CHAPTER VI PLAN FORMULATION OF THE PROJECT

6.1 Necessity of Water Resources Development in the Agos River Basin for Water Supply to Metro Manila

The present average daily water demand of 3,663 MLD in Metro Manila as of 2000 is mostly sufficed by water supplied from existing Angat Dam in the Pampanga River Basin. While, the Study projects the present water demand to increase to 6,980 MLD in the Study target year 2025, that is equivalent to 1.91 times the represent water demand. The projected water demands as well as their increments at five (5) year intervals over the Study horizon until 2025 are tabulated below:

Projected Average Water Demand for Metro Manila and its Increase in Each 5 Year

Year	2000	2005	2010	2015	2020	2025
Average Daily Water Demand (MLD)	3,663	3,783	4,250	5,033	5,866	6,980
Increment in 5 Year (MLD)	-	120	467	783	833	1,114

As seen in the above table, the water demand is projected to increase by only 120 MLD between 2000 and 2005, while the increment becomes larger in the latter periods, reaching 1,100 MLD between 2020 and 2025. This implies that the large-scale water source needs to be exploited to meet the water demand of Metro Manila that is projected to increase at an accelerated rate in the latter period, especially after 2010. This Study assumes that, out of the incremental water demand of 3,317 MLD for the period from 2000 to 2025, the interim schemes will supply about 317 MLD in the initial period up to 2010, while the remaining 3,000 MLD in the latter period after 2010 will be tapped from the Agos River Basin through new water resources development therein.

To meet the acceleratively increasing water demand of Metro Manila in the latter period, it would be natural to go for the exploitation of water resources in larger river basins where abundant water resources remain undeveloped. Out of the 20 major river basins in the Philippines that are in general defined to be the river basins with catchment area of more than about 1,000km^2, there exist two Major River Basins in the vicinity of Metro Manila. These are the Laguna Lake and Pampanga river basins. However, it is hardly possible to exploit on a large scale water resources of these river basins for the purpose of Metro Manila water supply, taking account of the future balance of water demand and supply in the former basin and environmental issues related to fishery and other activities in the latter basin.

On the other hand, the Agos River Basin is a sole river basin left undeveloped in the nearby area of Metro Manila that can suffice the increasing water demand thereof up to the target year 2025 as emphasized in Chapter I of Volume II. The Agos River Basin encompasses a catchment area of 940km^2 that can be almost categorized as one of the Major River Basins in the country. Taking into consideration the very limited potential water resources exploitable in other basins for the purpose of the Metro Manila water supply, it will have to rely on the water resources of the Agos River Basin in order to suffice the acceleratively increasing water demand after 2010.

6.2 Proposed Staged Development Plan of the Project

The Agos River Basin is the only water source exploitable on a large-scale to meet the water demand of Metro Manila after 2010 as explained above. In the Master Plan Study or Phase I of the Study carried out in 2001, a total of 8 development scenarios was worked out by combining the water resources development schemes in the Agos River Basin and water conveyance schemes to convey water from the Agos River Basin to Metro Manila. All of these 8 development scenarios are able to meet the water demands of Metro Manila until the target year 2025. As a result of the comparison study carried out in the Master Plan Study, the Development Scenario B was selected as the most economical in terms of unit cost of water to be supplied to Metro Manila.

In the Study, the components required to meet the water demands until 2025 are framed as the Project components on which a feasibility study has been performed during the Phase 2 of the Study spanning between January 2002 and March 2003. The Project components are largely divided into the following two (2) categories:

(i) Water resources facilities in the Agos River Basin: Kaliwa Low Dam and Agos Dam with Agos Power Station

(ii) Waterway facilities to convey water from the Agos River Basin to Metro Manila: 2 lanes of Kaliwa-Taytay Waterway

In the framework of the Development Scenario B, the Kaliwa Low Dam is proposed to be provided as the first water resources facility to meet a gap with the water demand of Metro Manila at earlier stage in consideration of its shorter construction period. Hence, the Study contemplates to develop the Project in two stages as shown below:

Proposed Staged Development Plan of the Project (Development Scenario B)

Development Stage of the Project	Division of Main Components of the Project	
	(i) Water Resources Facilities in the Agos River Basin	(ii) Waterway Facilities
i) Stage 1	Kaliwa Low Dam	1st Kaliwa-Taytay Waterway
Ii) Stage 2		
- Stage 2 -1	Agos Dam (w/ Agos Power Station)	-
- Stage 2 -2	-	2nd Kaliwa-Taytay Waterway

The main features of the Project (Development Scenario B) proposed in the Master Plan Study are reviewed in the present Feasibility Study based on the detailed data on topography, geology, hydrology, environment, etc. that have been obtained through the field survey and investigation works as described in the foregoing Chapter II.

In the present Feasibility Study, the Project is optimized concerning the following features:

i) Agos Dam axis
ii) Development scale of Agos Dam (FSL of Agos Dam/Reservoir)
iii) Type of Agos Dam
iv) Power operation mode of Agos P/S
v) Diameter of upper headrace tunnel (Tunnel No.1) of Kaliwa-Taytay Waterway
vi) Provision of Lagundi powerhouse to harness an effective head between the Agos Reservoir and Morong Water Treatment Plant, or Valve House No.1 instead of the Lagundi powerhouse

The results of the above examinations are described in the following Sections of this Chapter VI.

6.3 Selection of Agos Dam Axis

6.3.1 Assessment of Topographic and Geological Conditions of 2 Alternative Dam Axes

It was pointed out in the Mater Plan Study stage that the Agos damsite (upstream dam axis AS-1 in Figure 6.1) proposed in the 1981 JICA study is likely to have the following four (4) geological issues, although the upstream axis was tentatively adopted in the Master Plan Study:

i) Thick river deposit in the riverbed
ii) Thick residual soil or decomposed rock zone on the right abutment
iii) Fault in the riverbed and on the right bank
iv) Assumed active fault along the Kanan River, indicated by PHILVOLCS

Taking into consideration the above issues, an alternative site for Agos Dam was selected prior to the start of the present Feasibility Study, since two alternative axes for Agos dam were assessed to be geotechnically competitive based on existing 1 to 50,000 scale maps and the geological data collected up to that time as well as the results of site reconnaissance. The alternative damsite is located about 700 m downstream of the damsite selected in the Master Plan Study.

These two dam sites for Agos Dam, whose dam axes are called AS-1 and AS-3 for upstream and downstream ones, respectively, are shown in Figure 6.1. The upstream damsite is located 1km downstream of the confluence of the Kaliwa and Kanan Rivers.

The geotechnical investigations including core drilling, seismic prospecting, laboratory test and analysis of aerial photographs were carried out for the upstream and downstream damsites. As a result of the geotechnical investigations, the upstream site is assessed to be more favorable from the following aspects:

a) Both damsites are considered to have almost same condition on the thickness of riverbed deposit, shear strength of base rock and existence of faults.

b) In case of selecting the downstream site, most of potential landslide blocks identified at and around the Agos Dam site will be impounded by the Agos Reservoir to be created. The downstream dam axis requires larger scale treatment works to stabilize the landslide areas as compared with the upstream dam axis. The distribution of landslides as well as faults around the Agos damsite are shown in Figure 4.5.

c) It appears that there exists a large hydraulic gradient on the narrow ridge on the left bank of the downstream damsite.

6.3.2 Technical Assessment on 2 Alternative Dam Axes

In case of the optimum development case of FSL 159 m for the Agos Dam, its crest level comes to El.165.2 m as discussed in the succeeding Chapter VIII. The river valley widths at El. 165.2 m along the two dam axes AS-1 and AS-3 are measured to be 660 m and 690 m, respectively, on the newly produced 1 to 2,000 scale topographic maps. Accordingly, it appeared that there would not be a significant difference between dam embankment volumes of Agos dam at the two damsites because of the similar topographic condition as well as similar geological conditions of the two damsites including thickness of river deposits as mentioned above. On the other hand, these two (2) alternative damsites are assessed from the technical viewpoint as follows:

(i) The present feasibility-grade design suggests that the upstream cofferdam should be aligned about 600 m upstream of the Agos dam axis. The alignment will ensure to conduct safely excavation works of about 35-40m thick river deposit for the main dam foundation due to smaller seepage reaching to the excavated portion at the riverbed during the river diversion. In view of layout of Agos Dam and its appurtenant structures, the downstream dam axis AS-3 allows a cofferdam to be provided on the Agos mainstream keeping a sufficient distance with the main dam axis, while the upstream axis AS-1 requires the provision of a cofferdam on each of the Kanan and Kaliwa Rivers because of the rather short distance to the confluence of the two tributaries. Accordingly, it is considered that the cost of river diversion works in AS-3 would be smaller than that in AS-1.

(ii) As aforesaid, there exist potential landslide areas between the upstream dam axis AS-1 and downstream dam axis AS-3 as shown in Figure 6.1 and Figure 4.5. These potential landslide areas are to be submerged by the Agos Reservoir in case of selecting the downstream dam axis AS-3. Accordingly, the downstream dam axis AS-3 will require a higher cost as compared with the upstream dam axis AS-1, because of additional protective works required for the potential landslide areas to be submerged by AS-3.

6.3.3 Cost Comparison of 2 Alternative Dam Axes

The cost comparison is made for the two alternative dam axes assuming a FSL of Agos Dam at El. 159m and its dam type to be CFRD as optimized in the succeeding Sections 6.4 and 6.5, respectively. The general layout plan of Agos

Dam for each of the alternative two (2) axes is shown in Figures 6.2 and 6.3, respectively. On the basis of the general layout plans, the construction cost of Agos Dam and its appurtenant structures is estimated for each alternative axis as tabulated below:

Comparison of Construction Costs in Alternative Dam Axes of Agos Dam

Item	Unit	Upstream Axis (AS-1)	Downstream Axis (AS-3)
1. Main Features of Agos Dam			
(1) FSL	(El. m)	159	159
(2) Dam Height	(m)	163	164
(3) Dam crest length	(m)	660	690
(4) Total embankment volume of Agos Dam	(10^6m^3)	12.10	12.75
2. Construction Cost of Agos Dam and its Appurtenant Structures			
(1) Preparatory works	(10^6US$)	51.21	55.87
(2) River Diversion works	(10^6US$)	70.75	103.12
(3) Main Dam	(10^6US$)	152.37	145.49
(4) Landslide Protection Measures	(10^6US$)	6.50	9.00
(5) Spillway	(10^6US$)	108.16	120.01
Total Construction Cost/1	(10^6US$)	389.00	433.49

Note: /1; The above construction cost dose not include the costs of government administration, engineering service, and physical contingency.

The above table reveals that the upstream dam axis is more economically preferable than the downstream axis. Hence, it is determined to select the upstream axis for the Agos Dam.

The Agos Dam and its appurtenant structures which are designed for the selected upstream dam axis are explained in the succeeding Chapter VIII.

6.4 Optimum Development Scale of Agos Dam in Terms of FSL of Agos Dam/Reservoir

6.4.1 Procedures Adopted and Factors Considered

As described in the foregoing Section 6.1, the Project needs to have a capacity to convey an average daily discharge of 3,000 MLD to Metro Manila to meet the water demand thereof in 2025. Although the Kaliwa Low Dam is planned to be provided as the first water resources facility to tap water of the Agos River Basin, it is going to be submerged by the Agos Reservoir. Thus, the Agos Dam is to function as the permanent water resources facility in the Agos River Basin after the removal of the Kaliwa Low Dam.

The optimum development scale of the Agos Dam is determined in the following steps:

Step-1: To set up alternative development scales of the Agos Dam by varying FSL,

Step-2: To carry out reservoir operation study to estimate the exploitable water for Metro Manila water supply for each of the alternative development cases, Step-3: To determine the optimal development scale of the Agos Dam taking into account various factors.

The following factors are taken into consideration in determining the optimum development scale of the Agos Dam:

i) Unit water cost for Metro Manila water supply
ii) Submergence of Barangay Daraitan

6.4.2 Alternative Development Cases of Agos Dam and Reservoir Operation Study

(1) Alternative Development Cases Examined

A total of 6 alternative development cases for Agos dam are set up by varying the FSL from 145 m to 195 m at 10m intervals. The main features of these alternative development cases are shown in Table 6.1.

For every case, a MOL is set at El. 133 m corresponding to the economic diameter of Tunnel No.1 in the Kaliwa Taytay Waterway as discussed in the succeeding Section 6.7.

(2) Reservoir Operation Study to Estimate Exploitable Water

For each alternative development case, the exploitable discharge which can be conveyed from the Agos Reservoir to Metro Manila is estimated by means of the reservoir operation for the hydrological target year equivalent to a 10-year probable draughty. Since the hydrological data at the Agos Dam site are available for 31 years, the 3rd most draughty year is selected as the hydrological target year to estimate the dependable discharge for each reservoir scale. The general formula applied for the reservoir operation is expressed below:

$$\Delta S / \Delta T = Q_{in} - Q_{exp} - E_{vap} - Q_{spill} - Q_r$$

where,
- S : Reservoir storage volume (m^3)
- T : Time (sec)
- Q_{in} : Reservoir inflow (m^3/sec)
- Q_{exp} : Exploitable water for Metro Manila water supply (m^3/sec)
- E_{vap} : Reservoir evaporation (m^3/sec)
- Q_{spill} : Spillout from reservoir (m^3/sec)
- Q_r : river maintenance flow (m^3/sec)

Figure 6.4 shows a reservoir storage curve of Agos Dam which is newly worked out based on new 1 to 5,000 scale topographic maps produced in the present Feasibility Study. In accordance with the criteria on the river maintenance flow, suggested by the NWRB, the minimum river maintenance flow is adopted to be 10% of 80% discharge at the Agos Dam site. The yearly evaporation depth from reservoir surface is adopted at 996 mm (2.7mm a day) based on annual pan evaporation records observed at Cuyambay meteorological station as stated in Part-C of Volume III.

The estimated exploitable discharge for each development case is summarized in Table 6.1.

6.4.3 Selection of FSL Based on Unit Water Cost Taking into Account Submergence of Barangay Daraitan

In the Master Plan Study carried out in 2001, the optimum development scale of the Agos Dam was optimized to be the development scale with FSL 159 m so as to avoid submergence of Barangay Daraitan by the Agos Reservoir, although the unit water cost had a general tendency to decrease with increase of FSL, revealing more economical development case to be higher than the case with FSL 159 m. In that case, a powerhouse was planned to be built at a downstream toe of the Agos dam so as to harness a head to be created by the Agos Dam as well as discharge in excess of water supply to Metro Manila in 2025 out of the total discharge to be exploited by the Agos Dam.

On the basis of topographic and geologic data and EIA data obtained in the Feasibility Study stage, a relation between FSL and unit water cost of Agos Dam is updated to find out the most economical development case from a viewpoint of water resources development. Besides, an examination is made to finally determine the maximum FSL of Agos Dam based on the detailed topographic maps produced in the present Feasibility Study, which will not inundate the Barangay Daraitan. As a result, the following results are derived through these examinations.

(a) Optimum Development Scale of Agos Dam Based on Unit Water Cost

An index of unit water cost is applied to compare economic advantage of alternative development cases of the Agos Dam from a viewpoint of water resources development for Metro Manila water supply.

For each of the alternative development cases, the construction cost of the Agos Dam is estimated through applying work quantities derived based on the new topographic maps, as well as updated unit prices thereof discussed in the succeeding Chapter IX.

The exploitable discharge is herein defined to be a mean monthly discharge that can be constantly supplied from the Agos Reservoir in the 10-year probable drought year on the condition that a river maintenance flow is released from Agos dam to the lower Agos River channel. As the river maintenance flow at the Agos dam site, a flow of 4.35 m^3/sec that is equivalent to 10% of 80% firm flow on a flow duration curve thereat is adopted in accordance with the NWRB's criteria. Figure 6.5 and Table 6.1 show a relationship between FSL and unit water cost for the Agos Dam. As seen in these Table and Figure, the unit water cost generally decreases with increase of FSL up to FSL 185 m.

Nevertheless, the maximum FSL of Agos Dam is set at 159 m taking into consideration the social environmental impact to be caused by the submergence of Barangay Daraitan as explained below.

(b) Maximum Development Scale of Agos Dam to Avoid Submergence of Barangay Daraitan

In the Master Plan Study stage, a FSL of the Agos Dam was determined to be El. 159 m as the maximum development scale that does not submerge the residential area of Daraitan Barangay, the largest village in the area likely to be submerged by the Agos Dam. It is crucial to minimize the social environmental impact from the experience in the Laiban Dam Project (MWSP III). This policy on development of Agos Dam is retained in the present Feasibility Study.

The residential area of Barangay Daraitan spreads on the left bank of the Kaliwa River, one of two major tributaries of the Agos River, as seen in Figure 10.6 that is new topographic map produced for the present Feasibility Study. The number of households in the residential area is estimated at about 500 according to the results of the EIA study. Thus, the submergence of the Barangay Daraitan would cause a significant social impact.

Since most of the residential area in Barangay Daraitan is over El. 159 m in ground elevation, the maximum FSL of Agos dam should be limited to El. 159 m. Furthermore, the Study contemplates to protect lower lands of Barangay Daraitan from flooding of the Kaliwa River by means of providing a flood dike along the left bank as shown in Figure 10.6.

Also in the present Feasibility Study, the Agos Dam with FSL 159 m is recommended to be the optimal development case from a viewpoint of economic water resources development and social environment through the above examinations. Thus, it is confirmed that the outcomes in the 2001 Mater Plan Study are still valid.

6.4.4 Adequacy of Optimum Development Scale of Agos Dam with FSL 159m

As discussed above, the development scale of Agos Dam with FSL 159m is found to be the optimum one in terms of the unit cost of water resources development. The optimum development case can yield a discharge beyond the target water supply of 3,000 MLD to Metro Manila in 2025. Thus, the optimum development case can meet the water demand of Metro Manila beyond 2025. Taking into consideration that there exist no water resources to meet the water demands of Metro Manila over a long term after 2025, the optimum development case whose exploited discharge exceeds 3,000 MLD is considered to be consistent from the following aspects as explained hereinafter.

i) Effective utilization of water resources
ii) Keeping water supply capacity in severely drought year

(1) Effective Utilization of Water Resources

The implementation schedule of Agos Dam contemplated in the Study shows that it will take about 8 years for the water demand of Metro Manila to reach 3,000MLD in year 2025 after the completion of Agos Dam at the end of 2016. This means that some part of exploited water of Agos Dam will have to be released to the downstream without any use during immature period of the water demand of Metro Manila, unless a powerhouse is built downstream of Agos Dam. The immature period will be prolonged at the event of the lower water demand discussed in the foregoing Chapter III. From such aspects, the Agos Dam should be developed for the multi-purpose so as to utilize the water resources as well as head to be exploited by Agos Dam as long as it is economically justifiable. This policy is agreeable to the Water Law of the Philippines.

(2) Keeping Water Supply Capacity in Severely Drought Year

In case of Agos Dam with FSL 159m, the surplus discharge that exceeds a mean daily water supply of 3,000 MLD for Metro Manila is planned to be constantly utilized for power generation of the Agos P/S with an installed capacity of 51.5 MW during 95% of the total hydrologic years as mentioned in the succeeding Section 6.6. On the other hand, the surplus discharge secured for hydropower generation needs to be conveyed to Metro Manila during the rest of the hydrologic period, namely the severely drought period, in order to meet the water demand of Metro Manila.

In case that the smaller scale of Agos Dam is developed, it is obvious that the condition of water demand and supply balance in Metro Manila in the severe droughty year will be much more aggravated. Since the Kanan River Basin is adjacent to the Umiray River Basin, the similar draughty conditions may take place simultaneously in both Angat and Agos dams as experienced in 1997 and 1998. This will cause the excessively aggravated condition of water shortage in Metro Manila, leading to social disorder therein. Therefore, it is concluded that the development scale with a FSL of 159m is not too large, essentially required to cope with the unusual drought conditions to the maximum extent.

From the viewpoint of effective utilization of water resources in the Agos River Basin and dependability of water supply in severely draught year, a FSL of the Agos Dam is determined to be El.159m.

6.4.5 Economic Viability of Agos Power Scheme

As explained above, the discharge to be exploited by the Agos Dam with FSL 159m in excess of 3,000 MLD can be utilized to meet the water demand after the year 2025. On the other hand, the Study contemplates to utilize the excess discharge for hydropower generation through construction of Agos power station including a powerhouse located at the downstream toe of the Agos Dam.

The Agos power scheme is planned to developed as a semi-base load one with an installed capacity of 51.5 MW and its annual energy production is calculated at 280 GWh as discussed in the succeeding Section 6.5 and Annex H of Volume V.

To check the economic viability of the Agos power scheme, the economic annual equivalent benefit and cost are estimated based on a cash flow of benefit and cost applying the following conditions and assumptions:

- Discount rate is 12%
- The most competitive alternative thermal to Agos P/S is the combined cycle power station with the following kW and kWh costs, which are applied to estimate the economic benefits;

kW and kWh values of Most Competitive Alternative Thermal to Hydropower

Item		Combined Cycle	
		Cost	Adjustment Factor
1. kW Cost	- Capital Cost (US$/kW)	700.00	1.279
	- Fixed O&M Cost (US$/kW)	28.65	1.279
2. kWh Cost	- Fuel Cost (US$/kWh)	0.0217	1.061

- The concrete face rockfill dam (CFRD) is selected as the dam type for the Agos dam as discussed in the succeeding Section 6.5.
- Annual O&M cost of hydropower facilities is 0.5% and 2.5% of the direct construction costs for the civil works and electrical/metal works.
- The economic cost is equivalent to 90% of the financial cost.

The economic present worth of cost and benefit increments estimated under the above conditions and assumptions are then converted into economic annual equivalent benefit and cost. As a result, the annual net benefit is derived to be a positive value at a discount rate of 12% as follows:

-	Economic annual equivalent benefit:	B = 14,142 US$
-	Economic annual equivalent cost:	C = 11,790 US$
	Economic annual net benefit:	B-C = 2,352 US$

From the above, the development of Agos power station is economically justifiable.

6.5 Dam Type of Agos Dam

As discussed Part-E of Volume II, the concrete gravity dam is not the possible option for dam type of Agos Dam due to insufficient shear strength of foundation rock for about 160m high concrete dam that was clarified in the past study. While, concrete face rockfill dam (CFRD) as well as earth core rockfill dam (ECRD) are considered to be promising dam types for the Agos Dam.

CFRD has the following advantages as compared with ECRD:

(i) The total dam embankment volume of CFRD is smaller than that of ECRD because of steeper embankment slopes in CFRD. In case of CFRD, the dam embankment works can be continued even during the wet season, while it is difficult to perform embankment works of earth core materials during the wet season in case of ECRD. Therefore, ECRD requires a long construction period than CFRD taking into account the high annual rainfall of more than 4,000 mm in the Agos River Basin.

(ii) CFRD can resist against overtopping flow during the river diversion work, while ECRD is not absolutely allowed to be overtopped by the flood flow.

The larger magnitude of flood needs to be adopted as the design flood for the diversion works of ECRD.

In this Study, besides, the comparison study on dam type of Agos Dam is carried out in terms of construction costs of main dam and river diversion works based on topographic and geologic data made available through the 2nd Field Investigation. Figure 6.6 shows the typical cross sections of CFRD and ECRD for the Agos Dam. The general layout plan of the CFRD is shown in Figure 8.1 in the succeeding Chapter VIII, while Figures 6.7 shows a general layout plan of the ECRD. The construction costs of the Agos Dam in CFRD and ECRD are estimated based on the preliminary designs as summarized below:

Cost Comparison of CFRD and ECRD for Agos Dam (FSL=159m)

Item	Unit	Dam Type of Agos Dam	
		CFRD	ECRD
1. Agos Dam			
(1) Full supply level	(El. m)	159	159
(2) Total embankment volume	($10^6 m^3$)	12.1	14.0
2. Construction Cost			
(1) preparatory works		51.21	54.12
(2) River diversion works	(10^6 US$)	70.75	74.33
(3) Main dam and slope protection measures	(10^6 US$)	158.87	175.67
(4) spillway	(10^6 US$)	108.16	112.06
Total Construction Cost of Agos Dam	(10^6 US$)	389.00	416.19

Note: The above construction cost dose not include the costs of government administration, engineering service, and physical contingency.

As shown above, the construction cost of Agos Dam with FSL 159 m is estimated at 389 million US$ and 416 million US$ in case of CFRD and ECRD, respectively. In this Study, CFRD is adopted as the dam type of Agos dam since CFRD is more economically preferable than ECRD. Hence, CFRD is selected as the optimal dam type for the Agos Dam.

6.6 Power Operation Mode of Agos P/S

6.6.1 Operation Mode of Agos Power Scheme and Necessity of Afterbay Weir

This Study contemplates that, out of the discharge regulated by the Agos Reservoir, the discharge in excess of 3,000 MLD conveyed to Metro Manila will be utilized for hydropower generation as mentioned above. To determine the operation mode of the power plants of the Agos power scheme, the following four (4) alternative development cases are set up by varying the minimum daily plant factor in the dry season:

Development Cases of Agos P/S and Their Operation Modes in Dry Season

Development Case of Agos P/S	Minimum Daily Plant Factor	Possible Daily Operation Hours at its Full Capacity	Power Operation Mode
- Case-1	25%	6 hours	Peak operation
- Case-2	33%	8 hours	Peak operation
- Case-3	50%	12 hours	Semi-base operation
- Case-4	100%	24 hours	Base operation

For each alternative case, the power outputs which can be produced with the exploitable discharge in excess of that conveyed to Metro Manila (3,000 MLD) were estimated through the aforesaid reservoir operation study. The power output was calculated by the following formula:

$$P = 9.8 \times H_L \times Q_p \times C_E$$

where, P : Power output (kW)

H_L : Effective head (m)

Q_p : Maximum plant discharge (m^3/sec)

C_E : Combined efficiency of turbine and generator (=0.86)

For each alternative case, the power plants are planned to have two (2) generating units, which constantly produce primary energy with the minimum daily plant factor when the Agos Reservoir water level is below FSL (El.159m). While, these will generate secondary energy to the maximum extent of their installed capacities in addition to the primary energy when they can generate energy over the daily plant factor with the excess inflow discharge keeping the Agos reservoir water level at FSL 159m. The excess discharge which is not able to be fully used for the secondary energy generation is planned to be discharged downstream through the spillway.

The hydropower outputs of each alternative development case are estimated applying the reservoir operation rule mentioned above as shown below:

Hydropower Output in Each Development Case of Agos P/S

Item	Case-1	Case-2	Case-3	Case-4
- Minimum daily plant factor	25%	33%	50%	100%
- Plant discharge (m^3/sec)	110.8	83.1	55.4	25.6
- Installed capacity (MW)	103.4	77.5	51.5	25.6
- Annual Energy output (GWh)				
Primary energy	216.1	216.0	215.3	213.3
Secondary energy	253.3	186.8	102.9	0.0
Total	469.4	402.8	318.2	213.3

As seen in the above table, the annual total energy output decrease with the increase of the minimum daily plant factor, since the maximum plant discharge becomes smaller, thereby resulting in smaller secondary energy output. Taking into account the future power demand growth in the country, it is economically preferable that the Agos power plants are planned to bear larger peak load in the power system.

It is estimated that the Agos P/S will be generated for 6-8 hours a day in the minimum, in case that it is planned as a peaking station. The Case-1 and Case-2 above will not be able to release power discharge into the lower Agos through its turbines for the remaining off-peak hours a day, assuming that the minimum turbine output of hydropower plant is 40 % of installed capacity. Accordingly, an afterbay weir needs to be provided downstream of the Agos P/S so as to re-regulate the discharge used for peak generation in the Case-1 and Case-2.

The afterbay weir site is selected about 5 km downstream of the Agos damsite. In the Case-1, the required water storage volume is estimated at about 2.2×10^6 m^3

which can be gained by construction of the afterbay weir with a high water level of El. 25 m. On the other hand, the non-uniform analysis of the Agos mainstream clarified that the crest level of the afterbay weir needs to be raised up to El.37.1 m in case the layout plan and typical section of afterbay weir are adopted as shown in Figure 6.8. The total construction cost of the afterbay weir is estimated to be as high as about 36 million US$.

It is considered that the power generation can be done without afterbay weir in case that the Agos P/S is operated with the minimum daily plant factor of 50% and 100% in Case-3 and Case-4, respectively. In the Case-3, a warning system for the lower reach of Agos P/S would be required to be provided to deliver to the downstream riverine areas a notice of starting and stopping the release of discharge from the tailrace. However, the installation cost is estimated to be very small and can be fully covered by the miscellaneous cost allocated to the Project cost.

6.6.2 Comparison of Alternative Development Cases

The four (4) alternative development cases mentioned above were compared in terms of the following two indices to determine the most favorable development scale of the Agos P/S:

i) Economic Internal Rate of Return (EIRR)
ii) Financial Internal Rate of Return (FIRR)

The total construction cost of the Agos power waterway and power station which comprise power intake, headrace tunnel, penstock tunnel, powerhouse, and generating equipment is estimated based on their layout plan, profile and sections of waterway tunnels which are shown in Figures 8.6 and 8.7 in the succeeding Chapter VIII.

The economic benefit of the Agos power station was estimated applying the same methodologies and procedures as those described in the foregoing Subsection 6.4.5. While, a power tariff is set at a constant rate of 3.5 Peso/kWh over the project life of 50 years to estimate the FIRR. The results of the financial and economic analyses are summarized below and explained in detail in Annex H of Volume V:

Hydropower Output in Each Development Case of Agos P/S

Item	Case-1	Case-2	Case-3	Case-4
- Minimum daily plant factor (%)	25	33	50	100
- Minimum daily peak operation hours (hours)	6	8	12	24
- EIRR (%)	11.8	10.3	14.6	9.6
- FIRR (%)	15.8	15.1	17.9	14.3

The Case-3 whose minimum daily plant factor is 50% is selected as the most optimum case, since it gives the highest EIRR and FIRR values among the four alternative cases. Hence, it is determined to develop the Agos power scheme with an installed capacity of 51.5 MW that is planned to be operated at the full capacity for 12 hours a day.

6.7 Economic Diameter of Tunnel No.1 in Kaliwa-Taytay Waterway

The diameter of about 27 km long Waterway Tunnel No.1 constituting the uppermost section of the Kaliwa-Taytay Waterway, which connects an intake structure at Kaliwa Low damsite and Morong Water Treatment Plant (WTP), is one of important factors dominating the Project cost due to its very long distance. In case that a smaller diameter is adopted for the waterway tunnel No.1, the minimum operating level (MOL) of Agos Dam needs to be raised up to cope with an increased head loss of the Tunnel No.1 in order to secure a head to convey the daily maximum discharge of 3,630 MLD from the Agos Reservoir to the Taytay Service Reservoir with water level of 66 m to 72 m. Eventually, it requires higher crest elevation of Agos Dam in comparison with the case of larger tunnel diameter.

To find the economic diameter for waterway tunnel No.1, a total construction cost of waterway tunnel No.1 and Agos Dam is estimated for each of the following 3 cases that are set up by varying diameter of the Tunnel No.1:

Item	Unit	Diameter of Waterway Tunnel No.1		
		D=3.3m	D=3.5m	D=3.7m
1. Required Water level of Agos reservoir for water conveyance to Metro Manila				
- Head loss in Tunnel No.1	(m)	48.0	31.0	23.4
- Minimum operation level (MOL)	(El. m)	142.5	133.0	125.7
- Full supply level (FSL)	(El. m)	163.3	159.0	155.7
2. Construction Cost				
- Waterway Tunnel No.1	(10^6 US$)	325.0	359.2	394.8
- Agos Dam	(10^6 US$)	548.9	518.4	515.3
Total	(10^6 US$)	874.0	877.6	910.1

Notes: 1. For every case, an effective storage volume of $409x10^6 m^3$ is secured.
2. The above construction cost includes the costs of government administration, engineering service, and physical contingency.

As shown in the above table and Figure 6.9, the economic diameter of the Kaliwa-Taytay Waterway Tunnel No.1 is derived to be in a range of 3.3 m to 3.5 m. On the other hand, a FSL of Agos Dam should not be over El. 159 m taking into account ground elevations of residential areas of Barangay Daraitan as discussed above. Accordingly, the economic diameter of Tunnel No.1 is determined to be 3.5m where FSL and MOL of Agos dam are El. 159 m and El. 133 m, respectively.

6.8 Viability of Provision of Lagundi Power Station in Kaliwa-Taytay Waterway

6.8.1 Hydropower Potential in the Upper Section of Kaliwa-Taytay Waterway

The Agos River water is conveyed to the Morong Water Treatment Plant through about 27km long Tunnel No.1. The high water level (HWL) and low water level (LWL) of receiving well in the Morong WTP are set at El. 98.1m and El. 97.1m, respectively, while FSL and MOL of the Agos Reservoir are set at EL. 159m and EL. 133m, respectively, as mentioned above. Since the MOL of El.133m is determined to be the lowest one that enables to constitute a gravity flow in the Kaliwa-Taytay Waterway section from the Kaliwa Low Dam to the Morong WTP, no effective head in the section is available for hydropower generation when the

Agos reservoir water level is at MOL. On the other hand, the reservoir operation study clarifies that it is very less for the Agos Reservoir to go down to the MOL, while the available heads for hydropower generation are created in the section when the Agos Reservoir water level is at a certain level higher than the MOL.

Thus, it can be envisaged to develop the hydropower potential by means of providing a powerhouse at the downstream end of the Tunnel No.1 instead of a valve house described below. In case the Lagundi powerhouse site is selected as shown in Figure 6.10, the available heads for hydropower generation are estimated as follows:

Item	Unit	Power Discharge			
		Qm=3,000MLD /1 (34.7 m^3/sec)		Qmax=3,630MLD /2 (42.0 m^3/sec)	
(1) Agos Reservoir water level	(El. m)	159(FSL)	133(MOL)	159(FSL)	133(MOL)
(2) Tail water level of Lagundi P/H	(El. m)	99.5	99.5	99.5	99.5
(3) Total head loss	(m)	15.1	22.1	15.1	31.9
Available Head for Hydropower Generation (=(1)-(2)-(3))	(m)	44.4	11.4	44.4	11.4

Notes /1: The average daily discharge to be supplied by the Project for Metro Manila is 3,000MLD.
/2: The maximum peak discharge supplied by the Project for Metro Manila is 3,630MLD.

As seen in the above table, there is a large difference between the available heads of the Lagundi power plants at the FSL and MOL of the Agos Reservoir. This implies that it will be hardly possible to generate the power plants at the time of the Agos Reservoir water level being at MOL. Thus, it is conceived that the Lagundi power scheme is not so attractive one.

6.8.2 Alternative Plans to Regulate Discharge Flowing into Morong Water Treatment Plant

Taking into consideration the aforesaid hydropower potentials in the upper section from the Agos Reservoir to the Morong WTP, the following two (2) alternative plans are worked out to regulate the discharge flowing into the Morong WTP:

i) Alternative-1: Valve house Plan (Valve House No.1)
ii) Alternative-2: Powerhouse Plan (Lagundi Powerhouse)

The above two (2) alternative plans are explained hereunder.

(1) Alternative-1: Valve house Plan (Valve House No.1)

The Alternative-1 is to provide a valvehouse at the downstream end of the Tunnel No.1 in order to regulate discharge flowing into the Morong WTP. The general plan and profile of the Alternative-1 are shown in Figure 7.3 in the succeeding Chapter VII. The Valve House No.1 is designed to accommodate five (5) main valves at the full development stage. The valves' openings are to be operated in harmony with the water required to be conveyed to the Taytay Service Reservoir. The Valve House No.1 is designed to have a bypass way through which water will flow down when a valve needs to be closed due to its maintenance and repair. As shown in Figure 6.10, the lower waterway route of the lower part of Tunnel No.1 in Alternative-1 can take the slightly shorter route as compared with the Alternative-2, since it is not necessary to spill out the excess discharge into the nearby Creek.

(2) Alternative-2: Powerhouse Plan (Lagundi Powerhouse)

The Alternative-2 is to provide the Lagundi powerhouse at the downstream end of Tunnel No.1. As described above, the Alternative-2 contemplates to generate power utilizing discharge conveyed to Metro Manila as well as an effective head between the Agos Reservoir water level and the tail water level of the Lagundi powerhouse. The general plan and profile of the Alternative-1 are shown in Figure 6.11. The Lagundi powerhouse site is selected at the location 1 km north of the Valve House No.1, where a creek flows down. It is planned to house two (2) units of generating equipment. In addition to the bypass way in the Alternative-1, the Alternative-2 requires the spillway structures to spill out the excess water to the creek, when turbines of Lagundi powerhouse cannot be operated to comply with the fluctuation of the water to be conveyed to Metro Manila. Thus, the power operation of Lagundi power plants will be largely affected by the fluctuation of water conveyed to Metro Manila.

6.8.3 Economic Comparison of the Alternatives

The Alternative-2 can accrue the power benefit through the generation of the Lagundi power plants, although the Alternative-2 is more costly than the Alternative-1. To verify which alternative is more economically viable, the economic comparison of the alternatives is made using the present worth of the following two economic values:

- Power benefits of Alternative-2 (Lagundi Powerhouse),
- Incremental cost of Alternative-2 to Alternative-1 (Valve House No.1)

The project output of the Lagundi powerhouse in the Alternative-2 is estimated based on the results of reservoir operation study for the Agos Reservoir that is performed in accordance with the procedures described in the foregoing Subsection 6.6.1 as follows:

i) Installed capacity : 10.6 MW
ii) Dependable peak output : 5.65 MW
iii) Annual energy production : 77.2 GWh

The power benefits are derived from the above project outputs applying the same methodologies and procedures stated in the foregoing Section 6.4. In succession, the construction costs of the Alternative-1 and Alternative-2 are estimated based on their alignments and profiles shown in Figures 6.10 and 6.11. The results of the comparison study are summarized in the following table:

Economic Viability of Lagundi Powerhouse

(Unit: 10^6 US$)

Item	Alternative-1 (Valve House)	Alternative-2 (Lagundi Powerhouse)
- Construction Cost		
i) Tunnel No.1	292.4	298.0
ii) Valve House or Powerhouse	30.8	5.1
Total	323.2	303.1
- Incremental cost in Alternative-2	-	20.1
- Annual equivalent cost of the incremental cost (C)/1	-	5.01
- Annual equivalent benefit (B)/1	-	2.72
- Annual net benefit (B-C)/1	-	-2.29

Note: /1; the discount rate of 12% is applied to estimate the economic values.

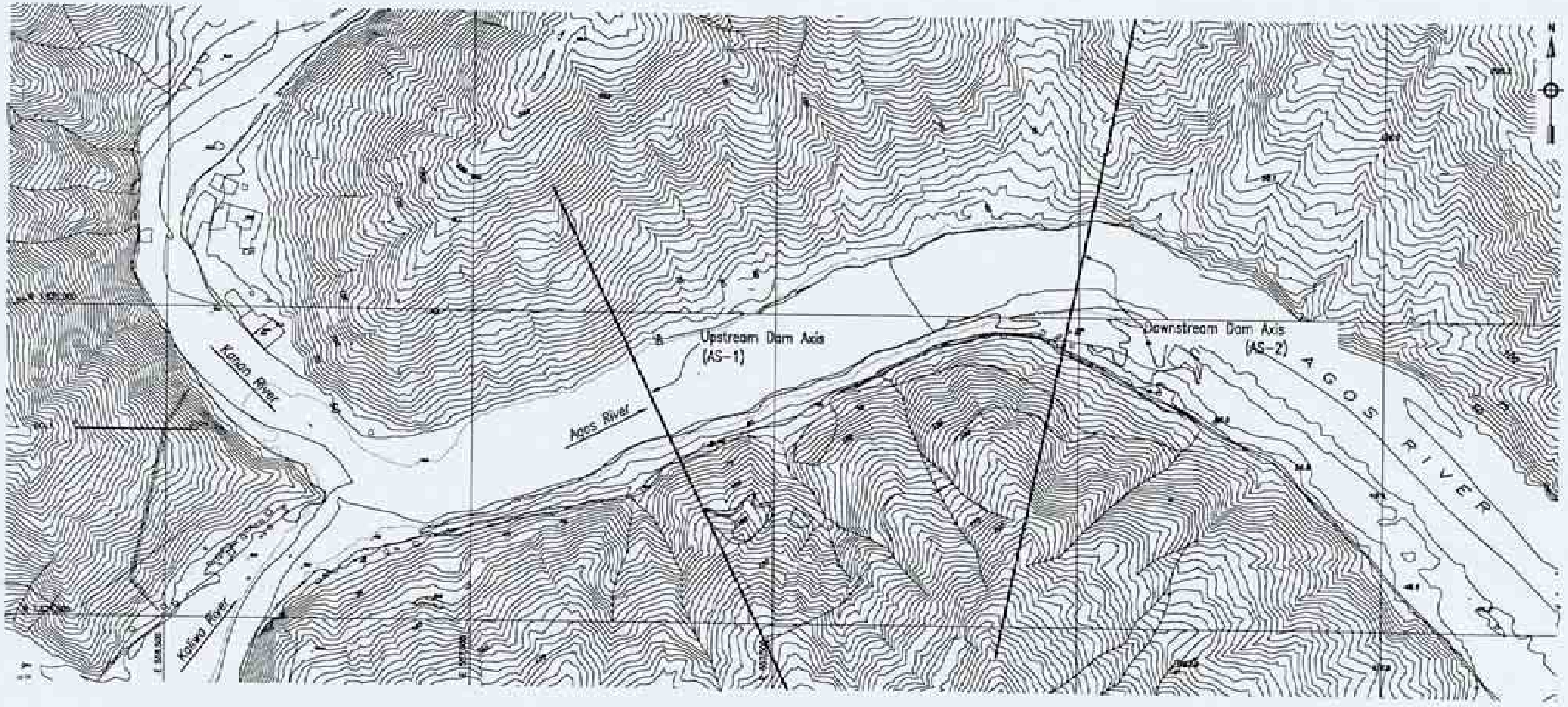
As shown in above table, the Alternative-2 is not economically justifiable. Besides, a FIRR of the Lagundi powerhouse is as low as 5.3 % as discussed in Annex H of Volume V. Thus, the Lagundi powerhouse is not justifiable from the economic and financial viewpoints. Therefore, it is determined to provide the Valve House No.1 instead of the Lagundi powerhouse at the downstream end of the Tunnel No.1.

Table 6.1 Unit Water Cost of Agos Dam by FSL

(Unit: Million US$)

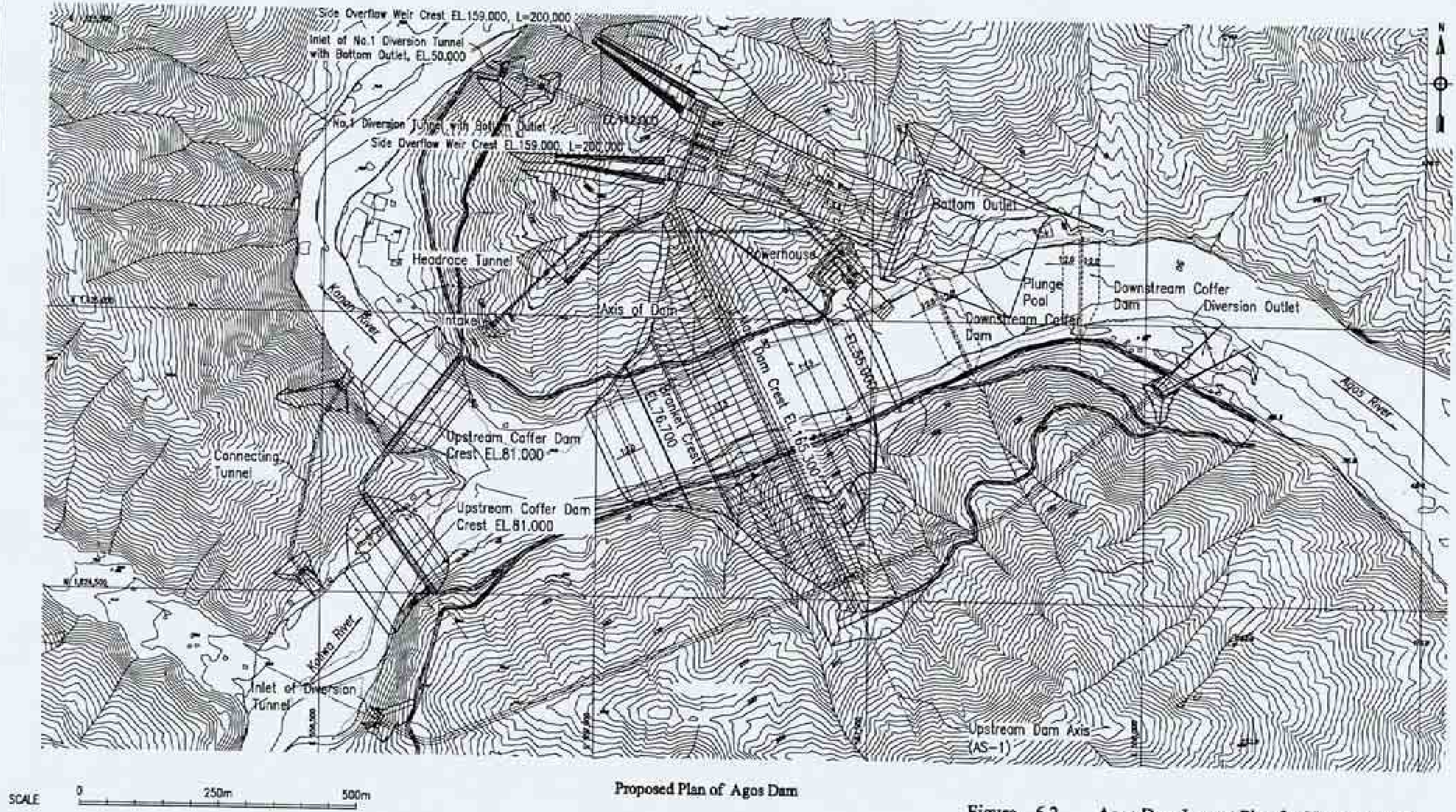
Item	Construction Cost of Agos Dam							
	Minimum Case)	Case-1	Case-2	Optimum Case)*	Case-4	Case-5	Case-6	Case-7
	FSL:143	FSL:145	FSL:155	FSL:159	FSL:165	FSL:175	FSL:185	FSL:195
	MOL:133	MOL:133	MOL:133	MOL:133	MOL:133	MOL:133	MOL:133	MOL:133
<u>Base Cost</u>								
(1) Preparatory Works	(37,602)	37,661	43,127	(51,212)	42,409	45,483	48,411	51,189
(2) Diversion Works	(60,678)	67,734	69,098	(69,560)	70,043	71,407	72,771	74,135
(3) Main Dam	(123,873)	116,786	142,450	(152,374)	166,893	190,117	212,121	232,905
(4) Landslide Protection Measures	(6,500)	6,500	6,500	(6,500)	6,500	6,500	6,500	6,500
(5) Spillway	(101,856)	102,375	103,403	(103,908)	104,528	105,556	106,585	107,589
(6) Hydromechanical Works	(5,445)	5,445	5,445	(5,445)	5,445	5,445	5,445	5,445
(7) Land Acquisition/Resettlement	(15,842)	15,500	17,169	(18,003)	79,764	82,545	85,326	88,107
Subtotal: Base Cost	(351,796)	352,000	387,192	(407,001)	475,582	507,053	537,159	565,869
<u>G/A, E/S, and P/C</u>								
8) Government Administration	(8,795)	8,800	9,680	(10,175)	11,890	12,676	13,429	14,147
9) Engineering Service	(17,590)	17,600	19,360	(20,350)	23,779	25,353	26,858	28,293
10) Physical Contingency	(56,727)	56,760	62,435	(65,629)	76,688	81,762	86,617	91,246
Total Construction Cost	(434,907)	435,160	478,666	(503,155)	587,938	626,845	664,062	699,556
<u>Unit Water Cost</u>								
- Water Exploited (m3/sec)	(34.7)	39.3	56.6	(62.4)	71.3	80.0	83.3	87.2
- Unit Water Cost (million US$/m3/sec)	(12.1)	11.1	9.2	(8.7)	8.8	7.8	8.0	8.0

Notes: *; The minimum case of the Agos Dam with FSL 143m can yield 3,000 MLD for Metro Manila water supply in the 95% draught year.
**; The optimum case of the Agos Dam with FSL 159m will not submerge existing Daraitan Barangay..



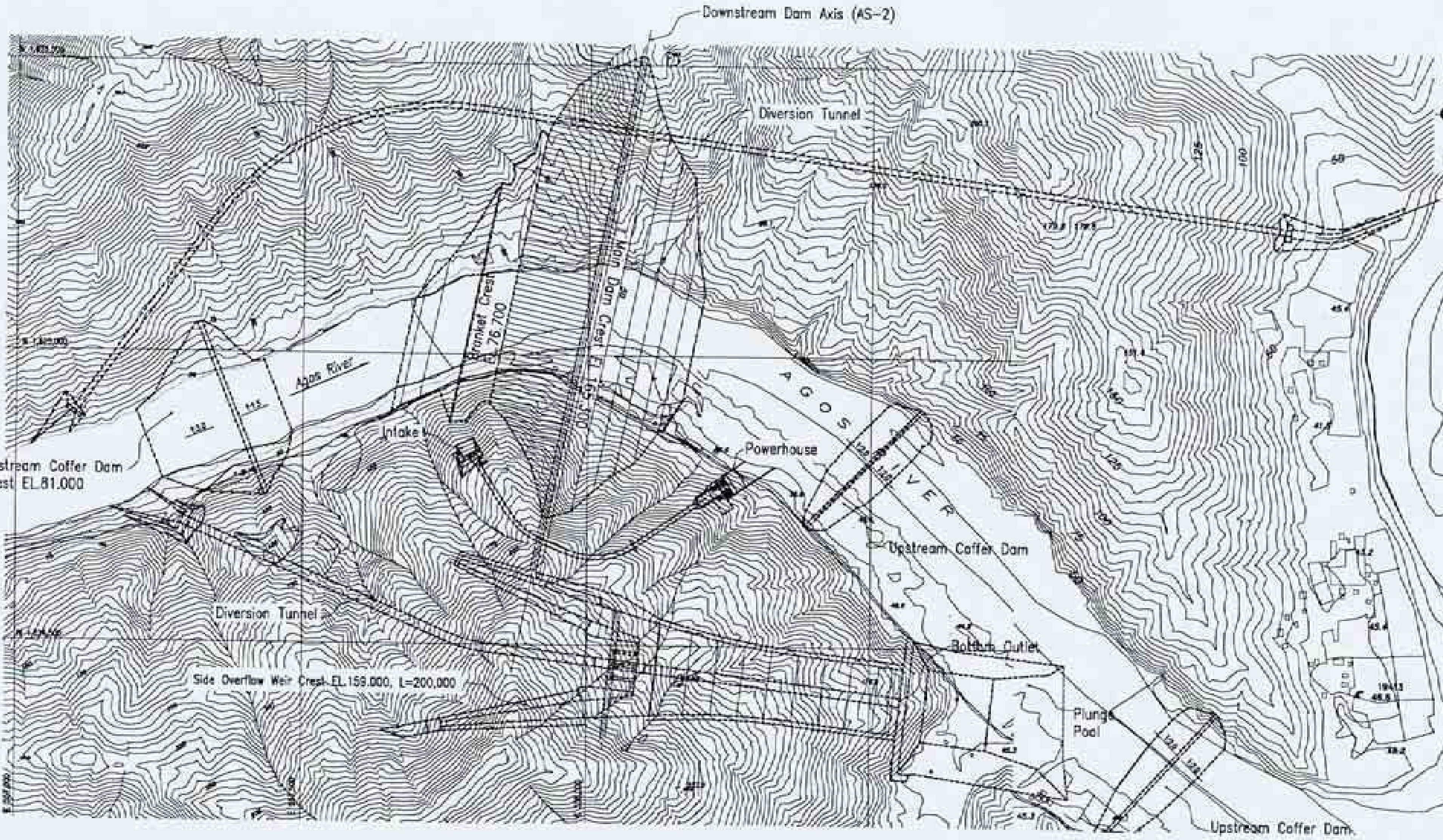
Alternative Location of Dam Axis

Figure 6.1 Alternative Axes of Agos Dam



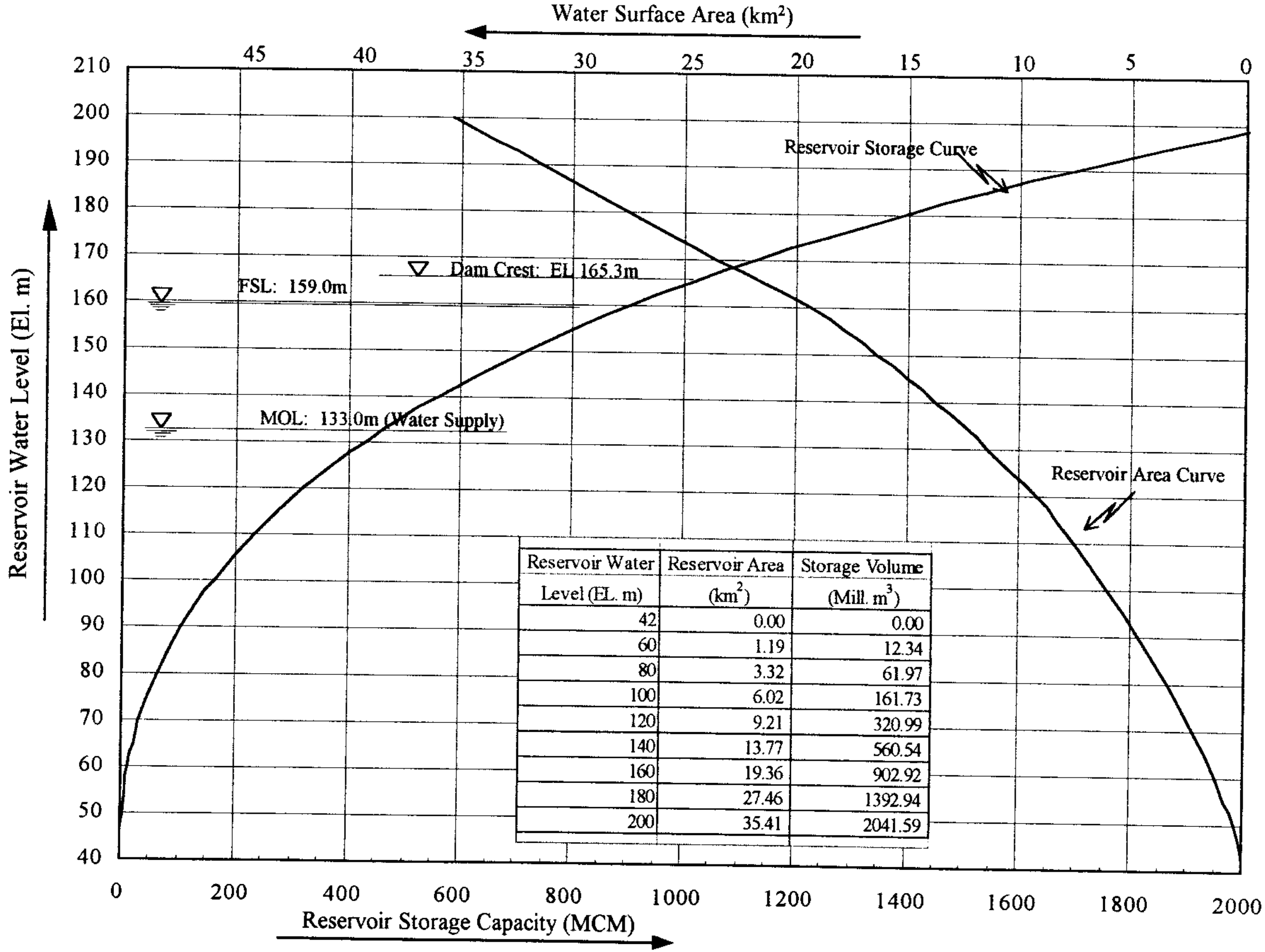
Proposed Plan of Agos Dam

Figure 6.2 Agos Dam Layout Plan for Upstream Axis



Alternative Plan of Agos Dam

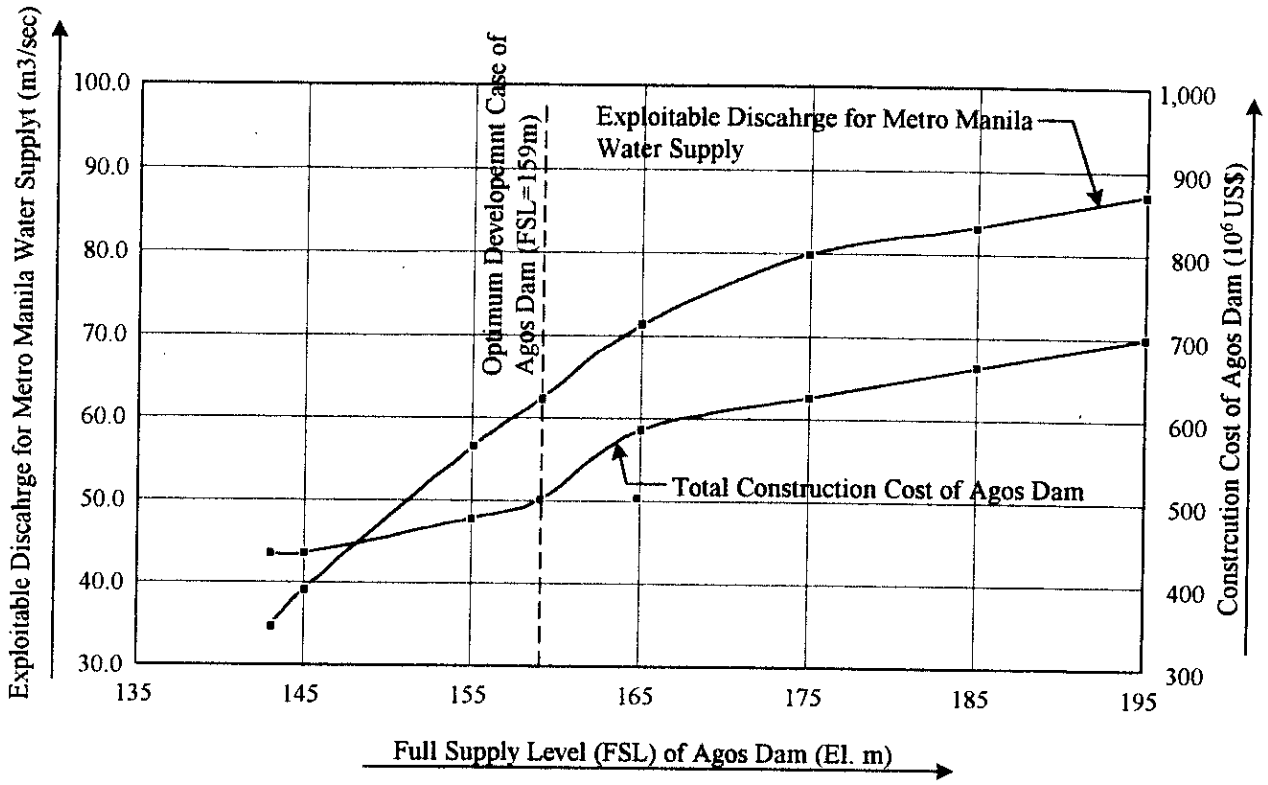
Figure 6.3 Agos Dam Layout Plan for Downstream Axis



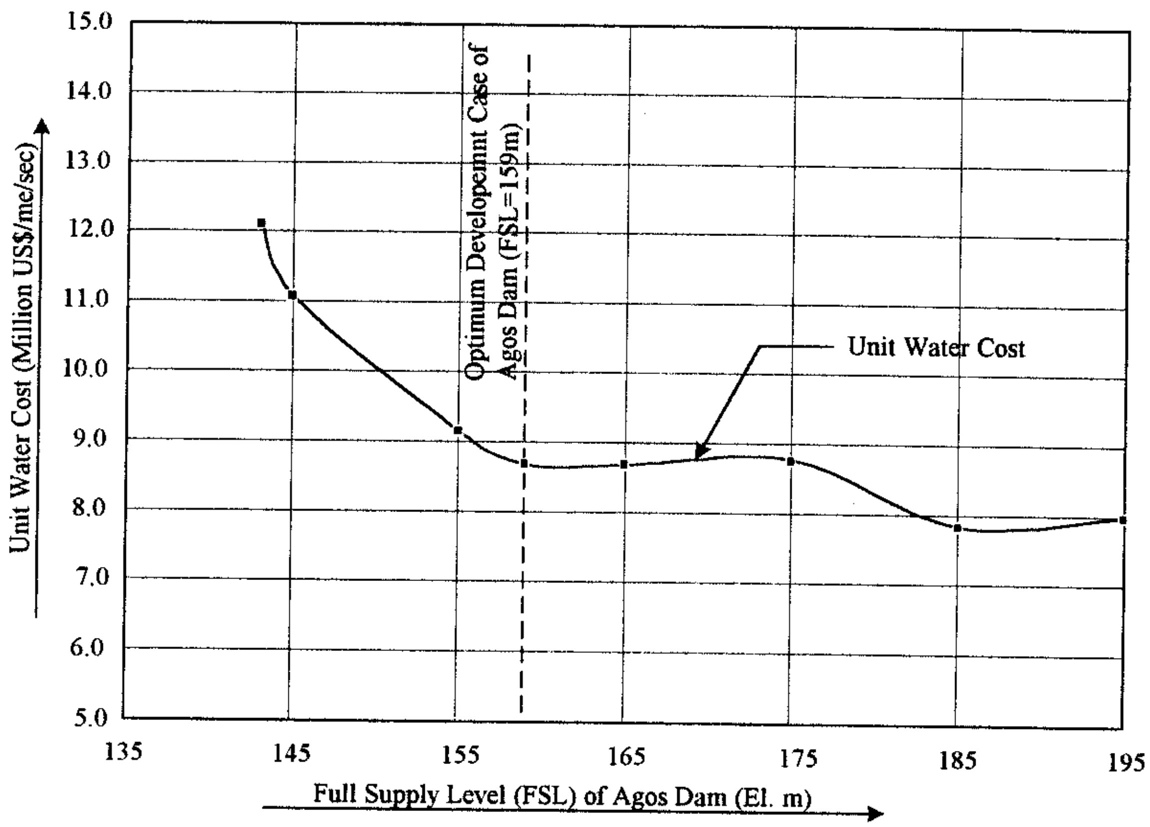
Reservoir Water Level (EL. m)	Reservoir Area (km^2)	Storage Volume (Mill. m^3)
42	0.00	0.00
60	1.19	12.34
80	3.32	61.97
100	6.02	161.73
120	9.21	320.99
140	13.77	560.54
160	19.36	902.92
180	27.46	1392.94
200	35.41	2041.59

Note: Area is based on 1:5,000 Topo Map (2002)

Figure 6.4 Reservoir Storage Curve of Agos Dam



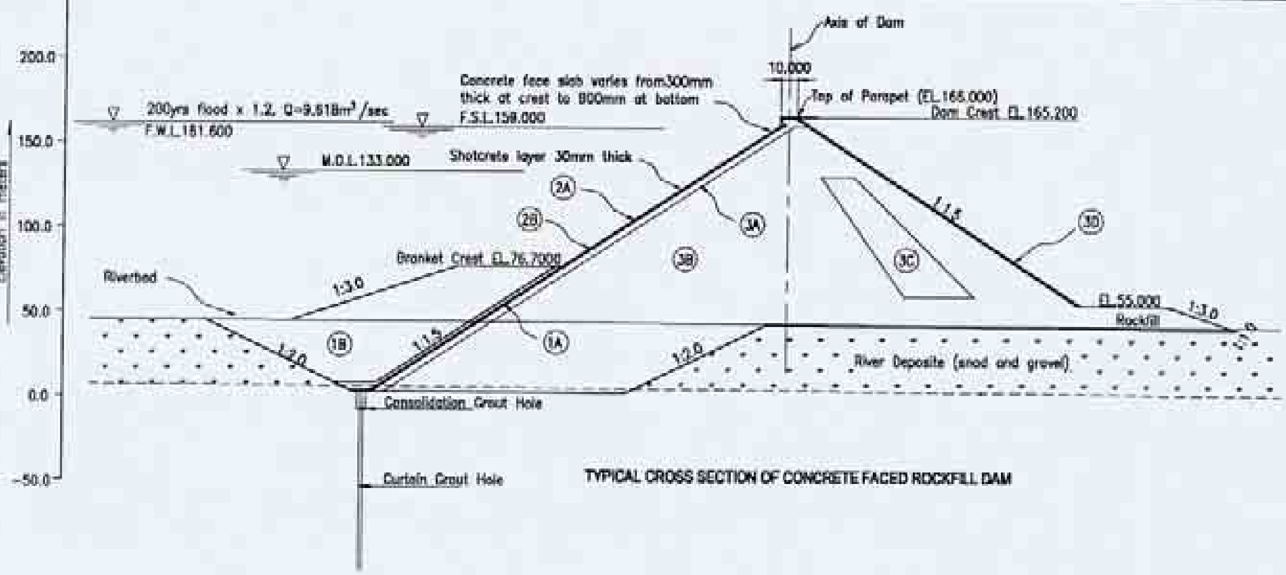
Exploitable Discharge for Metro Manila and Total Constrcution Cost of Agos Dam by FSL



Unit Water Cost by FSL

Figure 6.5 Relation between FSL and Unit Water Cost for Agos Dam

ZONE	CLASSIFICATION
1A	Impervious Earthfill on Plinth
1B	Random Fill on Plinth
2A	Fine Filter
2B	Coarse Filter
3A	Selected Small Rock
3B	Rockfill, Quarried Rock
3C	Rockfill, Random Rock and Gravel to be Obtained from Excavation of dam, Spillway and Other Structures
3D	Selected Large Rock for Riprap



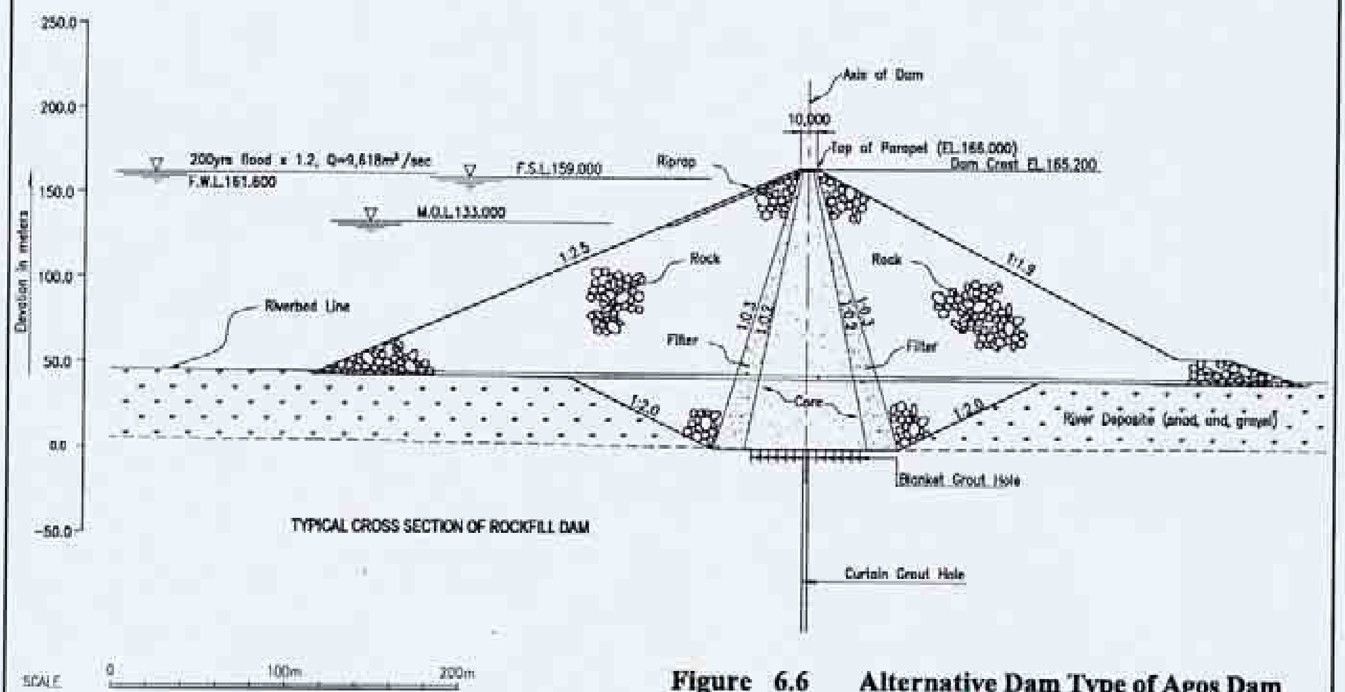


Figure 6.6 Alternative Dam Type of Agos Dam

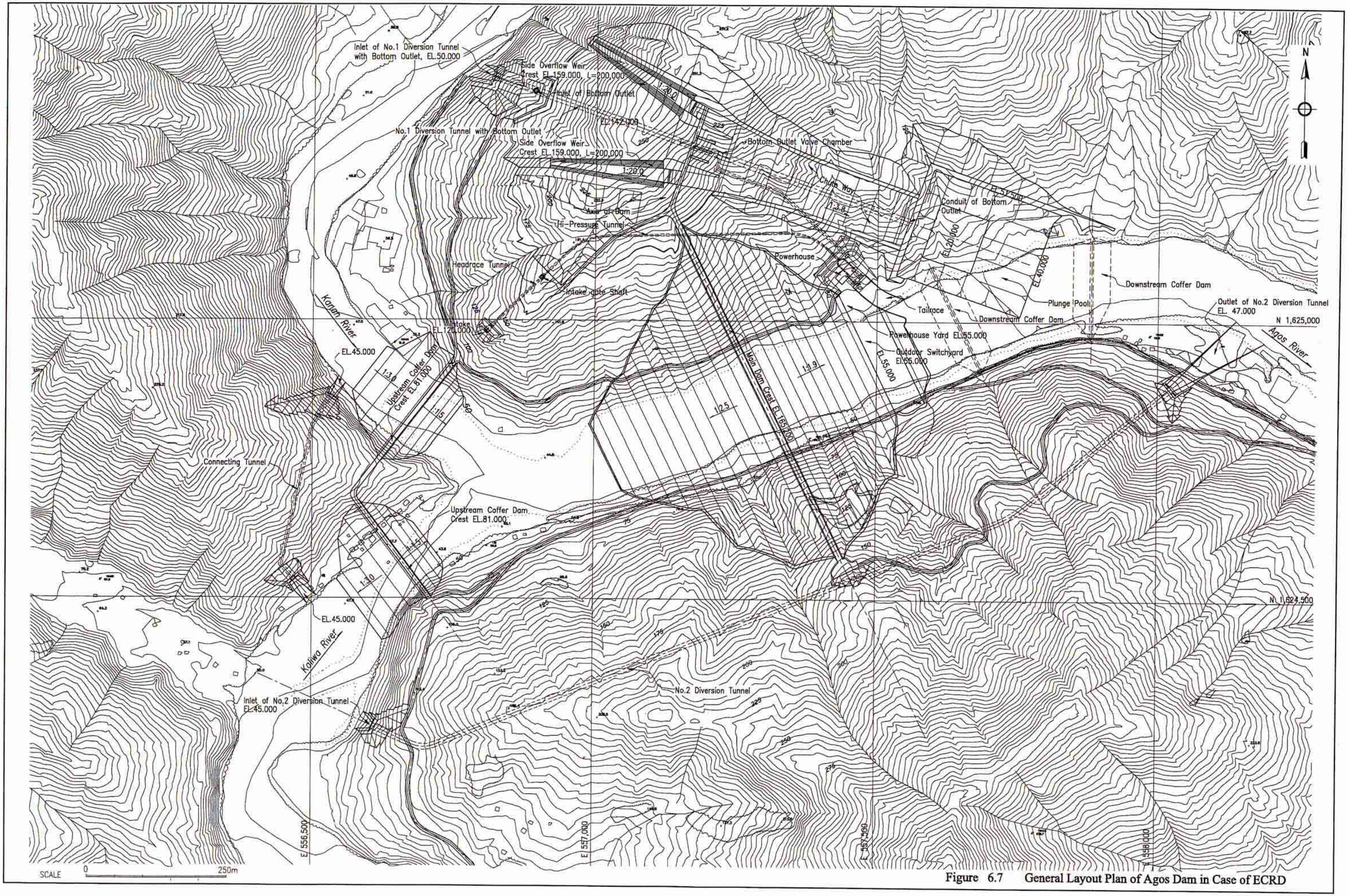


Figure 6.7 General Layout Plan of Agos Dam in Case of ECRD