REPUBLIC OF THE PHILIPPINES

NATIONAL POWER CORPORATION

FEASIBILITY REPORT ON AGOS RIVER HYDROPOWER PROJECT

APPENDIX D
OPTIMIZATION STUDY FOR THE DEVELOPMENT ON THE AGOS RIVER SYSTEM

MARCH 1981

JAPAN INTERNATIONAL COOPERATION AGENCY

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FEASIBILITY REPORT

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APPENDIX D OPTIMIZATION STUDY FOR THE DEVELOPMENT ON THE AGOS RIVER SYSTEM

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ABBREVIATIONS AND UNIT

JICA	Japan International Cooperation Agency
NAPOCOR (NPC)	National Power Corporation of Philippines
NK	Nippon Koei Co., Ltd.
PICOREM	Presidencial Inter-Agency Committee for re-study of the Marikina River Multi-purpose Project
NEA	National Electrification Administration
MOE	Ministry of Energy
MERALCO (MECO)	Manila Electric Company
MWSS	Metropolitan Waterworks and Sewerage System
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
BPW	Bureau of Public Works
ECAFE	Economic Commission for Asia and the Far East
CDM	Camp, Dresser and McKee International, Inc.
M + E (M & E)	Metcalf and Eddy, Ltd.
$	United States Dollars
₱ (P)	Philippines Pesos
¥	Japanese Yen
FC	Foreign Currency
LC	Local Currency
EIRR	Economic Internal Rate of Return
FIRR	Financial Internal Rate of Return
O & M	Operation and Maintenance
L.F.	Load Factor

AMSL	Above mean sea level
EL.	Elevation in m AMSL
W.L. (WL)	Water level in m AMSL
H.W.L. (HWL)	High water level in m AMSL
L.W.L. (LWL)	Low water level in m AMSL
F.W.L. (FWL)	Flood water level in m AMSL
D.F.W.L. (DFWL)	Design flood water level in m AMSL
P.M.F.W.L. (PMFWL)	Probable maximum flood water level in m AMSL
mm	millimeter(s)
cm	centimeter(s)
m	meter(s)
km	kilometer(s)
m^3	cubic meter
km^2	square kilometer(s)
ha	hectare
m^3/sec (cms)	cubic meter per second
m^3/sec·month	Water volume equivalent to the discharge of 1 m^3/sec for the duration of 1 month
kg	kilogram
t (ton)	metric ton
ℓ	liter
%	percent
^oC	centigrade
o	degree
N	north
rpm	revolution per minute

Hz	Hertz (cycles per second)
kcal	kilocalorie
kV	kilovolt
kVA	kilovolt ampere
MVA	megavolt ampere
W	Watt
kW	kilowatt
MW	megawatt
kWh	kilowatt hour
MWh	megawatt hour
GWh	gigawatt hour
V	volt
BTU	British Thermal Unit

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

From February 1979, JICA Survey Team for the Agos Hydro Power Development started investigation and reviewed many possible damsites, including five sites on the Kanan river, two on the Kaliwa river and two on the Agos river. In the five alternative damsites on the Kanan, the lowest Kanan No.5 damsite, suggested by Lahmeyer International GmbH was included. On the basis of the review and preliminary investigation, the JICA Survey Team issued an Inception Report in March 1979 in which preliminary assessment on the alternative development plans were made.

On the other hand, PICOREM started a comprehensive study for the water supply to Metro Manila from 1978. Through the study, diversion scheme from the Kaliwa reservoir is selected as the most optimum plan for the water supply to fulfill the demand until 1993. Furthermore, the Kanan water supply project is also proposed as the second stage for water supply to Metro Manila. Based on this study, detailed engineering works on the Kaliwa dam and appurtenant structures were planned to be commenced from mid-1980.

Therefore, the formulation of the optimum plan for the whole Agos river is to be made in due consideration of the results of both studies. Particularly, the drinking water supply to Metro Manila, now urgently needed, is to be considered as the first priority since there is no other suitable and economical sources of clean water around Metro Manila than the Kaliwa-Kanan-Agos river system, the plan of the Kaliwa dam, now under detailed study by PICOREM, was therefore, dealt as-built project for the optimization study on the river system.

In the Interim Report of the Agos river hydro power project submitted in December 1979, the following four combined alternative plans were compared, which were formulated in due consideration of the water requirement to Metro Manila.

Plan A-1: Kaliwa Water Supply Project
+ Kanan No.1, Agos No.1 and No.2 Hydro Power Project

Plan A-2: Kaliwa and Kanan No.2 W/S Project
+ Agos No.1 and No. 2 H/P Project

Plan A-3: Kaliwa W/S Project (with pumped storage P/S between the Agos reservoir and Kaliwa reservoir)
+ Kanan No.1, Agos No.1 and No.2 H/P Project

Plan B : Kaliwa W/S Project
+ Kanan No.5 and Agos No.2 H/P Project

Through the economic comparison, plan A-3 was preliminarily selected as the most beneficial project followed by plan A-2 and to conduct the detailed comparison for the two beneficial plans was recommended in the Interim Report.

1.2 Scope of the Optimization Study

Based on the results of the study made in the Interim Report, conceivable alternative development plans for the Agos river system were reviewed and modification or adjustment is made.

Under the framework of the conceived alternative development plans, the investigation such as topographical, geological and hydrological surveys are reviewed for each project component. More detailed study on the hydrology and reservoir operation are conducted for the comparative study. On the basis of these studies, preliminary design and the cost estimate are made for each project component. The optimum scale of each project component is determined through the comparison of the expected benefit and cost. Furthermore, the final draft report regarding the Kaliwa water supply project including the Kanan water supply project was furnished, in which the costs and benefits are shown.

The most optimum development plan for the Agos river system is finally recommended in this report based on the results of comparison on the expected net return from the four combined alternative plans.

CHAPTER 2

HYDROLOGY

2.1 General

There were four stream gauging stations in the Agos river system. Among them, long and reliable discharge records are available only at Banugao G.S. on the Agos river. The Banugao G.S., located at 6 km upstream from the estuary, has the 26 years' complete discharge records from 1950 to 1973, 1977 and 1978 which have been proven to be reliable in the Appendix A and listed in Table 2-1. The said discharge records give the specific discharge as high as 12.5 m^3/sec/100 km^2 equivalent to the effective rain of 3,940 mm per annum.

As the Kanan river basin is located near the east coast of Central Luzon, the rainy season of this area is mainly affected by the North-East Monsoon resulting the much rain from October to January. While the Kaliwa river basin is affected by both the North-East and the South-West Monsoons due to its location in the midland resulting the two peak months of rainfall in August and November. Further, the Kanan river basin has average monthly rainfall not less than 160 mm even in the dry season being affected by the trade winds, while the Kaliwa river basin has distinct dry season spanning over four months from January to April. Therefore the average monthly discharge of the Kanan river has the single peak in December while that of the Kaliwa river has the first peak in December and the second peak in August. The Kanan river has the average specific discharge of as high as 16.3 m^3/sec/100 km^2 equivalent to the effective rain of 5,150 mm per annum. The Kaliwa river has lower specific discharge than the Kanan river, that is, 9.30 m^3/sec/100 km^2 which is only 57 % of that in the Kanan river.

In the meantime, the 26 years' discharge records at Banugao G.S. include two very rich water years corresponding to the recurrence period of about 50 years. The said two rich water years could not be rejected by a statistical test and, therefore, the average discharge at Banugao G.S. is obtained at 118.1 m^3/sec as the logarithmic mean while the arithmetic mean is 120.63 m^3/sec. However from the stand point of the practical water utilization, it is optimistic to expect the occurrence of such rich water year twice in 26 years as may occur only once in 50 years. Hence the available discharge at Banugao G.S. is estimated to be 113.8 m^3/sec as the logarithmic mean excluding the above two rich water years.

Taking into consideration the discharge difference between the Kanan and Kaliwa rivers, the average discharge and its seasonal variation at the proposed damsites are estimated based on the above Banugao discharge of 113.8 m^3/sec, monthly discharge pattern at Banugao and Daraitan G.S. and the newly prepared isohyetal map. The results are given in Table 2-2.

As discussed in Paragraph 4.1.2 of Appendix A, rainy season in the Agos river system is delayed by four months in average than that in the western coast of Luzon. In addition, the annual discharge fluctuation, namely the ratio of peak month discharge to the lowest month discharge of the Agos river at Banugao G.S. is as small as 5.3. These discharge characteristics are great property of the Agos river system from the viewpoint of water utilization.

Detailed results of the study on run-off are given in Chapter 4 of Appendix A.

2.2 Long Term Discharge Series

Long term discharge series of the following four small basins are required for the reservoir operation study of the Kaliwa, Kanan No.1 and Agos dams.

i) Kaliwa river at Kaliwa dam

ii) Kaliwa river between Kaliwa dam and the confluence

iii) Kanan river at Kanan No.1 dam

iv) Kanan river between Kanan No.1 dam and the confluence

These discharge series are generated based on the 26 years' discharge series recorded at Banugao G.S. and on the average monthly discharges estimated for each basin. Natural discharge series at the Agos dam can be obtained by summing up the above four discharge series. The generated discharge series at the Agos, Kanan No.1 and Kaliwa dams are listed in Table 2-3 to 2-5.

The above discharge series have a coefficient of variation higher than 20 %. They also include a very droughty year corresponding to a recurrence period longer than 50 years. Thus it is judged that the generated discharge series have enough fluctuations and can be the base for water utilization study in the following section.

2.3 Evaporation

Pan evaporation records are available at Cuyambay, Tanay, Rizal, about 8 km south-west of the proposed Kaliwa dam. The average evaporation from 1970 to 1978 is 1,423 mm per annum.

CHAPTER 3

RESERVOIR OPERATION

3.1 General

Reservoir operation study is carried out in the 2 stages. First, the study is made to select the optimum development scheme of the water resources of the Agos river system among the 4 alternative development plans, namely plan A-1, A-2, A-3 and B. Then the study is made to optimize the development scale of the selected scheme.

The above 4 alternative development plans consist of the water supply project by PICOREM and the hydro power project by NAPOCOR. Brief explanations on the 4 plans are made hereunder from the viewpoint of reservoir operation study.

Plan A-1 consists of 3 dams, one each on the Agos, Kaliwa and Kanan rivers. The operation of three dams can be simulated independently each other in principle.

In case of plan A-2, the Kanan water will be diverted to the Kaliwa reservoir through a one-way interbasin tunnel for the water supply purpose to Metro Manila. If both the Kaliwa and Kanan reservoirs are operated comprehensively to utilize the different discharge pattern between the Kaliwa and Kanan rivers, their flow regulating capability would be much improved. As the operation rule of the Kaliwa and Kanan reservoirs had not been given by PICOREM in the course of the present study, it was simply assumed that the Kanan water diverted to the Kaliwa reservoir will be released immediately to the Pantay treatment station through outlet works of stage II without affecting water level of the Kaliwa reservoir. Then the operation of the Kaliwa and Kanan reservoirs can be simulated independently of each other. The operation study for the Agos reservoir can be carried out using the inflow series for each target year which are to be composed of the spilt water series from the Kaliwa and Kanan dams and the discharge series of the remaining basin.

In case of plan A-3, the Kaliwa and Kanan reservoirs are independent of each other, while the Kaliwa and Agos reservoirs are connected by the reversible pump-turbine. The pump-turbine will be installed to pump up water from the Agos reservoir to the Kaliwa reservoir for water supply to Metro Manila of stage II in place of an interbasin tunnel connecting the Kaliwa and Kanan reservoirs in plan A-2. The pump-turbine can be operated as a usual pumped storage type peak power plant as well as for water supply. Again it is assumed that the water pumped up from the Agos reservoir to the Kaliwa reservoir for water supply purpose will be released to the Pantay treatment station immediately.

However, a combined operation study of the Agos and Kaliwa reservoirs is required to utilize the potential energy of the excess water of the Kaliwa reservoir which would spill out to the Agos reservoir in vain. Therefore the pump will not be operated when the excess water is available, instead of pumping up the water requirement from the Agos reservoir.

In case of plan B, there is no relation between the Kaliwa dam and the Kanan No.5 dam. Their operation can be simulated by the standard method for a single reservoir.

Water supply to Metro Manila from the Kaliwa reservoir will be commenced in 1987 and reach full supply level of 22.1 m^3/sec in 1994 thereafter the Kanan water will be diverted through an interbasin tunnel or by pumping operation and reach full supply level of 36.7 m^3/sec in 2009. A simple arithmetic calculation gives the average inflow of 49.4 m^3/sec for the Agos reservoir in 2009 which is 46 % of the natural inflow of 108.2 m^3/sec. Therefore reservoir operation study is required to be carried out for every year in principle until the water requirement reaches full supply level.

It is the main feature of the operation study for the Agos dam that water will be diverted from the upstream reservoirs for water supply to Metro Manila and, therefore, available water for Agos P/S will be decreased year by year until the water supply will reach full supply level.

It is our understanding that PICOREM will divert the Kaliwa and Kanan water along with the water requirement as shown in Fig. 3-1, and that the surplus water and flood discharges exceeding capacity of the Kaliwa and Kanan dams will be spilt out into the Agos reservoir. Agos power station can utilize the surplus and the spillage as much as available within the plant capacity for power generation to save fuel of thermal plants in Luzon grid since its completion is at 1989.

The purpose of the present reservoir operation study is not to establish the best comprehensive operation rule of the proposed dams but to choose an optimum development plan of water resources of the Agos river system and to obtain an optimum development scale of the selected scheme. Therefore, the operation study is carried out based on the reasonably simplified model as mentioned in the above. Detail of the operation study is given in Chapter 7 of Appendix A.

3.2 Operation Rule

The following practical operation rule is adopted instead of ideal flow regulation because future monthly fluctuation of discharges cannot be known.

i) To be operated just to meet the requirements of water supply and/or power generation when reservoir water level (R.W.L) is between high water level (H.W.L.) and low water level (L.W.L.),

ii) To be operated for secondary energy in addition to the given electricity load within the plant capacity by the excess water, when R.W.L. is higher than H.W.L.,

iii) To be operated partially to the requirements by the available water giving priority to the water supply, when R.W.L. is at L.W.L.

In addition to the above general rule applicable to the Agos, Kaliwa and Kanan reservoirs, the following sub-rule is adopted for the operation of the Kaliwa reservoir:

iv) Water diverted from the Kanan reservoir through an interbasin tunnel or pumped up from the Agos reservoir for water supply purpose shall be released immediately to the Pantay treatment station through the tunnel of Stage II,

v) Excess water to be released to the Pantay treatment station within the water requirement of Stage II instead of pumping up from the Agos reservoir. If there is further excess water, secondary energy to be generated by the Kaliwa pump-turbine within the plant capacity (plan A-3).

Operation rule of the Kaliwa pump-turbine (plan A-3) as a usual pumped storage type power plant is simply assumed as follows:

vi) daily peak power generation for the given duration and to pump up the same quantity of water used so as not to interfere the Kaliwa reservoir operation for water supply.

3.3 Electric Load

As described in the foregoing Chapter 2, the seasonal discharge pattern of the Agos river system is fairly different from that of those rivers in the western coast of Luzon. Therefore if large reservoirs with large power plants can be constructed in the Agos river system, seasonal power generation is expected to be compensated between hydro power stations in the western coast and that in the Agos resulting increments of firm energy and reliability of the whole hydro power in Luzon grid. However it was proven in the course of the present study that large effect on Luzon grid could not be realized due to the small installed capacity of the Agos power station. Accordingly, no seasonal variation of electric load is considered. A uniform load is imposed upon the proposed power stations which is obtained as the firm energy to be assured 100 % against the 26 years' inflow series including a very droughty year corresponding to a recurrence period of more than 50 years. The above load on the Agos power station has to be decreased along with the decrement of inflow until the full water supply level.

It is also assumed that any secondary energy generated by excess water in rainy season will be accepted by Luzon grid to save fuel of its thermal plants.

3.4 Water Requirements

Water requirements to the Kaliwa and Kanan rivers are studied by PICOREM and given in Fig. 3-1. The water conveyance loss of 4 % is added to the above requirements and released from the reservoir in the simulation study. Benefit calculation is made based on the average supplied water excluding the conveyance loss.

3.5 Data for Operation Study

(1) Reservoir Capacity Curve

The Agos and the Kanan No.1 reservoir area curves are established based on one to five thousand scale maps provided by PICOREM and NAPOCOR. These area curves are shown in Fig. 3-2 and 3-3 together with reservoir capacity curves.

(2) Reservoir Loss

Reservoir loss consist of surface evaporation loss and sub-surface seepage loss. Reservoir evaporation loss is estimated at about 1,050 mm per annum based on the pan evaporation records as described in Section 2.3 while seepage loss is not clear. For the simplicity and conservative study, the reservoir loss is assumed at 1,500 mm per annum including seepage loss.

(3) Power Plant

Main features of the Agos, Kanan No.1, Kaliwa pumped storage and Kanan No.5 power stations are summarized in Table 4-1, 4-5, 4-10 and 4-19 respectively. The features of the finally selected Agos power station is given in Table 6-1.

The hydraulic head losses in the power tunnel are calculated by means of the respective loss formula and accumulated as the function of discharge for computational convenience sake.

(4) Water Supply Facility

Outlet tunnels from the Kaliwa reservoir to the Pantay treatment station are designed by PICOREM to have the discharge capacity of 28 m^3/sec for Stage I and 45.9 m^3/sec for Stage II. The discharge capacity of the interbasin tunnel between the Kanan No.2 and Kaliwa reservoir is 73.5 m^3/sec. Therefore the required water of 22.1 m^3/sec for Stage I and of 36.7 m^3/sec for Stage II can be released without any restriction through these tunnels. In case of plan A-3, required water for Stage II will be pumped up from the Agos reservoir by the Kaliwa pump-turbine which is designed to have the enough capacity as shown in Table 4-10.

3.6 Results of Operation Study

All the results of reservoir operation study carried out are listed in Appendix F and will be discussed in Chapters 4 and 6.

Some remarkable results of the reservoir operation study are described hereunder.

(1) Power Generation

The electric loads imposed on Agos, Kanan No.1 and Kanan No.5 power stations are assured 100 % against the 26 years' inflow series which include a very droughty year corresponding to a recurrence period of more than 50 years. The installed capacity is assured more than 90 % against the said inflow series.

(2) Water Supply

Water supply from the Kaliwa reservoir (Stage I) will be assured 95 % owing to the large reservoir capacity which corresponds to the capacity-inflow ratio of as high as 0.61.

Water supply from the Kanan reservoir (Stage II of plan A-2) will be assured 82 %. The reservoir will be empty more or less in 21 years during the 26 years of inflow series. This lower dependability compared with stage I is due to the capacity-inflow-ratio of Kanan reservoir of as low as 0.17.

On the contrary, in case of plan A-3, water requirement for stage II can be fulfilled by the operation of Kaliwa pumped storage plant. Furthermore, if it is allowed by Luzon grid to stop power generation at Agos power station in the emergency situation of drinking water shortage in Metro Manila, the Kaliwa pumped storage plant of plan A-3 can supply additional water of about 18.2 m^3/sec·month even in the driest month of the 26 years of inflow series. The calculation is shown below:

i)	Generated energy in the driest month		9,750 MWh
ii)	Power		112 MW
iii)	Effective head		85.2 m
iv)	Turbine discharge		156 m^3/sec
v)	Operation hour		87 hours
vi)	Mean discharge	iv) x v)/24 hours/31 days	18.2 m^3/sec

Note: H.W.L. of Agos dam = 165 m AMSL
Installed Capacity = 140 MW

CHAPTER 4

PLAN FORMULATION

4.1 General

4.1.1 Alternative Development Plans for the Agos River System

In this study, the four combined alternative plans studied in the Interim Report are reviewed and modified in due consideration of the results of discussions with NAPOCOR.

In the study of the Interim Report, the economic viability of the Agos No.2 dam was proved to be rather negative./1 The plan of the Agos No.2 is, therefore, discarded and excluded from the original alternative plans.

On the conditions mentioned above, alternative combined development plans for the Agos river system to be discussed are finally modified as follows.

Plan A-1: Kaliwa Water Supply Project
+ Kanan No.1 and Agos Hydro Power Projects

Plan A-2: Kaliwa and Kanan No.2 W/S Projects/2
+ Agos H/P Project

Plan A-3: Kaliwa W/S Project (with pumped storage P/S between the Agos reservoir and Kaliwa reservoir)
+ Kanan No.1 and Agos H/P Projects

Plan B : Kaliwa W/S Project
+ Kanan No.5 H/P Project

In the plans A-2 and A-3, it is assumed that the available water in the Kaliwa and Kanan reservoirs will be used for water supply to Metro Manila. While, the plans A-1 and B are planned assuming that the available water from the Kanan reservoir will not be used for the water supply and be used exclusively for the hydro power for both the Kanan and the Agos.

The combined alternative plans stated above are illustrated in Fig.1-1 to Fig.1-4.

/1: Refer to Section 6.4 of Interim Report on Agos river hydro power project.

/2: Kanan No.1 dam is also applied for the plan A-2 for fair comparison with the plan A-3.

4.1.2 Method of Comparative Study

On the basis of the results of the field investigation, study and analysis are conducted for each component of the combined plan. Particularly, the results of the hydrological study conducted in due consideration of the newly available data for estimating the discharges at the proposed alternative damsites and the long term discharge series are fully taken into account.

Prior to the comparative study on the proposed alternative plans, optimization study for each component such as the Agos dam, the Kanan No.1 dam and the Kaliwa pumped storage is preliminarily conducted on the basis of the estimated construction cost and the benefit. For the Kaliwa dam and the Kanan No.5 dam, and the Kanan No.2 dam, the estimated work quantities, and power generation and water supply volume which have been made by the previous studies/1 were used with adjusted price level of early 1980. Selection of the most optimum plans for the Agos river system is made through the comparison on the combined alternative plans incorporating all the results of the study for each component.

The construction costs are disbursed in accordance with the construction period as shown below. The required construction period is fixed at each project depending on the dam volume and length of tunnel. As for hydro power project, discounting during construction is ignored because the discounting of alternative thermal plant is also neglected.

Disbursement Schedule

Construction Period \ Year	1st	2nd	3rd	4th	5th	6th
4 years	-	-	15	35	35	15
5 years	-	10	15	30	30	15
6 years	7	10	15	25	25	18
Thermal plant	-	-	25	35	25	15

The following implementation schedules are tentatively applied.

/1: Study on the Kaliwa dam and Kanan No.2 dam was made by PICOREM. Study on the Kanan No.5 dam was made by Lahmeyer International GmbH.

	Construction period	Commercial oper.
Kaliwa water supply Ist stage	1981 - 1986	1987
Agos hydro power	1983 - 1988	1989
Kanan water supply (Kanan No.2 dam to Pantay)	1987 - 1993	1994
Kanan No.1 hydro power	1989 - 1993	1994
Kaliwa pumped storage project	1990 - 1993	1994
Kaliwa IInd stage (Outlet to Pantay)	1989 - 1993	1994
Kanan No.5 hydro power	1983 - 1988	1989

Operation and maintenance cost is estimated to be 0.5 % of dam cost and 2.5 % of waterway, powerhouse and electro-mechanical cost. Power benefit is evaluated by the least cost alternative thermal plant, which is determined to be coal fired thermal plant through the comparative study. (Refer to Section 7.1 Project Benefits in the Main Report). The applied kW value is US$160.25 per kW and US$0.0234 per kWh. Benefit from the water supply is also estimated by the water cost to be provided by the least cost alternative, which is valued at US$0.133 per cubic meter (or Peso 1.0 per cubic meter). All the costs and benefits are estimated at the price level of early 1980. Present net value is calculated for the comparison assuming that the project life is 50 years after completion using the discount rate of 10 %.

4.2 Agos Hydro Power Project

4.2.1 General Description

The dam site is located on the Agos river just downstream of the confluence of the Kaliwa and Kanan rivers, having a catchment area of 867 km^2 with the river bed elevation of EL.42 m. Based on the 26 years discharge record at Banugao and recent findings by newly installed automatic rain gauge and automatic water level recorder within the Agos watershed, the annual mean discharge is assumed to be 108.2 m^3/sec. Design flood for spillway is 10,600 m^3/sec which corresponds to 1.2 times of 200 year flood peak. Design flood for diversion works is 5,210 m^3/sec corresponding to a 30 year return period.

Regarding dam foundation, bed rocks are composed of alternating greywackes and conglomerates with occasional intercalations of thin shale layers, all of which are highly consolidated and hard in fresh condition. Average depth of the solid rock surface is 15 m to 20 m. Fresh rock zone is deemed sufficiently solid and stable for foundation for impervious core zone of fill dam. With respect to river bed excavation, recent drilling test revealed that about 40 m deep excavation is necessary.

4.2.2 Alternative Plans Formulation (Agos Dam)

The optimum development scale of the Agos dam is to be selected through the comparative study for two different cases: one case that the available water both in the Kaliwa and the Kanan reservoirs will be used for water supply gradually to Metro Manila and not be used for the Agos power station (the case for the combined alternative plan A-2 and plan A-3); and the other case is that the water in the Kanan river will be used for the hydro power purpose (the case for the combined alternative plan A-1).

For the comparative study on the Agos dam, four alternative plans with different reservoir high water levels are selected, namely EL.175 m, 165 m, 155 m and 145 m. The low water level is taken one third of gross head. Rated water level is fixed at one-half of draw-down.

Basic plan is formulated on the basis of these different high water levels of the reservoir. For the planning, it is assumed that the Agos dam can use the surplus water from the Kaliwa and Kanan reservoirs until the full utilization in 1994 and 2009, respectively (in case of plans A-2 and A-3). The expected power generation is computed under the condition of monthly uniform generation rule.

The installed capacity of the power station (generating equipment) is settled due to the reservoir capacity and the available head. Through the reservoir operation study for different scales of the Agos dam, the expected installed capacity is determined for each alternative scale assuming that the plant factor of the power station exceeds 33 % (or operation is more than 8 hours per day) on an average for the project life of 50 years. The expected installed capacity of the Agos hydro power station is 152 MW to 116 MW in case that the available water in the Kanan reservoir is used for water supply to Metro Manila, and 200 MW to 155 MW in case that the available water in the Kanan reservoir is also used for the Agos hydro power.

4.2.3 Preliminary Design

(1) Dam and Relevant Works

A rock fill type is selected for the Agos dam in view of the availability of materials and local conditions together with economical comparison. The dam will have the slope 1 in vertical to 2.5 in horizontal on the upstream side and 1 in vertical to 1.9 in horizontal on the downstream side based on the conventional stability analysis under the conditions that the coefficient of earthquake is 0.15 and the factor of safety should be more than 1.2. The width of the crest is 12.0 meters. The thickness of the core is more than 30 % of water head at any point.

The spillway equipped with 10 numbers gates is to be provided at the left bank of the Agos river to discharge the design flood of 10,600 m^3/sec. The gated open chute spillway is tentatively selected. The excavated rock from spillway will be used for the dam embankment. The free board from the high water level is fixed at 7 m for each alternative.

Two diversion tunnels with 12.0 m diameter are selected to discharge the routed design flood of 5,210 m^3/sec. Most of the cofferdams are planned to be incorporated in the main dam.

(2) Power Facilities

The location of the intake is selected at the right bank of 200 m upstream of the dam axis where sound rock outcrop appears. A vertical gate shaft is to be provided at about 100 m downstream of the intake. Power tunnel route is selected so as to run maintaining the sufficient rock covering. The velocity in the power tunnel is set at 5.5 m/sec. A chamber type surge tank is to be provided at the end of the tunnel. An underground type of penstock is selected and the velocity in the penstock steel pipe is set at 7.5 m/sec so as to limit the pressure rise within 40 % of static head due to water hammer. A wide area for powerhouse and switchyard is available at the right bank terrace deposit. Two units of the generating equipment are planned to be installed for each different scale with different rated head.

Main features of alternative schemes for the Agos Hydro Power Project are shown in Table 4-1 and 4-21.

4.2.4 Construction Cost and Benefit

The work quantities for the dam, spillway and diversion works for each different scale are computed on the basis of the preliminary design. With respect to the waterway to the powerhouse, the work quantities are derived from formulas related to the maximum discharge and head. The unit prices are applied for the estimation of the cost. The estimated construction cost for each different scale of the Agos project is presented in Tables 4-2 and 4-22.

The benefit of the Agos project is derived from the power generation, which is valued by the saving cost of alternative thermal plant. Details of the benefit estimate for each different scales are presented in Appendix F and their summary is presented hereunder.

Plan A-2 and A-3 (Water both from the Kaliwa and Kanan Reservoirs be used for Water Supply)

HWL	AG-175	AG-165	AG-155	AG-145
Installed Capacity (MW)	152	140	128	116
Average Annual Power Generation (GWh)	486.6	450.5	413.5	376.9
Discounted Power Benefit/1 (million US$)	382.1	352.2	322.4	292.71

/1: Discounted the power benefit for the economic life of 50 years at the year of 1989 using 10 % discount rate

Case II (The Kanan Reservoir Water be used for the Agos H/P)

HWL	AG-175	AG-165	AG-155	AG-145
Installed Capacity (MW)	200	185	170	155
Average Annual Power Generation (GWh)	739.0	682.9	626.9	572.3
Discounted Power Benefit/1 (million US$)	495.1	457.9	420.7	383.7

/1: Discounted the power benefit for the economic life of 50 years at the year of 1989 using 10 % discount rate

4.2.5 Selection of Optimum Scale

For the selection of the optimum sclae of the Agos project, the project cost including the construction cost, operation and maintenance cost and replacement cost, and the project benefit are compared. Present worth (at the year of 1989) for the cost and benefit is calculated using the discount rate of 10 %, based on which net present worth for the different scale of the project is calculated. The result of the calculation is presented in the following table.

As indicated below, the highest net present worth is given for the project scale with the high water level of EL.165 m in plan A-2 and that of EL.165 m in plan A-1. However, the most optimum scale of the Agos project is to be finally determined within the framework of the whole Agos river system, which is discussed in the succeeding Chapter 5.

Present Worth Net Benefit and B/C

HWL	AG-175	AG-165	AG-155	AG-145
A-2				
B - C (million US$)	61.83	65.87	64.18	50.46
B/C	1.19	1.23	1.25	1.21
A-1				
B - C (million US$)	150.62	154.18	145.66	129.7
B/C	1.44	1.51	1.53	1.51

4.3 Kanan Hydro Power Project

4.3.1 General Description

The proposed damsite is selected at a V shaped gorge about 21 km upstream from the confluence of the Kanan and the Kaliwa (called Kanan No.1 damsite). The elevation of the river bed is about EL.168 m AMSL. The selected site is about 1.3 km upstream from the Kanan No.2 damsite planned by PICOREM, whose river bed elevation is about EL.150 m AMSL. This gorge has parallel high cliffs on both banks. Although any type of dam can be constructed at the site, a very narrow river section and rapid flood at the damsite favours the plan to construct a concrete gravity dam instead of fill type dam.

The estimated annual mean discharge at the damsite is 47.6 m^3/sec and the design flood for spillway of concrete gravity dam is 6,450 m^3/sec which corresponds to a return period of once in 200 years.

Both banks form steep cliffs with nearly 45 degrees up to EL.300 m having some exposed basalts, and alternation of sandstones and shales.

4.3.2 Alternative Plans Formulation (Kanan No.1 Dam)

In order to select the optimum scale of the Kanan hydro power project, 12 alternative plans consisting of 3 cases of different tail-water level, which depends on the high water level of the Agos dam, are compared. Three alternative high water levels are EL.300, EL.290 and EL.280 m, while four cases of the tailwater level are EL.175, EL.165, EL.155 and EL.145 m.

Basic plan is formulated for each different scale of the project. For the reservoir operation, the monthly uniform firm energy generation rule is applied. The installed capacity of the power station is determined for each different scale based on the same assumption as applied to the Agos hydro power station. The expected installed capacity is 168 MW to 115 MW depending on the high water level and tailwater level of the Kanan dam.

4.3.3 Preliminary Design

A concrete gravity dam is planned in view of its location and required diversion works. The dam will have the slope 1 in vertical to 0.1 in horizontal on the upstream side and 1 in vertical to 0.8 in horizontal on the downstream side. The spillway is to be provided in the middle of the dam. The free board above high water level is planned at 5 m in each case. A powerhouse is to be provided at the downstream toe of the dam in case of AG-175 (Tailwater level EL.175 m) and AG-165 (Tailwater level EL.165 m). In case of AG-155 (Tailwater level EL.155 m) and AG-145 (Tailwater level EL.145 m) an intake is to be provided at the right bank of the Makariya creek so that the length of the waterway can be shortened. Since there is no space enough for open powerhouse, an underground type is planned in cases of AG-155 and AG-145.

Main features of the different scale of the Kanan project are summarized in Table 4-5.

4.3.4 Construction Cost and Benefit

The work quantities of the dam are computed for each alternative on the basis of the preliminary design while the work quantities for the power facilities are derived from the established graphs and formulas. The unit prices are applied for the estimation of construction cost. All the cost estimate is made at the price level of early 1980. The estimated construction cost for each different scale is summarized in Tables 4-6 to 4-8.

The project benefit expected from the power generation is also calculated for each different scale of the project, of which summary is presented below. (Details of the benefit estimation for different cases are shown in Appendix F. Computer Output)

Case I HWL KN-300 (High water level is EL.300 m)

TWL of Kanan		AG-175	AG-165	AG-155	AG-145
Installed Capacity	(MW)	188	149	158	168
Average Annual Power Generation	(GWh)	411.6	439.2	466.9	500.8
Discounted Power Benefit/1	(million US$)	314.76	338.64	359.35	383.16

/1: Discounted the power benefit for the economic life of 50 years at the year of 1994 using 10 % discount rate

Case II HWL KN-290 (High water level is EL.290 m)

TWL of Kanan	AG-175	AG-165	AG-155	AG-145
Installed Capacity (MW)	127	138	147	157
Average Annual Power Generation (GWh)	380.7	413.5	435.8	463.8
Discounted Power Benefit/1 (million US$)	290.10	315.19	334.22	356.59

/1: Discounted the power benefit for the economic life of 50 years at the year of 1944 using 10 % discount rate

Case III HWL KN-280 (High water level is EL.280 m)

TWL of Kanan	AG-175	AG-165	AG-155	AG-145
Installed Capacity (MW)	115	127	135	144
Average Annual Power Generation (GWh)	349.0	383.0	404.5	432.7
Discounted Power Benefit/1 (million US$)	263.69	290.65	308.34	329.17

/1: Discounted the power benefit for the economic life of 50 years at the year of 1994 using 10 % discount rate

4.3.5 Selection of Optimum Scale

For selecting the optimum scale of the Kanan hydro power project, the cost and benefit are compared. Using the discount rate of 10 %, present worth of the cost and benefit (at the year of 1994) is calculated for estimating the net present worth benefit and benefit cost ratio, the results of which are presented in the following table.

Among 12 alternatives, the optimum scale of the Kanan hydro power project as a single project is KN-300 with the tail water level of 145 m. However, the final selection of the most optimum plan for the Kanan hydro power project is to be determined within the whole Agos river system, which is discussed in the succeeding Chapter 5, Selection of Optimum Scheme.

Present Worth of Net Benefit and B/C

HWL \ TWL of Kanan		AG-175	AG-165	AG-155	AG-145
KN-300	B - C (million US$)	80.34	103.71	111.34	127.91
	B/C	1.34	1.44	1.45	1.50
KN-290	B - C (million US$)	82.66	105.27	110.73	125.46
	B/C	1.40	1.50	1.50	1.55
KN-280	B - C (million US$)	78.94	102.65	106.87	120.18
	B/C	1.43	1.55	1.53	1.58

HWL: High water level of Kanan project

4.4 Kaliwa Pumped Storage Project

4.4.1 General Description

The Agos and the Kaliwa reservoirs can be connected with waterway. In this plan, water required for Metro Manila will be pumped up from the Agos reservoir to the Kaliwa reservoir using the waterway.

The Kaliwa river, between the confluence of the Kaliwa and Kanan rivers and the Laiban damsite, has the river bed slope of 1:270 up to EL.120 m, 1:90 up to EL.140 m and 1:250 up to EL.200 m. The river runs towards south about 6.5 km from the Laiban damsite, then runs towards east about 12.8 km from the turning point and runs towards north about 13.0 km to the confluence.

As for the precipitation and the run-off records, Kaliwa has similar characteristics to these of the Angat river, having two heavy rainy months, in August and December influenced by typhoons and monsoon. Annual mean discharge at the Kaliwa damsite is estimated to be 26.0 m^3/sec as described in the preceding chapter.

Geological investigation was carried out by field investigation together with aerial-photo interpretation. The geological composition of the area are predominant limestone composing the Sierra Madre mountain range, the alternation of sandstone and shale and graywacke. The proposed waterway crosses over the alternation of sandstone and shale, limestone and graywacke with the length of about 1.5 km, 2 km, 1 km, respectively, from the upstream side. On the lower part of mountain slope of limestone zone, there is thick talus deposit over-laying the alternation of sandstone and shale and graywacke.

The alternation of sandstone and shale is extremely folded in general. Limestone is whitish and massive, cave is seldom present. Bedding plane is not found in graywacke. No major geological structure presents but minor fault may exist in the alternation of sandstone and shale. The geological condition along the proposed waterway is, in general, good and the rock is sound and hard. Along the boundary between limestone and the alternation of sandstone and shale and graywacke, the spring water may come out during the excavation of the tunnel.

4.4.2 Alternative Plans Formulation (Kaliwa Pumped Storage)

Through the implementation of this project, the Agos and Kaliwa reservoirs are planned to be connected. The required water for Metro Manila will be pumped up from the Agos reservoir to the Kaliwa reservoir. Peak power generation using a pumped storage power station is also to be studied for determining the optimum scale of the project.

For the comparative study, two (2) cases of installed capacity of the Kaliwa pumped storage plant are considered. One is of 250 MW capacity for which the required water of 36.7 m^3/sec can be pumped up within 6 hrs. In this case, spare time may be utilized for additional pump-up and generation purpose. The other is of 100 MW capacity which will be used only for pumping up the water of 36.7 m^3/sec. Because it takes about 13 hrs to pump up the water for water supply, there is not enough time for pump-up and power generation.

The tail water level of the pumped storage project varies depending on the reservoir water level of the Agos dam. Therefore, comparison is made on four different tail water levels for both the 250 MW and 100 MW capacities.

4.4.3 Preliminary Design

The Kaliwa pumped storage project consists of two project components, one is the pumped storage project at the Kaliwa dam and the other is Kaliwa 2nd stage development project (Additional facilities from the intake of the Kaliwa reservoir to Pantay power plant/water treatment facilities).

There are mainly two factors affecting the cost of the pumped storage project. One is the cost of waterway including pump turbine and the other is the energy cost for pumping up. If the diameter of the waterway is reduced, the construction cost of waterway becomes cheap, but resulted head losses require more energy for pumping up. Comparison of diameter for the waterway is carried out ranging from 9.0 m to 6.0 m. Through the comparison, the optimum diameter is determined according to the head and installed capacity. Main features of the two alternative plans with different tail water levels are determined as shown in Table 4-10.

The annual electric energy required for pumping water for the two cases is summarized as shown below.

Unit: GWh/year

HWL of Agos	AG-175	AG-165	AG-155	AG-145
Case I (250 MW)				
For power generation	648.3	654.3	642.6	638.8
For water supply	390.1	434.8	477.8	521.9
Case II (100 MW)				
For water supply	395.5	437.2	480.1	526.1

Note: Required energy for full supply year

If the Kaliwa reservoir is commonly used for water supply and pumped storage power generation, additional space of 20 cm shall be added to the Kaliwa dam in case of 250 MW capacity. (The incremental cost of the Kaliwa dam is added to the case of 250 MW). As for the installed capacity of 100 MW, the required installed capacity would be less than 80 MW (depending on high water levels of the Agos reservoir). But, additional reserve capacity of 20 MW is planned against any problems including mechanical troubles.

The water treatment facilities and the additional power plant to be installed as the second stage development of Pantay were already planned by PICOREM, which is used for our comparative study.

4.4.4 Construction Cost and Benefit

The construction cost for the headrace tunnel, penstock line and tailrace tunnel is estimated on the basis of the preliminary design, while that for the other portion is estimated using the established formula and graphs. For the cost estimate of headrace tunnel and underground powerhouse, further allowance is considered taking the geological condition into account.

With respect to the cost for the water treatment facilities and the power plant at Pantay, the estimated cost for the Kaliwa 2nd stage development project in PICOREM's final report is applied for the analysis.

The estimated construction cost for two cases with different tail water levels is summarized in Tables 4-11 and 4-12. The energy cost for pumping up is estimated at US$0.04709/kWh, from the cost for oil fired power plant.

The expected benefits from the project are as follows:

i) Water supply benefit of 36.7 m^3/sec

ii) Capacity and energy benefit of the pumped storage power plant based on 4 hrs daily operation plus energy benefit of spillage water from the Kaliwa reservoir (in case of 250 MW)

iii) Capacity and energy benefit of the Pantay power plant

With respect to the capacity benefit of the pumped storage project, 95 % dependable capacity is applied on the basis of reservoir operation. The average dependable capacity of 50 years operation is shown in Table 4-10. The power benefit from the Pantay power plant is assessed by the same alternative thermal plant as applied to the Agos and Kanan hydro power projects.

The estimated power benefit for two cases with different tail water levels is presented in Table 4-13.

4.4.5 <u>Selection of Optimum Scheme</u>

In order to select the optimum scale of the project, costs including operation and maintenance, and benefit are compared. Using 10 % discount rate, the present worth net benefit and benefit cost ratio are calculated for different cases as presented below.

<u>250 MW</u>

HWL of Agos	AG-175	AG-165	AG-155	AG-145
B - C (million US$)	174.17	172.2	160.21	128.23
B/C	1.15	1.14	1.13	1.10

<u>100 MW</u>

HWL of Agos	AG-175	AG-165	AG-155	AG-145
B - C (million US$)	250.07	238.71	225.41	204.37
B/C	1.33	1.31	1.29	1.26

As expected, the optimum alternative plan is that the tail water level is EL.175 m for both 250 MW and 100 MW, meaning that the shorter waterway length and less head are more economical.

The comparison between 250 MW and 100 MW shows that the case of 100 MW gives the higher net benefit as shown in Table 4-14. This is because the energy cost for the pumping up is high as compared with the expected benefit. As commented by NAPOCOR, if the Kaliwa pumped storage project is evaluated by the Kalayaan project now under construction whose kW value of 3rd unit is estimated at around $46.44/kW, the benefit becomes less. Thus, the Kaliwa pumped storage project is planned to function only for pumping up the required water with the installed capacity of 100 MW.

4.5 Kaliwa Water Supply Project

The Kaliwa project was planned as multipurpose project of water supply of 22.1 m^3/sec to Metro Manila and power generation of 153 GWh annually. Since the feasibility of the Kaliwa project was already confirmed and the project is now under detailed study, the planned figures for the project are used for our comparative study on the optimization of the Agos river system. The Kaliwa water supply project consists of a dam with spillway, outlet works, a powerhouse and water treatment plant at Pantay and distribution system. However the cost downstream of primary distribution system is excluded from the benefit cost computation in the PICOREM's evaluation.

According to the development plan prepared by PICOREM, the Kaliwa damsite was selected at about 0.5 km downstream of the confluence of Lenatin and Limutan rivers, 8 km upstream from Daraitan. The water is led to the power plant and water treatment plant at Pantay through a tunnel of 13.6 km long.

Main features of the Kaliwa water supply project as outlined by PICOREM are shown in Table 4-15. The total cost is estimated at US dollar 514.2 million at 1989. The power benefit at Pantay is modified on the basis of the recent values as used in this report. Furthermore, the power benefit is deducted in the early stage of the development because the surplus water is used for the energy generation at the Agos power plant. Details are shown in Tables 4-17 and 4-18. The present worth of net benefit and benefit cost ratio at 1989 are estimated to be US dollar 235.1 million and 1.46 respectively.

4.6 Kanan Water Supply Project

Preliminary study on the Kanan Water Supply Project was already conducted by PICOREM as the second stage project for water supply to Metro Manila. After the development of the Kaliwa water supply project, the Kanan project was also planned as a multipurpose project of water supply of 36.7 m^3/sec to Metro Manila and power generation of 245 GWh annually.

According to the preliminary design, the Kanan dam (called Kanan No.2 damsite) is located at about 1.3 km downstream of the Kanan No.1 damsite planned by JICA team. The water is diverted to the Kaliwa reservoir through the interbasin tunnel of 14.5 km long. From the Kaliwa reservoir, the water is led to Pantay water treatment plant where the power plant is also provided. Main features of the Kanan water supply project as outlined by PICOREM is shown in Table 4-16.

The total cost is estimated at US dollars 888.3 million at 1994. The benefit is estimated to be US dollars 954.0 million by adjusting the power benefit as described in Section 4.5. The present worth of net benefit and benefit cost ratio are estimated to be US dollars 65.7 million and 1.07 respectively.

4.7 Kanan No.5 Hydro Power Project

The plan for the Kanan No.5 dam project was formulated by Lahmeyer in the study on the Luzon power plan which is basically applied for the comparative study on the combined alternative plans of the Agos river system.

The preliminary plan formulated by Lahmeyer is to construct a rock fill dam of 164 m in height and 19.8 million m^3 in volume to have 480 million m^3 effective storage. The water will be diverted through a headrace tunnel of about 5.7 km and penstock line to the power station to be constructed on the Agos river. It was suggested to install 280 MW generating capacity. Based on the cross-sectional survey and the study, the fill volume of dam and design flood are corrected. The main features of Kanan No.5 project are shown in Table 4-19. The cost is computed using the unit prices derived for the feasibility study of the Agos project. The cost of Kanan No.5 project is shown in Table 4-20. The power benefit derived from the project consisting of the kW benefit of 280 MW (95 % dependable capacity is 264 MW) and the kWh benefit of 930.3 GWh is US dollars 635.3 million discounted to 1989. The present worth net benefit and benefit cost ratio is US dollars 206.8 million and 1.48 respectively.

CHAPTER 5

SELECTION OF OPTIMUM SCHEME

5.1 Comparison of Alternative Development Plans

On the basis of the results on the comparative study on each component for the development of the Agos river system, comparison on the four combined alternative development plans is made by calculating the present worth of the total costs and benefits. For the calculation of the present worth, all the costs and benefits are discounted at the year of 1989 (January) using the discount rate of 10 % per year. The calculation results are summarized below and the details are presented in Table 5-1.

Present Net Worth and B/C for Alternative Plans

	Optimum HWL		B - C (10^6US$)	B/C
	Agos (m)	Kanan (m)		
Plan A-1	165	290	504.07	1.48
Plan A-2	165	295	391.17	1.27
Plan A-3	165	290	504.85	1.53
Plan B	-	260	491.30	1.47

Benefits and costs are discounted at the year of 1989 using discount rate of 10 %.

As indicated in the table, plan A-1 shows the highest present worth net benefit out of the four combined alternative plans though the difference between the alternative plans is small.

Between the two alternative plans, plan A-2 and A-3, which are formulated in due consideration of the requirement of the water supply to Metro Manila, plan A-3 is superior to plan A-2 in terms of both benefit cost ratio and net benefit. The difference between two is derived mainly from the cost of the Kanan dam. PICOREM selected the Kanan No.2 damsite which is located at about 18 m lower in elevation than the Kanan No.1 damsite. The cost of the Kanan No.2 dam in plan A-2 is higher than the Kanan No.1 dam in plan A-3 and the difference of the dam construction cost is about US$90 million. The discounted value to January 1989 is US$73.1 million. Even if the plan A-2 is evaluated by applying the cost of the Kanan No.1 dam, the superiority of the plan A-3 will not be changed.

With respect to the benefit of the Agos project, the benefit in plan A-3 is decreased than that in plan A-2 because small reservoir capacity of Kanan planned by PICOREM makes the spilled water from the Kanan reservoir increase. The benefit of the Kanan and Kaliwa water supply projects are put the same value in the plan A-2 and plan A-3, though our computed results in plan A-3 are different from those (refer to Appendix F) which may be caused by different criteria of inflow series, of which in PICOREM study the droughty year 1969's inflow is shifted to the end of 1974's inflow, and different operation rule as described in Section 3.6.

At present the water supply project is already in detailed design stage and the Kanan river is also considered in the next stage as the most promising water sources to Metro Manila. However, if the Kanan water supply project is disqualified or discarded by some reasons, the Agos and the Kanan hydro power stations will be able to use all the discharges for the project life. Only in this case, either plan A-1 or plan B can be materialized. Between the two alternative plans, plan A-1 is marginally favourable to plan B and the Agos Kanan No.1 joint hydro power scheme is proved to be more beneficial than the single Kanan No.5 power scheme.

5.2 Selection of the Priority Scheme

As indicated in the cost benefit comparison, plan A-3 is to be selected as the most optimum development plan in the Agos river system. However, the priority or selection of the scheme cannot be judged only by the economic comparison. In fact, Metro Manila would need much more water even after the realization of Kaliwa project in a long run. Therefore, most probably the Kanan water supply project will be implemented in some future.

Under this situation, the Agos dam project is the only possible plan for the hydro power development utilizing the remaining watershed of the Agos river. As discussed in the earlier section, the Agos hydro power project still maintains its economic viability even if the Kanan discharge will be fully diverted to Metro Manila. Therefore, the Agos hydro power project is selected as the most promising project among other hydro power development plans in the Agos river system, for which detailed study is to be made in the subsequent stage.

CHAPTER 6

PROJECT OPTIMIZATION STUDY

In Chapter 5, it has been made clear that the Agos hydro power project is prominent project among Agos river system (including the Kanan and Kaliwa rivers). In fact, the project is the only one which utilize the indigeneous resources effectively in the remaining watershed of the Agos river. In this section, the optimum scale of the Agos hydro power project is discussed in detail based on the results of layout study described in Appendix E, though roughly compared in the preceding chapter.

In order to find out the most optimum reservoir capacity of the Agos project as well as the installed capacity, 4 cases of reservoir high water level, EL.175, EL.165, EL.155 and EL.145 m are examined. The case of EL.175 m is the one proposed in the pre-feasibility study and the maximum water level as the river bed elevation of the proposed Kaliwa dam is at EL.175 m.

6.1 Criteria for Optimization Study

The draw-down is taken one third of gross head. Rated water level is fixed at one-half of draw-down. The installed capacity is the function of reservoir capacity. Based on the daily load curve, the capacity of each alternative plant should be operated more than 8 hrs per day on an average for 50 years project life. The installed capacity of each alternative is shown in Table 6-1.

In order to select the optimum scale, the benefit cost analysis is applied. The values for 50 years project life are discounted to the year of commission at the discount rate of 10 %. Furthermore, sensitivity tests are carried out to examine the effects of increase or decrease of benefit and cost.

The unit prices in the early 1980 are applied for the estimation of cost of the Agos project. The operation and maintenance cost is estimated by multiplying 0.5 % for dam works and 2.5 % for power facilities by the construction cost. Replacement cost is derived assuming that the life time of hydro-mechanical and electro-mechanical equipment is 35 years.

6.2 Concept of the Work

The layout used for the optimization study is based on the result of the layout study in Appendix E.

The rock fill dam has the slope of 1 vertical to 2.5 horizontal on upstream side and 1 vertical to 1.9 horizontal on downstream side. The width of crest is 12.0 meters. The spillway equipped with 4 nos of 14.0 x 14.5 m gates and 2 lanes of 210 m long side channels is provided at the left bank to discharge the design flood of 10,600 m^3/sec. The two diversion tunnels of 9.0 m diameter are selected to discharge the routed design flood Q = 5,210 m^3/sec. The cofferdam, being fixed its crest elevation at EL.93 m, is mostly incorporated in the main dam. The power waterway and powerhouse is located at the left bank. The layout of the waterway is intended to utilize the part of the diversion tunnel as much as possible. The power tunnel consists of an intake tower, one headrace tunnel of 6.2 m diameter and penstock line of 6.1 m diameter keeping the velocity in the waterway less than 5.5 m/sec. Main features of alternatives are shown in Table 6-1.

6.3 Selection of Optimum Scale

The breakdown of cost estimates on each alternative is shown in Table 6-2. The benefit flows for 50 years project life of each alternative are shown in Appendix F. The summary of benefit is as follows.

HWL (m)		AG-175	AG-165	AG-155	AG-145
Installed capacity	(MW)	152	140	128	116
Generated energy in 1989	(GWh)	773	711	652	593
1994		677	625	572	521
2009		428	397	364	332
Present worth benefit	(million US$)	382.14	352.24	322.41	292.71

Note: 1989 is the year of commission of the Agos project.
1994 is the year of Kaliwa water is fully utilized for water supply.
2009 is the year of Kanan water is fully utilized for water supply.

As aforementioned, the economic comparison of the alternative plans has been made on the basis of the project cost and benefit. The results are explained in the values of net benefit (B-C), benefit-cost ratio (B/C) and production cost. The production cost is defined as annual cost divided by 50 years average annual generated energy. The selection should be done among alternatives which gives the maximum net benefit. In addition to the estimated benefit cost analysis, the sensitivity test has been carried out in the following cases;

-- 10 % cost increase tests the effect of cost increase to the selection to compensate the underestimation of cost or work quantities.

-- 10 % fuel cost increase tests the effect of recent trend of increasing fuel price for alternative thermal plant, thus leads the hydro power project more viable and avoids the undersizing the scale of the project.

-- 10 % cost decrease tests the overestimate of cost or another layout to lower the construction cost in further design stage.

-- Kanan water supply project's 10 years' delay of commissioning tests the effect of possible increase of energy generated by the Agos project.

-- Agos 20 years' delay verifies the project viability even if the Agos project is developed after Kanan and Kaliwa water are fully utilized for water supply.

The results are shown in Table 6-3. Optimum scale which gives the maximum net benefit is of HWL.165 m and its installed capacity of 140 MW in normal case. In most cases of sensitivity tests, the scale of HWL.165 m is favored. The most probable case would be of the combination of fuel cost 10 % up and may be the delay of Kanan water supply project for several years. In fact, due to the recent price-up and the disturbance in Middle East, the price of oil is rising to US$32/barrel or more. The HWL.165 m is also the best among all other alternatives in this most probable case. Even if the Agos project be delayed for sometime due to the future change of power demand, the HWL.165 m, though the HWL.155 m is preferable to HWL.165 m with a negligible small difference of only US dollars 1.6 million, is still attractive. Therefore taking the above economic comparison in due consideration, the scale of the Agos project is recommended to be at HWL.165 m having its installed capacity of 140 MW.

As the river bed elevation of Kanan No.2 site selected by PICOREM is around EL.150 m, the Kanan dam will be submerged about 15 m deep. This would result in the construction difficulty for construction of the Kanan dam. It is suggested that the damsite of the Kanan be shifted to upstream Kanan No.1 site so as to minimize the submergence. The difference of 18 m in elevation between Kanan No.1 and No.2 reduced the embankment volume of the Kanan dam, though the catchment area and reservoir capacity of No.1 site is almost the same with these of No.2 site.

TABLES

Table 2-1 Recorded Monthly Discharge Series at Banugao G.S. on the Agos River

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
1950	237.16	118.92	135.28	55.67	31.06	30.09	59.70	73.07	55.33	211.04	217.44	274.75	124.96
1951	198.22	118.41	44.14	36.78	94.19	49.19	54.04	162.97	67.49	81.44	405.81	386.36	141.59
1952	240.30	135.38	49.80	47.46	32.66	55.31	50.26	157.82	108.25	434.73	109.90	297.24	143.26
1953	180.02	188.07	54.84	56.21	27.88	56.10	34.37	106.79	49.31	182.14	190.28	410.10	128.01
1954	160.50	106.40	183.45	45.18	32.12	26.51	32.66	45.13	51.11	62.60	123.77	414.52	107.00
1955	333.78	74.20	46.96	49.98	31.96	65.03	56.13	37.45	71.54	160.01	282.56	191.60	116.77
1956	163.45	118.30	151.42	173.07	76.06	75.85	97.91	99.65	154.16	260.76	275.66	550.70	183.08
1957	254.14	79.98	41.15	31.36	21.65	23.66	39.53	81.86	61.98	89.04	106.15	73.54	75.34
1958	145.97	78.63	73.31	86.02	78.19	74.29	91.39	66.20	90.36	203.70	190.50	68.95	103.96
1959	140.80	92.21	137.06	33.50	21.23	26.40	41.75	60.09	69.82	86.15	220.91	205.25	94.60
1960	154.06	183.22	55.40	46.78	69.95	88.11	77.20	238.56	140.40	247.50	189.78	192.26	140.27
1961	196.13	154.70	119.01	77.43	100.68	76.30	64.69	60.61	112.18	197.45	289.52	117.47	130.51
1962	167.20	133.01	77.71	76.65	34.85	34.82	99.44	79.98	203.40	112.71	206.80	185.91	117.71
1963	147.76	161.74	81.04	69.57	25.04	48.27	61.80	103.67	143.33	113.13	106.90	192.50	104.56
1964	154.03	151.59	126.17	80.05	45.43	65.87	96.23	113.68	115.67	120.05	316.35	297.78	140.24
1965	193.82	113.68	70.88	31.20	26.63	27.27	68.14	58.37	72.58	143.85	223.91	306.72	111.42
1966	100.69	75.65	30.07	20.89	74.03	31.56	33.93	37.24	83.62	195.54	284.13	261.42	102.40
1967	201.66	77.33	74.45	55.51	44.97	65.33	51.04	105.50	79.42	64.83	222.95	183.30	102.19
1968	149.48	149.49	149.11	98.38	32.86	29.37	48.79	90.55	93.67	127.85	131.68	78.94	98.35
1969	82.09	34.49	43.11	27.38	15.52	12.60	37.42	57.70	69.06	70.08	111.90	300.75	71.84
1970	146.59	56.51	24.58	41.50	16.47	24.36	37.47	26.97	118.77	209.79	391.53	228.58	110.26
1971	128.61	175.54	161.45	48.88	194.96	239.70	267.25	103.18	53.56	233.52	256.11	343.03	183.82
1972	137.71	66.55	77.72	66.97	64.93	66.17	314.99	193.14	130.04	109.34	192.60	231.45	137.63
1973	90.90	105.30	56.50	47.10	44.70	59.80	64.30	44.80	55.40	184.70	316.00	412.60	123.51
1977	208.90	191.70	118.20	54.10	45.60	33.10	101.00	85.80	123.80	98.70	262.40	128.10	120.95
1978	96.70	72.70	42.20	19.80	32.20	43.40	45.00	130.50	148.90	326.20	224.10	285.30	122.25
TOTAL	4410.67	3013.70	2225.01	1477.42	1315.82	1428.46	2026.43	2421.28	2523.15	4326.85	5849.64	6619.12	37637.55
MEAN	169.64	115.91	85.58	56.82	50.61	54.94	77.94	93.13	97.04	166.42	224.99	254.58	120.63

Table 2-2 Estimated Average Monthly Discharge at the Proposed Damsites

(m^3/sec)

Month	Kaliwa Damsite (279 km^2)	Kanan No.1 Damsite (285 km^2)	Agos Damsite (867 km^2)	Agos Afterbay Weir (894 km^2)	At Banugao G. S. (911 km^2)
January	14.97	89.55	151.49	158.05	162.03
February	6.61	66.23	105.19	110.04	112.98
March	3.55	49.50	76.50	80.12	82.32
April	2.64	30.99	48.52	50.79	52.17
May	3.02	26.79	43.08	45.04	46.23
June	5.66	25.11	44.73	46.57	47.68
July	35.33	8.90	66.97	67.62	68.02
August	48.88	7.98	86.45	87.03	87.39
September	44.47	15.36	90.25	91.38	92.06
October	37.57	62.91	147.91	152.51	155.31
November	50.53	89.27	205.63	212.16	216.13
December	58.77	98.61	231.68	238.90	243.28
Mean	26.00	47.60	108.20	111.68	113.80
Specific Discharge per 100 km^2	9.32	16.7	12.5	12.5	12.5

Table 2-3 Available Discharge of the Agos River System

	A	Q	$\frac{Q}{A}$ x 100	Re/1	Rℓ	R/2	$\frac{Re}{R}$ x 100
	Km^2	m^3/sec	m^3/sec/100 Km^2	mm	mm	mm	%
Kanan No.1 Dam	285	47.6	16.7	5,270	730	6,000	87.8
Lower Kanan	108	16.6	15.4	4,850	750	5,600	86.6
Kanan River	393	64.2	16.3	5,150	740	5,890	87.4
Kaliwa Dam	279	26.0	9.32	2,940	590	3,530	83.3
Lower Kaliwa	194	18.0	9.30	2,930	640	3,570	82.1
Kaliwa River	473	44.0	9.30	2,930	600	3,550	82.5
Agos No.1 Dam	867	108.2	12.5	3,940	670	4,610	85.5
Agos River Confluence-Banugao	45	5.6	12.5	3,940			
Agos River at Banugao	911	113.8	12.5	3,940			

Note: /1; converted from the discharge

/2; obtained from the estimated isohyetal map

Table 2-4 Recorded Monthly Discharge Series at Matatio G.S. on the Kanan River

(m^3/sec)

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL MEAN
1946	122.6**	91.1**	76.5*	68.1	42.5	33.8	32.1	26.8	50.8	157.0	132.8	181.1*	84.6*
1947	110.2	79.0	104.4	56.4*	46.2	35.9	41.8	83.7	58.5	129.4	152.0	174.6	89.3
1948	116.7*	75.6	96.3**	50.1**	40.8	32.5	49.4	55.9	77.5	113.7	114.6	175.5	83.2*
1949	131.1*	109.5*	79.3*	27.7	21.8	13.4	18.6	12.3	41.4	81.7	185.7	168.9	74.3*
1950	132.3	100.2	125.0	48.1	27.2	23.7	29.8	42.7	35.2	109.2	149.5	176.0	83.2
MEAN OF 5 YEARS	122.6*	91.1*	96.3*	50.1*	35.7	27.9	34.3	44.3	52.7	118.2	146.9	175.2*	82.9*

* mark means incomplete record

** computed as the mean of other years

Table 2-5 Recorded Monthly Discharge Series at Daraitan G.S. on the Kaliwa River

(m^3/sec)

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL MEAN
1936											28.9	80.2	-
1937	17.1	7.8	4.0	1.8	2.5	4.6	43.3	88.2	39.1	27.9	67.8	111.4	34.6
1938	17.1	5.9	4.0	8.2	11.0	7.4	33.1	9.0	13.7	65.4	221.1	40.7	36.4
1939	19.6	9.1	3.6	4.7	7.6	5.3	24.9	32.7	28.2	11.6	40.4	311.2	41.6
1940	13.0	6.2	2.4	2.1	2.2	3.1	125.5	48.8	107.0	17.4	12.0	26.5	30.5
1941	7.7	3.8	1.6	1.1	0.9	6.4	54.8	56.2	70.1	43.1	24.2	15.6	23.8
1942						6.8	43.0	71.5	34.5	70.0	57.1		-
1946	16.1*	7.5*	5.2	3.1*			8.6	17.5	19.7	80.8	20.2	19.0	-
1947	10.9	3.5	4.6	2.7	1.9	5.8	11.2	54.6	22.7	48.8	120.7	77.2	30.4
1948	13.0	7.8	2.9	2.3	2.8	8.8	43.6	84.0	157.0	26.1	31.6	52.6	36.0
1949	15.8*	9.4*	5.2*	2.7*	1.9	5.8	14.1	14.6	12.2	19.2	43.9	88.9	19.5*
1950	19.6	11.6	4.7	3.1	2.1	6.3	23.4	32.4	13.4	48.1	34.4	62.7	21.8
Mean of 8 complete years	147.75	6.96	3.48	3.25	3.88	5.96	44.98	50.74	56.4	36.05	69.03	87.24	31.89
$\bar{Q}j/\bar{Q}m$	0.4625	0.2183	0.1091	0.1019	0.1217	0.1869	1.4105	1.5911	1.7686	1.1304	2.1646	2.7357	

* mark means incomplete record

Table 4-1 Main Feature of Alternative Scheme Agos Hydropower Project

	AG-175	AG-165	AG-155	AG-145
Reservoir				
HWL (m)	175.0	165.0	155.0	145.0
LWL (m)	135.0	128.0	120.8	113.8
Live storage ($x10^6m^3$)	695.0	550.0	438.0	336.0
Main dam				
Crest Elevation (m)	182.0	172.0	162.0	152.0
Crest length (m)	810.0	780.0	735.0	695.0
Dam height above foundation (m)	182.0	172.0	162.0	152.0
Dam volume incl. cofferdams ($x10^6m^3$)	20.1	16.8	13.95	11.4
Spillway				
Design discharge (m^3/sec)	10,600			
Type	12.5H x 12W x 10 nos. gated spillway			
Diversion tunnels				
Design discharge (m^3/sec)	5,210			
Number	2			
Diameter (m)	12.0			
Length (m)	830/935	780/885	740/845	650/755
Power tunnel				
Maximum discharge (m^3/sec)	167.6	168.5	167.7	167.6
Diameter (m)	6.3	6.3	6.3	6.3
Length (m)	800	800	800	800
Penstock line				
Type	Embedded in tunnel			
Number	1	1	1	1
Diameter of penstock (m)	5.4	5.4	5.4	5.4
Length (m)	285	275	265	255
Power house				
Installed capacity (MW)	152	140	128	116
Number of unit	2	2	2	2
Rated head (m)	107.6	98.6	90.6	82.1
Tail water level (m)	41.5	41.5	41.5	41.5

Table 4-2 Summary of Project Cost of Alternatives
Agos Hydropower Project

(million US dollars)

	AG-175	AG-165	AG-155	AG-145
1. Land acquisition	3.2	2.7	2.3	1.95
2. Preparatory work	1.9	1.66	1.46	1.35
3. Diversion tunnels	27.3	26.1	24.8	23.4
4. Main & Cofferdams	141.83	119.16	99.5	81.78
5. Foundation treatment	5.54	4.83	4.25	3.95
6. Spillway	15.72	15.72	17.23	26.32
(1-6)	(195.45)	(170.16)	(149.54)	(138.77)
7. Intake & Power Tunnel	6.01	5.96	5.89	5.84
8. Surge tank	1.10	1.10	1.10	1.10
9. Penstock line	3.25	3.06	2.87	2.67
10. Powerhouse	4.65	4.43	4.19	3.94
11. Tailrace	1.23	1.23	1.23	1.23
12. Switchyard & Sub st. (Civil)	0.6	0.6	0.6	0.6
13. Transmission line (Civil)	0.79	0.78	0.77	0.76
14. Permanent quarters & Flood forecasting system	3.6	3.6	3.6	3.6
15. Electro mechanical work	27.21	26.04	24.96	23.78
16. Transmission line	3.17	3.10	3.00	2.98
17. Switchyard	2.00	1.9	1.8	1.7
(7-17)	53.61	51.80	50.01	48.20
18. Contingency (10%)	24.91	22.20	19.96	18.70
19. Engineering and Administration	21.92	19.53	17.56	16.45
Grand Total	295.88	263.69	237.07	222.12
Operation and Maintenance cost	22.98	21.28	19.81	18.83
Replacement cost	1.45	1.40	1.35	1.30
Present worth total cost	320.31	286.37	258.23	242.25

Table 4-3 Summary of Benefit Cost Analysis
Agos Hydropower Project

Plan A-2

(million US dollars)

	Benefit	Cost	B/C	B - C
AG-175	382.14	320.31	1.19	61.83
AG-165	352.24	286.37	1.23	*65.87
AG-155	322.41	258.23	1.25	64.18
AG-145	292.71	242.25	1.21	50.46

Plan A-3 (Kanan No.1 HWL 290 m)

	Benefit	Cost	B/C	B - C
AG-175	381.25	320.31	1.19	60.94
AG-165	351.49	286.37	1.23	*65.12
AG-155	321.65	258.23	1.25	63.42
AG-145	291.91	242.25	1.20	49.66

Table 4-4 Installed Capacity and Generated Energy
Kanan Hydropower Project

HWL (m)	LWL (m)	Tail Water Level (m)	Installed Capacity (MW)	Generated Energy (GWh/y) Total	(Primary/Secondary)	Rated discharge (m^3/sec)
300	270	175	138	411.62	(239.25/172.37)	154.2
		165	149	439.20	(255.75/183.45)	152.1
		155	158	466.85	(272.63/194.22)	151.2
		145	168	500.75	(293.63/207.12)	148.8
290	260	175	127	380.66	(204.75/175.91)	156.0
		165	138	413.49	(223.50/189.99)	154.2
		155	147	435.81	(235.50/200.31)	152.7
		145	157	463.78	(251.25/212.53)	152.7
280	250	175	115	349.03	(162.00/187.03)	157.6
		165	127	383.02	(179.25/203.77)	156.2
		155	135	404.51	(189.38/215.13)	153.9
		145	144	432.65	(203.63/229.02)	152.6

Table 4-5 Main Features of Alternative Scheme
Kanan Hydropower Project

Dam and relevant works

	KN-300	KN-290	KN-280
Reservoir			
HWL (m)	300	290	280
LWL (m)	270	260	250
Live storage ($x10^6 m^3$)	452	350	257
Main dam			
Crest elevation (m)	305	295	285
Crest length (m)	465	425	390
Dam height (m)	155	145	135
Concrete volume ($x10^3 m^3$)	1,728	1,443	1,196
Spillway			
Design discharge (m^3/sec)		6,450	
Type	Gated overflow	15^h x 13.5^v x 4 nos	

Power facilities KN-300	AG-175	AG-165	AG-155	AG-145
Number of headrace	-	-	1	1
Diameter (m)	-	-	5.9	5.9
Length (m)	-	-	750	1,400
Number of penstock	2	2	1	1
Diameter (m)	3.6	3.6	5.1	5.1
Length (m)	205	220	185	200
Installed capacity (MW)	138	149	158	168
Rated head (m)	118.3	127.7	135.2	143.5
Rated discharge (m^3/sec)	154.0	152.2	151.2	151.4

Power facilities KN-290	AG-175	AG-165	AG-155	AG-145
Number of headrace	-	-	1	1
Diameter (m)	-	-	6.0	6.0
Length (m)	-	-	170	185
Number of penstock	2	2	1	1
Diameter (m)	3.7	3.6	5.1	5.1
Length (m)	190	205	750	1,400
Installed capacity (MW)	127	138	147	157
Rated head (m)	108.8	118.5	125.7	134.4
Rated discharge (m^3/sec)	156.4	154.0	152.9	153.0

Power facilities KN-280	AG-175	AG-165	AG-155	AG-145
Number of headrace	-	-	1	1
Diameter (m)	-	-	6.0	6.0
Length (m)	-	-	750	1,400
Number of penstock	2	2	1	1
Diameter (m)	3.7	3.7	5.1	5.1
Length (m)	175	190	155	170
Installed capacity (MW)	115	127	135	144
Rated head (m)	99.0	108.9	115.9	123.4
Rated discharge (m^3/sec)	158.0	156.4	153.9	152.8

Table 4-6 Construction Cost of Alternatives
Kanan Hydropower Project

HWL KN-300

(million US dollars)

	AG-175	AG-165	AG-155	AG-145
1. Land acquisition	3.20	3.20	3.20	3.20
2. Preparatory works	9.00	9.00	10.00	10.50
3. Diversion works	18.04	18.04	18.04	18.04
4. Main concrete dam	87.68	87.68	87.68	87.68
5. Foundation treatment	5.26	5.26	5.26	5.26
6. Spillway	2.52	2.52	2.52	2.52
7. Waterway	4.67	4.87	9.09	12.59
8. Powerhouse	4.26	4.44	6.40	6.57
9. Transmission & Substation (Civil)	3.63	3.64	4.86	4.86
10. Permanent quarters & Flood forecasting system	2.80	2.80	2.80	2.80
(Sub-total)	(141.06)	(141.45)	(149.85)	(154.04)
11. Electro-mechanical equipment	27.46	27.34	28.12	28.90
12. Transmission line	4.91	4.99	5.06	5.13
13. Substation at Malaya	6.09	6.09	6.09	6.09
(Sub-total)	(38.46)	(38.42)	(39.27)	(40.12)
14. Contingency (10%)	17.95	17.99	18.91	19.42
15. Engineering & Administration (8%)	15.80	15.83	16.64	17.09
Total construction cost	213.27	213.69	224.67	230.66
O & M cost	19.57	19.66	21.75	22.90
Replacement cost	1.58	1.58	1.59	1.63
Present Worth Cost	234.42	234.93	248.01	255.19

Table 4-7 Construction Cost of Alternatives
Kanan Hydropower Project

HWL KN-290

(million US dollars)

	AG-175	AG-165	AG-155	AG-145
1. Land acquisition	3.20	3.20	3.20	3.20
2. Preparatory works	9.00	9.00	10.00	10.50
3. Diversion works	15.16	15.16	15.16	15.16
4. Main concrete dam	73.26	73.26	73.26	73.26
5. Foundation treatment	4.40	4.40	4.40	4.40
6. Spillway	2.52	2.52	2.52	2.52
7. Waterway	4.58	4.67	9.00	12.57
8. Powerhouse	4.07	4.26	7.01	8.30
9. Transmission & Substation (Civil)	3.61	3.63	4.84	4.86
10. Permanent quarters & Flood forcasting system	2.80	2.80	2.80	2.80
(Sub-total)	(122.60)	(122.90)	(131.44)	(135.68)
11. Electro-mechanical equipment	24.77	26.08	27.05	28.10
12. Transmission line	4.83	4.91	4.98	5.05
13. Substation at Malaya	6.09	6.09	6.09	6.09
(Sub-total)	(35.69)	(37.08)	(38.12)	(39.24)
14. Contingency (10%)	15.83	16.00	16.96	17.49
15. Engineering & Administration	13.93	14.08	14.92	15.39
Total construction cost	188.05	190.06	201.44	207.80
O & M cost	17.91	18.33	20.51	21.74
Replacement cost	1.48	1.53	1.54	1.59
Present Worth Cost	207.44	209.92	223.49	231.13

Table 4-8 Construction Cost of Alternatives
Kanan Hydropower Project

HWL KN-280

(million US dollars)

	AG-175	AG-165	AG-155	AG-145
1. Land acquisition	3.20	3.20	3.20	3.20
2. Preparatory works	9.00	9.00	10.00	10.50
3. Diversion works	12.66	12.66	12.66	12.66
4. Main concrete dam	60.80	60.80	60.80	60.80
5. Foundation treatment	3.65	3.65	3.65	3.65
6. Spillway	2.52	2.52	2.52	2.52
7. Waterway	4.36	4.58	8.92	12.36
8. Powerhouse	3.84	4.07	6.09	6.22
9. Transmission & Substation (Civil)	3.58	3.61	4.82	4.84
10. Permanent quarters & Flood forcasting system	2.80	2.80	2.80	2.80
(Sub-total)	(106.41)	(106.89)	(115.46)	(119.55)
11. Electro-mechanical equipment	23.12	24.77	25.65	26.78
12. Transmission line	4.75	4.83	4.90	4.95
13. Substation at Malaya	6.09	6.09	6.09	6.09
(Sub-total)	(33.96)	(35.69)	(36.64)	(37.82)
14. Contingency (10%)	14.04	14.26	15.21	15.74
15. Engineering & Administration	12.35	12.55	13.38	13.85
Total construction cost	166.76	169.39	180.69	186.96
O & M cost	16.58	17.13	19.29	20.50
Replacement Cost	1.41	1.48	1.49	1.53
Present Worth Cost	184.75	188.00	201.47	208.99

Table 4-9 Summary of Benefit Cost Analysis
Kanan Hydropower Project

(million US dollars)

HWL	TWL	Cost	Benefit	B/C	B-C
KN-300	175	234.42	314.76	1.34	80.34
	165	234.93	338.64	1.44	103.71
	155	248.01	359.35	1.45	111.34
	145	255.19	383.16	1.50	*127.91
KN-290	175	207.44	290.10	1.40	82.66
	165	209.92	315.19	1.50	105.27
	155	223.49	334.22	1.50	110.73
	145	231.13	356.59	1.55	125.46
KN-280	175	184.75	263.69	1.43	78.94
	165	188.00	290.65	1.55	102.65
	155	201.47	308.34	1.53	106.87
	145	208.99	329.17	1.58	120.18

Table 4-10 Main Features of Alternatives

Kaliwa Pumped Storage Project

250 MW

Alternatives	AG-175	AG-165	AG-155	AG-145
Power tunnel				
Numbers		2		
Diameter (m)	8.3	7.6	7.6	7.6
Length (m)	1,720.	1,720.	1,720.	1,720.
Penstock line				
Numbers		2		
Diameter (m)	5.9	6.0	6.0	6.0
Length (m)	225.	240.	255.	260.
Tailrace tunnel				
Numbers		2		
Diameter (m)	8.3	7.6	7.6	7.6
Length (m)	2,400.	2,800.	3,400.	4,900.
Generating/pumping equip.				
Installed capacity (MW)		250		
Maximum discharge (m^3/sec)	392.6	352.4	311.4	281.7
95% dependable cap. when generating (MW)	210.8	213.5	214.	214.3

100 MW

Alternatives	AG-175	AG-165	AG-155	AG-145
Power tunnel				
Numbers		1		
Diameter (m)	6.5	6.5	6.5	6.5
Length (m)	1,720.	1,720.	1,720.	1,720.
Penstock line				
Numbers		1		
Diameter (m)	6.2	6.2	6.2	6.2
Length (m)	225.	240.	255.	260.
Tailrace tunnel				
Numbers		1		
Diameter (m)	6.5	6.5	6.5	6.5
Length (m)	2,400.	2,800.	3,400.	4,900.
Generating/pumping equip.				
Installed capacity (MW)		100		
Maximum discharge (m^3/sec)	175.6	146.1	127.8	117.6
95% dependable cap. when generating (MW)	84.3	85.4	85.6	85.7

Table 4-11 Summary of Project Cost (1/2)

Kaliwa Pumped Storage Project

250 MW

(million US dollars)

	AG-175	AG-165	AG-155	AG-145
1. Land acquisition	0.1	0.1	0.1	0.1
2. Preparatory work	1.0	1.0	1.0	1.0
3. Waterway	58.49	54.70	60.11	74.64
4. Powerhouse	14.45	14.33	14.19	14.07
5. Transmission line (c)	1.52	1.52	1.52	1.52
6. Quaters	0.50	0.50	0.50	0.50
Sub-total	(76.06)	(72.15)	(77.42)	(91.83)
7. Equipment	81.23	79.58	78.10	76.25
8. Contingency (20%)	31.46	30.35	31.10	33.62
9. Engineering (8%)	15.10	14.57	14.93	16.14
10. Kaliwa dam additional	0.52	0.52	0.52	0.52
Total const. cost	204.37	197.17	202.07	218.36
Present worth cost discounted to 1994	248.31	239.56	245.52	265.31
O & M cost	38.99	37.61	38.55	41.66
Replacement	2.92	2.86	2.81	2.74
Energy cost for power	300.10	302.94	297.50	295.74
Energy const. for w/s	107.09	119.39	131.24	143.42
Total cost	697.41	702.36	715.62	748.87

Table 4-11 Summary of Project Cost (2/2)

Kaliwa Pumped Storage Project

100 MW

(million US dollars)

	AG-175	AG-165	AG-155	AG-145
1. Land acquisition	0.10	0.10	0.10	0.10
2. Preparatory work	1.00	1.00	1.00	1.00
3. Waterway	23.28	24.06	25.77	30.96
4. Powerhouse	11.23	11.12	11.03	10.96
5. Transmission line (c)	1.38	1.38	1.38	1.38
6. Quaters	0.50	0.50	0.50	0.50
Sub-total	(37.49)	(38.16)	(39.78)	(44.90)
7. Equipment	36.09	35.37	34.59	34.05
8. Contingency (20%)	14.72	14.71	14.87	15.79
9. E & A (8%)	7.06	7.06	7.14	7.58
Total construction cost	95.36	95.30	96.38	102.32
Present worth cost discounted to 1994	115.86	115.79	117.10	124.32
O & M cost	18.24	18.23	18.43	19.57
Replacement	1.28	1.26	1.23	1.21
Energy cost for w/s	108.59	120.05	131.87	144.57
Total cost	243.97	255.33	268.63	289.67

Table 4-12 Kaliwa Pumped Storage Project

The cost for PICOREM's Kaliwa 2nd stage development (excluding the cost for dam, appurtenant works and interbasin tunnel)

(million US dollars)

Work Items	Amount
Outlet Works (Kaliwa Reservoir to Pantay)	59.1
Powerplant	25.9
Water treatment plant	79.9
Waterway & storage	54.0
Module 1 supply works	17.2
Permanent Facilities	2.8
Temporary Facilities	4.9
Sub-total	(217.9)
Engineering and Administration (12%)	26.1
Contingency (10%)	24.4
Total construction cost	268.5
Present worth cost discounted to 1994	334.82
O & M cost	165.7
Replacement	6.2
Total cost	506.72

Table 4-13 Summary of the Present Worth of Benefit (discounted to 1994)

Kaliwa Pumped Storage Project

250 MW

(million US dollars)

	AG-175	AG-165	AG-155	AG-145
Capacity and energy benefit of P.S.	371.27	373.63	374.15	374.73
Energy benefit of spillage water	6.30	6.92	7.67	8.36
Water supply benefit	915.60	915.60	915.60	915.60
Capacity and energy benefit at Pantay II	85.13	85.13	85.13	85.13
Total	1,378.3	1,381.28	1,382.55	1,383.82

100 MW

(million US dollars)

	AG-175	AG-165	AG-155	AG-145
Capacity and energy benefit of P.S.	-	-	-	-
Energy benefit of spillage water	-	-	-	-
Water supply benefit	915.60	915.60	915.60	915.60
Capacity and energy benefit of Pantay II	85.13	85.13	85.13	85.13
Total	1,000.76	1,000.76	1,000.76	1,000.76

Table 4-14 Summary of Benefit Cost Analysis

Kaliwa Pumped Storage Project

250 MW

(million US dollars)

	AG-175	AG-165	AG-155	AG-145
Benefit	1,378.30	1,381.28	1,382.55	1,383.82
Cost for Pump storage	697.41	702.36	715.62	748.87
Cost for Pantay	506.72	506.72	506.72	506.72
B-C	174.17	172.20	160.21	128.23
B/C	1.14	1.14	1.13	1.10

100 MW

(million US dollars)

	AG-175	AG-165	AG-155	AG-145
Benefit	1,000.76	1,000.76	1,000.76	1,000.76
Cost for P/S	243.97	255.33	268.63	289.67
Cost for Pantay	506.72	506.72	506.72	506.72
B-C	*250.07	238.71	225.41	204.37
B/C	1.33	1.31	1.29	1.26

Table 4-15 Main Features of Kaliwa Water Supply Project

Hydrology	
Catchment Area	276 km^2
Mean Inflow	25.2 m^3/s
Design flood	4,880 m^3/s
Reservoir	
Maximum Storage Elevation	270 m
Minimum Storage Elevation	235 m
Live Storage Volume	472 x 10^6 m^3
Project Works	
Main Dam:	
Type	Rockfill with central impervious core
Crest Elevation	281 m
Maximum Height above foundation	141 m
Volume of Fill	9.7 x 10^6 m^3
Spillway:	
Type	Free-overflow chute spillway
Crest Elevation	270 m
Design Discharge	2,800 m^3/s
Outlet Works:	
Invert Elevation	225 m
Tunnel - Diameter	3.3 m
- Length	9.3 km
Pipeline - Diameter	3.0 m
- Length	4.3 km
Design Discharge	28 m^3/s
Powerhouse (Pantay):	
Installed Capacity	21 MW
Number of Units	2
Tailwater Elevation	134.0 m
Water Treatment Plant (Pantay):	
Installed Capacity	28 m^3/s
Outlet Water Level	125 m
Pipeline - Treatment Plant to Storage Tank	
Tunnel - Diameter	3.1 m
- Length	6.7 km
Pipeline - Diameter	2.7 m
- Length	1.1 km
Treated Water Storage Tank (Cogeo):	
Capacity	306,000 m^3
Elevation	100 m

All elevations are based on mllw datum.
Prepared by PICOREM.

Table 4-16 Main Features of Kanan Water Supply Project

Hydrology	
Catchment Area	290 km^2
Mean Annual Inflow	50.7 m^3/s
Reservoir	
Maximum Storage Elevation	295 m
Minimum Storage Elevation	278 m
Live Storage Volume	255 x 10^6 m^3
Project Works	
Main Dam:	
Type	Rockfill with central impervious core
Crest Elevation	305 m
Maximum Height	160 m
Volume of Fill	15.8 x 10^6 m^3
Spillway:	
Type	Free-overflow chute spillway
Crest Elevation	295 m
Design Discharge	3,200 m^3/s
Interbasin Tunnel - Kanan to Kaliwa:	
Invert Elevation	268 m
Tunnel - Diameter	4.7 m
- Length	14.5 km
Design Discharge	73.5 m^3/s
Outlet Works from Kaliwa Reservoir:	
Invert Elevation	225 m
Tunnel - Diameter	4.3 m
- Length	9.3 km
Pipeline - Diameter	3.6 m
- Length	4.3 km
Design Discharge	45.9 m^3/s
Powerhouse (Pantay):	
Installed Capacity	32.5 MW
Number of Units	2
Tailwater Elevation	135.0 mllw
Water Treatment Plant (Pantay)	
Installed capacity	45.9 m^3/s
Outlet Water Level	125.0 m
Pipeline - Treatment Plant to Storage Tank	
Tunnel - Diameter	3.7 m
- Length	7.5 km
Pipeline - Diameter	3.5 km
- Length	1.9 km
Treated Water Storage Tank (Cogeo):	
Capacity	572,000 m^3
Elevation	100 m

All elevations are based on mllw datum.
Prepared by PICOREM.

Table 4-17 <u>Benefit Flow of Pantay Powerplant</u>

Surplus water used for Agos

Power value $160.25/kW
Energy value $0.0234/kWh

	Kaliwa		Kanan	
	21 MW	153 GWh	32.5 MW	245 GWh
1987	21.	153.0		
1988	↓	153.0		
1989		45.9		
1990		63.4		
1991		83.1		
1992		104.9		
1993		128.1		
1994		153.0	32.5	2.0
1995		↓	↓	15.1
1996				51.5
1997				82.9
1998				109.8
1999				130.6
2000				147.7
2001				162.8
2002				178.0
2003				189.3
2004				200.7
2005				209.4
2006				218.1
2007				226.4
2008				234.0
2009				245.0
2010				↓
⋮				
Present worth of power benefit	$63.60 x 10^6		$85.13 x 10^6	

Table 4-18 Summary of Benefit and Cost

Kaliwa-Kanan Water Supply Project

Kaliwa Water Supply Project

Present worth values for 50 years of project operation discounted by 10% at the year of Jan. 1, 1987

(million Peso)

	Benefit		Cost	
	Water supply	Power & Energy	Water supply	Power & Energy
Present worth values of 1979	2,399	178	1,655	144
Present worth values to 1987	5,142	382	3,548	309
(In US million dollars equiv.)	($685.7)	(50.9)	(473.0)	(41.2)
Recent power value (Generration by surplus water encluded)		(63.6)		
Total ($x10^6$ US$)	$749.3		$514.2	
B/C	1.46			
B-C ($x10^6$ US$)	235.1			

Kanan Water Supply Project

Present worth values for 50 years of project operation discounted by 10% at the year of Jan. 1, 1994

	Benefit		Cost	
	Water supply	Power & Energy	Water supply	Power & Energy
Present worth values of 1979	1,560	147	1,510	85
Present worth values to 1994	6,517	614	6,308	355
(In US million dollars equiv.)	($868.9)	(81.9)	(841.0)	(47.3)
Recent power value (surplus water excluded)		(85.13)		
Total ($x10^6$ US$)	$954.0		$888.3	
B/C	1.07			
B-C ($x10^6$ US$)	65.7			

Table 4-19 Main Features of Kanan No.5 Hydropower Project

Item		Dimension
Basic Data:		
Catchment area	km^2	357
Average streamflow	m^3/s	60.0
Average annual energy production	GWh/year	930.3
Reservoir:		
Total storage volume	$(x10^6\ m^3)$	800
Effective storage volume	$(x10^6\ m^3)$	480
Dead storage volume	$(x10^6\ m^3)$	320
Reservoir area at HWL	(km^2)	16.7
High Water Level	(m)	260
Minimum storage Water Level	(m)	220
Dam:		
Type of dam	-	Rockfill
Height above riverbed	m	164
Riverbed elevation	m	100
Crest elevation	m	264
Length of dam crest	m	770
Embankment volume	Mio m^3	22.8
Spillway:		
Type of spillway	-	Open chute with gates
Design discharge	m^3/s	7,000
Headrace Tunnel:		
Number	-	1
Length	m	5,675
Diameter	m	6.5
Surge Tank:		
Type of surge tank	-	Circular
Number	-	1
Height	m	103.25
Penstock:		
Number	-	1
Length	m	319
Diameter	m	5.3
Powerhouse:		
Length	m	83.2
Width	m	20.5
Height	m	27

Prepared by Lahmeyer

Table 4-20 Construction Cost of Kanan No.5 Hydropower Project

	Works	Construction Cost (10^6 US $ equivalent)
1.	Land Acquisition and Compensations	2.67
2.	Preparatory Works (Roads, Bridge, Quarters, etc.)	6.03
3.	Diversion Tunnels	13.40
4.	Main Rockfill Dam and Cofferdams	178.38
5.	Gated Open Chute Spillway (including Gates)	34.08
6.	Intake and Power Tunnel (including Gate)	22.59
7.	Surge Tank	1.60
8.	Penstock Line (including Pipes and Valves)	3.48
9.	Power House	3.47
10.	Tailrace	1.20
11.	Switchyard and Substation (without Equipment)	0.60
12.	Permanent Quarters	1.20
	Total (1 - 12)	268.70
13.	Electro-Mechanical Equipment	50.40
14.	Transmission Line (50 km)	3.93
15.	Substation at Malaya	6.09
16.	Contingencies (10%)	32.91
	Total (1 - 16)	362.03
17.	Engineering and Administration (8%)	28.96
	GRAND TOTAL	391.00
	Present worth O & M cost	35.07
	Present worth replacement cost	2.38
	Cost	428.45

Table 4-21 Main Feature of Alternative Scheme
Agos Hydropower Project (Plan A-1)

	Alternative Schemes			
	AG-175	AG-165	AG-155	AG-145
Reservoir				
HWL (m)	175.0	165.0	155.0	145.0
LWL (m)	135.0	128.0	120.8	113.8
Live storage (10^6 m^3)	695.0	550.0	438.0	336.0
Main dam				
Crest Elevation (m)	182.0	172.0	162.0	152.0
Crest length (m)	810.0	780.0	735.0	695.0
Dam height above foundation (m)	182.0	172.0	162.0	152.0
Dam volume incl. cofferdams (10^6 m^3)	20.1	16.8	13.95	11.4
Spillway				
Design discharge (m^3/sec)	10,600			
Type	12.5^H x 12^W x 10 nos gated spillway			
Diversion tunnels				
Design discharge (m^3/sec)	5,210			
Number	2			
Diameter (m)	12.0			
Length (m)	830/935	780/885	740/845	650/755
Power tunnel				
Maximum discharge (m^3/sec)	219.2	221.3	221.3	222.6
Diameter (m)	7.2			
Length (m)	800			
Penstock line				
Type	Embedded in tunnel			
Number	1			
Diameter of penstock (m)	6.2			
Length (m)	285	275	265	255
Power house				
Installed capacity (MW)	200	185	170	155
Number of unit	2			
Rated head (m)	108.3	99.2	91.1	82.6
Tail water lever (m)	41.5			

Table 4-22 Generated Energy and Benefit Cost

Year	Agos – Kanan No.1 Joint Scheme								Kanan No.5 (280 MW)	Remarks
	AG-175 (200 MW) KN-290 (127 MW)		AG-165 (185 MW) KN-290 (138 MW)		AG-155 (170 MW) KN-300 (158 MW)		AG-145 (155 MW) KN-300 (168 MW)			
	Agos	Kanan	Agos	Kanan	Agos	Kanan	Agos	Kanan		
1989	843.19 GWh		780.24 GWh		717.35 GWh		654.52 GWh		930.26 GWh	
1990	822.36		760.76		699.25		638.07			
1991	801.52		741.29		681.14		621.62			
1992	780.68		721.81		663.04		605.17			
1993	759.85		702.34		644.93		588.73			
1994	739.01	380.66 GWh	682.86	413.49 GWh	626.85	466.85 GWh	572.28	500.75 GWh		
Present Worth Benefit discounted to Jan. 1989	495.12	180.13	457.88	195.71	420.66	223.13	383.70	237.87		
Total Benefit	675.25		653.59		643.79		621.57		635.27	
Total Cost	344.5	128.8	303.7	130.34	275.0	154.0	254.0	158.5		
Total Cost	473.3		434.04		429.0		412.5		428.45	
Net Benefit	201.95		219.55		214.79		209.07		206.82	
B/C	1.43		1.51		1.50		1.51		1.48	

Table 5-1 Summary of Present Worth of Benefit and Cost
Optimization Study of Agos River System

(million US dollars)

Development Plan	HWL of Agos No.1 Dam	HWL of Kanan No.1 Dam	BENEFIT Agos	BENEFIT Pantay P/S Stage I 21MW	BENEFIT Pantay P/S Stage II 32.5MW	BENEFIT Kanan No.1	BENEFIT Sub total	BENEFIT Kaliwa	BENEFIT Kanan	BENEFIT Sub total	COST Agos	COST Pantay P/S Stage I	COST Pantay P/S Stage II	COST Kanan No.1	COST Sub total	COST Kaliwa Stage I	COST Kanan	COST Kaliwa pumping Station Construction cost	COST Kaliwa pumping Station Electricity	COST Sub total	Discounted at 10 % Benefit (B)	Discounted at 10 % Cost (C)	Discounted at 10 % Net Benefit (B - C)	B/C Ratio (B/C)
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
A-1	175	290	495.12	76.96	-	180.13		829.70	-	829.70	344.5	49.85	-	128.8	523.05	572.33	-	-	-	572.33	1,581.91	1,095.38	486.53	1.44
	165	290	457.88	"	-	195.71		"	-	"	303.7	"	-	130.3	483.85	"	-	-	-	"	1,560.25	1,056.18	504.07	1.48
	155	300	420.66	"	-	223.13		"	-	"	275.0	"	-	154.0	478.85	"	-	-	-	"	1,550.45	1,051.18	499.27	1.47
	145	300	383.70	"	-	237.87		"	-	"	254.0	"	-	158.5	462.35	"	-	-	-	"	1,528.23	1,034.68	493.55	1.48
A-2	175	295	382.14	76.96	52.86	-	511.96	829.70	539.52	1,369.22	320.31	49.85	29.37	-	399.53	572.33	522.19	-	-	1,094.52	1,881.18	1,494.05	387.13	1.259
	165	"	352.23	"	"	-	482.06	"	"	"	286.37	"	"	-	365.59	"	"	-	-	"	1,851.28	1,460.11	391.17	1.268
	155	"	322.41	"	"	-	452.23	"	"	"	258.23	"	"	-	337.45	"	"	-	-	"	1,821.45	1,431.97	389.48	1.272
	145	"	292.71	"	"	-	422.53	"	"	"	242.25	"	"	-	321.47	"	"	-	-	"	1,791.75	1,415.99	375.76	1.265
A-3		300	381.26	76.96	52.86	195.44	706.52	829.70	539.52	1,369.22	320.31	49.85	29.37	145.56	545.09	572.33	314.63	84.06	67.43	1,038.45	2,075.74	1,583.54	492.20	1.31
	175	290	381.25	"	"	180.13	691.20	"	"	"	"	"	"	128.80	528.33	"	"	"	"	"	2,060.42	1,566.78	493.64	1.32
		280	380.82	"	"	163.73	674.37	"	"	"	"	"	"	114.72	514.25	"	"	"	"	"	2,043.59	1,552.70	490.89	1.32
		300	351.51	"	"	210.27	691.60	"	"	"	286.37	49.85	29.37	145.87	511.46	572.33	314.63	84.00	74.54	1,045.50	2,060.82	1,556.96	503.86	1.32
	165	290	351.49	"	"	195.71	677.02	"	"	"	"	"	"	130.34	495.93	"	"	"	"	"	2,046.24	1,541.43	504.81	1.33
		280	350.96	"	"	180.47	661.25	"	"	"	"	"	"	116.73	482.32	"	"	"	"	"	2,030.47	1,527.82	502.65	1.33
		300	321.77	"	"	223.13	674.72	"	"	"	258.23	"	"	153.99	491.44	"	"	84.92	81.88	1,053.76	2,043.94	1,545.20	498.74	1.32
	155	290	321.65	"	"	207.51	658.98	"	"	"	"	"	"	138.77	476.22	"	"	"	"	"	2,028.20	1,529.98	498.22	1.33
		280	321.11	"	"	191.45	642.38	"	"	"	"	"	"	125.10	462.55	"	"	"	"	"	2,011.60	1,516.31	495.29	1.33
		300	292.14	"	"	237.87	659.83	"	"	"	242.25	"	"	158.45	479.92	"	"	90.10	89.77	1,066.83	2,029.05	1,546.75	482.30	1.31
	145	290	291.91	"	"	221.41	643.14	"	"	"	"	"	"	143.51	464.98	"	"	"	"	"	2,012.36	1,531.81	480.55	1.31
		280	291.61	"	"	204.39	625.82	"	"	"	"	"	"	129.77	451.24	"	"	"	"	"	1,995.04	1,518.07	476.97	1.31

Table 6-1 Main Feature of Alternative Scheme

Agos Hydropower Project

	Alternative Scheme			
	AG-175	AG-165	AG-155	AG-145
Reservoir				
HWL (m)	175.0	165.0	155.0	145.0
LWL (m)	135.0	128.0	120.8	113.8
Live storage ($x10^6m^3$)	695.0	550.0	438.0	336.0
Main dam				
Crest Elevation (m)	182.0	172.0	162.0	152.0
Crest length (m)	810.0	780.0	735.0	695.0
Dam height above foundation (m)	182.0	172.0	162.0	152.0
Dam volume incl. cofferdams ($x10^6m^3$)	20.21	17.03	14.31	11.91
Spillway				
Design discharge (m^3/sec)	10,600			
Type	14.0 H x 14 W x 4 nos. gated spillway with 2 lanes of 210 m long side channel			
Diversion tunnels				
Design discharge (m^3/sec)	5,210			
Number	2			
Diameter (m)	9.0			
Length (m)	816/817			
Power tunnel				
Maximum discharge (m^3/sec)	163.86	163.45	162.97	161.36
Diameter (m)	6.2			
Length (m)	226			
Penstock line				
Type	Embedded in tunnel			
Number	1			
Diameter of penstock (m)	6.1			
Length (m)	370	350	330	310
Power house				
Installed capacity (MW)	152	140	128	116
Number of unit	2			
Rated head (m)	110.1	101.6	93.2	85.3
Tail water level (m)	41.5			

Table 6-2 Summary of Project Cost of Alternatives
Agos Hydropower Project

(million US dollars)

		Alternative Scheme			
		AG-175	AG-165	AG-155	AG-145
1.	Land acquisition	3.2	2.7	2.3	1.95
2.	Preparatory work	13.48	11.57	10.33	9.61
3.	Diversion tunnels	9.08	9.08	9.08	9.08
4.	Main & cofferdams	148.42	125.54	105.86	88.28
5.	Spillway	24.15	24.15	25.66	34.74
	(1 - 5)	(198.33)	(173.04)	(153.23)	(143.66)
6.	Intake & power tunnel	1.97	1.92	1.85	1.80
7.	Penstock line	0.32	0.32	0.32	0.32
8.	Powerhouse and switchyard	3.08	2.92	2.76	2.60
9.	Tailrace	1.53	1.53	1.53	1.53
10.	Architectural work	2.20	2.14	2.07	1.99
	(7 - 10)	(9.10)	(8.83)	(8.53)	(8.24)
11.	Electro-mechanical work	31.46	29.42	27.26	25.17
12.	Transmission line	3.45	3.38	3.31	3.28
13.	Hydro-mechanical work	10.05	10.00	9.95	9.90
	(11 - 13)	(44.96)	(42.80)	(40.52)	(38.35)
14.	Contingency (10 %)	25.24	22.47	20.23	19.03
15.	Engineering and administration	16.66	14.83	13.35	12.56
	Grand Total	294.29	261.97	235.86	221.83
Operation and Maintenance Cost		23.23	21.38	19.75	18.67
Replacement Cost		1.60	1.52	1.44	1.36

Table 6-3 Optimization Study of Agos Hydropower Project

Normal	Cost	Benefit	Net benefit	B/C	Production Cost $/kWh	Average generated energy GWh/Y
175	319.12	381.56	62.44	1.20	0.066	484.44
165	284.86	351.66	*66.80	1.23	0.064	448.23
155	257.05	321.83	64.78	1.25	0.063	411.27
145	241.87	292.12	50.25	1.21	0.065	374.59
Cost 10% up						
175	351.03	381.56	30.53	1.09	0.073	
165	313.35	351.66	38.31	1.12	0.071	
155	282.76	321.83	*39.07	1.14	0.069	
145	266.05	292.12	26.07	1.10	0.072	
Fuel cost 10% up ($49.5/ton)						
175	319.12	395.57	76.45	1.24		
165	284.86	364.58	*79.72	1.28		
155	257.05	333.78	76.73	1.30		
145	241.87	302.90	61.03	1.25		
Cost 10% down						
175	287.21	381.56	94.35	1.33	0.060	
165	256.37	351.66	*95.29	1.37	0.058	
155	231.35	321.83	90.48	1.39	0.057	
145	217.68	292.12	74.44	1.34	0.059	
Kanan water supply project 10 years delay						
175	319.12	394.39	75.27	1.24		
165	284.86	363.39	*78.53	1.28		
155	257.05	332.58	75.53	1.29		
145	241.87	301.85	59.98	1.25		
Agos 20 years delay						
175	319.12	340.28	21.16	1.07		
165	284.86	314.00	29.14	1.10		
155	257.05	287.43	*30.38	1.12		
145	241.87	260.96	19.09	1.08		

FIGURES

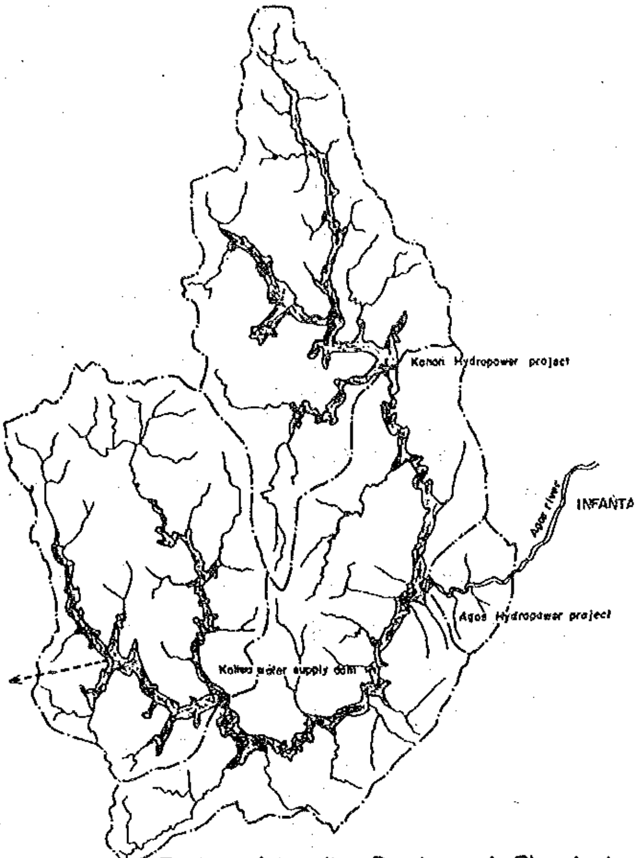


Fig.I-1 Alternative Development Plan A-1

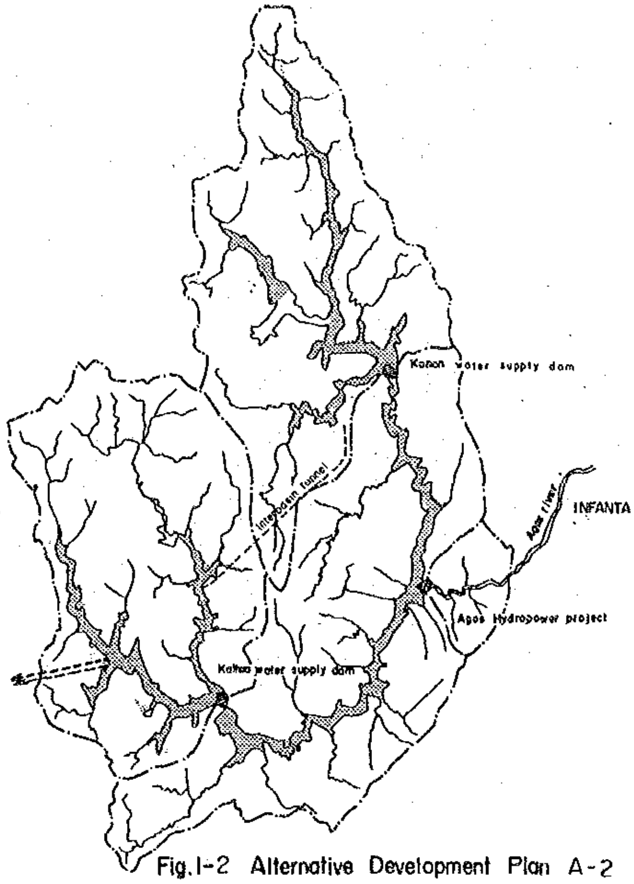


Fig.I-2 Alternative Development Plan A-2

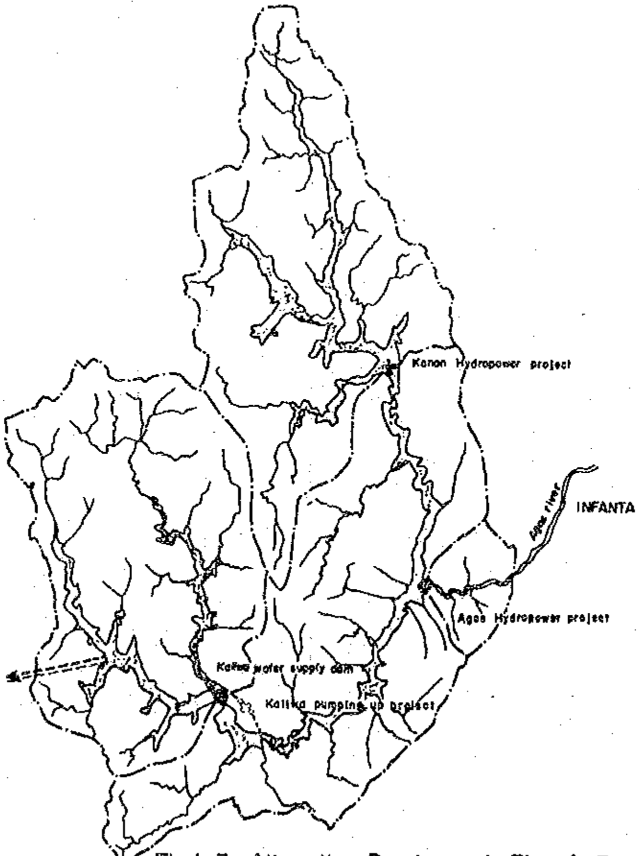


Fig.I-3 Alternative Development Plan A-3

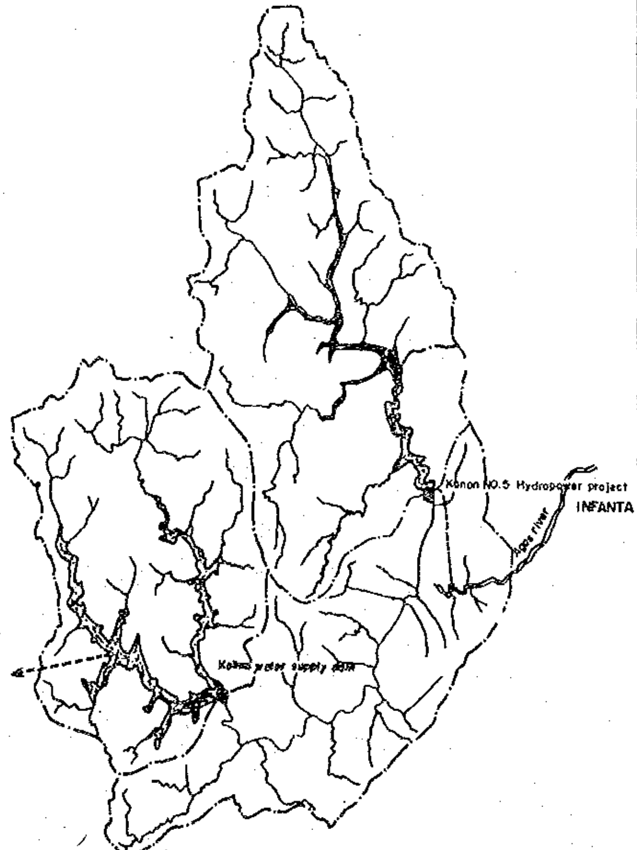


Fig.I-4 Alternative Development Plan B

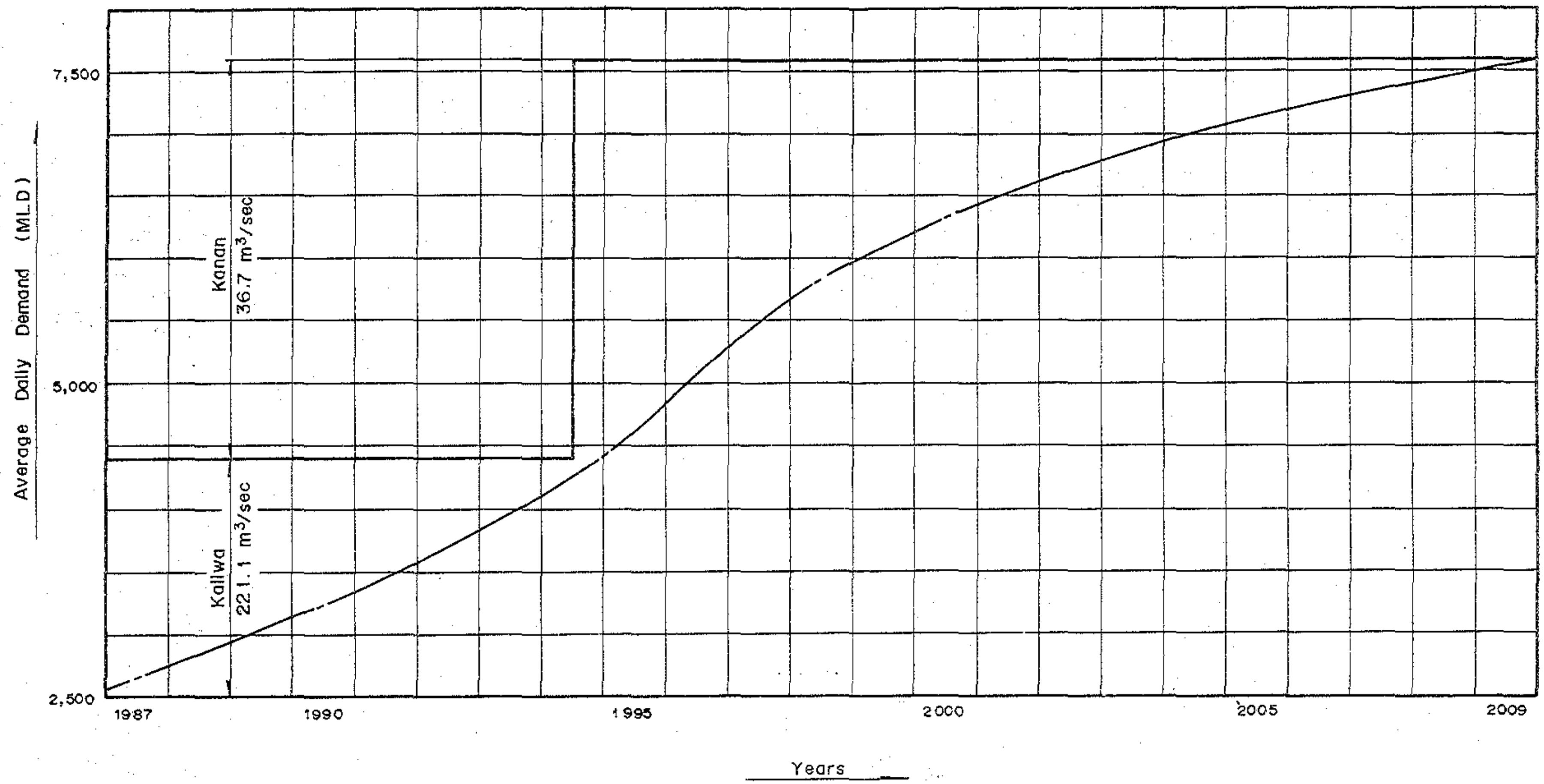


Fig. 3 — 1 Water Supply Requirement to Kaliwa and Kanan

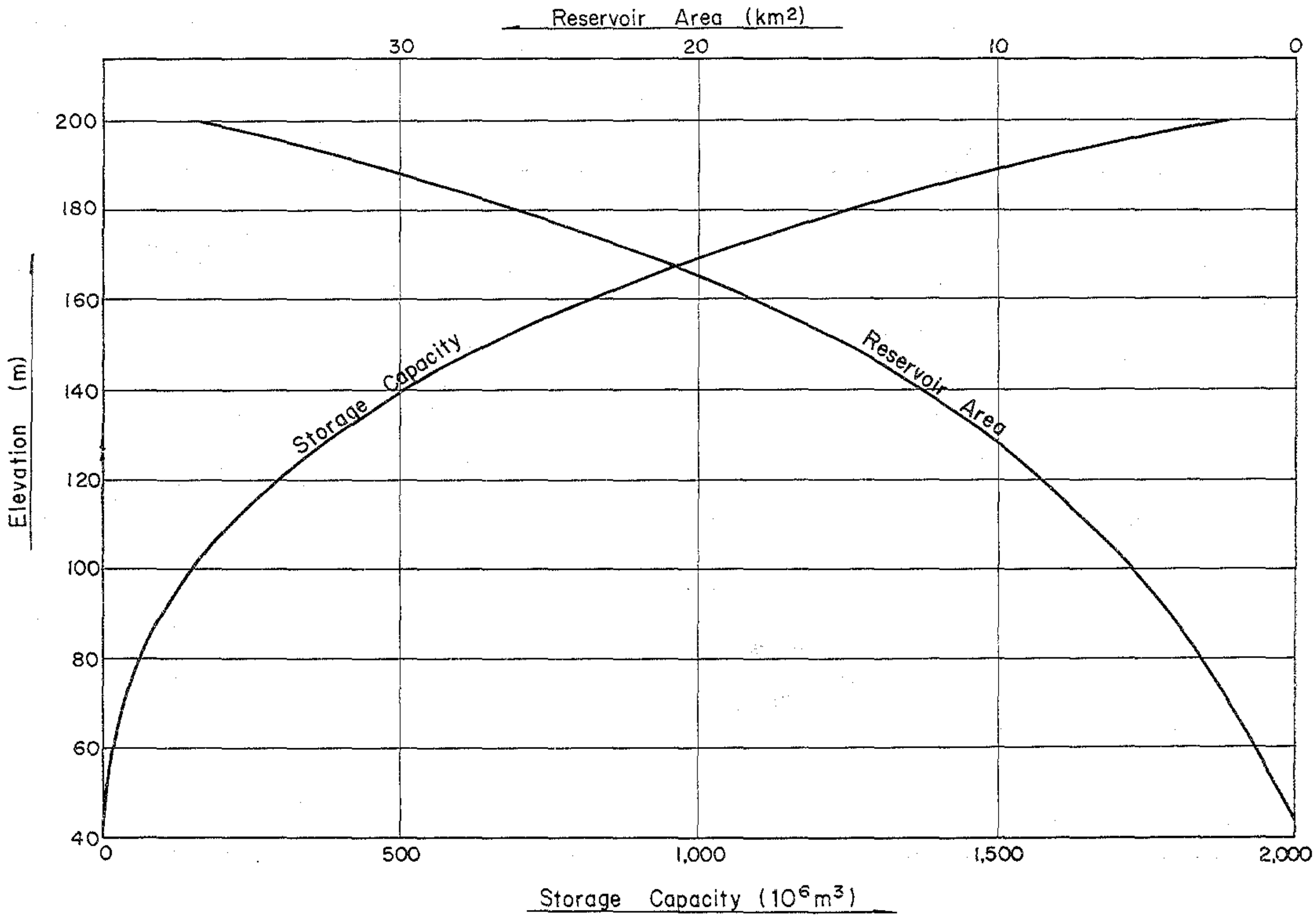


Fig. 3-2 Agos Reservoir Capacity Curve

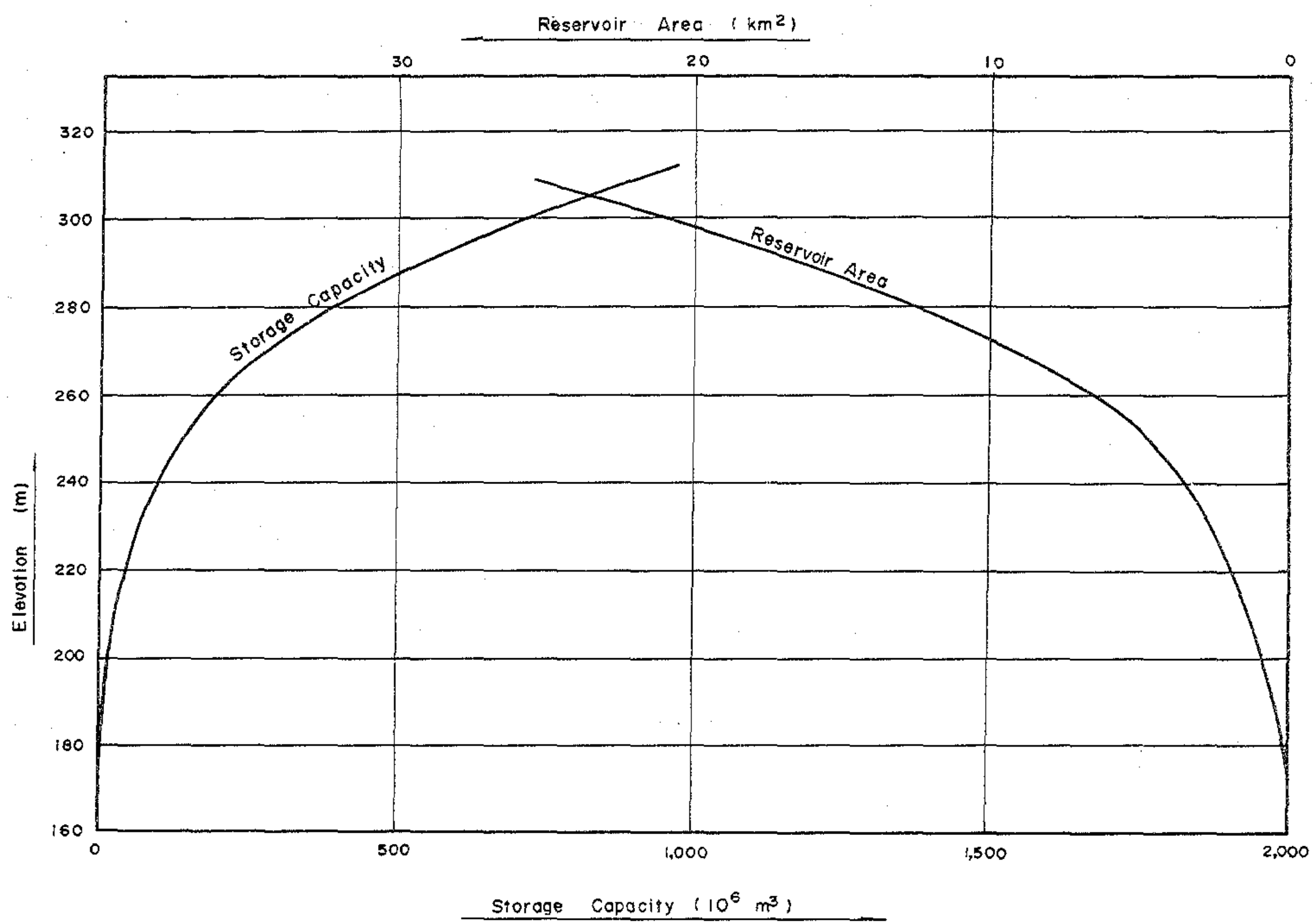


Fig. 3-3 Kanan NO.1 Dam Capacity Area Curve

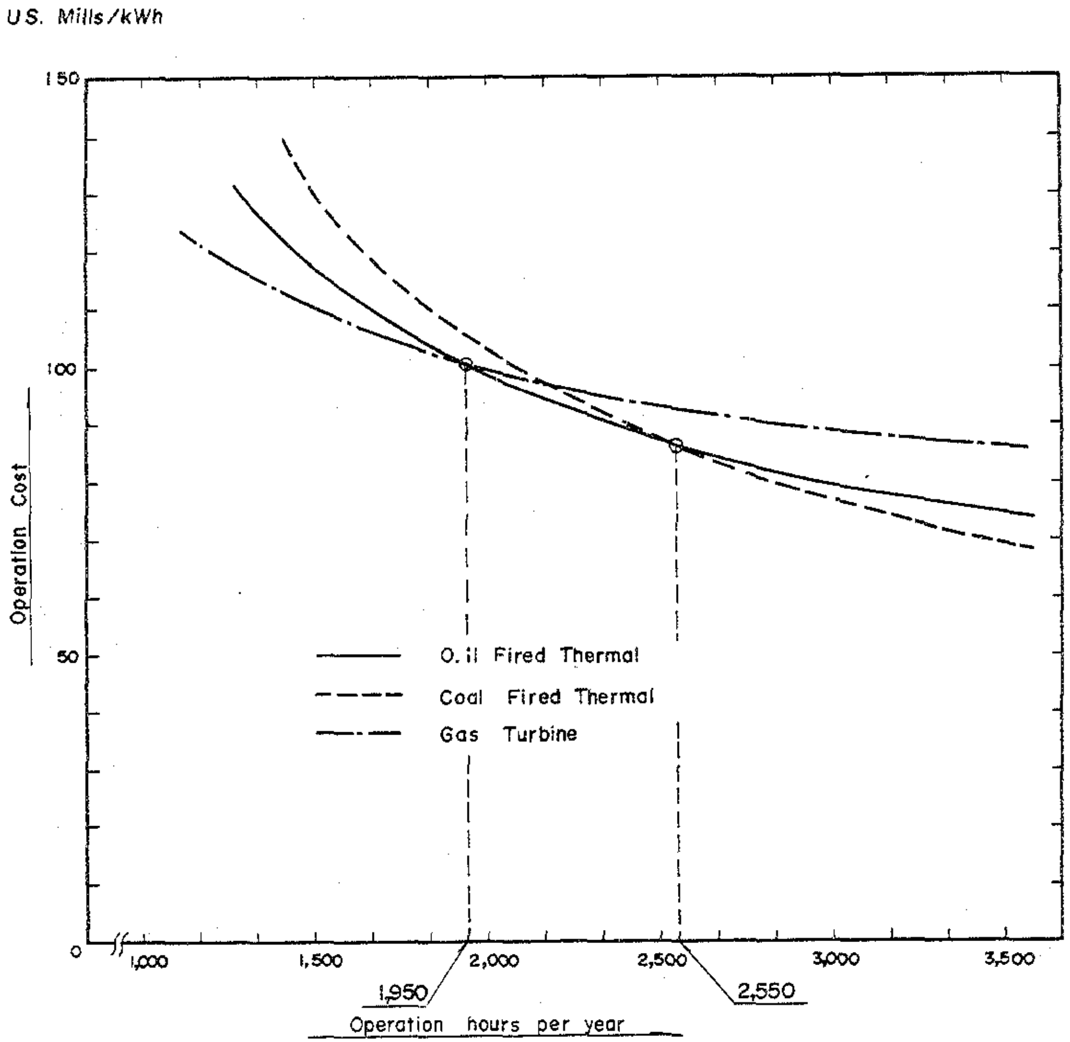


Fig. 4-1 Comparison of Power Cost by Alternative Plants

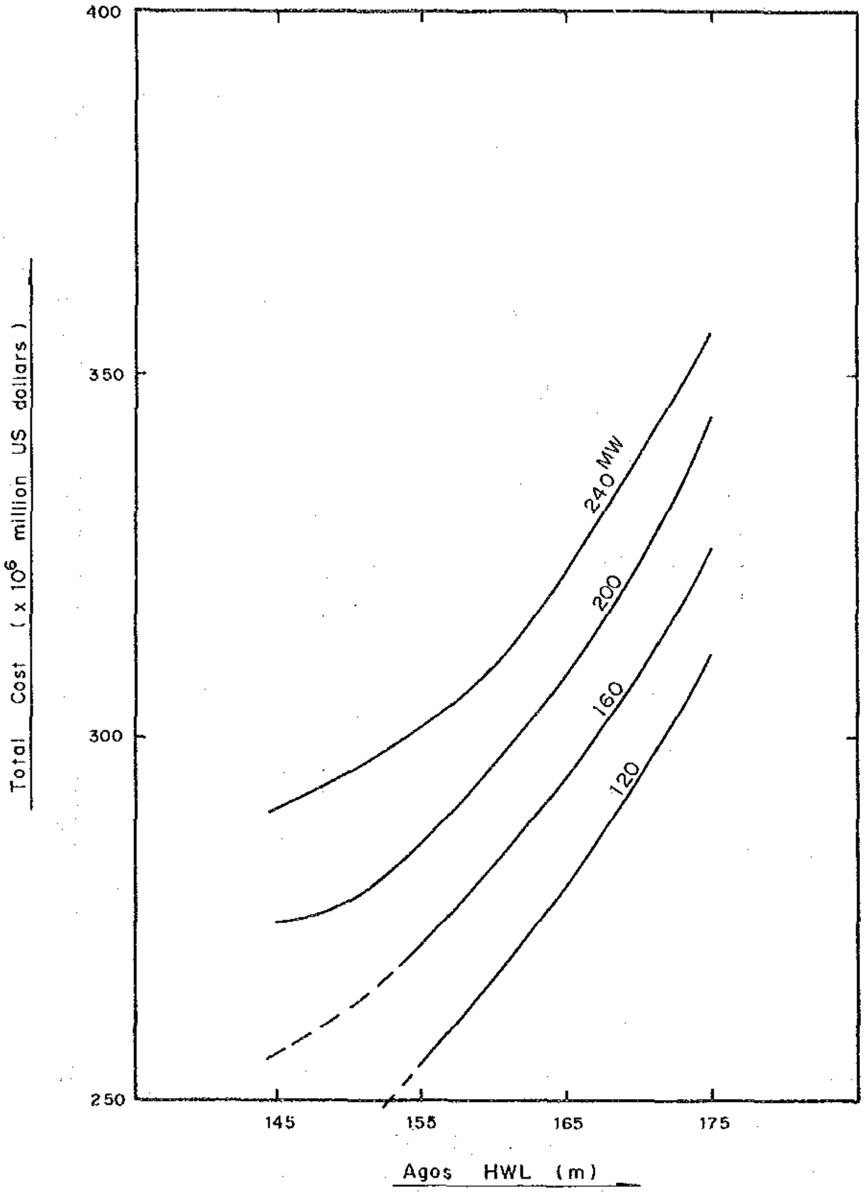


Fig. 4 - 2 Total Cost of Agos H/P Project

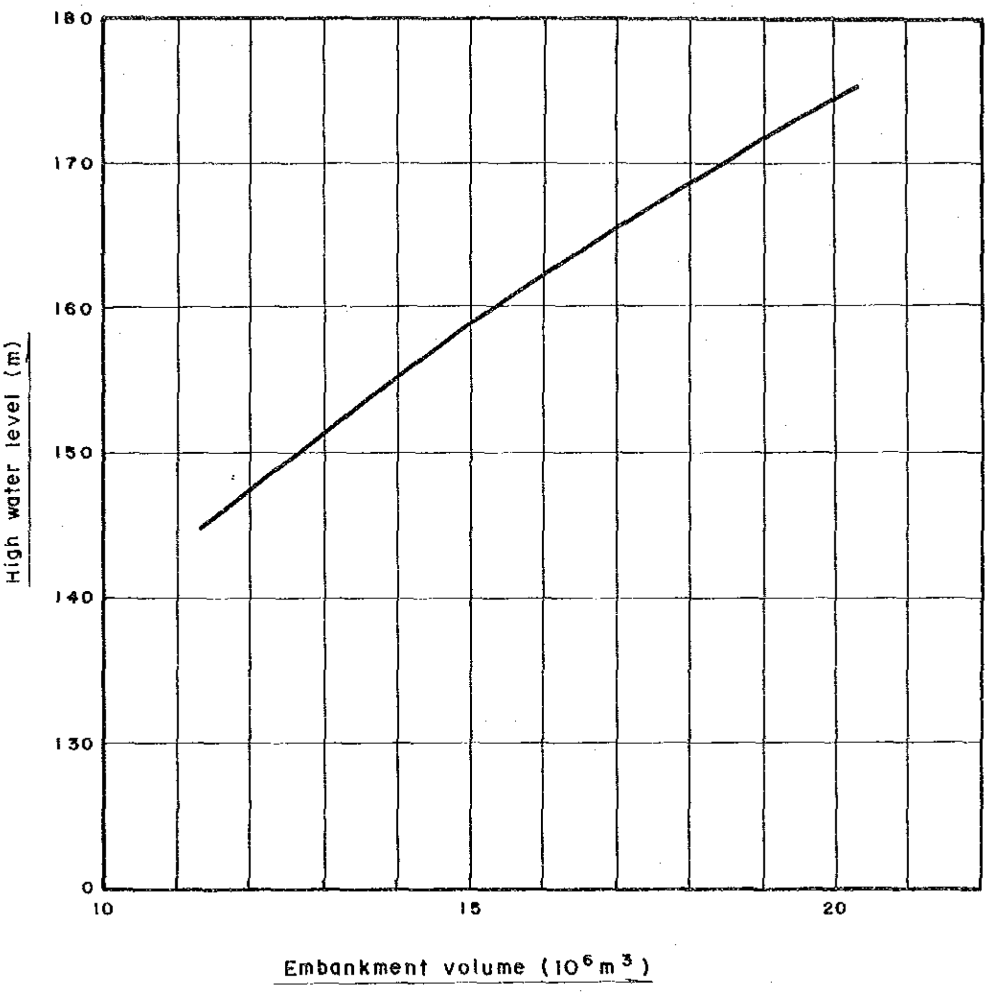
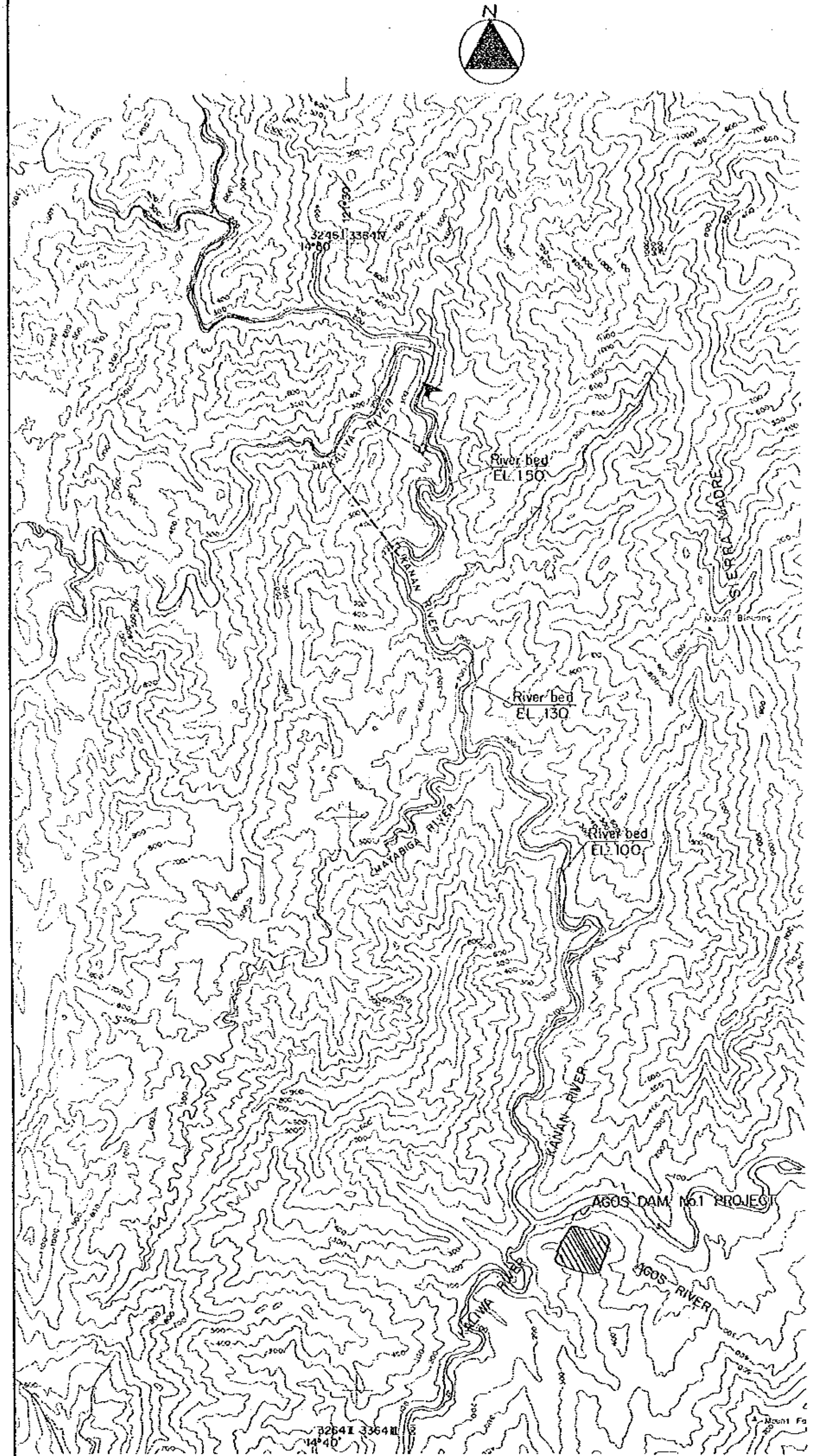
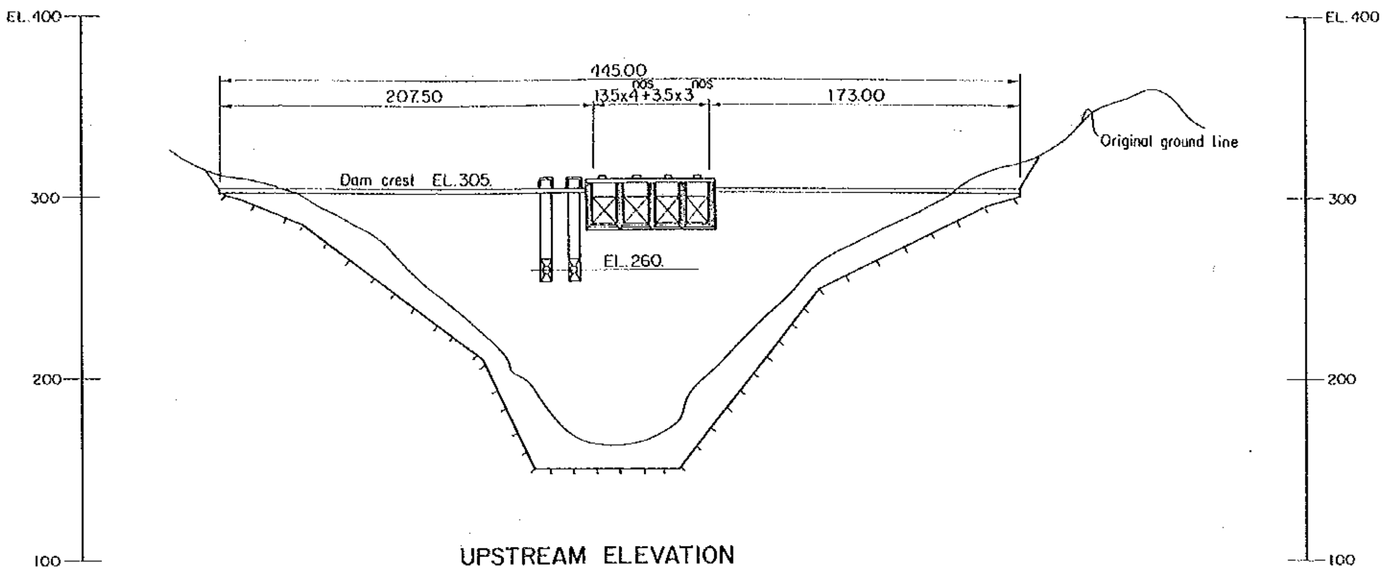


Fig. 6-1 Agos Dam H.W.L.-Fill Volume Curve

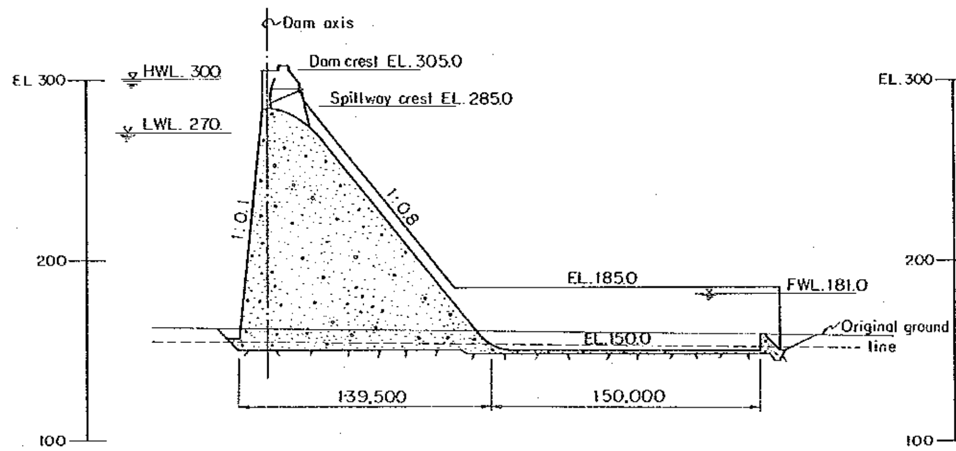
DRAWINGS



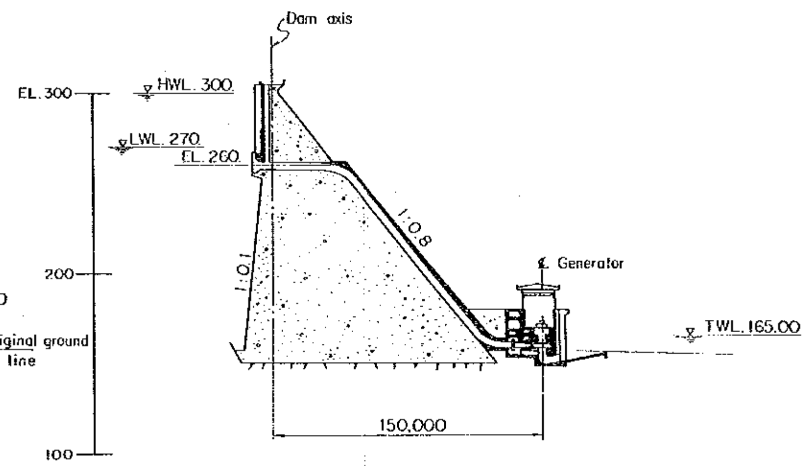
PLAN
SCALE A



UPSTREAM ELEVATION
SCALE B



PROFILE OF SPILLWAY
SCALE B



PROFILE OF WATERWAY
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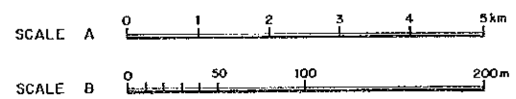
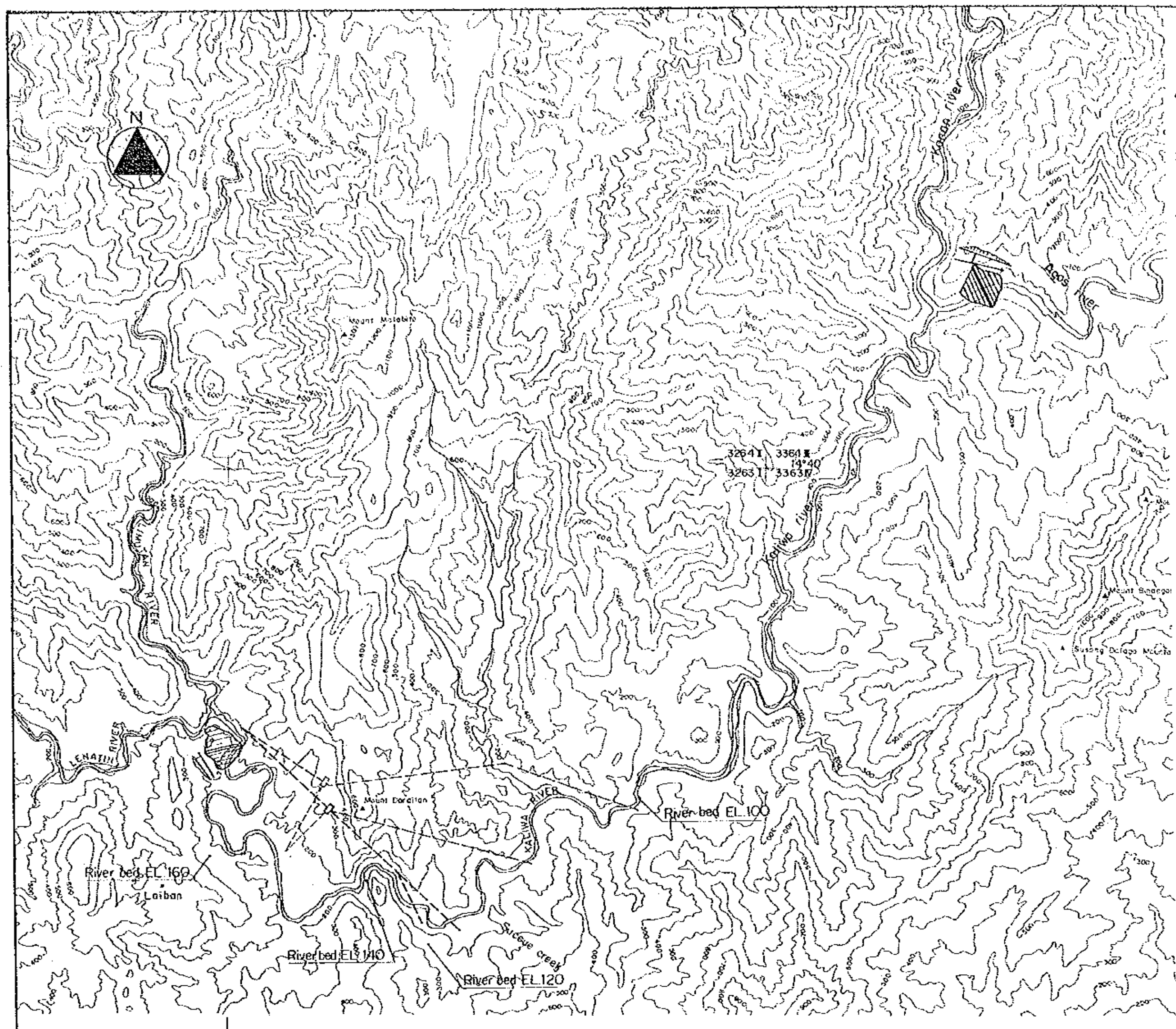


REPUBLIC OF THE PHILIPPINES NATIONAL POWER CORPORATION			
AGOS RIVER HYDROPOWER PROJECT			
KANAN HYDROPOWER PROJECT ALTERNATIVES			
DATE	DEC. 1980	DWG NO.	1
JAPAN INTERNATIONAL COOPERATION AGENCY			



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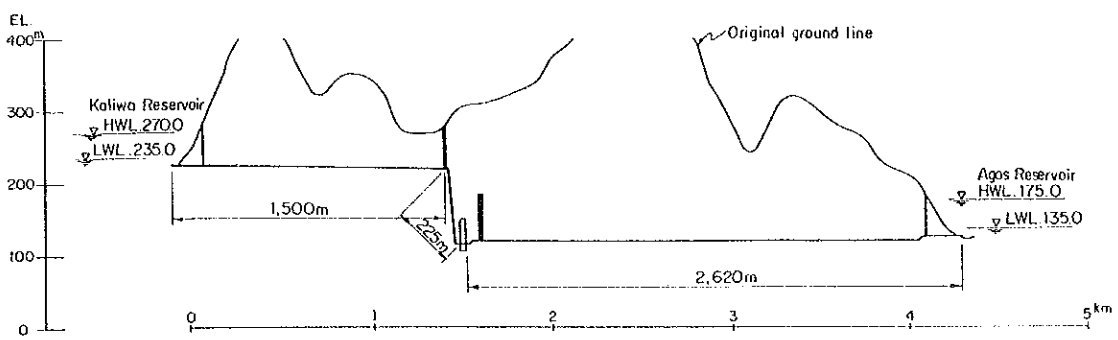
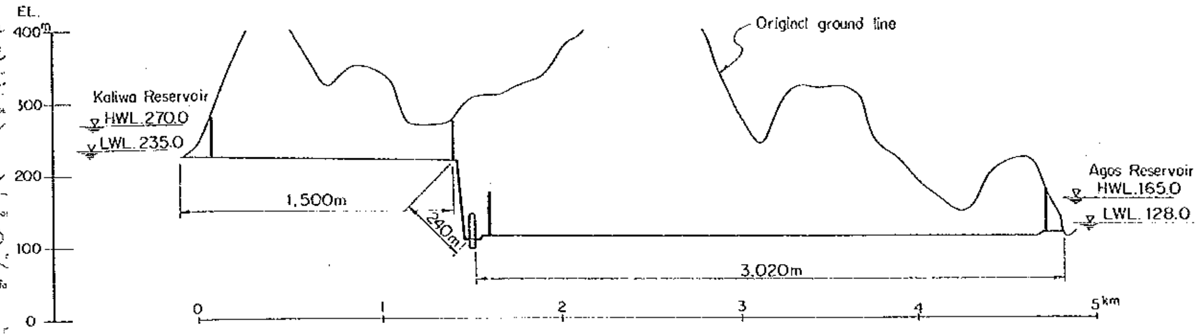
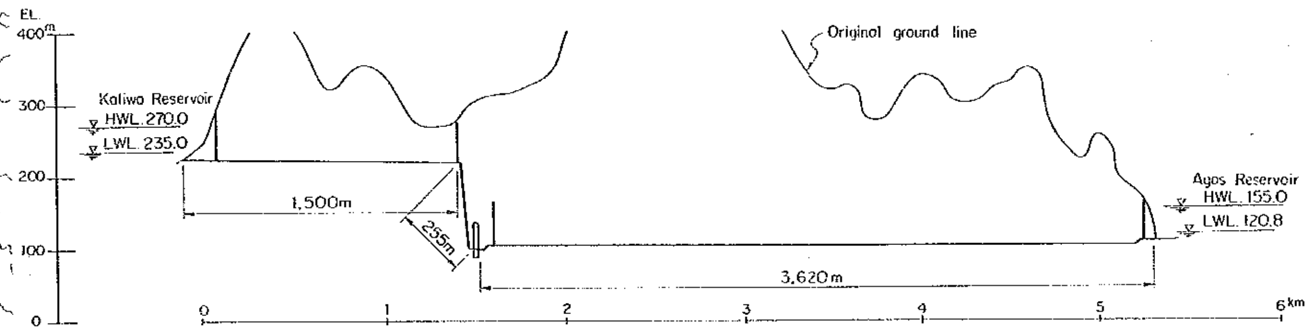


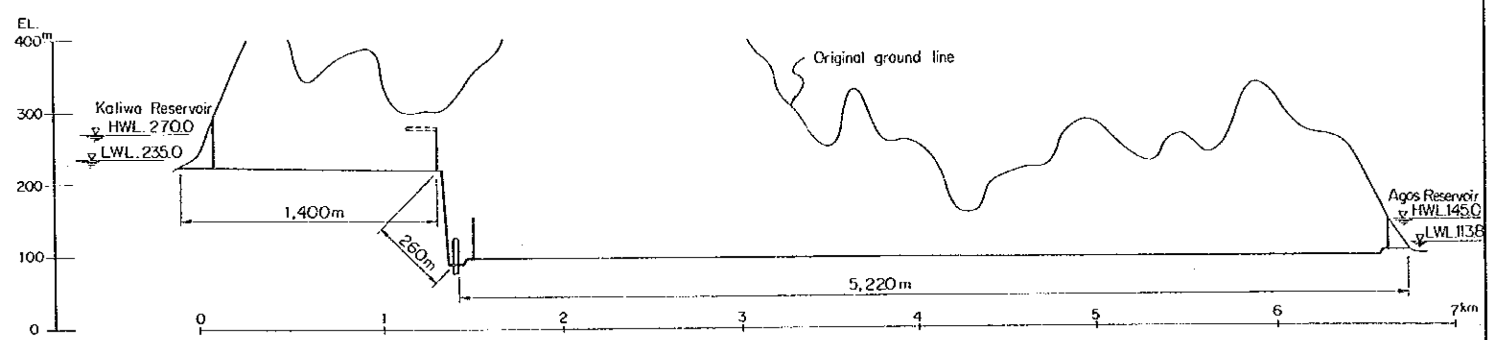
PROFILE OF WATERWAY (AG-175)



PROFILE OF WATERWAY (AG-165)



PROFILE OF WATERWAY (AG-155)



PROFILE OF WATERWAY (AG-145)

Horizontal : SCALE B
Vertical : SCALE C

SCALE A 0 1 2 3 4 5 km
SCALE B 0 1 2 km
SCALE C 0 500m

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KALIWA PUMPED STORAGE POWER PROJECT ALTERNATIVES			
DATE	DEC. 1980	DWG NO.	2
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