in Figure 25. Watershed conservation will be implemented for a total area of 11,260 ha covering 83 villages. After implementation, around 0.42 million m^3 of sediment inflow is expected to be reduced every year on the average. The majority of annual sediment inflow 1.22 million m^3/year from the Keduang River could be released in combination with the design sediment releasing capacity 0.70 million m^3/year of the

[1] Screening means deciding whether or not proposed projects are likely to have impacts that should be assessed by conducting environmental and social considerations studies according to project description and site description. JICA conducts screening by classifying proposed projects into three categories: A, B and C. Proposed projects classified as Category A are likely to have significant adverse impacts, and proposed projects classified as Category B are likely to have less adverse impacts than those of Category A projects. Category C projects are likely to have minimal or no adverse impacts. (Source: JICA Guideline for Environmental and Social Considerations)

proposed sediment storage reservoir (the number of gates is reduced from 4 to 2 nos.). [2]

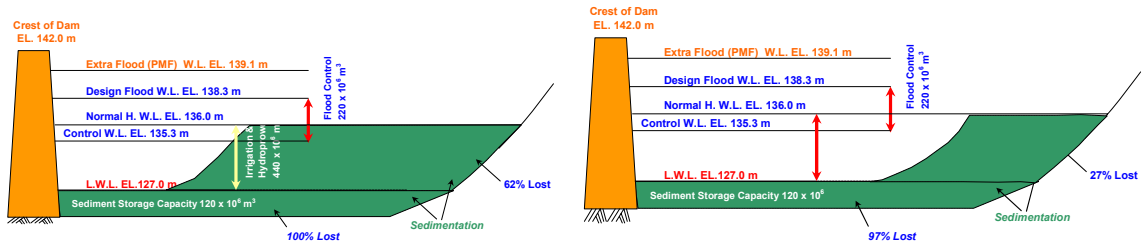
From the reservoir sedimentation simulation, sediment volume overflow into the main Wonogiri reservoir from the sediment storage reservoir and released from hydropower generation were estimated 0.10 million m^3/year and 0.14 million m^3/year. Annual sediment deposits in the Wonogiri reservoir are thus 1.92 million m^3/year. The sediment balance under the urgent plan is illustrated in Figure 28. As seen, sediment balance is almost secured in the sediment storage reservoir with provision of watershed conservation in the Keduang River catchment.

11.2 Mid Term Plan: Countermeasures for Sediment Inflows from Other Tributaries

The design annual sediment balance of the Wonogiri reservoir for the mid term plan is shown in Figure 28. Watershed conservation will be implemented for a total area of around 23,120 ha that covers 29 villages in the Tirtomoyo, 8 villages in the Temon, 25 villages in the Upper Solo, 19 villages in the Alang, 7 villages in the Ngunggahan, 7 villages in the Wuryantoro River basins and 2 villages in the remaining area. After implementation, annual sediment inflow into the Wonogiri reservoir is expected to be reduced by 0.92 million m^3. The annual sediment inflow would be reduced from 1.96 million m^3/year to 1.04 million m^3/year.

Annual sediment deposits in the Wonogiri reservoir are 1.00 million m^3/year. The sediment balance satisfies the basic concept that allowable annual sediment deposition rate is less than the original design sedimentation rate of 1.2 million m^3/year.

A preliminary projection for future sedimentation in the Wonogiri reservoir was made for both with- and without-condition of Midterm Plan. The projection period is 100 years. The future condition is projected based on the annual sediment balance of the both conditions. Projected future state of sedimentation is illustrated in Figure 27. By year 2055, the Wonogiri reservoir will lose around 28% of its effective storage capacity and completely lose its dead storage capacity. Furthermore, the Wonogiri reservoir will lose about 62% of the effective storage capacity by around the year 2105.

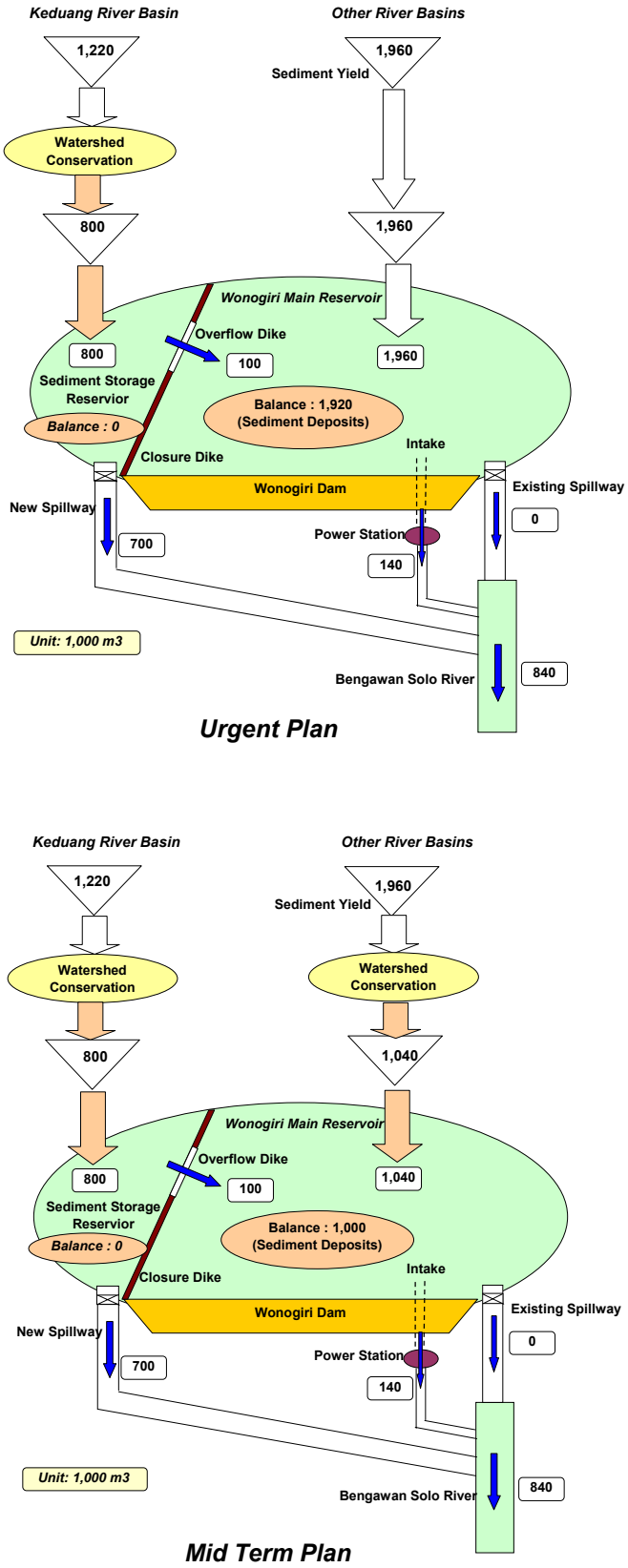


Without Mid Term Plan **With Mid Term Plan**

Source: JICA Study Team

Figure 27 Illustration of Predicted Sedimentation Condition in Wonogiri Reservoir in Year 2105

[2] As detailed in Subsection 11.3.1 of the Main Report, at the Steering Committee meeting on July 19, 2006, it was strongly requested that the construction costs of the sediment storage reservoir in the Master Plan should be reviewed for possible reductions. Along this line, reservoir sedimentation simulations were carried out to determine the number of gates and design capacity of annual average sediment releasing from the sediment storage reservoir. Finally, a total gate width of 15.0 m (=B7.5 m x 2 nos.) was selected in terms of the unit cost per m3.



Source :JICA Study Team

Figure 28 Design Annual Sediment Balance in the Wonogiri Reservoir by Urgent and Mid Term Plans

11.3 Prioritization of Proposed Countermeasures

The suggested prioritization of the proposed countermeasures is:

Table 23 Prioritization of Proposed Countermeasures

Phasing of Implementation	Purpose
1. Urgent Countermeasures	***▪Keep proper function of the intake***
a. Sediment Storage Reservoir with New Gate	▪Pass through and flush out the inflow of sediment and garbage from the Keduang River
b. Watershed Conservation in Keduang catchment	▪Mitigate sediment yield in the Keduang catchment and thereby reduce sediment inflow into the reservoir
c. Periodic Maintenance Dredging at Intake	▪Avoid blocking at the intake due to sediment deposits and garbage
2. Mid Term Countermeasures	***▪Keep in order the Wonogiri reservoir functions***
a. Watershed Conservation in other tributaries	▪Mitigate sediment yields from other tributary catchments and thereby reduce sediment inflow into the reservoir
3. Long-lasting Countermeasure	***▪ Keep in order the Wonogiri reservoir functions***
a. Rehabilitation of Watershed Conservation Areas	▪ Keep in order the conserved Wonogiri watershed function

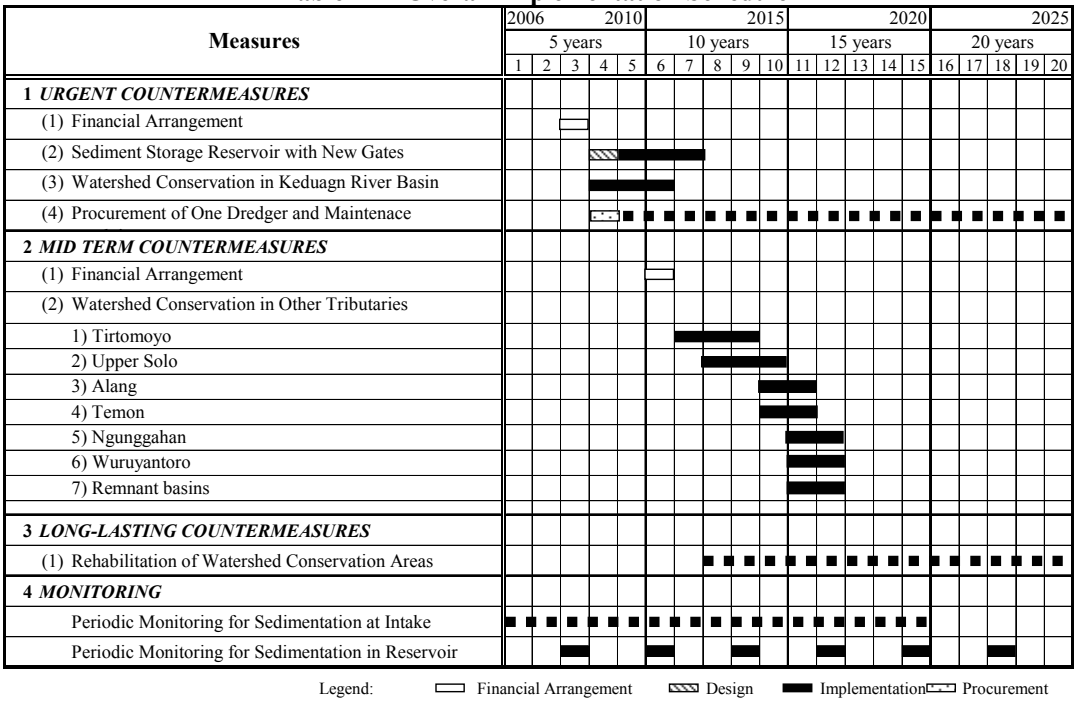
Source: JICA Study Team

The continuous rehabilitation, after completion of the mid term countermeasures, is categorized as a long-lasting countermeasure. This countermeasure aims at maintaining soil erosion rates at the design levels to avoid renewed deterioration of cultivated farmlands and to keep them in the improved state. The long-lasting rehabilitation works are intended to be implemented using local budget and under a funding framework that transfers some of the benefit from the downstream communities of the Wonogiri dam to the upstream ones.

11.4 Implementation Program

Overall implementation schedule is presented below.

Table 24 Overall Implementation Schedule



Source: JICA Study Team

Urgent plan should be commenced as early as possible to ensure proper function of the

intake is maintained. Implementation of the mid term plan can be commenced in the latter part of the urgent plan. Since the high sediment yield in tributaries, other than the Keduang River basin, will continue even after the completion of the urgent plan, mid term plan should be commenced at the earliest opportunity to mitigate sediment yield and thereby to prolong the dam reservoir life.

11.5 Project Cost

Total project cost is estimated below:

Table 25 Summary of Project Cost

Countermeasures	Cost (US$ thousand)
1. Urgent Plan	
a. Sediment Storage Reservoir with New Gates	36,070
b. Watershed Conservation in Keduang Catchment	13,835
c. Procurement of One Dredger	3,586
Sub Total	***53,491***
2.Mid Term Plan	
a. Watershed Conservation t in Tirtomoyo Catchment	10,433
b. Watershed Conservation in Upper Solo Catchment	11,049
c. Watershed Conservation in Temon Catchment	2,418
d. Watershed Conservation in Alang Catchment	4,856
e. Watershed Conservation in Ngunggahan Catchment	2,807
f. Watershed Conservation in Wuruyantoro Catchment	2,148
g. Watershed Conservation in Remnant Catchment	1,349
Sub Total	***35,060***
Grand Total	**88,551**

Source: JICA Study Team

11.6 Economic Evaluation

The economic feasibility of the Project is evaluated by calculating the economic internal rate of return (EIRR) for 50 years after the completion of the Project. The project benefit is defined as the difference of the profit between the future with project and without project conditions. The project benefits consist of irrigation, hydro-power and watershed benefits. In case of irrigation and hydro-power benefits, it is assumed that without the project, the intake to provide for irrigation and hydro-power will cease to function by the year 2022 because the forebay of intake will be fully of sediments.

The benefit from the watershed projects is as the incremental production of agricultural crops from land improvement and from fruit tree planting in the bench terrace areas. The EIRR of the Project is 16.4%. The Project is considered to be economically feasible.

11.7 Capacity for Operation and Maintenance

PJT I Bengawan Solo is responsible for the operation and maintenance of the Wonogiri dam (the responsibility was transferred by PBS in 2003). The main revenues of PJT I Bengawan Solo come at present from tariff collection for the Wonogiri dam water from: i) PLTA Wonogiri (hydropower generation), and ii) domestic and industrial users. These revenues can be used to cover the O&M expenditures. The revenue in 2005 was Rp. 6,101 million.

PJT I Bengawan Solo can spend up to 30% of its revenues on the O&M expenditures. In 2005, the O&M expenditure was about 24% of the revenue.

11.8 Current Institutional Issues and Recommendation for Watershed Management

An institutional study of the management of the Wonogiri watershed has been carried out at local, provincial and national levels. In general, the existing institutional framework for watershed management seems adequate. However, some significant issues were identified for which remedial actions have been recommended. The most important of these are summarized in the table below.

Table 26 Main Issues and Recommendations

Issue	Recommendation
1. Lack of law enforcement (leading to uncontrolled illegal activities in private / state forest areas)	Establish multi-sectoral taskforce in Kabupaten Wonogiri backed by Central and East Java governors, national authorities and funding
2. Lack of funds and other resources at kabupaten and province levels	More funds to be transferred from central government (Ministries of Forestry, Agriculture) as part of otonomi daerah decentralization, plus local efficiency drive. Increase field staff strength and resources in forestry and agriculture kabupaten
3. No adequate mechanism for multi-sectoral management of the Wonogiri watershed	Establish immediately a Wonogiri Watershed Coordination Committee with members from Wonogiri and Pacitan kabupaten
4. No standard Central Government regulation of both private and state forests. State forests contribute significant sediment run-off	BPDAS Solo (reporting to Ministry of Forestry) to regulate the work of State Forestry Corporation (as well as non-state forest) in Solo river basin
5. Insufficient importance attached to watershed management	In addition to the above, Sub Dinas Forestry in Kabupaten Wonogiri to be upgraded to full Dinas

Source: JICA Study Team