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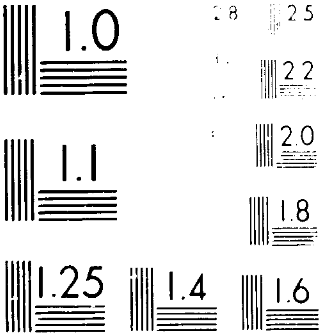
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Manila, Philippines, 3 - 8 November 1980

HYDROPOWER DEVELOPMENT PROJECTS IN THE PROVINCES OF BOHOL AND ANTIQUE, THE PHILIPPINES*

by

Gjermund Saetersmoen**

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1. BACKGROUND

The Government of the Republic of the Philippines has set a high priority on development of the country's hydropower sources, not only as an integral part of its rural development programme, but also in order to substitute and supplement the existing electricity generating system based on oil.

In May 1979 an agreement was signed with the Government of the Kingdom of Norway whereby Norway undertakes to assist in the development of the hydropower potential of the Philippines in areas as agreed with the Philippine Government.

For the implementation of the agreement National Electrification Administration (NEA) represents the Philippines and the Norwegian Agency for International Development (NORAD) represents Norway.

The hydropower development study in the provinces of Bohol and Antique, which has been carried out by Norconsult A.S. in cooperation with NEA, started in July 1979. The particular objectives of the present study are to identify and describe suitable hydropower schemes for immediate and future implementation in the provinces of Bohol and Antique. These two provinces are both located in the Visayas region. The terms of reference also call for study of the power market and require the Consultant to consider the benefits to water supply, irrigation and flood control.

The province of Bohol comprises about 4,100 km^2 and has a population of about 790,000, whereas the province of Antique is about 2,500 km^2 with a population of about 345,000. Existing installed generating capacity in Bohol is 1,200 kW of hydropower and 11,000 kW oil-based. No hydropower is as yet developed in Antique where the present installed oil-based capacity is about 1,000 kW.

The study area of Bohol as well as of Antique includes all the major rivers in the two provinces.

It should be noted that the terms of reference do not specify that the study should be concentrated on mini hydropower project only. The study group was free to consider all possible developments in the two provinces, making it possible to benefit from the economies of scale, i.e. the fact that the cost per installed kW and of produced energy usually decreases when the size of the projects increases.

2. GENERAL APPROACH

The work has essentially be carried out in the following three phases:

(1) Desk study with inventory of existing data

(2) Field reconnaissance with preliminary reports on identified projects

(3) Feasibility studies of selected projects.

Bohol and Antique are covered by topographic maps in scale 1:50,000 with contour interval 20 m. Occasionally there are supplementary contours at 5 and 10 m intervals. The maps are based on aerial photographs taken in the period 1947-53. These maps provided the basis from which Norconsult started the desk study. Possible hydropower developments, damsites, tunnel alignments, catchment areas, etc., were identified on the maps before going in the field.

Aerial photographs supplemented the topographic maps in providing essential information regarding the location of damsites, the identification of rapids, the evaluation of the geology, etc. The photographs are approximately in scale 1:15,000.

During the first phase of the study all the available data regarding rainfall and runoff were collected and subsequently computer analysed.

The next phase of the study was field reconnaissance on foot and by helicopter. All the major rivers were inspected and additional projects were identified. All possible project sites were inspected.

Additional foot reconnaissance was made of the projects identified during the desk study and during the aerial reconnaissance. A precision altimeter was used to determine or to check the river gradients and the available head of the identified projects. A vital part of the field reconnaissance was the evaluation of the geology and the hydrology of the project areas.

The results of the desk studies and the field reconnaissance were presented in a preliminary report describing the findings and presenting the Consultant's recommendations of projects selected for further technical and economic feasibility studies.

As agreed with the Philippine Government, Norconsult thereafter conducted feasibility studies of two hydropower projects in Bohol and one project in Antique. The feasibility studies include topographical mapping, geological field investigations, design and economic appraisal.

3. HYDROLOGY

3.1 General

A vital part of a hydropower study is of course the evaluation of the hydrology of the project area as the total runoff as well as the shape of the duration curve for a potential project site can have a crucial impact on the feasibility of any project.

It may therefore be of some general interest which data and records were available for this particular project and also what kind of considerations, that is the basis for some of the necessary hydrologic data in this case. The locations of the places in Bohol and Antique which are referred to in the next chapters are given in Figures 1 and 2.

3.2 Climate

The rainfall distribution in the Philippines is controlled by the topography and the following three major wind systems:

- The northeasterly monsoon during the period October to January
- The generally easterly trade wind February to April
- The southwesterly monsoon during the rest of the year.

Winds from the northwest and west are generally cyclonic by origin.

The climate is subsequently classified upon the rainfall distribution:

First type - Two pronounced seasons, dry from November to April and wet during the rest of the year.

Second type - No dry season and with a pronounced maximum rainfall from November to January.

Third type - Relatively dry from November to April and wet during the rest of the year. However, the seasons are not very pronounced.

Fourth type - Rainfall more or less evenly distributed throughout the year.

Antique has the first type of climate whereas Bohol belongs to the areas with the fourth type of climate.

The normal annual rainfall for the entire country is about 2350 mm. The annual rainfall in Bohol is in the order of 1500-2000 mm and in Antique 3000-4000 mm. The rainfall generally increases with the altitude.

3.3 Bohol

The Catchments

The geography of Bohol is dominated by three major river systems: the Loboc River, the Abatan-Sinigan River and the Wahig River. The Loboc and Wahig Rivers rise in the range of mountains along the eastern and southern outskirts of the Central Bohol plateau, running SW and NW respectively. The Abatan-Sinigan River starts its SW course from the western areas of the plateau.

Central Bohol is heavily cultivated, and represents the major part of crops in the province, as rainfall appears throughout the year. Though rainfall appears mostly during April to October caused by the SW monsoon, most rivers are perennial.

The geological features are mostly limestone and sandstone, causing a very low runoff from certain sub-catchments where the topography is dominated by numerous sinkholes. Evidence of natural springs in the hillside along the southern coast indicates disagreement between hydrological and topographical catchment boundaries in the mountain range, especially affecting the Bilar River catchment.

Existing Records

Runoff has generally been recorded since the late 1950s, though the network has suffered from financial cutback since 1972.

The Water Resources Bulletins include four river gauging stations within the area concerned. The Tibiao station gauges 618 km^2 of the Loboc River.

Records are available from 1958 to 1971 and represent the hydrology typical for a cultivated region, while the Bugsoc and Pamacsalan stations in Upper Wahig demonstrate the high runoff from small mountainous catchments. Records are available from 1955 to 1971 and 1959 to 1971 respectively.

The Owac station on the Bilar River is obviously heavily affected by karstic geology. The recorded runoff from this catchment is substantially lower than should be expected, clearly demonstrated by an occasionally dry riverbed immediately upstream the confluence with the Loboc River. Annual rainfall over the plateau as gauged in Bilar, Carmen, Dagohoy and Pamacsalan is 2000-2100 mm. The western and southern areas, i.e. from Loboc towards the Abatan-Sinigan River is probably receiving less rain, not gaining fully from the orographic effect.

Assessment of Runoff

Judging from the Loboc runoff records, the average evapotranspiration over Central Bohol is 900-1000 mm per year.

In an attempt to assess the effect of catchment leakage through limestone formation, the major loss of water is assumed to take place along the upper southern outskirts of the Bilar sub-catchment. Any underground drainage downstream of Owac, would probably lead to resurgence before reaching Tigbao gauging station. To achieve a reasonable figure for the runoff from the Bilar catchment, the area draining to Owac has to be reduced by as much as 80%. The corresponding adjustment of the Tigbiao runoff will be minor.

During field inspections diverting irrigation channels were found upstream of both Bugsoc and Pamacsalan gauging stations, especially at Bugsoc. To assess the average runoff at the proposed hydropower sites, a logarithmic relationship was established based on the Wahig and Loboc runoff considering the Bugsoc records somewhat dubious, especially concerning low flows. A similar theory was adopted for the firm (90%) and low flow in catchments not affected by loss through karst features.

The Abatan-Sinigan River has no rainfall or runoff stations within its catchment or in the near proximity. Nevertheless, based on topography, land use and exposition there is reason to believe that the climate and hydrology is comparable to that of the Loboc catchment. The only difference might be caused by slightly less rainfall in the western parts.

The dimensionless duration curve for Loboc River at Tigbao is adopted as representative for all sites in Central Bohol, where cultivated areas are included. The Upper Wahig duration curves are not applicable as they represent hilly areas with high rainfall and very little groundwater reservoir.

To estimate characteristic flows at project sites, the logarithmic relationships have been applied accordingly, unless severe catchment leakage is envisaged because of limestone formations. This applies especially to projects in the Loboc and Bilar Rivers. At Janopol, only 20% of the Owac catchment is considered effective. Hence, there are further possibilities of underground leakage towards the west caused by high difference in altitude between Bilar and Loboc. The shape of the Owac duration curve indicates that karst drainage is active at average flows and below. Therefore, the average flow at Janopol will be somewhat uncertain.

The Bilar River will be even more affected as the geology is unfavourable, especially in the Dagohoy area where numerous sinkholes appear in the landscape. As the Bilar River approaches the Loboc River, it tends to dry up but the clean riverbed indicates that floods are passing. Therefore, the Bilar River might be severely affected by karst, and average flow cannot be estimated without allowing for some variance within extremities.

3.4 Antique

The Catchments

The geography of Antique is characterised by a range of mountains running parallel to the west coast. Generally, all river catchments run west or southwest by quickly losing altitude before reaching heavily cultivated plains at 50-100 m above sea level.

The western hillsides are directly exposed to the southwest monsoon. Therefore heavy rainfall appears during May-October while the rest of the year is relatively dry, especially down on the plains. Still the highest areas in the mountains gain from the northeast monsoon causing the rivers draining west to keep flowing all through the year.

Numerous irrigation schemes are operated along the coast, and diversions are active as soon as the rivers reach the lower part of the hillsides.

Existing Records

Runoff records from Bacong River, Paliuan River and Sibalom River have been published for the period 1958-71, 1956-71 and 1958-71 respectively. The network has suffered from financial cutback since 1972.

Out of the three stations, the Valderrama gauge in Bacong River appears as the most reliable one.

Recorded average flow in Paliaun River seems somewhat higher than expected. This might be due to the location of the station where sand and gravel deposits dominate the riverbed and no firm control section could be traced. Still the average catchment altitude is higher than for Bacong River and generally more rainfall will appear.

Frequent changes in the elevation of zero of the Pangpang stream gauge in Sibalom River indicates shifting control. This was confirmed by field inspection. The station is located way out in one of several natural diversions on the Sibalom-San Jose plain where the stream pattern has changed substantially over the years. Especially average and low flow records are expected to be influenced by irrigation. Therefore, the Bacong and Paliuan records are preferred and adopted for this study.

Rainfall in Antique is recorded at Culasi, Barbaza and Valderrama. Generally more rain appears around Barbaza, probably because here the mountains are approaching close to the coastline.

Assessment of Runoff

It is difficult to carry out a proper water balance for the Antique catchments as there are no stations located in the mountains. The orographic effect has therefore been judged from the Ilocos rainfall stations, Masalep and Baguio where rainy seasons and catchment expositions are comparable to the Antique province. A linear relationship giving 7% linear rise per 100 m was applied to adjust the average runoff from Paliuan River catchment by estimating the annual evapotranspiration at 800 mm.

Based on 140 l/s km^2 and 130 l/s km^2 from Bacong and Tibiao catchments respectively, approximate curves for equal runoff were drawn on the 1:250,000 map taking general topography and rainfall pattern into consideration. This method is judged to be acceptable for the projects concerned, as a proper water balance would require a far better network of stream and rainfall gauging stations than what is the case in Antique at present.

Firm (90% availability) and mean flow have been estimated from the Bacong dimensionless flow duration curve which is adopted as representative for mountainous catchments.

4. FINDINGS IN BOHOL

Some of the most prominent physiographic elements in Bohol are two mountain ranges displayed at the southern and western coast of the island. The ranges are trending in northeast direction, reflecting the major structural units of the island. From an elevation of some 700-800 m above sea level they drop off steeply to the coast. The mountain ranges often display a monotonous karst topography with cavities and caves. The steep hillsides are frequently punctuated by deep valleys and gorges.

Between the mountain ranges, the central part of Bohol is characterised by a vast expanse of generally flat plains and gently rolling terrain. The famous chocolate hills are developed in the east central plain. These hills constitute three sets of summit elevations: 40, 80 and 120 m above the plain level. The province has a fairly good network of existing roads.

The first part of the study revealed that the Maribojoc limestone which occupies most of Bohol is porous, soft, chalky and non-compact with numerous sinkholes, caves and caverns.

The fact that caverns and solution cavities are evident makes leakage the most serious deficiency and problem. The chances are small that high dams with large reservoirs can be proven feasible in areas with this type of rock.

In any case, final conclusions on leakage properties, extent and cost of grouting, etc., cannot be made before an extensive investigation programme has been carried out. An important part of such a programme will be to localise and quantify the extent of cavities, to ascertain if passages exist between the cavities and to determine if the rock will take grouting by ordinary methods. The investigations must include core drilling and thorough water leakage testing, possibly also exploration adits in the dam abutments in order to estimate the amount of dental work needed to make the foundation watertight.

A feasibility study of such schemes would thus require such an extensive and time-consuming investigation programme that the cost of the investigations alone could be too high to be justified by the rather small possibility that the project could to be proven feasible. The work in Bohol was therefore at an early stage concentrated on run-of-river developments.

Another consequence of the geological conditions in Bohol was that any tunnelling work should be limited to areas outside the limestone formations because of the poor conditions for any tunnel in this rock.

The karstified rock formations would most likely cause stability hazards and sudden inflow of water during the construction period. In addition, the Maribojoc limestone per se is a very weak rock which would require heavy concrete lining along the entire tunnel length. Although it may well be possible to construct a tunnel under such conditions, the costs will be high and also difficult to estimate with a reasonable degree of accuracy.

The geological reconnaissance alone thus formed the basis for vital conclusions which considerably narrowed the spectrum of interesting developments in Bohol.

As the Bohol grid will cover most of the province in the near future, the power market is large enough to benefit from the economies of scale.

The final consequence of the above-mentioned considerations was thus that the most interesting developments in Bohol would be run-of-river projects with surface waterways and with a higher potential than only some few hundred kW. The only exception to this basic rule turned out to be the Tipolo project mentioned below. At this site detailed geological mapping revealed that an underground power station with adjoining tunnels and shafts could be excavated in a competent type of rock which is overlain by the previously mentioned soft limestone.

The most promising projects identified in Bohol are as follows:

Project	Gross head m	Length of waterways km	Installed capacity kW
Tipolo	27	800	7,500
Janopol	33	1,300	5,000
Causwagan	80	1,800	3,000
Baunos	40	1,500	2,500
Rizal	10	100	1,500
Camugau	30	150	300

The figures giving installed capacity are based on the assumption that there is, at all times, a market for the energy that can be produced. Under the same assumption there are good indications that feasible hydropower projects with a total installed capacity in the order of 20 MW have been identified in Bohol.

Based on the findings during the reconnaissance phase of the study the Tipolo and Janopol projects were selected for further technical and economic feasibility study. Although the feasibility studies are still in progress it may already now be stated that the projects are expected to be feasible and to show acceptable economic return on investment.

FINDINGS IN ANTIQUE

Antique is characterised by high and steep mountains with a strip of level area along the coast. Peak elevations are more than 2000 m above sea level.

The most striking topographic feature of the area is the parallel arrangement of the mountain ranges, composed of basement rocks, alternating with sedimentary areas of low to moderate relief. These main structures are tied to NE-SW tectonic lines. Further east, along the eastern boundary of the province, these tectonic lines are gradually bending in a N-S direction. The geological formations contain a series of Pretertiary basement rocks and younger rocks of Tertiary age.

The geology of Antique is in general very different from that of Bohol, both with respect to rock types and to tectonics. With some exceptions, the geology will provide fair to good conditions concerning damsites, tunnels and construction materials. The amount of cavernous limestone is very limited and should therefore not cause any major obstacles.

When evaluating the power market for hydropower developments in Antique, the whole Panay Island must be taken into consideration.

Antique will probably be connected to the Panay grid before any sizeable hydropower scheme is commissioned in the province. This means that also the provinces of Aklan, Capiz and Iloilo will be included in the power market. It is assumed that the total peak demand for the whole island will be near to 100 MW at the end of the coming 10-year period. The present generating capacity in operation on Panay is approximately 40 MW, all based on oil.

The potential market for hydropower developed in Antique is consequently large enough to benefit for the economies of scale too.

The topography of Antique also implies that any hydropower development should be of some size. The major rivers have all eroded deep valleys in the mountainous landscape, in most cases leaving tunnels as the only possible waterway. Most rivers level out quite far from the coast, some 10-15 km. Interesting areas for hydropower schemes are therefore located far inland where there are few, or no roads at all. The costs of road access and transmission lines will therefore in most cases be substantial and can only be justified by a rather large scheme.

Although there is an abundance of promising damsites in Antique, the catchment areas, and consequently also the water flows, are too modest to justify projects where the head is created solely by building a dam. The main justification for a dam of some size would therefore have to be its eventual storage volume, whereas the river gradient over some distance would provide the head to be developed.

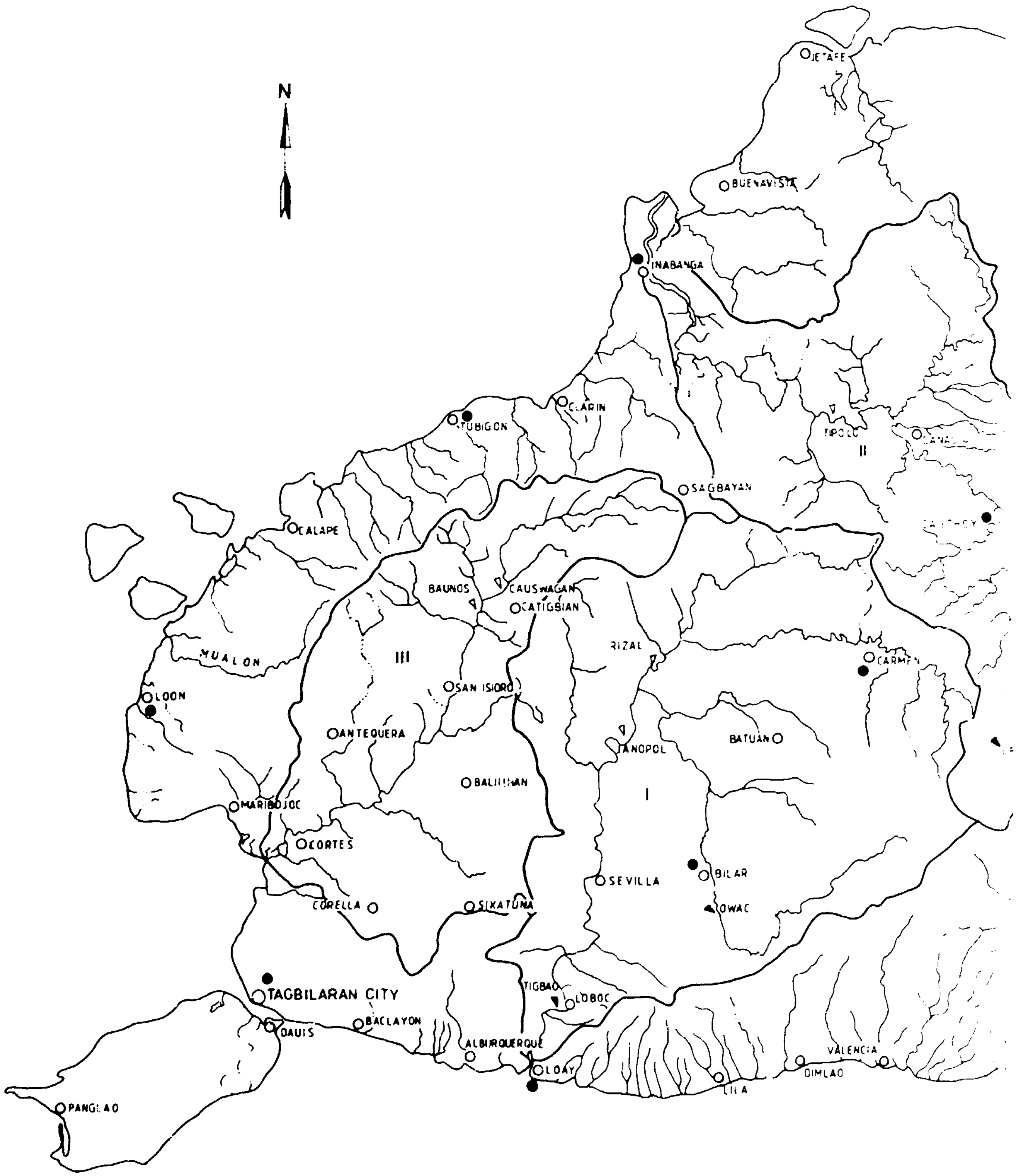
However, no such storage projects could be identified in Antique. The work was therefore at an early stage concentrated on run-of-river developments with tunnels as main waterways.

Of all the identified hydropower schemes in Antique some of the most interesting ones are listed below:

PROJECT		Gross head m	Length of waterways km	Installed capacity kW
Villa Siga,	Alt. 1	30	1.4	7 000
" " ,	Alt. 2	55	2.4	12 000
" " ,	Alt. 3	70	2.8	15 000
" " ,	Alt. 4	150	4.7	28 000
" " ,	Alt. 5	180	5.7	32 000
" " ,	Alt. 6	235	7.8	36 000
" " ,	Alt. 7	375	12.2	44 000
Dalanas		40	5.0	11 000
San Gregorio		135	3.0	10 000
Bauang,	Alt. 1	80	5.6	16 000
" ,	Alt. 2	90	4.0	17 000
" ,	Alt. 3	130	5.8	23 000
Walker		90	4.4	18 000
Bauang-Walker		300	16.7	50 000
General Fullon,	Alt. 1	90	4.2	15 000
" " ,	Alt. 2	115	5.4	20 000
" " ,	Alt. 3	180	9.2	30 000

Of all these alternative developments the Villa Siga project, alternative 4, was selected for further feasibility study. The feasibility study so far indicates that this project can be developed at quite a reasonable cost per installed kW or produced kWh.

With a sufficient big power market it seems possible in Antique to develop economically feasible hydropower projects with a total installed capacity in the order of 100 MW.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ANTEQUERA
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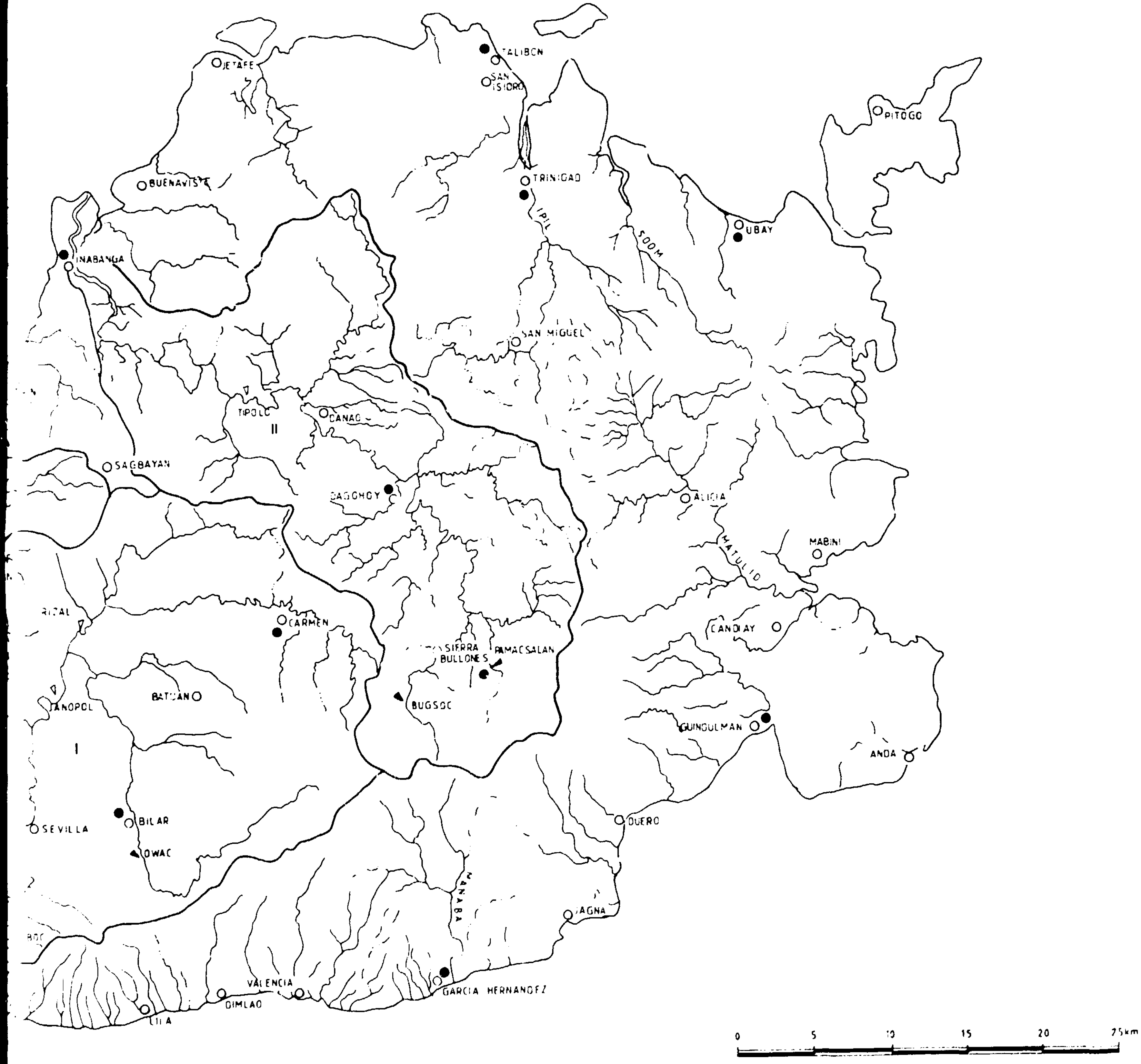
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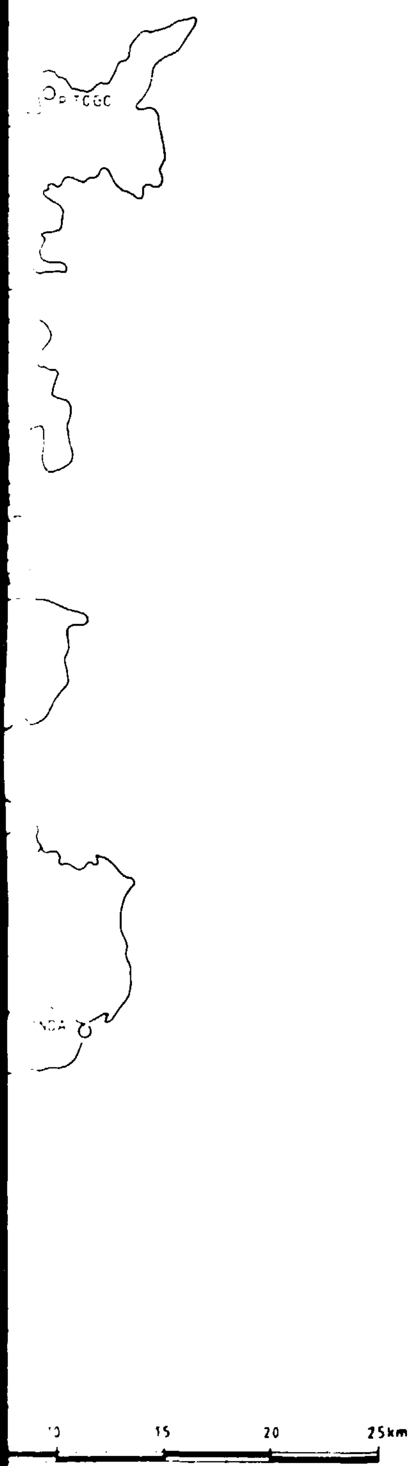


I LOBOC RIVER BASIN, 650 km²

II WAHIG/INABANGA RIVER BASIN, 605 km²

III ABATAN/SINIGAN RIVER BASIN, 365 km²

○ POPULATION CENTER

▼ EXISTING RIVER GAUGING STATION

▽ PROPOSED RIVER GAUGING STATION

● RAINFALL STATION

~ RIVER BASIN BOUNDARY

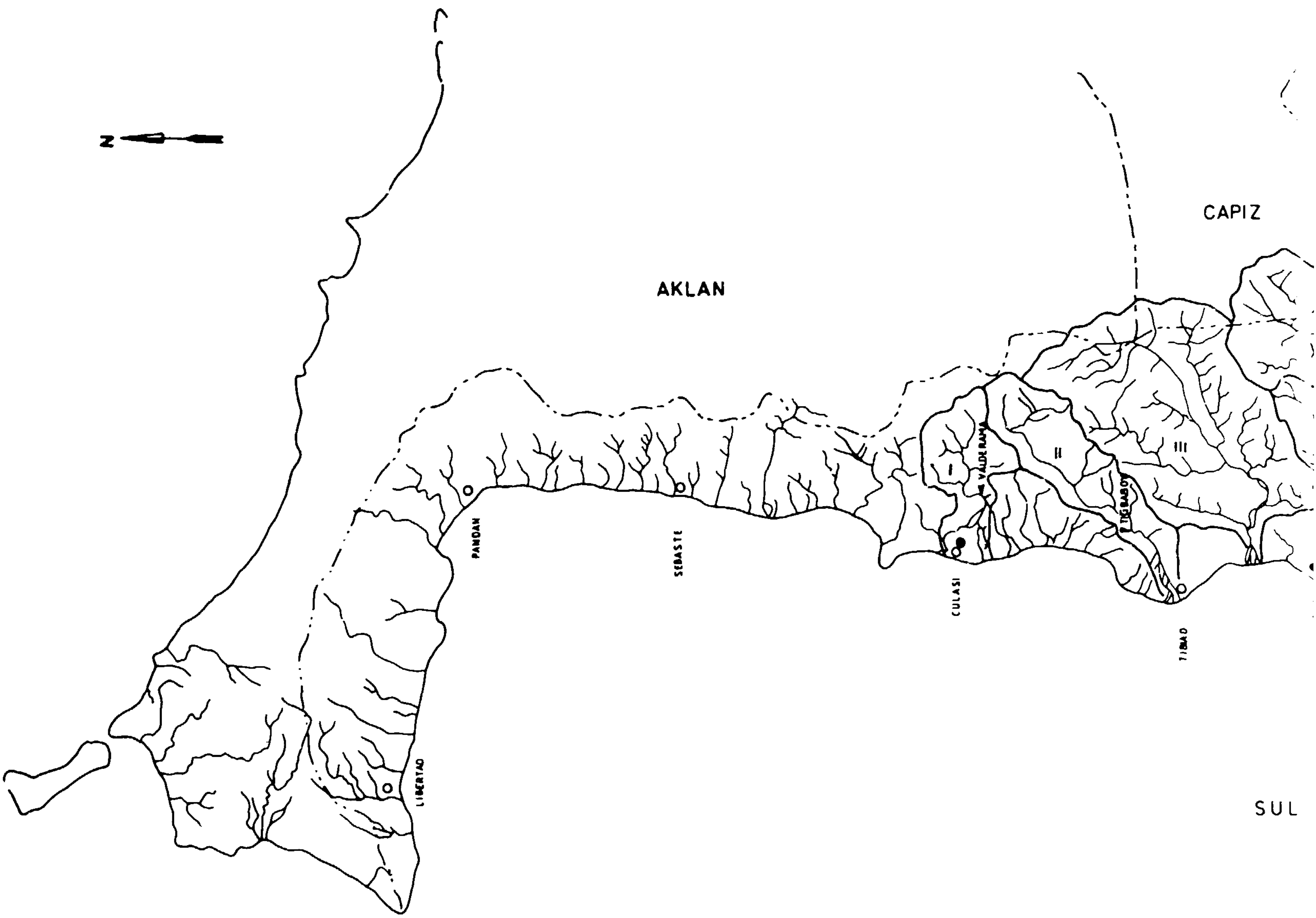
BOHOL HYDROPOWER STUDY

RIVERS AND GAUGING STATIONS

Norconsult A.S

FIG 1

SECTION 3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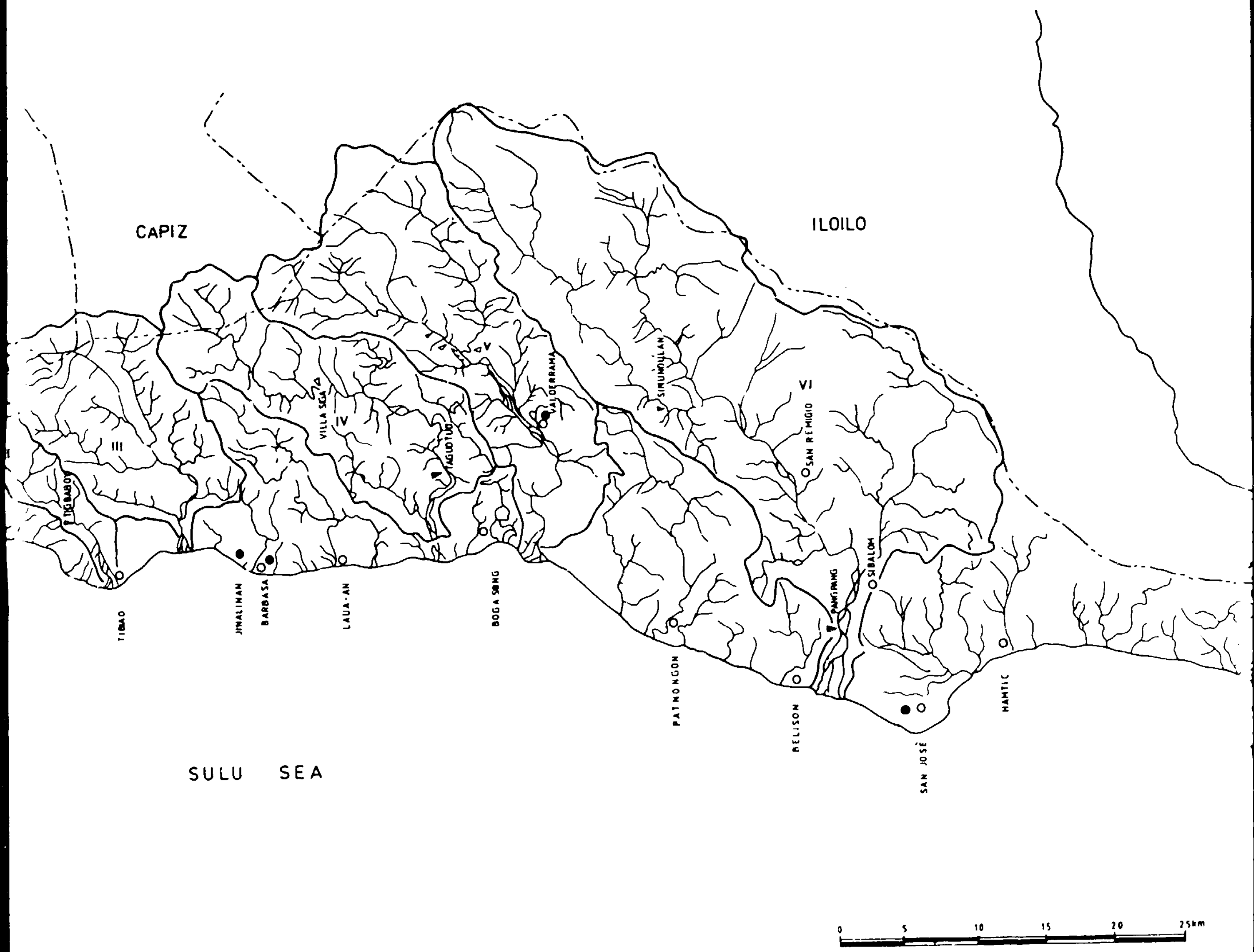
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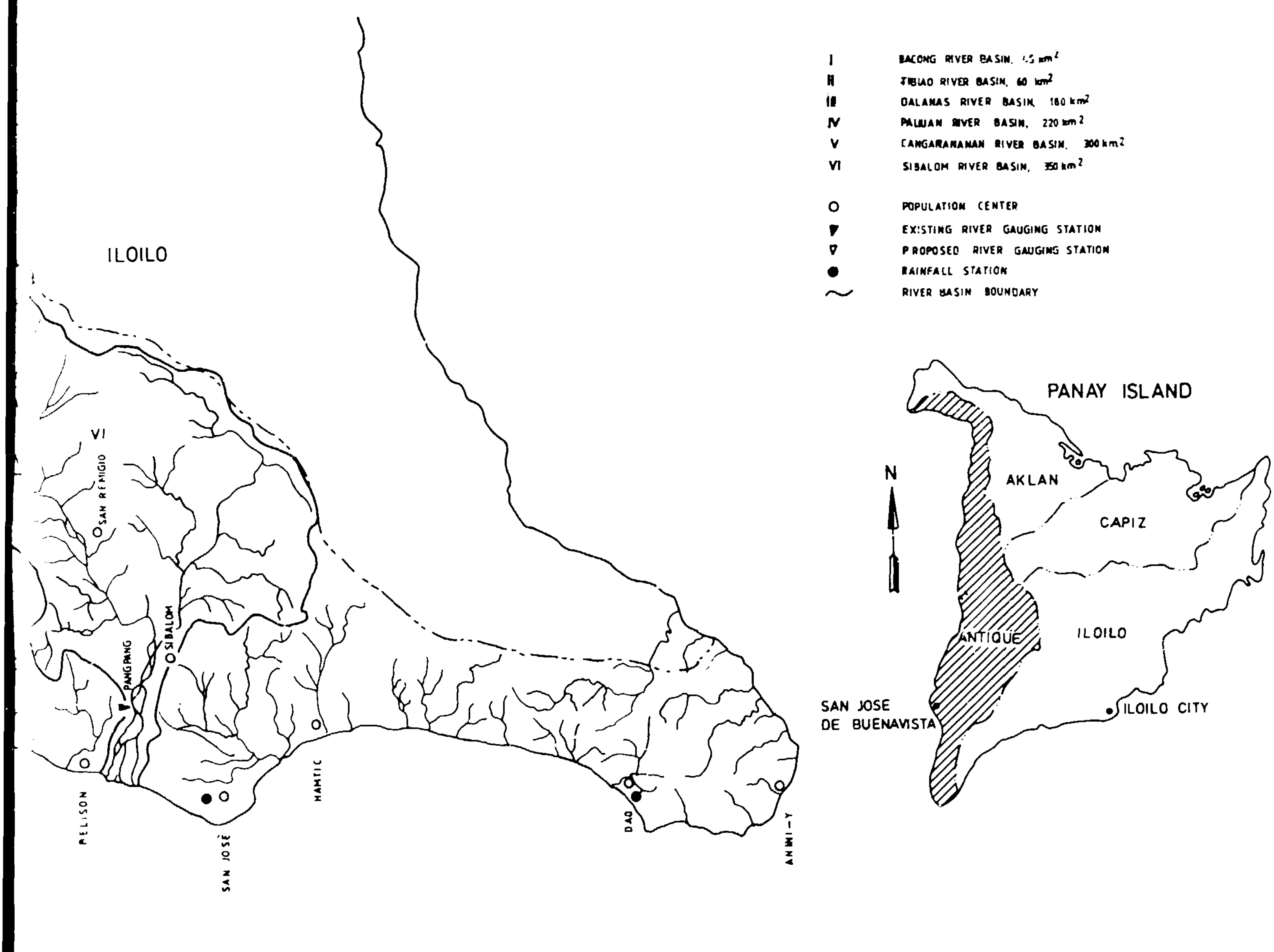

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ANTIQUE HYDROPOWER STUDY

RIVERS AND GAUGING STATIONS

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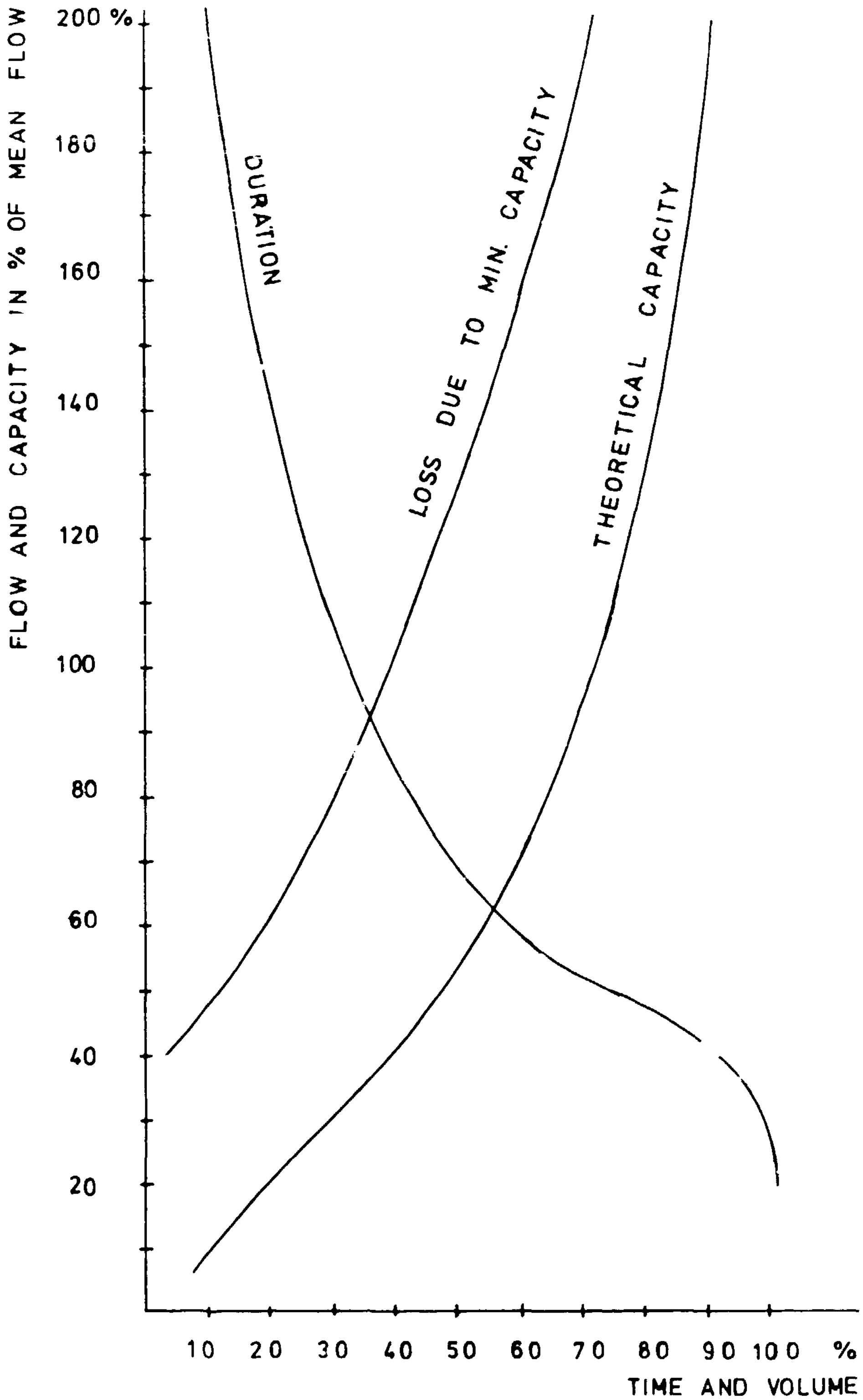
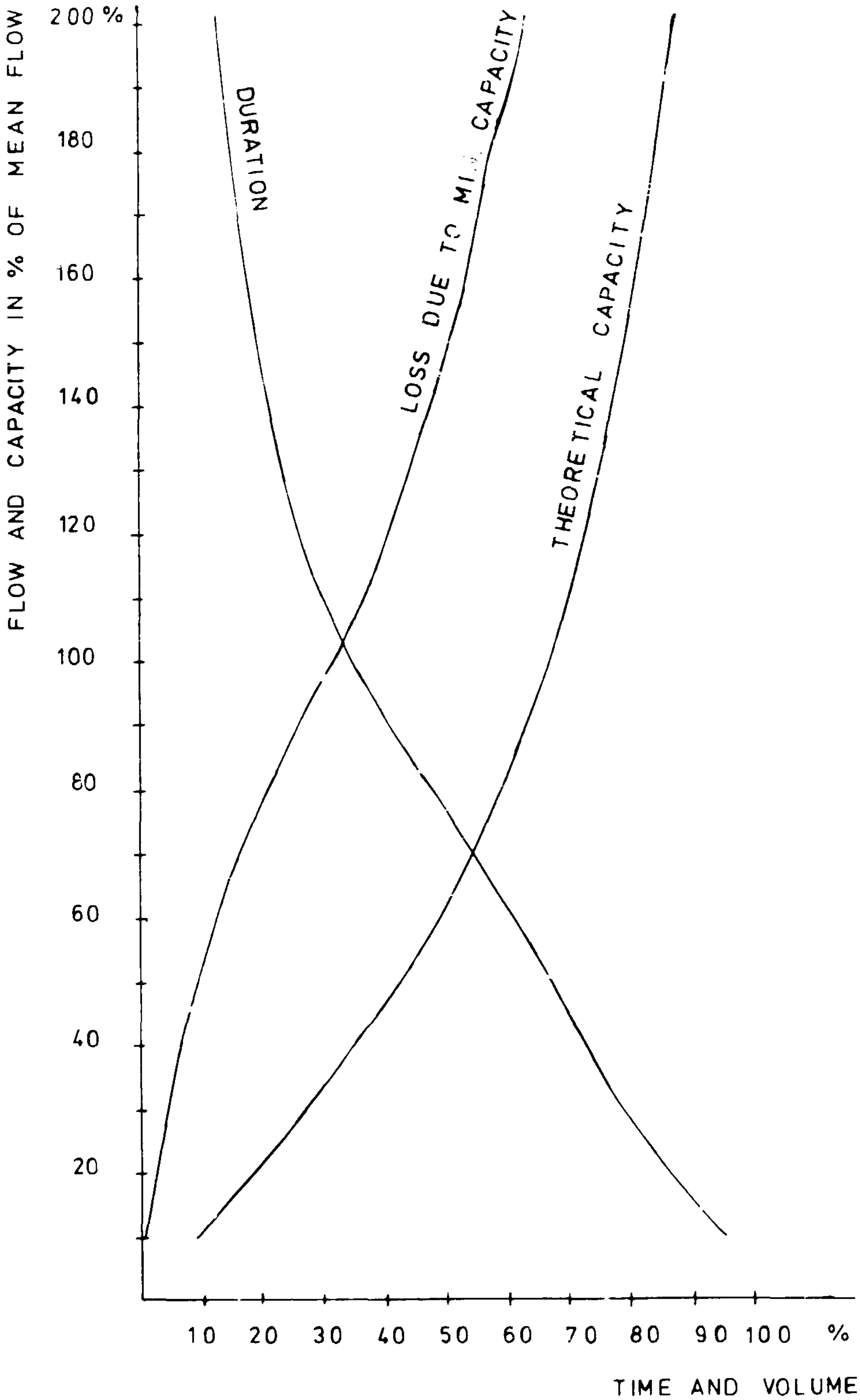
FIG 2

SECTION 3



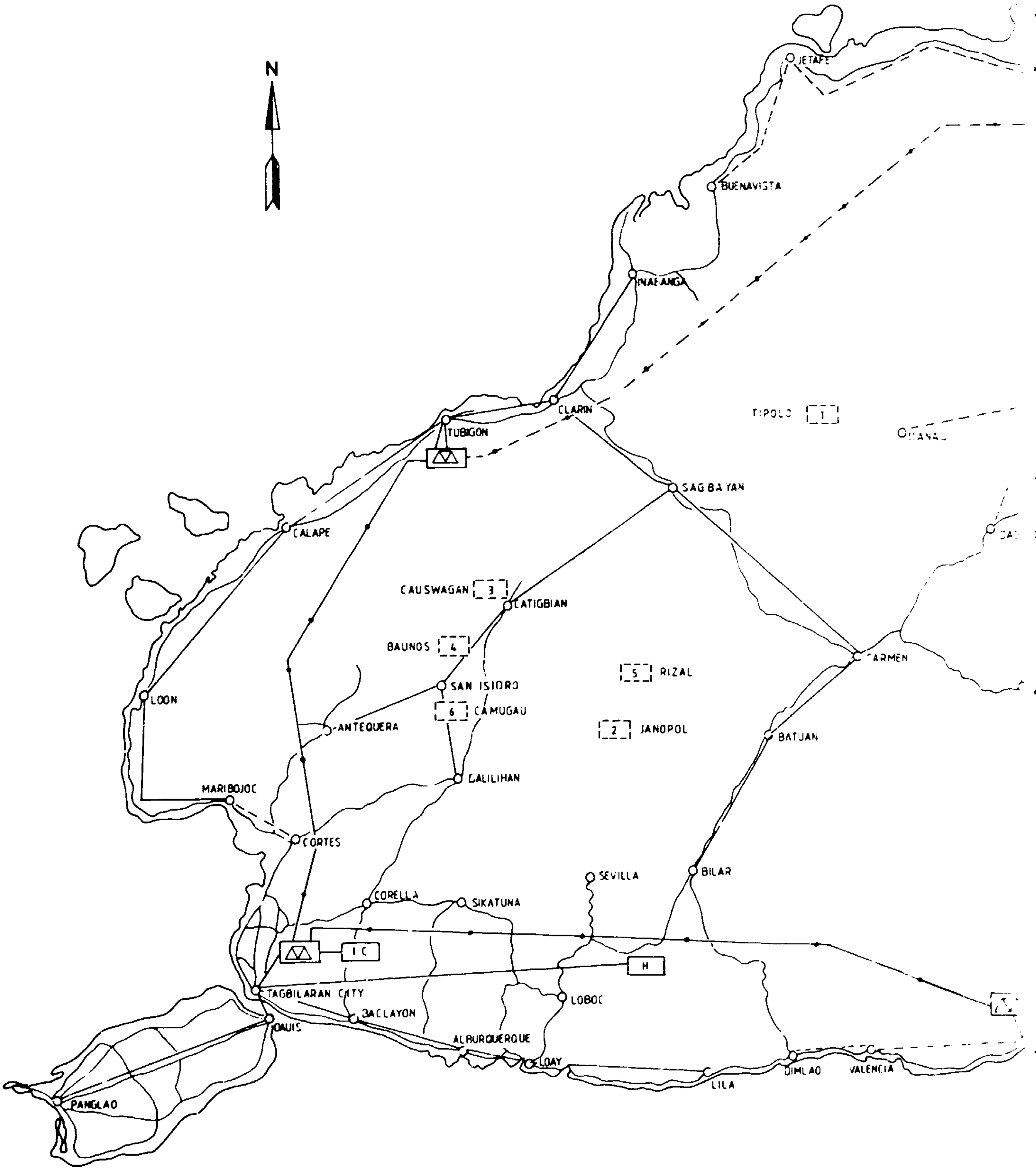
HYDROLOGICAL DURATION AND CAPACITY CURVES FOR BOHOL

FIG 3



HYDROLOGICAL DURATION AND CAPACITY CURVES FOR ANTIQUE

FIG 4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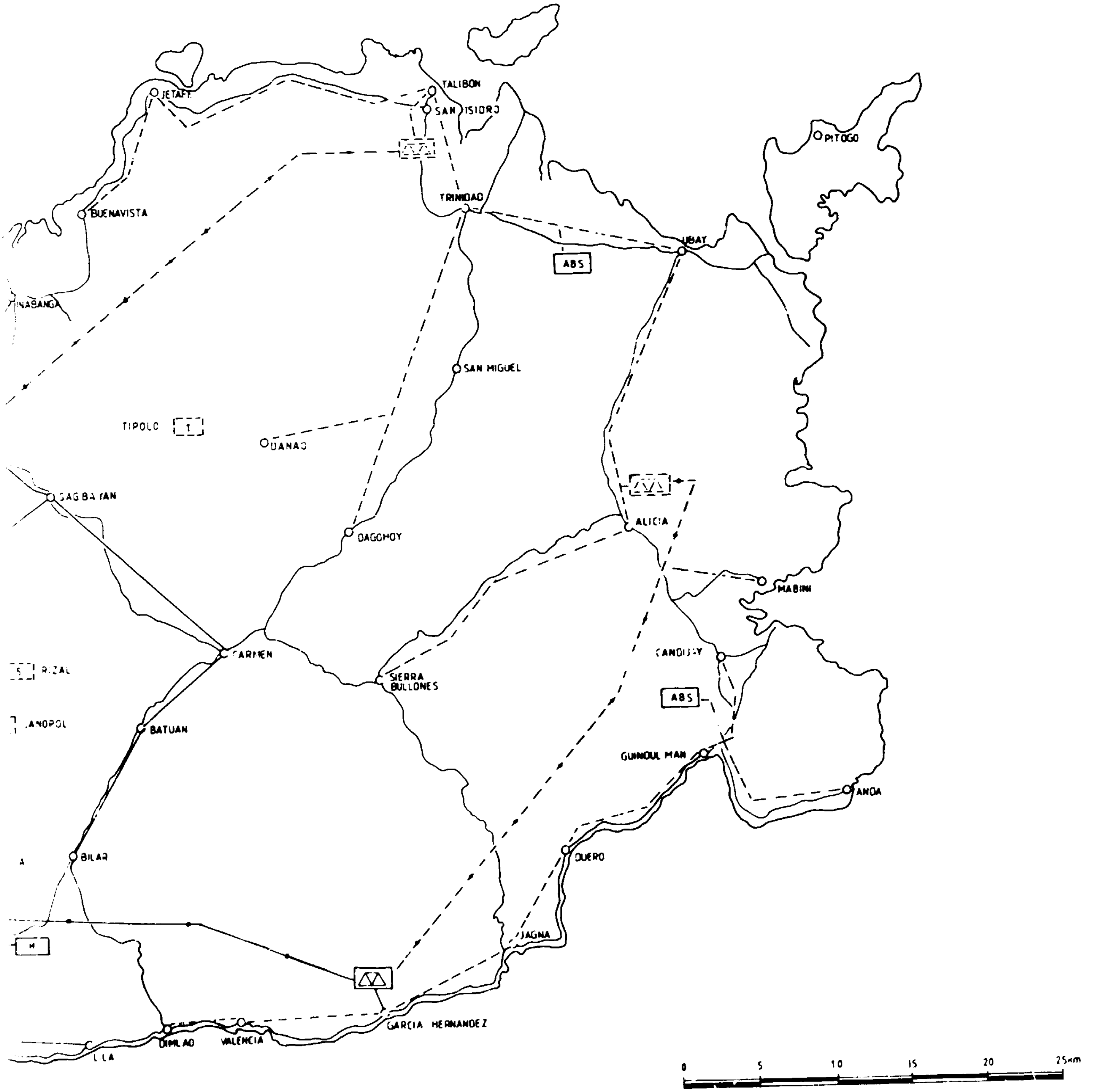
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SECTION 2

H	EXISTING LOBOC HYDROPOWER PLANT	1 200 kW
[dashed box]	POTENTIAL NEW HYDROPOWER PROJECTS	
1	TIPOLO	7 500 kW
2	JANOPOL	5 000 kW
3	CAUSWAGAN	3 000 kW
4	BAUNOS	2 500 kW
5	RIZAL	1 500 kW
6	CAMUGAU	300 kW

[line]	MAIN ROADS	
O	POPULATION CENTER	
[line]	EXISTING 69 kV TRANSMISSION LINES	
[line]	PROPOSED 69 kV TRANSMISSION LINES	
[line]	EXISTING 7.62 / 13.2 DISTRIBUTION LINES	
[line]	PROPOSED 7.62 / 13.2 DISTRIBUTION LINES	
[symbol]	EXISTING 69 - 7.62 / 13.2 SUBSTATION	
[symbol]	PROPOSED 69 - 7.62 / 13.2 SUBSTATION	
IC	EXISTING DIESEL POWER PLANT	11 000 kW
ABS	AIR BREAK SWITCH	

THE PROPOSED TRANSMISSION LINES AND SUBSTATIONS ARE ALL PLANNED BY NEA AND NPC BEFORE THE POTENTIAL NEW HYDROPOWER PROJECTS WERE IDENTIFIED

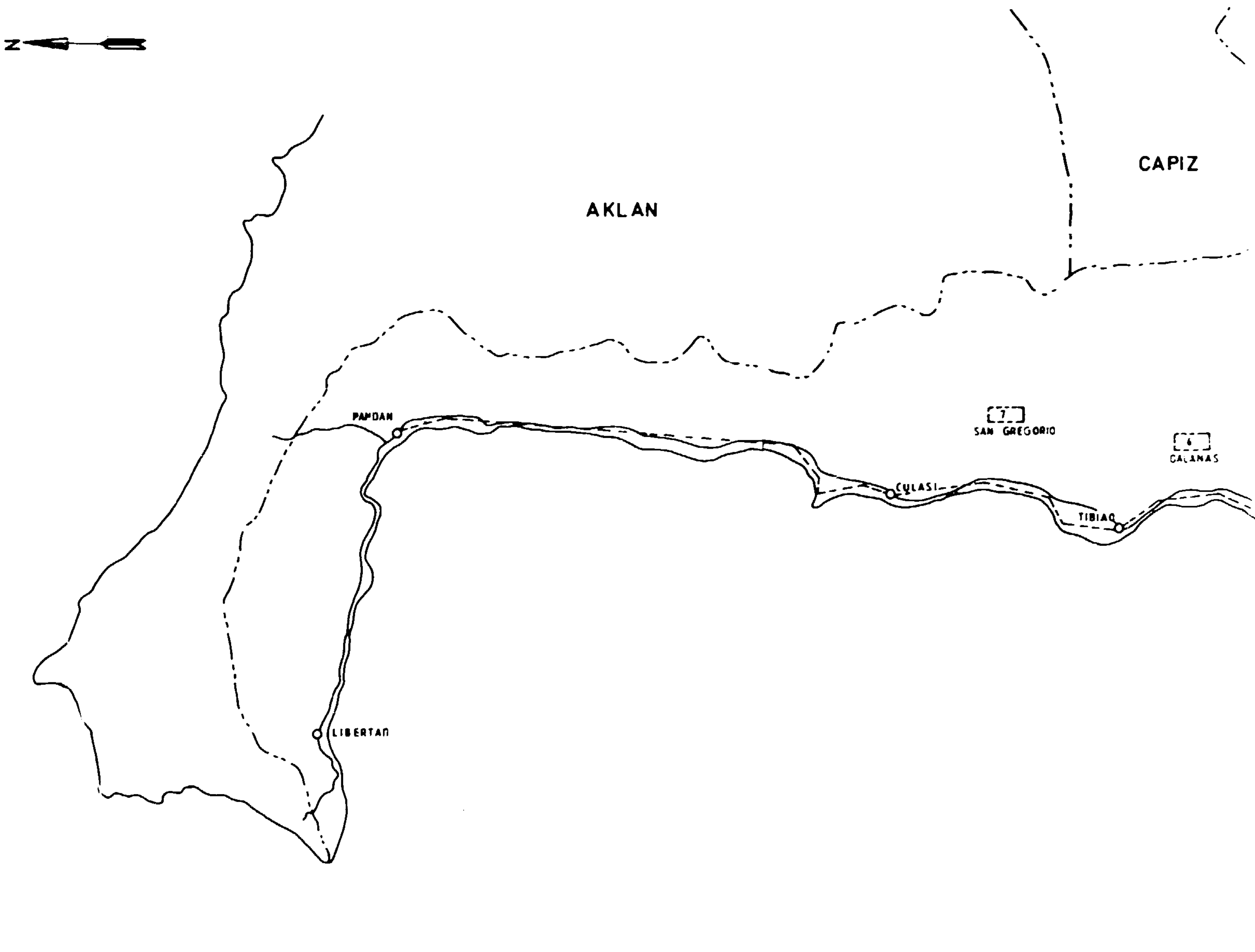
BOHOL HYDROPOWER STUDY

ROADS AND TRANSMISSION LINES
HYDROPOWER PROJECTS

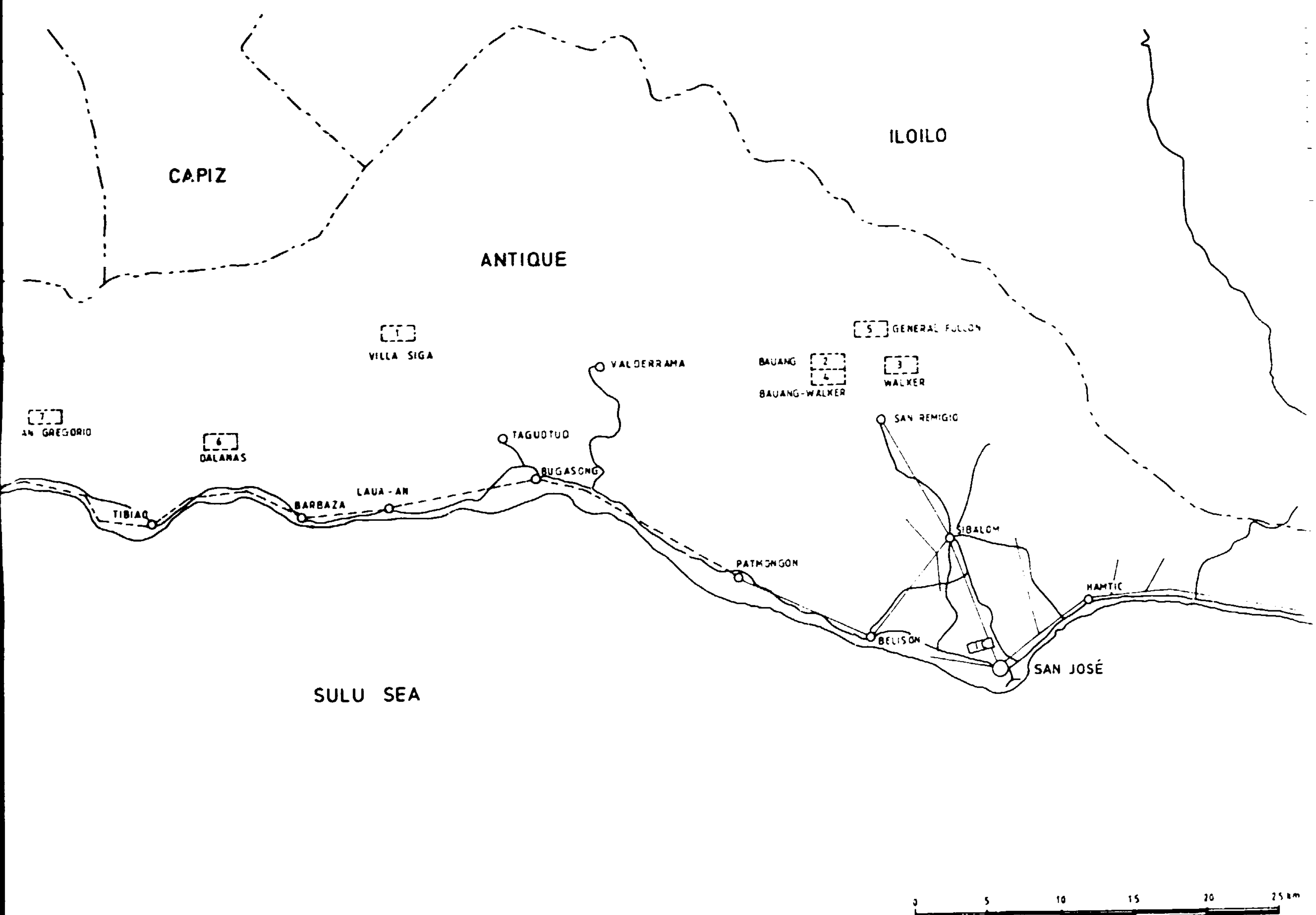
Norconsult A.S.
Consulting Engineers, Architects and Economists

FIG 5

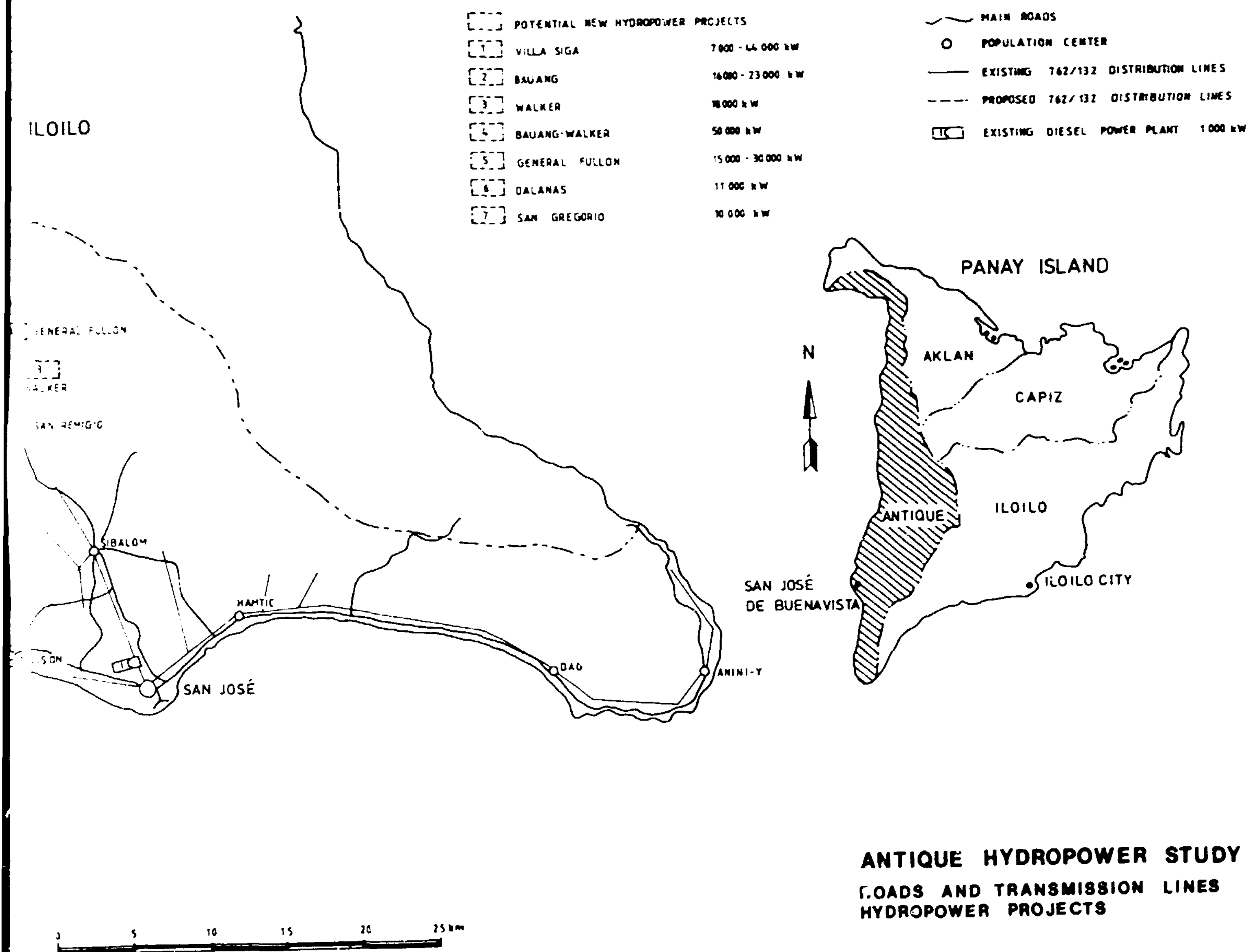
SECTION 3



SECTION 1


CAPIZ
ILOILO
ANTIQUE
1
VILLA SIGA
VALDERRAMA
5
GENERAL FULLON
BAUANG
2
4
BAUANG-WALKER
3
WALKER
7
AN GREGORIO
6
DALANAS
TAGUDTUD
SAN REMIGIO
BUGASONG
LAUA-AN
BARBAZA
TIBIAO
SIBALOM
PATNONGON
HAMTIC
BELISON
SAN JOSÉ
SULU SEA
0
5
10
15
20
25 km

SECTION 2



ANTIQUE HYDROPOWER STUDY

ROADS AND TRANSMISSION LINES HYDROPOWER PROJECTS

Norconsult A.S.

FIG 6

SECTION 3