4.3 Hydrology

4.3.1 General

There were four stream gauging stations in the Agos river system. Out of them, three stations were stopped their operation by 1950. Long and reliable discharge reocrds are available only at Banugao G.S. on the Agos river, which is located at 6 km upstream from the estuary and has the drainage area of 911 km^2. The Banugao G.S. has the complete discharge records for 26 years from 1950 to 1973 and in 1977 and 1978, which has been proven to be reliable. (Refer to Appendix A)

Annual maximum discharge records are available only at Banugao G.S. for 22 consecutive years from 1949 to 1970. An automatic water level recorder had been operated here since July 13, 1956 until July 26, 1972. No past records are available to correlate storm rainfalls and flood discharges in the Agos river system.

Most parts of the Kanan river basin are covered with the thick forest which protects the basin from land erosion in spite of such heavy rainfall as partly exceeding 6,000 mm per annum. While the Kaliwa river basin has been comparatively developed from its westmost tributary, the Lenatin river, by the past logging operation and by settlers. Therefore, specific sediment production of the Kaliwa river is expected to be higher than that of the Kanan river. Water quality of the Agos river system is confirmed to be quite clean except the turbidity by silt during high discharges. These water can be utilized for any purposes.

To resume the observations, NAPOCOR established three stream gauging stations with staff guages in 1978. They are Mahabang Lalim G.S. on the Agos river, Daraitan G.S. on the Kaliwa river and Malasolaso G.S. on the Kanan river. The latter two stations have only temporary staff gauges. In compliance with the recommendation by the JICA team, NAPOCOR established two more stream gauging stations at Nio on the Kaliwa river and at Binugawan on the Kanan river in 1980. The three stations, namely Mahabang Lalim, Nio and Binugawan, are located within 3 km from the confluence and equipped with an automatic water level recorder. Cableways are constructed at Mahabang Lalim G.S. in September 1979 and at Nio G.S. in June 1980 to enable the discharge measurement, sediment measurement and the access to the recorders during floods.

Based on the past records mentioned above and the records obtained by newly established rainfall and stream gauging stations, studies on run-off, flood and sediment transport are carried out for the Agos river system as described in the following paragraphs.

4.3.2 Run-off

The Banugao discharge records give the specific discharge of as high as 12.5 m^3/sec per 100 km^2 equivalent to the effective rain of

3,940 mm per annum. 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 as shown in Fig.4-3.

The 26 years' discharge reocrds at Banugao G.S. include two very rich water years corresponding to the recurrence period of about 50 years. The average discharge at Banugao G.S. is statistically calculated at 118.1 m^3/sec as the logarithmic mean. 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. Hence, the available discharge at Banugao G.S. is conservatively estimated to be 113.8 m^3/sec as the logarithmic mean excluding the two rich water years.

The available discharges at the proposed damsites are obtained based on the above discharge of 113.8 m^3/sec at Banugao G.S., the discharges estimated by CDM at Daraitan G.S. on the Kaliwa river and the newly prepared isohyetal map of the average annual rainfall in the Agos river basin. The estimated average monthly discharges at the proposed damsites and Banugao G.S. are shown as follows:

Average Monthly Discharge at the Proposed Damsites and Banugao G.S.

(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)	Banugao G.S. (911 km^2)
Jan.	14.97	89.55	151.49	158.05	162.03
Feb.	6.61	66.23	105.19	110.04	112.98
Mar.	3.55	49.50	76.50	80.12	82.32
Apr.	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
Aug.	48.88	7.98	86.45	87.03	87.39
Sept.	44.47	15.36	90.25	91.38	92.06
Oct.	37.57	62.91	147.91	152.51	155.31
Nov.	50.53	89.27	205.63	212.16	216.13
Dec.	58.77	98.61	231.68	238.90	243.28
Annual Mean	26.00	47.60	108.20	111.68	113.80
Specific Discharge per 100 km^2	9.30	16.7	12.5	12.5	12.5

The monthly discharge series for 26 years at Agos dam and its afterbay weir are generated by simply multiplying the recorded discharge series at Banugao G.S. by the ratio of the average discharge.

The monthly discharge series for 26 years at the Kaliwa and Kanan No.1 damsites are generated on the basis of the above average monthly discharges and the recorded discharge series at Banugao G.S. They have the fair discharge fluctuation, which include a dry year corresponding to the recurrence period of more than 50 years. Accordingly, it is judged that the generated discharge series can be used for the water utilization study to choose an optimum development scale.

4.3.3 Flood

Hydrograph of the recorded second largest flood on November 20, 1966 at Banugao G.S. having the peak discharge of 6,070 m^3/sec has been newly found out. The recorded maximum flood on October 26, 1978 was traced at this station on March 9, 1979 from its flood marks on coconut trees to obtain the peak discharge of 6,650 m^3/sec. The five largest floods recorded at Banugao G.S. on the Agos river are listed below:

Five Largest Floods at Banugao G.S. on the Agos River (D.A. 911 km^2)

No.	Date	Peak Discharge (m^3/sec)	Remarks
1	Oct. 26, 1978	6,650	- Traced on March 9, 1979.
2	Nov. 20, 1966	6,070	- Recording chart available.
3	Nov. 26, 1921	4,890	- Rating curve not clear.
4	Dec. 31, 1950	4,250	
5	Dec. 10, 1956	3,510	

Statistical analysis is carried out on the 22 years' annual maximum discharges recorded at Banugao G.S. from 1949 to 1970 using the four distribution functions and the results are given as follows:

An estimated frequency curve by Log Pearson type-III represents well the distribution of the flood sample as shown in Fig.4-4. Therefore, it is judged that the above results obtained by Log Pearson type-III are reliable though the recorded maximum flood in 1978 is not included in the sample due to lack of data for intermediate years from 1971 to 1977. Flood for a given recurrence period at each proposed damsite is obtained based on the above results at Banugao G.S. with the corrections by drainage area and annual basin rainfall.

Statistical Analysis of Flood at Banugao G.S. on the Agos River

(m^3/sec)

Recurrence Period (yr)	Log Extreme Type-A	Log Pearson Type-III	Iwai Method	Gumbel Method	The Largest
2	1,700	1,660	1,660	1,830/1	1,830
30	4,760	5,340/1	5,150	5,340/1	5,340
100	6,770	7,500/1	7,140	6,760	7,500
200	8,220	9,080/1	8,450	7,570	9,080
1,000	12,700	13,600/1	12,000	9,440	13,600
10,000	23,000/1	22,600	18,500	12,100	23,000

Note: /1; The largest estimate

On the other hand, an enveloping curve of unusual floods is prepared for the study based on the records as of 1969 at 409 stream gauging stations all over the Philippines. The curve is given by Creager's equation of C = 140.

The spillway design discharges of the proposed dams are obtained based on the 200-year flood. In case of a fill type dam, the discharge is multiplyed by 1.2 in accordance with the Japanese Standard. Final safety of a fill type dam is confirmed by the Probable Maximum Flood (P.M.F.) which is shown in Fig.4-5. The adopted spillway design discharges of the proposed dams are compared in the next page with the recorded maximum flood, 200-year flood, envelopes for Philippines and the Far East, P.M.F. and 10,000-year flood.

The adopted spillway design discharge and P.M.F. for the Agos dam correspond to the recurrence period of about 400 and 3,000 years, respectively. As seen in the table, the 200-year flood and the envelope for Philippines are fairly close to each other. The spillway design discharge of the Agos dam is close to the envelope for the Far East. The 10,000-year flood is unreasonably large compared with the P.M.F.

Comparison of Spillway Design Discharge with Various Floods

No.		Banugao G.S.	Agos Dam	Agos Afterbay Weir	Kanan No.1 Dam	Kaliwa Dam
	Drainage Area in km^2	911	867	894	285	279
	Dam Type	-	fill	concrete	concrete	fill
1	Spillway Design Discharge	-	10,600/1	8,970	6,450	5,170/1
2	Recorded Max. Flood	6,650	6,490/2	6,590/2	-	-
3	200-year Flood	9,080	8,830	8,970	6,450	4,310
4	Envelope of Unusual Floods in Philippines	9,530	9,300	9,440	5,220	5,160
5	Envelope of Unusual Floods of Region C in the Far East/3	11,000	10,800	11,000	6,170	6,100
6	P.M.F.	-	17,300	-	-	-
7	10,000-year Flood	23,000	22,500	22,800	16,400	11,000

Note: /1; Obtained as 1.2 times of 200-year flood in accordance with the Japanese Standard.

/2; Obtained from Banugao records by Creager's equation.

/3; Developed by ECAFE in 1967 for those countries Taiwan, Japan, Korea, the Philippines and Viet-Nam where typhoons strike most often.

4.3.4 Sedimentation

Suspended load of the Agos river is being measured at Mahabang Lalim stream gauging station which is located at 1,560 m downstream from the confluence of the Kanan and Kaliwa rivers. Based on the 36 measurements made in 1979 and 1980, a sediment rating curve is established as shown in Fig.4-6. The curve is given by the following equation:

$$Qs = 0.005802 \times Q^{2.4515}$$

where, Qs: suspended sediment load in ton/day

Q: discharge in m^3/sec

Applying the above sediment rating curve to the 26 years' daily discharge records at Banugao G.S. and multiplying by 1.2 to correct indispensable error due to daily calculation, the average annual suspended load of the Agos river at the Agos dam is obtained to be 423,000 m^3/year equivalent to the specific load of 464 m^3/km^2/year. The bed load is simply assumed to be 20 percent of the suspended load. Then, total specific sediment load is obtained to be 557 m^3/km^2/year.

The sediment volume in the Agos reservoir during 100 years will be as small as 17.9 million cubic meters taking into consideration the trap efficiency by the Kaliwa and Kanan No.1 dams. The above volume is only 5 percent of the dead storage of 378 million cubic meters. Even if all the sediments are accumulated in the live storage of 552 million cubic meters, 97 percent of the live storage will still be effective after 100 years' operation. Furthermore, if the trap efficiencies of the Kaliwa and Kanan dams are neglected, the total sediment volume will be 46.3 million cubic meters, only 8 percent of the live storage. It is, therefore, judged that reservoir sedimentation causes no practical problem for the Agos dam. Same conclusion is obtained for Kaliwa and Kanan No.1 dams.

4.4 Geology

4.4.1 General Geology

Rocks generally distributed in the Agos river basin are greywacke-conglomerate-shale alternation, which is associated with basic lava and pyroclastic rocks. Their geological age is assessed to be from Cretaceous to Paleogene. Greywacke is poorly-sorted angular to sub-angular rock fragments and is well consolidated and hard in fresh facies. It is remarkably massive in places with obscure bedding plane. A part of greywacke is classified as conglomerate which contains gravels and cobbles densely. It is also hard as greywacke in fresh condition. Thin beds of shales and fine-grain sandstones intercalate in greywacke and conglomerate. They are dark bluish to light brownish and homogeneous rock with high consolidation.

Massive limestones are found in the vicinity of Daraitan on the upstream of the Kaliwa river. Limestone masses trend to north-south direction, forming high mountain ridges.

Bedding planes show general trend of north-south to northeast-southwest in strike. Dip varies in direction and inclination with rather frequent minor foldings and faults. A major geological structure in this area is the Philippine Rift which has north-southerly trend through Polillo strait and major fault, Infata fault, western border of the Rift running north to south is about 5 km west of Infanta. Some other minor faults have strike of NE-SW to ENE-WSW, one of which runs nearly along the Agos river.

On the Kaliwa river upstream of Mount Daraitan, intensively warped minor foldings are observed frequently. These are deemed to be due to the movement related with faults.

4.4.2 Geology of the Project Sites

(1) Agos Damsite

a) Geological Condition

Bed rock in the damsite is composed of the sedimentary rocks of greywacke group of Cretaceous to Paleogene age, comprising most prevailling greywackes, conglomerates, fine sandstones and shales, which have been metamorphosed in low grade. The bedding planes are generally obscure but sometimes distinguished by the layers of fine sandstone and shale. The average strike and dip are N30° - 35°E/30° - 45°SE respectively. Joints and minor dislocation planes are developed dominantly in the direction of N70° - 80°W/60° - 90°NE.

Talus deposit is distributed over the foot of the slopes along the river. Terrace and flood deposits are limited in and around the damsite. River deposit is some 30 m to 40 m in thickness on the dam axis. This great thickness is deemed to be related with the regional subsidence of the above mentioned rift valley.

b) Foundation Engineering

The following three problems were found for foundation engineering in the Agos damsite.

i) Thick residual soil or decomposed rock zone on the right abutment.

ii) Thick river deposit in the river bed.

iii) Faults in the river bed and on the right bank

The weathered rock zone at least in the river bed and a part of abutment below EL.120 m are to be removed. The reliable foundation for the impervious core zone is the fresh rock which is 30 m deep on the right bank, 45 m deep in the river bed and 10 to 25 m deep on the left bank. The foundation rocks in fresh zone are sufficiently stable and hard for both concrete gravity dam and rockfill dam.

The foundation treatment will be performed by cement grouting. The grouting is to be carried out for the most part from the surface of the fresh rock zone. Leakage through open cleavages can be treated by ordinary cement grouting. Conceivable depth of curtain grouting for design is 60 m from the fresh rock surface around river bed, covering a little more than one third of the dam height and the possible high leakage portions. The depth of grout curtain is to be reduced to 30 m at the abutment of dam. For consolidation and blanket groutings, the depth of 5 m will be sufficient for generally solid fresh rock.

Construction of gallery for inspection and curtain grouting is recommended at the bottom of the impervious core foundation.

c) Geology of the Reservoir Area

The reservoir of the proposed Agos dam will develop to an extent of 22 km upstream along the Kanan river and 28 km upstream along the Kaliwa river at the high water level of EL.165 m.

Geologically, most part of the reservoir area is situated in the greywacke - conglomerate - shale province. General trend of the bedding planes shows NE-SW or N-S in strike and various degrees of eastward dip. Faults are dominantly oriented NE-SW or N-S but not of very major scale. Only a few development of cavities are found in limestone beds developing in vicinity of Daraitan on the Kaliwa river. But leakage problem seems negligible because of shallow water level at this point and the presence of impervious beds around the area. Development of thick residual soil are limited in the high parts of the mountain slopes and existence of typical land sliding is not observed, which leads that future land sliding will be limited to a small scale and not in so many places.

(2) Afterbay Weir Site

a) Geological Conditions

The proposed weir site is located at about 8 km downstream of the Agos damsite. The slopes of the both abutments are rather gentle and the width of river bed is around 260 m.

Bed rock comprises greywacke and conglomerate with intercalation of sandstone and shale layers, which are almost the same as those in the Agos damsite. The bedding plane is rather obscure but partly shows the strike of WNW-ESE to ENE-WSW and the dipping of 35° - 45°S in the fine sandstone layer. Major fault runs along the left bank, which appears on aerial photographs in straight line with the strike of N70°E. River bed deposit is about 50 m in depth at maximum on the conceived axis.

b) Foundation Engineering

The main problem is the treatment of thick river deposit, which reaches about 50 m in depth. Taking into consideration of rather small size of the afterbay weir, excavation of a big amount of river deposit for the dam construction seems not economical. A floating type dam, accordingly, is recommended for the afterbay weir. Gated weir part, however, is required to be supported by concrete piles placed on the foundation rock.

The creep length beneath the weir is to be elongated to prevent piping effect through river deposit. The both abutments of the weir can be placed on the hard foundation rock.

(3) Kanan No.1 Damsite

This damsite is selected at a V section gorge about 21 km upstream from the confluence of the Kanan and the Kaliwa. The elevation of the river bed is about 168 m AMSL. The area is composed of very hard and massive greywacke with the intercalation of thin fine sandstone layers. General directions of the bedding plane are NS in strike and 50°E to 60°E in dip.

It is judged that any type of high dam can be constructed with sufficient safety. However, a very narrow river section and very high and rapid flood at this damsite suggest that the Kanan No.1 dam is better to be constructed in type of concrete gravity dam instead of fill dam.

(4) Kanan No.5 Damsite

This damsite is at about 5 km upstream from the confluence of the Kanan and the Kaliwa. The river bed elevation is approximately 95 m AMSL with a width of 80 meters narrowed by a large talus deposits from the left bank. This site is composed of greywackes same as those of the Agos damsite. The trend of bedding plane is not so clear but seems to be N30°E in strike and 50°E in dip. A fault lies on the bed of small gully on the left bank slope having N23°E of strike and 48°W of dip accompanying with 10 to 30 cm thick fractured zone.

The weathered rocks and talus deposit on the left bank may be considerably deep, so that much quantity of excavation may be required and the dam volume will be nearly the same as the Agos dam.

(5) Quarry Site

The quarry site for the Agos dam is selected in the area, adjoing the dam site to the west. The distance between the quarry site and the Agos damsite is only 2 km. The topography is steep with about 30 degrees of inclination of the slopes. Bed rock is partly exposed on the river bed or on the hill slopes.

Approximately 3.5 million cubic meters of rock materials are to be quarried from this area and another 6 million cubic meters will be obtained from the spillway excavation.

Quarry rocks for the Kanan No.1 and Kanan No.5 dams is expected to be obtained in the vicinities of the damsites. Impervious core material is also expected to be obtained in the vicinities of the Kanan No.5 dam. Judging from the steep topography, favourable borrow area for impervious material is not easily found for the Kanan No.1 dam.

4.5 Construction Materials

4.5.1 Embankment Materials

Materials required for the construction of the dam embankment are rockfill including rip-rap (13.41 million cubic meters), filter (1.44

million cubic meters) and impervious core materials (2.17 million cubic meters).

(1) Soil Materials

All the borrow areas is covered with deep soils and decomposed rock layer in total thickness of 10 to 15 meters. The soils in this area have reddish brown color seemingly with rich silt and clay content of laterite weathered by strong sunshine and heavy tropical shower. The content of silt and clay (percent finer than No.200 seive) of this material is considerably high, mostly from 45 percent to 50 percent. This content clearly shows that the permeability is very low mostly in the order of 1 x 10^{-7} cm/sec. Natural moisture content is also very high, mostly ranging between 50 percent and 70 percent. The results of standard proctor compaction test show very low dry density, such as in a range of 1.10 to 1.4 g/cm^3 with very high optimum moisture contents more than 34 percent mostly. From all the above test results it is judged that those soils belong to laterite with very rich fine particles, mostly classified into MH and CH in accordance with the unified soil classification system.

In view of above-mentioned physical and mechanical properties of the materials, it is concluded that they can not be utilized as soil material for core zone of Agos dam. In order to improve the materials, certain quantities of decomposed rock fragment or sand and gravel shall be mixed with those soils.

According to the results of test drillings and seismic exploration, a weathered rock layer is underlain just beneath the top soil. Several tests have been carried out on the mixed samples of soil and weathered rock in different proportion. Of these mixed proportion, one to one proportion in thickness is selected based on the results. The content of silt and clay of the said material is in the range of 18 to 27 percent and Plastic Index is more than 10. The dry density of compaction test is around 1.43 g/cm^3.

Of those borrow areas, Agos I Downstream area is recommended for the material sources of soil and weathered rock judging from the distance to dam, availability of wide land area for stockpile yard and low natural moisture content of soil materials compared to other areas.

(2) Filter Materials

As for the filter material, alluvial deposits scattered from the confluence to the estuary were examined. The deposit is composed of well graded mixture of subrounded elements ranging from large boulders to fine sand containing small amount of silt.

Specific gravity is 2.62. The rate of water absorption is 1.5 percent and the results of abrasion by Los Angeles test is 16.5 percent on an average. The gradation of river deposit satisfies the requirement of filter against core material as shown in Fig.4-8. Thus the river deposit sand and gravel is used for filter material.

Among several deposits, just upstream area of afterbay weir site is selected. Furthermore, about 900 thousands cubic meters of filter material is available from foundation excavation of river alluvial deposit of the Agos dam.

(3) Rock Materials

A quarry site for the Agos dam was selected at both banks of a small stream at about 500 m upstream from the confluence of the Kaliwa with the Kanan. The distance from the Agos dam is only about 2 km. The rock to be excavated at the spillway and power tunnel is also to be used as rock material to save the construction cost. Boulders for rip-rap can be collected from the quarry site and spillway excavated rock.

Rocks in this proposed quarry are composed mainly of greywacke, dark green basaltic rocks, pyroclastics and schalsteins. Three (3) core samples extracted by core drilling were tested for compressive strength in NAPOCOR laboratory. The strength of 6 samples taken from 3 core samples are ranging from 1,160 kg/cm^2 to 1,430 kg/cm^2 showing that the rock is sufficiently hard and suitable for shell zone materials.

4.5.2 Concrete Aggregates Materials

The quantities of concrete required for diversion tunnels, spillway, power waterway and powerhouse are estimated at 310,000 m^3 in total.

River alluvial deposits were found along the Agos river scattered from the confluence to the estuary. The alluvial deposits are composed of mostly graywacke with some conglomerates and limestone. Most of river deposits consist of sand and gravel and very few sand deposits are scattered along the river. Therefore, they can not be economically explored and most of the sand will be supplied from the estuary area where the sand contains rather coarse particles and the beach where particles are fine.

(1) Fine Aggregates

The soundness test (chemical durability test) was carried out by washing with solution of sodium sulphate (Na_2SO_4) applying 5 cycles on sand. The loss rate is rather high, ranging from 10 to 13 percent for beach sand and 13 to 16.3 percent for river sand. The results in reduction in alkality Rc for alkali reactivity tests of beach sand were satisfactory following the provisions of ASTM. While the decantation test (washing test) clarifies the fact that silt and clay content smaller than 0.074 mm is 6.1 percent on an average for river sand and 2.8 percent for beach sand. It was also revealed by mortar strength test on 7 sand samples that the strength of mortar made of washed sands is higher than that made of unwashed sands by about 10 percent in both cases of 7 days and 28 days strength. The sand should be washed in the screening plant.

As for the gradation, the fineness modulus is 3.1 on an average for river sand and 2.4 for beach sand, both of which satisfy the recommended range of 2.30 to 3.10. In general, the river-run sand is coarse while beach sand is fine. Therefore, it is recommended to use both sands by mixing to improve the quality of sand.

(2) Coarse Aggregate

The coarse aggregates derived from river deposit are considered to be acceptable judging from JSCE standards except washing test. The seive analysis shows good gradation for concrete. The fineness modulus of river-run gravel less than 50 mm is between 6.0 to 7.5.

In relation to rather high loss by chemical durability test of fine aggregates, several tests on rock fragments of greywacke, sandstone and limestone have been carried out to find out the characteristic as to what component is most reactive, in particular the chemical durability and Los Angels tests.

It has been recognized that greywacke is the most reactive to sodium sulphate among them and weak in Los Angels test.

Therefore, two pieces of greywacke have been brought to Japan and tested on chemical durability and X-ray analysis in Nippon Koei Engineering Laboratory. According to the result, the loss by chemical durability is 1.6 and 1.2 percent almost the same as the test in NAPOCOR laboratory. X-ray analysis revealed that the greywacke is composed of mainly quartz, albite, pyrophyllite and includes a small amount of clay mineral. Though it can not be judged through one test, it is possible that pyrophyllite may react with the solution of sodium sulphate. It is recommended to carry out more tests in the detailed design stage.

The concrete strength tests have been carried out by using the river-run gravel as coarse aggregates and river-run sand and beach sand one to one proportion (1:1) as fine aggregate, but varying the water cement ratio raging from 40 to 50 percent. The results are shown in Table 4-1 together with the mortar strength test. The relation between $\sigma 28$ and c/w is on the recommended line of Japan Society of Civil Engineering's $\sigma 28 = 210 + 215$ c/w. Though the strength derived from the said formula is minimum requirement, it is judged that the aggregates obtained from proposed sources given the enough strength for construction use.

CHAPTER 5

OPTIMIZATION STUDY FOR THE DEVELOPMENT ON THE AGOS RIVER SYSTEM

5.1 Alternative Plans

As outlined in the Terms of Reference of the Agos River Hydropower Project, the object of the optimization study is to formulate the most beneficial development plan for the Agos river system. For attaining this objective, JICA Survey Team for the Agos River Hydropower 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 other hand, PICOREM started a comprehensive study for the water supply to Metro Manila from 1978. Through the study, the Kaliwa water supply project (the diversion scheme) 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 to fulfill the water requirement from 1994.

Therefore, the formulation of the optimum plan for the whole Agos river is to be made in due consideration of the results of both the preliminary studies.

Preliminary study and analysis were made for the following four alternative development plans on the Agos river system.

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

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

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 Projects

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

In the above plans, the Kaliwa water supply project is firstly taken into consideration for the Agos river development plan as the prerequisite. In plan A-2, the required water for Metro Manila from 1994 will be diverted by gravity flow through an interbasin tunnel between the Kaliwa and Kanan reservoirs, while the required water will be diverted by pumping through a waterway between the Agos and the Kaliwa reservoirs in plan A-3. In plans A-1 and B, the water requirement from 1994 is ignored (or the Kanan No.2 water supply project is disqualified) and the whole discharge in the Kanan river is used for exclusively hydropower generation purpose.

Plans other than listed above are not worth for comparison with them taking into technical, economical and project scale points of view.

The economic comparison in the pre-feasibility stage indicated that the plan A-3 was the most beneficial with the highest net benefit followed by the plan A-2. In the Interim Report, however, further detailed comparison of the two beneficial plans was recommended for selecting the optimum one.

In this study, the above four alternative plans are reviewed again and necessary modification is made taking into account the results of the previous study and discussions with NAPOCOR. The Agos No.2 dam is discarded and excluded from the alternative plans since its economic viability is rather negative/1. The alternative development plans, thus modified, are illustrated in Fig.5-2 to Fig.5-5.

Prior to the comparative study on the proposed alternative plans, study for each project component such as the Agos hydropower project, the Kanan No.1 hydropower project and the Kaliwa pumped storage project is conducted for assessing the optimum development scale on the basis of the preliminary study, and the estimated cost and benefit. In the study, construction cost, and operation and maintenance cost are estimated by using the same unit prices and the same criteria applied in Section 6.5 and Section 7.2. Power benefit is also evaluated by the least cost alternative, coal fired thermal plant as presented in Section 7.1, except the benefit from the Kaliwa pumped storage power station. Benefit from the water supply is estimated by the water cost to be provided through the least cost alternative. All the cost and benefit are estimated at the price level of early 1980.

Thus, summing up the project components, the most optimum development plan for the Agos river system is finally recommended based on the results of comparison on the expected net return of the each alternative and social requirement in due consideration.

5.2 Comparative Study on Single Project

Summary of the results on the comparative study for single project is presented hereunder. Details of the study are included in Appendix D.

/1 Refer to Section 6.4 of Interim Report and Paragraph 6.11 of this report.

5.2.1 Agos Hydropower Project

For the comparative study, four cases of a high water level of the Agos reservoir are studied; namely, EL.175 m, 165 m, 155 m and 145 m. Based on the high water level, layout plan of the dam and appurtenant structures and the power station with different installed capacity are prepared for each scale. The installed capacity and average annual power generation corresponding to its high water level are shown below.

HWL of Agos	AG-175	AG-165	AG-155	AG-145
Plan A-2 and A-3				
Installed Capacity (MW)	152	140	128	116
Average Annual Power Generation (GWh)	486.6	450.5	413.5	376.9
Plan A-1				
Installed Capacity (MW)	200	185	170	155
Average Annual Power Generation (GWh)	739.0	682.9	626.9	572.3

Construction cost for each different scale of the Agos hydropower project is estimated together with the operation and maintenance cost on the basis of the preliminary design. Required construction period is assumed to be 6 years from 1983 to 1988.

The expected benefit from the power generation is also calculated assuming that, in plans A-2 and A-3, the Kaliwa and the Kanan water supply projects will be completed by 1986 and 1993 respectively and the surplus water until the full utilization will be used for the power generation at the Agos powerplant (in plan A-2 and A-3).

For the comparison, present worth of the costs and benefit for each scale is estimated in the year of 1989 on the condition of the discount rate of 10 percent. Net present worth and benefit cost ratio are calculated as shown in the next page.

Present Worth Net Benefit and B/C

HWL of Agos	AG-175	AG-165	AG-155	AG-145
A-2				
B - C (x10^6 US$)	61.83	65.87	64.18	50.46
B/C	1.19	1.23	1.25	1.21
A-1				
B - C (x10^6 US$)	150.62	154.18	145.66	129.7
B/C	1.44	1.51	1.53	1.51

As indicated above, the highest net present worth is given to the project scale with the high water level of EL.165 m in both the plans A-2 and A-1. However, the most optimum development scale of the Agos project is to be determined within the framework of the whole Agos river system because the selection of the high water level of the Agos affects the other project component such as Kanan hydropower project and Kaliwa pumped storage power project.

5.2.2 Kanan Hydropower Project (Kanan No.1 Dam)

In order to select the optimum scale of the Kanan hydropower project, the comparative study was done on 12 alternative plans consisting of three cases of different high water level with 4 cases of different tailwater level which depends on the high water level of the Agos dam. Basic plan for the dam and appurtenant structures is formulated for each different scale of the project as well as the layout plan for the power station with different installed capacity. The installed capacity and the annual average power generation corresponding to the high water level and tail water level are shown in the next page.

Construction costs for different scale of the Kanan project are estimated together with the operation and maintenance cost on the basis of the preliminary designs and by partly using the established formula and graphs. It is assumed that the construction of the Kanan hydropower starts from 1989 and completes in 1993. The project benefit expected from the power generation is also calculated for each different scale of the project.

HWL \ TWL	AG-175	AG-165	AG-155	AG-145
HWL 300 m				
Installed Capacity (MW)	188	149	158	168
Average Annual Power Generation (GWh)	411.6	439.2	466.9	500.8
HWL 290 m				
Installed Capacity (MW)	127	138	147	157
Average Annual Power Generation (GWh)	380.7	413.5	435.8	463.8
HWL 280 m				
Installed Capacity (MW)	115	127	135	144
Average Annual Power Generation (GWh)	349.0	383.0	404.5	432.7

Present worth of the costs and benefit for each scale is calculated at the year of 1994 using the discount rate of 10 percent. Net present worth and benefit cost ratio are calculated as summarized below.

Present Net Worth and B/C

HWL \	TWL	AG-175	AG-165	AG-155	AG-145
KN-300	B - C ($x10^6$ US$)	80.34	103.71	111.34	127.91
	B/C	1.34	1.44	1.45	1.50
KN-290	B - C ($x10^6$ US$)	82.66	105.27	110.73	125.46
	B/C	1.40	1.50	1.50	1.55
KN-280	B - C ($x10^6$ US$)	78.94	102.65	106.87	120.18
	B/C	1.43	1.55	1.53	1.58

HWL: High water level of the Kanan dam

TWL: Tail water level of the plant

As shown above, among 12 alternative schemes, the optimum scale of the Kanan hydropower project is KN-300 with the tail water level of 145 m. But, the final selection for the optimum Kanan project is to be made in relation to the Agos project and within the whole Agos river system.

5.2.3 Kaliwa Pumped Storage Project

The Agos reservoir and Kaliwa reservoir can be connected with waterway. The length of waterway is about 4 km. In this plan, required water for Metro Manila will be pumped up from the Agos reservoir to the Kaliwa reservoir using the waterway. Peak power generation may be also planned in addition to the water supply.

For the selection of the optimum scale of the Kaliwa pumped storage project for water supply to Metro Manila, two different capacities of the pump (250 MW and 100 MW) are compared. Since the tail water level of the pumped storage project changes depending on the high water level of the Agos dam, comparison is made on four different tail water levels both for the 250 MW and 100 MW. In the case of 250 MW capacity, power generation is also considered, while only pumping up water to Metro Manila is considered in the case of 100 MW capacity, which compensates the same amount of water with that by the Kanan water supply project planned by PICOREM.

Based on the above conditions, layout plan for the facilities are prepared for each different scale of the project. The water treatment facilities and the additional power plant to be installed as the second stage development at Pantay were already planned by PICOREM, which is used for our comparative study.

Construction cost for each different scale is estimated together with the operation and maintenance costs. The energy cost for pumping up is estimated at US$0.0471/kWh. Required construction period is assumed to be 4 years from 1990 to 1993. The expected benefit is also estimated corresponding to each different scale, which consists of water supply benefit, power benefit at Pantay and power benefit from the pumped storage power station (only in case of 250 MW capacity). The kW benefit is evaluated by the construction cost of gas turbine.

For the comparison all the costs and benefit are discounted at the year of 1994 using the discount rate of 10 percent. The net present worth and benefit cost ratio are calculated for each different scale as summarized in the next page.

As shwon in the table, the case of 100 MW gives the higher net benefit. If the benefit is evaluated by the 2nd stage development of the Kalayaan pumped storage power project/1, the benefit of 250 MW become 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.

/1 Kalayaan P/S project is under construction and to be completed by 1982. The unit cost per kW of the 2nd stage of the project is estimated at US$46.44/kW.

Present Worth Net Benefit and B/C

HWL of Agos	AG-175	AG-165	AG-155	AG-145
250 MW				
B - C (x10^6 US$)	174.17	172.2	160.21	128.23
B/C	1.15	1.14	1.13	1.10
100 MW				
B - C (x10^6 US$)	250.07	238.71	225.41	204.37
B/C	1.33	1.31	1.29	1.26

5.2.4 Kaliwa Water Supply Project

The Kaliwa project was planned by PICOREM as multipurpose project of water supply of 22.1 m^3/sec to Metro Manila and power generation of 153 GWh annually. The Kaliwa water supply project consists of a dam with spillway, outlet works, a powerhouse and water treatment plant at Pantay and distribuiton system. The project is planned to be completed by 1986.

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 powerplant and water treatment plant at Pantay through a tunnel of 13.6 km long.

The total cost is estimated at US dollar 514.2 million at 1989. The power benefit at Pantay is modified according to 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 power generation at the Agos powerplant. 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.

5.2.5 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 multipurpose project of water supply 36.7 m^3/sec to Metro Manila and power generation of 245 GWh annually. The project will be completed by 1993.

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, the water is led to Pantay water treatment plant where the powerplant is also provided.

The total cost is estimated at US dollars 888.3 million at 1994. The benefit is assumed to be US dollars 954.0 million by adjusting the power benefit as described in Paragraph 5.2.4. The present worth of net benefit and benefit cost ratio are assumed to be US dollars 65.7 million and 1.07 respectively.

5.2.6 Kanan No.5 Hydropower Project

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, by JICA team the fill volume of dam and design flood are corrected.

The cost is computed using the unit prices derived for the feasibility study of the Agos project. The project is assumed to be completed by 1988.

The power benefit derived from the project consisting of the kW benefit of 280 MW (95 percent dependable capacity is 264 MW) and the kWh benefit of 930.3 GWh is US dollars 635.3 million discounted to 1989. The net present worth benefit and benefit cost ratio are US dollars 206.8 million and 1.48 respectively.

5.3 Selection of the Optimum Development Plan

On the basis of the results of 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 percent per year. The calculation results are summarized in the next page and the details are presented in Table 5-1.

Net Present Worth and B/C for Alternative Plans

	Optimum HWL Agos (m)	Optimum HWL Kanan (m)	B - C (10^6 US$)	B/C
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	1.33
Plan B	-	260	491.30	1.47

Benefits and Costs are discounted at the year of 1989 using discount rate of 10 percent.

As shown in the above table, plan A-3 is the plan with the highest net present worth out of the four alternative plans although the difference is small.

Between the two alternative plans, plan A-2 and A-3, which are planned with the aim to provide the requirement of the water supply to Metro Manila up to the year of 2009, plan A-3 seems more beneficial than the plan A-2. The difference between the two plans comes mainly from the cost of the Kanan dam and the hydropower benefit of the Kanan project. In plan A-2, the Kanan No.2 dam selected by PICOREM is considered to be more expensive than the cost of the Kanan No.1 dam applied in plan A-3. The cost difference is estimated at around US$73.1 million at the present value of 1989 and even if the plan A-2 is evaluated by applying the same cost with the Kanan No.1 dam, the superiority of the plan A-3 will not change.

Both the plans A-1 and B will be materialized only when the Kanan water supply project is disqualified or discarded by some reasons. Then, the Agos hydropower station will be able to use all the discharges of the river basin excluding that of upstream of the Kaliwa dam. Under this situation, plan A-1 is proved to be more favourable than the plan B and the Agos-Kanan No.1 joint hydropower scheme is considered as the most beneficial project.

Final selection for the most optimum development plan of the Agos river system is to be done not only by the economic comparison but also by the social aspect. Metro Manila may suffer from the shortage of the water supply in the near future and the Kaliwa and Kanan rivers are considered as the most economical available water sources. In view of this, the Kanan water supply project will possibly be implemented though it may be delayed.

Under this situation, the Agos hydropower project is the only possible plan for the hydropower development in the remaining watershed of the Agos river. The Agos project still maintains its economic viability even the discharge of the Kanan is diverted to Metro Manila water supply. The Agos hydropower project is, therefore, selected as the most promissing project among other hydropower development plans in the Agos river system for which detailed feasibility study is to be conducted from the succeeding chapters.

CHAPTER 6

AGOS HYDROPOWER PROJECT

6.1 Plan Formulation

In the preceeding chapter, the most optimum development plan for the Agos river system was formulated, in which the Agos Hydropower Project was proved to be the most beneficial project. The subsequent study from this chapter was concentrated on the selected Agos Project. Layout study of the main structures for the Project was firstly made, which includes comparison of several alternatives. The most optimum scale of the Agos Project was finally selected through the comparative study on the formulated alternative schemes with different dam heights and different installed power capacities.

6.1.1 Layout Study of Main Structures

Layout study for the Agos Project was made under the following basic concepts.

i) Dam axis is to be selected within one (1) kilometer long of the downstream stretch from the confluence of the Kanan and Kaliwa rivers in view of geological and topographical conditions.

ii) Spillway is to be planned so as to decrease its excavation volume as much as possible in consideration of cost as well as the geological and topographical conditions.

iii) Diversion tunnel routes and their capacities are to be determined in due consideration of possibility for utilizing the tunnel(s) as a part of a spillway or/and a power tunnel after construction.

(1) Dam

Prior to selecting the dam axis, type of the dam is to be determined by the technical and economic comparison. Through the comparative study, a rockfill type was selected for the Agos dam with the following reasons.

i) Rockfill dam is the most economical type among them in due consideration of the available materials.

ii) If concrete dam is selected, total dam volume will be more than 4 million cubic meters. In constructing such large dam, difficulties for preparation of large scaled concrete and aggregate plants, for smooth materials supply and for inland transportation of plants and equipment are anticipated.

iii) Compared with fill type dam, many difficult technical problems are to be cleared for the concrete dam including foundation treatment and dam cooling during construction.

For determining the dam axis, alternative lines located within one kilometer in the downstream stretch from the confluence were compared. Geological investigation was done by seismic exploration and test drilling. Topographical survey work was also made on this dam area and maps of 1/1,000 scale were prepared.

Based on the results of investigation and survey works, comparative study was made. In view of the geological and topographical conditions, dam axis located at about 400 m downstream from the confluence was finally selected with an alignment of crossing the river at a right angle.

(2) Spillway

The spillway site was selected on the left abutment from the topographical view point since the spillway on the right bank requires huge amount of excavation which cannot be accomodated in the dam embankment. The center of the spillway was so designed to coincide with the river course.

Several types of spillway such as fully gated spillway, gated spillway with side channels, non gated spillway and morning glory type untilizing diversion tunnels were conceived. Out of these types non gated spillway was discarded, because it required long spillway crest and higher dam crest. With respect to the morning glory type, the discharge in tunnel should be of free flow. The capacity of morning glory is therefore limited to the order of only around 500 m^3/sec. As described in later, it is more attractive if the diversion tunnel is used as a part of power tunnel. Hence, there is no space for morning glory. The layout study for spillway was carried out for the remaining two types, fully gated spillway and gated spillway with side channels.

For comparison, following criteria are applied.

i) the design flood of 10,600 m^3/sec should be discharged without flood routing and the probable maximum flood of 17,300 m^3/sec be passed with the effect of reservoir retardation.

ii) the free board is 3.0 m and 2.1 m for design flood and probable maximum flood, respectively.

The following four alternatives were considered for the comparison.

Alternative I

The spillway is equipped with 10 numbers of 12.5 m (H) x 12.0 m (W) radial gates. This is the original design of spillway used in pre-feasibility design.

Alternative II

The spillway is equipped with 6 number of 12.5 m (H) x 12.0 m (W) radial gates and 2 lines of 100 m long side channels at both sides.

Alternative III

The spillway is equipped with 6 numbers of 12.5 m (H) x 12.0 m (W) radial gates and 2 lines of 185 m long side channels at both sides.

Alternative IV

The spillway is equipped with 4 numbers of 14.5 m (H) x 14.0 m (W) radial gates and 2 lines of 210 m long side channels at both sides.

Cost comparison was made for the alternatives as shown below.

Construction Cost of Dam and Spillway

(million US dollars)

	Alternative Plans			
	I	I	III	IV
Dam	108.81	113.25	111.46	111.73
Spillway (civil)	5.59	6.51	7.56	6.74
" (metal)	4.08	2.45	2.45	2.45
Total	119.48	122.21	121.47	120.92

The least cost plan is the alternative I. Among the alternatives with non-gated side channels, the least cost alternative is the alternative IV. For the selection of the optimum spillway, safety under the critical condition is to be considered. Under the assumption that all gates do not open for some reasons, the expected levels of the reservoir water surface were computed for the flood of 200 years return period. This computation indicates that the flood water can be discharged without overtopping the dam crest in case of alternative IV, while the water surface level exceeds the dam crest and dam will be damaged in case of alternative I.

Since the cost difference between the two alternatives is US$1.4 million or about 0.6 percent to the total cost, the alternative IV was finally selected for the safety.

(3) Diversion Tunnels and Main Cofferdam

The design flood for diversion works is determined to be 30 years flood of 5,210 m^3/sec. (Refer to Appendix E). For the construction, only the tunnel method is applicable to the diversion works judging from conditions of topography, geology and in view of the large scale of the dam. Moreover, two lane tunnels will be required against the aforesaid flood of 5,210 m^3/sec because one lane tunnel shall be designed to have a big diameter over 12 m which will be more costly and not effective.

The diameter of diversion tunnels is the function of a main cofferdam height for the design flood. For selecting the optimum scale of the diversion tunnels, cost comparison was made for different diameter of the tunnel ranging from 8.0 to 12.0 m taking into account the cost of cofferdam and diversion gate. The results of the comparison indicates that the most economical diameter is 9 m with the cofferdam crest of EL.93 m.

Construction Cost of Diversion Works

(million US dollars)

Tunnel Diameter	8 m	9 m	10 m	11 m	12 m
Diversion tunnels	9.67	11.83	14.36	17.32	20.55
Diversion gates	0.18	0.21	0.27	0.36	0.48
Cofferdam	13.17	10.58	8.38	6.93	5.42
Total cost	23.02	22.62*	23.01	24.61	26.45

After selecting the optimum size of the diversion tunnels, the route of the tunnels was studied together with a waterway route. Although the waterway route is planned independently from the diversion tunnel in the pre-feasibility study (the optimization study on the Agos river system), possibility to utilize the diversion tunnels as a part of the waterway was also considered in this study.

From the comparative study on the various alternative schemes, the plan of constructing the diversion tunnels at each bank, one of which will be used for the power waterway was selected in due consideration of the geology, the cost, problems during construction and operational problem of the diversion tunnels. (Details of the comparison are presented in Appendix E)

(4) Afterbay Weir

In the pre-feasibility stage, the afterbay weir was designed to generate energy of around 78 GWh by 30 MW installed capacity to harness the remaining head as well as the regulation function of discharge released from the Agos powerplant. However, as the field investigation proceeds, it has been revealed that the foundation rock at the weir site is 40 to 50 m deep from the river bed. So the plan of constructing a high dam equipped with a powerplant was abandoned.

Judging from the population and the habit of the people near-by the river, the necessity of the re-regulating function of discharge released from the Agos powerplant may be very little because of the following reasons:

a) As the installed capacity of Agos powerplant is 140 MW, the plant will be operated for more than 12 hrs a day on average before Kanan water supply project is developed.

b) According to the computation results of unsteady flow of sudden switch in, the fluctuation of water surface is 1.05 m (EL.6.52 m to EL.7.57 m) and the rate of rising is 5 cm per minute at Banugao. Furthermore, it takes about two and a half hours for the released discharge to reach Banugao. There is an ample time to prepare the change. An alarm system will help this purpose.

c) There are two irrigation intakes supplying water for around 1,450 ha including the area of 200 ha to be extended in future. According to 26 year discharge records at Banugao the second driest monthly discharge is 15.52 m^3/sec. As the remaining area downstream of the Agos dam is 44 km^2, the discharge of 0.75 m^3/sec is anticipated.

Although above findings are to be checked in the detailed design stage, the afterbay weir might be excluded in the work.

6.1.2 Selection of the Optimum Scheme

Detailed study for determining the optimum scale of the Agos Hydropower was conducted on the basis of the results of the layout study and the reservoir operation study. For the study, four schemes with different high water levels of the reservoir, namely, EL.175 m, EL.165 m, EL.155 m and EL.145 m were examined.

The installed capacity of the power station is generally determined as the function of the reservoir capacity and the available head. Assuming that the required plant factor for the Agos is around 33 percent (or 8 hours operation per day) on an average for 50 years project life, the installed capacity for each alternative scheme was decided. Main different features of the four schemes are summarized in the following table. (Detailed of the alternative shcemes are presented in Table 6-1)

	Alternative Schemes			
	AG-175	AG-165	AG-155	AG-145
Reservoir HWL (m)	175.0	165.0	155.0	145.0
Dam Crest Elevation (m)	182.0	172.0	162.0	152.0
Dam Volume (10^6m^3)	20.1	16.8	13.95	11.4
Installed Capacity (MW)	152	140	128	116
Generated Energy/1 (GWh)	677	625	572	521

/1 Generated energy in 1994, when all the water of the Kaliwa reservoir is used for water supply to Metro Manila.

For selecting the optimum scheme, cost and benefit for each alternative were calculated. Construction cost, and operation and maintenance costs were estimated at the price level of early 1980 using the same criteria as explained in the succeeding Section 6.4 Project Costs. Summary of the costs for each alternative scheme is presented in Table 6-2. Power benefit was also estimated using the same values as applied in Chapter 7 Economic Analysis, which were calculated on the basis of the cost for the least cost alternative thermal plant. For the comparison, all cost and benefit were discounted at the beginning of 1980 price assuming that the economic project life is 50 years and the discount rate is 10 percent. Net benefit and benefit cost ratio for each scheme were calculated as presented below.

(million US dollars)

	AG-175	AG-165	AG-155	AG-145
Present Worth of Benefit	381.56	351.66	321.83	292.12
Present Worth of Cost	319.12	284.86	257.05	241.87
Net Benefit (B - C)	62.44	66.80	64.78	50.25
B/C Ratio	1.20	1.23	1.25	1.21

From this, the scheme having the maximum net benefit was selected as the optimum scheme, which is the scheme with the high water level of 165 m and the installed power of 140 MW. (Details of the selection for the optimum scheme are presented in Appendix D, Optimizaiton Study)

6.2 Project Works

The Project is composed of the Agos dam of 172 m in height, spillway, diversion works, power tunnel, powerhouse with generating equipment of 140 MW installed capacity, and 230 kV transmission line of about 43 km long including a substation at Malaya to connect with the truck line around Metro Manila. The general layout of the proposed facilities is shown on Dwg.6.

6.2.1 Diversion Works

Diversion facilities consist of a system of two concrete lined diversion tunnels with upstream and downstream cofferdams which are designed to be the parts of the main dam embankment. The diversion works are planned to discharge flood of 5,210 m^3/sec (30 years flood).

The layout and details of the two diversion tunnels finally selected are shown on Dwg.6 and 7. The tunnel No.1 located at the left bank is of 9 m diameter circular section with 816 m in length. The sill elevation of inlet is set at EL.45 m and about 3 m above river bed so as to be utilized as an access tunnel during construction and to make installation of penstock line easier. The sill elevation of outlet is set at EL.40 m to coincide with the river bed elevation. The middle portion of the tunnel is planned to be used for power waterway. The tunnel No.2 located at right bank is of 9 m diameter circular section with 817 m in length.

The crest elevation of the upstream cofferdam is set at EL.93 m. Judging from the large and deep excavation for main dam foundation, an impervious material facing was selected to minimize the seepage water thorugh foundation beneath the upstream cofferdam and to lower the hydraulic gradient of seepage water. In addition, a number of dewatering wells will be provided into river alluvial deposit adjacent to the slope ends of cofferdams. The upstream cofferdam consists of three zones, namely, impervious, filter and rock. The crest width of upstream cofferdam is 8 meters and the cofferdam has the slope of one to three (1:3) for upstream side and one to two (1:2) for downstream side.

The downstream cofferdam consists of two zones, Zone I is of clay core and Zone II is of river alluvial deposit. The crest width of downstream cofferdam is 6 meters and the cofferdam has the same slope of one to three (1:3) for both upstream and downstream sides.

Since the cofferdams will be incorporated into the main dam particulary a part of the downstream cofferdam is used for switch yard ground, the cofferdams are to be placed and compacted in the same method for the main dam.

6.2.2 Dam and Reservoir

The proposed Agos damsite is located on the Agos river just downstream of the confluence of the Kanan and Kaliwa rivers. The Agos reservoir has a gross storage capacity of 955 million cubic meters of which effective storage capacity is 570 million cubic meters. High water level is set at EL.165 m and low water level at EL.128 m with the drawdown of 37 m. The area of the Agos reservoir is around 21.5 km^2 at HWL.165 m.

The plan of the Agos dam is shown in Dwg.6. The dam is designed as a zoned rockfill dam with a center core zone. The slope of center core zone is one in vertical to point two in horizontal (1:0.2) for upstream and one in vertical to point one in horizontal (1:0.1) for downstream. The width of the crest is 12 m. The thickness of the core is planned to be more than 30 percent of water head at any height. Materials used for the core will be mixed silty-clay with weathered rock to obtain the sufficient strength for high dam. One layer of the filter zone is provided on both upstream and downstream sides. Most of the filter material is taken from the river alluvial deposit downstream of damsite and from dam foundation excavation.

Excavated rock produced mainly from the spillway excavation and quarry will be used for the shell zone. The slope of the shell zone is one in vertical to two point five in horizontal (1:2.5) for upstream side and one in vertical to one point nine in horizontal (1:1.9) for downstream side.

For determining the freeboard requirements, the following two criteria are compared.

i) Design flood can be fully discharged without taking account of reservoir retardation effect.

ii) Probable maximum flood can be discharged with the reservoir retardation effect.

In case i), the freeboard is computed at 3 m which consists of wave height of 1.1 m, an allowance of 0.5 m for the gates, an allowance of 1.0 m for filltype dam and crest pavement of 0.4 m. In case ii), the freeboard is computed at 2.1 m which consists of wave height and the allowance for the filltype dam. The higher value of 3 m is adopted, resulting in the crest elevation to be at EL.172 m.

For the foundation of the core and filter zones, its excavation line is determined at the fresh rock surface. All top soil is stripped to the depth ranging from 2 to 5 m for shell zones at both the abutments. Furthermore, rock embankment for the shell zone is to be done on the river alluvial deposit at the river bottom without any excavation. Except for the concrete replacement of faults, the foundation treatment will be performed by cement grouting. Curtain grout holes are prepared at 2 m intervals in two lines. For consolidation and blanket groutings which solidify the foundation surface and prevent pressured water from passing through cracks and between the base and impervious earth core, required depth will be 5 m for solid fresh rock. Conceivable interval of the grout holes is 3 m. For the purpose of the curtain grouting and inspection after impounding water, a grouting gallery will be provided beneath the core.

Slope stability of the dam is checked by slip circle method./1 As shown in the table below, the minimum safety factors of slopes are more than 1.5 under the normal condition and more than 1.2 with earthquake considered. The corresponding critical slip circles are illustrated in Fig.6-1.

Minimum Factors of Safety

Case	Condition	Slope Applied	Min. Factors of Safety	
			Without Earthquake	With Earthquake
1	H.W.L. (EL.165 m)	Upstream	2.64	1.20
		Downstream	1.78	1.23
2	Immediately after Completion	Upstream	2.59	1.97
		Downstream	1.77	1.45
3	Rapid Drawdown	Upstream	2.28	1.54
4	Max. Water Level (168 m)	Upstream	2.65	1.68

6.2.3 Spillway

The spillway site is planned on the left abutment from the topographical point of view. Plan & profile of the selected spillway are shown in Dwg.9.

The spillway has a capacity to discharge the design flood of 10,600 m^3/sec without any retarding effect of the reservoir (inflow is equal to outflow). In addition, the probable maximum flood of 17,500 m^3 /sec can be discharged without endangering the dam when the retarding effect is taken into account.

/1 According to "Design Criteria for Dams" by Japanese National Committee on Large Dams.

The crest elevation of the gated portion is set at EL.154 m. Four numbers of radial gates of 14 by 14.5 m are provided. Side channel spillways of 2 lanes with each 210 m in length are arranged symmetrically on both the sides. The crest elevation of the side spillway is EL.165 m. The water will be led to chuteway whose profile is level in the upper portion of 110.5 m and 1 in vertical to 3.71 in horizontal in the lower portion. Most part of chuteway will be founded on fresh rock. The height of wall is designed against the design flood water surface where an allowance for air incursion is added. Furthermore, the freeboard of 2 m is taken in the design of the whole chuteway wall. The chuteway is terminated at a flip bucket at EL.57.5 m with an angle of 20 degrees. The discharge released from spillway is returned to the Agos river through a plunge pool where energy is dissipated.

In the detailed design stage, hydraulic model test shall be conducted to check and confirm the function to the satisfactory. The following data and aspect are also to be fully taken into account for the final design.

i) Additional data for meteorology and hydrology to be obtained by continuous observation of rainfall and water levels.

ii) If the upstream projects such as the Kanan and the Kaliwa are qualified to implement, there is the effect of two reservoirs to the flood lag time and reservoir retardation for the design flood.

6.2.4 Power Tunnel

Power tunnel and powerhouse are planned to be constructed at the left bank. The layout of the waterway is intended to utilize some part of the diversion tunnel as much as possible. The power tunnel consists with 6.8 to 9.0 m diameter and penstock line of 350 m in length with 6.1 m diameter.

The maximum discharge is 162.8 m^3/sec at the reservoir rated water level EL.146.5 m. The net head available at rated water level is 105 m. Total loss head at the maximum discharge is calculated at 3 m, about 2 percent of the net head.

The intake tower is a reinforced concrete structure, and has a service deck at EL.172 m, a hoist deck at EL.180 m and a control shaft in which the intake gate is accommodated. The foundation concrete is utilized as the inlet sill having a bellmouth entrance and transition section for intake gate. The sill elevation is at EL.114 m allowing 14 m depth from the low water level preventing air intrusion into tunnel.

Total length of the headrace tunnel is 225.8 m including the inlet portion. From the lower end of the inlet structure, the discharged water will be led into an inclined tunnel and then a horizontal tunnel. The length of the diversion tunnel to be utilized as a part of headrace tunnel is 80 m. The tunnel is jointed to the diversion tunnel with the transition of gradual expansion from 6.8 m to 9 m. The headrace tunnel is terminated in front of the plug portion with the provision of the transition part.

The penstock line is divided into two parts. For the upper portion of 256 m, the penstock steel pipe will be installed in the diversion tunnel, while for the lower portion of 94 m, the pipe is embedded in the tunnel. The penstock is bifurcated in front of powerhouse then led to inlet valve and turbine. Diameter of the penstock will be 6.1 m. Maximum pressure rise is calculated at 34 percent of the static water head at high water level setting that the closing time of the valve is 7 seconds.

6.2.5 Powerhouse and Tailrace

The powerhouse and tailrace are planned to be located at the downstream toe of the dam between the spillway and the downstream cofferdam. The location of the powerhouse is selected to keep the sufficient distance from the lowermost part of diversion tunnel No.1.

(1) Civil Works

The powerhouse is planned to be semi-underground type with dimensions of 30 m in width by 56 m in length and the maximum height of 39 m, accommodating two units of turbine and generator and other ancillary equipment such as inlet valves, tailrace gates, and overhead crane. Level of casing center of turbine is set at EL.38 m which is 3.6 m lower than the water level at the tailrace at the maximum discharge. Most of the generating equipment is planned to be installed below EL.51 m.

The discharge from draft tube culvert will be returned to the Agos river through the tailrace channel. The tailrace channel is designed to make the head loss as small as possible. The tailrace walls are hightened to minimize the fluctuation of water surface transmitted from the plunge pool during spillage. The effect of the discharge released from the flip end to the tailrace shall also be examined by model test during the detailed design stage.

(2) Architectural Work

Architectural work of the Agos project consists of mainly powerhouse superstructure, appurtenant buildings of the power station and dam observatory house at dam crest. The architectural works include all works of structure, architecture, utilities and gardening, gate and fence.

6.2.6 Power Generating Equipment and Transmission Line

The generating equipment comprises the unit system of two units of turbine generators and transformers. The turbine will be of vertical shaft Francis type with rated output of 72,000 kW under the effective net head of 102 m and the maximum discharge of 163 m^3/sec and the speed of 225 revolution per minute.

The generater will be of vertical shaft semi-umbrella type synchronous generator and of revolving field type with static excitation system. The rated capacity is 78,000 kVA at 0.9 lagging power factor. The control system for each unit will be of one-man control type with a master controller and necessary protective device.

The main transformer will be of forced oil circulation with cooling fan, outdoor use type with the rated capacity of 78,000 kVA and the rated voltage of 13.8 kV/230 kV.

The outdoor switch yard will be provided on the land between the main dam and the downstream cofferdam. The arrangement of the switch yard is ring bus system, connecting two units of 70,000 kW generators and double circuits of 230 kV transmission line to the Malaya thermal power station with about 43 km distance from the Agos power station. At Malaya power station site, realignment of the southern transmission line will be required to avoid crossing with the Agos line. For the local power supply, one transformer of 5,000 kVA with rating voltage 13.8 kV/69 kV is provided. But, construction works of the 69 kV transmission line is not included in the Project.

6.2.7 Hydromechanical Equipment

Four sets of radial type spillway gates will be provided in the spillway crest. The width and height of the gates are 14 m and 14.5 m respectively. The gates will have the radius of 18.0 m from the trunnion pin center to the inside of skin plate. The anchorages are designed of the prestressed steel cable type. One complete set of stoplog comprising of five leaves of 1.0 m height for the upper portion and four sets of the guide frames are to be provided for servicing to the spillway gates.

Six lanes of vertical fixed type trash racks, each comprising of eight panels, and a flat type bulkhead gate will be provided on the intake tower. One set of fixed wheel type gate of 5.4 m by 6.8 m is to be provided in the intake tower. The intake gate will be used for normal closing and opening, for emergency shutoff and for filling water into the headrace tunnel.

One lane of steel penstock with 6.1 to 3.1 m diameter and around 340 m in length will be provided. The beginning and end portion of the penstock will be encased by reinforcement concrete and remaining portion of penstock be supported by shoe type ring girders at interval of 12 m. Two sets of slide type tailrace gates of 4.0 m by 5.0 and four sets of their guide frames are to be provided in the tailrace. The tailrace gates will be used to close one turbine draft tube for inspection and maintenance purposes. Two sets of slide type diversion gates of 4.5 m by 9.0 m will be provided in the intake of diversion tunnel No.2.

6.3 Construction Schedule and Plan

6.3.1 Construction Schedule

The construction of the project works for the Agos Hydropower Project is planned to be completed by the end of 1988. In order to achieve this target, the following implementation schedule is planned.

Engineering service	:	October 1981 - December 1988
Tender call and contract	:	April 1982 - January 1983
Commencement of construction	:	February 1983
Commencement of commercial operation of generating equipment	:	January 1989

During the tender works, a contract for the diversion tunnels and cofferdams shall be concluded so as to start the construction work in the early part of 1983 considering that the main dam works be commenced in the middle of 1984.

Overall implementation of the Agos Project is presented in Fig.6-2.

6.3.2 Mode of Construction

All the project works are assumed to be executed by selected international and/or local contractors. Some contractors for special works are to be selected by selective tender or direct order in view of limited time schedule. The following are modes of construction for the project works.

	Work Item	Contents	Mode of Construction
1.	Preparatory work	Access road, temporary building, water & power supply system etc.,	Local tender
2.	Diversion tunnels & cofferdams	Diversion tunnel Nos. 1 and 2, and upper and downstream coffers	International selective tender
3.	Main civil works	Main dam, spillway, power tunnel, and powerhouse	International open tender
4.	Generating equipment	Turbines, generators, draft tubes, overhead crane, switchyard equipment and others	International open tender
5.	Transmission line	Transmisssion line and sub-station	International open tender
6.	Metal works	Spillway gates and stop-logs, intake gates and trash-rack, tailrace gates and gantry crane, diversion gates, and penstock	International open tender
7.	Engineering services	Detailed design and construction supervision	Direct order

6.3.3 Construction Plan and Method

(1) Diversion Tunnels and Cofferdams

Basic plans for the construction of the diversion tunnels and cofferdams are described as follows.

a) Construction of the diversion tunnel No.1 is planned to be started from January, 1983 and to be completed by the dry season of April 1984, when the river diversion is to be executed.

b) Construction period of the diversion tunnel No.2 is 17 months from April 1983 till August, 1984 just before the flood season starting.

c) The main cofferdam embankment is planned to be performed for approximately 6 months from March 1984. The river diversion from the original river course to the diversion tunnel No.1 is planned to be done in May 1984 when the tunnel No.1 be completed. The embankment of the cofferdam is to be completed by the end of September 1984 when the tunnel No.2 is completed.

d) The tunnel No.1 is planned to be closed in April 1987 and the installation works for the penstocks to be started from May in that year. For the tunnel No.1 closure, the main dam is to be embanked up to EL.110 m by the end of August 1987, so that floods less than 5,210 m^3/sec can be discharged only through the tunnel No.2. Impounding of the reservoir will be commenced after the tunnel No.2 closure in May, 1988. Most of the dam works including the spillway works are to be completed by the end of the dry season 1988 for the final closure of the diversion tunnel No.2.

A top heading and bench cut method is recommended to be applied for the tunnel excavation. The tunnel excavation in the top heading will be done from both end sides (inlet and outlet sides). To save the cost of the main construciton equipment such as crawlers mounted drill jumbo and sliding forms for concrete lining, a tunnel construction plan is to be carefully made. In view of this, commencement of the tunnel excavation of No.2 is planned to be delayed by 3 months from that of the tunnel No.1.

The cofferdam of about 1,600,000 m^3 is planned to be embanked during 6 months in the dry season. The expected work volume per month for the cofferdam is approximately 50 percent of that for the main dam.

(2) <u>Main Dam</u>

All the main dam works are scheduled to be carried out for about 5 years from the early part of 1984. The main works for the dam consists of excavation of 2,844,000 m^3, embankment of 15,418,000 m^3, inspection gallery of 1,100 m long and grouting of 60,000 m long in total. From the existing rainfall data, workable days for embankment works are estimated to be 152 days per year for core and filter, and 273 days per year for rock. Monthly embankment volume of the main dam is planned to be 350,000 m^3 on an average assuming that the workable hours are 14 hours per day using two shift work system.

Foundation excavation and treatment are planned as described below.

a) Foundation excavation for the core portion is scheduled to be made between March 1984 and September 1985.

b) The inspection (and grout) gallery of 1,000 m long will be constructed within 2 years starting from October 1984 and the river bed portion of 160 m long is to be constructed till the end of March 1985, just before starting the core embankment.

c) Grouting works consisting of blanket grout of 24,000 m in total and curtain grout of 34,000 m in total length are to be executed for 15 months from September 1984 for blanket and for 30 months from January 1986 for curtain. Most of the curtain grout works will be done in the inspection gallery.

(3) Spillway

Total volume of the spillway foundation excavation is approximately 8.4 million cubic meters. Excavated rocks of 6.4 million cubic meters from the spillway foundation is utilized as the rock embankment materials for the main dam. For this purpose, the spillway rock excavation is planned to be done so as to follow the schedule of the main dam embankment for the period of 5 years starting from the early part of 1984.

The estimated concrete volume of the spillway is 195,000 m^3. The concrete work is planned to be conducted for about 3 years from October 1985.

(4) Waterway

The closure of the diversion tunnel No.1 is scheduled in April 1987 and the penstock installation works are planned to be commenced in May as mentioned above. The following tunnels are to be constructed prior to the aforesaid closure.

a) The inclined tunnel of 110 m long between the intake structure and diversion tunnel No.1.

b) The connection tunnel of 94 m long between the powerhouse and diversion tunnel No.1.

With regard to the penstock, its installation works are scheduled to be completed within 14 months from May 1987 immediately after the closure of the tunnel No.1. The total length and weight of the penstock is 350 m and 1,450 tons. All the installation works including tests are to be completed by the end of August 1988 just before the final tests of the generating equipment.

6.4 Project Costs

6.4.1 General

Construction cost of the Project and its operation and maintenance costs were estimated on the basis of the feasibility design and the proposed construction plan and schedule. All the cost estimates were made at the price level of early 1980 using exchange rates of 7.50 Pesos and 250 Yen to one US dollar. The basic conditions applied for the cost estimate are as presented below:

a) The civil works will be conducted under the contracts of selected contractors. Unit prices are estimated on the basis of the proposed construction plan and cost data referring to the bid prices of current construction works on the similar projects.

b) Prices for the electro-mechanical equipment including installation are estimated on the basis of the recent bids of similar units and prices in the international market.

c) Most of the construction materials are to be supplied by the contractors mainly from local markets, the costs of which are estimated as the local currency portion. But, the costs of steel products such as structural steel and reinforcement bar, cement and fuel oil are estimated as the foreign currency portion.

d) Construction machineries, equipment and plants including spare parts are to be brought by the contractor, the cost of which are estimated as the foreign currency portion.

e) Costs for freight, insurance and inland transportation as well as import tax and duty are included in the costs of all materials, plants and equipment, which are to be imported.

f) Costs for transmigration and land compensation for the submerged and construction areas are estimated tentatively as the land acquisition cost.

g) For unforeseen changes in physical conditions, physical contingency amounting to 10 percent of the estimated direct costs is added.

h) Engineering service including detailed design and construction supervision, and NAPOCOR's administration costs are estimated at around 6 percent of the direct cost plus contingencies.

i) Price contingency is estimated by applying the inflation rate of 7 percent per annum on foreign currency portion and 10 percent annum on local currency portion.

6.4.2 Total Construction Cost

The total construction cost excluding price contingency was estimated at US$295.6 million which comprises US$248.5 million of foreign currency portion and US$47.1 million (or Peso 353.3 million) of local currency portion. With price contingency included, the total project construction cost was estimated at US$456.6 million as presented below. The disbursement schedule of the project construction cost is shown in Table 6-4.

Cost Item	Cost (10^3 US$)		
	Foreign	Local	Total
1. Land Acquisition	-	2,700	2,700
2. Civil Works	177,500	30,500	208,000
- Dam & Appurtenant Structures	167,800	28,600	196,400
- Power Facilities	9,700	1,900	11,600
3. Generating Equipment & Metal Works	35,600	7,200	42,800
- Generating Equipment	27,800	5,000	32,800
- Metal Works	7,800	2,200	10,000
4. Physical Contingency [10 % of (1 + 2 + 3)]	21,300	4,000	25,300
5. Engineering Service & Government Administration	14,100	2,700	16,800
Sub-total (1 - 5)	248,500	47,100	295,600
6. Price Contingency	125,607	35,370	160,977
Total (1 - 6)	374,107	82,470	456,577

6.4.3 Operation and Maintenance Costs

Annual operation and maintenance costs of the Project were estimated on the basis of the following assumption and actual expenses.

a) Annual OM costs for dam and appurtenant structures are 0.5 percent of the construction cost.

b) Annual OM costs for hydropower plant are ₱45.7/kW.

c) Annual OM costs for transmission line are 2.5 percent of the construction cost.

The estimated annual operation and maintenance costs for the Project are US$4.17 million.

6.4.4 Replacement Cost

Economic life of the generating equipment and the metal works is assumed at 35 years after the installation. Replacement cost of them was calculated by summing the installation cost and the cost for the civil works related to this replacement in due consideration of the salvage value of these equipment, only the installation cost was included as the replacement cost.

6.5 Organization for Project Implementation

Fig.6-3 presents overall construction organization chart. NAPOCOR will have overall responsibility for the implementation of the Project. Design and construction of the Project will be executed by NAPOCOR. Resettlement in the project area will be cared by NAPOCOR.

For the execution of construction works, the field office of NAPOCOR tentatively named Agos Project Office will be required to be built. The construction works will be carried out by the contract basis with international/local contractors under the supervision of the Project Office. A technical assistances by foreign and/or local consulting engineers will be provided for successful performance of the construction work.

After completing construction of the Project works, operation and maintenance will be transferred to and managed by the hand of Manager, Luzon Project Office, NAPOCOR.

CHAPTER 7

ECONOMIC AND FINANCIAL ANALYSIS

7.1 Project Benefits

7.1.1 General

Most significant economic benefit of the project is that derived from electric power generation. Beside this, other benefits to the region such as flood control, fishery, irrigation and tourism development are expected from the project. In this chapter, however, only the power benefit is studied in detail which is incorporated in the economic evaluation of the project.

7.1.2 Power Benefit

Economic benefit to be derived from power generation is estimated by the cost of the least cost alternative power plant. As the alternative plants, oil-fired thermal, coal-fired thermal and gas-turbine plants are compared taking into account the power operation of the Agos power plant. Economic comparison for the three alternative plants is made on the following conditions. All the costs used in the benefit estimate are at the price level of early 1980.

	Oil-fired Thermal	Coal-fired Thermal	Gas-turbine
Investment Cost ($/kW)	630	790	370
Annual OM Cost (% of investment)	3.65	5.25	2.5
Plant Life (years)	30	30	15
Thermal Efficiency (%)	38	37	25
Heating Value (BTU/Lb)	18,600	8,500	18,400
Fuel Cost ($)	28/barrel	45/ton	31/barrel

On the basis of the above figures listed, the cost of generated power per kWh is calculated on different plant factors for each plant. The results are presented in Fig.7-1. The comparison indicates that the least cost alternative plant is the coal-fired thermal plant when the plant factor is more than 25 percent or 2,250 hours per year. As the plant factor of the Agos hydropower station reduces from 58 percent to 32 percent, the power benefit is evaluated by the cost of the coal-fired thermal plant.

(1) kW Value

On the basis of the average construction cost of the coal-fired thermal plant which excludes the interest during construction, annual equivalent cost required for producing the expected power is estimated for three discount rates with the following assumptions.

	Discount Rate		
	10 %	12 %	14 %
Capital recovery of the investment (%)	10.61	12.41	14.28
Major overhaul and replacement (%)	3.00	3.00	3.00
Operation and maintenance (%)	1.80	1.80	1.80
Other expenses (power cost for general use, insurance, etc.)	0.45	0.45	0.45
Annual equivalent cost (%)	15.86	17.66	19.53

Annual equivalent costs per kW are US$125.29 (10 percent discount rate), US$139.51 (12 percent discount rate) and US$154.29 (14 percent discount rate).

For the calculation of the kW value, advantageous factor of hydropower to the thermal power is to be considered. In due consideration of the expected energy loss and time loss for the both plants, the compensation factor for hydropower is estimated at 1.279/1. The kW values, thus estimated, are as follows:

/1 Power loss and time loss are:

	Hydropower (%)	Coal-Fired Thermal Power (%)
Transmission loss	3.0	2.0
Forced outage	1.0	5.0
Outage for overhauls and inspection	2.7	14.0
Consumption for station service	0.3	9.0

$$\text{Compensation factor} = \frac{(1 - 0.03)}{(1 - 0.02)} \times \frac{(1 - 0.01)}{(1 - 0.05)} \times \frac{(1 - 0.027)}{(1 - 0.14)} \times \frac{(1 - 0.003)}{(1 - 0.09)} = 1.279$$

Discount Rate	kW Value (US$)/1
10 %	160.25
12 %	178.43
14 %	197.34

(2) kWh Value

The kWh value of the hydropower is the saved fuel cost of the coal-fired thermal plant and is calculated on the following assumptions.

Price of coal	US$45/ton (0.0204/Lb)
Heating value	8,500 BTU/Lb
Required calory for 1 kWh	3,413 BTU/kWh
Overall thermal efficiency	37 %

Fuel cost required for generation per kWh is estimated at US$0.0221. the kWh value is calculated at US$0.0234 incorporating the difference of loss/2 for providing kWh between hydropower and thermal power.

7.2 Economic Evaluation

Economic evaluation of the project is made by calculating Economic Internal Rate of Return (EIRR), Benefit Cost Ratio and Net Present Worth on the basis of the project benefit estimated in the preceding section and economic cost of the project. As described earlier, all the costs and benefits are estimated at the price level of early 1980.

/1 For applying the kW value to the benefit estimate, discounting during construction is considered.

/2 Energy loss

	Hydropower (%)	Coal-Fired Thermal Plant (%)
Transmission loss	3.0	2.0
Station service	0.3	7.0

$$\text{Compensation Factor} = \frac{(1 - 0.03)}{(1 - 0.02)} \times \frac{(1 - 0.003)}{(1 - 0.07)} = 1.061$$

7.2.1 Economic Cost

For the economic evaluation of the project, economic cost is estimated by adjusting the calculated financial cost as follows:

a) Import tax and duties to be imposed on the imported goods and local taxes on locally produced goods are deducted from the financial cost.

b) Price contingency is excluded from the financial cost.

Total economic cost for the project is estimated at US$262 million. Details of the economic cost and its disbursement are presented in Tables 7-1 and 7-2.

7.2.2 Evaluation

Economic evaluation of the project is made using the economic cost and benefit on the basis of the following assumptions.

a) The Agos power plant starts its operation from 1989 with the economic life of 50 years.

b) Annual power production will decrease in proportion to the increased water volume for Metro Manila Water Supply and become 395.5 GWh in 2009 from 710 GWh at the initial stage.

The estimated Net Present Worth and Benefit Cost Ratio are presented below. The EIRR of the project is estimated at 12.5 percent, which indicates that the project is economically feasible.

Discount Rate	B - C (10^6 US$)	B/C
10 %	46.03	1.14
12 %	8.24	1.02
14 %	-21.97	0.94

For ascertaining the project viability under different conditions, sensitivity tests are made with the following different assumptions.

Case I Construction cost increases by 15 percent

Case II Completion of the Agos project works is delayed by five years (to be completed in 1994)

Case III Completion of the Kanan water supply project is delayed by 10 years (to be completed in 2004)

Case IV	(II) + (III)
Case V	Energy price (coal price) increases by 15 percent
Case VI	Available water from the Kanan river is used for exclusively hydropower on the Agos/1

The results of the sensitivity study are presented in Fig.7-2 and summarized below.

	EIRR (%)
Case I	9.8
Case II	11.5
Case III	13.1
Case IV	12.5
Case V	13.6
Case VI	18.2

As shown in the sensitivity analysis, cost increase is quite sensitive to the project viability. Delays of the completion of the project both for the Agos and the Kanan do not affect the economic viability so much. The highest economic rate of return of 18.21 percent is expected if the Kanan water supply project is discarded and all the water from the Kanan river basin become available for the Agos hydropower station.

7.3 Financial Analysis

7.3.1 General

For the financial analysis, investment cost of the project is firstly estimated on the basis of the assumed financial conditions. The investment cost includes the project construction cost with price contingency, interest during construction and commitment charge.

Revenue and expenses for the project operation are estimated, from which income statement and cash flow statement are derived. Using these figures, financial rate of return and debt-service ratio are calculated to assess the financial viability of the project. All the costs and revenue for the financial analysis are valued at the price level of 1989.

/1 If all the water from the Kanan river is used for the Agos hydropower, optimum installed capacity will become 185 MW and the expected energy generation will be 683 GWh. The sensitivity study is made based on this optimum plan.

7.3.2 Investment Cost Estimate

Investment cost of the project is estimated by adding interest during construction and commitment charge to the estimated project construction cost including the price contingency. For the estimation, the following assumptions are made for the finance of the project.

a) All the foreign portion of the investment cost will be financed by international loans with the following conditions:

		Loan A	Loan B
Financed to	:	Detailed investigation and design	Supervision and construction
Interest rate	:	8.5 percent per annum	
Grace period	:	Construction period (1981 to 1988)	
Repayment period	:	20 years excluding the grace period	
Commitment charge	:	1 percent of the unutilized international loans	

b) All the local portion of the investment cost, the interest during construction and the commitment charge will be provided by the Government contribution.

Total investment cost of the project is estimated at US$543.9 million, which consists of US$461.4 million of foreign currency portion and US$82.5 million (or Peso 618.8 million) of local currency portion as summarized below.

(US$ million)

	Foreign	Local	Total
Construction Cost	248.5	47.1	295.6
Price Escalation	125.6	35.4	161.0
Interest During Construction	75.5	0	75.5
Commitment Charges	11.8	0	11.8
Total Investment Cost	461.4	82.5	543.9

Disbursement schedule of the investment cost and its financing plan is presented in Table 7-5.

7.3.3 Income Statement and Financial Rate of Return

For preparing income statement of the project, revenue and expenses estimated under the following conditions. All the revenue and expenses are valued at the price level of 1989, the expected commencement year of the project.

a) Power revenue is estimated from the sold energy after deducting transmission loss/1. The tariff rate to be adopted in 1989 is estimated at 0.95 Peso per kWh (or US$0.126 per kWh)/2.

b) Operating expenses of the project is estimated at Peso 31.3 million per annum by escalating the calculated operation and maintenance cost in Chapter 6, at the price level of 1989.

c) Depreciation cost was estimated by applying a straight line with 2-percent per annum to the total investment cost.

d) Interest on the debt was estimated based on the assumed interest rate of 8.5 percent per annum.

On the basis of these assumptions, income statement was prepared as presented in Table 7-6. Financial Internal Rate of Return (FIRR) is calculated at 11.4 percent/3, which shows that the project is financially viable even if the project costs are financed by any international organizations.

7.3.4 Cash Flow Statement

Cash flow statement is prepared to assess the cash flow condition based on the assumed fund sources and applications. As the sources of the fund, external financing and internal cash generation are considered. The external financing sources include international agencies loan and government contribution, which will be provided during the construction time. The internal cash generation is the balance of gross revenue and operating expense. For the repayment of the loan from international agencies, constant annual installments are assumed. The cash flow statement of the project implementation is presented in Table 7-7.

As shown in the table, the funds from the proposed external financing sources cover the cost required during the construction period. The internal cash generation is expected to cover the debt service from 1989 and the cash surplus will reach US$336 million in 2008 when all the debt service will be repaid. The accumulated surplus will be turned into positive figure in 1993 only 5 years after the project commissioning. The maximum accumulated debt will reach US$170 million in 1988 when the project will be completed as shown in Table 7-8. Debt-service ratio of 1.54, ratio of accumulated internal cash generation to accumulated debt service of 20 years, exceeds the minimum accepted standard of 1.3 as shown in Table 7-7, which indicates the financial solidity of the project.

/1 3 percent of the generated energy.

/2 The tariff rate is Peso 0.4023/kWh at September 12, 1980.

/3 If the tariff rate of ₱0.7575/kWh in 1990 projected by CORPLAN is applied, the FIRR become 9.0%.

CHAPTER 8

ENVIRONMENTAL STUDY

8.1 Present Environmental Conditions

8.1.1 Physical Conditions

Physical conditions of the project area are already described in Chapter 4., Results of Survey and Investigation.

8.1.2 Biological Conditions

Affected by tropical weather as described in the meteorology and hydrology of the drainage area of the Agos river, the farm land is covered with the tropical rain forest including lauan, apitong, tangile, mayapis and pahutan.

According to the study "Vegetation of Philippine Mountain", 1919 by Brown, there are four vegetation types in the mountain area and they are as follows:

a) Parang (0 - 200 meters)
b) Dipterocarp (200 - 600 meters)
c) Mid-mountain forest (600 - 900 meters)
d) Mossy forest (900 meters over)

Parang area was covered with rain forest in old days, but it is now developed into many small farms for coconuts, banana and other cereal crops after logging or burning the forest. Parts of the Parang area are still covered with substitution vegetation, i.e., a plain with Imperata (alang-alang) or Saccharum Spontaneum and substitution rain forest. All the dipterocarp forest is a mixed evergreen forest composed of Parashorea Malaanonan and Diplodiscus Pariculatus. Mid-mountain forest is also mixed evergreen forest with Quercus-Neolitsea Association and Astronia Rolfei Association, which is different from Parashorea-Diplodiscus Association. Mossy forest has a unique association, Cyathea-Astronica Association.

The vegetation of the whole Agos river basin corresponds to the classification mentioned above. The vegetation of the Kanan river basin consists of the Dipterocarp forest, mid-mountain forest and mossy forest. This vegetation in the Kanan river basin is, in other words, still well covered with thick virgin forest.

The other basin, the Lenatin river basin, which is one of the major branch streams of Kaliwa river, has already been developed for cultivated land and Parang area. While the Limutan river basin, another major branch stream of the Kaliwa river, has still been covered with vegetation like the Kanan river basin. The area along the Kaliwa river has been cultivated but the left side bank of it is still covered with virgin forest like the Kanan river basin.

Main wild animals living in the Agos river basin are wild pigs and wild deers. Main birds living there are mountain doves, mountain swallows and wild roosters. Main reptiles living there are lizards, small crocodiles and some kinds of snake.

Kinds of fish living in Agos river are milkfish - commonly known as "bangus", mudfish - popularly known as "dalag", eel or "palos" and carp which is known as "carpa". Kinds of aquatic animals inhabiting in the Agos river are fresh water crab, some kinds of fresh water shrimps, shellfish and aquatic insects like Plecoptera, Ephemeroptera and Trichoptera.

8.1.3 Socio-Economic Conditions

Socio-economic conditions in the project area are already described in Chapter 2., The Project Area.

8.2 Environmental Consequences of the Project Development

8.2.1 Impacts on the Reservoir Area

(1) Inundated Area and Population

The reservoir areas of Agos dam, Kanan dam and Kaliwa dam are 21.5 km^2, 19.0 km^2, 20.0 km^2, respectively.

Dam	Reservoir Area	Elevation
Agos Dam	21.5 km^2	165.0 m
Kanan Dam	19.0 km^2	295.0 m
Kaliwa Dam	20.0 km^2	270.0 m
Total	59.0 km^2	

With the creation of the reservoir, some villages will be inundated: about 450 - 500 houses in the proposed reservoir of Agos dam and Kaliwa dam; and about 50 houses in the proposed reservoir of Kanan dam. Assuming that one household consists of six persons, around 3,000 to 3,300 people will have to be resettled. About 15 km^2 or 25 percent of the total reservoir area is cultivated and open land which are located along the Lenatin river and the Kaliwa river, and about 45 km^2 or 75 percent of the total reservoir area is the forest which distributes along the Limutan river and the Kanan river.

(2) Fishery

As mentioned in the preceding chapter, fishing activity in Kaliwa, Kanan and Agos rivers is limited to self-sufficiency. Construction of dam and reservoir is not expected to affect the river fishery since most of the existing fish can be lived though some species of fish may be changed.

On the contrary, the creation of the reservoir will give substatial positive impact on the fishery development in the region. Appropriate species for cultivation in the reservoirs are milkfish, catfish and some kinds of carp. Assuming that the expected fishery products are 10 to 15 t/km^2 per year,/1 around 600 to 900 tons of products will be produced by the four reservoirs, which is almost 1.5 times of the present fish production including brackish and seawater fish.

(3) Transportation & Tourism

Construction of the dam is expected to influence the local transportation. At present, there is no bridge to cross the Kanan, Kaliwa and the Agos rivers. People can cross river by using boat or on foot only in dry season. Even between the major towns such as Infanta and General Nakar, transportation of people and goods is being undertaken by small canoe.

Upon completion of the dam, the crest of the dam will be used as the main transportation roads across the rivers, which will facilitate the economic activity in the region.

Tourism is not well developed in the region at present though there are enough potential sites for resorts including beautiful coast and scenic mountains. Besides, the left bank area of the Kanan river is already designated to National Park and Wildlife Sanctuary and Game Preserve Reservation. The creation of the reservoir will further promote the tourism development in the region by providing additional opportunity for picnic and camping.

In particular, the Marcos Highway, now under construction, will connect Metro Manila with Infanta by around two hours drive and contribute the tourism development substantially. Then, Infanta will be the most convenient resort with beautiful sea, mountains and lakes.

(4) Biological Impact of the Reservoir

The vegetation of inundated area is cultivated land and tropical rain forest and inundated area is relatively small compared with that of the catchment area. Therefore, the project development will not

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/1 Estimate based on the average product of fresh water fish in fishponds.

seriously affect the vegetation in the region. On the contrary, the logging of trees now being conducted at the left bank of the upstream of the Kanan river is expected to give more negative influence on the vegetation in the region.

The life of animals inhabiting in the project area will not be affected seriously by constructing the reservoir. Instead it will be affected more by the change in the vegetation caused by logging.

After the creation of the reservoir, river water system will change from fluvial system to stationary water system. This will make it impossible for fish to go up and down the stream. The food-chain in the river will be changed subsequently from the chain of periphyton to aquatic insect to stream fishes, to the chain of plankton to fishes. And species of fish will also be changed. In other words, the aquatic life including periphyton, aquatic insect and fish is expected to adjust themselves to the new circumstances as they adjust themselves to the seasonal and daily variations of the water discharge.

(5) Water Quality

One of the influential factors to water quality is the inflow of organic matter to the reservoir. Future increase in the organic matter inflow in the reservoir is estimated preliminarily on the basis of the existing population data, the expansion program of Metro Manila and future agricultural development plan. The estimated inflow of the organic matter is still small/1 and it cannot be considered that the reservoir will become eutrophic lake in the near future unless rapid industrialization or extraordinary population increase occur in the area.

Another factor influencing the water quality in the reservoir is the unlogged trees in the submerged area. The unlogged trees will change its material and leave organic matter in the water which will affect water quality.

8.2.2 Impacts on the Downstream Area

(1) Flood Control

According to the information collected, the areas extending about 2 km from both sides of the lower Agos river have been inundated twice a year. Damaged by the flood are agricultural crops such as palay, livestock and those infrastructures such as the barangay roads and bridges. Among them, the damage on agricultural products is the largest at present.

Construction of the Agos dam will regulate the natural run-off of the river and the flood in the region will be completely controlled except in cases caused by the inland water.

/1 BOD = 0.071 ppm, N = 0.10 ppm, and P = 0.006 ppm (These figures are expected contamination in the Agos reservoir in the year 2000, when the population in the drainage area will be around 29,000).

(2) Irrigation and Municipal Water Supply

As explained in the preceding chapter, irrigation system is already installed in the downstream area of the Agos river and the water source is sufficient at present, even in dry season. Impact on irrigation is, therefore, not so much and it is only to facilitate the additional irrigation development both in terms of area (200 to 300 ha) and water management.

At present, quantity of various water sources is sufficient for the municipalities though coverage of the systematic water supply is still low. However, water demand in the region will increase substantially in the future in parallel to the development of Metro Manila (Infanta, General Nakar and Real towns are included in Module 4 of the Metro Manila expansion plan). The expected population in the Module 4 will be around 581,000 in the year 2000. For sustaining the population, 109 million litres per day/1 of the water supply will be required. Taking into consideration this expansion, the Agos reservoir would be one of the most economical and realible water source for these municipalities in the future.

8.2.3 Impact on Regional Development

According to the Metro Manila expansion plan considerable investments are planned to be made in Module 4. One of them is the Marcos Highway connecting Metro Manila with Infanta with two-hour drive, which is now under construction. Other major projects proposed are an international airport in Infanta and international port in Real.

The Agos River Hydropower Project is expected to facilitate the regional development by supplying sufficient electricity and water. Complete electrification and provision of reliable electricity will not only improve quality of life of the inhabitants but also stimulate the development of agro-industries. Potential agro-industries to be set up are sawmill, coconut processing and fish processing both for seawater and fresh water fish expected to be caught from the reservoir to be constructed.

As mentioned earlier in this chapter, potential of the tourism development is substantial. Improvement of transportation facilities will enhance further development.

Employment opportunity in the reigon will be drastically increased by setting up these agro-industries and the tourism development, which will increase the regional products which may result in improved quality life of the people in the region.

/1 Water Resources for Metro Manila, PICOREM, April 1979.

8.3 Countermeasures for Environmental Impacts

8.3.1 Resettlement

About 3,300 people reside in the inundated area of the Kaliwa dam, Agos dam and Kanan dam. For the implementation of the Project, plan for resettlement is to be carefully prepared on the basis of the detailed survey on the inundated area. The survey shall cover the investigation of household number, occupation, family structure, assets, land use and ownership, social infrastructures in the region, etc.

The resettlement plan is to be set up in the framework of overall development plan in the region including the expansion plan of Metro Manila. The resettlement plan shall include compensation plan for the properties of the people to be inundated and preparation of the new settlement area. Construction of the community infrastructures such as roads, water supply, community buildings are also taken into account in the resettlement plan.

8.3.2 Water Quality Control

Although contamination of the water in the reservoir is not serious in the foreseeable future, the water quality will be deteriorated after some time due to dissolution of organic matters, agricultural fertilizers and chemicals, and sewerage. Therefore, some measures for intercepting sewerage system and control system of industiral and agricultural waste water are to be considered in the next stage.

Besides, in order to keep the water quality, the trees which will be submerged in the reservoir are to be logged as completely as possible.

Eroded sands and soils from the watershed are another causes of water contamination in the reservoir. In view of the present vegetation, protection works are to be considered on the Kaliwa river basin. Much attention shall be paid to prevent erosion of the slope and control run-off of soils and sands for the Marcos Highway, which passes along the hillside located at the right bank side of the Kaliwa river.

8.3.3 Flood Alarm System and Land Slide Protection

Upon completion of the Agos dam and power station, about 163 m^3/sec of the released water runs out to the downstream for about 7 - 12 hours per day. To protect the residents and their property from the flood, a flood alarm system is to be installed.

In view of the large draw-down depth of 37 m, landslide occur in the reservoir area. Investigations of the possible landslide sites is to be conducted and the countermeasure to avoid it must be taken.

CHAPTER 9

DETAILED DESIGN AND INVESTIGATIONS

9.1 Detailed Design

Detailed design work is required before the commencement of construction works, aiming to prepare tender documents for construction after detailed investigations added to the feasibility investigation.

The work is assumed to be done by an overseas consultant working together with NAPOCOR engineers.

The work is to be completed within two years after starting the investigation from possible earliest date in the year of 1981. The work schedule corresponding to main investigation items are expected as below assuming that the service is started in October 1981.

- Inception work : October 1981 through November 1981
- Detail investigation (at site): February 1982 through January 1983
- Detail design : October 1981 through November 1983
- Tender document : October 1981 through November 1983

9.2 Scope of Detailed Design and Investigation

The scope of the works is termed as follows in due considerations on the results of feasibility study.

Inception works

- To review the feasibility report and to prepare work plans on the detail design and necessary additional investigations.

- To assist NAPOCOR to perform tender and mobilization of local contract works for detailed investigation executed at the site.

Detail investigations

- To perform detail geological study in the project area consisting of mainly core drillings at the Agos dam site, quarry site and borrow area, adit excavation in which in-situ rock shear test and loading test be carried out.

- To carry out detail material investigations consisting of material tests, field compaction test and field shear test on rockfill, filter and impervious core materials.

- To perform spillway hydraulic model tests on two alternative plans.

- To perform seismic stability analysis of the dam both in case of dynamic approach and static approach.

- To perform detail topographical survey of the structure sites.

- To perform additional collection and analysis of hydrological data especially on flood observed by newly installed automatic rainfall recorders and water level recorders.

- To collect information on construction planning.

- To discuss principal conditions on preparing tender documents with NAPOCOR.

- To perform detail investigations on transmission line route and substation area and local contract works for preparatory works.

- To assist NAPOCOR performing detail investigation on land acquisition.

Detail design

- To perform detail design of civil structures, such as dam and appurtenant structures.

- To perform basic design of electrical works.

- To perform basic design of metal works.

- To establish construction plan.

- To prepare Bill of Quantity and Engineer's cost estimate.

Tender documents

- To prepare tender documents for civil works (probably of two packages), electrical works (probably of two packages) and metal works.

Reports

Along with the progress of investigations, the following reports will be prepared.

- Work progress report: To report progress of work each three-month

- Inception report: To report basic program for implementation and consultant work plans, methods and schedule after finishing the works.
- Design criteria report: To submit design criteria report preceding to the detail design work to obtain NAPOCOR's agreement on it.
- Tender documents: To prepare tender documents for civil works (two packages), electrical works (two packages) and metal works.
- Design report: To compile methods, procedures, calculation and alternative design if necessary (including the detail investigation works).