CHAPTER 7 BASIC STRATEGY FOR FORMULATION OF MASTER PLAN

7.1 Summary of Current Status of Sedimentation in Wonogiri Reservoir

Table 7.1.1 below summarizes the results of the reservoir sedimentation survey performed in 1993, 2004 and 2005 that are discussed in detail in Chapter 3.

Table 7.1.1 Historical Change of Wonogiri Reservoir Capacity and Sediment Deposit

Reservoir Zone	Reservoir Capacity (million m^3)				Sediment Deposit (million m^3)	
	1980	1993	2004	2005	1993	2005 (%)
Below EL. 127.0m (LWL)	114	69	58	58	45	56 (49%)
Below EL. 136m (NHWL)	547	468	435	433	79	114 (21%)
Below EL. 138.3m (DFWL)	730	650	618	616	80	114 (16%)

Source: JICA Study Team

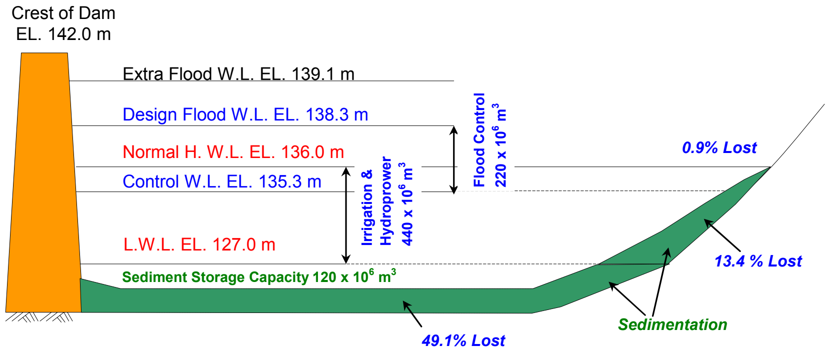
The losses of reservoir storage capacities due to sedimentation in the three (3) storage zones between 1980 and 2005 are estimated as summarized in Figure 7.1.1 below:

Table 7.1.2 Wonogiri Reservoir Capacity Loss by Storage Zone between 1980 and 2005

Reservoir Zone	Reservoir Capacity (million m^3)		Capacity Lost due to Sedimentation	
	1980	2005	Volume (million m^3)	Ratio to Original Volume (%)
Flood Control Storage (EL. 135.3-138.3m)	232	230	2	0.9
Water Use Storage (EL. 127.0-136.0m)	433	375	58	13.4
Dead Storage (below EL. 127.0m)	114	58	56	49.1

Note: Reservoir capacity is reevaluated based on the DEM created under the Study. Reservoir capacity in 1980 was re-estimated based on the DEM. As shown in Figure 3.1.1, the flood control storage capacity overlaps the effective storage capacity in the range of EL. 135.3 m – EL. 136.0 m.

Source: JICA Study Team



Source: JICA Study Team

Figure 7.1.1 Wonogiri Reservoir Loss of Capacity by Storage Zone as of 2005

From the above sedimentation survey results, the current status of the Wonogiri reservoir is assessed as follows:

i) There is almost no change in the flood control storage zone between EL. 135.3 m and EL. 138.3 m. This is because the sediment inflow occurs during the wet season and then sediment deposition occurs dominantly in a range of the storage zone between LWL (EL. 127.0 m) and NHWL (EL. 136.0 m).

ii) Therefore, hardly any sediment deposits occur in the flood control storage zone above NHWL even though bank failures/erosions readily occur and visible around the fringe of reservoir area due to wave action in the reservoir. Therefore flood control effect of the Wonogiri dam against a PMF is secured even under the current severe sedimentation condition.

iii) In the dead (sediment) storage zone below EL. 127.0 m, a volume of 56 million m^3 in total or 49.1% of the original storage capacity has been lost due to sedimentation in 1980-2005 (see Table 7.1.2 above).

iv) The volume of the water use storage zone between El. 127.0 m and 136.0 m 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 storage capacity due to sedimentation between 1980 and 2005 (see Table 7.1.2 above).

v) Approximately 16% of the original gross storage capacity (= 730 million m^3) below DFWL (EL 138.3 m) was lost due to sedimentation between 1980 and 2005. The average annual rate of reservoir capacity loss is therefore around 0.64%/year (=16%/25 years) (see Table 7.1.1 above).

7.2 Projection of Future State of Wonogiri Reservoir Sedimentation in Case without Countermeasures

Massive sedimentation has occurred in the Wonogiri reservoir. As a result, the storage volume of Wonogiri dam has been reduced every year due to continuous sedimentation. Based on the annual average loss rate of the reservoir capacity mentioned above, the future state of the Wonogiri reservoir, without any countermeasures for the sedimentation problems, is preliminarily projected as described below:

i) If no reservoir sediment management measures are put in place from now on, it is apparent that problems of sediment blocking at the intake structure will take place within the projection period of 100 years. However, it is assumed that no sediment blocking at the intake will occur within the projection period.

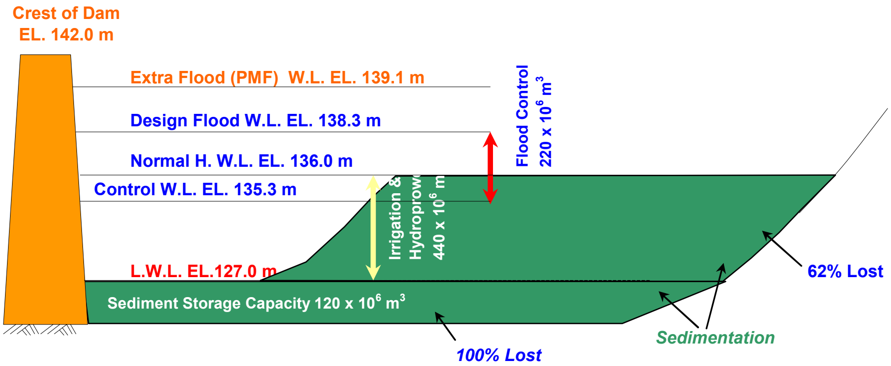
ii) The continuing sedimentation occurs only in both the water use and dead storage zones below NHWL (EL. 136.0 m).

iii) The current sedimentation condition in 2005 that is illustrated in Figure 7.1.1 above is adopted as the initial condition for the projection.

iv) The annual average sediment inflow volume is assumed to be 3.2 million m^3, which is equivalent to the average in 1993-2005 (see Table 5.4.1). On the other hand, the annual sediment outflow is assumed to be 0.41 million m,^{3} which is the estimated average one for the period from 1993 to 2004, consisting of 0.26 million m^3 contained in water used for power generation and 0.15 million m^3 in water released through the existing spillway. The estimation was made by the Wonogiri reservoir sedimentation analysis model developed under the Study.

v) Annual deposition rates are assumed at 50% for the water use storage zone and at 50% for the dead storage zone based on the sedimentation volume in 1980-2005 (See Table 7.1.2 above).

The future condition of the Wonogiri reservoir sedimentation is projected based on the annual sediment balance applying the above conditions and assumptions. The projected condition in the year 2105 is illustrated in Figure 7.2.1 below:

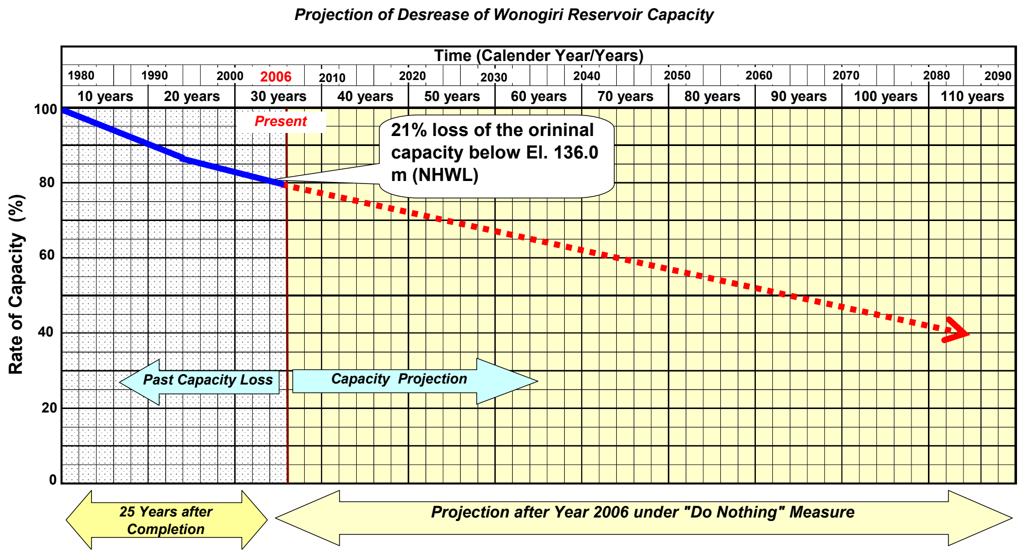


Source: JICA Study Team

Figure 7.2.1 Projected Sedimentation Condition of Wonogiri Reservoir in Year 2105

By year 2055, the Wonogiri reservoir will lose around 28% of its water use storage capacity and completely lose its dead storage capacity. Furthermore, the Wonogiri reservoir will lose about 62% of the water use storage capacity by around the year 2105. As of 2005, around 21% of the original capacity below NHWL (El. 136.0 m) is lost as shown in Table 7.1.1 above. The decrease of the total capacity in both the water use and dead storage zones (total storage capacity below NHWL (El. 136.0 m)) after completion of the Wonogiri dam is projected as illustrated in Figure 7.2.2 below.

In general, impact or severity of reservoir sedimentation problems is represented by the years taken to lose half of the initial reservoir volume. It is generally recognized that reservoirs often experience serious operational constraints by the time half of its original capacity is lost.[1] As projected in Figure 7.2.2 below, the Wonogiri reservoir will lose half of the capacity by around the year 2062. In case of the Wonogiri reservoir, however, it is noted that serious sedimentation issues have occurred a long way before half the capacity has been lost, especially concerning the current water uses such as hydropower generation, irrigation and domestic water supply.



Source: JICA Study Team

Figure 7.2.2 Simplified Projection of Decrease of Wonogiri Reservoir Capacity

[1] Gregory L. Morris、P.E. Ph.D., Reservoir Sedimentation management, Worldwide Status and Prospects, Session on Challenges to the Sediment Management for Reservoir Sustainability, The 3rd World Water Forum, 2003

7.3 Sedimentation Issues and Problems in Wonogiri Reservoir

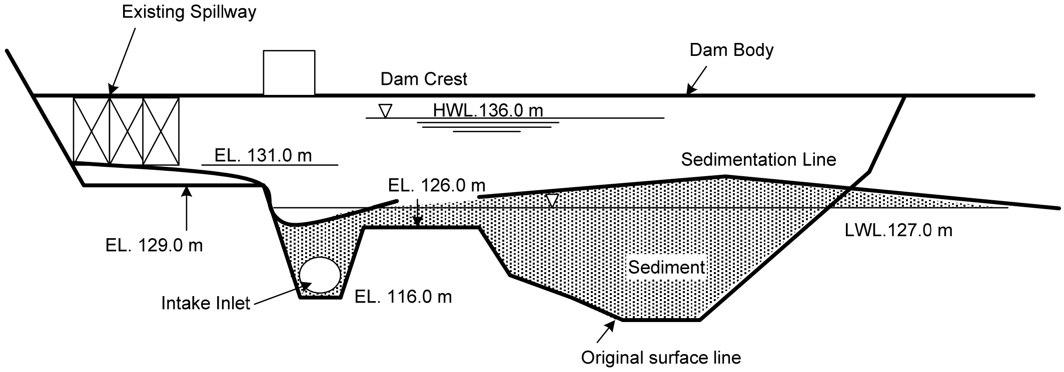
The sedimentation issues and problems of the Wonogiri reservoir are summarized below:

i) Sediment deposits and garbage at the intake structure,
ii) Decrease of water use storage volume due to high sediment yields in the Wonogiri dam watershed, and
iii) Risky reservoir operation against PMF due to the decrease of effective storage volume.

The current situations of sedimentation issues and problems are briefed below.

7.3.1 Sediment Deposits and Garbage at Intake

The intake structure is a head structure to feed the reservoir water into a power waterway through which the water is conveyed to turbines for power generation and the downstream irrigation systems. It has been seriously affected by sediment deposits transported by the Keduang River. Sediment levels have risen almost to LWL 127 m in the forebay located immediately upstream of the dam as illustrated below:



Source: JICA Study Team

Figure 7.3.1 Typical Cross Section in Forebay of Intake

The sediment inflow into the reservoir from the Keduang River basin is the primary cause of the current sediment-related problems on the intake structure. The Keduang River enters the reservoir portion just upstream of the dam and has deposited massive quantities of sediments in the forebay adjacent to the dam.

Photos below show the debris and garbage at the intake. The last flushing of debris through the spillway was conducted on December 29, 2004 at RWL (El. 133.4 m). The garbage in front of the spillway was moved by manpower from the surroundings of the floating booms for the purpose of flushing.

Photo: Removed vegetative debris and garbage at intake (December 29, 2004)


Photo: Debris flushing on December 29, 2004


Photo: Debris flushing on December 29, 2004

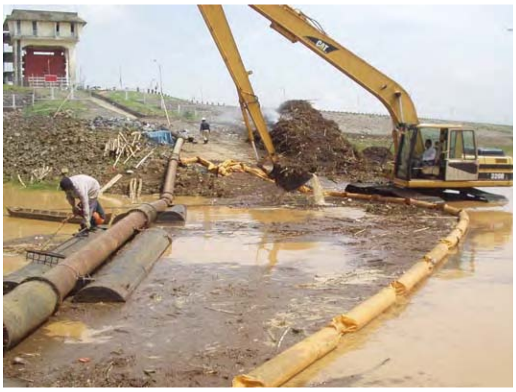



Photo: Debris removal in January, 2004

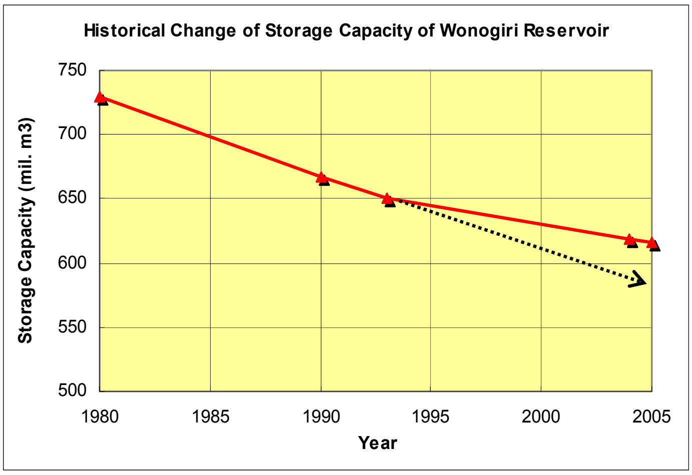
From a preliminary analysis on the suction effect of the intake inlet, it appeared that the velocity at the inlet is around 0.24 m/s, which is far larger than the estimated critical tractive velocity of 0.009 m/s for the sediment deposits at the intake ($D_{60\%}$=0.01 mm). This implies that, if no garbage deposits exist, the intake blockage would not occur.

7.3.2 Decrease of Effective Storage due to High Sediment Yield in Wonogiri Dam Watershed

The average annual sediment inflow into the Wonogiri reservoir in 1993-2004 is around 3.18 million m^3 (see Table 4.6.1). The Wonogiri reservoir has filled with sediments more rapidly than initially conceived since its completion in 1980. As discussed in Section 7.2, it is forecast that the main water supply functions will be seriously affected within the coming 50 to 60 years.

The source of the sediment deposits is the Wonogiri dam watershed. As discussed in detail in Chapter 4, almost 93% of the source is surface soil erosion from cultivated lands. The Upper Solo (Wonogiri) Watershed Protection Project funded by IBRD was carried out by the Ministry of Forestry for the period from 1988/89 to 1994/95. The purpose of the project was to reduce the surface soil erosion from the Wonogiri dam watershed and thereby to extend the reservoir life. Soil conservation practices were adopted, including improving farming techniques to reduce sheet and rill erosion, and structures provided to reduce gully and river bank erosions.

Historical change of the Wonogiri storage capacity (sum of the water use and dead storage zones) since its completion in 1980 is shown in Figure 7.3.2 below together with the reservoir sedimentation surveys, which were conducted in 1990, 1993, 2004 and 2005.



Source: JICA Study Team

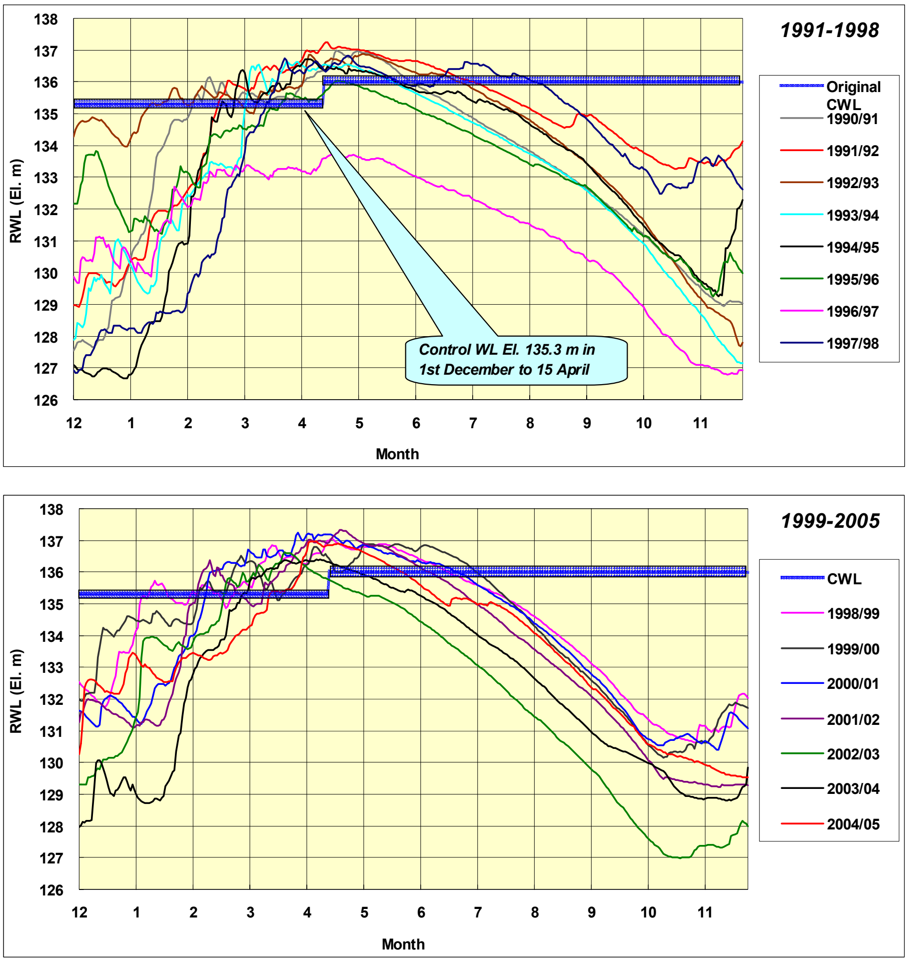
Figure 7.3.2 Historical Change of Wonogiri Reservoir Capacity

The average reservoir sedimentation rate was around 6.2 million m^3/year in 1980-1990, 5.7 million m^3/year in 1980-1993, 4.6 million m^3/year in 1980-2004 and 4.7 million m^3/year in 1980-2005. On the other hand, the sedimentation rate apparently decreased from 5.7 million m^3/year in 1980-1993 to 2.8 million m^3/year in 1993-2005.

The annual sediment inflow volume highly depends on hydrological conditions in each year, which are usually represented by the hydrological dry year and wet year. Therefore, it can be said that the sedimentation rate varies year by year. It appears that one of the causes for such significant difference in sedimentation rates before and after 1993 is that many historic large floods with a peak discharges of more than 2,500 m^3/s only occurred in 1980s (see Table 2.3.2), resulting in massive sediment inflows into the Wonogiri reservoir. The other conceivable cause is the reduction of surface erosion rate from the Wonogiri dam watershed after completion of the said project by the Ministry of Forestry in 1988/89-1994/95 (detailed in subsection 2.6.4). The historical change of the Wonogiri reservoir capacity reveals that a significant reduction in the soil erosion has occurred as a result of the project.

7.3.3 Risky Reservoir Operation against PMF due to Decrease of Effective Storage

Figure 7.3.3 below graphically shows the operation records of the Wonogiri reservoir in 1991-2005. According to the operation rule, during the flood period from December 1 to April 15, the reservoir water level has been controlled so as not to exceed the Control Water level (CWL: EL. 135.3 m) for ensuring safety of the dam against PMF. However, as far as the actual operation practices show there has been no observance of the rule to maintain the reservoir water level below the CWL except for the hydrological dry years of 1996 and 1997.

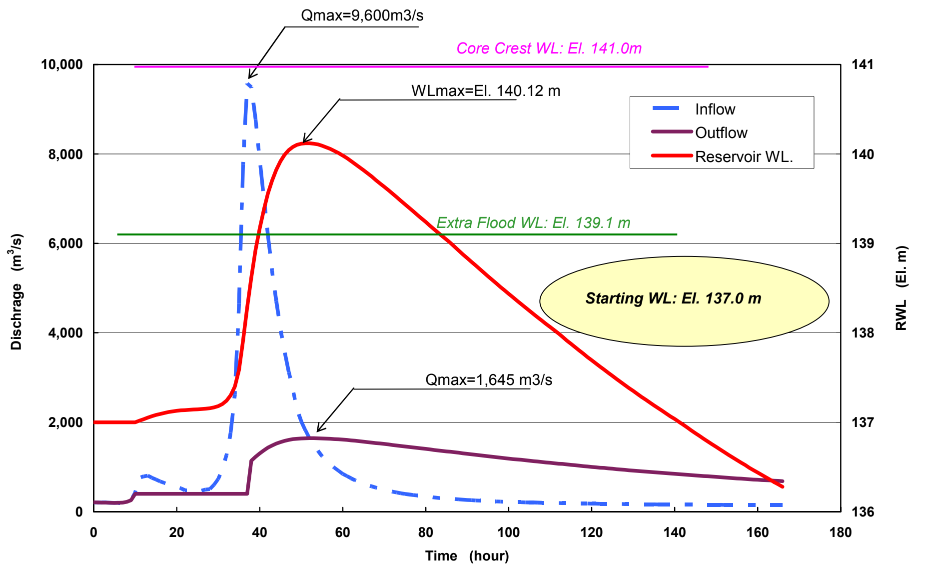


Source: JICA Study Team

Figure 7.3.3 Wonogiri Reservoir Operations in 1991-2005

In hydrologically ordinary years, the reservoir water level has been raised up to around EL. 137 m exceeding CWL (EL. 135.3 m) and NHWL (EL. 136.0 m). With regard to the release of PMF and keeping the required freeboard, the safety of the Wonogiri Dam under the current reservoir operation practice was assessed. The assessment was made based on the simulation of reservoir operation against a PMF, applying the current practice with the starting water level of El. 137.0 m. The simulation results are shown in Figure 7.3.4 below.

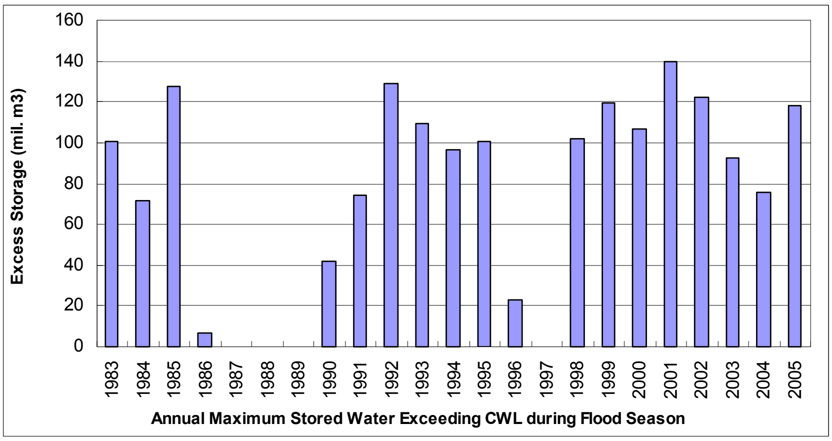
As seen in the figure, the reservoir water level rises up to El. 140.12 m with a maximum release of 1,645 m^3/s under the current reservoir operation practice. In the original design, the maximum water level for the PMF was at El. 139.1 m with a freeboard of 1.9 m between the maximum water level and the crest elevation of the impervious center core zone (El. 141.0 m). Although the PMF might not overtop the dam crest, the freeboard decreases to 0.88 m. Considering that the freeboard of 1.9 m in the original design was determined by taking into account the additional freeboard required to allow for the wave height caused by concurrent wind at the time of occurrence of the PMF, it can be said that the current reservoir operation practice is risky against PMF from the dam safety viewpoint (because of insufficient freeboard).



Source: JICA Study Team

Figure 7.3.4 Operation against PMF at Starting Water Level of El. 137.0 m

Figure 7.3.5 below presents the annual maximum water volume stored in the reservoir for water levels higher than CWL (EL. 135.3 m) during the flood period. The excess water of 140 million m^3 was stored when the maximum reservoir water level was El. 137.23 m on April 5, 2001 exceeding CWL (EL. 135.3 m) by 1.93 m.



Source: JICA Study Team

Figure 7.3.5 Annual Maximum Stored Water Volume Exceeding CWL during Flood Season

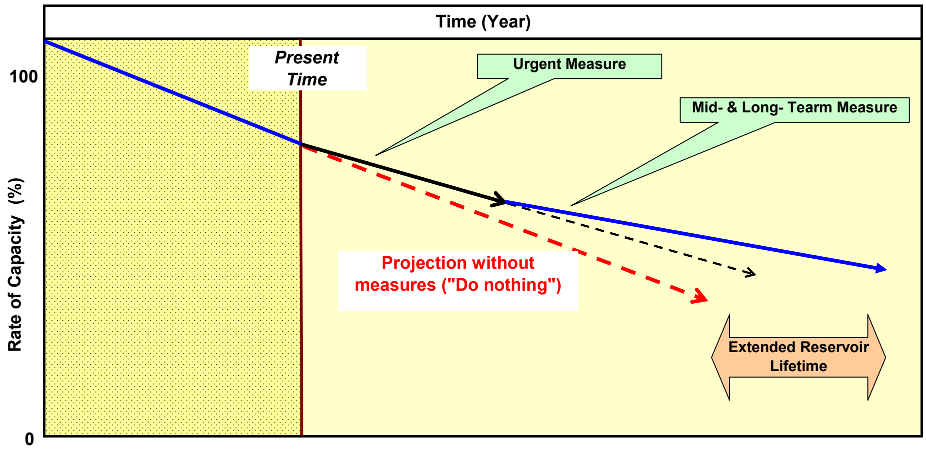
The current capacity of water use storage zone between LWL (EL. 127.0 m) and NHWL (EL. 136.0 m) has decreased from 440 million m^3 in 1980 to 375 million m^3 in 2005. Therefore, under the current practice of the Wonogiri reservoir operation of storing water up to around El. 137.0 m, totally 450 million m^3 (= 375 +75) of water has been additionally stored and used for hydropower generation and irrigation water supply. The storage volume exceeds the initially allocated storage of 440 million m^3.

7.4 Goal and Strategies for Master Plan Formulation on Wonogiri Reservoir Sediment Management

The primary purpose of the Study is to establish a master plan for sustainable countermeasures for sedimentation problems of the Wonogiri reservoir. The uppermost goal of the Study, which has been already set up between both Governments of Indonesia and Japan, is to implement the countermeasures in accordance with the master plan to secure the long-term ability of the reservoir to supply water for irrigation and hydropower generation as well as flood control. The proposed master plan will provide the framework and indicates the direction towards which comprehensive sediment management of the Wonogiri reservoir should go. The measures to be proposed under the Study shall be realistic and practical ones. Further, it is highly expected that the Study will provide solutions and technical approaches for the similar sedimentation problems in other existing reservoirs in Indonesia.

The Wonogiri reservoir is the sole large one that exists on the Bengawan Solo mainstream. 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. In this sense, the Wonogiri dam is one of the lifelines in the national infrastructure. The economic value of the Wonogiri dam for water storage is undoubtedly very high. In the highly populated Java Island, a reservoir is a precious resource that is very difficult to replace when it is completely filled with sediments.

From the realistic viewpoint, it is considered difficult to exploit other reservoir sites in Java on a similar scale to the Wonogiri reservoir. Although the complete restoration of the Wonogiri reservoir is a very hard task, the sustainable management of the Wonogiri reservoir function is crucial for preserving the future welfare of all the stakeholders in the basin. Hence, it is recommended that the Wonogiri reservoir shall be operated in a sustainable manner through provision of an effective reservoir sediment management system to prolong the reservoir lifetime as illustrated in Figure 7.4.1 below:



Source: JICA Study Team

Figure 7.4.1 Illustration of Effects by Master Plan Implementation

Considering the above, the master plan has the following goals:

i) **The Wonogiri dam should continue to contribute to stabilization of the livelihood of the community as well as improvement of social welfare for at least the next 100 years.** This goal will be achieved only by securing and maintaining the initial 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 the reservoir operation rule. The Wonogiri reservoir should be operated properly, from the dam safety viewpoint, at the time of occurrence of any floods of magnitude.

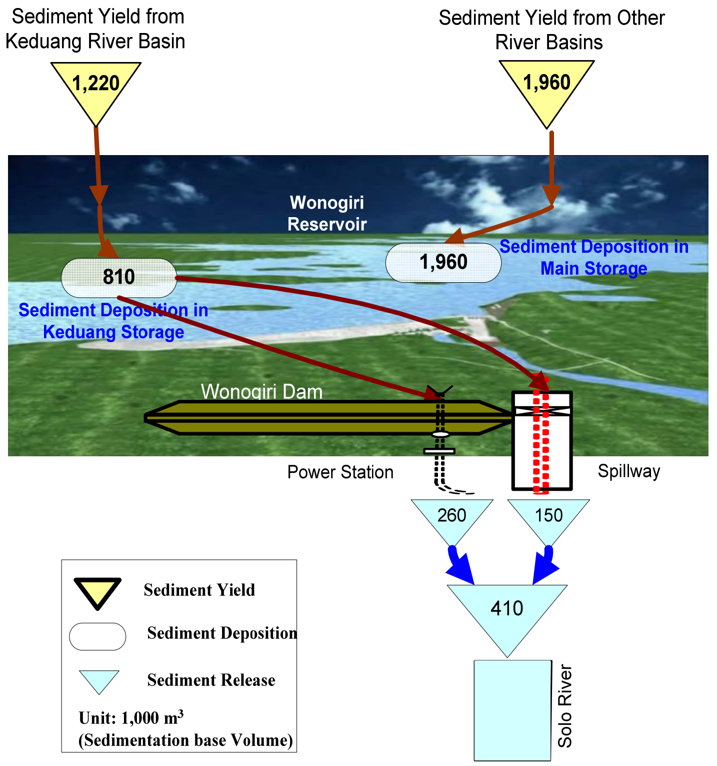
iii) **Sustainable management of the Wonogiri reservoir will be achieved through the**

linkage with good management and conservation of the Wonogiri dam watershed. The Wonogiri dam watershed will be managed and conserved in harmony with improvements in the quality of life of the farmers within its watershed.

In order to achieve the goal above, a master plan on the Wonogiri reservoir sediment management system has been formulated based on the following strategies:

A. Combination of Reservoir Sediment Reservoir Management Measures and Watershed Management and Conservation Measures:

i) The current annual average sediment yield and sediment balance in the whole Wonogiri reservoir for 1993-2005 is worked out as shown in Figure 7.4.2 below:



Source: JICA Study Team

Figure 7.4.2 Current Annual Wonogiri Sediment Balance

The annual average sediment inflow into the reservoir is 3.18 million m^3, out of which 1.22 million m^3 of sediment enters the reservoir from the Keduang River. The annual sediment outflow is estimated at 0.41 million m^3, consisting of 0.26 million m^3 through power generation and 0.15 million m^3 from the spillway. From the sediment balance, 2.77 million m^3 of sediment is deposited in the reservoir. From the reservoir simulation results, most of sediments inflowing into the reservoir from tributaries other than the Keduang River are deposited in the reservoir.

ii) Every year around 3.18 million m^3 of sediment enters the reservoir. For the preliminary design of structural measures, **the target design sediment deposition rate has been determined to be equal to or less than the rate of 1.2 million m^3/year adopted in the original design of Wonogiri dam in 1975**. Accordingly, the target total sediment deposition in the next 100 years is estimated at up to 120 million m^3 (=1.2 million m^3/year x 100 years).

iii) Whatever measures are proposed in the master plan, reduction of water supply from the Wonogiri reservoir is unavoidable to some extent as the current remaining sediment storage capacity of around 58 million m^3 in 2005 is not enough to accommodate the next 100-years' sediment volume of 120 million m^3, resulting in sediment deposition in the effective storage zone of the reservoir. The allowable or acceptable limit of reduction of the irrigation water supply in the next 100 years constitutes one of the key factors.

B. Reservoir Sediment Management Measures with Less Social Impacts:

i) Massive sedimentation has already occurred in the Wonogiri reservoir. The best solution to overcome the Wonogiri reservoir sedimentation problems is a complete restoration of the reservoir (e.g. mechanical dredging of sediment deposits of around 114 million m^3), but it would require huge expenditure, as well as acquisition of vast spoil bank areas. On the other hand, it was discovered through the field investigation that only very small areas are available for disposal of the dredged sediment materials. Taking into account the annual average sediment inflow of 3.12 million m^3 into the Wonogiri reservoir, **the most practical and appropriate way is to reduce sediment inflow into the reservoir through implementation of the watershed management and conservation to such an extent that the reservoir lifespan will be extended.**

ii) The proposed Wonogiri reservoir sedimentation management system aims to enable the reservoir to properly function over a long-term period. **The system aims to effectively utilize the sediment transport capacity in the lower reaches of the Bengawan Solo River to the maximum extent** for the purpose of conveying sediments released from the Wonogiri dam to the estuary.

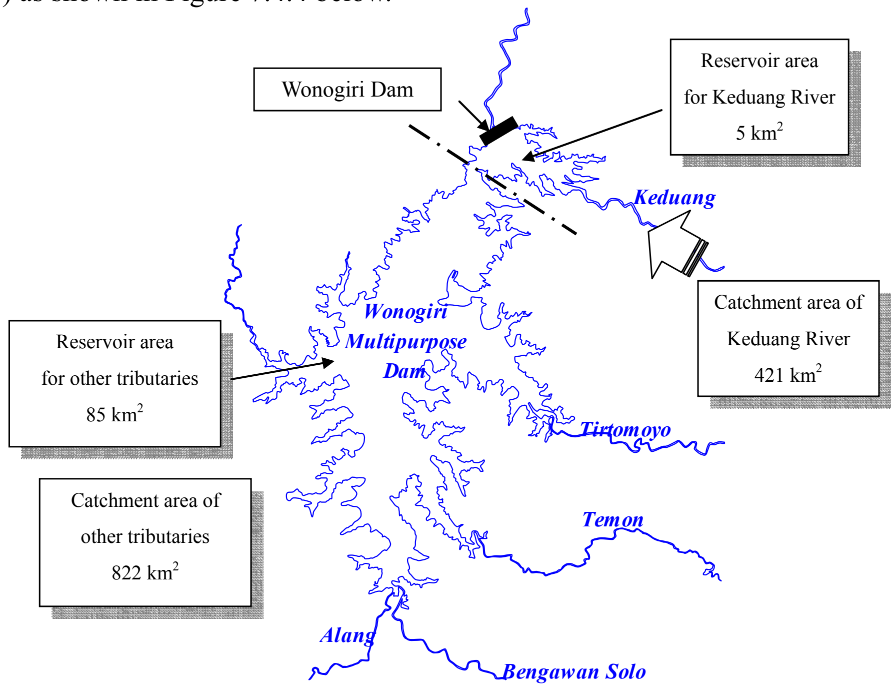
iii) In this connection, the system is designed to **minimize the impacts on the natural environment and social environment issues** such as resettlement of local inhabitants and land acquisition of private lands.

C. Prioritization of Urgent Measure and Mid- and Long-Term Measures:

i) From the technical viewpoint the blockage of the intake due to sediment deposits and garbage has to be avoided to ensure continuing water supply. **Top priority is placed on formulation of measures to prevent garbage deposition at the intake structure.** Since almost all of the garbage at the intake has drifted down the Keduang River, the urgent measure aims at resolving the garbage inflow from the Keduang River. If the garbage problems at the intake structure are resolved, no intake blockage is likely to occur.

ii) The Wonogiri reservoir is characterized by a particular shape on the right bank where the Keduang River pours into the upstream reservoir end situated very close to the dam. Out of the major five (5) tributaries, the Keduang River basin is the largest one with a catchment area of 421 km^2 or 34% of the total Wonogiri dam watershed area. However, the reservoir area accommodating the Keduang sediment inflow (hereinafter referred to as the "the Keduang reservoir area") is only 5 km^2 or 6% of the whole reservoir area as illustrated in Figure 7.4.3 below. Because of the relatively small storage volume of the Keduang reservoir area as compared with the large catchment area, progress of sedimentation in the Keduang reservoir area is much faster than those of other tributaries. As a result, a large quantity of sediments has been deposited in the portion close to the dam, especially in the forebay adjacent to the intake structure.

iii) Table 7.4.1 below shows the reservoir capacity losses of the Keduang reservoir area. Around 66% of the water use storage zone in the Keduang reservoir area has been lost due to sedimentation between 1980 and 2005. The dead storage zone in the sub-area has been completely filled with sediments. It is estimated that the storage capacity (below NHWL) in the Keduang reservoir area will be lost by around the year 2022 applying the annual average sediment deposition of 0.77 million m^3 (see Figure 7.4.2) as shown in Figure 7.4.4 below.



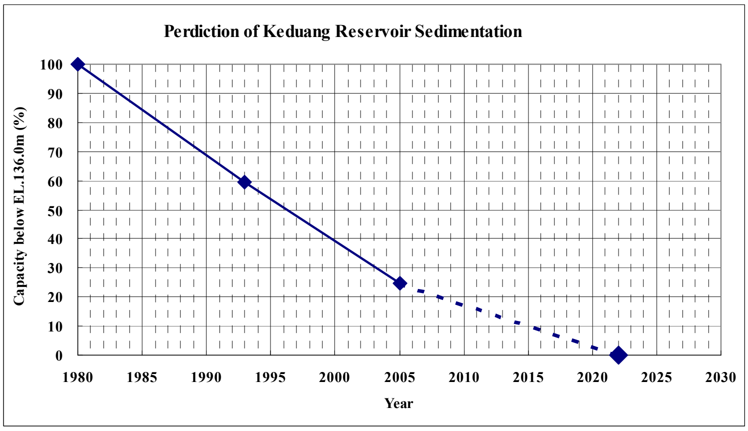
Source: JICA Study Team

Figure 7.4.3 Reservoir Area for Keduang River

Table 7.4.1 Reservoir Capacity Loss of Keduang Reservoir Area between 1980 and 2005

Reservoir Zone	Reservoir Capacity (million m^3)		Capacity Lost due to Sedimentation	
	1980	2005	Volume (million m^3)	Ratio to Original Volume (%)
Flood Control Storage (El. 135.3 – 138.3 m)	18	12	6	33.7
Water Use Storage (El. 127.0 – 136.0 m)	40	14	26	65.6
Dead Storage (below El. 127.0 m)	16	0	16	100

Note; Reservoir capacity is reevaluated based on the DEM created under the Study.
Source: JICA Study Team

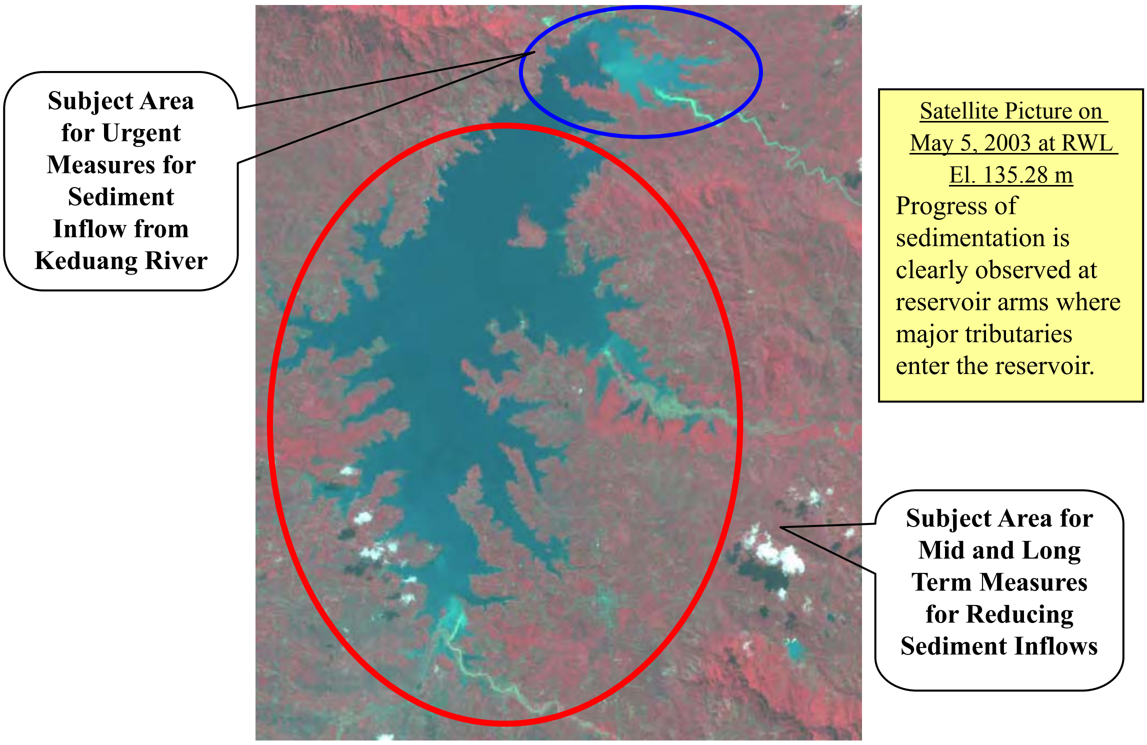


Source: JICA Study Team

Figure 7.4.4 Prediction of Capacity Loss in Keduang Reservoir Area

iv) Sediment and garbage inflow from the Keduang River into the reservoir is the primary cause of the current sediment-related problems on the intake structure. **Countermeasures for the problems at the intake structure need to treat the sediment and garbage inflow from the Keduang as the top priority.**

v) Sediments inflowing into the reservoir from the Bengawan Solo, Tirtomoyo, Alang and Temon Rivers are deposited between LWL and NHWL forming a delta at each reservoir arm (mouth of tributary). Although each delta has a tendency to extend into the downstream deeper and wider portions of the reservoir, the longitudinal growth rate seems to be slow. It will take a long time before the deltas approach the area causing serious impact on the intake. For the other four (4) major tributary basins, **it is judged to be practical to adopt watershed management and conservation to reduce the sediment yield rate therein as the mid- and long-term measures.**



Source: JICA Study Team

Figure 7.4.5 Priority Areas of Master Plan

D. Comprehensive Approach for Watershed Management:

i) Soil erosion is a natural process that cannot be completely prevented. The majority of reservoir sediment deposits are composed of eroded soils from the cultivated dry lands in the Wonogiri dam watershed that are categorized as highly fragile to surface erosion. To mitigate the soil erosion and sediment yield in the Wonogiri dam watershed, **the Master Plan proposes to implement a comprehensive approach for watershed management, which comprises both structural and non-structural components.** Furthermore, it needs to focus on public involvement through encouraging the local farmers to improve their current land use practices by motivating a socio-economic development in the upland areas and thereby reducing the rate of erosion from dry land farming areas.

ii) As mentioned earlier, past efforts were made for large-scale soil conservation in the Wonogiri dam watershed with the Upper Solo (Wonogiri) Watershed Protection Project in 1988/89-1994/95 (detailed in subsection 2.6.4). The project appears to have reduced significantly the rate of soil erosion in that watershed. **The lessons learnt from the project should be considered and incorporated in the formulation of the conservation measures for the Wonogiri dam watershed management master plan.** Taking into consideration the linkage between poverty and poor management of dry farm land, which is one of lessons learnt from the aforesaid project, it is essential to implement the combined package of conservation measures and improved agricultural practices to be successful. In such a way, the watershed management program will be able to provide farmers with adequate, immediate and long term financial gains and thereby ensure positive participation of dry land farmers in the watershed. Besides, it is recommended that soil and land management measures are formulated in order to secure the livelihood of future generations.

E. Careful Observance of Current Reservoir Operation Rule:

i) As discussed in subsection 7.3.3, the Wonogiri reservoir has been operated with a level around 1 m above the original NHWL since year 1991 in order to store additional water of around 75 million m^3 therein. This practice was adopted to meet the strong water demands of the downstream water users.

ii) The aforesaid current reservoir operation practice in which the reservoir water level is raised above the original NHWL is 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 by around 75 million m^3, all the stakeholders have to recognize that the dam safety is of the utmost importance. In the Study, to be discussed in succeeding Chapter 8, various alternative measures are examined and compared from the technical and economic aspect. The technical evaluation and preliminary design of structural alternative measures fully take into account the current Wonogiri reservoir operation rule.