2. Brantas River Basin Development Planning

(1) Hydroelectric power development planning

(a) Power situation as of 1961 (year of the first master plan)

In 1961 East Java generated a combined power output of 53,250 kW; 31,650 kW out of three hydroelectric power stations and 21,600 kW from four thermal power stations (see Table 2-2). It is estimated that the actual total output was in the range of approximately 35,000-40,000 kW, due to repair or maintenance inspection reasons.

All the hydroelectric power stations were located in the Brantas Basin, of which Sengguruh Power Station (2,650 kW) has been taken out of service due to the establishment of the Karangkates Dam. As a result, existing power stations had a total installed capacity of 50,600 kW, excluding the Karangkates Power Station.

The annual power consumption in the province, hydroelectric and thermal, increased by about nine times from 22,550,000 to 202,380,000 kWh between 1928 and 1960 (see Table 2-3). The electrification rate of the Basin soared 70% during these 23 years from 15% in 1970 to 85% in 1993. Just for reference, electrification of Java Island was 76% as of 1993.

Table 2-2 Existing power stations in East Java (1961)

	Power station	Maximum output (kW)
Hydro	Mendalan	20,000
	Siman	9,000
	Sengguruh	2,650
	Subtotal	31,650
Thermal	Ngagel	6,400
	Semampir	12,200
	Malang	1,200
	P.A.L.	1,800
	Subtotal	21,600
Total		53,250

Table 2-3 Trends in power consumption

Unit: 10^3 kWh

Year	1928	1930	1935	1940	1945	1950	1955	1960
Power usage	22,550	61,469	59,935	68,041	79,145	83,127	178,557	202,384

(b) Potential hydropower

A survey was made for each master plan on the hydropower potential that could be economically developed in the Basin, the first in (1961), second in (1972), and the third in (1982). The potential was estimated to be 165,000 kW, 404,000 kW, and 291,000 kW, respectively (excluding already developed hydropower) as listed in Table 2-4.

Power transmission test at Waru Substation

Table 2-4 Survey on potential hydropower

Master plan	Point of measurement	Maximum output (kW)	Possible generated output (10^6 kWh)	Remarks
First	Karangkates	70,000	300	Constructed
	Selorejo	15,000	100	Constructed
	Wlingi	30,000	120	Constructed
	Kesamben	15,000	60	Under planning
	Others	30,000	100	Under survey
	Total	165,000	680	
Second	Wlingi	54,000	75	Constructed
	Kesamben	15,000	60	Under planning
	Tulungagung	30,000	100	Constructed
	Sengguruh	29,000	100	Constructed
	Others	276,000	1,045	Under survey
	Total	404,000	1,380	
Third	Beng	19,000	55	Under planning
	Konto II	62,000	207	Under planning
	Genteng II	12,000	10	Under planning
	Lumbangsari	11,000	47	Under planning
	Others	187,000	650	Under survey
	Total	291,000	969	

Remarks: Maximum output was calculated at the time of potential water power surveys, which may differ from actually developed scale.

(c) Demand prediction

Each master plan made an estimation of increased power demands during the respective period, and power consumption went up as was estimated. The third master plan, which is shown on the following page, calculated demands up to the year 2003.

The installed capacity of power generation developed in East Java totaled 628,000 kW in 1983 including the hydroelectric power stations of Karangkates, Lahor, Kalikonto, and Wlingi. Of this, hydroelectric power totaled 210,500 kW, of which 200,000 kW was developed in the Brantas Basin (see Table 2-5).

Table 2-5 Installed capacity of power generation in East Java (1983)

Unit: kW

Hydropower stations (9 locations)	210,500
Thermal power stations (2 locations)	350,000
Diesel/gas turbine power stations (2 locations)	67,500
Total	628,000

The power consumption in 1983 was 1.8 billion kWh, half of which was for industrial use. It has increased at an average annual rate of 25% since 1975 and the past five years, especially, have seen a higher rate of 34% (see Table 2-6).

Table 2-6 Power demands by use (1983)

	Demand (GWh)	Consumption rate (%)	Annual average increase rate (%)
(a) Residential	641	35.7	19.2
(b) Commercial	232	12.9	23.1
(c) Industrial	863	48.0	34.3
(d) Others	62	3.4	1.8
Total	1,798	100.0	25.4

The annual peak output rate of increase was 20.6% on average between 1975 and 1983. The power demands are estimated for the period from 1983 to 2003, as shown in Table 27.

There were four power stations under construction in 1983. Their completion in 1989 increased the total peak output to 958,000 kW. The demand prediction says that the installed capacity required for the peak load in 1998 will be 2,892,000 kW, so the actual output will run short by 1,934,000 kW. However the fact was that the total output of general hydroelectric power possible for economic development was 291,000 kW as of 1983 (see Table 2-4), which is far from the future requirements. This is the reason for the prediction that a combination of peak load power stations as well as large-output thermal power stations would need to be constructed. Power consumption has been on the rise at almost the predicted rate, reaching 9.62 billion kWh as of 1993, slightly below the predicted figure.

Table 2-7 Predicted power demands

	Estimated rate of increased power consumption (%)	Peak output demand (MW)	Power supply (GWh)
1983	—	446	2,735
1988	20.6	958	5,671
1993	20.6	1,740	10,604
1998	20.6	2,892	17,560
2003	20.6	4,446	27,356

(d) Hydropower development planning

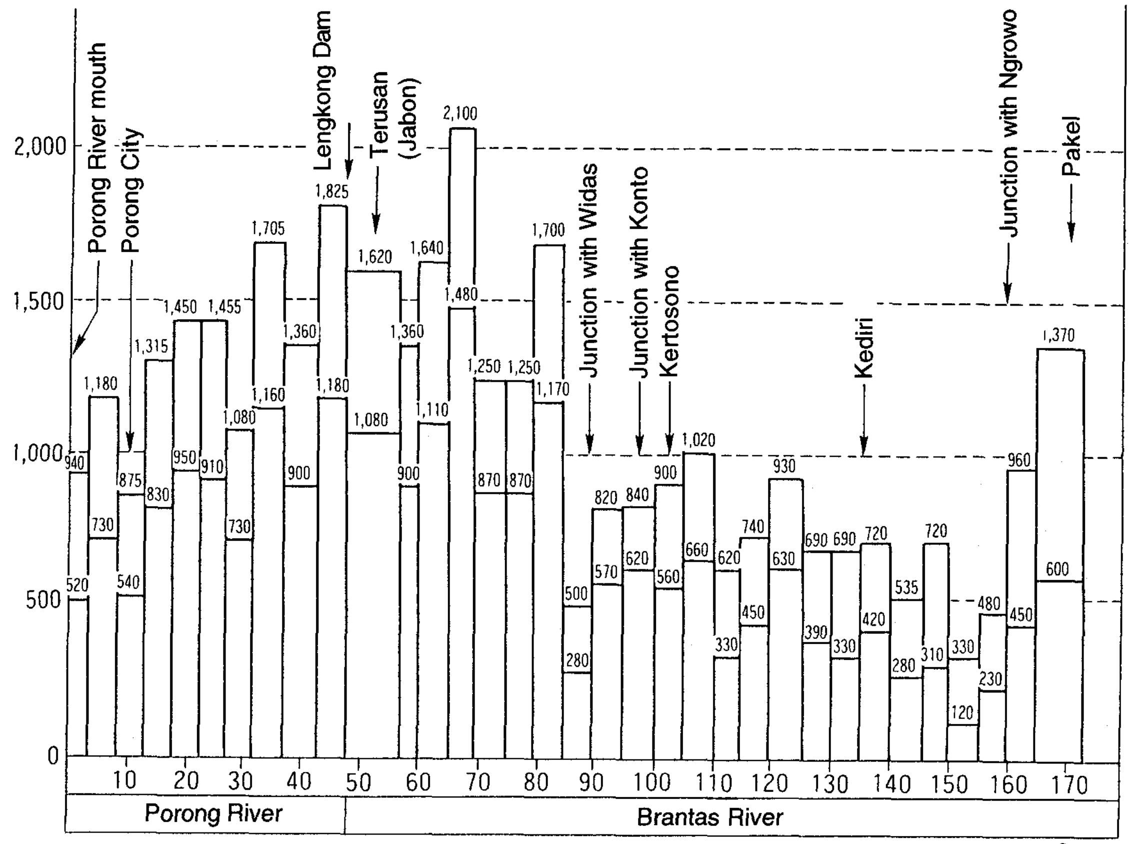
Although the surface water potential in the Brantas Basin amounts to 12,000,000,000 m^3, it varies considerably by season. And there are only a few sites suited for a large-capacity reservoir dam due to geographical conditions. For these reasons, it was decided that many multi-purpose dams equipped with hydroelectric power stations would be constructed for effective river water use. These multi-purpose dam projects were executed at selected points, in order of economy, out of those that were examined in the potential hydropower survey. Basically the design plan was that hydroelectric power stations were to provide for peak loads and thermal for base loads. Also planned were small-scale hydroelectric power stations making use of the low head of diversion weirs for irrigation water. In the early stages of hydroelectric power generation development, demand for peak load was low and hydroelectric power stations were also used for base load.

(2) Flood protection planning

Flood protection planning for the Brantas main stream was based on the following: 1) Retarding basins were utilized as they were or by expanding their functions; 2) Dams were allowed to retain flood waters to reduce peak flow; 3) Flood discharge into each river channel was calculated using the amount of flood water after being reduced (flood distribution planning), and then river training plans were prepared; and 4) River sections and bed slopes were designed so as to enable the planned flood waters to flow downstream safely and in consideration of the tractive force to carry sediment.

(a) Channel capacity

Before the river improvement projects under the Brantas Project, the flow capacity for flood water was 1,370 m^3/sec at Pakel; 690 m^3/sec at Kediri; and 1,620 m^3/sec at Terusan (Jabon). For the Porong River, the lowest stream and having the smallest channel capacity, it was 875 m^3/sec at Porong City. The flow capacities for flood water were acquired in the first and second master plans based on actual survey results of river channel cross sections and they were used in the river improvement planning for the Porong and the Brantas middle reaches (see Fig. 2-1).



Vertical axis: m^3/sec

Fig. 2-1 Flow capabilities of Brantas and Porong

(b) Floods

A flood discharge analysis of the Brantas was examined with new hydrologic data added for consideration in each master plan. The flood discharge became higher year by year as changes in the runoff occurred with the basin development. The Brantas had natural retarding basins at two locations near the junctions with the Ngrowo and the Widas. There were plans to utilize them as they were in the first and second master plans, however the third plan was to increase their capacities for more active utilization. This was intended to prevent flood waters from flowing out into the Brantas main stream and to deal with the flow increase resulting from the basin changes. Due to the storage effects offered by these natural retarding basins, the flood flow of the lower streams is small for the basin area. The following are the results of the flood discharge analyses and the flood distribution plans in each master plan.

The first master plan analyzed the flood flow at the Karangkates Dam and Jabon just upstream of the Porong. From the records for the years between 1951 and 1960 we can see that the maximum daily point rainfall was 200 mm. This is a very small figure in terms of average rainfall in the basin because of its limited rainfall area (see Table 2-8).

Table 2-8 Maximum precipitation on basin average (upstream of Karangkates Dam)

Unit: mm

Order of precipitation	Precipitation	Date of occurrence
1	62.7	Nov. 12, 1995
2	59.7	Dec. 04, 1958
3	57.9	Jan. 07, 1959
4	56.6	Mar. 24, 1960
5	53.5	Feb. 18, 1951
6	49.5	Dec. 11, 1954
7	45.8	Dec. 06, 1956
8	45.3	Feb. 27, 1957
9	44.9	Feb. 17, 1952
10	34.1	Dec. 21, 1953

The flood runoff coefficient of the Brantas main stream (total flood runoff/total precipitation) was estimated at 50%. Flood peaks occurred at almost 24-hour intervals, so 2-3 days of large rainfall causes a great flood 2-3 days later. Records from 1951 to 1960 say that the largest flood at Karangkates took place at 1,270 m^3/sec in January 1961; the second largest, at 1,038 m^3/sec in November 1955; and the smallest, at 179 m^3/sec in February 1953 (see Table 2-9).

Probable floods at Karangkates were calculated as below based on three-days of consecutive rainfall that usually leads to a great flood: A 100-year probable flood would be at 1,540 m^3/sec; the possible maximum flood, 2,580 m^3/sec; and a 50-year probable flood at Jabon, 1,500 m^3/sec. The results of these analyses were used in planning for the Karangkates Dam and the Porong river improvement projects.

Bridges across Porong

Table 2-9 Records of great floods

	Karangkates (basin area: 2,050 km^2)		Jabon (basin area: 9,675 km^2)	
	Flood (m^3/s)	Date of occurrence	Flood (m^3/s)	Year of occurrence
1	1,270	Jan. 15, 1961	1,070	1954
2	1,038	Nov. 12, 1955	1,000	1951
3	862	Dec. 05, 1956	997	1952
4	705	Dec. 23, 1950	968	1954
5	670	Feb. 18, 1951	942	1953
6	501	Dec. 10, 1954	917	1957
7	368	Mar. 24, 1960	901	1955
8	360	Jan. 07, 1959	798	1956
9	317	Feb. 17, 1952	743	1950
10	291	Feb. 28, 1957	730	1958
11	278	Dec. 04, 1958		
12	179	Feb. 08, 1953		

The second master plan analyzed the storage effects of retarding basins in the middle reaches to calculate flood flow. Flood hydrograph at every measuring station are sharply pointed for upper reaches, gradually becoming gentler toward lower reaches as shown in the Flood Hydrograph in the Attachments. Such changes in hydrograph resulted from stored flood water in rivers and inundation into embankments. For tributaries, floods were caused by a rise in the river beds and were stored in the basin before flowing into the Brantas, thus not leading to a sharp increase in the peak flood flow of the Brantas.

The storage effects analysis of retarding basins revealed that the flood discharge of the Brantas overflowed onto embankments at some point between Pakel and Kediri, and that the stored water rate varied in the range of 15-30 x 10^6 m^3 depending on the flood scale, with a reduced peak flow rate due to this storage effect of 150-300 m^3/sec.

In a marsh situated at the Widas junction, flood water from the Brantas and Widas lay stagnant and then gradually flowed into the Brantas. Calculations showed that the stored water rate was at 30-40 x 10^6 m^3 and that the resultant reduced peak flow rate was 300-400 m^3/sec.

During floods, discharge occurred into the Marmoyo (branch of Surabaya) at about 80 m^3/sec from Gedek Water Gate on the Brantas left bank 5 km upstream of Terusan. With this channel state in view, flood flow rates of chance floods were obtained at four points, after being subjected to flood control in the Karangkates reservoir as listed in Table 2-10.

The flood discharge capacity of the Brantas at certain points were presented as follows: 1,370 m^3/sec at Pakel, which was equivalent to the flow rate for a 30-year probable flood; 620 m^3/sec between Kediri and Widas, which was very low although provided with embankment; 690 m^3/sec at Kediri, which was equal to the flow rate for a 5-10 year probable flood. These analyses were used in planning for the Wlingi Dam and the Middle Reaches River Improvement Projects.

The third master plan mentioned changes in the mechanism of flood runoff. A large flood took place along the Brantas in 1984. Flood flow of 1,000 m^3/sec was recorded at Kediri and 1,470 m^3/sec at Porong, which were almost equivalent to planned flood flow rates. From these, it was estimated that there was some change occurring in the flood runoff mechanism as the basin development advanced. This called for review of the flood safety level of the basin with the most current flood data added for consideration. The review revealed that the currently planned 50-year probable flood was equivalent to the newly calculated 20-40 year one, falling short of the planned scale (see Table 2-11). To keep flood waters from flowing into the Brantas main stream, a proposal was made to reinforce the function of retarding basins at the river mouth in the Widas River Improvement Project examined in this master plan.

Table 2-10 Probable flood runoff

Unit: m^3/sec

Year of occurrence probability	Karangkates	Pakel	Kediri	Terusan
5	400	1,000	660	1,130
10	470	1,090	720	1,190
20	490	1,250	790	1,260
30	500	1,350	820	1,290
50	530	1,440	860	1,330
100	560	1,560	910	1,380

Remarks: Terusan is located just upstream of Jabon Flow Gauging Station.

Table 2-11 50-year probable floods

Unit: m^3/sec

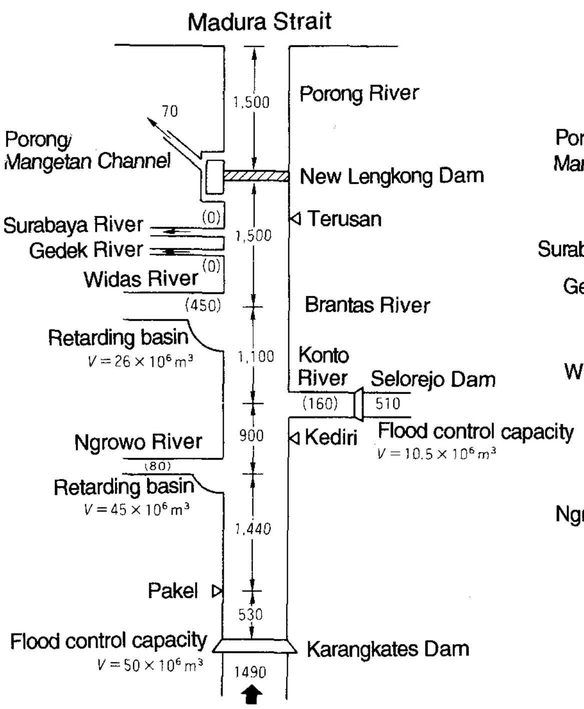
Section	Current planned flood flow	Newly planned flood flow
Ngrowo Junction - Konto Junction	900	1,050
Konto Junction - Widas Junction	1,100	1,250
Widas Junction - New Lengkong Dam	1,500	1,500
New Lengkong Dam - River mouth	1,500	1,600

(c) Flood discharge distribution planning

The flood discharge distribution plan of the first and second master plans was intended for 50-year probable floods after they had been subjected to flood control in the reservoirs of Karangkates and Selorejo. The basic concepts of the plan were: 1) to use the inundated area near the middle Ngrowo River mouth and the swamp near the Widas junction as retarding basins (because it would cost too much to secure any site on the lowest reach because they are already in an advanced stage of development); and 2) to not discharge water from Gedek and the Mlirip Intake Gate into the Surabaya River at the time of flood in view of the importance of Surabaya City.

Based on this conception, the flood discharge distribution plan was set as follows: 1,200-900 m^3/sec between the Ngrowo and Kediri, 900 m^3/sec between Kediri and the Konto junction, 1,100 m^3/sec between the Konto junction and that with the Widas, and 1,500 m^3/sec between the Widas junction and Terusan.

To allow the above mentioned 50-year probable floods, whose flow rates were freshly obtained in the third master plan, to flow downstream safely even after an eruption of Mt. Kelud, the following two ideas were considered: 1) overall river improvement and 2) diversion of flood waters from the Lodoyo regulation pond into the Indian Ocean. Plan one would result in costly work and possibly cause social problems for the shoreside residents. Plan two sounded appropriate, however the fact was that the Brantas River had a flow capacity equal to 20-40 year probable floods as described above, which still remained at a higher level than that of other Indonesian rivers. Consequently it was judged unnecessary at that time to construct a diversion channel. After all, it was decided that the natural retarding basins of Ngrowo and Widas would be utilized as they were simply by enhancing their functions to secure the required filling capacity. This would maintain the current status of the discharge into the Brantas main stream. The flood discharge distribution plan was decided as shown in Fig. 2-2. For reference, the reference flood discharge distribution diagram is shown in Fig. 2-3.



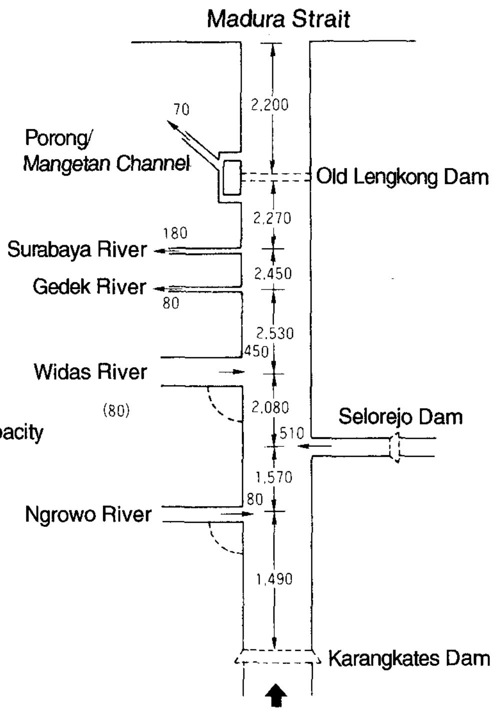


Fig. 2-2 Flood discharge distribution plan (third master plan) (Unit: m³/s)

Fig. 2-3 Basic flood discharge distribution (Unit: m³/s)

(d) Sediment balance

A great deal of ejecta produced by Mt. Kelud eruptions mixes with flood waters and flows into the Brantas subsequently becoming riverbed sediment. The balance, or inflow and outflow, of sediment in the Brantas can be conceptually described as follows: 1) A Mt. Kelud eruption causes a large quantity of ejecta to flow into the Brantas; 2) The river bed has a remarkable temporary rise and the flow capacity of flood water falls; 3) in every rainy season, floods carry the sediment to the river mouth and the bed level gradually drops; however 4) if subsequent eruptions occur before the bed level is restored to its pre-eruption state, the bed level will increase to an even greater extent.

Until the first master plan, the sediment balance was quantitatively analyzed by using the 1951 eruption of Mt. Kelud as a reference year. Past records found that Mt. Kelud yielded 200,000,000 m^3 of ejecta in one eruption, of which 140,000,000 m^3 was estimated to fall outside of the basin, while 60,000,000 m^3 stayed within the basin. Of this, 30,000,000 m^3 flowed into the Brantas all at once, while the remaining accumulated on the side of Mt. Kelud and then flowed out gradually. The amount of ejecta flowing into rivers over the course of time was estimated at 6,500,000 m^3 per year including sediment discharge resulting from erosions in regions not affected by eruptions.

The average particle size of sediment on the Brantas riverbed is finer at reaches downstream. That at Blobo 148 km upstream of the Lengkong Dam is 0.45 mm; at Kediri 61 km upstream, 0.36 mm; and at Lengkong, 0.23 mm. Particles of 0.105 mm or smaller are rarely found on the bed, these are carried away to the mouth rather than accumulating on the bed. With the amount of sediment on the Brantas riverbed being zero in 1936, the amount in 1957 was estimated at 14.7 x 10^6 m^3 (see Table 2-12).

The tractive force of the river near Mojokerto on the lowest reach was calculated, by survey, as being 9,000,000 m^3 annually. By survey map, the sediment amount at the Porong River mouth was estimated at 280 x 10^6 m^3 during the 40 years between 1914 and 1954, which was equivalent to an annual average sediment discharge of 7,000,000 m^3. This figure did not include sediment that overflowed onto fields at the time of floods or earth carried past the mouth of the Porong, for example carried into the Surabaya. Considering this, the 9,000,000 m^3 tractive force of the Brantas was judged reasonable.

Table 2-12 Riverbed sediment heights

Unit: cm

Year	Sediment	Balance	Remarks
1936	0		
1952	20.9	+20.9	Mt. Kelud erupted in 1951
1953	23.0	+2.1	
1954	17.5	-5.5	
1955	30.0	+12.5	
1957	14.7	-15.3	

Although the balance between sediment inflow and outflow was found to be almost even on a long term basis, a sudden rise in riverbed due to post-eruption sediment discharge posed a great threat from the viewpoints of flood control and water utilization. Naturally checking measures were urged against the sudden discharge of the above mentioned 30,000,000 m^3. Later this figure was subjected to further reviews and corrections with observation results of tractive forces etc., newly added for consideration.

The second master plan examined mountainsides, checking the sediment amount for every region looking for effects of the 1965 eruption. It revealed among other things that the rise in the Brantas main stream riverbed, during the five years after an eruption, mainly resulted from a large amount of sediment flowing into the river channel.

The annual amount of sediment for each section was calculated from the data for the 20-years between 1951 and 1970. It turned out that the bed showed a sharp post-eruption height increase for five years before showing a considerable drop in increase rate. The sediment that accumulated in the section between Kaulon and the Porong River mouth was calculated at 48,000,000 m^3 (see Table 2-13).

Table 2-13 Sediment amount

Section	Section distance (km)	Sediment (10^6 m^3)
Kaulon - Jongbiru	80	15.7
Jongbiru - Kertosono	33	8.3
Kertosono - Jabon	48	9.2
Jabon - Porong River mouth	51	15.1
Total	212	48.3

Table 2-14 shows the relationship between the estimated amount of sediment on mountainsides (ejecta) and the sediment on riverbeds.

From the 1951-70 flow records, along with riverbed slopes and cross sections, it was estimated that the annual average transport capacity of bed load, suspended load, and wash loads were in the ranges of 1.0-1.1 x 10^6 m^3 and 4.0-4.5 x 10^6 m^3. In other words, the Brantas sediment transport capacity was 5-5.5 x 10^6 m^3 on an annual average.

Table 2-14 Amounts of ejecta and riverbed sediment

	Sediment on mountainside (10^6 m^3)	Bed sediment over five years (10^6 m^3)	Ratio (%)
1951 eruption	192	26.86	14
1966 eruption	90	16.40	18
Total	282	43.26	15

From the sediment amount that accumulated in the Brantas river channel and that which was carried down river, an estimation was made on the amount of sediment flowing into the Brantas river channel from the mountainsides around Mt. Kelud. Sediment amounts supplied from eruption-affected regions were obtained by subtracting that from regions not affected by eruptions from the total sediment supply amount, the results of which are shown in Table 2-15.

Table 2-15 Amounts of sediment flowing into river channel

Unit: 10^6 m^3

Period	Bed load and suspended load	Wash load	Total
1951-1955	30.85	25.74	56.59
1956-1965	10.27	33.35	43.62
1966-1970	18.09	9.51	27.60
Total	59.21	68.60	127.81

For river improvement planning, the amount of sediment flow into the river channel was calculated by the analysis results mentioned above to plan adequate river cross-sections to provide sediment transport without allowing sedimentation on riverbeds. It was also planned to remove the accumulated sediment from the riverbeds by means of dredging (riverbed dredging) which would affect the planned river channel (vertical and cross-sections).

(e) Flood control dams

The function of flood control for the Brantas main stream was incorporated into the Karangkates Dam in the first master plan and the Wlingi Dam in the second. Since there were sites available for large dams only in the area upstream of Pohgajih where the Lahor branches from the Brantas, comparison was made in economic terms between Pohgajih and Karangkates located upstream of it. It was found that Karangkates could offer a storage capacity of 340,000,000 m^3 including a possible increase in storage to be created by the modification of the Lahor River basin with bedrock suited to a large dam, accordingly providing cost efficiency. The Karangkates Dam was thus planned in the first master plan. The second master plan decided on a medium-scale dam, Wlingi, to be about 25 km downstream of the Karangkates Dam.

The Brantas has major four branches, Lesti, Ngrowo, Konto, and Widas. It was calculated as possible to construct a dam of up to 50 m in height, with a total storage capacity of 54,000,000 m^3 in Selorejo on the upper reaches of the Konto. Also the Selorejo site was estimated to come next to Karangkates in economy. As a consequence, the Selorejo Dam was planned as one of the top-priority projects along with the Karangkates Dam in the first master plan. The Lesti did not offer a site suitable for a large dam equipped with flood control functions, so a multi-purpose dam for irrigation and power generation, the Sengguruh Dam, was constructed. The Ngrowo Basin was a large rice production area, where the reclamation project on its middle reaches had already been in progress, the South Tulungagung Drainage Project. Flood flow that occurred in the Ngrowo was allowed to be discharged through the Nejama Diversion Tunnel into the Indian Ocean, with little affect on the Brantas main stream. The Widas, with a basin area of 1,538 km^2 offered an available dam site on its upper reaches but with small storage capacity. The Bening Dam planned in the second master plan as part of the Widas River Improvement Project was intended only for irrigation and power generation.

The planned flood control discharge is shown in Table 2-16 for the flood control dams; Karangkates, Selorejo, and Wlingi.

Table 2-16 Flood control discharge

Unit: m^3/sec

Flood control dam	River	Flood control discharge
Karangkates	Main stream	1,490
Selorejo	Main stream	460
Wlingi	Konto	470
Total		2,420

(f) River improvement planning

The first master plan dealt with river improvement planning for the Porong. The second laid out a plan for the middle reaches of the Brantas main stream, during which the Surabaya river improvement plan was separately formulated. The third master plan covered the Widas.

Porong River

The Porong serves as the flood diversion channel for the Brantas main stream, with a basin area of 11,169 km^2 (at its mouth). Mount Kelud eruptions caused the riverbed to rise with a resultant fall in flood discharge capacity. In this basin there are urban areas such as the cities of Mojokerto and Porong and agricultural areas for rice-production as well. The Porong had a channel capacity of 900 m^3/sec which was equivalent to only 1-5 year probable flood rates, resulting in an annual increase in flood damages. For this reason, river improvement work was urged and plans were proposed on the establishment of a river channel with a 50-year probable flood flow capacity and a channel to stabilize the watercourse at its mouth.

The main stream of the Porong is 46 km in length, equipped with embankment and a double section on both banks, except the brackish-water fishery area covering about 5 km near its mouth. Along the river, 150-300 m in width and with a 1/3,500-1/8,000 bed slope, there were many sections where the riverbed was higher than the surrounding ground, so called ceiling river sections. (Its narrowest section, near Porong City, is 120 m wide and equipped with only a single section.) The embankments were dilapidated due to lack of maintenance and repair, and so the threat of floods and bank collapse was common along almost the entire length of the river.

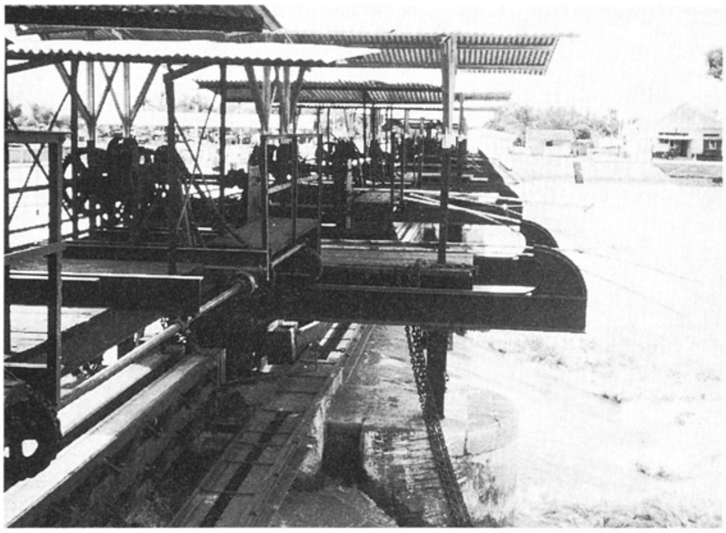
An improvement plan aimed at increasing the height and width of the embankments (maximum height increase: 3 m, crown width: 3 m) and revetment (wet masonry and gabions). For the river channel, a double section was adopted as a design section in consideration of the flood flow capacity and the tractive force. A cut-off was planned for the mouth to prevent a decrease in the flood flow capacity.

It is thought that the mouth of the Porong was situated off Porong City at the time when it was constructed in the 1850's to be a flood diversion channel for the Brantas (currently situated about 15 km downstream of the city). This may be why the river width at the original mouth, 120 m, was narrower than that on the upper reaches. Its intent was to increase the flow velocity so that the sediment from the upper stream could be discharged along with flood water into the sea. Sedimentation caused the mouth to move inland toward the lower reaches (about 15 km) over the course of time, forming the current channel state. Currently the river channel is narrow near Porong City, a section where the largest width is needed. This situation formed a bottleneck in the improvement work.

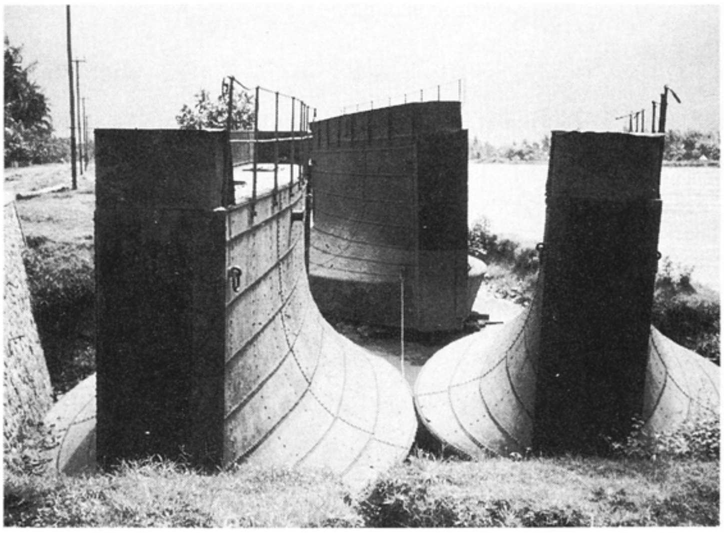
Flooded town

New Lengkong Dam

On the outskirts of Mojokerto City there is a point where water from the Brantas river is diverted into the Sidoarjo irrigation canals and the Surabaya River for domestic and industrial use. The Lengkong Dam was constructed across the Brantas main stream in 1857 as just such a diversion weir. The dam however was quite old, equipped with stop log and wooden needle gates, and was cumbersome to operate because of a manually operated winch, hence being poorly equipped for floods. Such being the case, it was proposed that it be rebuilt as a sluice gate dam which is easier to operate.



Old Lengkong Dam



Ship-shaped gates left behind from Old Lengkong Dam

The Lengkong Dam was originally constructed in 1857, when Japan was still in chaos shortly before the Meiji Restoration, the beginning of Japan's modern era. When seeing it for the first time, Japanese civil engineers marveled that the Westerners had the advanced technologies to construct such a dam as early as that. This kind of dam, large or small, can be found around the Brantas Basin, where the chronological progress of technologies for dam main facilities, the hydrological structure of stilling pools, intake methods, etc., can be traced, the sight of which has a similar atmosphere to that of a technological museum.

Of these, the Lengkong Dam was of the largest scale and equipped with state-of-the-art or seemingly innovative technologies for the era such as Voor canal (intake with a settling basin), flood stilling pools (end-still method), water stop between floor slab concrete blocks (joints filled with lead), and water-fill and -draw type gates (ship-shaped steel boxes).

Brantas middle reaches

It was estimated that the Brantas Middle Reaches River Improvement Project, covering a basin area of 9,675 km^2, would take an extended work period and considerable construction costs. Therefore it was planned in two stages: the overall plan (50-year probable floods) and the first plan (tentatively dealing with 10-year probable floods). Estimations were made as follows: For the overall plan, amount of dredged riverbed: 15,000,000 m^3; embankment: earth volume 7,000,000 m^3; work period: 10 years; and total construction costs: US$24 million (as of 1972). For the first plan, amount of dredged riverbed: 7,000,000 m^3; embankment earth volume: 7,000,000 m^3; work period: 5 years, and construction costs: US$14 million (of those in the overall plan).

This project covered the approximately 95 km long river channel between Kediri and the Lengkong Dam and was to connect, through the dam, the Brantas and the Porong whose improvement work was already complete. The area near the Ngrowo junction, about 25 km upstream of Kediri City, had low ground level and so flooding was likely (accordingly this area was utilized as a good natural retarding basin). The areas upstream of Kediri City, except for the area mentioned above, had high ground levels with almost no flooding experiences whereas those downstream of the city were equipped with embankment but as it was not high enough, they sustained flood damage every year. Considering this situation, planned flood discharges for the three sections were set as shown in Table 2-17.

The enhancement in channel capacity was achieved by creating a planned section after increasing the embankment height and dredging riverbeds. For channel section, embankment section, and embankment type, this project adopted those previously adopted in the Porong River Improvement Project. Integrated weirs (rubber dams) were planned at two places to establish an integrated intake system as there were many intake facilities for irrigation water in this project section. (See Reference Material: Specification of Projects.)

Table 2-17 Planned flood discharge

River channel	Current channel capacity (m^3/sec)	Section length (km)	Planned flood discharge (m^3/sec)
Kediri City - Konto Junction	620	43	900
Konto Junction - Widas Junction	820	7	1,100
Widas Junction - New Lengkong Dam	1,250	40	1,500

Remarks: 1) All current channel capacity figures are the minimum amounts.
2) Channel capacity in the vicinity of the Widas River junction, 280-500 m^3/sec, is excluded from the table above since it serves as a retarding basin.

Ngrowo River

The Middle Reach River Improvement Project included a flood control plan for the Ngrowo River with a basin area of 1,500 km^2, the largest tributary of the Brantas. The Ngasinan River covering the 424 km^2 basin upstream of the Ngrowo was the first in the Brantas Project to be subjected to development work. This work allowed the flood waters in the river to be discharged through the Nejama Diversion Tunnel into the Indian Ocean. The areas along the banks of the Ngrowo and its tributaries were liable to flooding due to their raised riverbeds. Among other areas, drainage was poor in the outskirts of Tulungagung City situated to the right bank 7 km upstream of the Ngrowo river mouth. After considering several ideas for drainage improvement, a proposal was made to provide a collecting channel around the mountains as an effective means of preventing flood water from flowing into the swamp surrounding the city. This was intended to cause the flood water from the branches to be discharged directly into the Brantas main stream.

Surabaya River

The Surabaya River Improvement Project was formulated separately from the second master plan in January 1975. Surabaya with a basin area of 631 km^2 is to head water from the Brantas to Surabaya City for household, industrial, and irrigation use. Floods generated in the Brantas main stream were discharged into the Porong in the rainy season, hence floods occurred only in the limited area of 631 km^2 originating from the branch, Marmoyo, with a small flood flow of 400 m^3/sec (50-year probable flood rate). This meant that the current channel capacity was enough to allow flood waters to run down to the mouth safely. Consequently, improvement work for the Surabaya River was mainly directed at constructing and rebuilding of dilapidated facilities such as the Gunungsari Dam and the drainage gates at the Mas mouth and the dredging of sediment on the Mas riverbeds around Surabaya City (cleaning of river channel).

This project has been continuously implemented since then and work was under way to enable storm water in Surabaya City to be drained into the Mas as of 1995.

Widas River

The Widas is the second largest branch in the Brantas Basin with a 1,538 km^2 basin area. It had poor channel capacity which frequently caused floods. A great flood in 1979 caused damage to 9,000 ha of paddy fields and villages taking a toll of 20 lives. The second master plan outlined an improvement plan and then the third master plan elaborated on it.

The Widas River originating from the north side of Mt. Wilis travels approximately 30 km north and then is joined by a left bank tributary, the Bening, before running approximately 20 km to the south. It is then joined by the largest right bank tributary in the basin, the Kudungsoko, where it shifts to the east-northeast to flow into the Brantas.

There are three natural retarding basins on the Widas lower reaches. Their storage capacity was set as listed in Table 2-18 and the discharge rate into the Brantas main stream is limited to 270 m^3/sec. The Widas River Improvement Project was designed to be executed independently of projects for the Brantas main stream.

Table 2-18 Storage capacity of retarding basins

Retarding basin	Storage capacity (x 10^3 m^3)	Retaining area (km^2)
Widas retarding basin	13.6	13.2
Kudungsoko retarding basin	5.6	6.5
Ulo retarding basin	4.8	6.3
Total	24.0	26.0

This project was divided into two implementation stages; the overall plan and the emergency plan with planned floods set as 25- and 10-year probable floods, respectively. The following is an outline of this project:

1) Section of channel improvement
   Widas: From its junction with the Brantas to the Ngudikan Dam (42.7 km)
   Kedungsoko: From its junction with the Widas to Badoun Bridge (10.0 km)
   Ulo: Upstream from its junction with the Kudungsoko (17.8 km)
   Kuncir: Upstream from its junction with the Kudungsoko (13.0 km)

2) New waterway
A new flood diversion channel is to be constructed connecting the upper Ulo with the upper Widas to protect Nganjuk from floods.

3) Conversion of natural retarding basins into artificial regulating reservoirs.
The said natural retarding basins are to be converted into reservoirs with the capability of being artificially regulated.

(3) Planning for agriculture and irrigation

(a) Situation of the Basin

Irrigation in the Brantas Basin is divided into 12 areas: Malang, Kepanjen, Blitar, Tulungagung, Kediri, Nganjuk, Jombang, Pare, Mojoagung, Mojokerto, Sidoarjo, and Surabaya.

Of the total 11,800 km^2 Basin area, 727,000 ha was used for agriculture, or 62% of it as of 1961, when the first master plan was elaborated. Of the farming land, 300,000 ha was paddy fields. Irrigation was conducted exclusively for paddy fields. Rice fields along the Brantas main stream were 76,000 ha in area, of which technical irrigation was carried out for 66,300 ha, semi-technical 5,700 ha, and non-technical 4,000 ha. In addition to these paddy fields, there were plantations, orchards, etc., spreading over 46,000 ha at the foot of Mt. Kelud and Mt. Kawi. (Non-technical irrigation areas: the areas that are equipped with such simple water intake facilities as those made of cobbles, gabions, etc. as will drift away in a flood period or become useless in a droughty season.)

The years between 1960 and 1993 saw only an increase of 2,738 ha in irrigated area, making up less than 1% of the total paddy field area in the Basin. Among others, the Surabaya urban area expanding since 1980 led to a considerable decrease in irrigated area in Sidoarjo and Wonokromo. Farming land in the Brantas Basin had already been developed to its maximum extent at that time and the expansion of agricultural land was not expected as much. Trends in irrigated paddy field area in the Basin are shown in Table 2-19.

Table 2-19 Trends in paddy field area

Unit: x 10^3 ha

Region	1961	1970	1975	1980	1985	1990	1993
East Java	—	3,553	3,596	4,176	3,192	3,228	3,205
Brantas Basin	300	314	312	316	317	325	324

In 1961 the situation in the Basin could have been described as follows: 1) There were barrages provided at 18 locations along the Brantas main stream. Although the water level was controlled for water intake by stop logs, it was difficult to control water levels due to the wide fluctuations in the Brantas main stream. In addition, soil carried down by floods accumulated in irrigation canals, forming a bottleneck for water management. 2) 12 mm of water was used daily for the entire 76,000 ha of cultivated land along the Brantas main stream. This was a waste of water as 8-9 mm should have been sufficient. The development of new irrigation areas would have been possible if proper attention had been given to water distribution and use. 3) Cropping pattern in the Basin consisted of a combination of rice (rainy season) and field crops for 250,000 ha; and yearly or rotational planting of sugarcane and field crops for 50,000 ha. 4) The dry season was short of irrigation water, making only 78,000 ha, approximately one third of the total paddy field area, available for use.

The above problems can be said to be ones that the Brantas Basin was destined to have. All the master plans worked out development projects keeping in mind such problems, as well as situational changes taking place in the Basin.

(b) Agriculture and irrigation development planning

The first master plan focussed on the effective use of irrigation water and the improvement of existing irrigation areas. The irrigation areas along the Brantas main stream were all supplied with an excessive amount of water for the land area, for example, Sidoarjo being provided with 5,000 mm (irrigated area: 32,937 ha) and Kertosono with 4,500 mm (irrigated area: 12.937 ha). It was estimated that approximately one third of the Basin's water could be saved and a yield increase of 135,000 tons was expected through the use of this water in other irrigation areas.

Effective use of Karangkates and Selorejo Dams in the dry season would lead to a natural increase in yields, by the amounts of 126,000 tons in irrigation areas and the improvement of existing irrigation areas to 83,300 tons, resulting in a combined increase in rice yields of nearly 210,000 tons. Based on this estimation, the improvement of irrigation facilities in the Basin's largest irrigation area, the Brantas Delta, and the provision and build-up of irrigation facilities and the development of irrigation areas as listed in Table 2-20 including new developments were proposed.

The second master plan worked out a proper water distribution plan for the Brantas main stream in light of the Middle Reach Irrigation Project and city and industrial water demands in the lower areas, especially the Surabaya district. Agricultural planning was then performed based on the second master plan.

Table 2-20 New irrigation projects

Site	Area (ha)	Estimated yield increase (tons/year)
1. Lodoyo	1,200	3,600
2. Ngunut	2,000	6,000
3. Tulungagung	1,800	5,400
4. Kediri	16,000	48,000
5. Widas	9,000	7,700
6. Welirang Utara	35,000	12,600
Total	65,000 (21,000)	83,300

Remarks: Parenthesized figure is for newly developed area.

The unit yield of rice was estimated at 3.4 t/ha for the rainy season harvest and 3.1 t/ha for the dry season harvest, amounting to an annual yield of 1,200,000 tons (stock paddy), approximately 10% of Java Island's entire harvest. The Basin's primary farming products were rice, sugarcane, soybeans, peanuts, and corn. The gross income of a standard farming household in the Basin (ownership of 0.5 ha land) was US$82 for households engaged in rice, field crop planting, US$104 in semiannual rice harvest, and US$111 in rice, sugarcane, field crops.

To increase the income of farming households, the agricultural development planning aimed at 1) the improvement of irrigation facilities in existing irrigation areas totaling 24,800 ha of areas along the middle Brantas main stream; the Warujayeng - Kertosono 13,300 ha, the Turi-Tunggorono 9,600 ha, and the Jatimlerek - Bunder 1,900 ha. Also new irrigation development totaling 48,300 ha close to the Brantas River; Lodoyo - Tulungagung 13,500 ha, Pare - Nganjuk 9,600 ha, and Blitar - Kediri 25,200 ha. The Blitar to Kediri area was not developed until extra water was created in the main stream by rationing efforts of water supply and distribution in the Basin or by groundwater development.

When the third master plan was prepared 578,700 ha of the Brantas Basin area was used for farming including 345,000 ha of paddy fields. At the time the second master plan was formulated (1973) there were only 321,000 km^2 under cultivation, thus we can see there was a rise in paddy field area including non-technical irrigation areas by the time the third master plan was prepared. All usable land, however, had been developed.

As can be seen from the data of 1979 to 1983 rice yield and production increased considerably whereas there was no remarkable increase in secondary crop yields (other than rice). Table 2-21 shows the average crop yields during these four years.

Table 2-21 Crop yields

Crop	Yield (t/ha)	Yield area (10^3 ha)	Average yield (t/ha)	Production (10^3 t)
Rice	3.9-5.8	418	5.39	2,252
Corn	0.6-3.1	228	2.00	457
Soy beans	0.6-1.1	85	0.76	64
Peanuts	0.5-1.2	32	0.76	24
Cassava	4.9-18.4	96	12.20	1,176
Sugarcane	55-97	82	76.00	6,262

At that time the repair and renovation of existing irrigation facilities were under way or was being planned, aiming at an increase in agricultural, especially rice, production. The third master plan laid out the irrigation improvement projects as listed in Table 2-22 for five locations with the cropping intensity below 130%. The aim of these projects were: 1) improve planting rate of existing irrigation areas, 2) preferential development of low-developed areas, 3) effective use of water resources due to repair and renovation of irrigation canals, and the implementation of water resources development, and 4) promote and increase production of rice growing in the rainy season and secondary crops in the dry season.

Table 2-22 Irrigation improvement projects

Project	Irrigation area (ha)	Planting rate (%)
1) Beng Irrigation	3,090	<130
2) Lesti Left Bank Irrigation	2,300	<130
3) Gottan-Losari Area Irrigation	4,240	<130
4) Widas Extension Area	2,280	
Kedungwarak Dam	(980)	<130
Semantok Dam	(1,300)	<130
5) South Widas Irrigation	6,000	<130

Since 1990, dams were operated by Perum Jasa Tirta while irrigation facilities rehabilitation were kept under the Provincial Ministry of Public Work & Energy Office.

(4) Volcanic disaster prevention planning

(a) Mount Kelud eruption and affecting range

Mount Kelud produced 90,000,000-323,000,000 m^3 of ejecta per eruption since 1919 as shown in Table 2-23.

Table 2-23 Ejecta amounts from Mt. Kelud

Unit: x$10^6$$m^3$

Year of eruption	1919	1951	1966	1990	Average
Ejecta amount	323	200	90	125	185

The basin on the right bank of the Brantas River can be roughly divided into two areas: one that is highly affected by Mt. Kelud eruptions and the other, that is less. The former is the south and west sides of the mountain, covering most of the right bank basin between Kaulon and Kertosono. The basin areas 500 m or higher above sea level (with 1/20 or more gradient) consist of about 62 km^2, which was considered appropriate for establishment of debris control facilities. Of this area, 10,000-15,000 ha is estimated to be available for future checkdams. This is equivalent to a pocket capacity of 100,000,000-300,000,000 m^3.

(b) Debris control planning

Mount Kelud debris control falls into two categories: volcanic disaster prevention and normal prevention (for areas not affected by eruptions).

During the 15 years between the 1951 and the 1966 eruptions the outflow of sediment from the affected area into river channels reached 100,000,000 m^3, 70% of which ran down into the Brantas main stream. Based on this situation, a project was established to construct 100,000,000 m^3 worth of pockets on mountainsides with some leeway. The proposal of pocket distribution was 47,000,000 m^3 between Kaulon and Jongbiru, 30,000,000 m^3 between Jongbiru and Kertosono, and 23,000,000 m^3 between Kertosono and Jabon.

After the 1966 eruption, checkdams were constructed on the south and west sides of mountains in the Mt. Kelud Debris Control Project. Pockets for sediment storage of about 45,000,000 m^3 were provided up to 1983, of which 14,500,000 m^3 of sedimentation had already occurred, leaving 30,400,000 m^3 of capacity left. Although no official data was released on the amount of sediment on mountainsides caused by the 1990 eruption, judging from the sediment status in river channels and the fact that the Wlingi Dam Reservoir became filled with sediment, it was assumed there was sediment of 50,000,000 m^3 or so remaining on the mountainsides. It was therefore supposed that the checkdams were nearly filled, and new volcanic disaster prevention plans should be formulated against the next possible eruption.

The Lesti River, a major tributary of the Brantas, originates from Mt. Semeru, and joins the Brantas at Sengguruh. It stretches over 625 km^2 and is located upstream of the Karangkates Dam. The Lesti basin is undergoing surface erosion, allowing a large amount of earth to flow out of its basin, therefore afforestation efforts have been continuing since

1969. Initially sediment flowed into the Karangkates reservoir, however after the completion of the Sengguruh Dam in 1988, it shifted to the Sengguruh reservoir. With Lesti's estimated annual sediment flow rate of 3,000,000 m^3 and the storage capacity of the reservoir being 19,000,000 m^3, the reservoir will be filled in ten years, on the assumption that its catch rate of sediment is 60%. The third master plan proposed the construction of check dams and afforestation for the Lesti Basin.

Sediment in Wlingi reservoir (1990)

(5) Water resources development in the Basin

Water resources development third master plan which was formulated in 1987 is given below. Separately from this master plan, a supplemental irrigation plan by using ground water was formed.

(a) Water quality survey

Water pollution was found in the Surabaya urban area along Surabaya and Mas in the 1982 dry season. Water quality control is critical to this area which has rapidly progressing industrialization and urbanization. This survey dealt with the relationship between flow rate and water quality of the Surabaya and the Brantas main stream, based on the assumption that the flow rates of these rivers was an essential factor affecting water quality.

The Surabaya Public Water Company (PDAM) periodically conducted water quality testing of the Surabaya River at a point of potable water intake at the Jagir Dam. According to the 1982 and 1983 test results (chemical and physical), it was revealed that the Cipta Karya, Surabaya (DGCK) took readings for BOD values, a water pollution index, eight times during the 1982 dry season along Surabaya and the Brantas main stream. These results also showed an annual fluctuation of ammonia , dissolved oxygen, nitrogen, and manganese values (Dec. 1982 - Nov. 1983). All values, excluding that for ammonia (NH_3), did not always decline even with the increased flow rate in the rainy season. Ammonia values varied to a great extent during the dry season, May through November.

Regarding the correlation between water quality at the Gunungsari Dam and the flow rate at Jabon and Mlirip, an obvious increase in ammonia was found with a flow rate of 40 m^3/sec or lower at Jabon, and 15 m^3/sec or lower at Mlirip. BOD values were at 6.1 mg/liter at Peroring and 2.5 mg/liter at Gunungsari with a flow rate of 13 m^3/sec or higher in the Surabaya and 41 m^3/sec or higher in the Brantas (see Attachment Relationship between water quality and flow rate). Since then, this water quality survey has been conducted regularly.

(b) Domestic and industrial water

Water demands are on the sharp increase especially in the urban areas of Surabaya. Droughty water discharge of the Brantas is, however, almost completely utilized even though the multipurpose dams of Karangkates, Selorejo, and Wlingi were constructed. The 1982 drought resulted in a restricted and deteriorated water quality for Surabaya City.

Needless to say, a stable water supply is indispensable to the Basin residents. To predict future household water demands, taken into consideration was the unit demand increase often associated with population growth, urbanization, and a rise in income. Basin population forecasts totalled 14,250,000 in 1990 and 17,552,500 by the year 2000.

The domestic water demands for the basin in 2000 were estimated at 914,000 m^3/day in the Surabaya urban area; 159,000 m^3/day in other cities; 128,000 m^3/day in city areas of every municipal/regency and 396,000 m^3/day in regional areas.

Industrial water is taken at 6 m^3/sec from the Brantas main stream and branches. Industrial water demand in 2000 (including commercial and infrastructural use water) is estimated to be 8.86 m^3/sec in Surabaya and 1.07 m^3/sec in other areas, however there is almost no droughty water discharge left to spare and the Provincial Water Resources Services has no plans for further distribution to industrial uses.

(c) Fish Culture

The coastal areas on the Brantas lowest reaches are actively used for fish breeding; for example milkfish, shrimp/prawns/lobsters, and crabs. Sidoarjo especially, having a 13,000 ha brackish water fishery, was estimated at needing a flow rate of not less than 13.5 m^3/sec for its improvement.

(d) Total water demand and usable water volume

Once river water is taken in downstream from Jabon or downstream of Surabaya from Perning, it eliminates the possibility to use the return flow in areas further downstream of them. To obtain the usable water volume in the dry season June to November, for a droughty year, the combined flow rate between Jabon and Perning is treated as the usable water volume of the Brantas River as shown in Table 2-24.

Table 2-24 Available water volume in drought year

Unit: 10^6 m^3

Drought frequency	Water volume
Approximately twice in 20 years	833.5
Approximately 4 times in 20 years	867.1
Approximately 10 times in 20 years	1,251.7

As indicated in Table 2-25, predictions for the total dry season water volume demands for the area between Jabon and Perning would be 1,871 x 10^6 m^3, by the year 2000 (see Table 2-26).

From the above data it can be determined that as of 2000 the total dry season water demand will surpass the usable water volume (in an ordinary year). This will cause water shortages, accordingly calling for new water source development.

Table 2-25 Estimated total water demand

Unit: 10^6 m^3/year

Year	1985	1990	2000	2010	2020
Water demand totals	1,308.2	1,680.6	1,870.2	2,114.7	2,507.7

Table 2-26 Total estimated dry season water demand (as of 2000)

Unit: 10^6 m^3

	Water demand by section	Total water demand
(1) Domestic water	345.5	345.5
(2) Maintenance water	237.3	582.7
(3) Irrigation water (with intake rights)	636.5	1,219.2
(4) Industrial water (with approval)	80.0	1,299.2
(5) Future irrigation water	271.1	1,570.3
(6) Future industrial water	74.3	1,644.6
(7) Rice growing in dry season (without intake rights)	47.4	1,692.0
(8) Fishery	179.0	1,871.0

(e) Water source development

The Brantas Basin has no sites left for large-scale dams but has many sites for medium-scale reservoir dams. Table 2-27 shows highly economic dam points that were selected as an effective means to help eliminate expected water shortages in the future. Plans were eventually made for these points as construction sites for multi-purpose dams equipped with hydroelectric power stations.

Table 2-27 Planned dam sites

Unit: 10^6 m^3

Dam	Active storage capacity	Embankment volume
Genteng I	70	3.0
Konto II	63.3	9.3
Kedungwarak	54	0.2
Beng	150	0.5
Babadan	85	8.3
Kuncir	22.5	6.9
Semantok	40	5.3

Separate from the water source development in the master plan, IBRD (World Bank) conducted groundwater surveys for the stabilization of rice planting through groundwater irrigation during the rainy season and for the increase in crops by means of double or triple planting. The surveys under phases I and II covered the Madiun area in 1972 and 1982. Survey reports were prepared in 1986 for East Java and a groundwater utilization plan was established for the basin areas rich in groundwater: Blitar, Kediri, Nganjuk, Mojokerto, and Sidoarjo Irrigation Areas. This plan was to be implemented by boring numerous wells 100-150 m deep, to pump up groundwater at 30-60 liters/sec per well for irrigation use, as outlined in Table 2-28.

Table 2-28 Planned irrigation use of groundwater

Area	Blitar, Kediri, and Nganjuk areas	Mojokerto and Sidoarjo areas
Irrigation area	3,600 ha	2,650 ha
Pumped groundwater	2.4-4.8 m^3/sec	1.8-3.5 m^3/sec

(6) Evaluation and priority

The priority of implementation for the projects developed in the master plans was decided based on economic evaluation by means of the benefits (B) versus construction costs (C) method and the economic internal rate of return (EIRR) method; social conditions were also a consideration. To obtain the EIRR of each project, the evaluation period was set at 50 years and the base year of evaluation was set at the time of completion. The economic feasibility and priority of projects are described below for each master plan.

(a) First master plan projects

The average annual flood damages for the entire Basin were estimated at approximately US$4.0 million (at current values for that time), of which those for the Porong Basin in the lowest reach, approximately US$1.0 million, accounted for a considerable part. The issues addressed by the first master plan were to reduce such flood damage, to supply power to East Java including the Surabaya industrial areas (in accordance with the government policy focusing on further industrialization), and to increase food production.

Highest-priority projects were selected from each sector to meet the prevailing social requirements. They included the multi-purpose dam projects of Karangkates and Kali Konto (to also provide droughty water discharge supplement to an existing 29,000 kW power station); flood protection projects of the Porong River Improvement and the Lengkong Dam Reconstruction; irrigation facilities improvement project for the Brantas Delta, the largest irrigation area in the basin; and Mt. Kelud debris control.

The projects listed above were treated as a series of inter-related projects, priority for commencement of work was determined as listed in Table 2-29.

Table 2-29 First master plan projects

Project	B/C	Priority
1) Karangkates Dam 2) Selorejo Dam	(0.82 Cent/kWh)*	1
3) Porong River Improvement 4) Lengkong Dam	1.96	3
5) Brantas Delta Irrigation	—	2
6) Debris Control Project	—	To be continued
7) Wlingi Dam	—	Next phase
8) Lodoyo Irrigation	—	Next phase
9) Lodoyo Debris Discharge	—	Next phase

Remarks: 1) Projects 7), 8), 9) are to be reviewed in the next phase.
2) Asterisked figure refers to electricity prices at that time.

Also listed in the table are the projects of the Wlingi Dam and Lodoyo Irrigation using water conveyed from the Wlingi reservoir. It was decided that these projects were to be reviewed in the next phase because they use water discharged from the Karangkates Dam. The Lodoyo Debris Discharge Project was also on the list of projects to be reviewed in the next phase. This project was to discharge, along with flood waters, sediment flowing into river channels, after Mt. Kelud eruptions, from the Wlingi Dam through a tunnel into the Indian Ocean .

Later, in 1965, Nippon Koei conducted an experiment using a large-scale hydraulic model on the site for the Lodoyo Debris Discharge Project (the experiment reports were highly regarded by Indonesian universities and still appear in local universities' civil engineering faculties textbooks as a good example of hydraulic experiments). The experiment results indicated the economic difficulty of allowing the sediment which has once accumulated in a reservoir to be discharged with flood water into a drainage canal. This consequently postponed the project. It was in the third master plan that the project was carefully reconsidered as part of a flood protection plan (discharge rate: 600 m^3/sec) to the extent that cost effectiveness was sufficiently assured. However it was concluded that the project was not to be carried out at that time since the river channel had higher flow capacities than other local rivers. Later, after changes in the basin including the 1990 eruption of Mt. Kelud, which caused a large amount of sediment to flow into the Wlingi Dam and temporarily fill the reservoir (it also serves as a checkdam), a general feeling of reconsidering the project has been growing.

(b) Second master plan projects

This master plan examined the economic feasibility of all the planned projects and determined their precedence as shown in Table 2-30.

The direct flood damages on an annual average was estimated at US$4.6 million for the Brantas shoreside from the Ngrowo junction to Terusan, thus judging the economic feasibility of the Middle Reach River Improvement Project to be high.

Of agricultural development projects, development of the Lodoyo-Tulungagung area was given top priority. The project plan called for irrigation water to be taken from the Wlingi reservoir. It was therefore judged desirable to execute the Wlingi Multi-purpose Project and the Lodoyo-Tulungagung agricultural development simultaneously for faster realization of benefits from both projects. The Wlingi Multi-purpose Dam was intended for power generation, re-regulating (reservoir), irrigation, flood control, and volcanic disaster prevention, and the combined internal rate of return (EIRR) of the two projects was estimated to be high at 15.5% with high economic feasibility.

Table 2-30 Second master plan projects

	Project	EIRR	Precedence
1)	Wlingi Multi-purpose Dam	} 15.5	} 1
2)	Lodoyo-Tulungagung Agricultural Development		
3)	Middle Reach River Improvement	15.7	2
4)	Pare-Nganjuk Agricultural Development	12.3	3
5)	Ngrowo Shoreside Flood Control	5.1	4
6)	Blitar-Kediri Agricultural Development	9.0	5

Other projects subjected to economic evaluation based on the EIRR method were the agricultural development projects on the shorelines of the big three tributaries, Widas, Beng, and Ngasinan. This resulted in a high internal rate of return, in the range of 12-15%. However the calculation process of the EIRR contained various uncertain factors and so it arrived at the judgement that a fair evaluation of these projects toward the previously stated ones required alternatives to dam sites, benefit calculations, and other surveys. These projects were under reconsideration until the third master plan.

(c) Third master plan projects

With the major projects of the Brantas main stream completed for the most part, the third master plan focused on balanced development among regions. Projects formed in this plan were evaluated for economy and precedence by sector, such as water resources development, agricultural and irrigation development (see Tables 2-31 and 2-32). The economic evaluation of the dam and hydroelectric power developments was made in a comprehensive manner treating them as the same project for water resources development.

Table 2-31 Dam and hydroelectric power development

Dam	Active storage capacity ($\times 10^3$ m^3)	Embankment volume (10^3 m^3)	Installed capacity of power generation (kW)	EIRR (%)	Precedence
1) Genteng I	70	3	12,000	12.4	2
2) Konto II	63.3	9.3	62,000	12.7	1
3) Kedungwarak	54	0.2	—	5.3	4
4) Beng	150	0.5	18.6	16.6	3

Table 2-32 Agricultural and irrigation development

	Project	EIRR (%)	Precedence
1)	Beng Irrigation	23	1
2)	Lesti Left Bank Irrigation	18	2
3)	Gottan-Losari Area Irrigation	13	3
4)	Widas Extension Area		
	Kedungwarak Dam	11	4
	Semantok Dam	0.5	5
5)	South Widas Irrigation	4	6

As a result, it was found possible to draw up highly economic multiple projects with EIRR exceeding 10% for both sectors.

In addition, this master plan recommended the introduction of an integrated water management system for the entire Basin for efficient and effective use of limited water in the dry season and for assured safety against floods in the rainy season. The flood forecast and warning system for the middle reaches was established in the Middle Reaches River Improvement Project and the all-Basin water management system was implemented after reconsideration of both software and hardware.