REPUBLIC OF INDONESIA

REPORT
ON
BRANTAS RIVER BASIN DEVELOPMENT

(MAIN REPORT)

JULY 1972

PREPARED FOR

OVERSEAS TECHNICAL COOPERATION AGENCY

GOVERNMENT OF JAPAN

BY

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TOKYO, JAPAN

PREFACE

The Government of Japan, in response to the request of the Government of Indonesia, agreed to undertake a survey on the river flow and the present condition of the Brantas River Basin which is necessary for the water resources development and entrusted the execution of the survey to the Overseas Technical Cooperation Agency.

The Agency made a contract for the survey with Nippon Koei Co., Ltd. and dispatched a team comprising eight experts, headed by Mr. Kazuo Hosoda, Managing Director of Water Resources Development Corporation, to the Republic of Indonesia over a period from August to November 1971.

Meanwhile, the Agency established the Inspection Committee comprising six experts, headed by Mr. Akira Miyazaki, Director, River Planning Division, the Ministry of Construction, and entrusted it to examine the result of the survey and to advise accordingly.

The survey team conducted field investigation in close cooperation with the Indonesian authorities concerned. After its return to Japan, the team made various studies and analyses of the data with the advice of the Inspection Committee. As a result, the final report has been completed and is hereby ready for submission to the Government of the Republic of Indonesia.

I sincerely hope that this report will contribute to the planning for the further development of water resources in the Brantas River Basin and will serve to promote friendly relations between Indonesia and Japan.

In closing, I wish to express my heartfelt gratitude to the authorities concerned of the Republic of Indonesia, Embassy of Japan in Djakarta, Ministry of Foreign Affair, Ministry of Construction and Ministry of Agriculture and Forestry for their kind assistance and cooperation for the execution of this enterprise.

July, 1972

Keiichi Tatsuke,
Director General,
Overseas Technical Cooperation
Agency, Tokyo, Japan

LETTER OF TRANSMITTAL

Mr. Keiichi Tatsuke
Director General
Overseas Technical Cooperation Agency
Tokyo, Japan

Dear Sir,

Submitted herewith is the report on the results of the surveys necessary for the water resources development in the Brantas River Basin, East Java, the Republic of Indonesia in compliance with your request.

The Brantas River Basin has been developed as a granary in Java since long before using its land and water resources. However, Mt. Kelut, an active volcano located in the center of the basin, erupts at an interval of 15 to 30 years and produces a huge amount of volcanic materials in each eruption. The present river bed of the Brantas is heavily silted up due to the deposit of these volcanic materials and the levees in the middle reaches are now endangered of overtopping of floods.

Out of the total basin area of 1,180,000 hectares about 60 percent is occupied by the farmlands. The total irrigated areas depending on both the main stream and its tributaries are about 320,000 hectares. The existing irrigation facilities were constructed before the World War II and mostly deteriorated at present. Thus the farmers in the basin face much difficulties on the proper water distribution and operation, resulting in very low cropping intensity in the dry season.

Surabaja, the second largest sea port next to Tandjung Priok (Djakarta), has prospered as a commercial and industrial center in East Java. However, severe shortage of the municipal water supply in Surabaja is recently caused by the conspicuous concentration of the population. Water pollution caused by the shortage of water supply and sewerage capacity in Surabaja now threatens not only the public health but also constraints further industrial development.

Much efforts have been paid by the Indonesian Government for the realization of various flood control and water utilization projects in recent years to cope with the above-mentioned situations. However, the eruption of Mt. Kelut in 1966 changed the conditions of the Brantas River further worse. Thus, to-date study is further necessitated for the planning of the water resources development taking into account the effects of the recent eruption. For this purpose, it was urgently needed to make clear the problems for the planning of river training and water utilization by collecting and analyzing the available data of the river discharges.

To attain the above purpose, the survey team conducted the field investigation over a period from August to November 1971 with the advices of the Inspection Committee. After its return to Tokyo, the team made various studies and analyses of the data collected. As a result, the report with due recommendations on the analyses of the basic data necessary for the planning of water resources development has been completed and is herewith submitted to the Agency. In the course of compilation of the report, all the studies and analyses are examined and reviewed by the Inspection Committee.

It is wished to expresss sincere appreciation and gratitude to the Government officials of Indonesia and the authorities concerned for their generous assistance and cooperation in performing the field surveys.

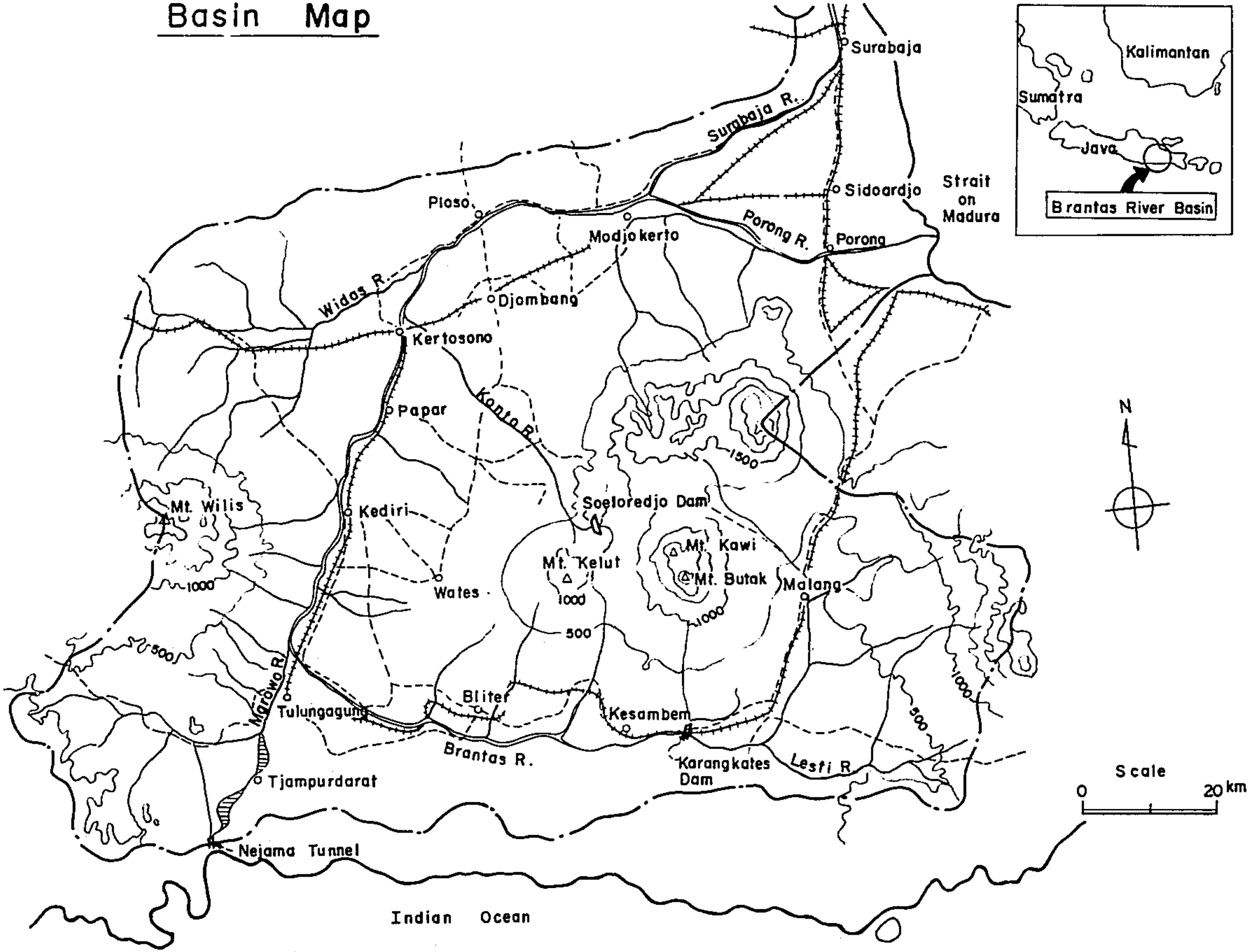
It is our sincere hope that the detailed planning of the water resources development will be promoted as soon as possible, based on the suggestions presented in this report.

July, 1972

Y. Kubota

Yutaka Kubota
President
Nippon Koei Co., Ltd.
Tokyo, Japan

Basin Map



Surabaja
Sidoardjo
Porong
Strait on Madura
Kalimantan
Sumatra
Java
Brantas River Basin
Surabaja R.
Porong R.
Ploso
Modjokerto
Djombang
Widas R.
Kertosono
Papar
Konto R.
Kediri
Wates
Mt. Wilis
Soeloredjo Dam
Mt. Kelut
Mt. Kawi
Mt. Butak
Malang
1500
1000
500
Marowo R.
Tulungagung
Bliter
Kesambem
Brantas R.
Karangkates Dam
Lesti R.
Tjampurdarat
Nejama Tunnel
Indian Ocean
N
Scale
0
20 km

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4. CRITERIA FOR DEVELOPMENT

1. SUMMARY AND RECOMMENDATION

1-1 Socio-Economic Conditions for Development and Problems

The Brantas River Basin, blessed with favorable natural conditions such as land and water resources as well as the tropical climate, has been developed as the granary of Java. Aside from this, various industries have been recently developed around Surabaja city using its favourable situation. This is attributable to not only the above available resources but also the favourable transportation conditions, such as the well developed railway, highway link with Middle Java, the second largest sea port located in a center of inter-insular trade among Java, Kalimantan, Sulawesi and other islands, etc.

However, the labor force engaged in industries is still small as about eight percent in the East Java's total, compared with 70 percent engaged in agriculture. The total production of the milled rice in the basin in 1971 is about 600,000 tons accounting for about five percent in the country's total. The basin produces about 230,000 tons of sugar annually. It occupies about 30 percent of the total sugar production in Indonesia.

Out of about 12,000 square kilometers of the Brantas river basin, the total farmland occupies 730,000 hectares being about 60 percent of the basin area. The remaining areas are mostly occupied by mountain slopes where the lands are not so suitable for irrigation farming due to the topography and soils as well as less availability of water. These unfavourable conditions limit further reclamation of the lands into farmlands. Aside from this, it is not advisable to reclaim the forest from the viewpoints of the land and soil conservation as well as the water sources conservation.

The population density in the basin is as high as about 850 persons per square kilometer. It naturally limits the average holding size of farmlands as small as about 0.7 hectares per farming family. There are substantial surplus labor force in the rural areas to be available for industries to be developed in future. However, such unemployment or underemployment now being absorbed in agriculture has to be mitigated by intensification of crop farming for the time being until future industrial development could absorb them. Thus, special attention should be paid for the increase of crop yield to raise the living standard and to stabilize the farm economy. Future crop diversification will also have to be studied to improve the diet of the people from depending on the present starchy foods to protein and vegetable fat.

Among about 730,000 hectares of the farmlands in this basin, the paddy area occupies 321,000 hectares. The irrigation areas depending on the Brantas main stream are about 77,000 hectares. The river water used for municipal water supply and pollution control is so little yet. Much more effective utilization of the water has to be planned under a well-balanced allocation and distribution of the available river discharge.

To plan the most optimum use of water resources, the first study shall be directed to know the correct river discharges available including flood discharges. As for the flood problems in Brantas, a special attention shall be paid to the effects of eruption of Mt. Kelut on the river bed raising. At present the flood carrying capacity of the middle reaches of Brantas has been much reduced by silting. Especially, the flood carrying capacity near Kediri corresponds to 5 - 10-year return period of flood peak discharge.

The present peak flood discharge is reduced by retardation in Pakel-Kediri stretch and the swamp storage at the confluence of Widas River. To solve these flood problems, various measures shall be comprehensively studied in relation with the erosion control, flood control by reservoirs, heightening of levees or the reinforcement and enlargement of the river channel.

This studies made in 1971, therefore, placed an emphasis on survey and analysis for the river discharge of the Brantas main stream and its tributaries as a fundamental information for the basis of future planning.

However, the results of river discharge analysis clarified that the river discharge data recorded during 1951-1970 period contain some errors and discrepancies. Thus more detailed check survey will be needed for the planning of water utilization schemes.

1-2 River Flow Analysis

Among the river discharge data collected at 18 gauges in the Brantas main stream and its tributaries, the daily discharge records at eight gauges along the main stream during 1951-1970 period are analyzed. The river flow analysis revealed that the 1964-1970 records at Djombiru and Kertosono gauges had much discrepancies. Such records were tentatively corrected based on the correlations among the discharges at the said gauges and Djabon gauge during 1951-1963 period.

The effects of the Karangkates and Soeloredjo reservoirs were studied. Average discharge increased by the regulation of the reservoirs during the dry season from May to October is estimated to be 13.5 cubic meters per second at the Karangkates damsite and 1.7 cubic meters per second at the Soeloredjo damsite respectively.

The flood characteristics in the Brantas River was investigated to obtain necessary data for planning purposes. Data used are the hourly water level records. The effects of the flood regulation by the reservoirs are mentioned in Section 1-4.

1-3 Sedimentation and Its Control

Mt. Kelut, located at the center of the Brantas River Basin, is an active volcano and erupts at a cycle period of 15 - 30 years. The volcanic materials produced by an eruption are estimated to be the order of 100 million to 200 million cubic meters. When much water is reserved in the crater lake the eruption causes a hot mud flow rushing down on the mountain slope destructing everything including forests, farms, roads, houses, etc. on its course. This is called the "primary lahar". Besides, the river bed of the Brantas has been largely affected by heavy silting due to efflux of volcanic sand and silt from the mountain slopes of Mt. Kelut. The rise of river bed of the Brantas during 1951-1970 period was about 1.5 meters on an average. This silting on river bed is especially remarkable for several years after an eruption. The critical situation of the river channel in the middle and downstream stretches has arisen mainly from the silting.

The records of the river bed elevation measured at 22 sites in the stretch of the Brantas and Porong Rivers during 1951-1970 and the data of the debris control works on the slopes of Mt. Kelut were collected in this investigation. Based on these, the studies were made for the sediment yield from the mountain slopes, the forecast of the future river bed movement and the required capacity of lahar pocket for future probable eruption.

The studies revealed that the annual sediment transporting capacity of the Brantas River is approximately 5 - 5.5 million cubic meters on an average. The total sediment yield from the slopes of Mt. Kelut during 1951-1970 was estimated to be 128 million cubic meters. The study on future probable river bed movement after 1970 suggests that the river bed deposit in the investigated river stretch as a whole will neither increase nor decrease in the 1971-1980 period. It is also estimated that the total capacity of 100 million cubic meters of the lahar pocket is necessary for protection of the Brantas River if next eruption occurs on the same scale as the 1951's.

The study of the sedimentation analysis has certain limitation because of the scarce data available. For the planning of the detailed river improvement in connection with the sediment control problem, the measurement of the sediment load in the Brantas River and tributaries around the slopes of Mt. Kelut should be continuously carried out throughout a year.

1-4 Flood Discharge and Its Distribution

The flood characteristics in the Brantas River was analyzed by use of hourly water level records at four gauges along the middle reaches of the main stream.

The flood analysis revealed that the flood peak in the Brantas River is largely reduced by the inundation over the lands along Pakel-Kediri stretch and the retardation in the swamp at the confluence of Widas. The cut of peak flood in these two stretches is estimated to be 150 - 300 cubic meters per second for Pakel-Kediri stretch and that in Kediri - Terusan stretch is assumed to be 300 - 400 cubic meters per second. However, detailed survey in the retardation effects in connection with the flood in the tributaries is necessary for the solution of the flood problems.

A part of flood discharge in the downstream reaches is diverted to the Marumojo River through the existing Gedek gate located at five kilometers upstream from Terusan gauge. The maximum flood discharge diverted through the gate is estimated to be 80 cubic meters per second at the flood peak time.

The flood carrying capacity in the Brantas River was estimated based on the results of river profile and cross section survey. The comparison of the discharging capacity estimated and the probable flood peak discharges calculated at the existing gauges shows that the discharge capacity near Kediri for the water surface just coinciding the levee top corresponds to a flood peak of 5 - 10 -year return period.

A flood discharge distribution plan was proposed based on the result of the flood analysis. Its basic principles are as follows:

(i) The plan is formulated against the flood peak of 50-years recurrence taking into consideration the regulation by the Karangkates reservoir.

(ii) The flood retardation near the Ngrowo mouth and the Widas mouth are tentatively left as they are now.

(iii) The Gedek and Mlirip gates will be closed off to protect the urban area of Surabaja. No flood discharge will be diverted through both the gates.

The proposed design flood discharges in the main stream calculated based on the above principles are as follows:

(i) Stretch between the Ngrowo mouth and Kediri: 1,200 - 900 m^3/sec

(ii) Stretch between Kediri and the Konto mouth: 900 m^3/sec

(iii) Stretch between the Konto mouth and the Widas mouth: 1,100 m^3/sec

(iv) Stretch between the Widas mouth and Terusan: 1,500 m^3/sec

1-5 River Improvement Planning in the Middle Reaches

The river improvement planning to pass safely the above-mentioned design flood discharges through the river channel is studied. The plan involves the dredging volume of 15 million cubic meters and the levee embankment volume of seven million cubic meters. The total construction cost is estimated to be about 26 million US dollars equivalent. The construction of this scheme will require a period of more than ten years.

For the purpose of saving the initial capital cost and time for construction, it is proposed to initiate the construction with first stage in which the flood carrying capacity of the river channel shall be increased against ten-year recurrence flood. The earth works required for the first stage will be about eight million cubic meters less than the overall plan. The total construction cost required will be about 17 million US dollars equivalent.

An alternative plan for the flood control in the main stream was reviwed. This is a flood diversion scheme at the upstream reaches of the Brantas River to the Indian Ocean by constructing a gated weir near Pakel gauge with a 30 kilometer long open canal and tunnel. The total construction cost will be about 40 million US dollars. It seems not so feasible because of a higher construction cost, but some merits as mentioned in "Technical Study Report" will be contemplated.

In the upstream rechaes, there are no promising damsites suitable for creating considerably large reservoirs to attain effective flood regulation.

1-6 Flood Control Planning of the Tributaries

Among the main tributaries joining with the Brantas in the middle and downstream reaches, the flood of the Konto River will be controlled by the regulation of the Soeloredjo reservoir under construction except some inundation at the lowest reaches due to shortage of drainage capacity.

In the Ngrowo River Basin, the lowland near Tulungagung city suffers from inundation. The possible solutions contemplated for this flood problem are as follow.

(i) The plan to ristrict the inundation area by providing an artificial retardation basin surrounded by embankment.

(ii) The plan to divert flood peak of the Song, Klantur and Babakan Rivers into the Brantas River by constructing a ten-kilometer-long short cut canal.

(iii) The plan to divert flood peak of the tributaries into the Indian Ocean by effective use of the existing Nejama tunnel and by enlarging the existing short cut canal and adding some new canals or dredging.

Among them, the best plan should be decided by the economic evaluation based on the further detailed topographic and river cross section surveys as well as the measurement of hourly water levels at the existing and new gauges to be added.

A rough idea to regulate the flood peak discharge by providing the reservoir in the upper reaches of the Widas River has been contemplated on a reconnaissance level. However, the control of the flood by this reservoir will be not so effective for the swamp at the Widas mouth because of small catchment area at the proposed damsite. The existing retardation swamps at Widas confluence and Ngrowo confluence shall be carefully studied regarding their functions in relation with the flood in the main stream. If some retardation area should be saved from flooding, other measures substituting the existing flood regulation function by the swamps shall be carefully studied.

1-7 Planning of Water Utilization

There exist many irrigation facilities constructed before the World War II in the Brantas River Basin. In addition, the Karangkates and Soeloredjo dam projects are under construction at present. Furthermore, the investigations for the irrigation project in the delta area, water supply project in Surabaja city and Lahor and Wlingi dam projects with main purpose of power generation are being carried out in the basin.

The Government of Indonesia plans to construct the Lahor dam on the upper reaches of the Lahor River. This plan contemplates to increase the discharge for power generation and irrigation uses through a tunnel connected the Karangkates and Lahor reservoirs. Average discharge increased by this project is estimated to be two cubic meters per second in the dry season.

The feasibility report of the Wlingi dam project prepared by the Government is technically reviewed based on the results of the sediment and hydrological analyses. Consequently, it is concluded that the estimate of the sediment load from the Putih and Semut Rivers and the discharge records used in the said report are reasonable. In this project, it is contemplated to control the flood and sediment by the reservoir. These control effects should be studied in connection with the river improvement planning in the middle reaches.

1-8 Recommendations

(1) Reinforcement of the hydrological measurement

The water level and discharge records of the existing gauges were collected and evaluated in this investigation. However, these records involve some discrepancies. Thus, it is recommended to check the discrepancies and to advise an improvement of measuring method of river discharge in the next investigation.

In the Brantas River Basin, there are some discharge gauges in the tributaries. Reinforcement of the gauge network is necessary for the future planning of flood control and water utilization development in the tribularies.

(2) Measurement of sediment load

The measurement data of sediment load in the river are so scarce to assess the silting quantity despite the special importance for planning. Thus, the measurement of the sediment load, especially in the high water season should be carried out with proper measurement equipment.

(3) Recommendation for flood control problem

(i) More detailed investigation and planning for the debris control around the slopes of Mt. Kelut are necessary not only for preventing the silting of the Brantas River but also protect the outskirts of the mountain slope.

(ii) Planning of river improvement in the middle reaches is necessary. Especially, it is advisable to plan the river improvement in few stages according to the priority.

(iii) Preliminary investigation is necessary for the flood control planning in the tributaries of the Ngrowo, the Widas and Konto Rivers in connection with the flood problem in the main stream.

(4) Recommendation for water utilization

(i) No suitable damsites are conceivable along the downstream reaches below Wlingi and also even in the upstream reaches there are almost no possibilities to create considerably large reservoir to regulate flood and seasonal flows. Several additional dams in small scale can be constructed mainly for irrigation and hydropower generation. However, those dams would not increase so much discharges in the dry season. Thus, it is advisable that the dam projects in the upper reaches will have to be developed under a well-balanced combination of hydro and thermal power generation.

(ii) Water utilization for irrigation

To improve the present unstable water supply for irrigation, it is necessary not only to improve the irrigation facilities but also to reinforce the water management with proper control of water distribution. For the effective utilization of water and land resources, more detailed survey will have to be carried out to find the best allocation of available water for irrigation and other uses, such as municipal water supply, industrial water and sewerage, etc. In field of agriculture, agro-economic survey, irrigation water requirement survey and agronomic survey shall be carried out in future.

(iii) Possibility of ground water utilization

The investigation of the ground water is being carried out in some places in the Brantas River Basin. For the irrigation projects in higher elevation around the mountain slopes it is recommended to carry out groundwater survey in future.

2. INTRODUCTION

2-1 Present Status of the Brantas River Basin

The Brantas is the second-largest river in Java. The total length of the main stream of about 320 kilometers covers its catchment area of 12,000 square kilometers which corresponds to about one quarter of 48,000 square kilometers of the Province of East Java. The basin is densely populated with about ten million in 1971 accounting for 36 percent of about 28 million in East Java Province.

Surabaja, the second-largest port city in Indonesia, is located at the delta of Surabaja River. The Surabaja having the population of more than 1.4 million has prospered as a center of administration, transportation and inter-insular trade. There are also some industrial zones around the Surabaja city. The total amount of the cargoes in inter-insular trade is about 1.5 million tons per annum.

The major industry in the basin is agriculture and about 70 percent of the population in the basin is engaged in agriculture. The total farmland in the basin amounts to about 730,000 hectares which occupy about 60 percent of the basin area. The total area of uplands, estates and orchards amounts to 409,000 hectares which mostly occupy the outskirts of mountain slopes of Mt. Wilis in the west, Mt. Ardjuno in the east and Mt. Kelut in the center of the basin. There are 321,000 hectares of paddy lands which corresponds to 44 percent of the farmland. The paddy fields are located mostly along the Brantas River and its tributaries where lands are flat and mostly irrigated. The irrigation areas depending on the Brantas main stream are 77,000 hectares.

The agricultural product in the basin comprises mainly rice, cassava, soybean and maize. The prevailing crops are paddy in the rainy season, and cassava, soybean and maize in dry season. Paddy is grown even in the dry season in some areas where water is available.

The Brantas River Basin had been a major sugar-producing area before the World War II. However, the insufficiency of foods and the deterioration of sugar factories caused by the great confusion during and after the World War II resulted the decrease of the sugar product. The total annual production of sugar cane is still as much as about 2.4 million tons at present.

The Brantas River Basin lies 7^{o} - 8^{o} south latitude and there are very little variation in air temperature throughout a year. The annual rainfall in the basin is about 2,000 millimeters of which about 80 percent occurs in the rainy season from November to April. The soils in the basin are generally fertile because of volcanic deposit of Mt. Kelut. The agricultural products will be largely increased when the water of the Brantas is effectively utilized with proper water control.

However, the large variation of river discharge in the rainy and dry seasons makes it very difficult to supply dependable irrigation water. The most of the existing irrigation projects along the main stream have not any barrages to control intake water levels because of wide river and large floods which make the cost very expensive.

The control of inflow into the irrigation canal is attained by adjusting the stop logs at the intake. Proper adjustment of inflow is difficult due to large variation of the river water level. Thus, the river water in the Brantas main stream is not always effectively utilized in the dry season.

The existing irrigation facilities are largely deteriorated and the irrigation water is not properly distributed. This is attributable to incomplete facilities, insufficient maintenance and water management. One of the major difficulties to operate and maintain those facilities is the heavy silting transported in the river water.

Both the Karangkates and Soeloredjo dams are nearly completed and their contributions not only for flood control in the rainy season but also for the increase of discharge in the dry season are expected. Average discharge increased by the regulation of the two reservoirs during the dry season from May to October is estimated to be 13.5 cubic meters per second at Karangkates damsite and 1.7 cubic meters per second at Soeloredjo damsite respectively.

Mt. Kelut (1,731 meters above the mean sea level) is an active volcano located at the center of the Brantas River Basin. It erupts at an interval of 15 to 30 years and produces a huge amount of the volcanic materials.

These "lahar" materials flow down not only into the Brantas main river channel but also into the irrigation canals on the mountain slopes of Mt. Kelut. Special attention should be paid to the canal maintenance by constructing suitable desilting devices at the intakes and providing regular maintenance of canals.

For preventing aggradation of the main stream the measures for flood control, river channel maintenance and debris control will have to be taken comprehensively in the Brantas River Basin.

Many areas habitually suffered from inundation locate in the middle reaches along the main stream, near the confluences of its tributaries, and also there exist the back swamps due to insufficient drainage of lands.

In order to approach the solution for the above problems, fundamental surveys and studies of the survey team were directed to the following main items:

(i) To collect and analyze all the meteorological and hydrological data available including flood discharge analysis.

(ii) To review the past information and reports regarding the water resources development of Brantas River.

(iii) To collect and analyze the sediment data in the basin especially due to the eruption of Mt. Kelut.

(iv) To take into consideration the effects of major projects under way, such as Karangkates and Soeloredjo reservoirs.

(v) To plan the proper design flood peak discharges for the future river improvement.

(vi) To recommend further actions to be taken for approaching the solution of flood control, future planning of water utilization schemes and their related survey works required.

2-2 Past Data Available for Investigation and Planning

The maps on a scale of 1:250,000 and 1:50,000 are available all over the Brantas River Basin. In addition, the following reports are used in this investigation and studies as references.

Date issued	Title of report	Author
(1) Sep. 1955	Reconstruction Report on Porong Delta Relief Channel	White Engineering Corporation
(2) Jan. 1958	Preliminary Report on Diversion Tunnel Project at Tulungagung South	Nippon Koei Co., Ltd.
(3) Apr. 1961	Comprehensive Report on Kali Brantas Overall Project	Nippon Koei Co., Ltd.
(4) Sep. 1962	Design Report on Kali Konto Project	Nippon Koei Co., Ltd.
(5) Oct. 1966	Design Report on Kali Porong Project	Nippon Koei Co., Ltd.
(6) May 1969	Feasibility Report on Mt. Kelut Volucanic Debris Control Project	DPUT
(7) 1971	Interim Report on Delta Irrigation Project	OTCA
(8) Dec. 1971	Feasibility Report on Wlingi Project	DPUT
(9) Mar. 1972	Study on Long Range Electric Power Development Program in East Java	OTCA

Besides, the various informations were obtained through the other survey teams for the river improvement of the Surabaja River, city planning of Surabaja and irrigation project in the delta area.

2-3 Present status of Project Implementation

The construction works of the water resources development projects completed or under way are as follows.

	Title of project	Progress
(1)	Diversion Tunnel Project at Tulungagung South	Completed in 1962
(2)	Karangkates Multi-purpose Dam Project	Dam completed in 1971. Power station will be completed in 1973.
(3)	Soeloredjo Multi-purpose Dam Project	Dam completed in 1970. Power station will be completed in 1973.
(4)	Mt. Kelut Volcanic Debris Control Project	Nine of lahar pocket completed. Additional works are under way.
(5)	Kali Porong Project	New Lengkong dam will be completed in 1973.
(6)	Lodjo Irrigation Project	Pumping station and main canal completed.

Among the above works, both the Karangkates and Soeloredjo dams were completed. These two projects will be put into regular operation after impounding water by the middle of 1973.

In Kali Porong Project, new Lengkong dam is being constructed at immediate downstream of the existing dam. After this new dam is completed, the flood discharge in the Brantas River will be easily drained by the electric-driven gate spillway instead of the existing man-power operational stop logs.

Mt. Kelut Volcanic Debris Control Project aims mainly at safeguarding the menaced areas at the mountain slopes of Mt. Kelut and preventing the lahar material from flowing into the Brantas River.

2-4 Scope of Works in the Investigation

The scope of works agreed by the meeting between the Government of Indonesia and Japanese Survey Team held on 25th and 26th August 1971 is as follows:

(i) Collection of data concerning to meteo-hydrology, flood control, sand arresting, present status of the water use and socio-economic conditions.

(ii) Analysis of river flow discharge.

(iii) Study on river bed movement and present irrigation condition.

(iv) Planning of the design flood discharge distribution.

Priority study of the water resources developments in the whole Brantas River Basin will be sequently worked out by the more detailed study in the next stage. The individual project of flood control in Tulungagung area, river improvement in the middle reaches and Wlingi Multi-purpose Dam Project are technically studied in response to the strong request of the Government of Indonesia.

However, the priority of these projects could not be clarified due to insufficient data availalbe, very complicated relationship between each project, but it will be made clear after the detailed survey in the next stage.

2-5 Scope of Report

The results of the investigation and studies were compiled in the following three separate volumes:

(i) Main Report

(ii) Technical Study Report

(iii) Data Book

This volume forms the main report and presents the summary of "Technical Study Report".

The main report comprises four chapters, Chapter 1 presents the summary and recommendations of this investigation. The explained in Chapter 2 are back ground for the performance of the investigation and necessity of the investigation. Chapter 3 gives the present status of the Brantas River Basin with emphasis of the water resources potential and the river bed movement in connection with the Mt. Kelut eruption. Chapter 4 deals with the problems for the flood control and water use, and also the outline of the projects contemplated in the Brantas River Basin.

2-6 Organization of the Japanese Survey Team

In due consideration of the importance of the investigation of the Brantas River Basin, Inspection Committee for this investigation was established in Japan. The members of Inspection Committee are as follows:

Name of member		Duties	Government office attached
(1)	H. Miyazaki	Head of Committee	Ministry of Construction
(2)	H. Kikkawa	Hydrology and sand arresting	Tokyo Institute of Technology
(3)	K. Hosoda	Flood control	Water Resources Development Corporation
(4)	Y. Togano	Hydrology	Ministry of Construction
(5)	S. Okabe	Irrigation and agriculture	Ministry of Agriculture
(6)	H. Nakamura	Hydroelectric power	Ministry of International Trade and Industry

Among the above members, Mr. K. Hosoda and Mr. Y. Togano were dispatched to the site as an advisory team together with the survey team consisting of six members and took the duties of liaison with the Government of Indonesia and advices to the survey team at the site.

The members and their specific duties of the survey team are as follows:

Name of member	Duties
(1) K. Hayashi	Head of survey team
(2) K. Shibata	Irrigation and agriculture
(3) S. Ohnuma	Hydrology and sand arresting
(4) K. Yanagisawa	Socio-economy
(5) K. Onaka	Irrigation
(6) N. Hirose	Hydrology

The survey team and the staff of the Directorate General of Water-Resources Development (Ministry of Public Work & Power) held the meeting about the scope of the works at Djakarta on 25th to 28th, August 1971. In conformity with the scope of works agreed by the meeting, the survey team engaged in the works for the data collection at the site for three months from 30th, August to November 1971. While, the advisory team engaged in the advising and study works for the investigation at the site for about one month from 30th, August to the end of September. After returning to Tokyo, the survey team analyzed the data collected and compiled the reports. On this work, the Inspection Comittee checked and advised the results of the data analyses and planning process in several times.

2-7 Acknowledgement

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3. GENERAL DESCRIPTIONS

3-1 Topography and Geology

(1) Topography

The Brantas River Basin is bounded by Mt. Semeru (3,676 meters high above the sea level) on the east, Mt. Wilis (2,169 meters high above the sea level) on the west, and a series of low hills, 300 to 500 meters high, separating the Brantas Basin from the Indian Ocean on the south. The catchment area is about 12,000 square kilometers.

The Brantas River, originating from the southeastern slope of Mt. Arjuno (3,339 meters high above the sea level), runs around the outskirts of Mt. Butah (2,868 meters high above the sea level) and Mt. Kelut (1,731 meters high above the sea level) and finally empties itself into Java Sea through the Porong and the Surabaja Rivers, branching off near Modjokerto city. Total length of the Brantas River is approximately 320 kilometers.

The average river slope is 1/800 in the upstream stretch of Pakel gauge, 1/1,250 to 1/1,900 in the middle stretch between Pakel and Terusan gauges, and 1/3,000 in the further lower stretch. The major tributaries joining with the Brantas main stream are the Lesti, the Ngrowo, the Konto and the Widas Rivers.

(2) Geology

Java island is formed by a series of volcanic activity of east-west trend, together with a large scale upheaval in Mio-pliocene or later periods. Geology of the island is, therefore, characterized by Eolian and sedimentary formations of Neogene Tertiary and andestic and basaltic rocks of volcanic origin.

Geology of the Brantas River Basin is mostly of Pleistocene of Neogene Tertiary with many volcanic members and sometimes containing coral limestone. Generally, the erupted materials form fertile soil in the hilly areas around Mt. Kelut.

3-2 Meteorological Conditions

The climatic condition in the Brantas River Basin, which is much affected by monsoon, is clearly divided into two seasons, namely, rainy season from November to April and dry season from May to October. The general meteorological conditions throughout a year are explained below:

(1) Temperature

There is very little variation in temperature throughout a year. The average monthly mean temperature recorded during the 1928-1947 period at Malang (445 meters above the sea level) shows that the temperature varies between 22.5°C and 24.5°C and the yearly mean temperature is 23.7°C.

(2) Relative humidity

The humidity in the basin is relatively high. The average monthly humidity recorded during the 1928-1947 period at Malang shows that the relative humidity varies from 74 to 87 percent throughout a year and the yearly mean relative humidity is 82 percent.

(3) Evaporation

The average monthly evaporation recorded during the 1938-1947 period at Malang shows that the annual evaporation is about 700 millimeters. This figure seems too low. According to the data at Pasuruan and Djember the average evaporation amounts to 1110-1150 millimeters.

(4) Rainfall

The daily rainfall is measured at 250 gauges in the Brantas River Basin. Among them, the records of the monthly mean rainfall during the 1951-1970 observed at 52 gauges are compiled in "Data Book".

The isohyetes based on those records show that the annual rainfall is as much as 3,000 to 4,000 millimeters on the southern and western slopes of Mt. Kelut and 1,500 to 2,000 millimeters in the downstream reaches of the Brantas River. The average annual rainfall during 1951-1970 period calculated for about 10,000 square kilometers of the catchment area upstream from Terusan gauge amounts to 2,030 millimeters, of which 80 percent occurs in the rainy season of six months.

The rainfall occurrence in a day is regular in the rainy season. The records of the hourly rainfall observed at Karangkates and Lodojo gauges show that most rainfall usually begins between two o'clock and seven o'clock in the afternoon. The duration time of one continuous rainfall ranges from three hours 15 hours.

3-3 Population

The population in the Brantas River Basin estimated from the data on the population divided by the administrative district is about ten million in 1971 which constitute about 13 percent of the population of Java or eight percent of the country's total. The estimated average population density is 847 persons per square kilometer and the average rate of annual population growth is 1.81 percent during 1961-1971 period.

The population of the basin comprises about eight million in the rural area and two million in the urban area. More than 60 percent of the urban population concentrate in Surabaja city. The population density in the urban area of Surabaja is estimated to be about 7,300 persons per square kilometer. Approximately 70 percent of the population of the basin is engaged in agriculture and the remaining 30 percent in other industries and service business.

As the arable lands suitable for farming are limited an average holding size of farmland per family is as small as 0.7 hectare. Heavy population pressure even in the rural areas tends to migrate to the urban area as to find their ways of living. However, the urban area is faced to serious unemployment problem due to insufficient growth of employment for them.

Therefore, latent underemployed population is still absorbed in the farming families.

3-4 Electricity

The Kali Konto transmission line system operated by National Electric Power Cooperation (P.L.N.) covers the electric power supply in the basin. The total installed capacity of the generating facilities of the system as of 1970 is about 96 MW as broken down below.

	Installed	Dependable Peak
Hydro power plant	36,400 KW	25,000 KW
Thermal power plant	50,000 "	50,000 "
Diesel power plant	9,200 "	5,500 "
Total	95,600 KW	80,50C KW

The annual consumption of electric energy in the Kali Konto system in 1970 was 276 million kilowatt-hours, comprising 209 million kilowatt-hours for residential use and 67 million kilowatt-hours for industrial and commercial uses. The consumption per customer averaged by 164,0C0 consumers is as small as about 1680 kilowatt-hours. The past annual growth rate of power consumption in East Java was about nine percent in 1969/70.

The long-range forecast of power demand estimated based on the growth of national economy is as follows.

Year	Assumed annual growth rate (%)	Peak demand (KW)	Energy requirement (Million KWH)
1975	15	145,000	890
1980	15	280,000	1,720
1985	12	495,000	3,020

The expected extension of power generating by 1973 is as follows.

Karangkates power station	70,000 KW
Soeloredjo power station	4,500 "
Sengruh power station	-2,600 " /1
Total	71,900 KW

/1: This is attributable to the situation submerged by the Karangkates reservoir.

These facilities together with the existing facilities of 95,60C kilowatts will result in a total installed capacity of 167,500 kilowatts. Judging from this figure and the estimated future power demand, a new source of power supply will become necessary in the beginning of 1976.

3-5 Irrigation

(1) Soils

Soils in the Brantas River Basin are generally fertile because they contain the volcanic deposit of Mt. Kelut. They are classified into nine great soil groups, ie, Alluvials, Mediterranean Soils, Lithosols, Regosols, Andosols, Grumusols, Humus Gley Soils, Latosols and Brown Forest Soils. Among those, Alluvials and Regosols occupy about 50 percent of the Brantas River Basin. Alluvials are most important agricultural soils. They are used extensively for rice cultivation. The area distributed with Alluvials is already fully utilized as paddy field.

(2) Land use

Total farmland area in the Brantas Basin is 727,000 hectares or 62 percent of the basin area, being classified into 321,000 hectares of paddy fields, 247,000 hectares of upland farm, 46,000 hectares of estates and orchards and 113,000 hectares of cultivated lands in the settlement areas.

Paddy fields are located along the Brantas River and its tributaries where land is flat and irrigable. The upland crop areas mostly extend on the lower slopes of Mt. Kelut and Mt. Kawi.

(3) Irrigation area and cropping pattern

The irrigation areas total about 321,000 hectares comprising 276,000 hectares of paddy field, 32,000 hectares of sugar cane plantation and 13,000 hectares of upland or fallow. The irrigation areas depending on the Brantas main stream cover an acreage of about 77,000 hectares.

The prevailing cropping pattern is paddy in the rainy season and fallow in the dry season. Upland crops are grown in some area in the intermediate period. Paddy is grown also in the dry season in areas where water is available. The seeding time of the wet monsoon paddy ranges from mid-November to mid-February and the hervesting period ranges from mid-April to mid-July. In the case of the dry monsoon paddy, the seeding period is between mid-March and mid-June and the harvesting period is from mid-July to mid-October.

The average cropping intensities in the rainy and dry seasons for 321,000 hectares of the irrigated area are as follows.

	Crop intensity in the rainy season (%)	Crop intensity in the dry season (%)
Paddy area	86	24
Sugar cane area	10	10

(4) Irrigation water supply

The typical irrigation method in the Brantas River Basin is mostly the gravity irrigation depending on the river water except very few cases of pump irrigation.

The discharge of the Brantas River is mostly utilized for irrigation use and the irrigation intakes face to the river directly except the Voor canal. Those intakes have the stop logs to control the inflow into irrigation canals. However, proper adjustment of inflow is very difficult by this method under the condition that the river water level widely fluctuates. The sediment-bearing water reduces canal capacity by depositing sediment. The intakes and canals in the middle stretch of the Brantas River are especially affected by heavy silting. These facts may well explain the low intensity of the dry season crop in the middle stretch.

There are 17 intakes along the main stream. Discharge records are available at only seven intakes observed by the Irrigation Service. The average intake discharge, irrigation area and water consumption in depth are summarized in the following table.

Name of intake	Irrigation area (ha)		Intake discharge (m^3/s)		Water consumed in depth (mm/day)	
	Dry season	Rainy season	Min.	Max.	Dry season	Rainy season
Blobo	2560	4275	4.2	8	14	16
Mritjan) Besuk)	700(p)/1 1,900(s)/1	13,363	6.7	11.1	23	7
Turi-Tunggrono	3850	9,626	3.6	6.7	8	6
Djatikulon	260	644	0.4	0.7	13	9
Porong) Mangetan)	12,700(p)/1 5,020	26,800(p) 5,020(s)	31.9	67.5	16	18

Remark /1 (p) and (s) mean the paddy and sugar cane areas respectively.

According to a report/2, the potential evapo-transpirations on farm per day is four millimeters. The effective rainfall in the dry season in the Brantas River Basin is regarded to be nil. Assuming that the deep percolation is one millimeter and the overall irrigation efficiency is 50 percent, the estimated daily diversion requirement in the dry season is ten millimeters. The rainfall in the rainy season is plenty and evenly distributed, and this makes the daily diversion requirement in the rainy season very small.

/2: Report on Sempor Dam and Irrigation Project

Comparing the above water consumed in depth with daily diversion requirement, it seems that the intake discharge is too large in the rainy season and most of the intakes take more water than is required for raising crops in the dry season. The crop intensity in the dry season can be increased if the irrigation canals are rehabilitated and proper water management be attained. It seems that too much water for irrigation in the rainy season, which may be mostly wasted, is the conventional custom of the farmers without adjustment by stop logs.

(5) Municipal Water Supply in Surabaja

The present water utilization in Surabaja city is as follows.

Intake site	Intake discharge (m^3/s)	Purpose
Wonokromo	1.6	Municipal water
Gunungsari	0.3	Industrial water
Ngagel	0.3	"
"	0.1	"
"	0.5	Drainage use
Total	2.8	

The intake discharge at Surabaja city is negligibly small at present. However, much more water will be needed in the future for the pollution control and municipal and industrial water supply. For future optimum use of water in Brantas will have to be planned with due consideration to balanced allocation and distribution to the various purposes.

(6) Crop yield

The average yield of the dry stalk paddy/1 in the Brantas River Basin is estimated to be 3.4 tons per hectare for the wet monsoon paddy and 3.1 tons per hectare for the dry monsoon paddy. The annual total production in the whole basin is about 1.2 million dry stalk paddy tons as shown below:

/1: "Stalk paddy" consists of the rice panicle, cut off by hand, with about 15-20 centimeters of the stalk attached. When dry, it converts to about 50 percent milled rice by weight.

Season	Production (ton)
Dry	239,600
Rainy	933,000
Total	1,172,600

The milled rice obtained from the above dry stalk paddy is estimated to be 0.6 million tons which ccrrespond to about 10 to 12 percent of the total rice production in Java. Milled rice is consumed mostly within the basin except a small quantity sold to outside of the basin.

The total production of sugar is about 230,000 tons accounting for about 30 percent of the country's total. It is an important cash crop in this area.

3-6 River Flow

(1) Discharge records

The river flow measurement in the Brantas River Basin has long been carried out at 18 gauges on the main stream and its tributaries. The eight gauges exist on the main stream, namely, Karangkates, Pohgadjih, Kaulon, Pakel, Djeli, Djombiru, Kertosono and Djabon. The daily water level observation is made twice a day at most of the gauging stations and daily surface velocity measurement is made with a stem of banana. A few check measurements by a current meter were made by the Hydrology Department in Bandung. The monthly mean discharge calculated based on these data is compiled in "Data Book".

The monthly discharge generally is the largest in February/ March and the smallest in September. Comparing this fact with the rainfall at Djabon gauge where the monthly rainfall is the highest in December and the lowest in September, it could be said that a large part of rain water flows out within two or three months.

(2) Check of the discharge data

During the survey period a few times of check measurements by a current meter were made at Pakel, Djombiru, Kertosono and Djabon gauges from the middle of July to early August 1971. The results of the regular measurements were very close to those of the check measurements at Pakel and Djabon gauges but quite different at Djombiru and Kertosono gauges.

Based on the rainfall records obtained at 52 gauges, the annual rainfall-discharge correlation at the gauges along the main stream was evaluated. The discharges obtained at Djabon gauge show a good linear correlation with the annual rainfalls. But the discharges at Kertosono has an unreasonable discrepancies from the rainfalls.

The Djabon gauge is located 1.3 kilometers upstream of the junction of the Surabaja and the Porong Rivers. The Mlirip gauge on the Surabaja River just downstream of the junction has 1951-1970 discharge record. The Lengkong dam is located on the Porong River 200 meters downstream of the junction. It diverts the Porong water to Voor irrigation canal. Kepadjaran gauge is located immediately downstream from the Lengkong dam. The 1951-1970 discharge records are available at both the heads of the Voor canal and Kepadjaran gauges.

To cross-check the Djabon records, the discharge records at Djabon gauge were compared with the records at Mlirip, Kepadjaran gauges and Voor canal. The result shows that most of the data are very close to the equal line. All the results of the check measurement, rainfall-discharge correlation and the above cross-check proved that the discharge records of Djabon gauge is very reliable.

(3) Record adjustment

According to the monthly discharge hydrograph of the gauges along the main stream, the 1964-1970 records at Kertosono and Djombiru gauges seem rather high compared with the records of other gauges, and the records of both gauges for the period before 1964. Then, the 1964-1970 records of Kertosono and Djombiru gauges were corrected by the correlogram of the monthly discharge records for the 1951-1963 period at Djabon and Kertosono gauges and those at Djabon and Djombiru gauges respectively.

(4) *Run-off Coefficient*

The run-off coefficients in 1951-1970 period at seven gauges on the main stream were calculated by using the corrected discharges and the basin mean rainfall. They range between 42 and 58 per cent which seems reasonable taking into consideration of evaporation and infiltration losses.

(5) Effects of Karangkates and Soeloredjo reservoirs

The Karangkates dam was constructed at about one kilometer upstream from Pohgadjih gauge. The Soeloredjo dam has already been completed on the upstream reaches of the Konto River.

Based on the monthly discharge records at both damsites during 1951-1970, the increase of the monthly discharge after regulation by the reservoirs is estimated assuming that the reservoirs are operated as mentioned in "Technical Study Report". The average increase of discharge during the dry season from May to October is 13.5 cubic meters per second at Karangkates damsite and 1.7 cubic meters per second at Soeloredjo damsite respectively.

3-7 Eruption of Mt. Kelut and River Bed Movement

(1) Volcanic activity of Mt. Kelut

Mt. Kelut is an active volcano, locating at 35 kilometers east of Kediri. The present bed of the Brantas River is heavily silted up due to the frequent eruption of Mt. Kelut. Recent eruptions in this century happened in 1919, 1951 and 1966. The river channel capacity has become too small to discharge floods. Sediments carried by the Brantas River has deposited around the intakes and canals of the irrigation system. Such a condition makes it difficult to protect the land from floods in the rainy season and to achieve proper irrigation water control.

According to a report prepared by the Directorate General of Water-Resources Development (Ministry of Public Work & Power) in 1969, Mt. Kelut has erupted ten times during 1811-1966 period with intervals of 3-37 years.

The crater of Mt. Kelut usually retains water in it. If Mt. Kelut erupts when much water is stored in the crater, enormous hot mud flow rushes down to destruct everything on its course. After the eruption in 1919 tunnel construction was commenced to reduce the water kept in the crater. In the eruptions of 1951 and 1966 the tunnel was partly destroyed. But the tunnel has been excavated seven times altogether until 1972 through the southern crater wall. At present it reduces the crater water to about four million cubic meters. Judging from the past records of mud flow and the present amount of crater water, the travelling distance of the mud flow in next eruption may be about 13 kilometers.

Apart from the primary lahar, some part of the volcanic efflux such as ashes, sands, lapillis and volcanic bombs still lie on the hill slopes. They run down mainly in rainy season along the small streams. This mud flow is called the "Secondary lahar". The secondary lahar is also destructive due to its high gravity.

Most of the primary and secondary lahars settle on the slopes as loose deposits which are easily eroded by subsequent rains and travel toward the main stream of Brantas. The total volume of the deposit is estimated to be 90 million cubic meters in the 1966 eruption. The same in the 1951 eruption is estimated to be 192 million cubic meters.

(2) Debris Control Works

Based on a MPWP report/1, the debris control works has been carried out since the 1966 eruption. This work is featured by the construction of low check dam and dikes to trap and settle the lahar deposit on the mountain slopes. The principal features of the lahar pockets constructed until 1970 are as follows:

Planned pocket capacity	$36.2 \times 10^6 m^3$
Trapped volume upto 1970	19 x "
Area occupied by pockets	1,840 ha
Construction cost	173.9×10^6 Rp

The construction cost per cubic meter of the pocket capacity ranges between 3.3 to 16.2 Rupiah. It is noted that this low cost is attributable to low man-power cost and no compensation cost for the land occupied.

(3) River bed movement

The river bed elevation of the Brantas has been measured at 22 sites in the river length of 220 kilometers between Ngambul near Wlingi village and the estuary of the Porong River. The records of the river bed elevation cover most of the 1950-1970 period.

/1: MPWP "Mt. Kelut Volcanic Debris Control Project (Feasibility Report)" Director General of Water-Resources Development Djakarta 1969.

Based on these records, the volume increase in the river deposit between the adjacent measurement sites in each year was calculated. As the general tendency, the river deposit largely increases in a period of five years after an eruption and the increasing rate reduces thereafter. The total deposit on the river stretch between Kaulon and the estuary of the Porong River during 1951-1970 is about 48 million cubic meters as shown below:

Stretch	Distance of stretch (km)	Deposited volume ($10^6 m^3$)
Kaulon - Djabon	175	33
Djabon - Porong estuary	31.5	15
Total	206.5	48

The deposit increased in the initial five years after the eruption and the estimated deposit on the slopes of Mt. Kelut are as follow.

	Mountain deposit ($10^6 m^3$)	5-yr river deposit ($10^6 m^3$)	Percentage
1951 eruption	192	26.86	14
1966 eruption	90	16.40	18
Total	282	43.26	

(4) River sediment load

The river sediment may be classified into two kinds by the movement characteristics, namely one is the bed load moving on the river bed, and the other the wash load in which finer materials are transported in suspension in the river water. The movement of the bed load material causes either aggradation or degradation depending on the discharges at the given site.

The water sampling for the bed and wash load measurements was carried out at Djombiru, Kertosono and Djabon in 1959/1960 and 1971. The sediment load passing through the above three sites are estimated by a relationship between the sediment discharge and a hydraulic parameter of the river cross section. The results show that the annual bed load and wash load are within a range of 1-1.1 million cubic meters and 4-4.5 million cubic meters respectively with only little differences among the three measurement sites.

(5) *Sediment yield from the slopes of Mt. Kelut*

The sediment yield in a catchment area of the Brantas River can be estimated as a sum of the increase of the river deposit and the sediment load carried to the outside of the area through the river. The bed and wash load materials in the 1951-1955, 1956-1965 and 1966-1970 period respectively are estimated as follows:

(Unit: $10^6 m^3$)

Period	Bed load material	Wash load material	Total
1951-1955	30.85	25.74	56.59
1956-1964	10.27	33.35	43.62
1966-1970	18.09	9.51	27.60
Total	59.21	68.60	127.81

The measures contemplated for preventing aggradation of the Brantas River are:

(i) To trap the lahar materials on the slopes of Mt. Kelut as much as possible.

(ii) To dredge the river channel

(iii) To divert the sediment bearing water into the Indian Ocean.

Among the above measures, the debris control works to trap the lahar materials are being carried out on the slopes of Mt. Kelut. In addition, it may be necessary to dredge the river channel to increase its channel capacity. The plan of diverting the sediment bearing water into the Indian Ocean is studied in Chapter 4. However, further survey will be needed on this plan for solving the problem of the sedimentation and hydrological problems. As a practical measures for the time being, it would be advisable to proceed a suitable combination of the debris control works on the mountain slopes and the dredging work in the Brantas River.

(6) River bed movement after 1970

The river bed movement after 1970 is estimated from the amount of volcanic products in the 1966 and 1951 eruptions as well as the amount of sediment yield during 1951-1970 period.

The sediment yield in the 1971-1980 period is assumed to be 47 percent of the 1956-1965 yield. This percentage is the ratio of the estimated volcanic products in the 1966 and 1951 eruptions. As the bed load yield in the 1956-1965 period is 10.27 million cubic meters, the bed load yield in 1971-1980 is estimated to be 4.82 million cubic meters. Based on this figure, the river bed movement after 1970 is predicted taking into account the length of the river stretch, average width of the river channel and the sediment transporting capacity.

The result shows that the river bed deposit in the investigated stretch as a whole will neither increase nor decrease in the 1971-1980 period. However, aggradation occurs in the Porong River due to the unbalanced tractive force in the river channel. Thus, the tractive force in the Porong River should be increased by river channel improvement.

3-8 Flood Discharge

(1) Flood discharge data

The flood characteristics in the Brantas River was investigated to obtain necessary data for planning purpose. Data used are hourly water level records at Pohgadjih, Pakel, Kediri and Terusan gauges. The measurement duration period of the hourly water level data is 20 years at the longest at Pakel gauge and about three years at the shortest at Pohgadjih gauge.

(2) Flood characteristics

Based on the hourly water level records and stage-discharge relationship, the flood hydrographs were drawn for the case of the largest flood in each year during the 1951-1970 period. The hydrographs thus drawn are compiled in "Report on Technical Studies". The flood hydrographs in the upstream reaches have remarkably rapid increase and decrease of flood discharge with very high peaks, while the flood hydrographs in the downstream reaches have very flat and elongated pattern. This phenomenon can be explained from the fact that the retardation of the flood by the river channel storage considerably flattens the flood peak. Moreover, the inflow from the silted-up tributaries is once retained in the back swamp and gradually drained. Consequently, the flood peak discharge in the downstream reaches of the Brantas River is very small compared with the large drainage area.

(3) Retardation effect

The flood discharge analysis has revealed that the flood peak discharge in the Brantas River is largely reduced by the inland inundation along the river stretch between Pakel and Kediri, and retardation in the swamp located near the confluance of the Brantas and the Widas Rivers in the stretch between Kediri and Terusan.

The river stretch between Pakel and Kediri is not provided with levees, and the river width narrows after joining with the Ngrowo River. The water volume retained in this river stretch ranges between 15 million - 30 million cubic meters depending on the magnitude of floods. The decrease of flood peak discharge by this retention is estimated to be 150 - 300 cubic meters per second.

The flood inflow from the areas along Kediri-Terusan has been retarded by the swamp located at the Widas mouth. The water volume retained in the swamp is about 30 million - 40 million cubic meters.

It is presumed from the water volume capacity in the swamp that the flood peak in the downstream reaches might be higher by about 300 - 400 cubic meters per second without this swamp.

In addition, the flood in the downstream reaches is reduced by the flood diversion to the Marumojo River through the Gedek gate located five kilometers upstream from Terusan gauge on the left bank of the Brantas River. The hourly water level records during the 1951 - 1962 period at the end of the stilling pool of the gate shows that the flood discharge diverted through the gate at the flood peak time is estimated to be 80 cubic meters per second on an average.

(4) Probable flood

The probable floods at Karangkates, Pakel, Kediri and Terusan gauges after the regulation by Karangkates reservoir are estimated by the flood routing applied the storage function method as shown below:

(Unit: m^3/sec)

Return period (year)	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	1,390

(5) River discharge capacity

The river cross section survey has been carried out at an interval of five kilometers on the Porong River in 1970 and on the Brantas River up to Pakel gauge in 1971 by the Government. Based on the results of this survey, the river discharge capacity is calculated assuming a non-uniform steady flow. The detail of discharge capacity in the river stretch is illustrated in Fig 6-26 in "Report on Technical Studies".

The results of calculation show that the discharge capacity at Pakel is 1,370 cubic meters per second which corresponds to a flood peak of 30 years return period. But the levees are low between Kediri and the Widas mouth. The full capacity of 690 cubic meters per second at Kediri corresponds to 5 - 10-year return period of flood. This indicates that the levees along the Kediri-Widas stretch are quite liable to be overtopped by floods.

This meager discharge capacity of the middle reaches is attributable to the heavy silting due to the recent eruption of Mt. Kelut.

(6) Flood damage estimate

A rough estimate of the flood damage was carried out for Kediri-Terusan stretch based on the river cross section survey of 1971 and 1:50,000 map. The annual flood damage estimated is in the order of 0.4 million U.S. dollars except the indirect damages. The estimate of the flood damage is merely a very preliminary one and is based on many assumptions. Detailed survey of the areas vulnerable to flood should be carried out to get information necessary for making a more accurate estimate and for investigating the economic aspect of the flood control.

4. CRITERIA FOR DEVELOPMENT

This chapter presents the criteria required for the future water resources development in the Brantas River Basin. The development criteria involve flood control, debris control and dam projects. The flood control project deals with the river improvement planning in the middle reaches of the Brantas River and the flood control planning in Tulungagung area. The debris control project deals with the future debris control works required on the slopes of Mt. Kelut in connection with the prevention of aggradation of the Brantas River. The dam project deals with the technical review of Wlingi Multi-purpose Dam Project planned by the Government.

4-1 Flood Control Project

The need of flood control has recently been felt in the middle reaches of the Brantas River and the Ngrowo River Basin as frequent floods happened. A study was made on the possible flood control measures for both areas.

4-1-1 River Improvement Plan in the Middle Reaches

It is quite natural that the improvement of a river system proceeds from the main stream especially from its downstream reaches to the upstream tributaries depending on the intensity of the human activity. However, in many cases, more important areas in the downstream reaches are compelled to repeat the reconstruction of river structures due to the ever-increasing flood discharge resulted from the river improvement carried out in the upstream reaches.

In the Brantas River Basin, the retardation effects caused by the inundation of unleveed area, water storage in swamps and river channel storage in the upstream reaches reduce the flood peak in the downstream reaches. Besides the areas in the downstream reaches are better protected by the existing river structures than other areas. This fact implies that the flood control works of the Brantas River Basin was well balanced in view of the economic and social importance of the leveed areas.

If the river improvement works on the main stream and its tributaries are independently carried out under the present condition of the Brantas River Basin, the basin may suffer much loss from unbalanced allocation of flood discharge. A systematic construction of the river structure should be based on a well-balanced allocation of flood discharge. The flood discharge distribution required for the river improvement plan is explained below:

(1) Flood discharge distribution

The following flood discharge distribution plan is proposed based on the results of the flood analysis. Its basic principles are as follows.

(i) The plan is formulated against the 50-year flood taking into consideration the regulation by Karangkates reservoir.

(ii) Retardation near the Ngrowo mouth and the Widas mouth is left as it is. Thus, the planned flood peak discharge in the main stream between the Ngrowo mouth and the Widas mouth is smaller than that in the other stretch.

(iii) Inflow from the Konto River is 160 cubic meters per second.

(iv) The Gedek and Mlirip gates, through which the flood discharge is diverted to the Surabaja River, are closed off to protect the urban area of Surabaja.

The flood discharge distribution based on the above principles is made as illustrated in Fig. 7-1 in "Report on Technical Studies". Thus the design flood discharge in the main stream is decided to be 1,200-900 cubic meters per second between the Ngrowo mouth and Kediri, 900 cubic meters per second between Kediri and the Konto mouth, 1,100 cubic meters per second between the Konto mouth and Widas mouth and 1,500 cubic meters per second between the Widas mouth and Terusan.

(2) River improvement plan

The river improvement planning comprises the overall plan and the first stage plan. The overall plan was prepared in conformity with the flood distribution proposed above. The first stage plan is proposed for the purpose of saving the initial cost and time for construction since a huge volume of dredging work in the overall plan will need long construction period and a substantial amount of cost.

The overall improvement plan comprises the increase of the discharge capacity of the Brantas River on its stretch between the Ngrowo mouth and the Lengkong dam by dredging and levee heightening, drainage improvement of the area along the Ngrowo River by construction of a cut-off canal, and improvement of the lower stretch of the Konto River.

The design criteria for determining the river cross sections are as follows:

(i) The river width is confined to the present width.

(ii) The bottom elevation of the river is determined taking into account the elevations of the existing irrigation intakes, bridges and other structures.

(iii) The free board between the top of designed levee and designed water level is one meter.

(iv) The bottom width of the low water channel is 70 meters upstream from the Widas mouth and 100 meters downstream from the Widas mouth respectively.

The overall plan involves the dredging volume of 15 million cubic meters and the embankment volume of seven million cubic meters. Total construction cost is roughly estimated to be about 26 million US dollars equivalent.

The first stage plan is formulated for the probable peak flood discharge of ten years recurrence. The flood discharge distribution for this plan is shown in Fig. 7-4 in "Report on Technical Studies". The proposed improvement of the stretches is almost the same as that in the overall plan. In determining the river cross section, the free board is decided at 80 centimeters. The bottom width of the low water channel is limited to 40 meters on the upstream of the Widas mouth and 50 meters downstream of the Widas mouth respectively.

The first stage plan involves seven million cubic meters of dredging and the same quantity of embankment. The construction period will be six years and the estimated construction cost is about 17 million US dollars equivalent.

(3) Diversion canal scheme

As an alternative plan substituting the above overall river improvement, a flood diversion canal scheme was contemplated to reduce the flood in the downstream reaches by diverting the flood discharge in the upstream reaches of the Brantas River into the Indian Ocean. The plan involves the construction of a gated weir near Pakel gauge, a 30-kilometer-long diversion canal and tunnel from upstream of the weir to Nejama site. This plan will make possible drainage of the area between Pakel and Kediri, the improvement of the Konto River and the closure of Gedek and Mlirip gates are made possible without changing the present cross section of the Brantas River.

The flood discharge distribution diagram of this plan is as shown in Fig. 7-5 in "Report on Technical Studies". The design flood discharge of the diversion canal is 1,440 cubic meters per second at the inlet and 2,040 - 2,240 cubic meters per second at the outlet. The total construction cost will be 40 - 50 million US dollars equivalent.

The sedimentation in the lower river stretch will be much reduced by this scheme, but it may cause the same trouble in the new diversion canal itself. Since the sediment transportation mechanism in the volcano-affected Brantas River has not yet been clarified fully, this scheme requires a further detailed survey and study. Furthermore, the hydrological mechanism should be studied carefully because the catchment area of the diversion canal is about half of the whole basin area, and the implementation of this scheme will largely change the hydrological condition of the downstream reaches of the Brantas River.

4-1-2 Flood Control Plan in the Area along the Ngrowo River

The Ngrowo River Basin is located in the southwest corner of the Brantas River Basin. There are many remarkable swamps in the Ngrowo River Basin. Efforts have long been made for the drainage and utilization of these swamps.

Tulungagung city is located on the right bank of the Ngrowo River about eight kilometers upstream form the confluence with Brantas. The lowland near this city is ill-drained because the Ngrowo River and its tributaries have been silted up.

Herein presented are the results of the studies of the flood problem made for the areas along the Ngrowo River and some possible solutions have been worked out.

(1) Flood control structure

The Ngrowo River Basin is bounded by the Gamping hill which is a narrow, east-west trending ridge facing the Indian Ocean on the south, a series of mountains such as Mt. Sumber, Mt. Bulu and Mt. Gepeng on the west and Mt. Wilis on the north. The catchment area of the basin is about 1,500 square kilometers.

The Ngrowo River cuts the central plain and joins the Brantas River running northeastwards. The Ngasinan River originating from Mt. Gepeng on the west runs eastwards collecting many small tributaries and joins the Ngrowo River. The main stem of the Ngrowo River is about 14 kilometers long and further southwestern stretch forms the Gesikan and Bening swamps.

In 1939, the Government comtemplated a plan of retaining the flood flow from the Ngasinan River by diverting it to the Gesikan swamp through the new Ngasinan floodway in order to reduce the flood peak discharge of the Brantas River.

The structures constructed under this plan are Sumbergajam gate on the Ngasinan River, the Ngasinan floodway connected with the gate and the Gesikan swamp, the Ngasinan-Ngrowo canal connected with the gate and the Ngrowo River and the Tjelok gate on the upstream of the Ngrowo River.

However, the diversion of the Ngasinan flood largely silted up the Gesikan swamp. The Tjelok gate has become unmovable due to the sediment and since then the direct connection of the Gesikan swamp with the Ngrowo River has been hindered.

The Japanese army constructed a small diversion tunnel in the Gamping hill to drain the swamps to the Indian Ocean after a serious flood which occurred in November 1942. However, this tunnel has almost been buried due to lack of maintenance.

The 1951 eruption of Mt. Kelut caused a heavy aggradation of the Brantas River. Consequently, the discharge capacity of the Ngrowo River has decreased to such an extent that the lowland near Tulungagung city is often inundated.

To cope with this situation, a diversion plan to the Indian Ocean has emerged in a different form. The plan involves the construction of Parit Raja canal connecting the upstream reaches of the Ngasinan River with the Gamping hill, and a diversion canal passing through the Gamping hill and Kendal canal connected with the Bening swamp and the Parit Raja canal.

The main purpose of this plan was to lessen the flood discharge by diverting the Ngasinan and Tawing Rivers to the Indian Ocean through the Parit Raja canal and diversion canal. In implementing this plan, the diversion canal was changed to a diversion tunnel because the excavation of an open diversion canal required long construction period and considerable amount of cost. In 1962, the Nejama diversion tunnel, about 900 meters long, was completed with a maximum discharge capacity of 500 cubic meters per second.

With the above-mentioned structures, the flood discharge of the Ngasinan River is diverted to the Indian Ocean through the Parit Raja canal and Nejama tunnel by operating the Bendo gate as far as the capacity of the Parit Raja canal allows. For a larger discharge, part of the flood flow is diverted to the Gesikan swamp through the Bendo and Sumbergajam gates and released to the Nejama tunnel.

(2) Problem area and flood water balance

The Ngrowo River is 14 kilometers long with an average bed slope of 1/2,500. The result of the river cross section survey carried out by the Government in 1971 and the aerial photograph show that the river bed is higher than the riparian areas in the upper stretch of the Ngrowo River. The tributaries running down the steep slopes of Mt. Wilis on the left bank of the Ngrowo River are silted up due to much sediment transported from the upstream reaches. When a tributary inundates the land, water is retained in the depression between the natural levee of the Ngrowo River and the hill slope. The swamp thus created can not be drained for a long time because the river beds are elevated. On the right bank of the Ngrowo River, there is a remarkable depression upstream from Tulungagung city.

The water level of the Ngrowo River was measured at Tulungagung gauge about eight river kilometers from the mouth and at the Pakendjen gauge on the river mouth. The river water levels recorded at these gauges in 1968 and 1969 show that the water level at the Tulungagung gauge is 1 - 1.5 meters higher than that of the Pakendjen gauge in the rainy season, because much discharge from the tributaries flows in the Ngrowo River. High water level of the Ngrowo River in flood season checks up the water levels of all the tributaries joining it.

The average width of the Ngrowo River is approximately 20 meters at the bottom and the height from the bottom of the river bed to the top of the natural levee is less than three meters. Assuming that about one meter per second of the water velocity, it is estimated that the maximum discharge capacity is less than 70 cubic meters per second or less than six million cubic meters per day.

The calculation of the probable one-day rainfall in the Ngrowo River Basin shows that the flood discharge from all the tributaries joining with the Ngrowo River is about 11 million cubic meters per day with a probability of 20 percent, namely once in 5 years. The water volume inundating the land was calculated as a balance between the flood discharge from the basin and the discharge through the Ngrowo River. The water volume inundating the land is five million cubic meters or 500 hectares with an average water depth of one meter.

(3) Possible Solution for drainage

Lowering of the river bed of the Ngrowo and improvement of the tributary river channels may reduce the flood problem to a certain extent. However, the effect of such measures can hardly be expected because the volume of water inundating the land is too large to be drained satisfactorily unless the discharge capacity of the Ngrowo River has to be doubled.

The Song River, the largest tributary of Ngrowo, occupies about 31 percent of the Tulungagung basin. The Gondong, Blendis, Sengan and Gador Rivers entering into the Ngasinan-Ngrowo canal has the total catchment area about 28 percent of the Tulungagung basin. The inundated area will be largely reduced if the diversion of the Song River and the Ngasinan-Ngrowo canal to the Indian Ocean through the Gesikan and Bening swamp is realized. The works required for this purpose are as follows:

(i) Construction of a canal connecting the Song River to the Ngasinan-Ngrowo canal (about 4 km long).

(ii) Improvement of the river channel between the Tjelok gate and the Gesikan swamp (about 4 km long).

(iii) Improvement of the Kendal canal and the downstream end of the Parit Raja canal (about 4 km long).

The total construction cost will be about 1.6 million US dollars equivalent.

Another possible plan is a diversion of the Song, Klantur and Babakan Rivers to the Brantas River by constructing a short cut canal about ten kilometers long. The construction cost will be about 1.2 million US dollars. This plan seems to be the best among all others from the viewpoint of the effective drainage. But careful studies shall be made on the relation between the floods of the Brantas and this floodway.

4-2 Debris Control Project

Herein explained is a rough orientation of the future debris control project on the slopes of Mt. Kelut based on the results of the sedimentation analysis.

The sedimentation analysis in Chapter 3 shows that the total sediment yield was about 100 million cubic meters during the period of 15 years after the 1951 eruption. About 32 million cubic meters remained on the river bed out of the bed load yield of about 46 million cubic meters in the same period. This means that if an eruption of the same scale as the 1951's occurs in the future, about 70 percent ($32 \times 10^6 m^3 / 46 \times 10^6 m^3$) of the bed load materials must be trapped on the mountain slope for preventing aggradation.

The lahar pocket should have a capacity of storing about 70 million cubic meters (70 % x 100 x $10^6 m^3$) of the sediment materials against next eruption. Adding some allowance, it may be better to adopt 100 million cubic meters of pocket capacity for the sake of caution against unexpected eruption.

According to the Government, areas having a total acreage of 10,000 - 15,000 hectares are made available for lahar pocket on the southern and western slopes of Mt. Kelut. These areas may have a total pocket capacity of 100 million - 300 million cubic meters. Moreover, the pocket capacities of the existing lahar pockets can be also increased to some extent by heightening the levees. This means that it would be possible to construct lahar pockets having a total capacity sufficient to trap sediments to prevent aggradation of the rivers which may be caused by one to three eruptions in the future. However, the amount of the lahar material from the southern and western slopes of Mt. Kelut varies widely depending on the topography of the slopes and the shape of the crater rim. Thus, the future debris control should be planned with fully taking into consideration the estimated distribution of the lahar material.

4-3 Dam Project

4-3-1 Dam Project in the Brantas River Basin

The Karangkates and Soeloredjo dams have been constructed in the Brantas River Basin. The Karangkates dam is located in the upper reaches of the Brantas River about one kilometer upstream of Pohgadjih gauge. The construction work was commenced in 1964 and completed in 1972. The Soeloredjo dam is located in the upper reaches of the Konto River. The construction work was commenced in 1964 and completed in 1970. The main purpose of these two dam projects are the control of flood discharge, increase of the discharge for irrigation in the dry season and for power generation.

In addition, there are two dam projects which are being planned by the Government, namely, the Lahor dam on the upper reaches of the Lahor River which is one of the tributaries neighboring the Karangkates reservoir, and Wlingi dam on the main stream about 30 kilometers downstream from the Karangkates dam. The Lahor dam project is proposed to increase the discharge for power generation and irrigation uses by constructing a tunnel connecting the Lahor and the Karangkates reservoirs.

The possible damsites on the Brantas main stream are confined to the upstream reaches due to the topography. No suitable damsite is found on the middle and lower reaches of the Brantas River.

Some dam projects on the tributaries have been conceived but all of those are of small scale. Further investigations and studies are necessary for their evaluations.

4-3-2 Wlingi Dam Project

Wlingi dam project now being planned by the Government has the purpose of power generation, control of flood discharge and irrigation.

In addition, this project has a function of afterbay for the future Karangkates peak power generation.

The project is reviwed based on the results of the hydrological and sedimentation analyses carried out in the investigation of the Brantas River Basin in 1971, and the result of the investigation of electric power in East Java.

(1) Power generation and the function of afterbay

The investigation of electric power in East Java has made it clear that a new source of the electric power generation facilities will become necessary in early 1976.

In the Wlingi dam project, an economical scale of power generating capacity is studied to supplement the deficiency after 1976. Consequently, the installed capacity of power generating equipment is decided at 27,000 kilowatts as the most suitable scale.

The result of the investigation of electric power in East Java also revealed that the peaking capacity in Kali Konto system will become necessary in or around 1979. This would mean that the Karangkates power station will have to be operated as a peak power plant when a thermal power plant is operated to supply the base load. The Wlingi dam project is contemplated to utilize its reservoir as an afterbay for the Karangkates peak power operation. However, a further study will become necessary for the 30 kilometer-long river stretch between the Karangkates dam and the Wlingi reservoir to check if there is any danger in sudden variation in the water level.

(2) Flood control and sedimentation

It is expected under this project that the Wlingi reservoir will regulate the flood peak discharge to a certain extent at immediate downstream of the damsite. However, it has not been made clear as to the behavior of the flood discharge thus regulated in the downstream streatch after flowing down the retardation area near the Ngrowo mouth. Then, more detailed study will be necessary for the retardation affect on the downstream stretch.

The Wlingi project contemplates to prevent the aggradation of the downstream river stretch by trapping the excessive sediment transported from the lahar pockets on the Putih and Semut Rivers into the Wlingi reservoir.

The results of the review based on the sedimentation analysis show that the estimated sediment load yield from the slopes of Mt. Kelut used for Wlingi project is quite reasonable.

The sedimentation analysis has made clear that the travelling distance of the primary lahar in the next eruption will be about 13 kilometers from the crater lake on Mt. Kelut. The lahar pockets in the Putih and Semut Rivers are located at about 25 kilometers away from the crater lake. Judging from these facts, it is concluded that the Wlingi reservoir will not be affected by a huge amount of sediment materials flowing directly into it from the slopes of Mt. Kelut.

The effect of sediment control on the downstream stretch by means of the Wlingi reservoir should, however, be made clear by the comparative investigation and study in connection with river improvement in the middle reaches. The sediment and flood control benefits estimated in Wlingi project are so small compared with those of other purposes. Thus, the results of the flood and sediment controls may not affect substantially on the economic evaluation of this project.

(3) Irrigation

Irrigation Service in East Java has planned a new irrigation project for irrigating 13,600 hectares in Lodjo and East Tulungagung areas on the left bank of the Brantas River. The proposed intake site of this project is at about five kilometers upstream from the Wlingi damsite. In this plan under the Wlingi dam project, it is being planned to save the canal cost by constructing the intake structure on the reservoir.

When constructing an intake structure at the point about five kilometers upstream from damsite, it will be difficult to secure the stable water intake because of the large variation of water level which may occur after the Karangkates power station is operated as a peak power supply plant. It would be advisable both technically and economically to provide the intake site within the reservoir. However, further studies will be necessary for this irrigation project from the viewpoint of suitable river discharge distribution.

(4) Geology of damsite

The geology of damsite has been investigated by boring test. The geology of damsite consists of basal limestone with small cavities, residual clay of limestone and volcanic series. Judging from this geological condition, proper measures should be taken to prevent the seepage after the reservoir is impounded. For the sake of safety it would be advisable to carry out an additional geological investigation supported by the boring and water pressure tests.