

## 6.5 Evaporation

Evaporation is measured at No. 815 meteorological station, EL. 500 m, in the Seti River basin. The average monthly evaporation from 1977 to 1997 is as shown in **Table 6.5-1**.

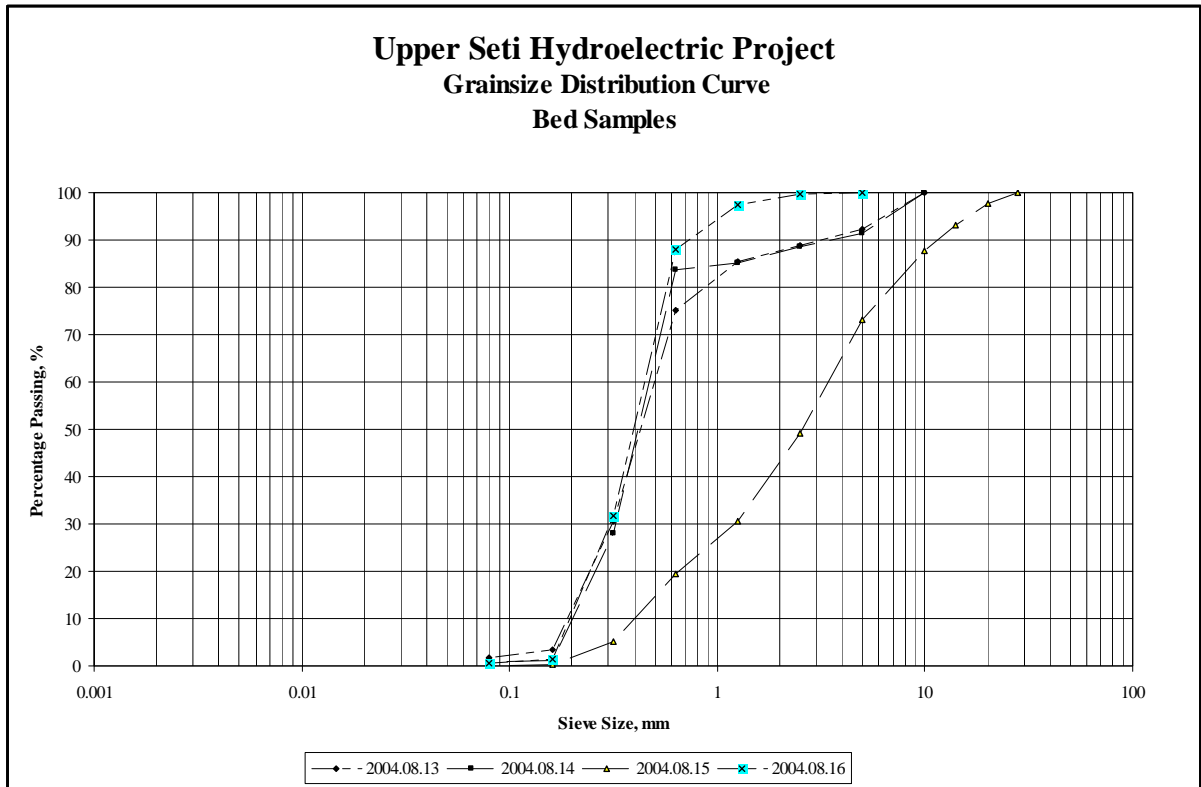
**Table 6.5-1 Average Monthly Pan Evaporation at No. 815 Meteorological Station**

(Unit: mm / day)												
Month Year	1	2	3	4	5	6	7	8	9	10	11	12
1977	NA	NA	NA	3.5	5.8	7.1	5.7	6.2	4.7	3.5	2.6	1.3
1978	1.6	2.1	4.8	3.7	6.2	5.0	5.9	4.7	3.9	3.2	2.3	1.6
1979	1.7	2.8	4.7	5.6	6.0	6.6	3.9	4.5	3.9	3.4	2.4	1.6
1980	1.4	2.7	4.4	5.9	5.3	5.1	4.8	4.6	4.4	3.4	2.3	1.9
1981	2.2	2.5	4.5	5.2	6.1	5.6	4.9	4.4	4.7	3.4	2.4	1.8
1982	2.3	2.5	3.8	6.9	5.6	6.0	5.3	5.1	3.9	2.9	2.1	1.7
1983	1.9	2.5	4.2	4.1	5.6	6.8	6.2	5.3	5.9	3.5	2.4	1.5
1984	1.5	2.7	4.4	4.7	6.4	3.3	7.2	4.4	3.7	3.1	2.8	NA
1985	1.5	2.3	4.2	4.3	4.9	5.2	4.1	3.7	3.4	2.8	1.9	1.6
1986	1.4	2.5	3.7	4.4	5.3	5.2	3.1	3.6	3.4	3.7	2.0	NA
1987	NA	2.9	4.1	4.3	5.5	5.8	5.2	3.9	3.5	2.6	1.9	1.2
1988	1.2	1.7	2.9	4.3	3.7	5.7	4.1	3.2	3.7	2.7	2.1	1.1
1989	1.8	1.6	3.1	5.1	4.9	4.8	2.7	3.1	3.1	3.0	2.0	1.8
1990	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1991	1.8	NA	NA	NA	NA	NA	4.4	3.7	3.9	2.6	1.7	1.4
1992	1.2	2.1	4.0	5.9	6.6	5.4	4.8	4.4	4.1	2.8	1.8	1.1
1993	1.1	2.0	3.8	5.4	5.2	6.4	5.5	4.4	3.2	2.8	1.7	1.2
1994	1.2	2.5	3.4	5.1	5.9	5.2	NA	4.5	3.7	2.3	1.7	0.9
1995	1.4	2.2	3.5	4.8	5.8	NA	4.5	4.7	3.4	2.6	1.6	0.6
1996	1.5	1.9	3.1	4.2	4.7	4.3	4.1	4.4	3.1	2.0	1.4	0.4
1997	0.9	1.8	3.0	4.5	NA	NA	NA	NA	NA	NA	NA	NA
Avg	1.5	2.3	3.9	4.8	5.5	5.5	4.8	4.4	3.9	3.0	2.1	1.3

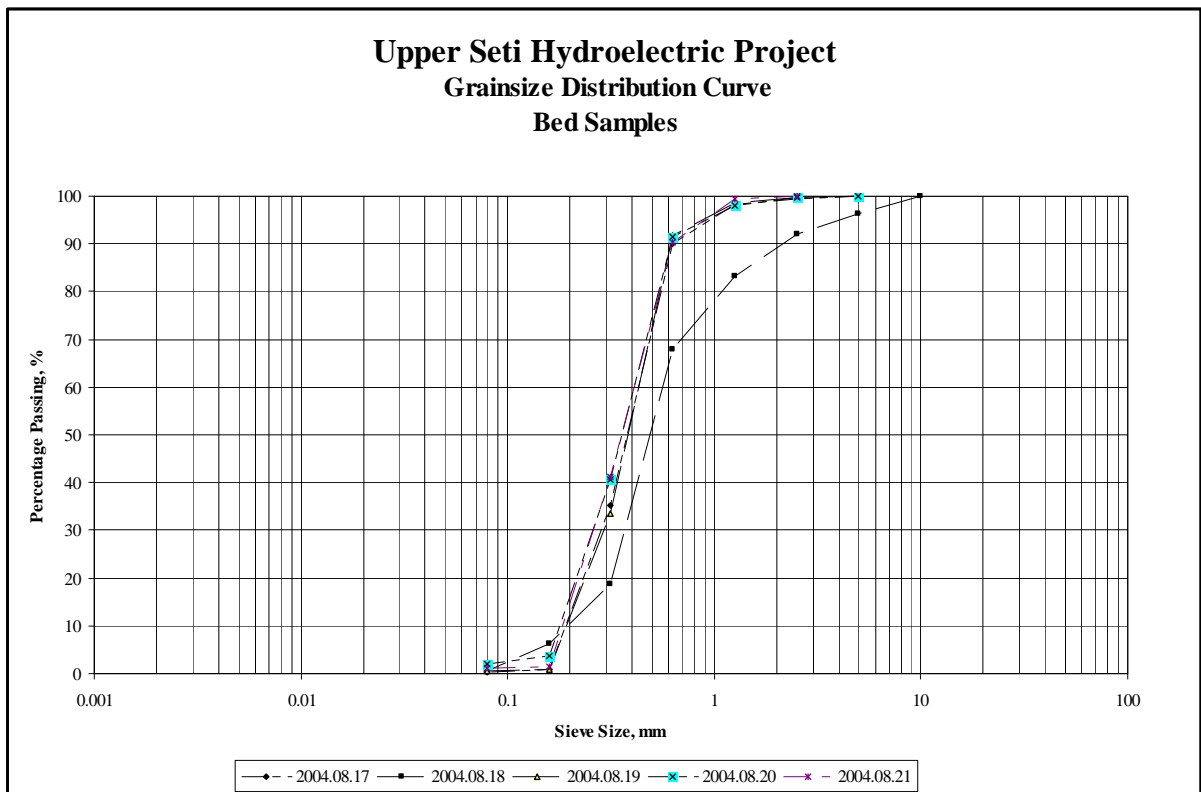
## 6.6 Sedimentation

### 6.6.1 Sediment Measurement

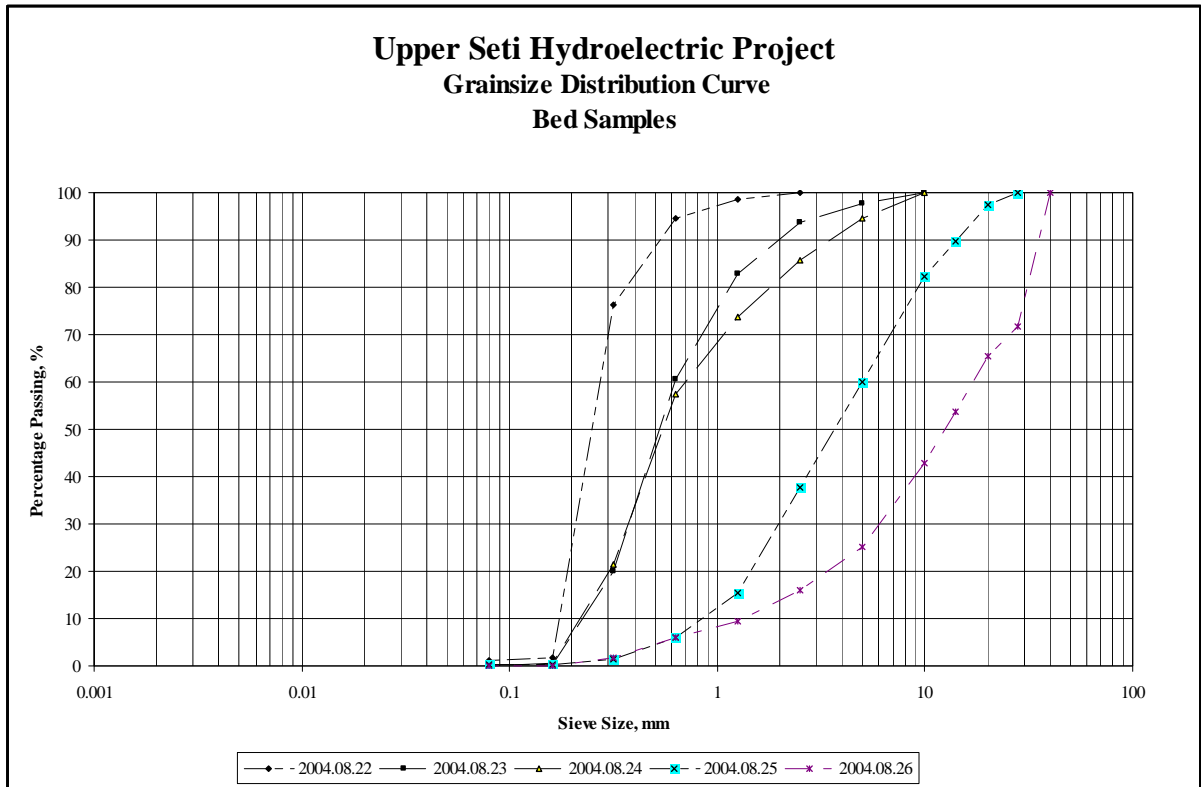
Suspended load sampling has been carried out at No. 430 gauging station from 1974 to 1978 by DHM, at No. 430.5 from June to December, 2000 by the Nepal Irrigation Sector Project (NISP), and at the Bhimad Bajar bridge on the Seti River, located 25km upstream of the Dam site, from June to September, 2001 and from July to October, 2004 by NEA, respectively. These records of suspended load concentration are attached in **Appendix-6**. Suspended and bed load samples are taken at the Bhimad Bajar bridge and gradation curves are exemplified as shown in **Figs. 6.6.1-1 to 6.6.1-6**.



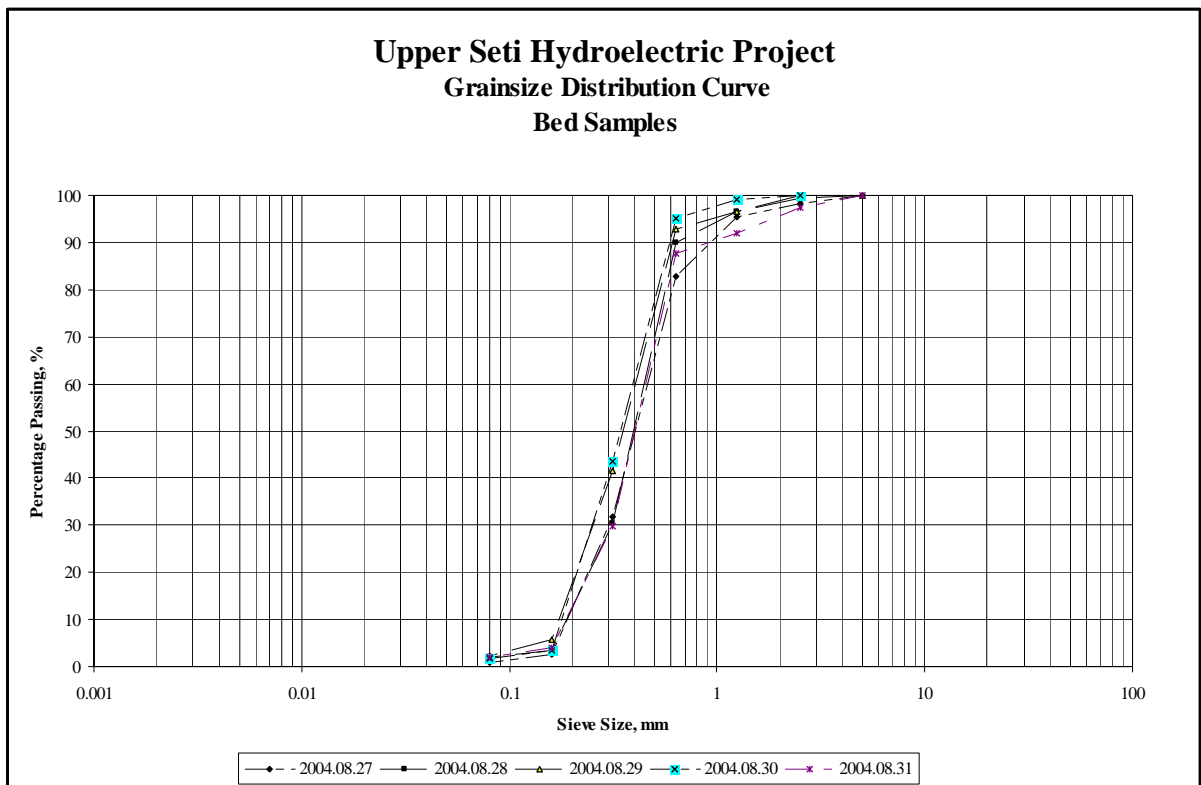
**Fig. 6.6.1-1 Gradation Analysis Result of Bed Load**



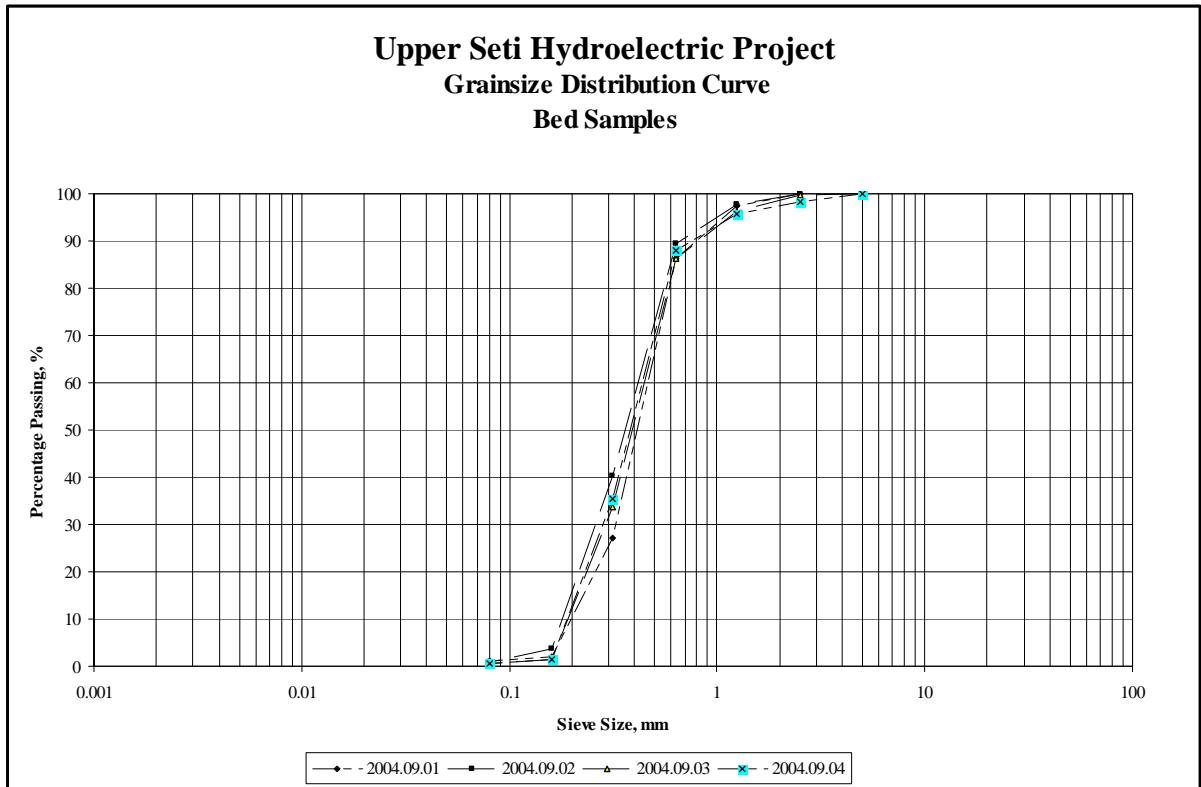
**Fig. 6.6.1-2 Gradation Analysis Result of Bed Load**



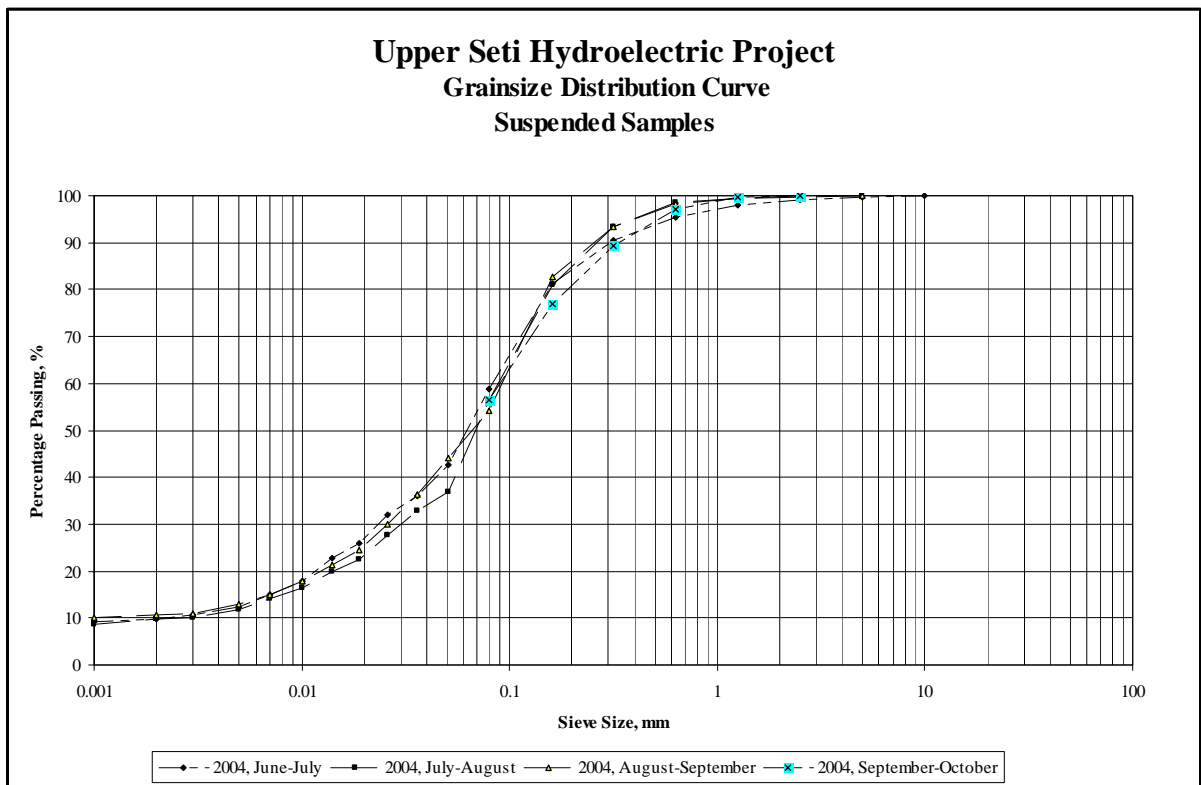
**Fig. 6.6.1-3 Gradation Analysis Result of Bed Load**



**Fig. 6.6.1-4 Gradation Analysis Result of Bed Load**



**Fig. 6.6.1-5 Gradation Analysis Result of Bed Load**



**Fig. 6.6.1-6 Gradation Analysis Result of Suspended Load**

## 6.6.2 Estimation of Reservoir Sedimentation

The Project is the first reservoir type hydropower development project planned on the Seti River basin, so sedimentation of the reservoir is estimated by the following three methods described in (1), (2) and (4) due to little information available to estimation of sedimentation of the Seti River and validity of those estimates are confirmed.

### (1) Estimation of Specific Sediment Yield

NEA examined reports on hydropower projects in Nepal which have been studied up to this date and collected specific sediment yield as shown in **Table 6.6.2-1**.

**Table 6.6.2-1 Specific Sediment Yield (1/2)**

Project name	Catchment area (km <sup>2</sup> )	Average annual flow (m <sup>3</sup> /s)	Specific sediment yield (m <sup>3</sup> /km <sup>2</sup> /year)	Remarks
Kulekhani-I	126	4.0	9,573 3,175 1,746 4,444 5,238 2,063	Based on survey result Average from 1982 to 2000 1996 1997 1998 1999 2000
Andhi River	475	32.35	2,600 600 3,224 2,118	Based on measurement result of suspended load, including bed load 15% of suspended load 1995 1997 1998 1999
Sarada	832	14.0	2,014	Average of measurement result of suspended load from 1973 to 74, 76 to 78, 85 to 87
Marsyangdi	3,850	209	1,996 2,405 2,787 2,597 3,593 3,146 2,452 4,176	Measurement result of suspended load 1991 1992 1993 1994 1995 1996 1997 1998
Jhimruk	645	27.0	3,333 to 4,333	Estimation based on measurement result of suspended load from 1995 to 97, including bed load and unmeasured load 15 to 30% of suspended load

**Table 6.6.2-1 Specific Sediment Yield (2/2)**

Project name	Catchment area (km <sup>2</sup> )	Average annual flow (m <sup>3</sup> /s)	Specific sediment yield (m <sup>3</sup> /km <sup>2</sup> /year)	Remarks
Pancheswor	12,100		3,904 1,852	Measurement result of suspended load 1990 1991
Kaligandaki "A"	----	----	4,000	Feasibility study
Kabeli River	----	----	2,700	Feasibility study
Tamur River	----	----	1,693	Feasibility study
Upper Karnali	----	----	1,213	Feasibility study
Dudh Koshi	----	----	1,483	Feasibility study
Karnali Chisapani	----	----	3,968	Feasibility study
Arun III	----	----	880	Feasibility study

NEA calculates the average of suspended sediment load measured at No.430 gauging station, catchment area of 582 km<sup>2</sup>, from 1976 to 1978 out of those which have been measured there from 1974 to 1978 and estimates specific amount of suspended load at 6,497 t/km<sup>2</sup>/year as shown in **Table 6.6.2-2**.

**Table 6.6.2-2 Suspended Sediment Yield at No.430 Gauging Station**

Year	Specific suspended sediment yield (t/km <sup>2</sup> /year)	Remarks
1974	----	Measured from December to middle of March, only concentration of low flow months
1975	> 909	Measurement not available for August and September
1976	10,694	Measured all year round
1977	3,134	Measured all year round
1978	5,663	Measurement not available for September, October and November
Average	6,497	Average of 1976 to 78

Estimating the ratio of bed load to suspended load at 10 % as NEA describes in the Feasibility Study Report of 2001, specific sediment yield is calculated as  $6,497 \times 1.1 = 7,147$  t/km<sup>2</sup>/year. Using the average density of sediment at 1.5 t/m<sup>3</sup>, specific sediment yield is calculated as  $7,147 / 1.5 = 4,765$  m<sup>3</sup>/km<sup>2</sup>/year in terms of volume.

As shown in **Table 6.6.2-2**, in 1977 specific amount of suspended load becomes less than in 1976 and increase in 1978. According to measurement records of sediment in reservoirs of Japan, sediment inflow shows a tendency to become less than an average in a year following a flood. The cause of this tendency is estimated that, when a flood erodes soil at a stretch in a certain year, a less amount of soil is washed away to a river in the next year.

NEA calculates specific amount of sediment load based on measurement records of suspended sediment load at No. 430.5 gauging station located 500 m downstream of the projected Dam axis assuming the ratio of bed load to suspended load at 15 % as shown in

**Table 6.6.2-3.**

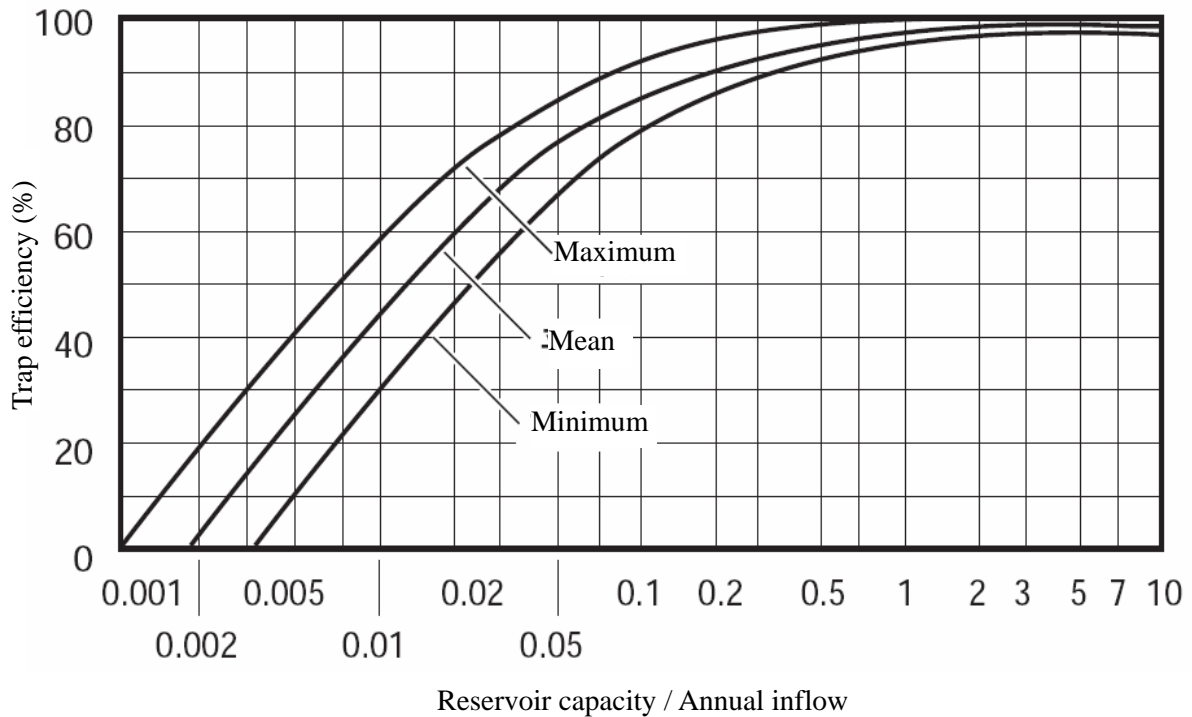
**Table 6.6.2-3 Specific Sediment Yield at No.430.5 Gauging Station**

Year	Specific sediment yield (t/km <sup>2</sup> /year)
2000	9,332
2001	9,966
2004	8,799
Average	9,366

Specific sediment yield in terms of volume assuming average density of sediment at 1.5 t/m<sup>3</sup> is calculated as 9,366 / 1.5 = 6,244 m<sup>3</sup>/km<sup>2</sup>/year. This value is larger than that of the other hydropower projects in Nepal shown in **Table 6.6.2-1**.

NEA sets FSL at EL.425.00 m in the Upgrading Feasibility Study Report in 2004 and the ratio of gross capacity of the Reservoir to annual inflow at the Dam site is calculated at 331.7 MCM / 3,380 MCM = 0.10 and trap efficiency of the Reservoir is estimated at 85 % as shown in **Fig. 6.6.2-1** developed by Brune<sup>3</sup>.

Average sediment deposit of the Reservoir is 6,244 × 1,502 × 0.85 = 7.97 MCM / year, and the necessary number of years when the Reservoir will be filled with sediment is calculated at 270.3 MCM / 7.97 MCM / year = 34 years in terms of effective capacity and 331.7 MCM / 7.97 MCM / year = 42 years in terms of gross capacity of the Reservoir respectively.



**Fig. 6.6.2-1 Trap Efficiency as Related to Capacity-Inflow ratio**

<sup>3</sup>

Brune, Gunnar M., Trap Efficiency of Reservoirs, Trans. Am. Geophys. Union, vol 34, no. 3, June, 1953

## (2) Simulation of Reservoir Sedimentation

The sedimentation of the Reservoir is estimated as per the above paragraphs and the following indicates the results of simulation analysis to calculate the sedimentation with a program named EPDC/KCC FLOW 500 MODEL.

### 1) Calculation Process

- a) Preparation of a calculation model, using river sections measured by NEA
- b) Calculation of sediment inflow at the starting section of the model, using the formula which NEA developed based on the observation results of suspended load
- c) Calculation of sediment load based on sediment formulae
- d) Estimation of riverbed fluctuation by the equation of continuity and then estimation of the surface elevation of the deposit
- e) Repeated calculation of the above on a daily basis

### 2) Prerequisite for Calculation

#### a) River sections

A topographic model of the Reservoir is made using 68 river sections from the Dam axis to the upstream end of the Reservoir out of which NEA measures in the Feasibility Study of 2001. The river sections used in this simulation are attached in **Appendix-6**.

#### b) Suspended load

NEA formulates the relation between average daily river discharge and concentration of suspended load by regression analysis using measurement records of suspended load at No.430.5 gauging station from June to December, 2000 as shown in **Fig. 6.6.2-2**.

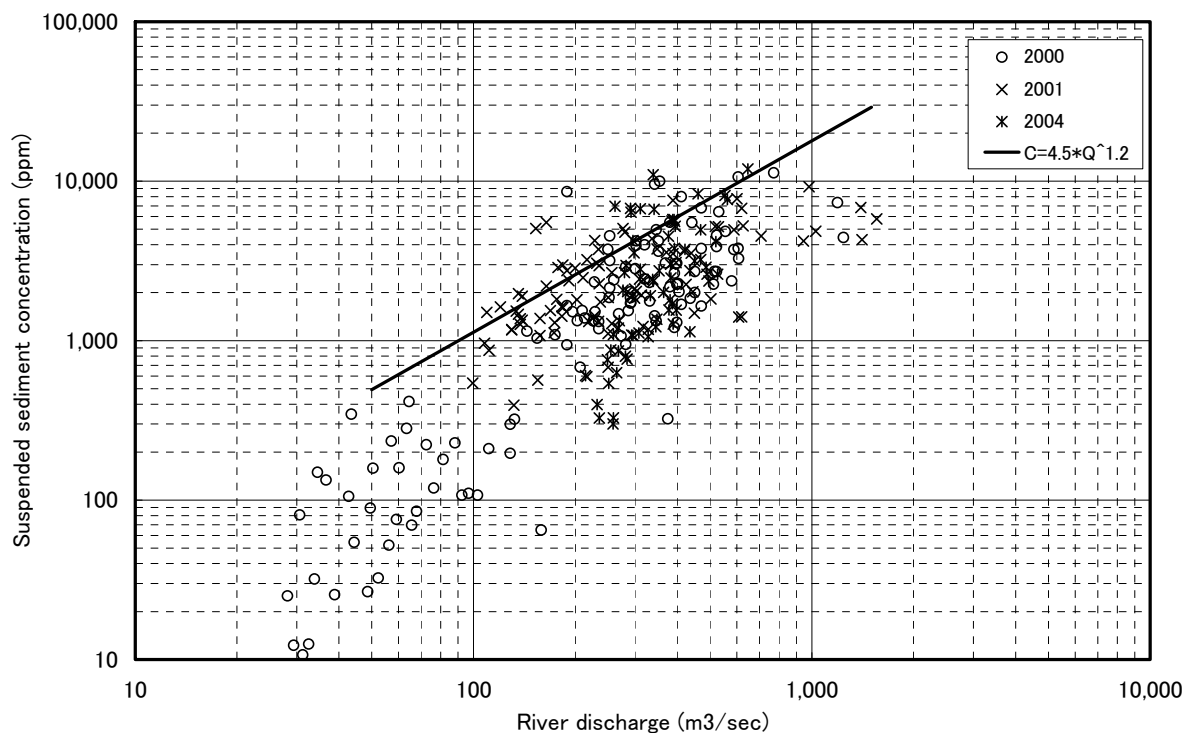
$$C=4.5 \times Q^{1.2}$$

where :

C : Concentration of suspended sediment load (ppm)

Q : Average daily river discharge (m<sup>3</sup>/s)

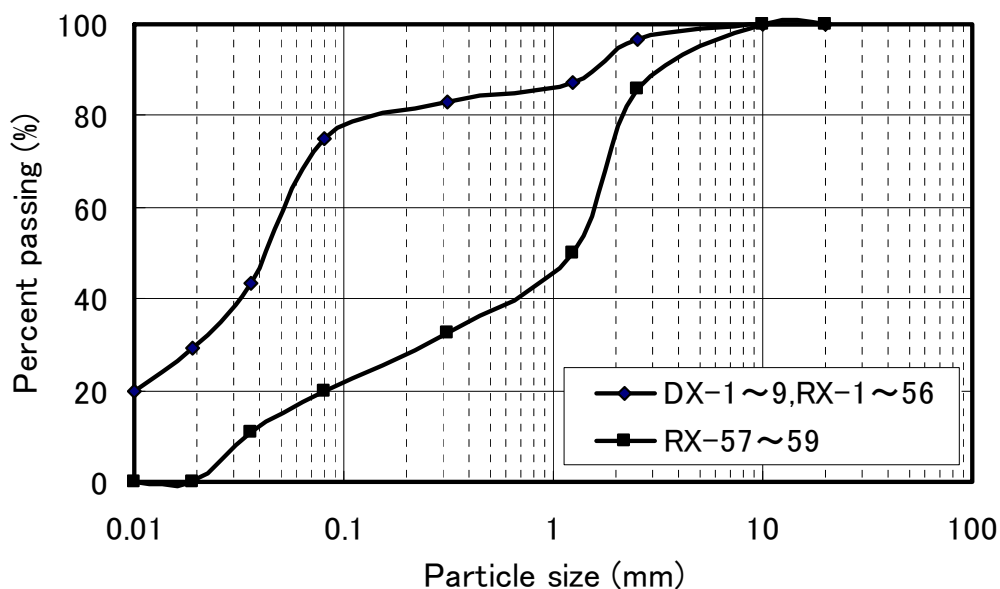




**Fig. 6.6.2-2 Rating Curve of Suspended Load Concentration**

c) Particle diameter of sediment

NEA develops the gradation curves as shown in **Fig. 6.6.2-3**, based on those in **Fig. 6.6.1-1** to **Fig. 6.6.1-6**, dividing the gradation into two classes. One curve shows a distribution of smaller particles in the section between the Dam and about 27 km upstream from it, described “Downstream” in the figure, and the other shows that of larger particles in the remaining section of 1 km long, described “Upstream.” The porosity of 0.5 is used for the simulation.



**Fig. 6.6.2-3 Gradation Curve of Sediment used for Simulation Analysis**

d) Bed load

It is quite difficult to measure quantity of bed load directly moving on a riverbed<sup>4</sup> because its quantity varies greatly from time to time and with a place. Amount of bed load is measured using noise when bed load moves on a riverbed on an experimental basis. So amount of bed load is expressed by its ratio to that of suspended load, and the ratio hardly exceeds 25 %<sup>5</sup>. The ratio is estimated at 20% in this simulation.

e) River discharge

Average daily river discharge from 1964 to 1999 at the Dam site is used for this simulation as calculated in 6.3.

f) Reservoir water level

FSL is set at EL. 425.00 m and MOL at EL. 370.00 m, respectively, following the NEA's Feasibility Study.

3) Simulation of Deposit Shape

The riverbed profile is as shown in **Fig. 6.6.2-4**. The calculation result tells that foreset beds reach near the Dam and that the Reservoir is to be filled with sediment after 39 years from completion. That result is almost the same as the estimation developed by the Brune's diagram, telling that the Reservoir will be filled with sediment after 42 years from completion, described in the previous paragraph, (1).

The average annual sediment yield corresponding to the average daily river discharge

<sup>4</sup> Gregory L. Morris, Jiahua Fan, Reservoir Sedimentation Handbook, McGraw-Hill Books Company Inc., 1997

<sup>5</sup> Calvin Victor Davis, Handbook of Applied Hydraulics, McGraw-Hill Books Company Inc., 1952

from 1964 to 1999 is 11.55 MCM, and this is converted into specific sediment yield as  $11.55\text{MCM} / 1,502 \text{ km}^2 = 7,690 \text{ m}^3/\text{km}^2/\text{year}$ . NEA calculates specific sediment yield based on the measurement records of suspended sediment at No. 430.5 gauging station at  $6,244 \text{ m}^3/\text{km}^2/\text{year}$  and it almost equals to the Study team's estimation.

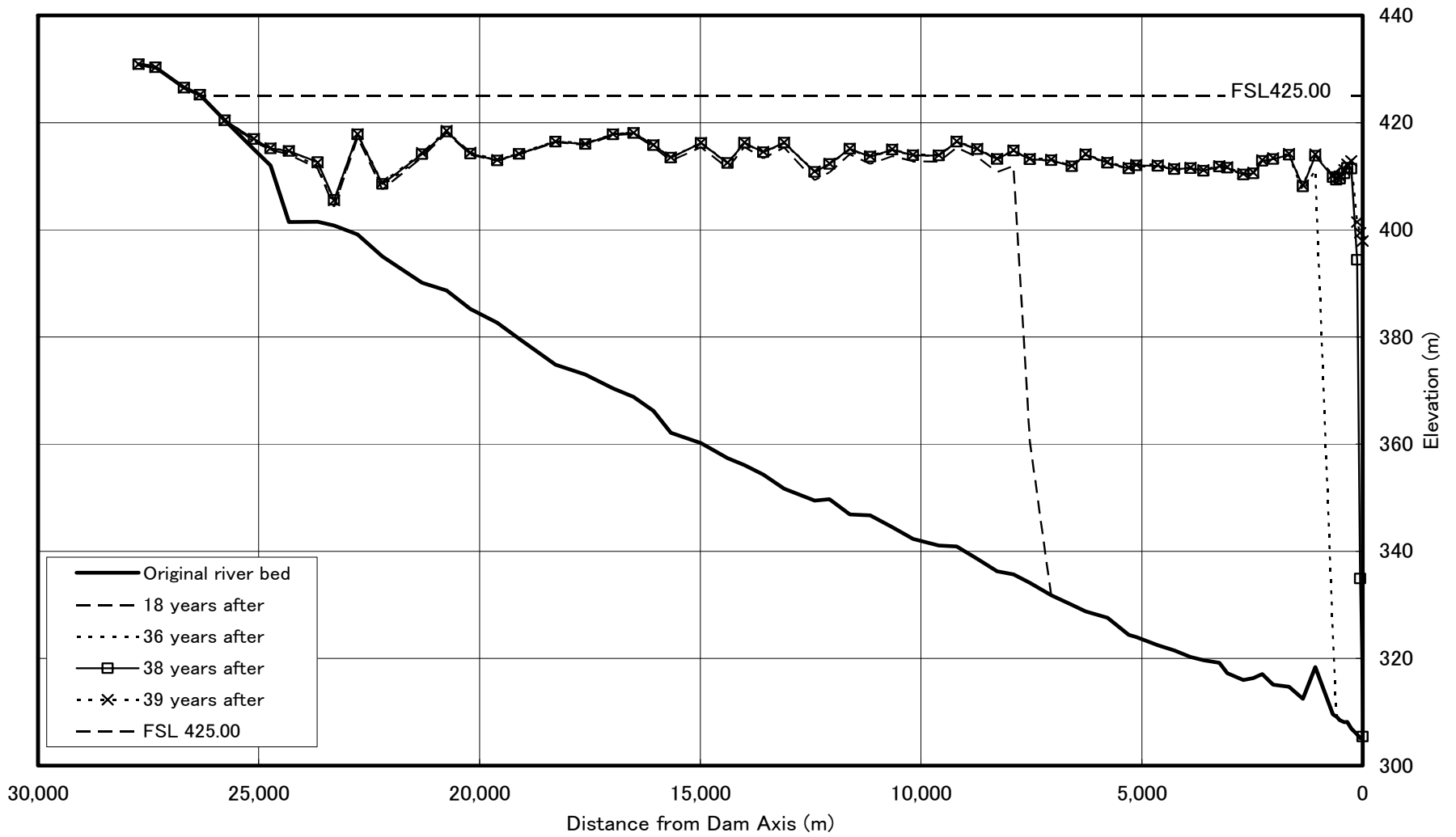


Fig. 6.6.2-4 Riverbed Profile of Reservoir without Sediment Flushing Gates

(3) Comparison with NEA’s Simulation Results

NEA estimates the riverbed fluctuation in the Feasibility Study of 2001 and the Upgrading Feasibility Study of 2004 using a simulation program named HEC-6<sup>6</sup>. To compare both simulation results, the riverbed fluctuation is calculated by EPDC/KCC FLOW 500 MODEL using input and conditions of the simulation in the NEA’s Upgrading Feasibility Study of 2004.

The difference of input and conditions of the simulation between the NEA’s Upgrading Feasibility Study of 2004 and the Study Team as described in 6.6.2 (2) 2) is as follows.

a) Amount of suspended sediment load

NEA formulates the relation between average daily river discharge and concentration of suspended load by regression analysis using measurement records of suspended load from June to December, 2000 at No.430.5 gauging station and from June to September and from July to October, 2004 at the Bhimad Bajar bridge as shown in Fig. 6.6.2-5.

FSL is set at EL. 425.00 m and MOL at EL. 370.00 m following the NEA’s Feasibility Study.

$$C=0.0369*Q^{2.0686} \quad (Q<100m^3/s)$$

$$C=15.939*Q^{0.8607} \quad (Q>100m^3/s)$$

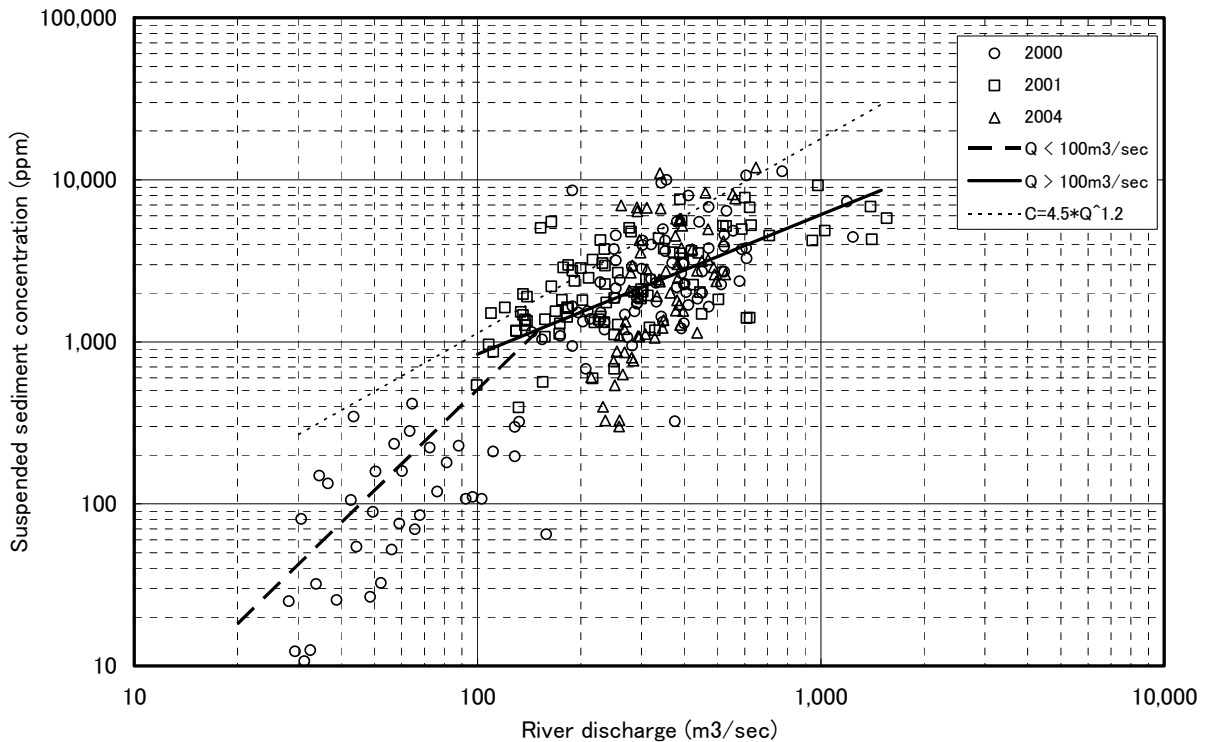


Fig. 6.6.2-5 Rating Curve of Suspended Load Concentration

<sup>6</sup> NEA does not estimate the riverbed fluctuation with sediment flushing operation

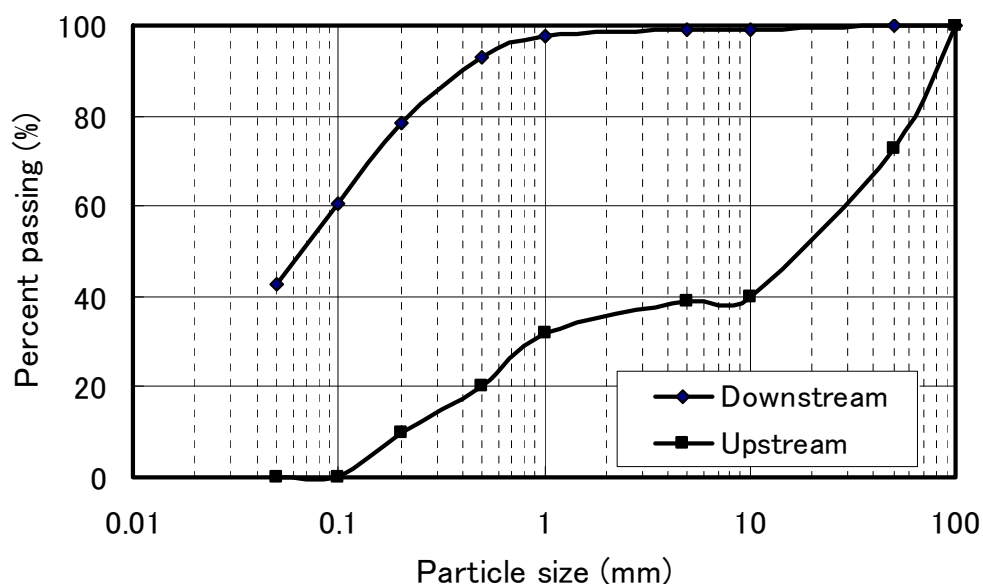
where :

C : Concentration of suspended sediment load (ppm)

Q : Average daily river discharge (m<sup>3</sup>/s)

- b) Particle diameter of sediment

NEA develops the gradation curve as shown in **Fig. 6.6.2-6** based on a sediment sample collected in 2004. The porosity of 0.5 is used for the simulation.



**Fig. 6.6.2-6 Gradation Curve of Sediment used for Simulation Analysis**

- c) Bed load

NEA estimates the ratio of bed load to suspended load at 10%.

- d) River discharge

NEA uses average daily river discharge at No. 430.5 gauging station from 2000 to 2004 ten times to simulate the riverbed fluctuation for 50 years.

- e) Reservoir water level

NEA sets the Reservoir water level at the end of each month as shown in **Table 6.6.2-4**.

**Table 6.6.2-4 Reservoir Water Level**

Year /Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
2000	420.7	414.3	405.0	393.1	404.7	410.0	410.0	410.0	425.0	425.0	425.0	421.9
2001	415.6	407.1	391.7	370.5	370.5	421.1	410.0	410.0	425.0	425.0	425.0	423.2
2002	418.2	411.2	399.7	385.2	391.9	410.0	410.0	410.0	425.0	425.0	425.0	424.7
2003	422.5	418.8	412.4	405.0	399.7	413.6	410.0	410.0	425.0	425.0	425.0	422.8
2004	417.6	410.0	399.3	393.2	404.7	410.0	410.0	410.0	419.7	425.0	425.0	418.5

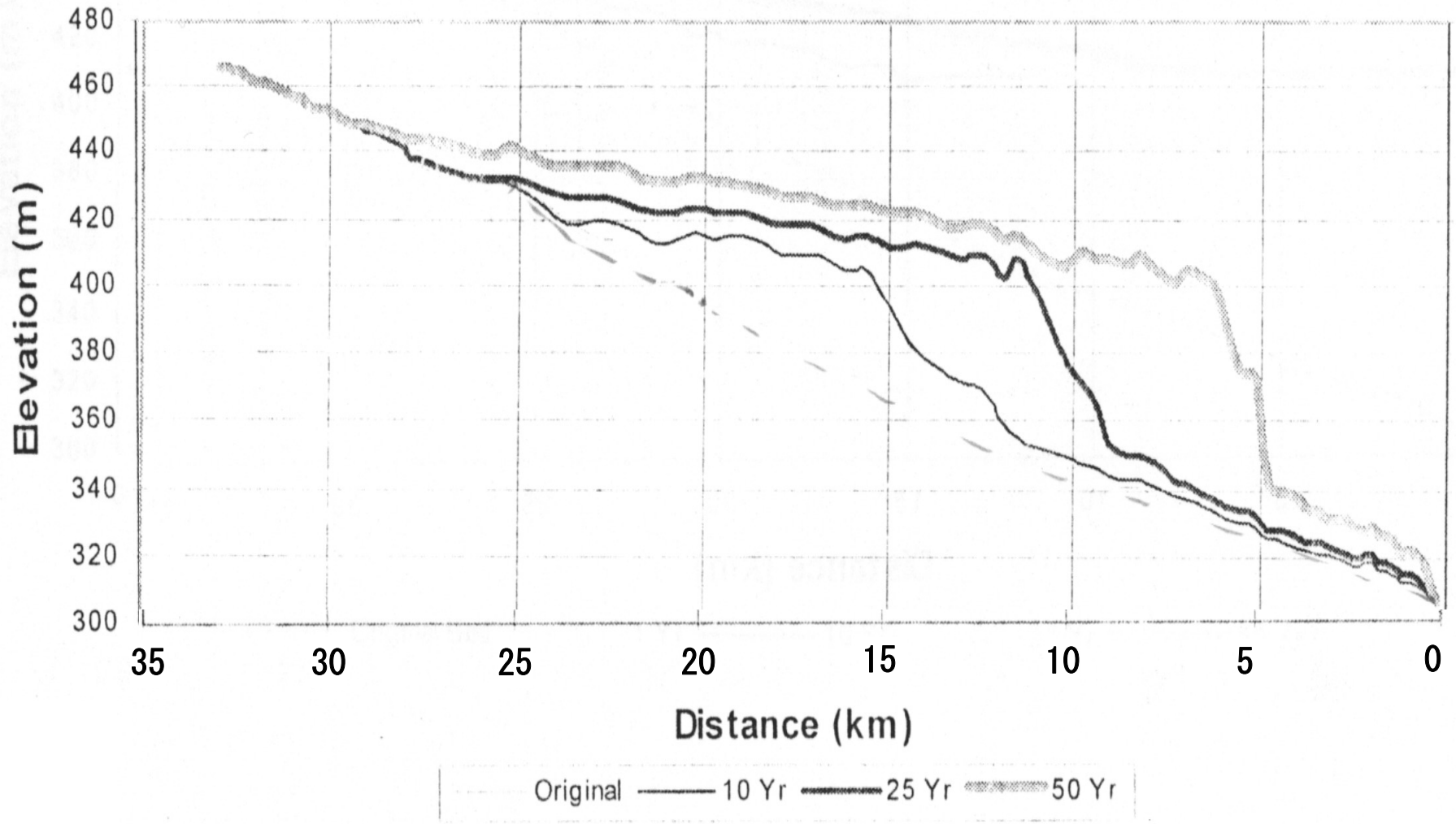


Fig. 6.6.2-7 Riverbed Profile of Reservoir Simulated by NEA with HEC-6

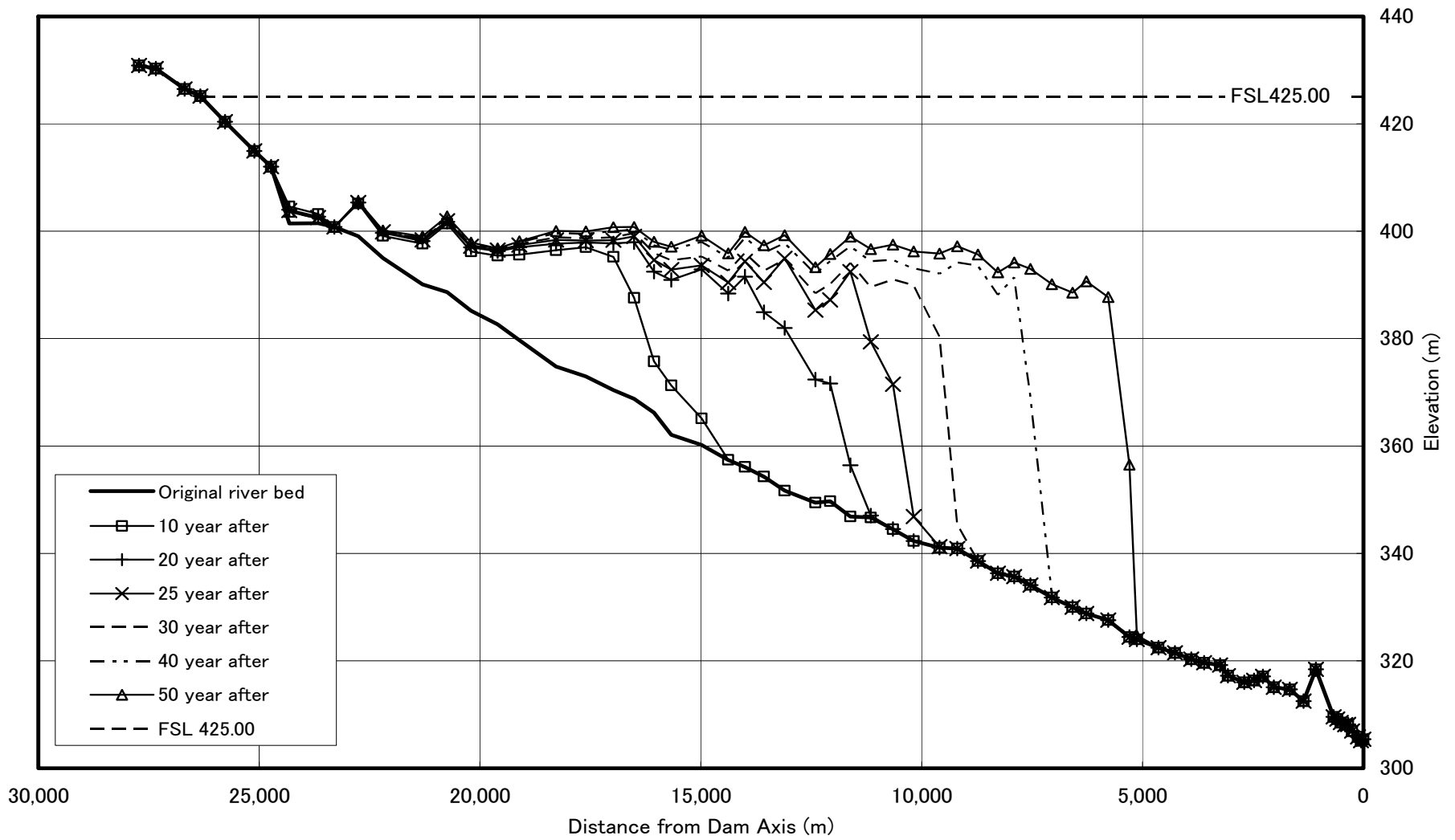


Fig. 6.6.2-8 Riverbed Profile of Reservoir with Same Conditions as HEC-6



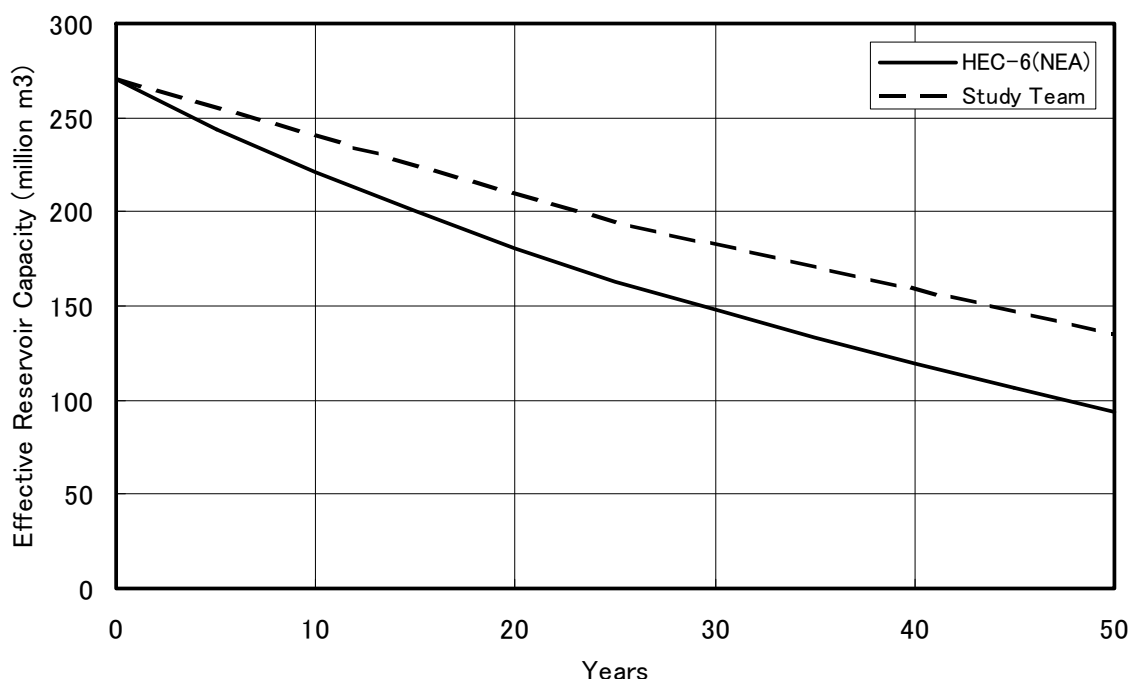
The riverbed profile simulated by NEA is as shown in **Fig. 6.6.2-7** and by the Study team in **Fig. 6.6.2-8**, respectively. The figures tell as follows.

- There is difference in a slope of top-set beds between the both simulation results, and it considered that the difference is caused due to applying different formula for sediment transport;
- Foreset beds of the both simulation results make almost same progress; and
- There is little difference between the both simulation results.

A decrease in effective storage capacity of the Reservoir is as shown in **Table 6.6.2-5** and **Fig. 6.6.2-9**. A difference in a decrease rate of effective storage capacity by the both methods is estimated to be made by a difference in a slope of top-set beds.

**Table 6.6.2-5 Decrease in Effective Storage Capacity of Reservoir**

Years after Completion	Effective Storage Capacity (MCM)	
	HEC-6 (NEA)	Study Team
0	270.30	270.30
25	163.21	197.40
50	93.59	134.81



**Fig. 6.6.2-9 Decrease in Effective Storage Capacity of Reservoir**

(4) Geology in the Seti River Basin and Estimated Source of Sediment

Geology, a distribution and an estimated source of sediment in the Seti River basin are described below being divided into the following three areas;

- 1) from Dam site to the upstream end of the Reservoir, Bhimad Bajar;
- 2) from the upstream end of the Reservoir to Pokhara and its environs extending over 25 km; and
- 3) from Pokhara to the watershed of the basin

Details shall be referred to the separate volume of the Report, “Environmental and Social Considerations Study Report, Part B Physical Environmental Assessment, February 2007,” and “Feasibility Study Report on Upper Seti Project, Appendix-B, 2001, NEA.”

- 1) Area from Dam site to the upstream end of the Reservoir, Bhimad Bajar

This area is located in the Lesser Himalayan zone and consists of Pre-Cambrian to Paleozoic dolomite, slate and phyllite. Out of this area, a section between the Dam site and Geruwa shows a steep valley consisting of less weathered dolomite and slate. This area has no large-scale landslides and few sources of sediment yield. The area between Geruwa and Bhimad Bajar shows vertical cliffs consisting of terrace deposits, named the Pokhara formation, in the right bank. The Pokhara formation consists of low-cemented deposits of a matrix of calcareous silt and fine sand and fine to middle pebbles as described in the next paragraph, 2). Degradation caused by the Reservoir impoundment and erosion can demolish these cliffs, which can be a source of sediment.

- 2) Area from the upstream end of the Reservoir, Bhimad Bajar, to Pokhara

This area is located in the central part of the Lesser Himalayan zone and consists of the Kunchha formation composed of low-grade metamorphic rocks such as phyllite and quartzite. Quaternary deposits, the Ghachok formation and the Pokhara formation, range in the Pokhara valley with thickness of more than 100 m and the both banks of the Seti River show vertical cliffs with height of more than 60 m. The Ghachok formation consists of a matrix of calcareous silt and pebbles to boulders. The matrix containing much calcareous components is well cemented and has shows karst phenomena such as sinkholes and caves. The Pokhara formation ranging on the Ghachok formation consists of fine pebbles and is less-cemented. These Quaternary deposits can be a source of sediment if the river water erodes them. There are many landslides and gullies at Bijapur Khola joining to the Seti River at downstream of Pokhara on the left bank and Phusre Khola joining to it on the right bank. These landslides and gullies yield sediment but these may not flow into the Reservoir at once because these are scattered in tributaries of the Seti River 25 to 35 km away from the upstream end of the Reservoir.

- 3) Area from Pokhara to the watershed of the basin

This area consists of low-grade metamorphic rocks of the Lesser Himalayan zone and high-grade metamorphic rocks, mainly composed of gneiss and partly containing quartzite and amphibolite, of the Higher Himalayan zone. The upstream part of this area shows

many eroded slopes and gullies, which carries sediment in the downstream area. Satellite image analysis results show some small-scale glacier lakes less than 100 m in diameter in the area higher than EL. 3,500 m of the basin. Eroded slopes in this area and deposits under the slopes provide sediment to the Seti River, but this sediment may not be washed into the Reservoir at once because these sources of sediment is away more than around 50km from the upstream end of the Reservoir. There is little possibility that glacial lake outburst flood may carry a lot of sediment to the Reservoir at once because these lakes are small and far from the Reservoir.

Judging from geological conditions in the Seti River basin as stated above, the main sources of sediment in the Seti River basin is estimated as follows;

- Quaternary deposits ranging along the Seti River from the upstream end of the Reservoir to Pokhara;
- Slopes with landslides and gullies ranging along tributaries joining to the Seti River on the both banks downstream of Pokhara; and
- Deposits from eroded slopes ranging around the upstream end of the Seti River near the watershed.

Floods carry sediment from these sources down the Seti River. There is little possibility that a lot of sediment may be washed away into the Reservoir at once considering a positional relation between sources of sediment and the Reservoir.

#### (5) Result

Studies in the above paragraphs, (1), (2) and (4), conclude as follows;

- The Seti River basin is dotted with sources of sediment;
- Specific sediment yield of the Seti River is larger than other project areas in Nepal; and
- The Reservoir will be filled with sediment about 40 years after completion without sediment measures.

### 6.6.3 Measures against Sedimentation of Reservoir

As studied in 6.6.2, the Reservoir is estimated to be filled with sediment in several decades, so some measures against sedimentation shall be taken. A degree of importance for sediment management is classified with the following two indexes as shown in Fig. 6.6.3-1<sup>7</sup>.

$$\text{Life of reservoir} = \text{Reservoir capacity (CAP)} / \text{Average annual sediment inflow (MAS)}$$

$$1 / \text{Turnover rate of reservoir} = \text{Reservoir capacity (CAP)} / \text{Average annual inflow (MAR)}$$

Numerical values of the above indexes are calculated as follows for the Project.

$$\text{Life of reservoir (CAP / MAS)} = 331.7 \text{ MCM} / 11.55 \text{ MCM} = 28.72$$

$$1 / \text{Turnover rate of reservoir (CAP / MAR)} = 331.7 \text{ MCM} / 3,381 \text{ MCM} = 0.098$$

The values of the Project are placed in the lower middle of the figure, which means that the Reservoir will be filled with sediment in a short period of year without sediment management and that it has relatively large turnover rate.

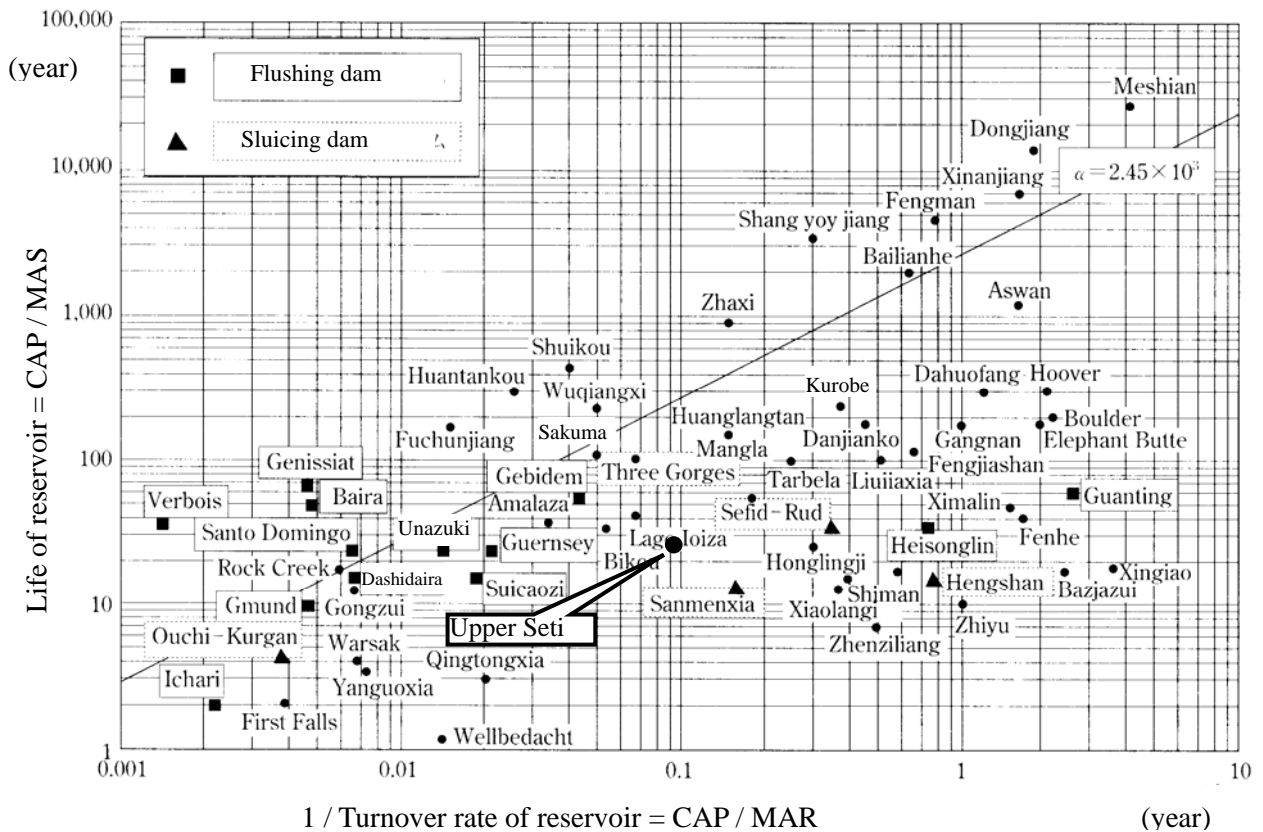


Fig. 6.6.3-1 Relation between Turnover Rate of Reservoir and Life of Reservoir

7

Tetsuya Sumi, Research on Discharge Efficiency of Reservoir Flushing, Dam Engineering, Oct., 2000

The following measures against reservoir sedimentation are listed.

(1) Mitigation of sediment inflow

The mitigation of sediment inflow is one of the most effective measures against sedimentation if it is feasible to reduce yield and outflow of sediment in the upper reaches of the basin. This measure is especially feasible in a small basin.

A catchment area of the Project is 1,502 km<sup>2</sup>, so it is difficult to take measures to mitigate sediment inflow all over the Seti River basin as a part of the Project from economic point of view. As described in 2.2 of the separate-volume “Environmental and Social Consideration Study Report, Part B : Physical Environmental Impact Assessment,” no sediment management programs are carried out all over the basin but the District Forest Office and the District Soil Conservation Office carry out conservation programs of forest, soil and natural environment in small tributary basins. As feasible measures to mitigate sediment inflow, small-scale slope protection is planned in the basins between Pokhara and Bhimad Bajar as described in 2.3 of the above Report. Slope protection of the Seti River in Bhimad Bajar is planned as a part of the Project as described in 11.2.7.

(2) Measures to let sediment inflow pass through reservoir

The sediment management measures next to mitigation of sediment inflow are to let sediment flowing into a reservoir pass through it to prevent sediment from being piled up in it. The following methods are listed.

1) Sediment bypass

This method lets inflow of sediment pass through a reservoir and lets all or part of water containing high sediment detour around a reservoir and discharges it downstream of a dam. Applying this method to the Project, it is difficult to construct a bypass waterway which lets much amount of water detour around the Reservoir of about 25 km long from economic point of view.

2) Sluicing

This method lowers a reservoir water level less than a normal water level while water containing high sediment concentration flows into a reservoir so that tractive force which becomes more than critical value may transport sediment. Carrying out this method in the flood season, sediment inflow will be washed away to the downstream part of a reservoir and progress of sediment in the effective capacity will be decreased. If a dam has sediment flushing facilities, sediment washed away near a dam can be discharged out of a reservoir.

3) Reservoir on tributaries

If water of the main stream contains high sediment concentration, river water of the main

stream is taken at an intake weir and conveyed to a reservoir constructed on a tributary. Sediment will not be stored in a reservoir but only water, so progress of sediment in a reservoir will be prevented. The Kulekhani-I Project adopts this method.

(3) Removal of sediment deposited in reservoir

This method removes sediment deposited in a reservoir. The following methods are listed.

1) Excavation

Sediment deposited in a reservoir is excavated and removed by an excavator. Land excavation is possible if the reservoir water level is operationally reduced over a certain period of time, so this method is applicable only around the upper end of a reservoir. As described in 6.6.2 (2) 3), annual sediment inflow of the Project is estimated as 11.55 MCM, and it is difficult to excavate and remove such amount of sediment deposited in a reservoir economically considering excavation, transportation and disposal method etc., if this method is carried out around the upper end of the Reservoir.

2) Dredging

This method is to dredge sediment deposited in a reservoir under the water and to carry it out of the reservoir. Similar to the method described in the above paragraph, 1), it is difficult to remove sediment economically if a lot of sediment has to be dredged.

3) Flushing

In this method tractive force of flowing water is increased to more than critical value by lowering the reservoir water level, and sediment deposited in a reservoir downstream of a dam is carried through flushing facilities installed in a dam body or near it with such tractive force. It is generally difficult to apply excavation and dredging as described in the above paragraphs, 1) and 2), to a measure against reservoir sedimentation of high sediment inflow rate because many excavators, many trucks and a large disposal area shall be provided to cope with large amount of sediment. Flushing can be a permanent measure against reservoir sedimentation if a project site satisfies all requirements which enable flushing to be carried out in an economical way. Although flushing is evaluated as an effective measure against reservoir sedimentation as regards using tractive force of natural river flow, it is necessary to confirm that conditions of a project site such as river flow, sediment inflow, reservoir capacity, reservoir operation, etc. satisfy a requirement to apply this method. To make this method a success, sediment flushing facilities shall be installed at the lowest possible elevation, and sufficient amount of river inflow and a period of time for the sediment flushing operation shall be prepared. A lot of river water inflow is required so that a reservoir will go through the process of lowering the reservoir water level, flushing sediment and restoring the reservoir water level. This method can be applied to a project site with sufficient amount of annual inflow compared with reservoir

capacity.

Considering a sediment inflow, a river water inflow, reservoir capacity and a sediment flushing method as shown in **Fig. 6.6.3-1**, the Project does not have a high turnover rate of a reservoir compared with the reservoirs which discharge sediment by flushing. So a period of time for flushing shall be prepared as long as possible

Sediment flushing facilities may be installed in a dam body or in a diversion tunnel. If sediment flushing facilities are installed in a diversion tunnel, another gate shall be installed upstream of the facilities to empty the tunnel for inspection and repair works of the facilities. It costs higher to construct a gate shaft for the gate for inspection and repair works of the facilities at the inlet of the diversion tunnel. It is more economical to have a gate for inspection and repair works and sediment flushing facilities built in a dam body, so it is recommended that the sediment flushing facilities should be installed in the Dam body.

For example, the Dashidaira Dam and the Unazuki Dam in Japan, the Gebidem Dam and the Verbois Dam in Switzerland<sup>8</sup>, etc. have sediment flushing facilities built in a dam body and maintain reservoir capacity by discharging sediment periodically.

#### **6.6.4 Sediment Discharge**

The study described in **6.6.3** shows that the sediment flushing facilities shall be prepared in the Dam body. The riverbed fluctuation is estimated by the same simulation as described in **6.6.2** (2) when sediment is discharged by sediment flushing facilities.

Sediment flushing facilities shall be installed at the lowest possible elevation, as described in **6.6.3** (3) 3), so the sill elevation of the facilities is decided at EL. 320.00 m in this study. It is recommended that a hydraulic model test should be carried out during the detailed design stage to confirm the validity of the sill elevation of the facilities and to decide those detailed shapes. The riverbed fluctuation is estimated for FSL of the optimum development scale with another sill elevation of sediment flushing facilities in (2) of this section.

The Reservoir water level is lowered less than MOL during the sediment flushing operation which is carried out in the rainy season, so power generation is suspended during the operation. It is estimated that suspension of power generation of the Project in the rainy season does not affect electricity supply in Nepal because other run-of-river type hydropower plants supply sufficient electricity during the suspension. Considering effect of flushing, the Reservoir water level shall be lowered as long as possible.

The sediment flushing operation is to be carried out in the former half of the rainy season by the following reasons;

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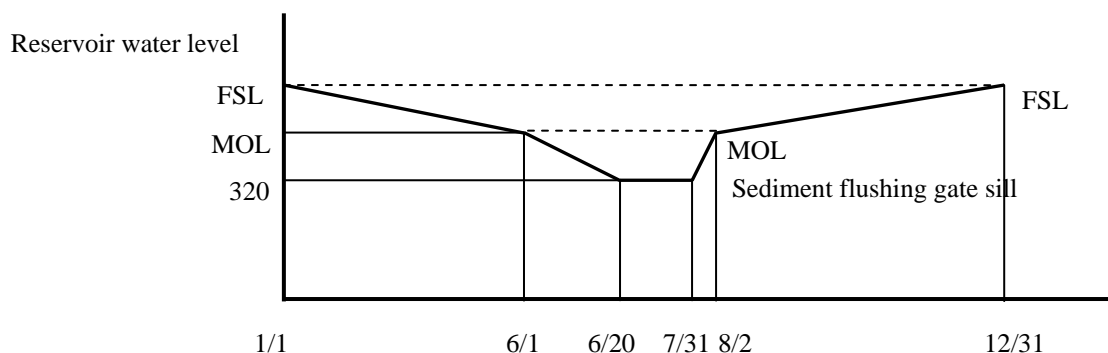
<sup>8</sup> Proceedings, International Symposium on Sediment Management and Dams, the 2nd East Asia Dam Conference, Oct. 25-26, 2005

- Because a flood forecast network is not prepared in Nepal, the sediment flushing operation may not be completed within the rainy season if the operation is planned in the last period of the season in which inflow of river water decreases;
- According to the average daily river discharge record from 1964 to 1999, the average monthly river discharge gets to the maximum in August, so it is not desirable that the sediment flushing operation is carried out in August so that river water flows through sediment flushing facilities of the least possible total sectional area in an open channel condition;
- It is desirable that the sediment flushing operation is completed within July to restore the Reservoir water level to MOL and higher in the shortest possible period of time after the operation; and
- It is not desirable that the sediment flushing operation is carried out in August so that secondary electricity generation decreases due to flushing operation as little as possible.

Here, the Reservoir water level is estimated to be lowered in the first half of the rainy season as shown in **Fig. 6.6.4-1**.

- 1) The sediment flushing gates are fully opened on June 1, in the beginning of the rainy season, and the Reservoir water level is lowered from MOL to the sill elevation of sediment flushing gates.
- 2) It is assumed that it takes about 20 days to lower the Reservoir water level from MOL to the sill elevation of sediment flushing facilities as shown in **Table 6.3-1** supposing that outflow from the gates is around 200 m<sup>3</sup>/s, twice as much as the average monthly river discharge in June, 113.3 m<sup>3</sup>/s.
- 3) The River flow is restored to its original state. Sediment deposited in the Reservoir is washed away to the Dam by flooding at the beginning of the rainy season and discharged from the Reservoir through sediment flushing gates, while water containing a high sediment concentration is allowed to flow out via the reservoir.
- 4) The sediment flushing gates are closed on July 31 and the Reservoir water level rises to the MOL.





**Fig. 6.6.4-1 Reservoir Operation Curve**

All of suspended load is assumed to be discharged from the reservoir and the bed load is also discharged at a ratio of 50% of the total amount washed away by tractive force, corresponding to the discharge from the sediment flushing facilities. The other input data are the same as in described in 6.6.2 (2).

(1) Riverbed Fluctuation for Various FSLs

The riverbed fluctuation is simulated for a combination of FSLs of EL.375.00 m, EL. 395.00 m, EL. 425.00 m and EL. 435.00 m, and MOL of EL.370.00 m so that the simulation results will be used for a study on optimization of the development plan implemented in Chapter 10. The simulation results are as shown in Figs. 6.6.4-2 to 6.6.4-5.

The results are interpreted as follows:

- 1) The shapes of a riverbed will remain almost constant after 72 years from completion, but there are small fluctuations because the sediment inflow changes every year.
- 2) No pivotal point of the sedimentation delta is found in any of the FSLs. Since river discharge data change every year and the sediment flushing operation is conducted every year, no such pivotal point is presumed to appear.
- 3) The riverbed shapes will not be in parallel with the original riverbed in the upstream area of the Reservoir, but rather parallel to the downstream area. Cumulative sediment volumes for each of the FSLs after 108 years from completion, and the maximum sediment volume in the course of 108 years, as well as the year in which the maximum sediment volume appears, are as shown in Table 6.6.4-1. The change in sediment volume for each FSL is as shown in Fig. 6.6.4-6. Because the sediment inflow varies year by year as the river discharge varies, the sediment volume of the Reservoir does not always peak at the 108 year interval.

**Table 6.6.4-1 Summary of the Sediment Volume in Reservoir**

FSL	Sediment in Reservoir		
	After 108 years (1,000 m <sup>3</sup> )	Maximum sediment volume	
		Volume (1,000 m <sup>3</sup> )	Years in after Completion
375.00	106,772	115,918	73
395.00	117,257	130,829	89
425.00	108,643	125,727	53
435.00	119,257	138,799	89
Average		127,818	

- 4) As shown in **Table 6.6.4-1**, the maximum sediment volume in the Reservoir for FSL of EL. 395.00 m exceeds that of EL. 425.00 m. In addition, as shown in **Fig. 6.6.4-6**, the sediment volume for FSL of EL. 425.00 m exceeds that for FSL of EL. 395.00 m up to around 65 years after completion, and from around 75 years after completion, sediment volume for FSL of EL. 395.00 m has exceeded that for FSL of EL. 425.00 m. Although **Figs. 6.6.4-3** and **6.6.4-4** show almost constant sediment deposit shapes in both cases after 72 years, sediment volume for FSL of EL. 395.00 m shows a growth trend although that for FSL of EL. 425.00 m shows no trend to increase.

The distribution of a flow velocity at each section of the Reservoir after 72 years is shown in **Fig. 6.6.4-7**. A flow velocity in the upstream section in the cases of FSLs of EL. 375.00 m and EL. 395.00 m is much faster than that in the cases of FSLs of EL. 425 m and EL. 435 m. There are narrow river sections in the Reservoir in the cases of FSLs of EL. 425.00 m and EL. 435.00 m, and a flow velocity slows due to sediment stored in those sections. While, these sections are not included in the Reservoir in the case of FSLs of EL. 375.00 m and EL. 395.00 m, the fast river flow seems to transport relatively large particles to the downstream area of the Reservoir, where those particles are then deposited. Such large particles tend not to flow out from the Reservoir during the sediment flushing operation, meaning that the sediment volume will continue increasing in the cases of FSLs of EL. 375.00 m and EL. 395.00 m.

The relation between the river discharge and water level near Bhimad Bajar, which lies at the upstream end of the Reservoir, corresponding to the original riverbed profile and four kinds of FSLs as stated above, after 108 years from completion, are calculated. The results are as shown in **Table 6.6.4-2** and rating curves are in **Fig. 6.6.4-8**, respectively, showing that the progress of sedimentation does not cause an increase in the river water level at Bhimad Bajar.

**Table 6.6.4-2 Rating Curve of the Seti River at the RX-54 Section**

River discharge (m <sup>3</sup> /s)	Original riverbed	FSL (EL. m)				
		375.00	395.00	415.00	425.00	435.00
		Water level at the RX-54 Section after 108 years from completion (EL. m)				
0	415.10	415.10	415.12	416.93	425.00	435.00
1,000	421.33	421.27	421.27	421.12	425.12	434.99
2,000	423.51	423.51	423.51	423.23	425.40	434.96
3,000	424.86	424.86	424.86	424.47	425.74	434.88
4,000	426.31	426.31	426.31	426.31	426.31	434.75
5,000	428.10	428.10	428.10	428.11	428.10	434.55
6,000	429.79	429.79	429.79	429.80	429.79	434.26
7,000	431.40	431.40	431.40	431.40	431.40	433.83
7,500	432.17	432.17	432.17	432.17	432.17	433.53

The relation between the river discharge and the water level at the RX-53 section, where the Seti River narrows and there is some possibility of the flowing water eroding both sides of the riverbank, corresponding to the original riverbed profile and four kinds of FSLs, as stated above after 108 years from completion, is calculated and the results are as shown in **Table 6.6.4-3**.

**Table 6.6.4-3 Rating Curve of the Seti River at the RX-53 Section**

River discharge (m <sup>3</sup> /s)	Original riverbed (EL.m)	FSL (EL. m)				
		375.00	395.00	415.00	425.00	435.00
		Water level at RX-53 section after 108 years from completion (EL.m)				
0	412.11	412.31	413.15	412.20	425.00	435.00
1,000	418.46	418.51	418.51	418.48	425.12	435.03
2,000	420.85	420.85	420.85	420.85	425.42	435.08
3,000	422.63	422.63	422.63	422.62	425.94	435.18
4,000	424.23	424.49	424.49	424.25	426.65	435.31
5,000	425.54	426.46	426.46	425.55	427.54	435.46
6,000	426.62	428.26	428.26	426.64	428.61	435.65
7,000	427.61	429.81	429.81	427.61	429.82	435.91
7,500	428.08	430.52	430.52	428.10	430.44	436.06

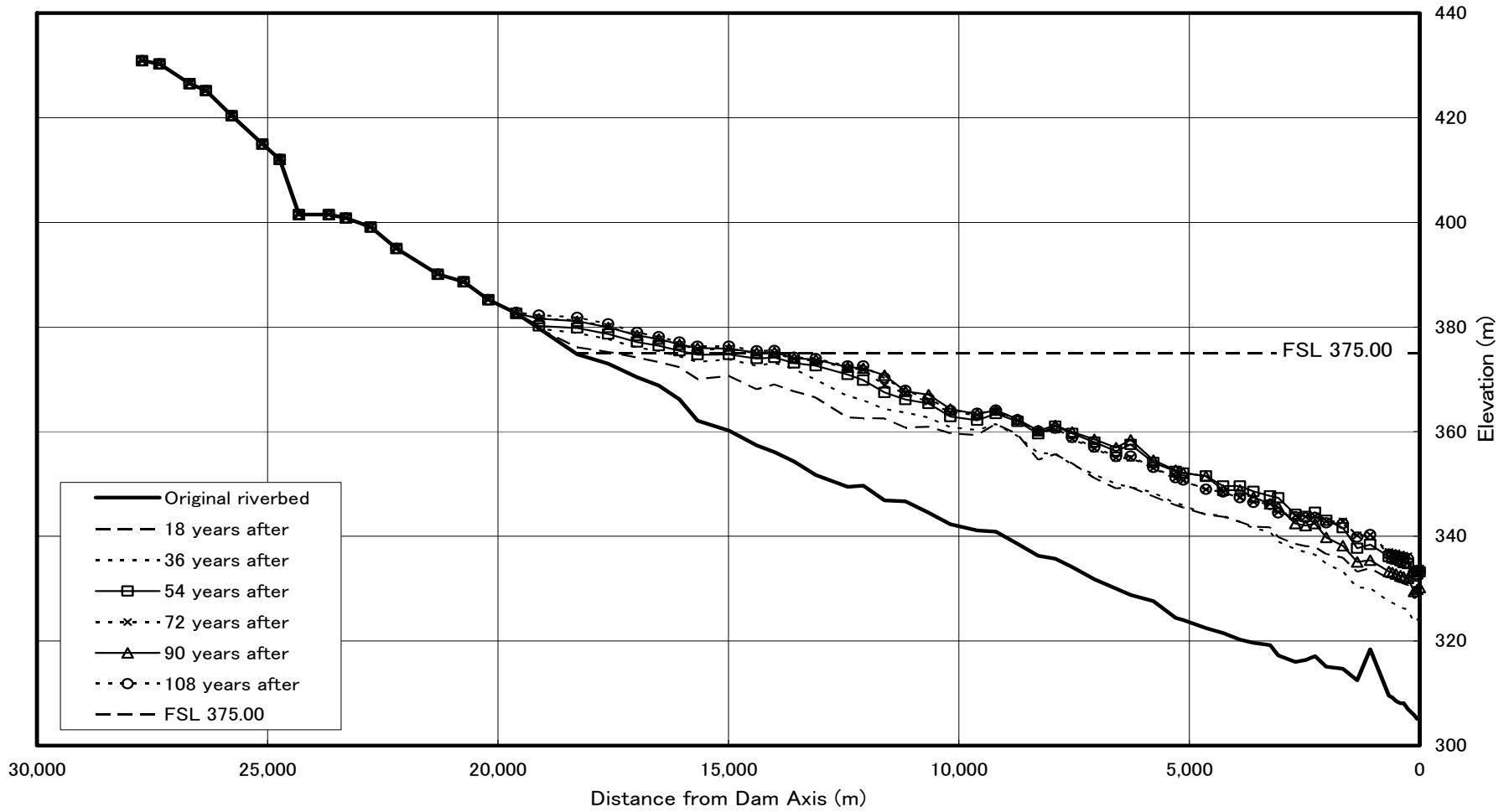


Fig. 6.6.4-2 Riverbed Profile of Reservoir with Sediment Flushing Gates (FSL = EL. 375.00)

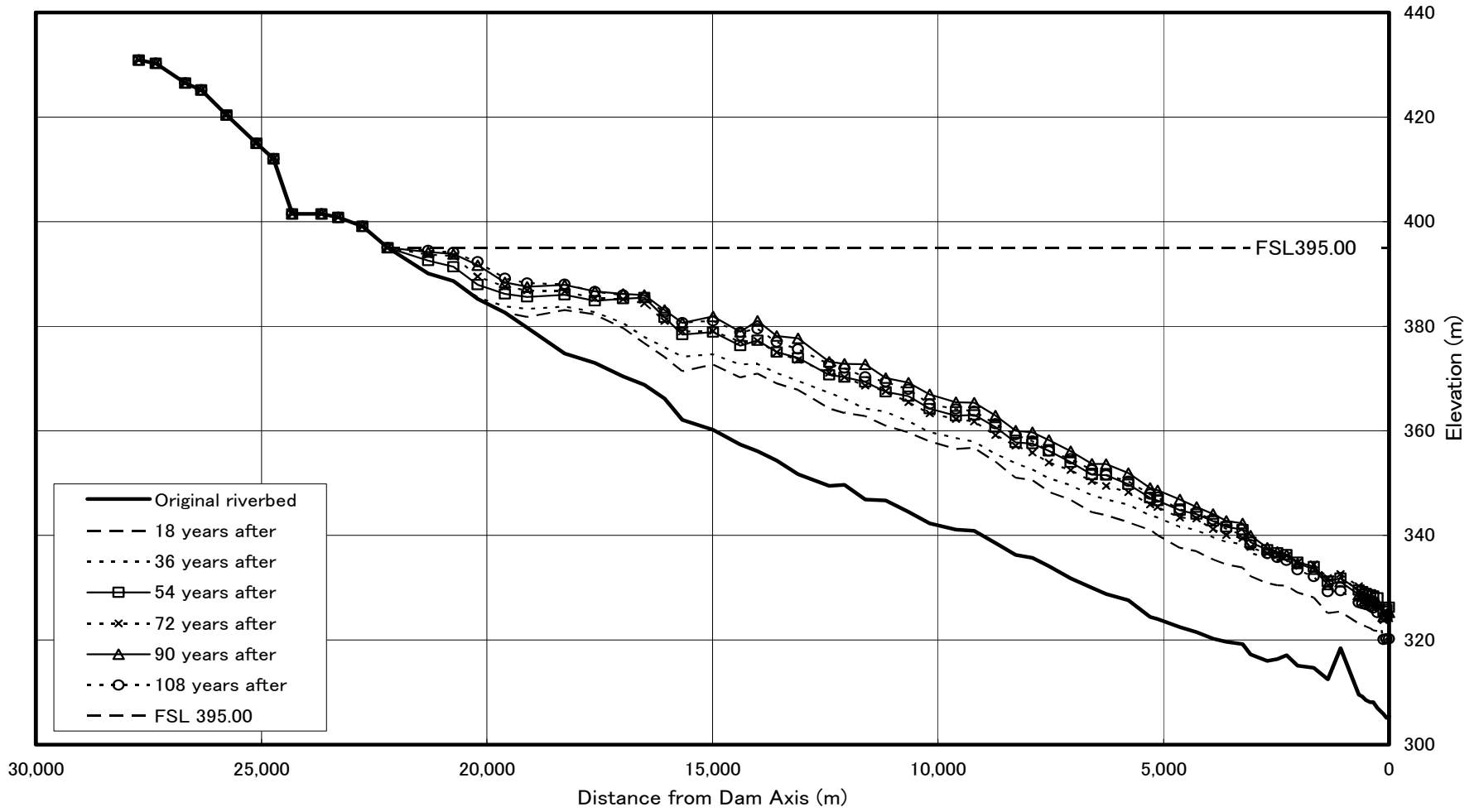


Fig. 6.6.4-3 Riverbed Profile of Reservoir with Sediment Flushing Gates (FSL = EL. 395.00)

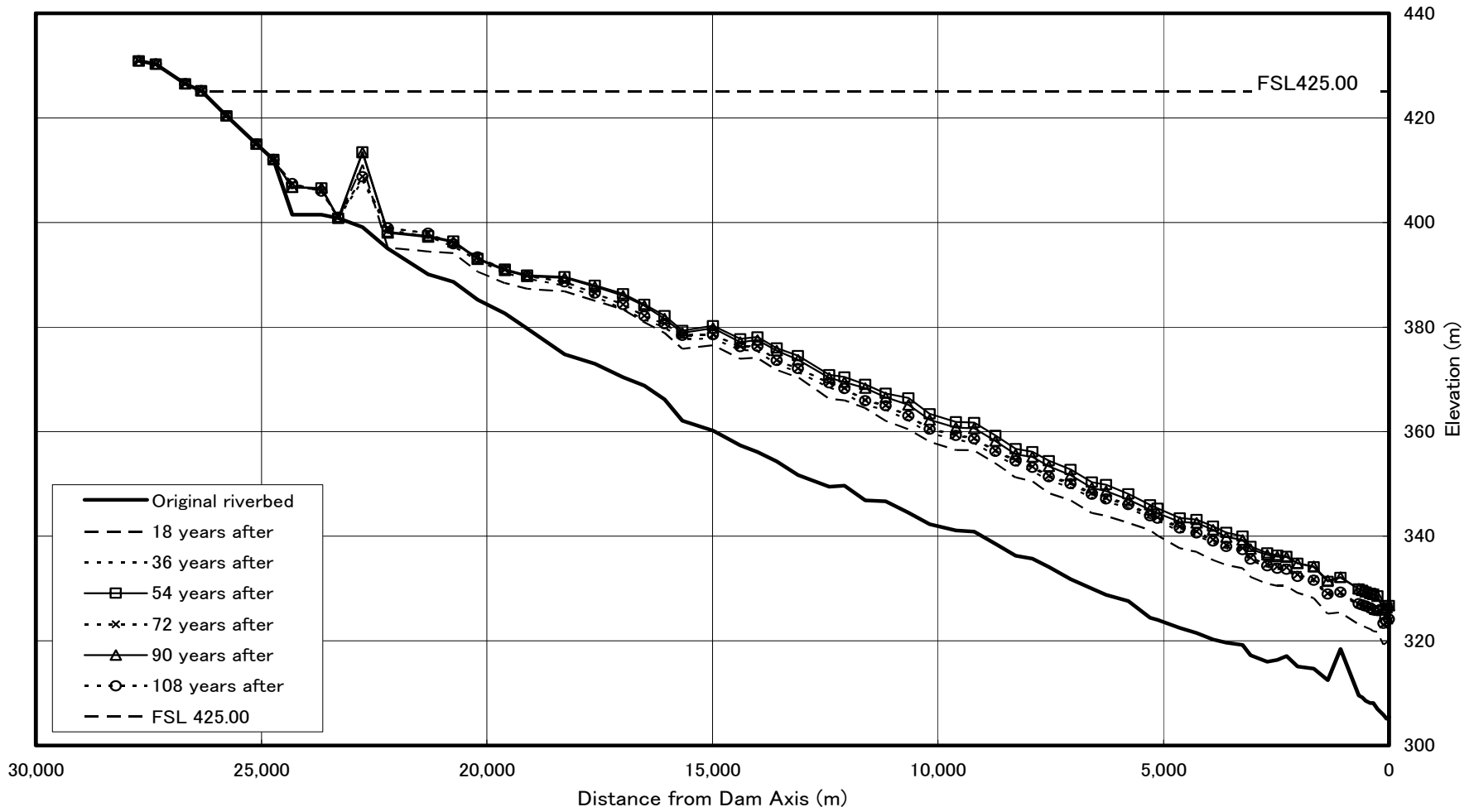


Fig. 6.6.4-4 Riverbed Profile of Reservoir with Sediment Flushing Gates (FSL = EL. 425.00)

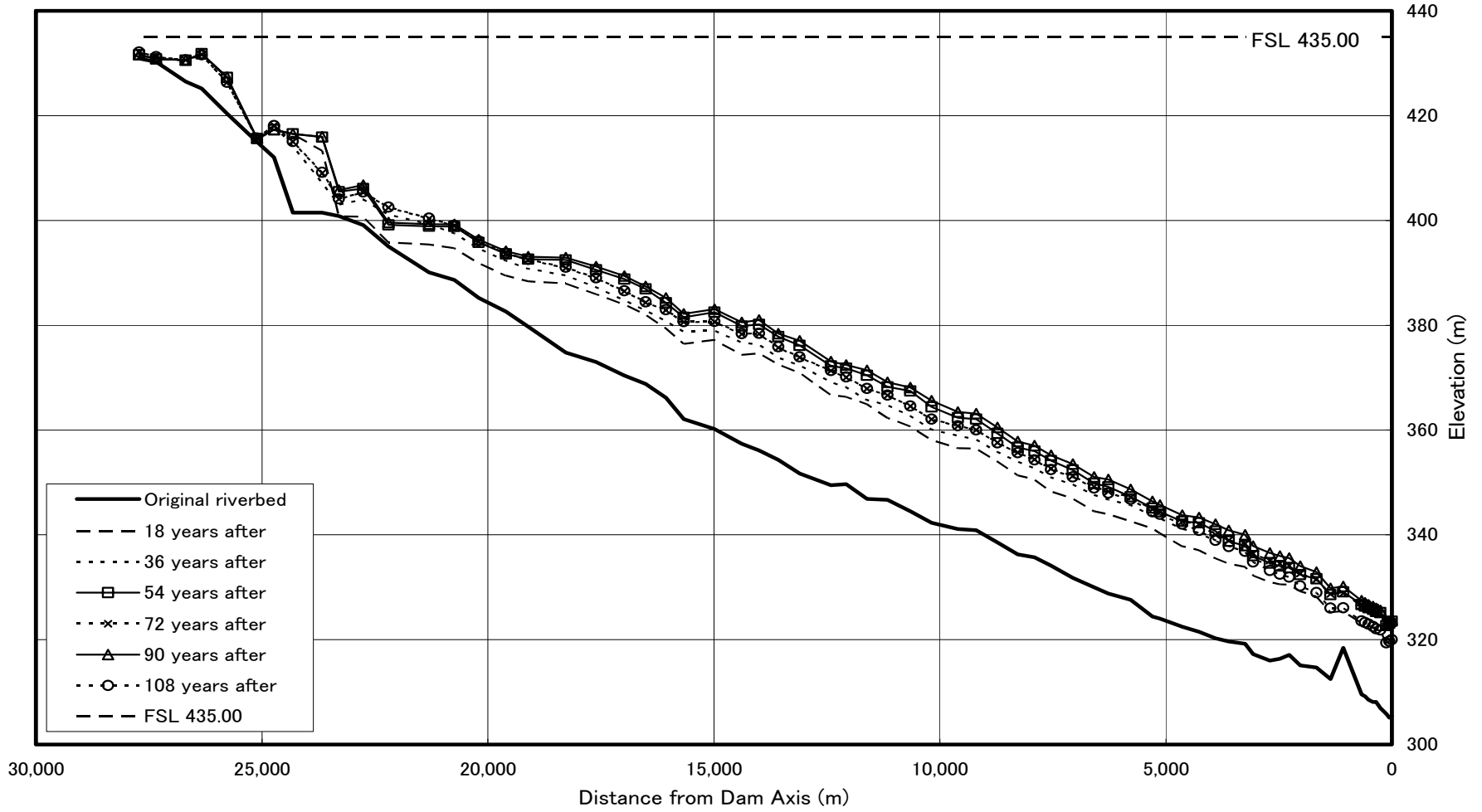


Fig. 6.6.4-5 Riverbed Profile of Reservoir with Sediment Flushing Gates (FSL = EL. 435.00)

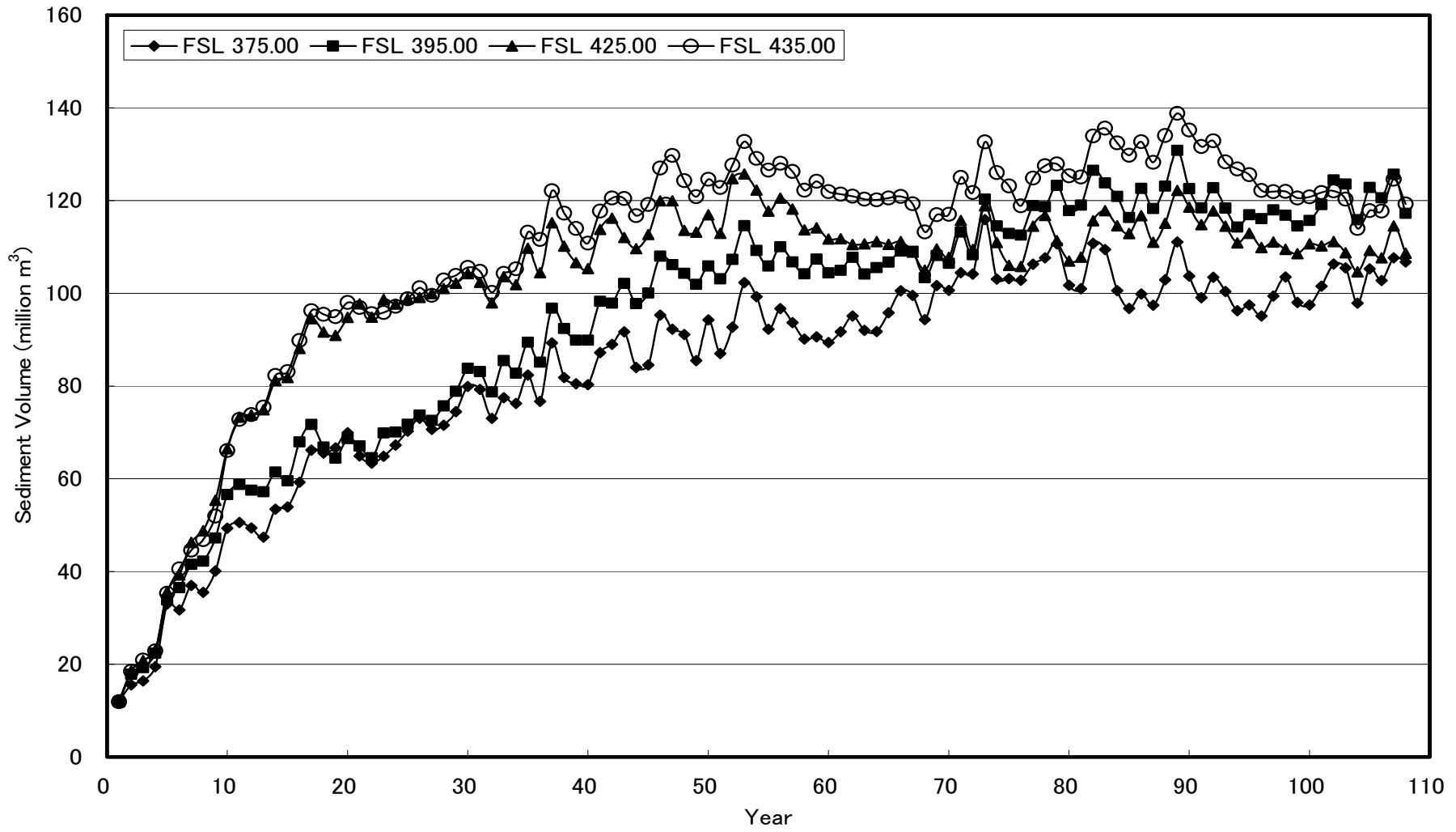


Fig. 6.6.4-6 Cumulative Sediment Volume in Reservoir



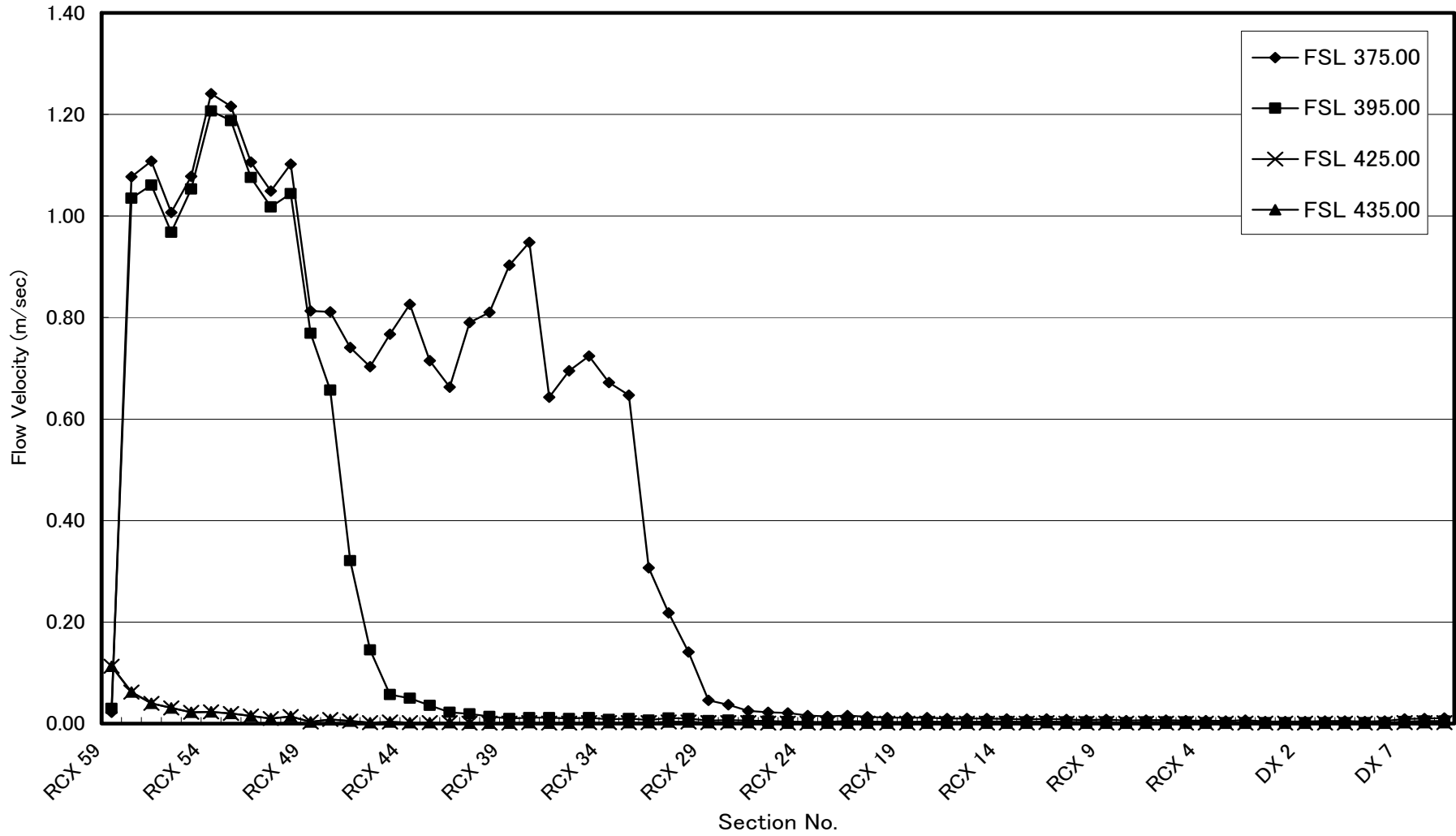


Fig. 6.6.4-7 Velocity of Each Section after 72 Years

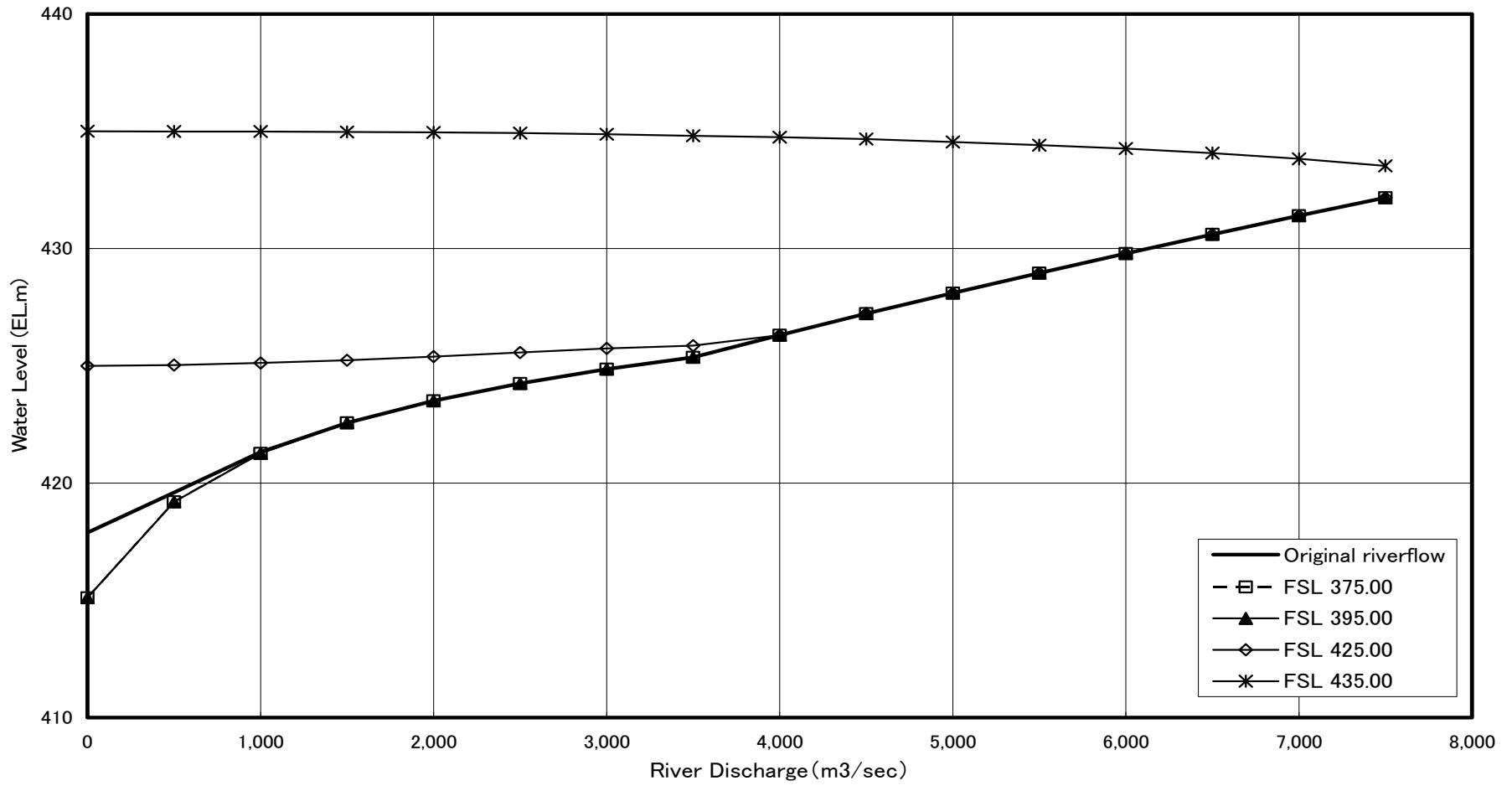


Fig. 6.6.4-8 Rating Curve of Seti River at the RX-54 Section

(2) Riverbed Fluctuation for the Optimum Development Scale

The optimum development plan is decided as the FSL of EL. 415.00 m and MOL of EL. 387.20 m in **Chapter 10**, while the simulation result of riverbed fluctuation over 108 years is as shown in **Fig. 6.6.4-9**.

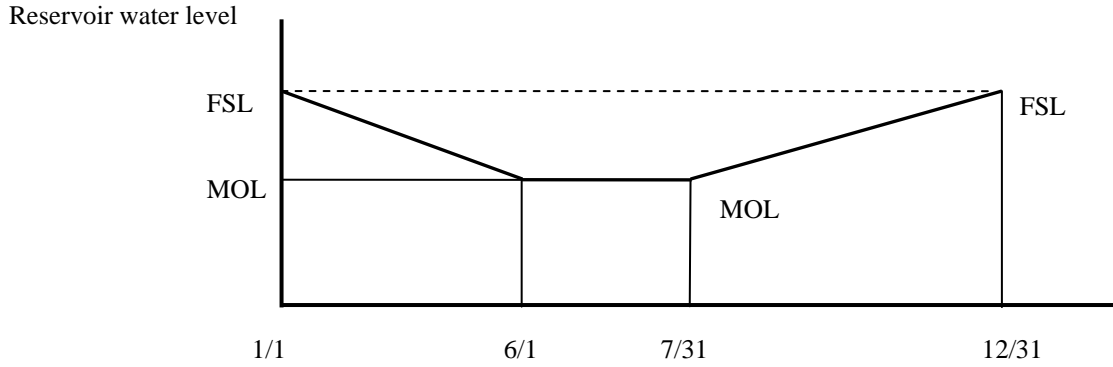
To study the relation between the sill elevation of sediment flushing facilities and a situation of sediment in the Reservoir, the riverbed fluctuation is simulated when the sill elevation of the facilities is raised by 10 m to EL. 330.00 m as shown in **Fig. 6.6.4-10**. The cumulative and maximum sediment volumes after 108 years from completion, as well as the year in which the sediment volume peaks, are as shown in **Table 6.6.4-4**, while the change in sediment volume is as shown in **Fig. 6.6.4-11**. Here, the case with the sill elevation of EL. 320.00 m is referred to as “Case 320”, and that of EL. 330.00 m as “Case 330”, respectively. The table and figure prove that, in Case 330, the riverbed elevation rises by the difference in the sill elevation all over the Reservoir and that the amount of sediment in the Reservoir shows an increase of about 25 % over Case 320. Case 330 can shorten the necessary time to lower the Reservoir water level from MOL to the sill elevation by only on the order of one day from Case 320. Judging from differences between Case 320 and Case 330 as stated above, the sill elevation of Case 320 decided from topographical conditions is better than that of Case 330.

**Table 6.6.4-4 Summary of Sediment Volume in Reservoir**

Sediment flushing gate sill elevation	Sediment volume in Reservoir		
	After 108 years (1,000 m <sup>3</sup> )	Maximum sediment volume	
		Volume (1,000 m <sup>3</sup> )	Years after completion
320.00	126,434	138,635	89
330.00	162,952	169,943	89

(3) Study on Frequency of the Sediment Flushing Operation

To confirm the effect of the sediment flushing operation, the riverbed fluctuation is simulated when the flushing operation is carried out every two years, namely, in two, four, six, eight and so on years after completion, and every three years, namely, in three, six, nine, twelve and so on years after completion. The Reservoir is operated as shown in **Fig. 6.6.4-1** in the years when the sediment flushing operation is carried out, and in **Fig. 6.6.4-12** in the years when this is not done, respectively.



**Fig. 6.6.4-12 Reservoir Operation Curve without Flushing**

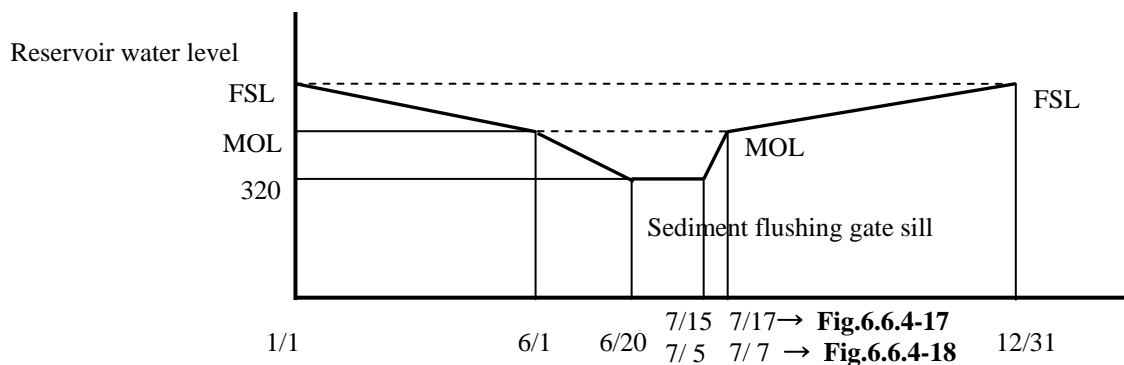
The simulation results are as shown in **Fig. 6.6.4-13** and **Fig. 6.6.4-14**, proving that sediment advances year by year without the yearly sediment flushing operation. The cumulative and maximum sediment volumes after 108 years from completion, as well as the year in which the sediment volume peaks, are as shown in **Table 6.6.4-5**, while the change in sediment volume is as shown in **Fig. 6.6.4-15**.

**Table 6.6.4-5 Summary of Sediment Volume in Reservoir**

Frequency of sediment flushing operation	Sediment volume in Reservoir		
	After 108 years (1,000 m <sup>3</sup> )	Maximum sediment volume	
		Volume (1,000 m <sup>3</sup> )	Years after completion
Every year	126,434	138,635	89
Every 2 years	246,733	261,389	89
Every 3 years	283,314	288,390	107

(4) Study on the Sediment Flushing Operation Period

To confirm the effect of the sediment flushing operation period, the riverbed fluctuation is simulated for FSL of EL.415.00 m, when the sediment flushing operation period is shortened. The Reservoir is operated as shown in **Fig. 6.6.4-16** when the flushing operation is carried out from June 20 to July 15 and from June 20 to July 5.



**Fig. 6.6.4-16 Revised Reservoir Operation Curve**

The simulation results are as shown in **Fig. 6.6.4-17** when the flushing operation is carried out from June 20 to July 15 and in **Fig. 6.6.4-18** from June 20 to July 5, respectively. The table and figure prove that sediment advances year by year when a period of the sediment flushing operation is shortened from that of **Fig. 6.6.4-1**. The cumulative and maximum sediment volumes after 108 years from completion, as well as the year in which the sediment volume peaks, are as shown in **Table 6.6.4-6**, while the change in sediment volume is as shown in **Fig. 6.6.4-19**.

**Table 6.6.4-6 Summary of Sediment Volume in Reservoir**

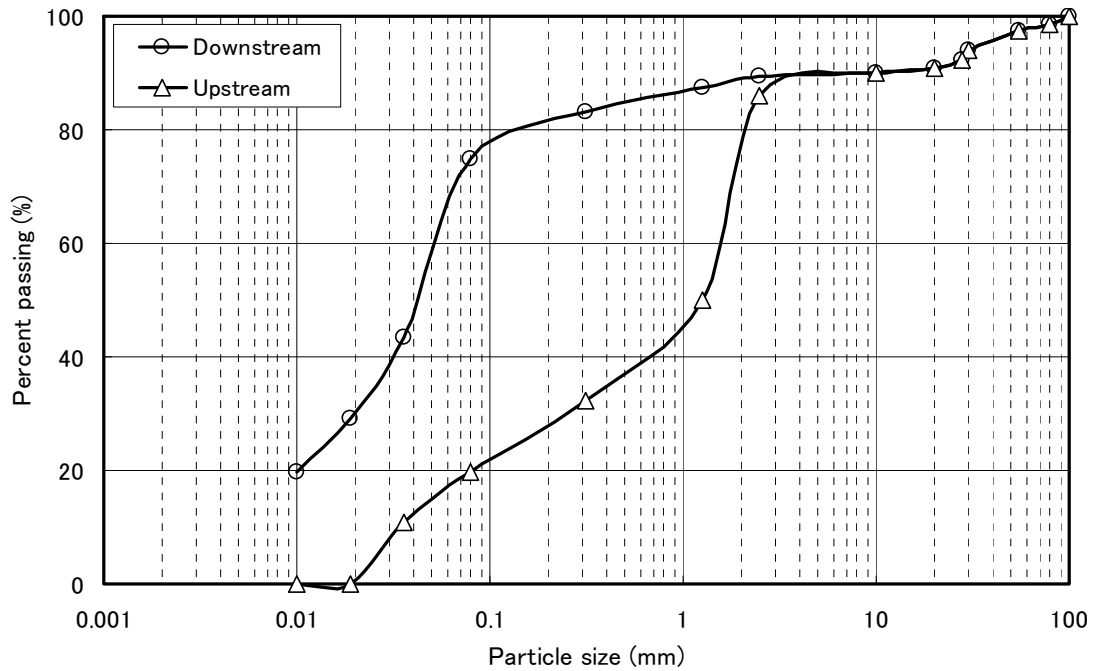
Date when sediment flushing gates are closed	Sediment in Reservoir		
	After 108 years (1,000 m <sup>3</sup> )	Maximum sediment volume	
		Volume (1,000 m <sup>3</sup> )	Years after completion
On July 31	126,434	138,635	89
On July 15	272,726	281,211	93
On July 05	322,935	324,193	102

(5) Study on Influence of 100-year Probable Flood

The riverbed fluctuation is simulated when a flood occurs. The simulation result of a case when a flood returning once a century, peak discharge of 3,126 m<sup>3</sup>/s, occurs in the 36th year, is shown in **Fig. 6.6.4-20** and in the 72nd year in **Fig. 6.6.4-21**, respectively. The figures prove that the flood hardly affects the riverbed profile.

(6) Study on Influence of Gradation Curve

The riverbed fluctuation is simulated by using the gradation curve as shown in **Fig. 6.6.2-3** converted from NEA's gradation curves as shown in **Fig. 6.6.1-1** to **Fig. 6.6.1-6** in the other simulations. Another riverbed fluctuation is simulated using another gradation curve taking gravels in the riverbank into the curve as shown in **Fig. 6.6.4-22**.



**Fig. 6.6.4-22 Gradation Curve of Sediment used for Simulation Analysis**

The simulation result is as shown in **Fig. 6.6.4-23**. The cumulative and maximum sediment volumes after 108 years from completion, as well as the year in which the sediment volume peaks, are as shown in **Table 6.6.4-7**, while the change in sediment volume is as shown in **Fig. 6.6.4-24**.

**Table 6.6.4-7 Summary of Sediment Volume in Reservoir**

Gradation curve	Sediment volume in reservoir		
	after 108 years (1,000 m <sup>3</sup> )	Maximum sediment	
		Volume (1,000 m <sup>3</sup> )	Year after completion
Fig. 6.6.2-3	126,434	138,635	89
Fig. 6.6.4-22	100,859	109,093	107

The figure proves that more contents of coarse particles reduce quantity of a sediment movement. In the Study, annual energy production is calculated using the simulation result for the gradation curve of **Fig. 6.6.2-3**, because such gradation gives less effective storage capacity of the reservoir, which results in disadvantageous conditions for energy production.

(7) Conclusions and Further Studies

The study results of sedimentology in this chapter are concluded as follows.

- 1) The Project has a lot of sediment inflow to the Reservoir, and sediment flushing facilities are indispensable to maintenance of the effective Reservoir capacity (see **6.6.2**).

- 2) The Seti River basin is dotted with a source of sediment, and there is little possibility that a lot of sediment may be washed away into the Reservoir at once considering a positional relation between sources of sediment and the Reservoir (see **6.6.2 (4)**).
- 3) It is better to install sediment flushing facilities in the Dam body from economic point of view (see **6.6.3 (3)**).
- 4) It is necessary to install sediment flushing facilities at the lowest possible elevation, and it is recommended that the facilities should be installed at EL. 320.00 m considering topography of the Dam site, the riverbed elevation and the positional relation between the facilities and the spillway (see **6.6.4 (2)**).
- 5) It is recommended that the sediment flushing operation should be carried out from June 20 to July 31 lowering the Reservoir water level to the sill elevation of sediment flushing facilities (see **6.6.4**).

Items to be studied in the detail design stage are as follows.

- 1) The simulation method of riverbed fluctuation used in this study cannot estimate three-dimensional sediment distribution near the inlet of the sediment flushing facilities, but the riverbed in the Reservoir may approximately fluctuate as described in the study. It is recommended that a hydraulic model test should be carried out during the detailed design stage to decide detailed shapes of the facilities as described in **14.1**.
- 2) A method of the sediment flushing operation shall be studied besides a hydraulic model test as stated above.
- 3) In this study, riverbed fluctuation is estimated, and measures are taken in a feasibility study stage. The WB proposes a life cycle sediment management method of a circular type<sup>9</sup> to compare some feasible management methods of reservoir sedimentation in planning, design, construction and maintenance stage, and not a linear management method to carry out a management method of reservoir sedimentation decided during a planning stage until a reservoir ends its life. It is necessary to choose the optimum management method out of the feasible management methods of reservoir sedimentation from technical and economic point of view and to carry out it during a maintenance stage in response to quantity of sediment and progress of sedimentation in the Reservoir and based on the above idea.
- 4) It is recommended that the sediment flushing operation should be carried out from June 20 to July 31 every year lowering the Reservoir water level to the sill elevation of sediment flushing facilities. This sediment flushing operation period is only a standard

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<sup>9</sup> A. Palmieri, Socio-economic Aspect of Reservoir Conservation, Sedimentation Management Challenges for Reservoir Stability, Third World Water Forum, March, 2003

to confirm the validity of the sediment flushing operation and the period shall be adjusted to a pattern of river discharge in each year in a maintenance stage. For example, it is recommended that a sediment flushing operation period should be adjusted to a degree of sedimentation in the Reservoir measured by a periodical survey in a maintenance stage.

- 5) It is recommended that the Reservoir water should be discharged out of sediment flushing facilities instead of a spillway in the rain season to prevent the inlet of sediment flushing facilities from being blocked by sediment and water quality in the bottom of the Reservoir from being deteriorated.



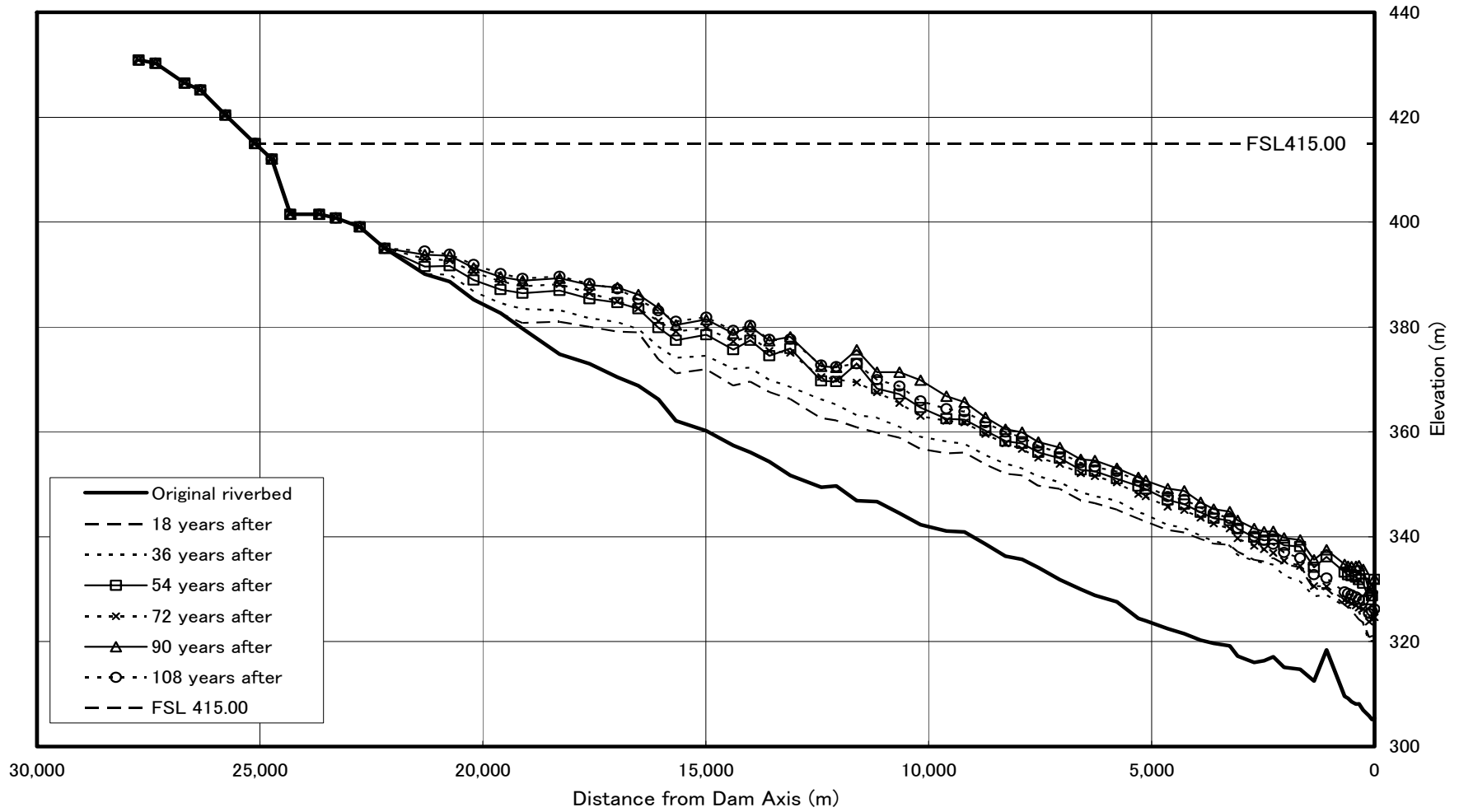
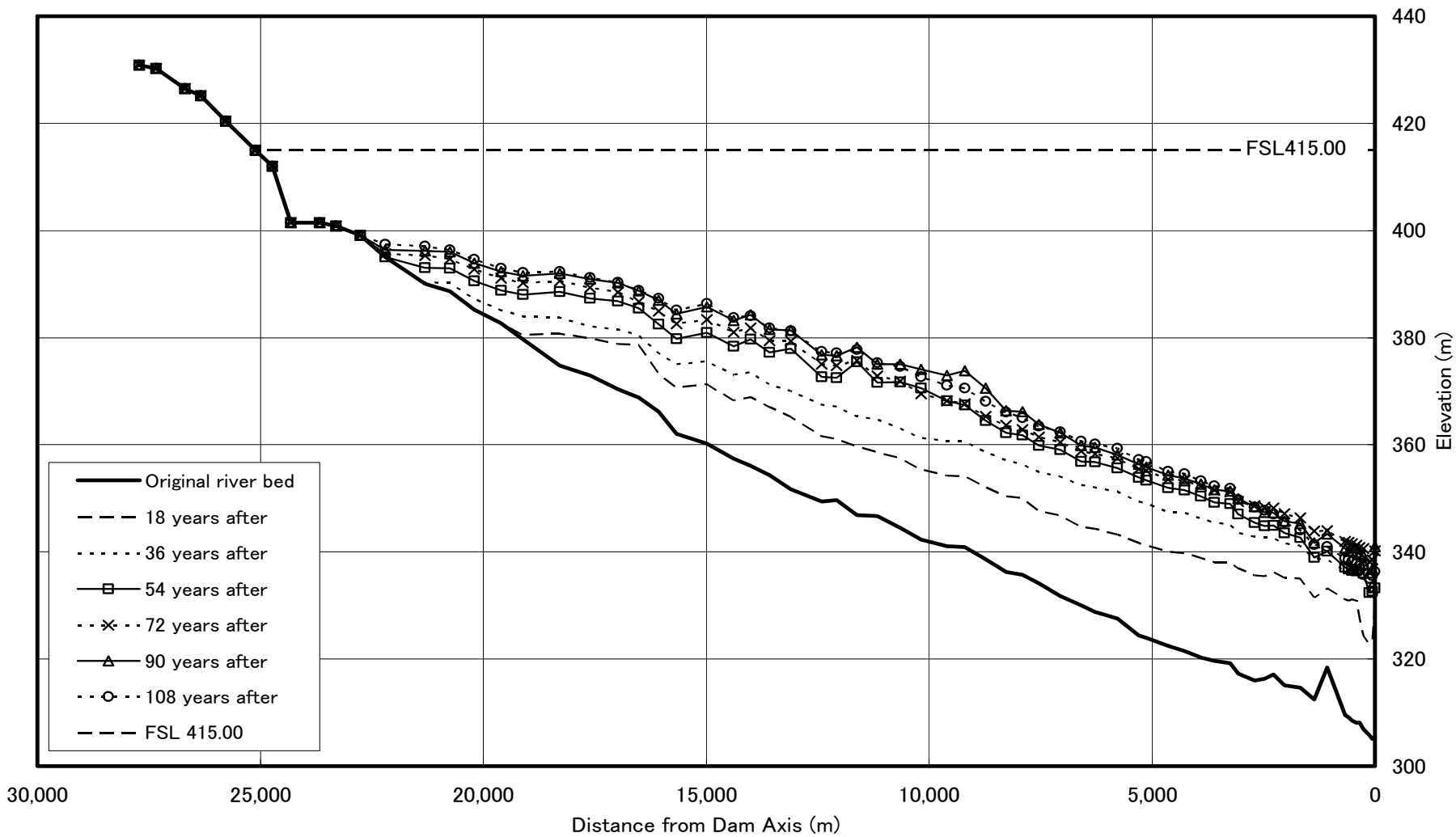


Fig. 6.6.4-9 Riverbed Profile of Reservoir with Sediment Flushing Gates (FSL = EL. 415.00)



**Fig. 6.6.4-10 Riverbed Profile of Reservoir with Sediment Flushing Gates (FSL = EL. 415.00, Flushing Gates Sill = EL. 330.00)**

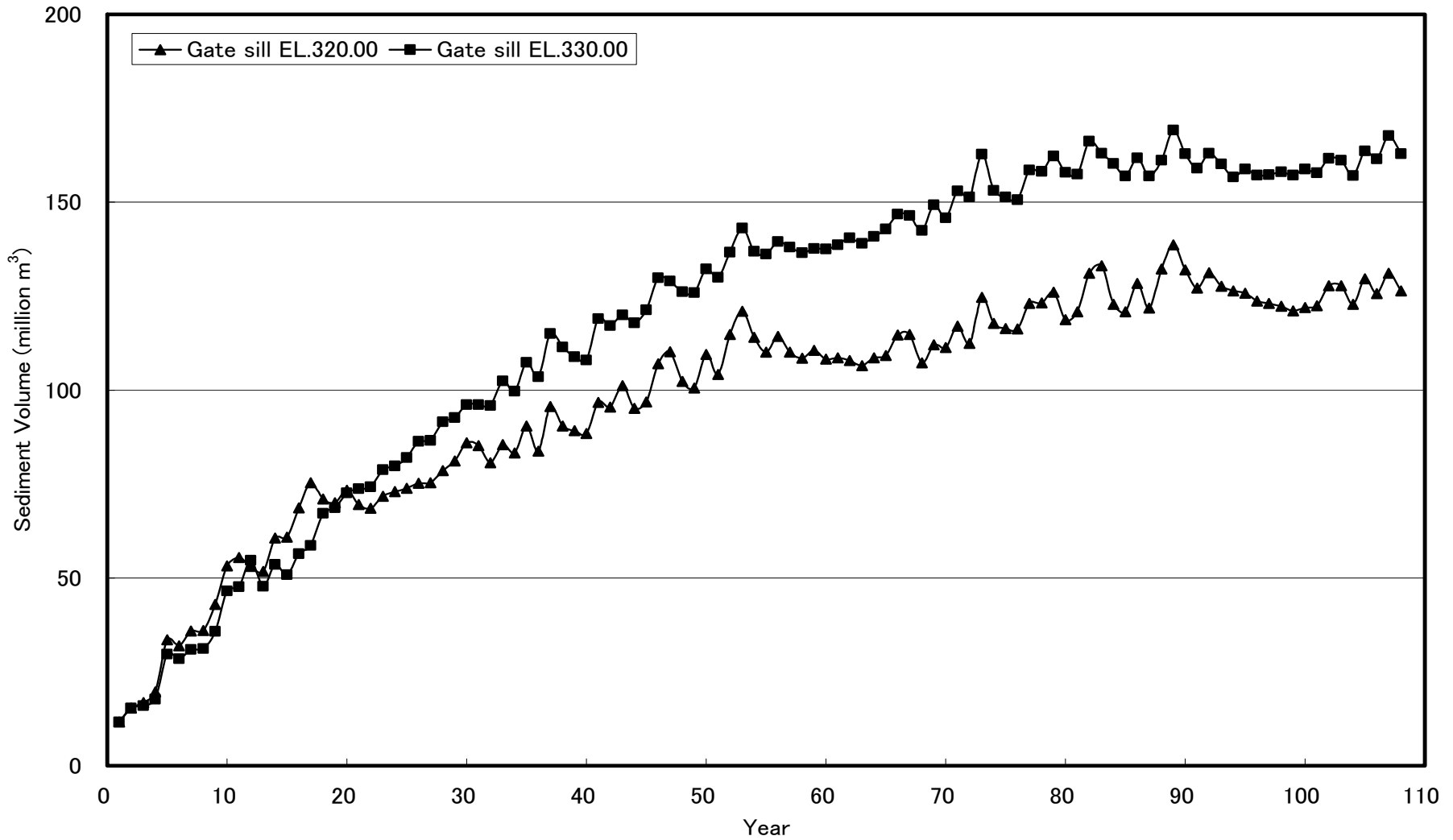


Fig. 6.6.4-11 Cumulative Sediment Volume in Reservoir

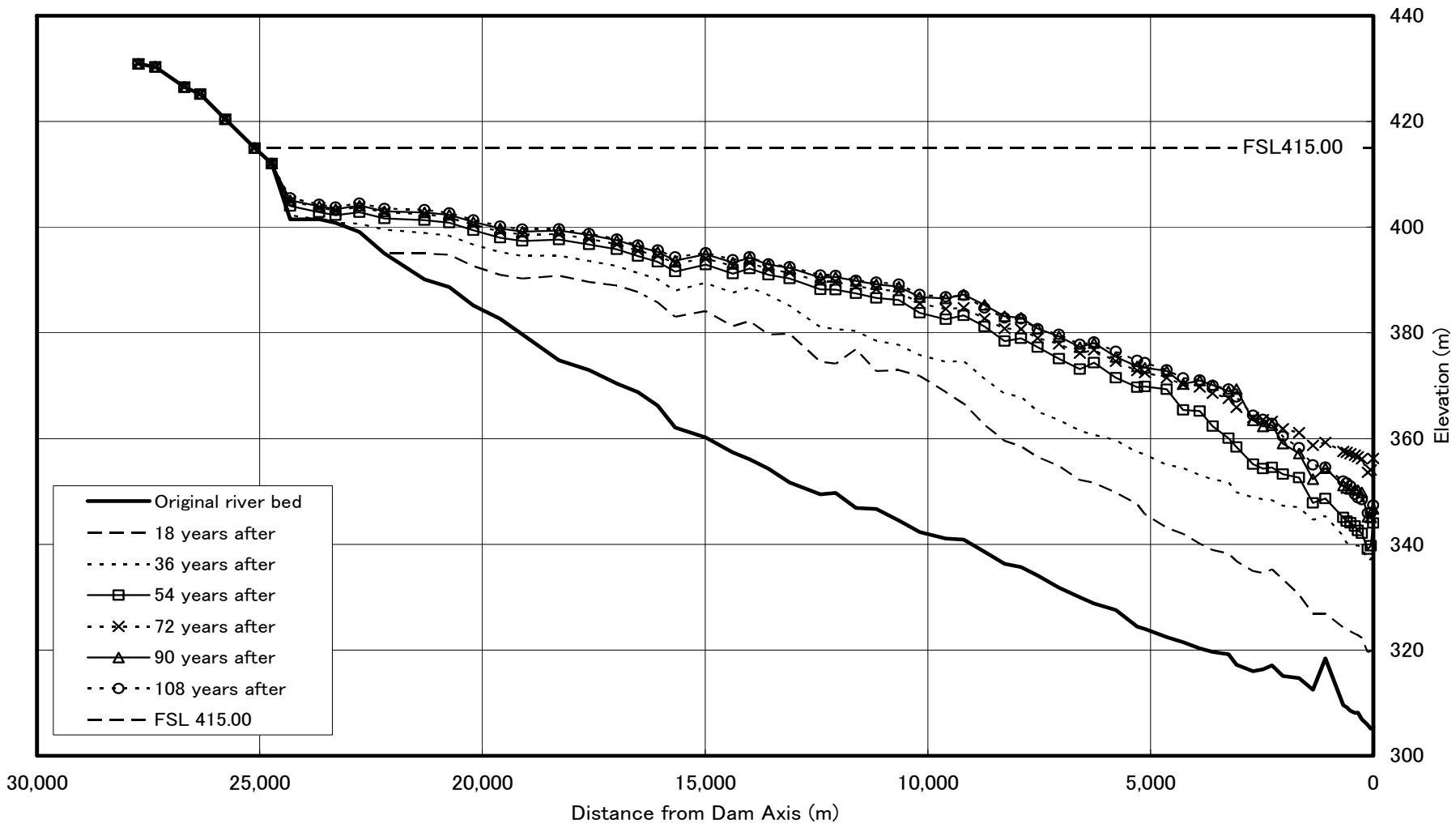


Fig. 6.6.4-13 Riverbed Profile of Reservoir with Sediment Flushing Gates (FSL = EL. 415.00, Flushing every 2 years)

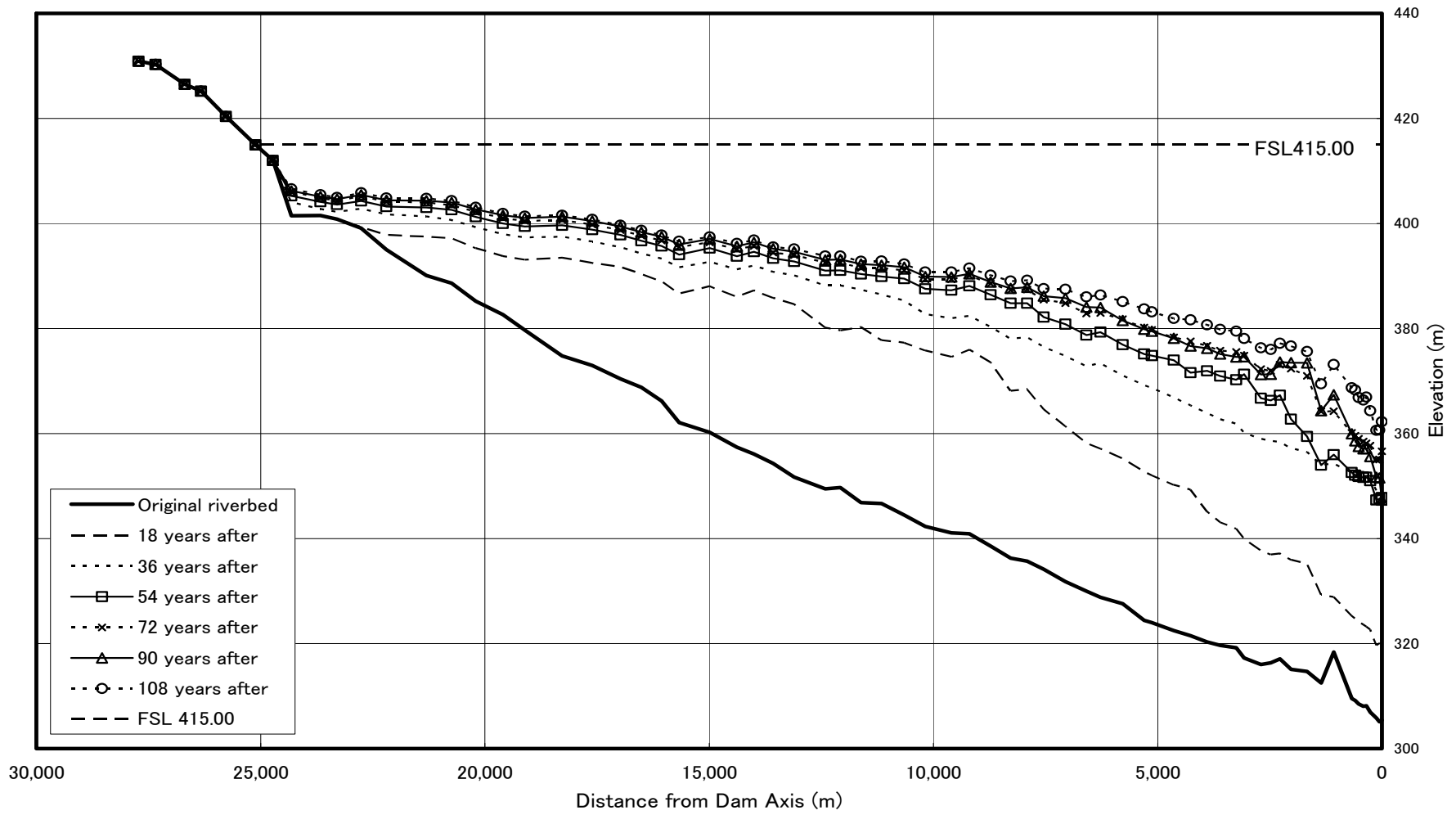


Fig. 6.6.4-14 Riverbed Profile of Reservoir with Sediment Flushing Gates (FSL = EL. 415.00, Flushing every 3 years)

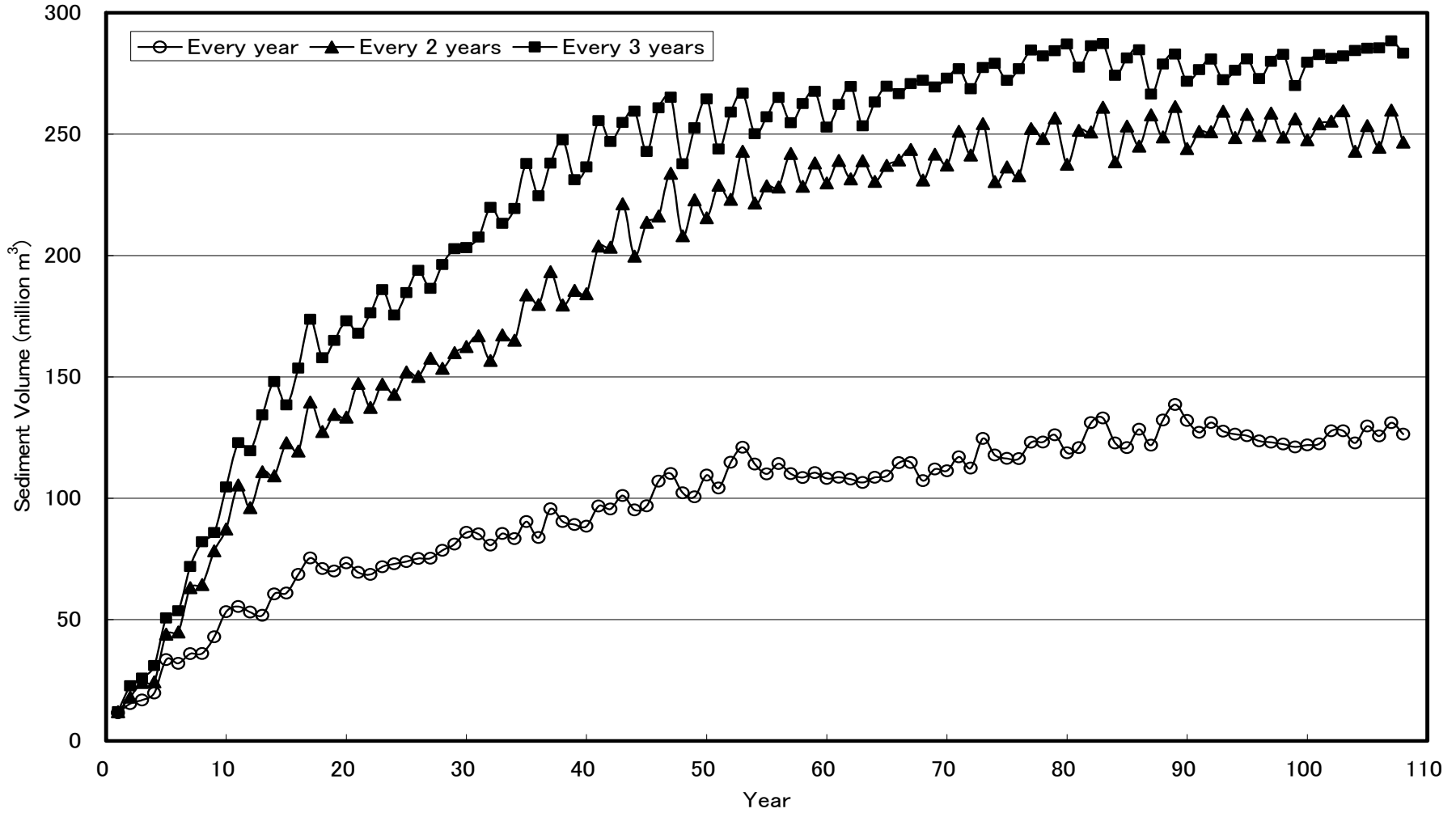


Fig. 6.6.4-15 Cumulative Sediment Volume in Reservoir

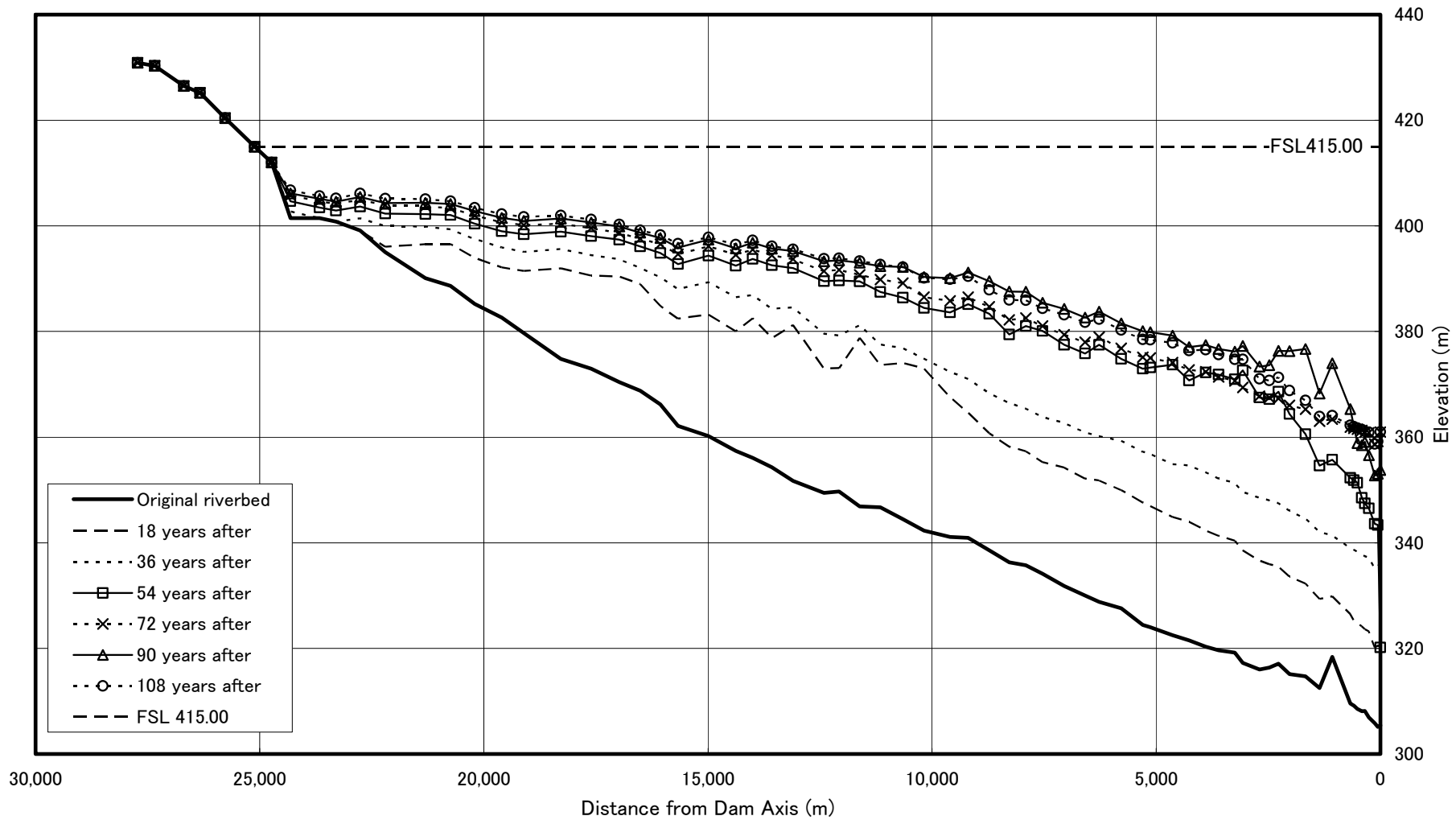


Fig. 6.6.4-17 Riverbed Profile of Reservoir when Sediment Flushing Operation Ends on July 15

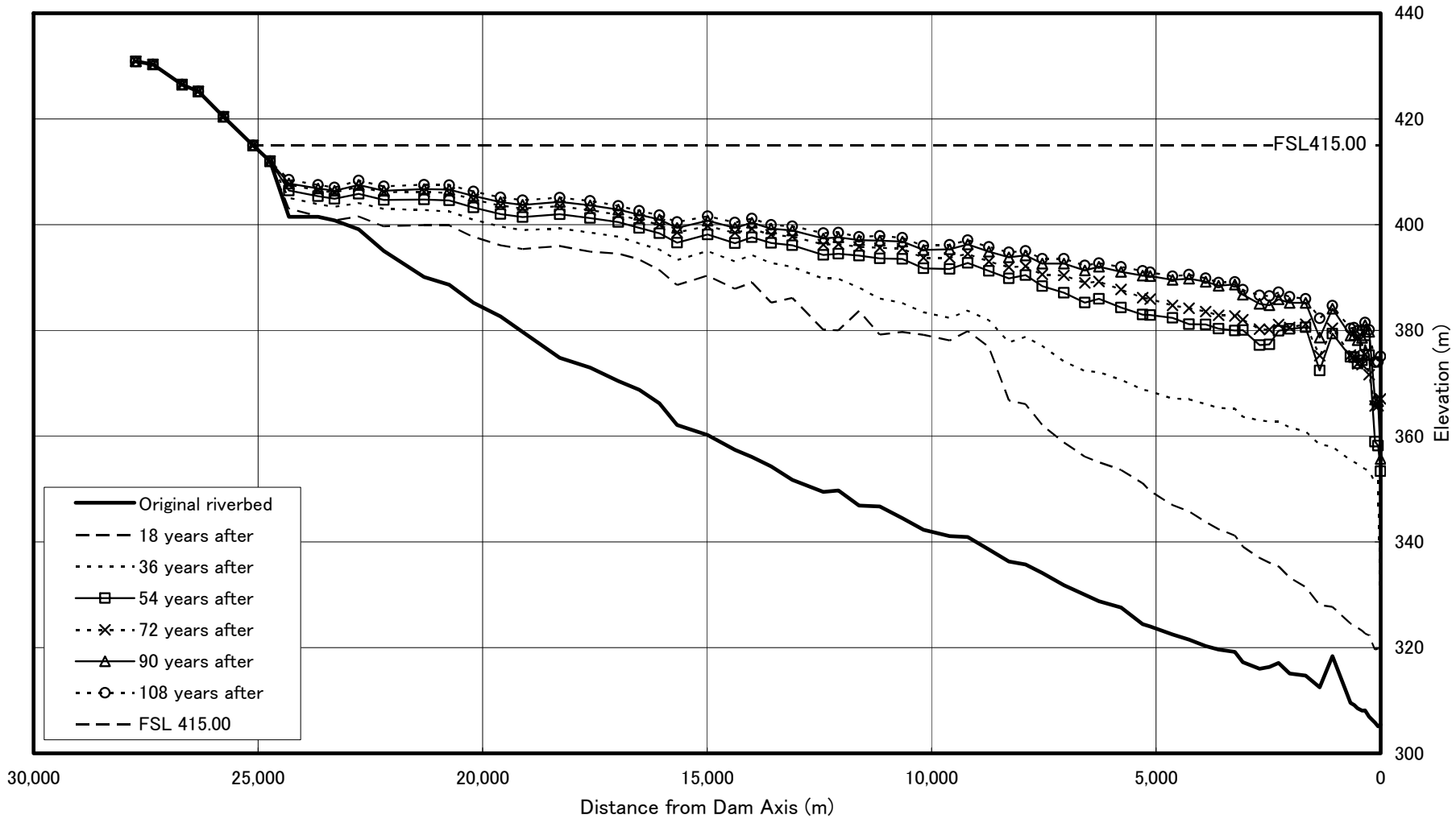


Fig. 6.6.4-18 Riverbed Profile of Reservoir when Sediment Flushing Operation Ends on July 5



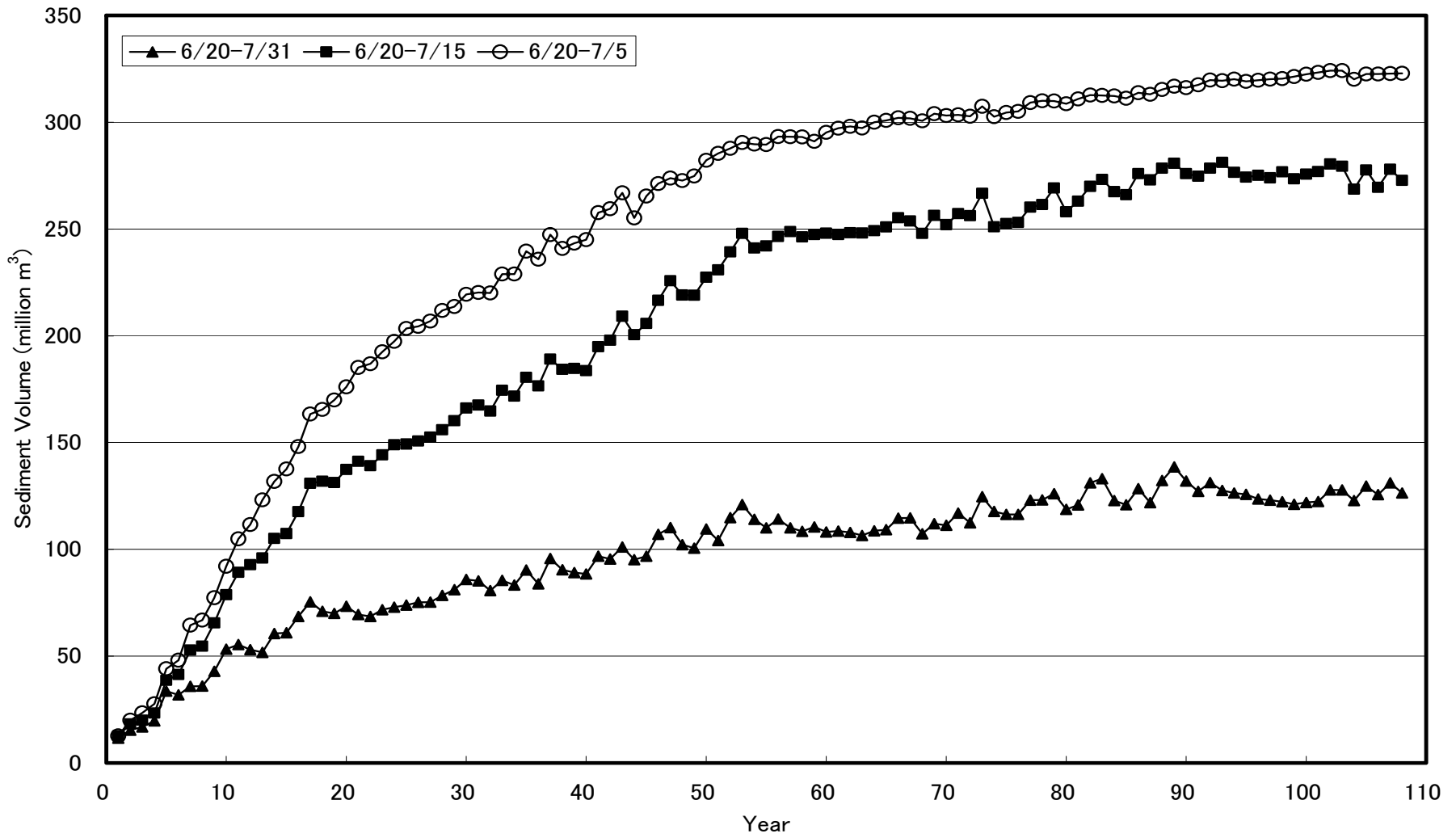


Fig. 6.6.4-19 Cumulative Sediment Volume in Reservoir

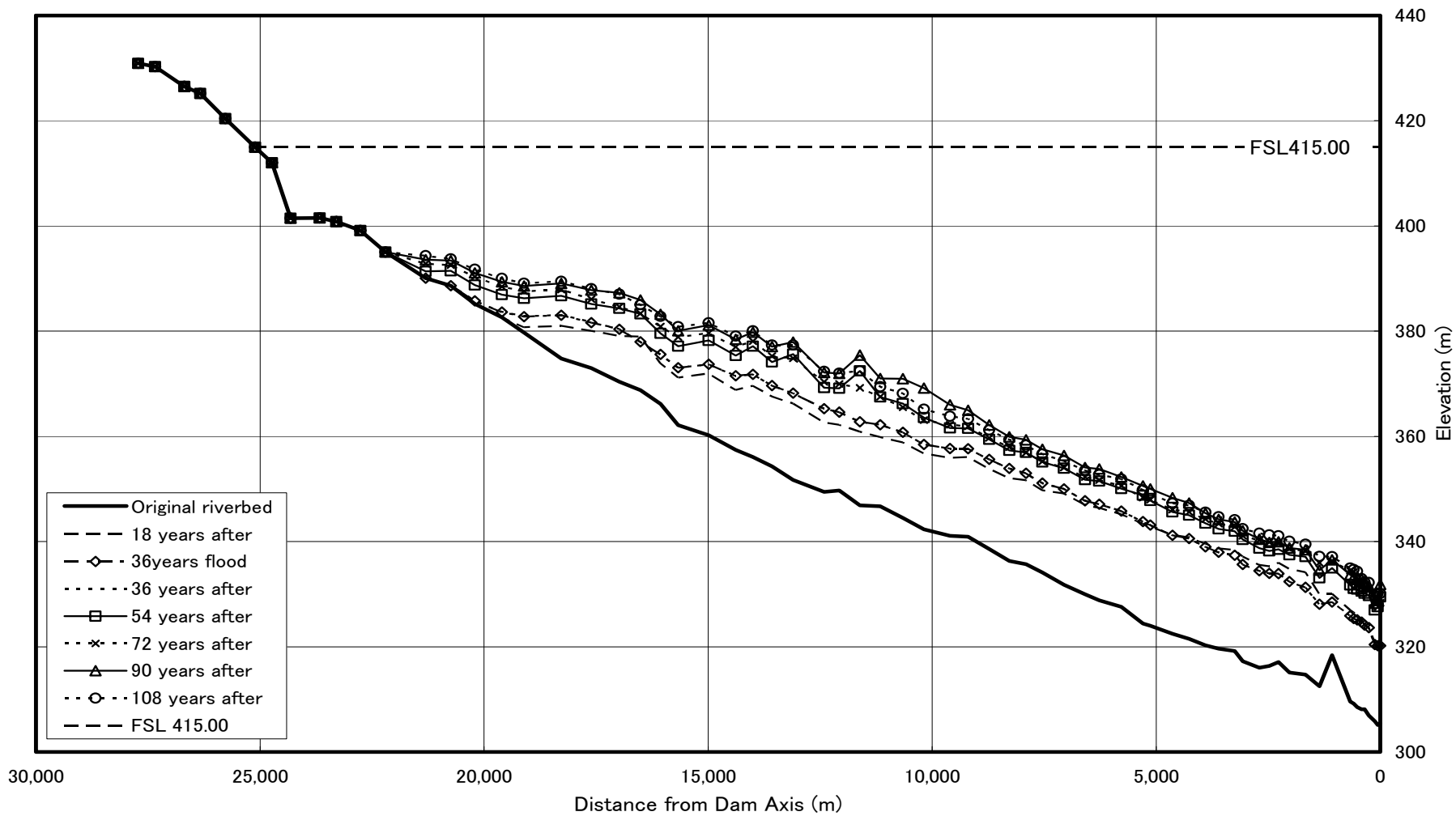


Fig. 6.6.4-20 Riverbed Profile of Reservoir with 100-year Probable Flood in 36th year

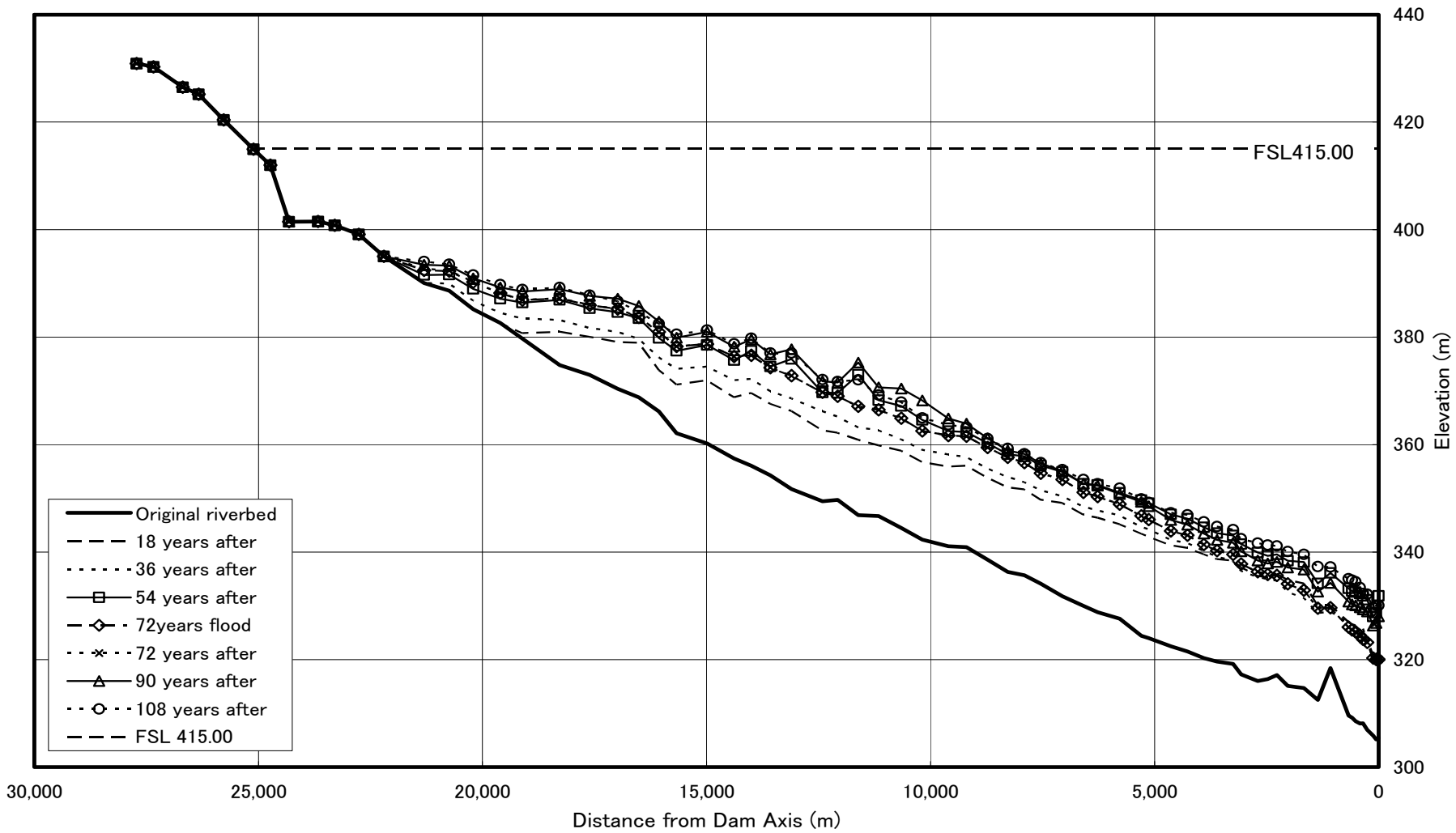


Fig. 6.6.4-21 Riverbed Profile of Reservoir with 100-year Probable Flood in 72nd year

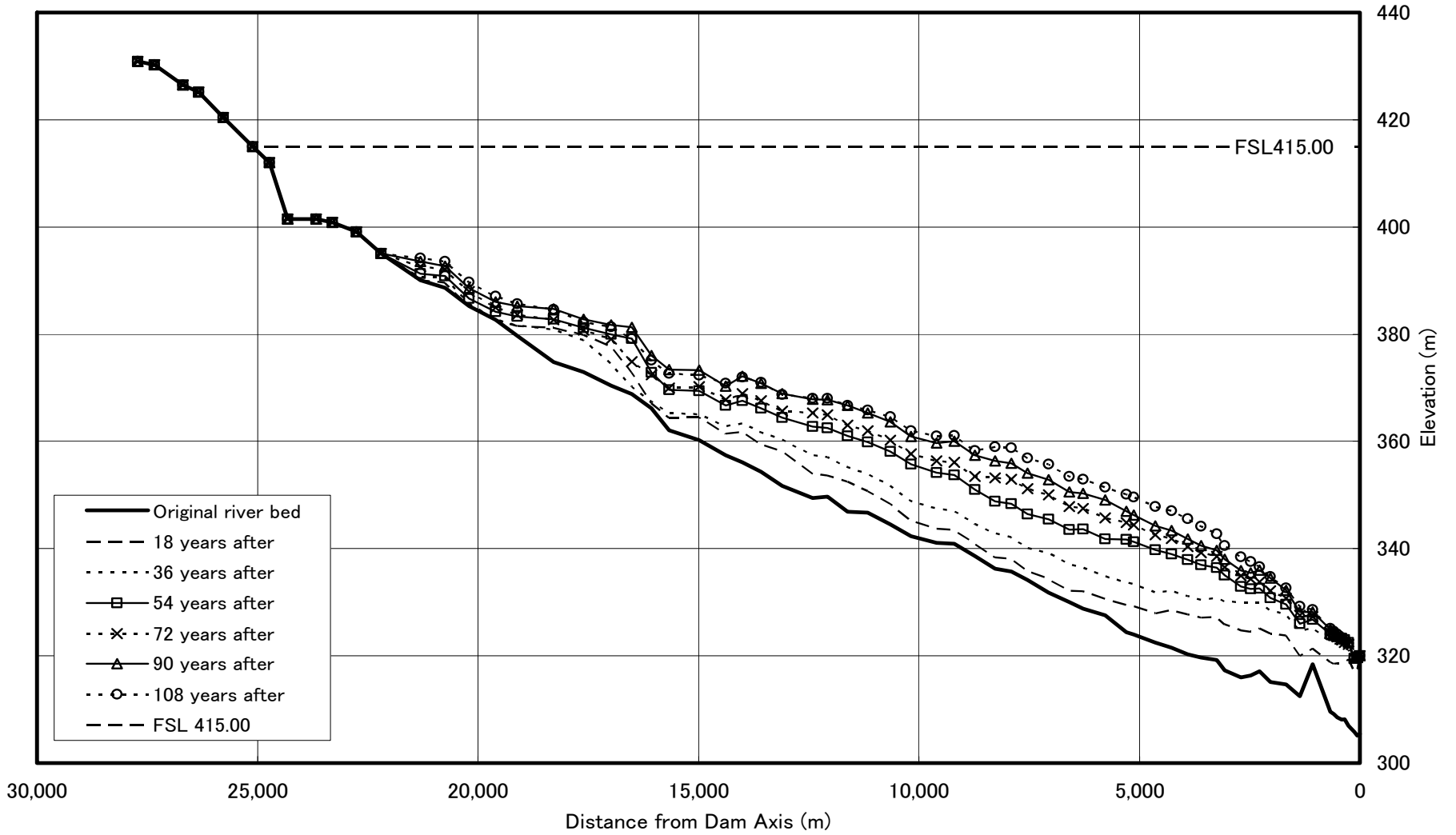


Fig. 6.6.4-23 Riverbed Profile of Reservoir with Sediment Flushing Gates (FSL = EL. 415.00, Gradation Curve of Fig.6.6.4-22)

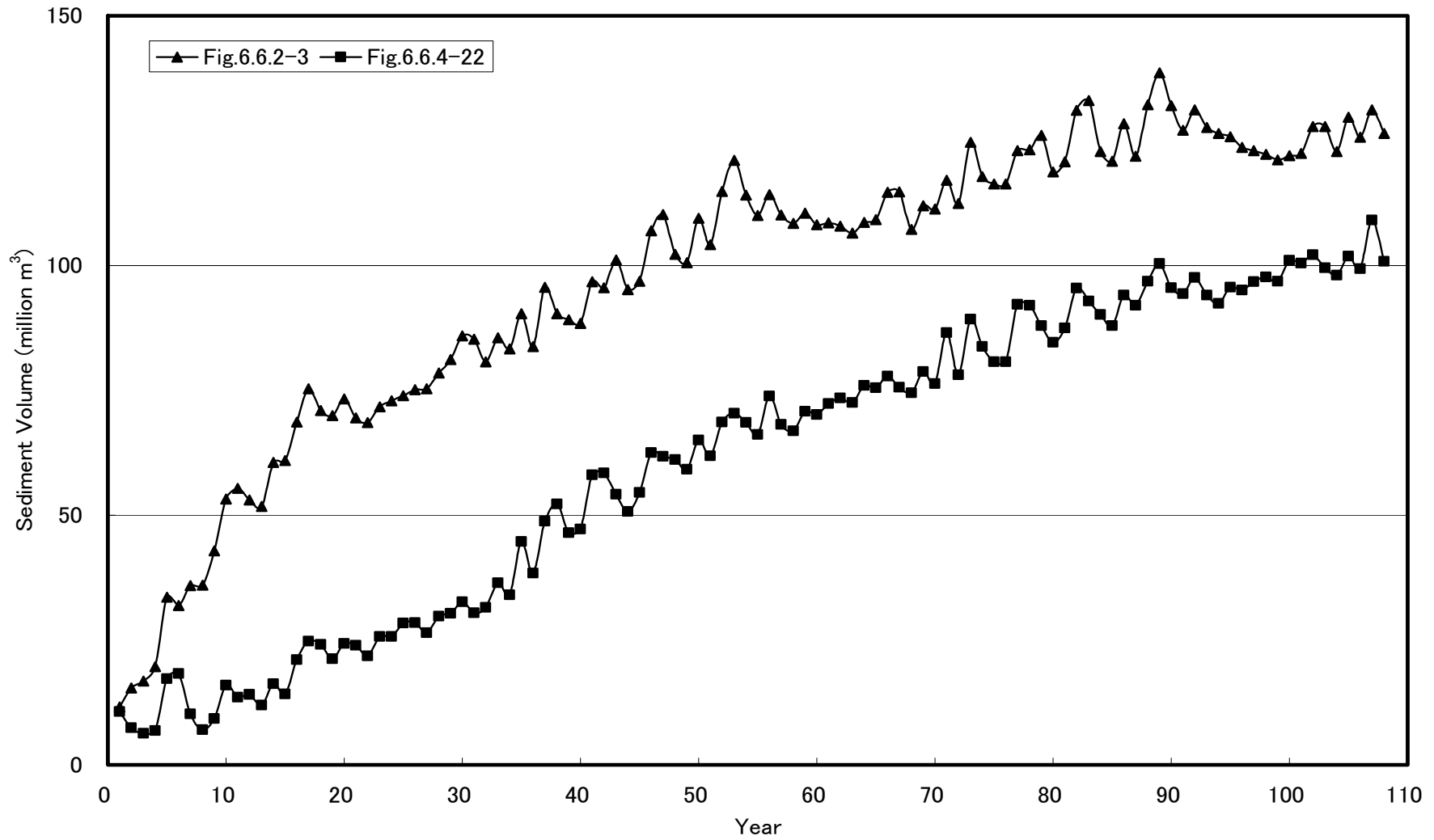


Fig. 6.6.4-24 Cumulative Sediment Volume in Reservoir