ENGINEERING, GEOLOGICAL and GEOHAZARD ASSESSMENT REPORT

OF THE PROPOSED

CATUIRAN MINI-HYDROELECTRIC POWER PLANT PROJECT

BARANGAY MALVAR, NAUJAN, ORIENTAL MINDORO

OF

STA. CLARA INTERNATIONAL CORPORATION

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ENGINEERING GEOLOGICAL AND GEOHAZARD ASSESSMENT REPORT OF THE CATUIRAN MINI-HYDROELECTRIC POWER PLANT PROJECT LOCATED AT BARANGAY MALVAR, NAUJAN, ORIENTAL MINDORO

1.0 GENERAL INFORMATION

1.1 Introduction

The engineering, geological and geohazard assessment (EGGA) of the Catuiran Mini-hydroelectric Power Plant Project located at Barangay Malvar, Naujan, Oriental Mindoro was carried out by the undersign upon the commissioning of STA. CLARA INTERNATIONAL CORPORATION. The main purpose of the study is to determine the surface geology and identify geologic hazards that may compromise the stability of the infrastructures of the project. This is relative to DENR Administrative Order No. 2000-28 and MGB Memorandum Circular No. 2000-33, requiring proponents to submit engineering geological and geohazard assessment report as an additional requirement in the Environmental Compliance Certificate (ECC) application. The report was made in accordance with the Geohazard Identification Report of the staffs of Mines and Geosciences Bureau - Region 4A dated June 1, 2015.

Fieldwork was undertaken last October 16 – 18, 2015.

1.2 Location and Accessibility

The Catuiran Mini-hydroelectric Power Plant project is located at Barangay Malvar, Naujan, Oriental Mindoro within blocks bounded by geographical coordinates of 10° 28' 00" to 10° 28' 30" north latitude and 123° 05' 30" to 123° 06' 00" east longitude (Refer to Figure 1 and 2).

It is accessible from Manila via the South Superhighway going to Batangas City Pier by any land transport vehicle. Thence, several sea vessels are available at Batangas City Pier that ferries towards Calapan

Pier in Oriental Mindoro. From Calapan Pier, Naujan can be reached by land passing via the National Highway with roughly distance of 34 kilometers southwest from Calapan City. The project located at Barangay Malvar, Naujan can be reached via the provincial and barangay road (Power Plant and Catuiran Temfacil) and through an old logging road to the Catuiran Weir.

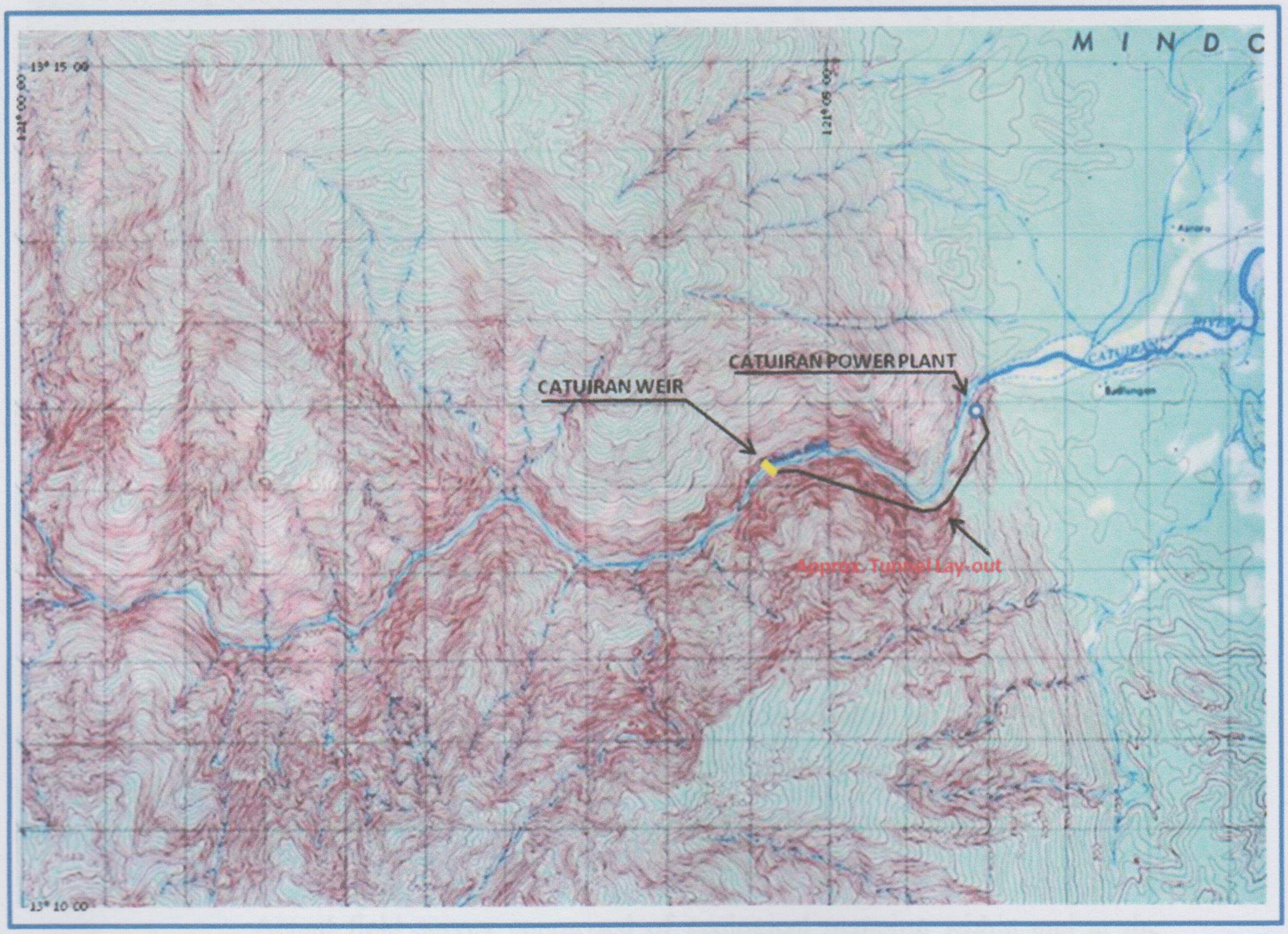


Figure 1. *Location and Topographic Map of Catuiran Mini-hydroelecric Power Plant Project*



Figure 2. *Google Map Showing the Catuiran Mini-hydroelecric Power Plant Project*

1.3 Methodology

Geologic assessment comprised of: (1) collation of existing geologic reports and literature in the area, (2) interpretation of topographic, and geologic maps, and (3) actual field verification/mapping of rock units, rock sampling and (4) identifications of geologic structures.

Actual field survey comprised of geological mapping within and at the periphery of the vicinity of the project location. Mapping includes identification of rock types occurring in the project area, determination of rock orientation (attitudes) and characteristics, measurement of outcropping structures (bedding planes, joints, etc.), and the identification of potential geologic hazards.

1.4 Nature/Source of Information

The geological assessment commenced with literature research of all available geologic, and seismological maps covering the project area previously conducted at the Mines and Geo-Sciences Bureau (MGB), and the Philippine Institute of Volcanology and Seismology (PHIVOLCS) Topographic maps covering Oriental Mindoro and its vicinity were acquired from the National Mapping and Resource Information Agency (NAMRIA). Climatological data covering the project area was gathered from the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA). Geotechnical study of Engr. Renante B. Dela Cruz, provided by the proponent was also used in the preparation of this report.

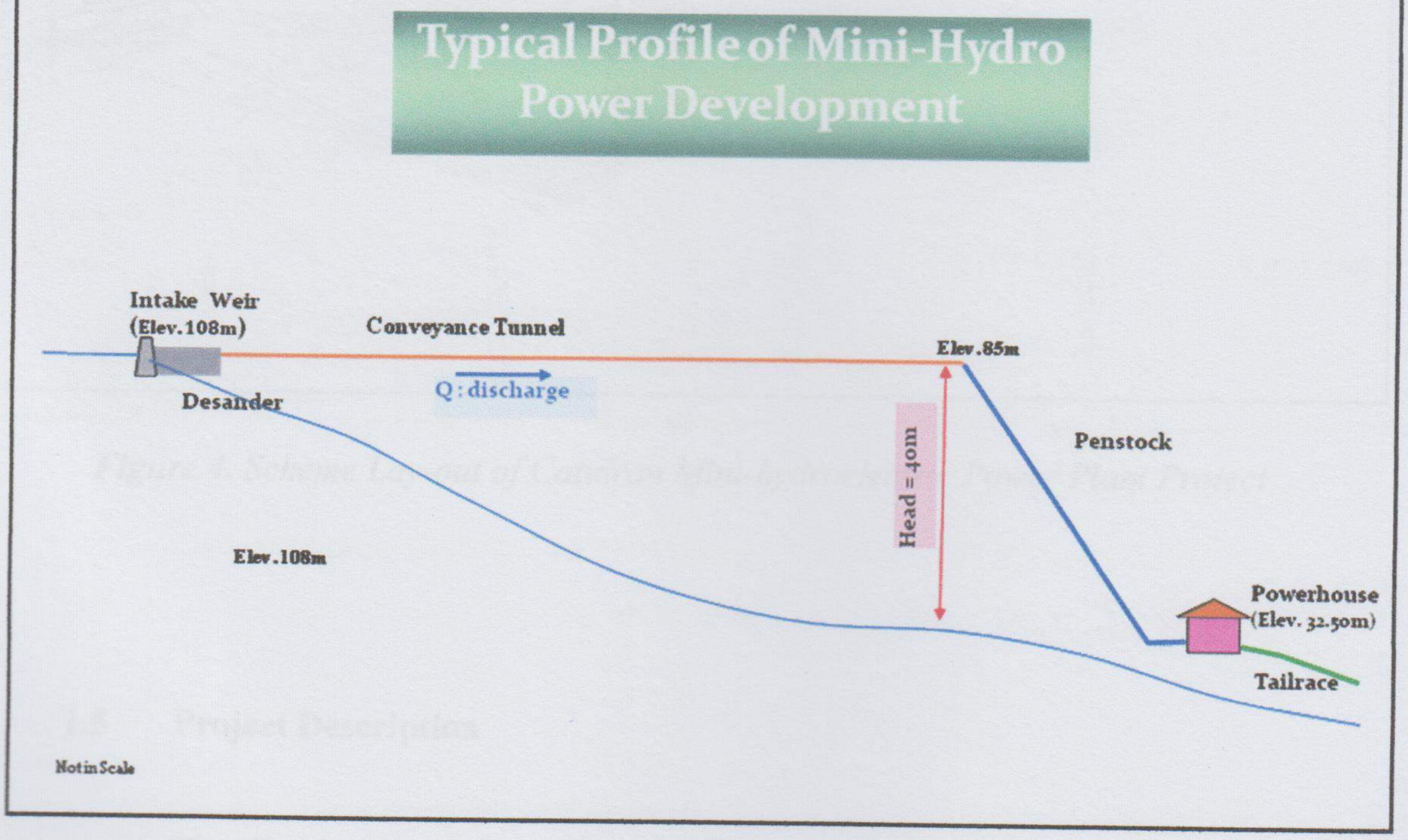


Figure 3. *Section Showing Profile of the Proposed Catuiran Hydro-electric Power Project*

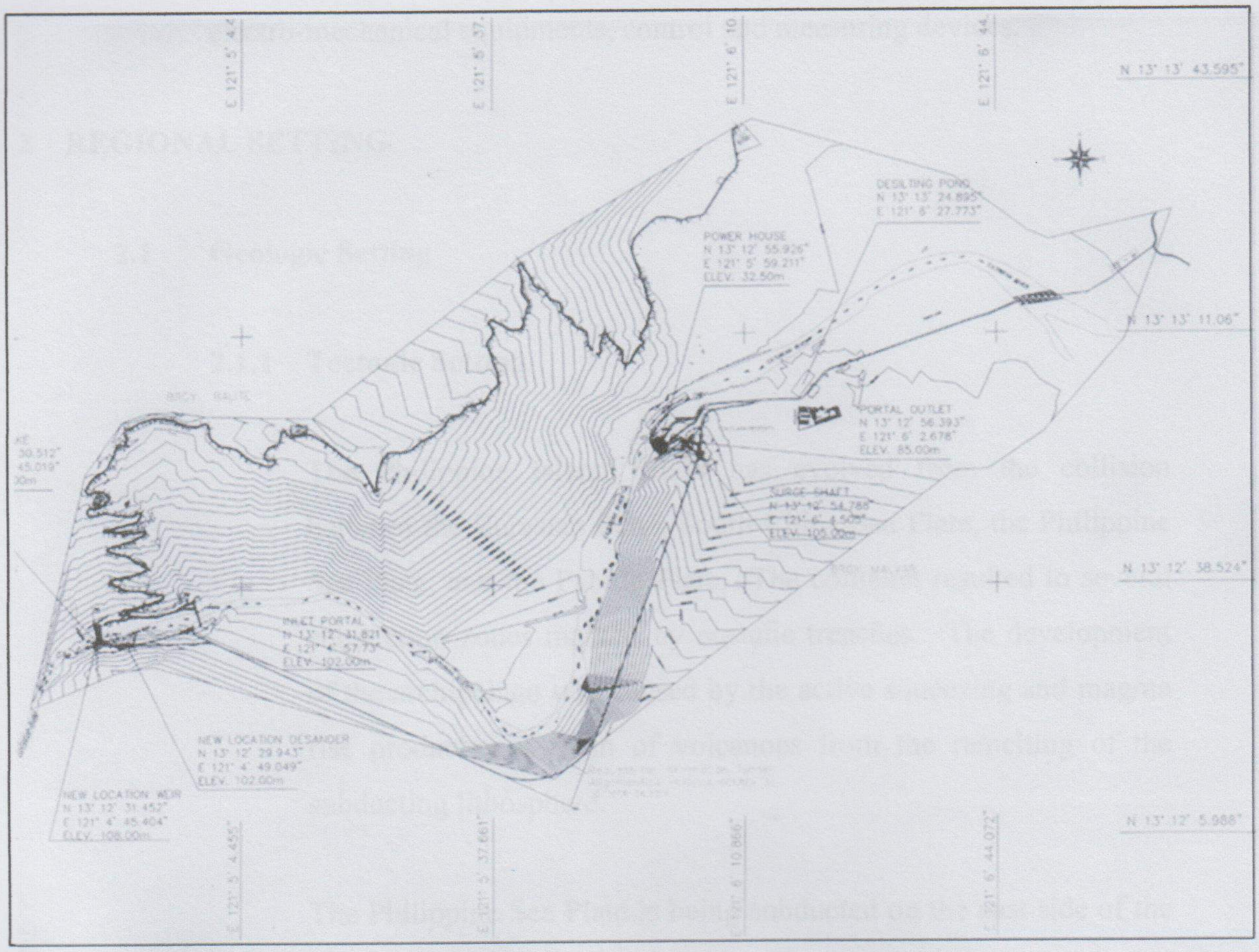


Figure 4. *Scheme Lay-out of Catuiran Mini-hydroelectric Power Plant Project*

1.5 Project Description

The Catuiran Hydro-electric Power Plant project (Targeted Capacity – 8.00 MW) aims to produce a sustainable renewable energy to augment power supply of Naujan, Oriental Mindoro and its nearby community *(Figure 3 and 4)*. The project schemes consist of diverting the water from

the Catuiran River through an overflow weir and allow water to pass through an intake diversion structure to the desander then through a 3.0m by 3.5m low pressure tunnel and to high pressure steel penstock to the hydraulic turbine. A power plant building will be constructed to house the electro-mechanical equipments, control and measuring devices.

2 REGIONAL SETTING

2.1 Geologic Setting

2.1.1 Tectonic Setting

The Philippine Island Chain has evolved from the collision between the Eurasian Plate, South China Sea Plate, the Philippine Sea Plate, and the Pacific Plate. The collision resulted to several subduction zones marked by oceanic trenches. The development of the archipelago was caused by the active squeezing and magma rise producing a chain of volcanoes from the remelting of the subducting lithosphere.

The Philippine Sea Plate is being subducted on the east side of the archipelago along the Philippine Trench and the East Luzon Trench. On the other side of the archipelago, the seafloor of the South China Sea Plate subducts near the west side of Luzon along the Manila Trench, producing an opposite dipping subduction zone.

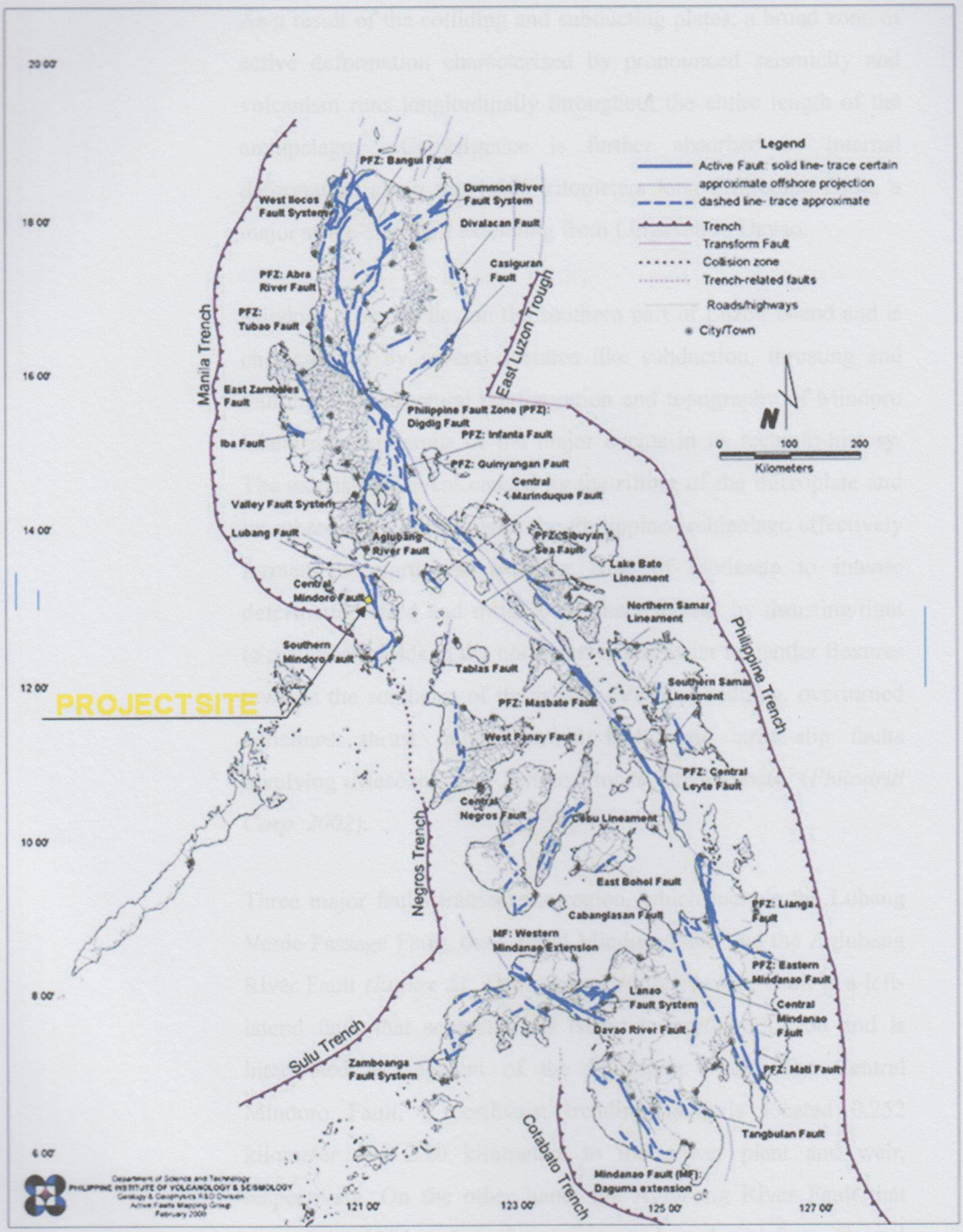


***Figure 5**. Tectonic Map of the Philippines*

As a result of the colliding and subducting plates, a broad zone of active deformation characterized by pronounced seismicity and volcanism runs longitudinally throughout the entire length of the archipelago. Convergence is further absorbed by internal deformation along the 1,600 kilometers long Philippine Fault, a major strike-slip fault extending from Lingayen to Davao.

Mindoro province lies on the southern part of Luzon Island and is characterized by several features like subduction, thrusting and faulting. The structural configuration and topography of Mindoro Island are the results of the major events in its tectonic history. The extensional event caused by the rifting of the microplate and its subsequent collision with the Philippine archipelago effectively formed the northwest trending zone of moderate to intense deformation (fold and thrust bed) characterized by thrusting/tight to recumbent folds in the northwest and broader to gentler flexures towards the southeast of the island. (Vertical bedding, overturned anticlines, thrust faults, normal faults and strike-slip faults involving Mesozoic to Tertiary rocks predominate (*Philodrill Corp. 2002*).

Three major faults transect the region, which include the Lubang Verde Passage Fault, the Central Mindoro Fault and the Aglubang River Fault *(Figure 5)*. The Lubang Verde Passage Fault is a left-lateral fault that separates the island to northern Luzon and is interpreted as segment of the Philippine Fault. The Central Mindoro Fault, a northwest trending fault is located 0.252 kilometer and 2.20 kilometers to the power plant and weir, respectively. On the other hand, the Aglubang River Fault that caused the 1994 earthquake appears to branch out from Central Mindoro Fault.

2.1.2 Stratigraphy

The core of Mindoro Island is dominated by a broad expanse of basement complex rocks of pre-Jurassic age. These rocks are overlapped and uncomformably underlain by a thick sequence of volcanic and sedimentary rocks and range in age from Jurassic to Quaternary Recent. Neogene intrusives are meagerly represented in the north central portion of the island and Quaternary volcanic rocks noted only at the eastern section of Mindoro.

The project site and its vicinity are underlain by four rock formations, which include – Quaternary Alluvium, Socorro Group, Mansalay and the Halcon Formation (*Figure 6*). Quaternary Alluvium consists of extensive alluvial deposits of clay, silt, sand and gravel and are commonly found in the valleys and near the shore of Mindoro.

This is commonly underlain by the Socorro Group mainly terrace deposits, tuffaceous shale and andesitic tuff. Mansalay Formation consists principally of sandstone, shale, siltsone, minor limestone, and conglomerate.

Halcon Metamorphics, the major rock formation covering the project site consist of amphibolites (mica schist and greenschist), phyllites, slates, marble, gneisses and metagabbro.

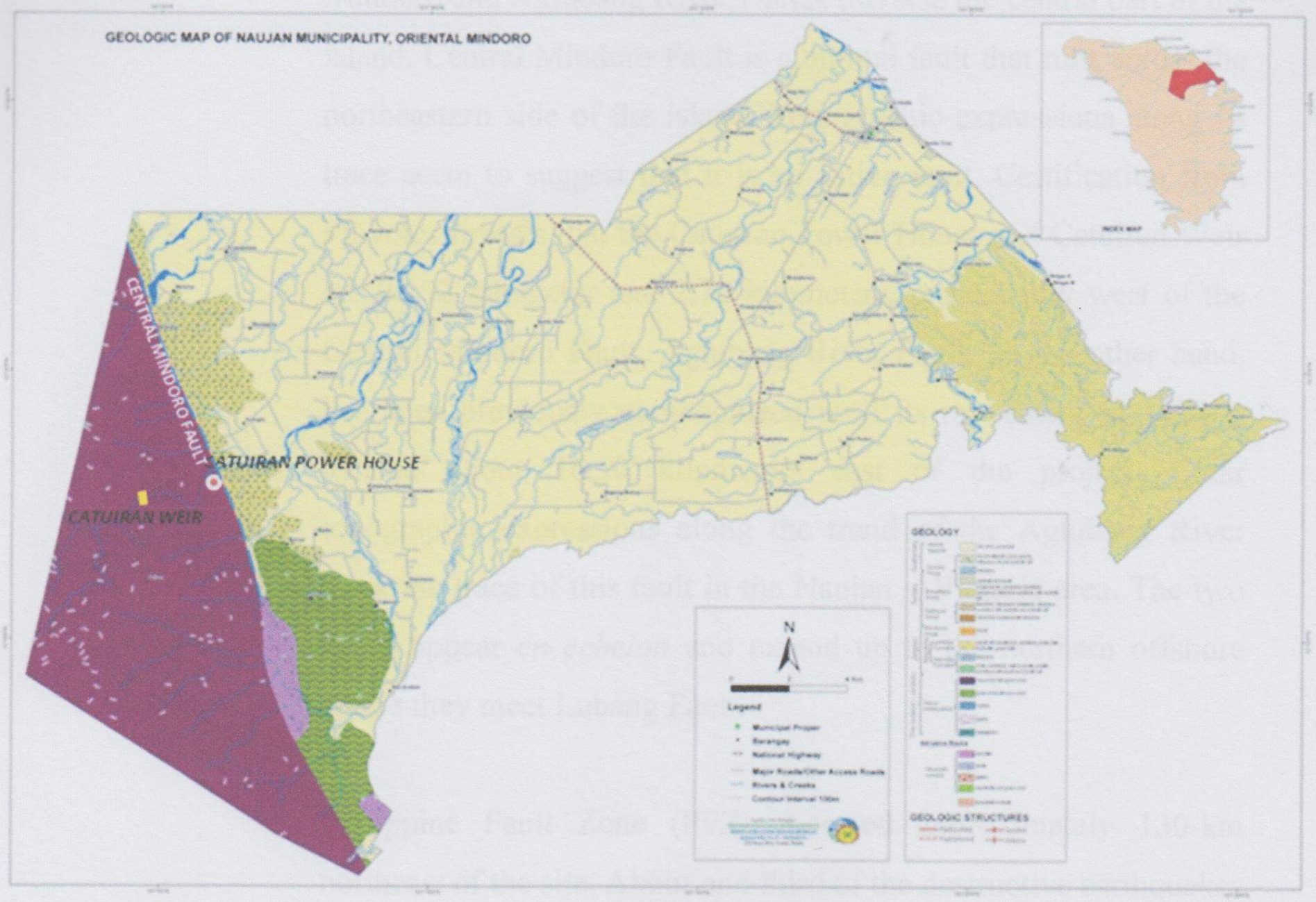


Figure 6. *Geologic Map of the Municipality of Naujan, Oriental Mindoro*

2.1.3 Structural Geology

Mindoro Island lies within a tectonically active region (*Figure 5 and 7*). Three active faults are found in proximity to the island. The first one is the Lubang Verde Island Fault, an active strike-slip structure that passes in the offshore areas between Batangas Province and Lubang – Ambil – Mindoro Islands, had also been the site of large earthquakes in the past, notably that of 1852 and 1972, the most recent one was the 1994 in Mindoro, which registered a seismic magnitude of 7. Its nearest section is 45 aerial

kilometers north of the project site. The other two faults, Central Mindoro and Aglubang River Faults, traverse the central part of the island. Central Mindoro Fault is a normal fault that runs across the northeastern side of the island. Topographic expressions along its trace seem to suggest that it is an active fault. Certification from Phivolcs reveals that the Catuiran Power House and Catuiran Weir are 0.252 kilometer and 2.70 kilometers, respectively west of the Central Mindoro Fault. Aglubang River Fault, on the other hand, has been previously unrecognized until its movement in 1994 is located about 10.50 kilometers east of the project. Clear topographic expressions along the trend of the Aglubang River mark the trace of this fault in the Naujan – Victoria area. The two faults appear *en echelon* and extend up to the northern offshore where they meet Lubang Fault.

Philippine Fault Zone (PFZ). Located approximately 130-km northeast of the site. About one-third of the destructive earthquakes that have affected Metro Manila and vicinity were generated from the Philippine Fault Zone, an approximately 1,200 kilometers long strike-slip fault transecting the whole Philippine archipelago. The movement of the Philippine Fault Zone produced majority of the most devastating earthquakes in Philippine history, including the 16 July 1990 event. A seismic gap along this fault located about 60 kilometers east of the site can produced a future earthquake in the order of at least magnitude 7.50 is highly possible (upon the released of large stresses stored along the locked portion).

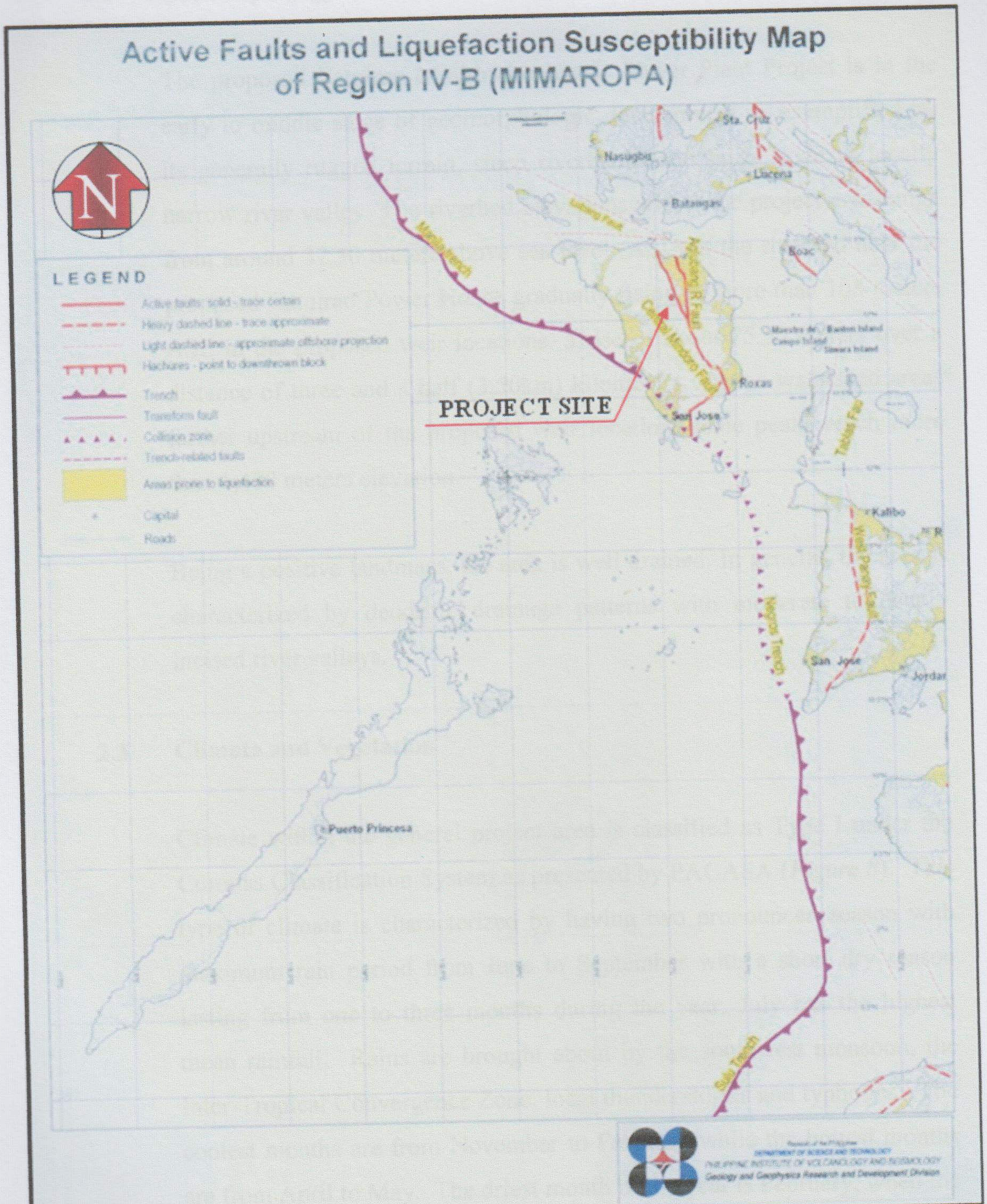


***Figure** 7. Acitve Faults and Liquefaction Susceptibility Map of Region 4B*

2.2 Geomorphology

The proposed Catuiran Mini-hydroelectric Power Plant Project is in the early to middle stage of geomorphologic development as exemplified by its generally rugged terrain, steep riverbanks and fairly wide to locally narrow river valley. The riverbed elevations within the project area range from around 32.50 meters above sea level (ASL) at the riverbed near the proposed Catuiran Power House gradually rising to more than 108 meters ASL in the proposed weir locations, a rise of about 75.50 meters over a distance of three and a half (3.50km) kilometers. In the watershed areas farther upstream of the proposed weir location, some peaks reach more than 1,400 meters elevation.

Being a positive landmass, the area is well drained. In general, the area is characterized by dendritic drainage patterns with moderate to deeply incised river valleys.

2.3 Climate and Vegetation

Climate within the general project area is classified as Type I under the Coronas Classification System as presented by PAGASA (*Figure 8*). This type of climate is characterized by having two pronounced season with maximum rain period from June to September with a short dry season lasting from one to three months during the year. July has the highest mean rainfall. Rains are brought about by the southwest monsoon, the Inter-Tropical Convergence Zone, local thunderstorms and typhoons. The coolest months are from November to February while the hottest months are from April to May. The driest month of the year is February, when the northeast monsoon prevails. Data collected from the nearest PAGASA station located at Calapan, Oriental Mindoro Mindoro (2005 – 2014)

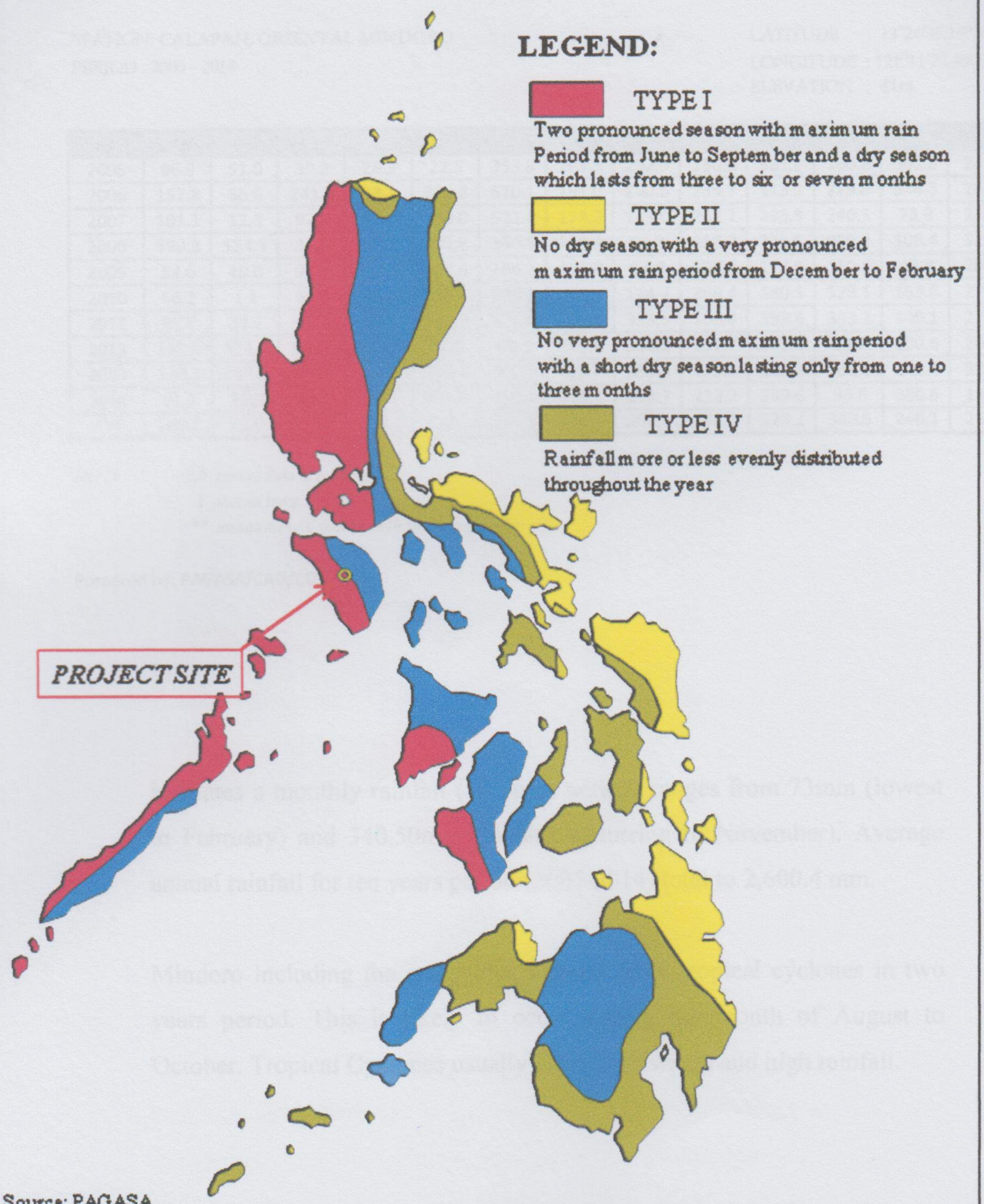


***Figure 8**. Climate Map of the Philippines*

Table 1. Monthly Total and Annual Climatic Data Rainfall of Oriental Mindoro

STATION: **CALAPAN, ORIENTAL MINDORO**
PERIOD : 2005 - 2014

LATITUDE : 13°24'35.19"N
LONGITUDE : 121°11'22.80"E
ELEVATION : 41m

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
2005	96.9	51.0	30.2	28.3	22.5	353.8	203.3	292.5	150.6	581.0	160.6	501.6	2472.3
2006	152.8	56.6	241.9	58.4	352.8	670.1	191.0	200.6	235.7	113.2	229.8	344.3	2847.2
2007	101.1	12.3	97.6	28.0	250.0	522.4	173.2	149.0	263.1	296.8	240.5	75.8	2209.8
2008	399.8	154.3	27.8	291.6	303.8	260.5	110.3	63.8	318.2	243.8	999.2	106.4	3279.5
2009	64.6	40.0	91.0	322.6	447.6	186.2	166.8	94.8	257.6	177.0	110.8	48.8	2007.8
2010	56.2	1.1	84.2	76.0	76.2	209.1	440.0	174.7	369.4	580.5	528.1	163.6	2759.1
2011	93.8	32.2	63.0	65.5	189.7	421.0	268.4	353.3	103.4	393.4	393.2	405.1	2782.0
2012	135.6	171.7	320.0	154.8	11.0	68.1	509.4	259.1	257.7	442.4	88.7	200.6	2619.1
2013	128.3	187.5	175.1	62.0	253.2	397.5	470.7	293.4	275.8	104.1	558.8	228.4	3134.8
2014	51.8	22.8	32.0	19.4	194.9	154.4	219.1	192.7	223.2	299.6	95.6	386.6	1892.1
AVE	128.1	73.0	116.3	110.7	210.2	324.3	275.2	207.4	245.5	323.2	340.5	246.1	2600.4

NOTE : *-2.0 means data is missing*
T means trace
** means annual values with missing months*

Prepared by: PAGASA/CAD/CDS

indicates a monthly rainfall (10 years period) ranges from 73mm (lowest in February) and 340.50mm (highest occurring in November). Average annual rainfall for ten years period (2005-2014) total to 2,600.4 mm.

Mindoro including the study area expects three tropical cyclones in two years period. This is likely to occur during the month of August to October. Tropical Cyclones usually bring high winds and high rainfall.

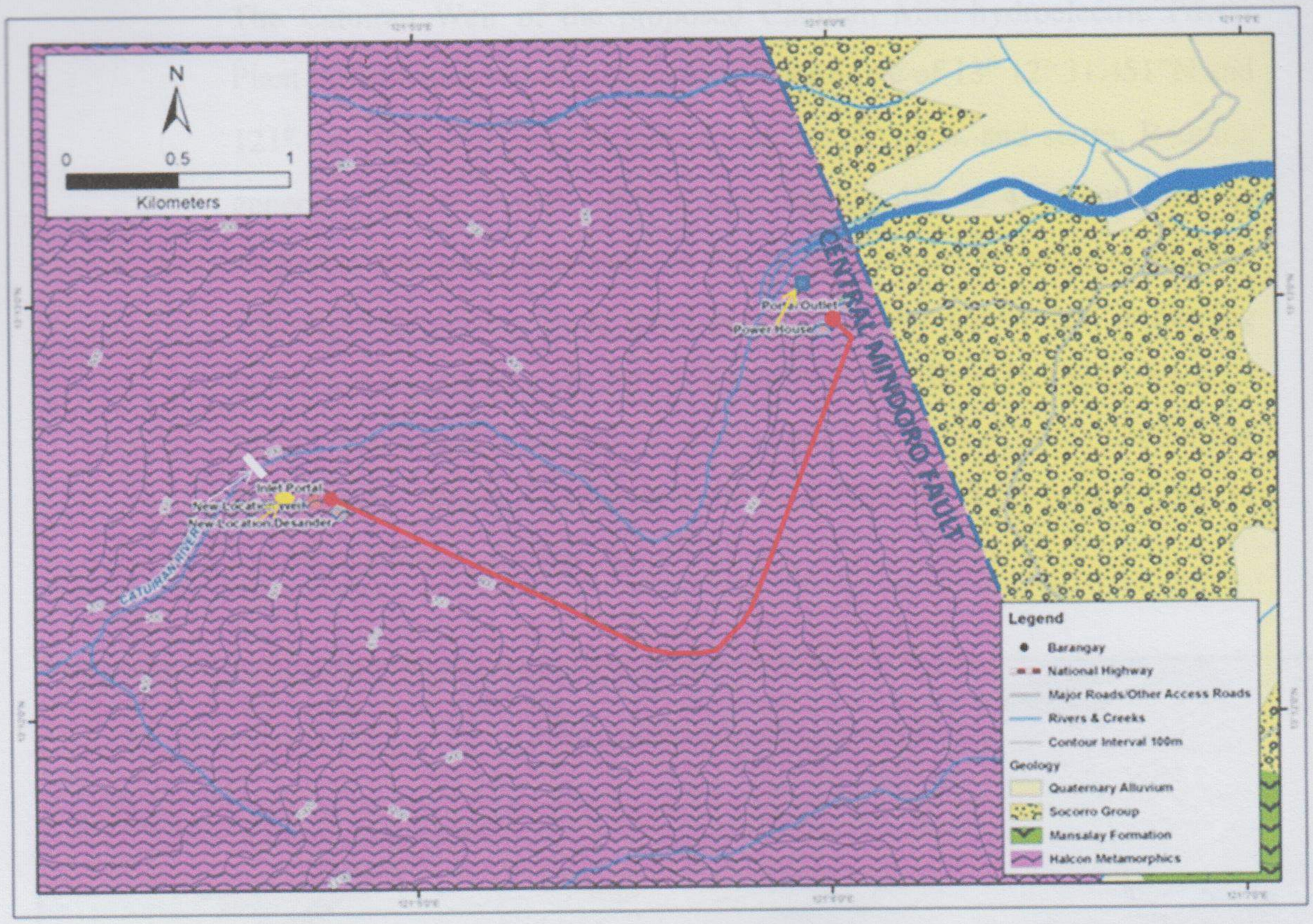


Figure 9. *Local Geology of the Proposed Catuiran Mini-hydroelectric Power Plant*

3.0 LOCAL GEOLOGY

3.1 Bedrock Lithology

Barangay Malvar of the Municipality of Naujan, the site of the project is generally underlain by Halcon Formation mostly amphibolites (mica schist and greenschist), metagabbro, gneiss, phyllites, slates, and marble.

The Catuiran Weir of the proposed Catuiran Mini-hydroelectric Power Plant Project centered at geographical coordinate of 13° 12' 31.451"N and 121° 04' 45.404"E is underlain mainly by phyllites, and slates. Bedding generally trends N 60° - 80° E and dipping 40° to 45° southeast. As observed, the south abutment of the weir is hosted by massive phyllite with tight fracturing. Beds trend parallel to river course and is dipping towards the slope face (Photo 2). Geotechnical drilling, however reveals a highly fractured (moderately weak) phyllitic rocks with unconfined compressive strength ranging from 2.10 Mpa to 3.10 Mpa (Refer to Laboratory Result for BH 2).

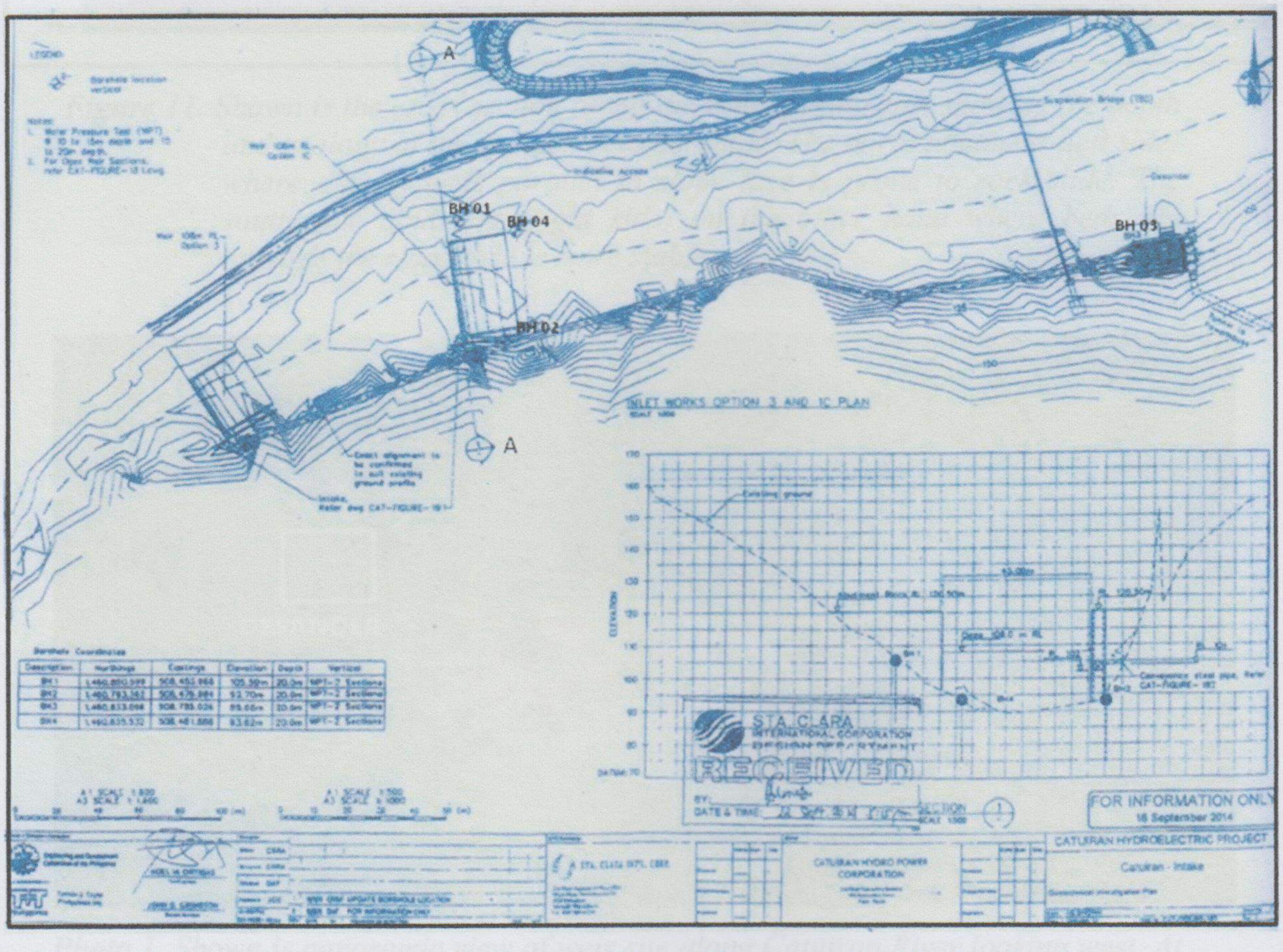


***Figure 10**. Geotechnical boreholes location Map of Catuiran Mini-hydroelectric Power Project .*

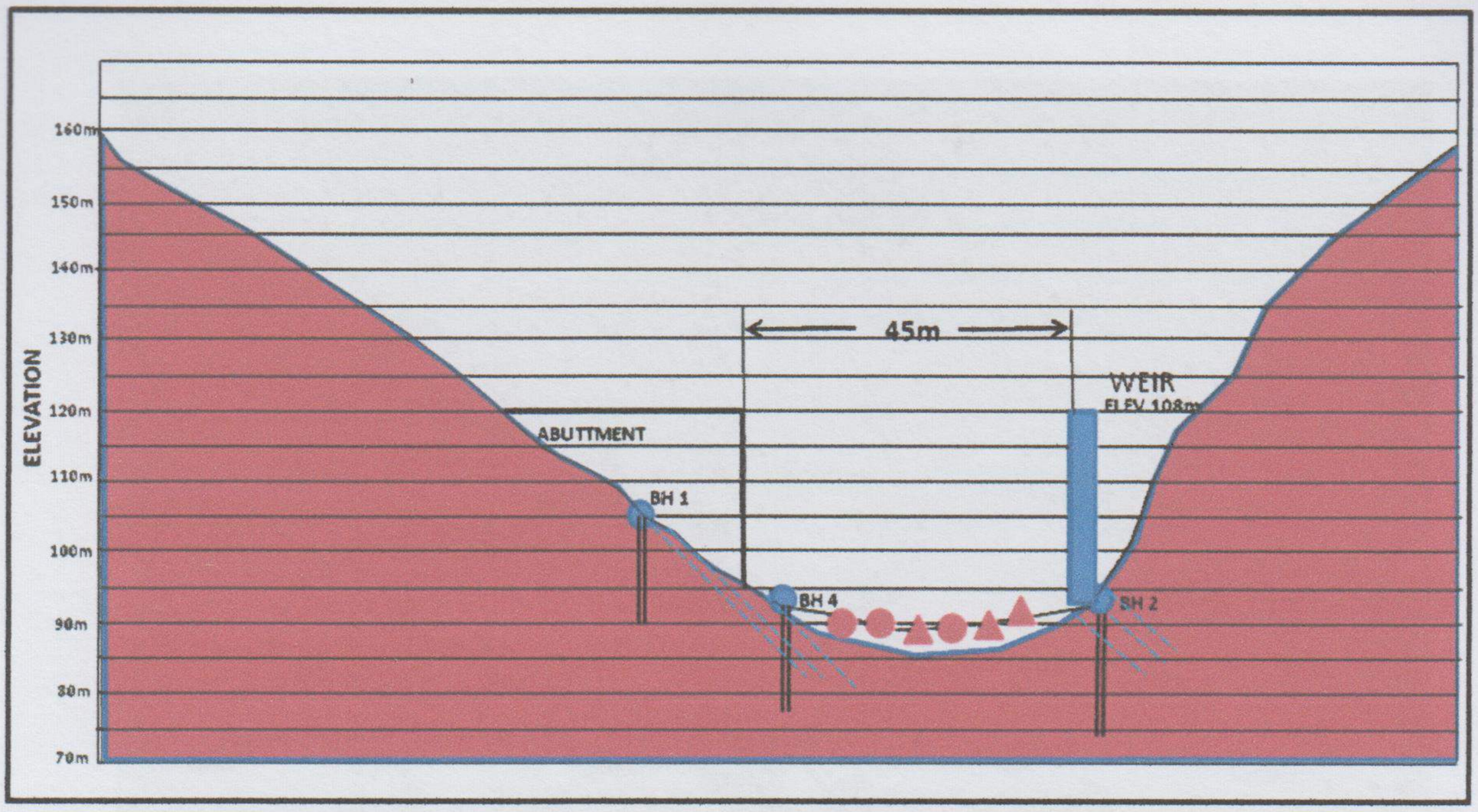


***Figure 11**. Shown is the cross section along the weir looking east showing the depth and geology of the geotechnical borehole. The north abutment (left side) where dips of beds parallel to slope face is prone to rock slide. The south side abutment (right side) on the other hand where beds dip towards the slope face is more stable.*



***Photo 1**. Shown is panoramic view of weir site along Catuiran River looking west. At right side is an outcrop of phyllite and slate dipping parallel to slope face and is susceptible to rock slide. The south abutment is moderately stable since beds dips towards slope face.*



Photo 2. *Shown is the massive phyllitic rock dipping 38 degrees to southeast (towards the slope face).*

On the other hand, the north abutment is hosted by weak phyllites and slates with dip of beds noted parallel to slope face (Photo 3). This is susceptible to rock slides and rock fall. Borehole 4 drilled at this portion shows a phyllite and slate rock with recorded unconfined compressive strength ranging from 1.90 Mpa to 3.10 Mpa (weak rock).



***Photo 3**. Shown is an outcrop of phyllitic rock and slate at the north abutment of the Catuiran Weir dipping 44 degrees to southeast (dips parallel to slope face). This portion is prone to rock slide and must be properly protected by riprap, rock bolt, and retaining wall.*

The 3.085 kilometers tunnel, which will serve as conveyance are generally underlain by massive and fresh phyllite with noted quartz occurring as lenses and bands. Portion however of highly fractured rock noted was supported by steel cribe and will be shotcreted (Photo 6 and 7). The tunnel entire lengths are now being shotcreted to restore stability and avoid seepage of water.



***Photo 4**. Shown is the tunnel inlet of Catuiran Hydro-electric Power Project. The upper portion of the tunnel is shotcreted to prevent rockfall, while the lower portion is protected by riprap.*

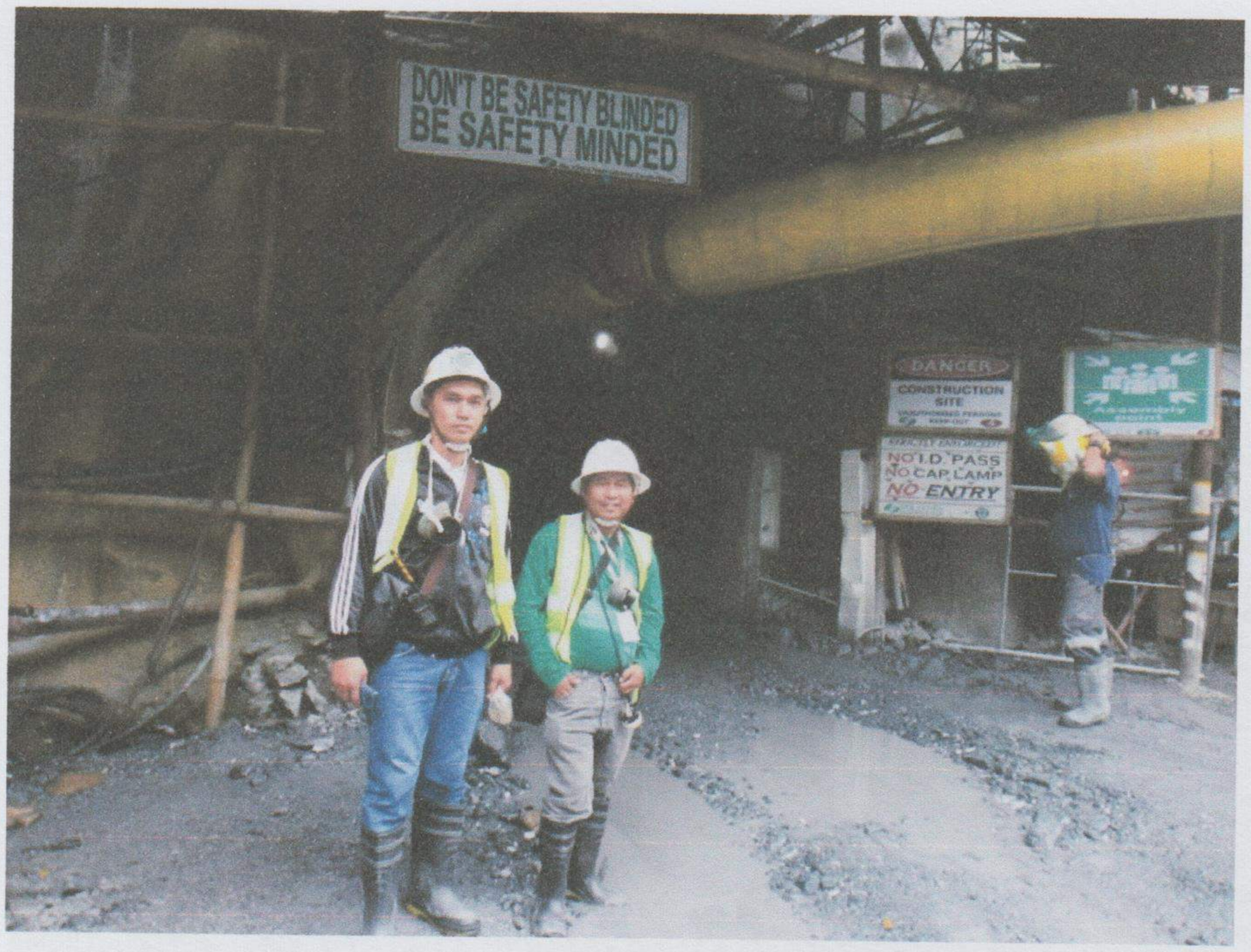


***Photo 5**. The inlet portal of the conveyance tunnel at the upper portion of the Catuiran River.*



Photo 6. *Steel Cribe Support on a fractured rock*



Photo 7. *Shown is the on-going shotcreting of the ±3.085 kilometers tunnel which will serve as conveyance.*

The Catuiran Power House and the tunnel outlet is predominantly covered by thick highly weathered Halcon Metamorphics mostly amphibolites (mica schist and greenschist), metagabbro, gneisses, phyllites, and slates. (*Photo 8*).



***Photo 8**. Shown is an outcrop of highly weathered metagabbro, gneisses, phyllites, mica schists, and slates belonging to Halcon Formation noted at the tunnel outlet and at the location of the power house. This highly weathered zone (behaving like soil) is prone to slide.*



***Photo 9**. Shown is a highly weathered metagabbro, gneisses, phyllites, mica schists, and slates that underlies the power house. This highly weathered zone (behaving like soil) is prone to slide.*

3.2 Structural Features

There were no major structures identified in the surveyed area. However, the proposed site lies near the Central Mindoro Fault, which is about 0.252 kilometer and 2.70 kilometers to the power house and weir respectively.

4.0 GEOLOGIC HAZARD AND RISK ASSESSMENT

4.1 Seismic/Earthquake Hazard

Seismic hazard is the perceptible trembling to violent shaking of ground caused by either tectonic movements or volcanic activity. Areas that are susceptible to this hazard are those underlain by unconsolidated soils and sediments deposited on the low-lying areas (***Figure 12***). The potential earthquake related hazards that are likely to occur in the project area are ground shaking, landslides, rock falls and slope failures.

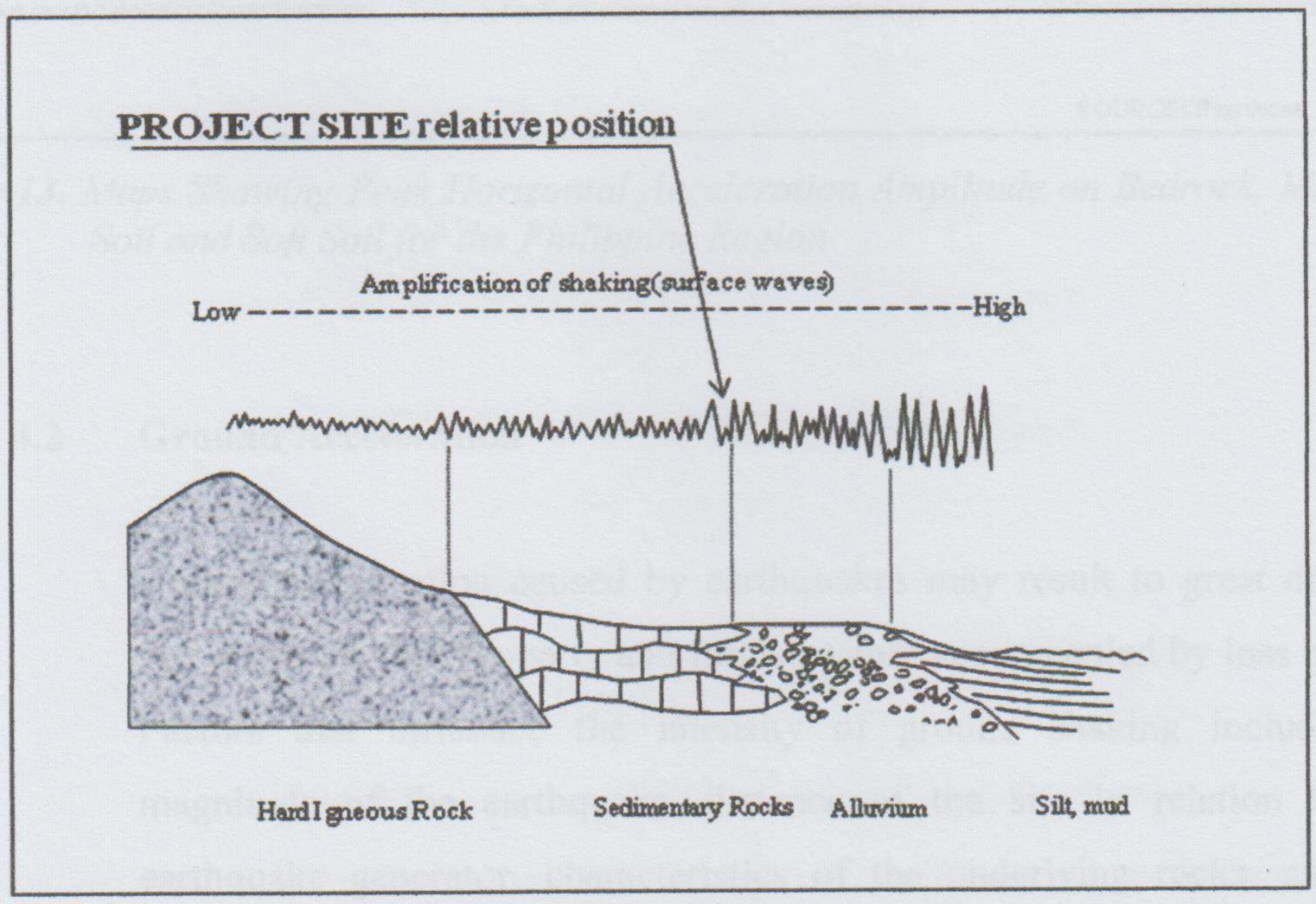


Figure 12. *Shaking Amplification*

The area investigated is prone to ground shaking hazards due to the presence of several earthquake generators in the region (Punongbayan, 1989). These possible seismogenic structures include the Manila Trench, Philippine Fault Zone, Lubang Verde Island Fault, Central Mindoro Fault, and the Aglubang Fault.

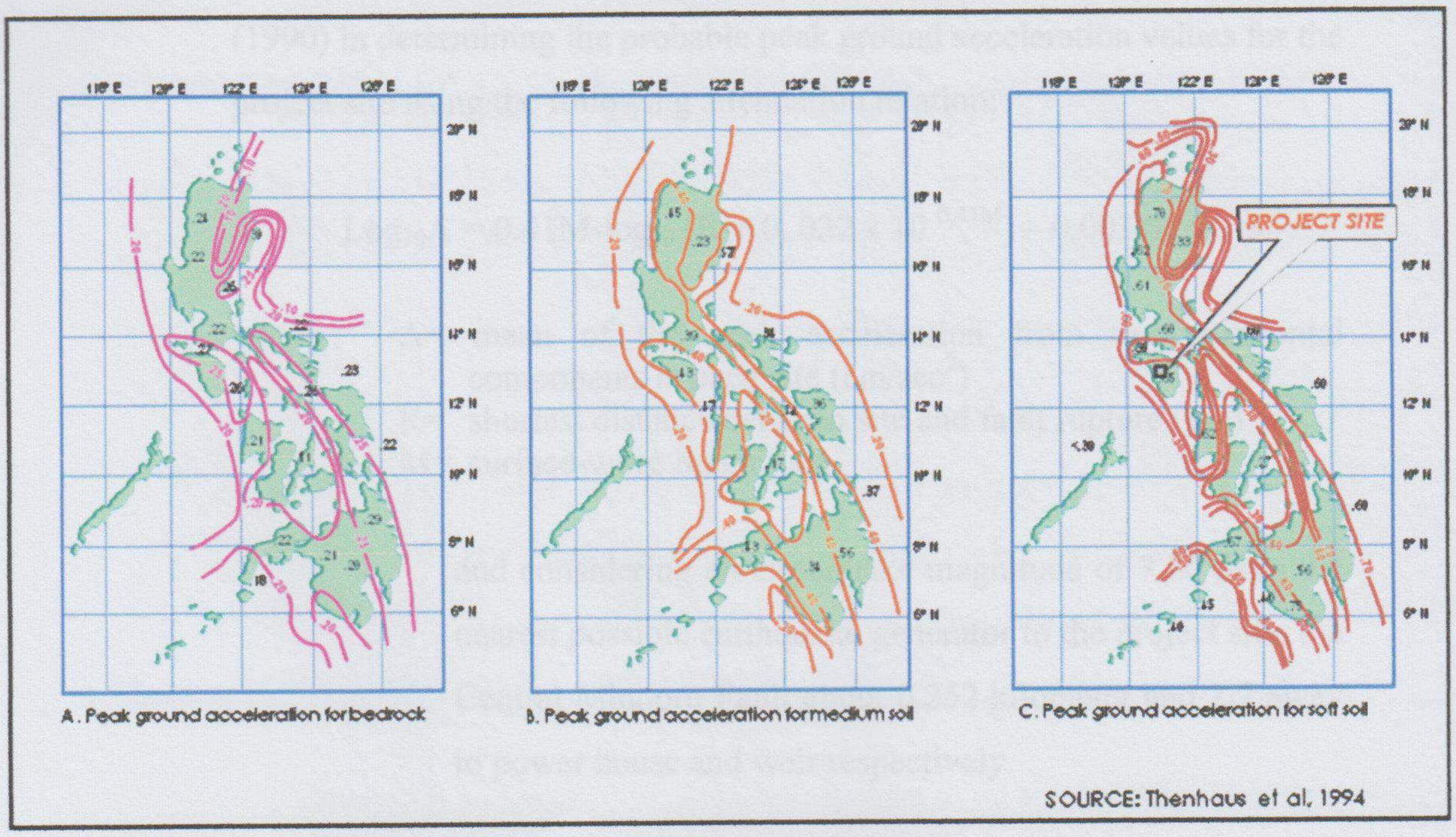


Figure 13. *Maps Showing Peak Horizontal Acceleration Amplitude on Bedrock, Medium Soil and Soft Soil for the Philippine Region*

4.2 Ground Acceleration

Ground acceleration caused by earthquakes may result to great damage and destruction to property and infrastructure accompanied by loss of life. Factors that influence the intensity of ground shaking include the magnitude of the earthquake, distance of the site in relation to the earthquake generator, characteristics of the underlying rocks, and the soundness of the structures. The proposed project nearness to the Central Mindoro Fault, Aglubang Fault, Lubang Verde Island Fault, and Manila

Trench makes the area susceptible to shaking. Ground motion estimates by Phivolcs and USGS at a 10% probability of exceedance in 50 years reveals 0.25g, 0.43g, and 0.65g for rock, medium soil and soft soil respectively (*Figure 13*).

Applying directly the deterministic method of Fukushima and Tanaka (1990) in determining the probable peak ground acceleration values for the project site using the following attenuation relation:

$$Log_{10}A = 0.41M - log_{10} (R + 0.032 \times 10^{0.41M}) - 0.0034R + 1.30$$

where : A= mean of the peak acceleration from two horizontal components at each site (cm/sec^2)
R= shortest distance between site and fault rupture (km)
M= surface-wave magnitude

and considering an earthquake magnitude of 7.20 from the nearest possible earthquake generator to the project site, the Central Mindoro Fault about 0.252 kilometer and 2.7 away to power house and weir respectively.

Considering an earthquake magnitude of *7.2* and distance of the proposed weir site of 2.70km from the Central Mindoro Fault, the following peak ground acceleration (PGA) values of ***0.341g***, ***0.495g*** *and* ***0.874g*** for ***bedrock***, ***medium soil*** and ***soft soil*** condition, respectively, were computed. The area studied which is underlain by fractured with weak unconfined compressive strength, falls under medium soil to soft soil condition.

The proposed plant site, being located about 0.252km from the Central Mindoro Fault, has a computed peak ground acceleration of ***0.377g***, ***0.547g*** *and* ***0.874g*** for ***bedrock***,

medium soil and ***soft soil*** condition, respectively. The site being underlain by highly weathered and deformed metamorphic rock behaving like soil falls under soft soil condition.

4.2 Ground Rupture

This hazard is seemingly absent in the project area since the nearest active fault, the Central Mindoro Fault is about 252 meters and 2.20 kilometers away to the Catuiran Power Plant and Catuiran Weir, respectively.

4.3 Flood Hazard

Floods usually occur during or after heavy rainfall wherein the river channels are saturated with water resulting to river swelling and overflowing of floodplains. The low-lying areas with poor drainage system are susceptible to flood hazard.

The project site, considering its morphological characteristics having steep channel embankments, narrow moderate to steep channel gradient makes the site less susceptible to flooding but is considered prone to flash flood The Catuiran Mini-hydroelectric Power Project falls outside the delineated flood prone areas by Mines and Geosciences Bureau (Figure 14).

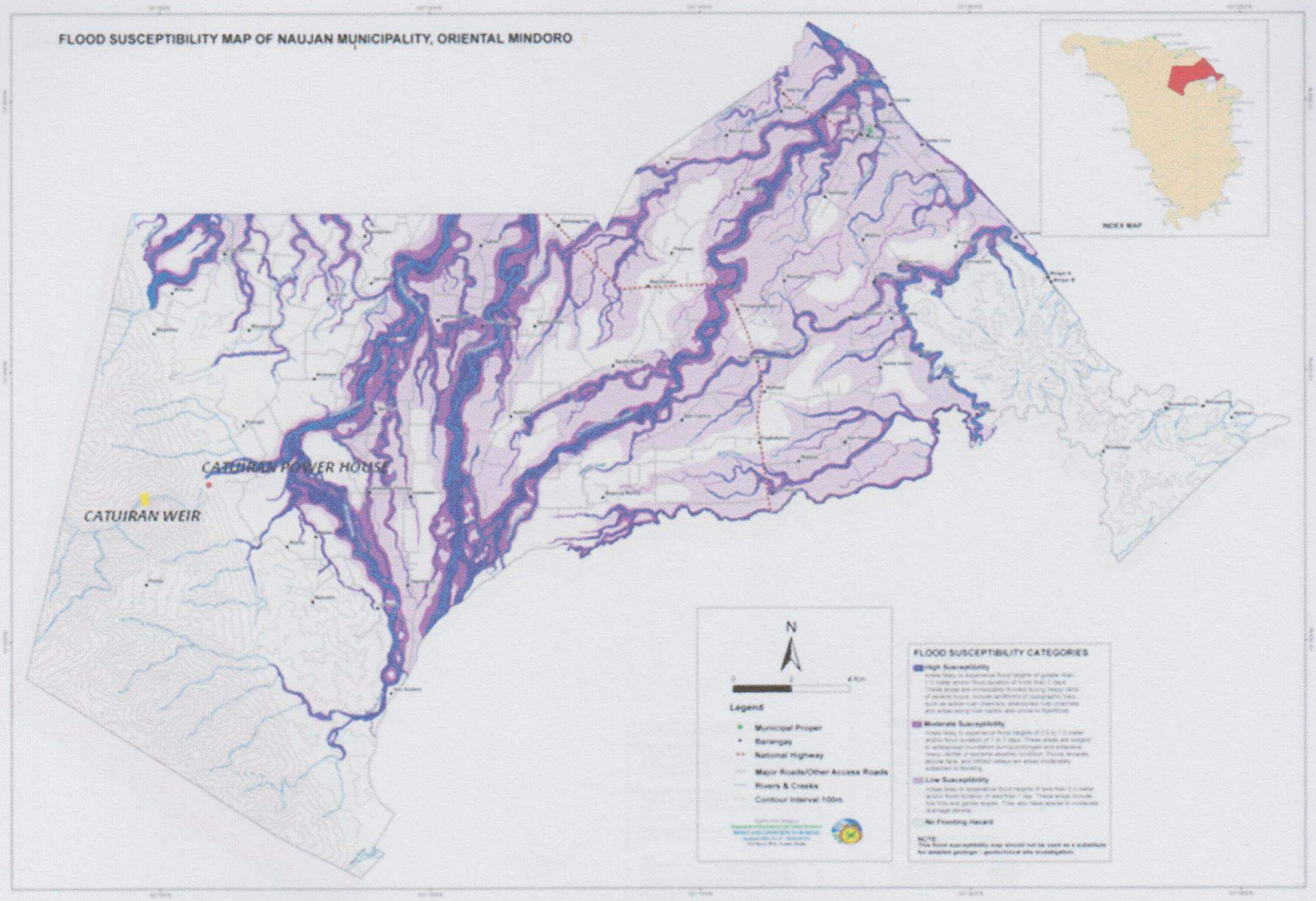


***Figure 14**. Flood Susceptibility Map of Naujan Municipality, Oriental Mindoro*

4.3 Mass Wasting/Erosion

Mass movement involves the bulk transfer of masses under the influence of gravity. Common down slope hazards includes landslide, slump and increased erosion, which commonly occur along steep slopes, encarpments, steep terrain underlain by highly weathered, fractured and loose materials. This is usually triggered by prolonged and heavy precipitation, ground shaking and possibly slope excavation. The Catuiran Mini-hydroelectric Power project falls on high risk prone area for mass movement and landslide as delineated by the Mines and Geosciences Bureau (*Figure 15*).

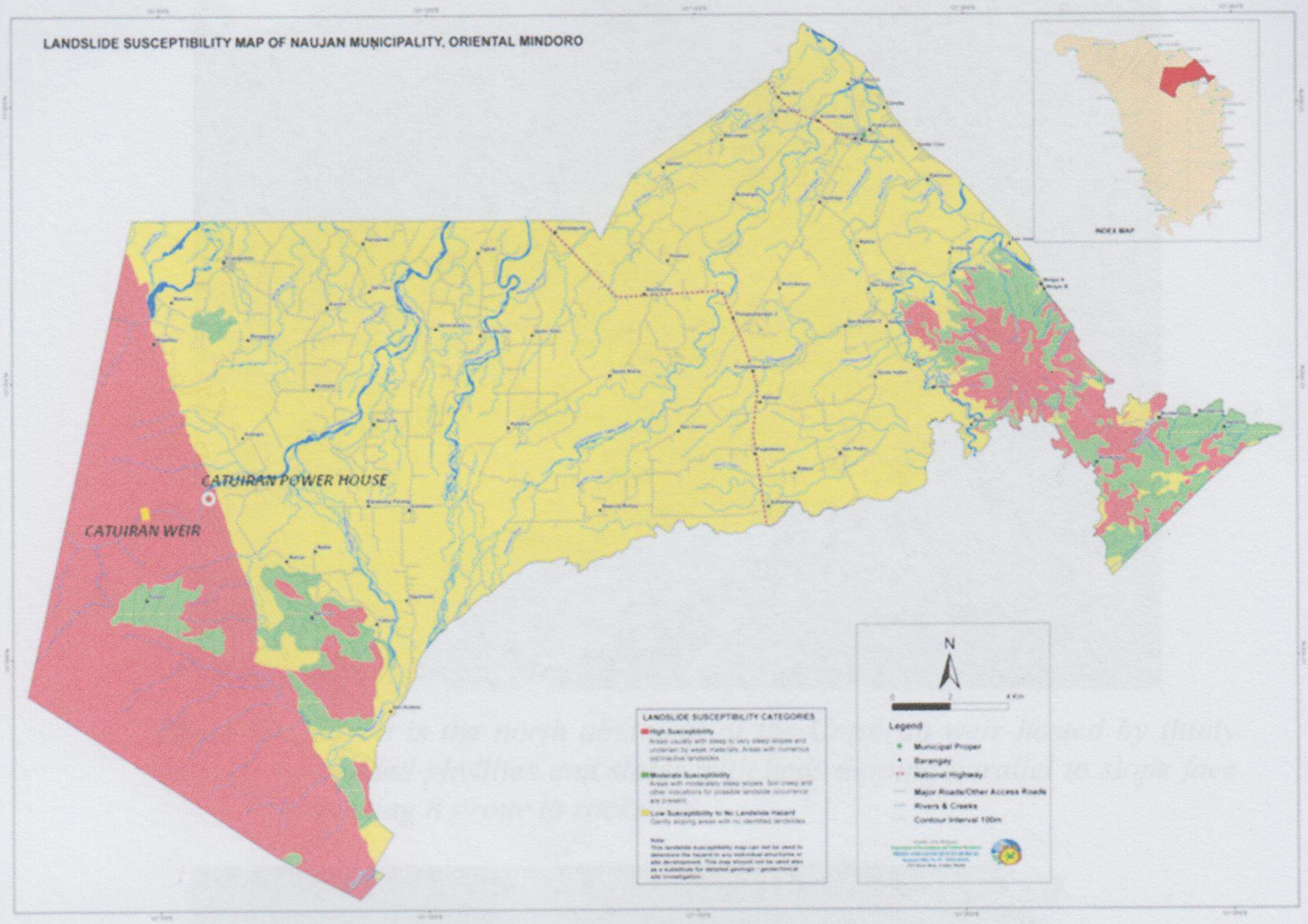


***Figure 15**. Landslide Susceptibility Map of Naujan Municipality, Oriental Mindoro*

As observed, the north side abutment of the Catuiran weir is hosted by thinly bedded phyllites and slates with beds dipping parallel with slope face making it susceptible to rock slide (Figure 3, 10 and Photo 10).

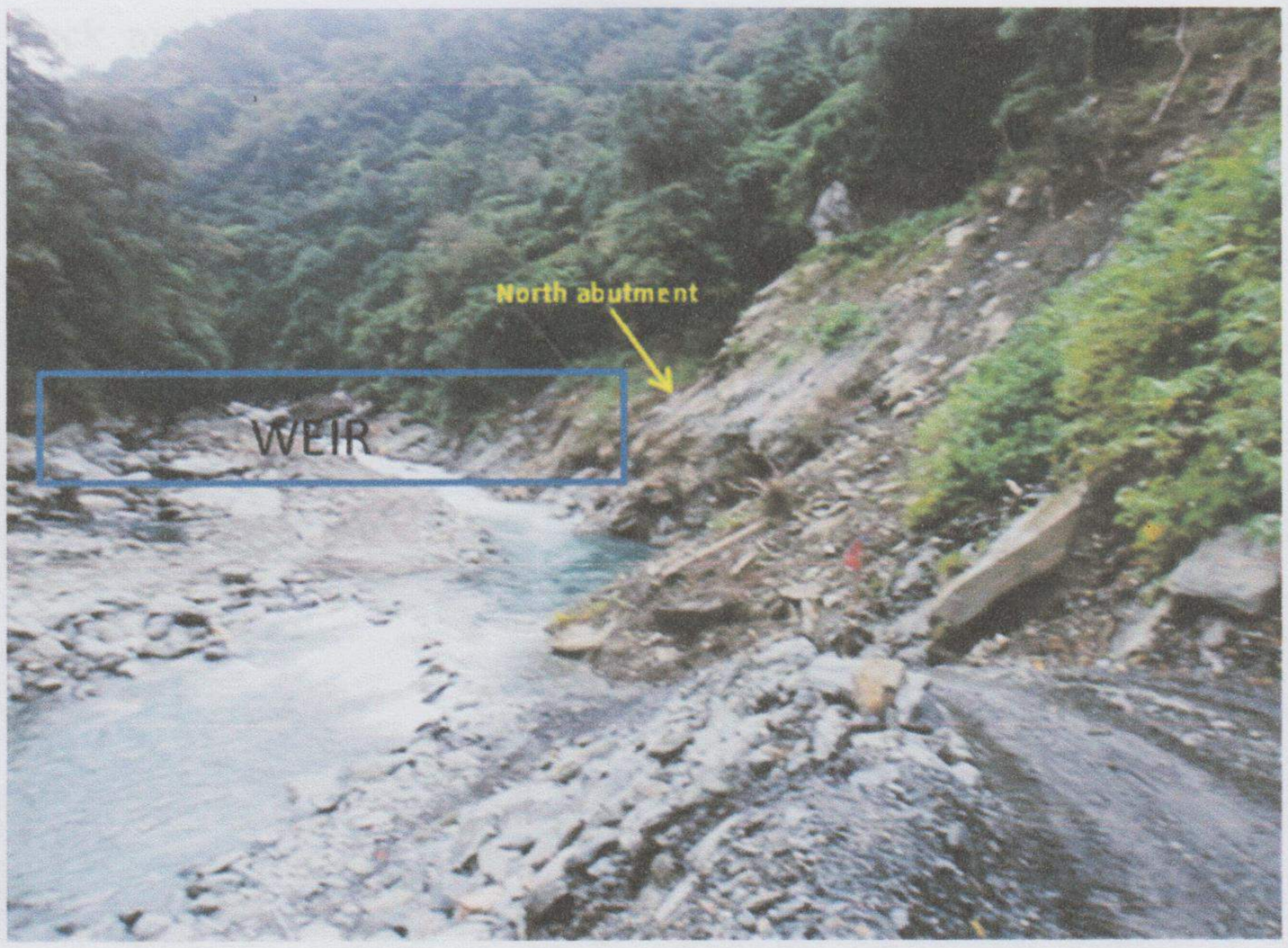


Photo 10. *Shown is the north abutment of the Catuiran weir hosted by thinly bedded phyllites and slates with beds dipping parallel to slope face making it prone to rockslide*



Photo 11. *Shown is a highly fractured rock with beds dipping parallel to slope face exposed at the road leading to tunnel that is prone to rock slide. Blocks of phyllite, noted at the floor of the road is a product of rock fall/slide.*

Rock mass of blocky with several discontinuities considered prone to rockslide and block fall. As observed at the previous location of desander near the tunnel inlet, the exposed highly fractured rock is prone to rock slide and block fall (Photo 12).

***Photo 12**. Shown is a highly fractured rock west of the inlet portal (previous location of desander) prone to block fall/rock fall*

The tunnel outlet and power house location is generally underlain by a highly weathered phyllites, mica schists, greenschists, and slates behaving like soil and is prone to landslide and debris slide. Though this was been stabilized by shotcreting, and supported by wire mesh, continouos and long exposure to rain and sunlight would weaken the integrity of material and may result to landslide and or debris slide. Photo 13, 14 and 15 shows a landslide prone area.



Photo 13. *Shown is the location of the penstock underlain by a highly weathered, phyllites, greenschists and slates with noted bedding plane*



Photo 14. *Shown is a highly weathered phyllites, greenschists, and slates behaving like soil prone to landslide (100 meters northeast of tunnel outlet)*



***Photo 15**. Shown is a highly weathered rock belonging to Halcon Formation behaving like soil and is prone to debris slide and or landslide. This however, was being stabilized and was covered by wire mesh and shotcrete.*

5.0 CONLUSIONS AND RECOMMENDATION

Based on the results of engineering, geological and geohazards assessment of the Catuiran Mini-hydroelectric Power project, the following are the summaries and conclusions:

5.1 The proposed Catuiran Mini-hydroelectric Power project to be located along Catuiran River at Barangay Malvar, Naujan, Oriental Mindoro aims to produce a sustainable renewable energy of at least 8 Megawatt to augment power supply of the province of Oriental Mindoro and its vicinity.

5.2 The projects preliminary development scheme consist of diverting the water from the main Catuiran River through a runoff river dam or weir and allow water to pass through an intake diversion structure then through a low pressure tunnel connected to high pressure steel penstock to the hydraulic turbine. A power plant building will be constructed to house the electro-mechanical equipments, control and measuring devices.

5.3 The project site is generally characterized by rugged terrain with and elevation of 32 meters at the power house to 108 meters above sea level (masl) at the weir and with highest elevation reaching about 1,400 masl.

5.4 The potential earthquake generators found in the region that could affect the project include the Central Mindoro Fault, the Aglubang Fault, Lubang Verde Island Fault, the Manila Trench and Philippine Fault.

5.5 The Catuiran Weir located at the intersection of geographical coordinates 13° 12' 31.451"N and 121° 04' 45.404"E some three and a half (3.50) kilometers upstream from the Catuiran Power House, is underlain by weak, fractured phyllites and slates.

5.6 The north and south side abutment of the proposed weir consists mainly of fresh, and fractured, phyllites and slates has rock strength ranging from 1.90 to 3.1 Mpa (Refer to geotechnical report). Beds generally trends N 62° - 80° E, dipping 38° to 44° SE. The north abutment where beds dip parallel with the slope face is prone to rockslide. The right side abutment on the other hand, is relatively stable.

5.7 The Catuiran Power House located at the intersection of geographical coordinates 13° 12' 55.926"N and 121° 05' 59.211"E is underlain by weathered, highly deformed, and fractured metamorphic behaving like soil.

5.8 The project lies near the active earthquake generator particularly the Central Mindoro Fault. Earthquakes resulting from fault movements are unavoidable and unpredictable phenomena the project site could experience. The site's proposed power plant and weir is about 0.252 km and 2.70 km, respectively, from the Central Mindoro (refer to attached Phivolcs Certification).

5.9 The computed ground acceleration of the proposed weir site using the Tanaka and Fukushima formula reveals peak ground acceleration (PGA) value of 0.341g, ***0.495g*** *and* ***0.791g*** for bedrock, *medium soil and* ***soft soil*** condition, respectively.

5.10 The computed ground acceleration of the proposed plant site, on the other hand, reveals peak ground acceleration (PGA) values of **0.377g, 0.547g** *and* ***0.874g*** for bedrock, medium soil and ***soft soil*** condition respectively.

5.11 Ground rupture hazard is deemed to be not much of a concern in the project area as the nearest active fault, the Central Mindoro Fault is about 0.252 kilometer and 2.70 kilometers away, respectively, from the proposed power plant and weir sites.

5.12 The project's proposed Mini-hydro Electric Power Plant site is considered not prone to flooding. It however, falls outside the delineated flood susceptibility map of the Mines and Geosciences Bureau, CAR.

5.13 The projects weir, tunnel outlet, and power plant are generally susceptible to landslide and rock slide considering its topography, thickness of soil cover and characteristics of the underlying rock formation and the presence of geological structures. It falls under the delineated Moderate to High Landslide Susceptibility Map of Mines and Geosciences Bureau – Region 4B.

5.14 Slope stabilization measures however, like shotcreting, riprapping, and rock bolting were being undertaken by the company to ensure stability of the projects facilities.

5.15 The tunnel which, will serve as conveyance was being shotcreted. Highly fractured zone were supported by steel cribe.

Based on the results of the geohazard assessment, the proposed Catuiran Mini – Hydro Power project is suitable for the intended development. However, the following mitigating measures are recommended:

5.16 The weir site underlain by relatively fresh rock falls under weak to moderately weak rock category. Rock strength recorded in the geotechnical study generally range from 1.90 Mpa to 3.10 Mpa. Computed ground acceleration is 0.495g to 0.791g (medium soil to soft soil). Design of the structures should consider this computed ground acceleration to ensure stability of the weir.

5.17 Weir and weir abutments must be properly anchored at fresh bedrock. The north abutment must be rock bolted as protection against rock slide. In addition, embankments must be riprap and or supported by retaining wall to avoid scouring that may damage the structure. Flooring must be concreted to avoid piping that may weaken the weir structure.

5.18 The power house, generally underlain by highly weathered, fractured and deformed rock is susceptible to settlement. Computed ground acceleration is 0.874g (soft soil). Computed ground acceleration and settlement must be considered in the structural design of the power house.

5.19 The upper portion of the power house consist mainly of highly weathered metamorphic rocks behaving like soil were being shotcreted and riprapped as mitigating measure against slope failure. Regular monitoring for signs

of weakness like cracks, fractures, and faults must be regularly undertaken by safety engineers for immediate and proper remedial measures.

5.20 During development of the project, unwanted rock and soil must be properly handled to avoid siltation.

5.21 Above findings and recommendations in this report in addition to the geotechnical findings must be strictly observed and implemented to ensure long term safety and stability of the projects related infrastructures.

6.0 WARRANTY AND CLOSURE

This engineering, geological, and geohazard assessment report for the Catuiram Mini-hydroelectric Power Project was prepared using geological procedures in conducting the engineering–structural geological assessment and geo-hazards investigation. Its scope is limited to the project and location described here-in and represents my understanding of the surface and sub-surface conditions of the site at the time of the assessment. The contents of this report are valid as of the date of the preparation, however, should there be appreciable changes in the site as a result of man-made or natural activities, the undersign should be immediately notified so that supplemental recommendations can be provided. Consequently this report should not be relied upon after an elapsed period of three years without the review of the authors for verification and validity. This warranty is in lieu of all other warranties, either expressed or implied.

Prepared by

Hernani I. Bayani
Senior Geologist
PRC # 0871
PTR # 2236169
January 8, 2015
Paombong, Bulacan

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APPENDIX - A

Republic of the Philippines
Department of Environment and Natural Resources
MINES & GEOSCIENCES BUREAU
Regional Office No. IV-B (MIMAROPA)
7/F DENR Building, 1515 Roxas Blvd., Ermita, Manila
Telefax: (632) 310-1369; e-mail: mines_4b@yahoo.com

June1, 2015

MEMORANDUM

FOR : **THE REGIONAL DIRECTOR**
Mines & Geo-Sciences Bureau,
Regional Office No. IV - MIMAROPA

THRU : **THE OFFICER-IN-CHARGE**
Geosciences Division

FROM : **ARNOLD A. VILLANUEVA**
Sr. Science Research Specialist

SUBJECT : ***Geohazard Identification Report (GIR) on the Proposed Site of the 8MW Catuiran Hydroelectric Power Plant Project at Barangay Malvar, Naujan, Oriental Mindoro.***

I. INTRODUCTION

In response to the paid request dated May 13, 2015 of Sta. Clara International Corporation represented by Atty. Levie U. Copahan, a geohazard identification survey (GIS) was conducted by the undersigned last May 18, 2015 to assess the site of the 8MW Catuiran Hydroelectric Power Plant Project located in Barangay Malvar, Naujan, Oriental Mindoro.

This undertaking is in compliance to the implementing guidelines for the Geohazard Assessment of housing projects and other infrastructures under MGB Memorandum Circular No. 2002-02-43 dated January 18, 2002 as well as DENR's Administrative Order 2000-28.

The main objective of the field survey is to identify potential geologic hazards present in the area based on different geological and geo-environmental parameters including the condition of the existing development at the site.

During the course of geohazard survey, the undersigned was accompanied by Engrs. Renin Belo and Philip Eduard S. Causing, Vice President and Project Manager of Sta. Clara International Corporation, respectively.

II. PROJECT DESCRIPTIONS

Based on the project description submitted to this Office, the major structures to be developed under the hydroelectric power plant project comprise of the following (Figure 1):

a. Main tunnel, 3.085 kilometers in total length
b. Weir
c. Supplemental Tunnel
d. Desander
e. Penstock
f. Powerhouse
f. Tailrace
g. Switchyard.

The flow of the project runs in the following order:

- Water will be impounded at the Weir and will go through the Intake structures.
- From the Intake Structure, water will go through the Supplemental Tunnel and enters the Desander where desilting process will take place.
- Water will enter the Main Tunnel via the Inlet and will then travel the 3.085 km tunnel and exits at the Outlet.
- From the Outlet, the water will go to the Turbine at the Powerhouse to generate power.
- Water will then be discharged to the waterways/river through the Tailrace.

At the time of survey, about 1 km long tunnel from the outlet portal and 210 meters from the inlet portal of the proposed main tunnel have already been driven. During the course of tunnel excavation, rock mass rating (RMR) is being recorded in sequence using the standard rock mass rating format as basis for tunnel support system adoption.

III. PROJECT LOCATION AND ACCESSIBILITY

The project site is situated in the mountainous area of Barangay Malvar in Naujan municipality, Oriental Mindoro. The outlet of the main tunnel is near geographic coordinates 120^0 05' 57.4" East longitude and 13^0 13' 02.0" North latitude while the inlet tunnel is at 121^0 04' 49.7" East longitude and 13^0 12' 37.8" North latitude. More specifically, the project site for 8MW Catuiran Hydroelectric Power Plant lies at the footslope of Mount Halcon-Baco mountain ranges in Barangay Malvar.

The municipality of Naujan is accessible from Calapan City by any four-wheel vehicles along the National Highway. Calapan City, on the other hand, can be reached from Manila by a two-hour bus trip going to Batangas City port and then by ferryboat to Calapan port for 45 minutes.

From the National Highway in Naujan, the outlet of the main tunnel (Photo 1) near the proposed Powerhouse can be reached using the provincial and barangay roads while the area going to the inlet portal (Photo 2) (where weir and desander facilities are to be located) is accessible via an old logging road.

IV. TOPOGRAPHY AND DRAINAGE

The topography of the project site is characterized by rugged terrain with steep slopes. Elevation of the area where the main tunnel passes through varies from 100 to 350 meters above sea level and this elevation ascends to about 1200 meters high toward the south. Abrupt changes of topographic landform was noted towards the east (See Figure 2). Located north of the project site is the V-shaped valley of Catuiran River (Photo 3), which is the main river system in the area.

V. LOCAL GEOLOGY

Based on the geologic map of Minodro Island prepared by the JAPAN International Cooperation Agency (JICA), the Metal Mining Agency of Japan (MMAJ) and the Mines and Geosciences Bureau (MGB) in 1983 (Figure 3), the project area and vicinity is underlain by Halcon Metamorphics, Socorro Group of rock formation and Alluvium.

Pre-Jurassic to Jurassic Halcon Metamorphics of Mica Schist with Greenschist (HMms) is the oldest rock formation in the project area and is composed of amphibolites, metagabbro, gneisses, greenschists, phyllites, slates and marble (Photo 4). These rocks are well exposed along the Catuiran River. Mock-out rock materials from the tunnel are mainly phyllites, gneisses and dark-colored metagabbro. Quartz lenses were likewise noted inside the tunnel near the inlet portal (Photo 5).

Socorro Group is Quaternary in age and is composed mainly of terrace gravel and sand deposits, tuffaceous silt and andesitic tuff. Drilling conducted during the subsurface investigation for the proposed Catuiran Hydro Electric Power Plant encountered sandstone and andesite rocks at BH-1. This group of rocks is distributed west of the project area.

Quaternary Alluvium is composed of detrital deposits formed on valleys by stream action and essentially made up of silt, sand, and gravel.

Major geologic structures in Mindoro Island are the Central Mindoro Fault and Aglubang River Fault (Figure 4).

VI. IDENTIFIED GEOLOGIC HAZARDS

A. Seismic/Earthquake Hazards

The tectonic setting of the area is characterized by major earthquake generators which make the project site susceptible to seismic/earthquake hazard in the form ground shaking/ground acceleration and earthquake-induced landslide. Regionally, the active Manila Trench, the Philippine Fault Zone, Aglubang River Fault, Central Mindoro Fault and Lubang Fault comprise the active tectonic structures surrounding the project site. These structures make the site prone to both weak and strong ground shaking when an earthquake is generated along these fault lines. The nearest active earthquake generator to the project site is the Central Mindoro Fault, which is roughly 200 meters east of the outlet portal of the main tunnel.

B. Mass Movement Hazard

Mass movement or mass wasting refers to the downslope movement of soil and/or rock under the action of gravity. This occurs in many forms.

The stability of rock mass is governed by the orientation and inclination of geological discontinuities like bedding planes, foliation planes, joints, shear zones, faults etc. that divide the rock body into a rock mass. The bedding and joint orientation in relation to the slope face is considered crucial in structurally controlled failure mechanism.

Based on the landslide susceptibility map generated by MGB, the proposed project site is within the area highly prone to landslide (Figure 5). Potential slope failures and landslide on natural slope or cut slope identified in the area are in the form of rock fall, wedge failure, toppling and debris slide.

Rock falls

Most of the rock masses at the project area are blocky and characterized by interlocked, partially disturbed rock mass with complex angular blocks formed by four or more discontinuities. These characteristics of rock mass are prone to rock fall.

Wedge failure

Wedge failure results when rock masses slide along two intersecting discontinuities both of which dip out of the cut slope at an oblique angle to cut face, forming a wedge shaped block. Crisscrosing joints are normally seen along the slope wall observed at the site and occurrence of this type of landslide is imminent along the steep cut slope wall, if not properly mitigated.

Toppling

Toppling is a displacement or forward movement of rock blocks or bodies along a pivotal point that is brought about by the triggering factors like the action of gravity, water and earthquake.

Debris Slide

A debris slide is a type of slide characterized by the chaotic movement of rocks, soil, and debris mixed with water. Slope that is prone to this type of failure during incessant rains usually comprises soil and rock debris materials overlying a bedrock. These deposits were observed on the opposite side of the inlet portal across Catuiran River (Photo 6).

VII. GEOTECHNICAL INVESTIGATION CONDUCTED AT THE PROJECT SITE

Based on the submitted reports provided by the proponent, a number of geotechnical investigations were already conducted at the site, to wit:

1. Geotechnical Report containing subsurface investigation at the Site of Catuiran Hydroelectric Power Plant prepared by Engr. Celestino C. Avis for and On Behalf of A.M. GEOCONSULT AND ASSOCIATES.

   The primary objective of the investigation was to obtain the engineering properties of foundation materials underlying the site, which shall be used as a basis in the analysis and design of foundation elements for the proposed structures. The field investigation was carried out during the period May 01 to August 18, 2013.

2. Geotechnical Investigation Report for the 8MW Catuiran Hydroelectric Power Plant prepared by Engr. Renante B. Dela Cruz.

   The investigation conducted is for the design of foundation for weirs. Its specific objective is to review/assess the existing subsurface data from the site and nearby areas and to provide recommendations on the following:

   - Geotechnical Parameters for foundation design; and
   - Depth to groundwater and anticipated dewatering requirements

3. Preliminary Geotechnical Report: Subsurface Investigation for the Proposed Catuiran Hydro Electric Power Plant prepared by Engr. Redentor S. Jarding of R.S. Jarding & Associates.

   The report is part of the comprehensive geotechnical database inclusive of both field and laboratory tests (with borehole location plan) to support the foundation analysis for the 8 MW Catuiran Mini Hydro Electric Power Plant Project. The geotechnical investigation aims to determine or provide the following for the project:

- The bearing capacity at every prescribed depth, the associated foundation type and settlement conditions of the critical areas;
- Evaluate the liquefaction potential of the site;
- Recommend ground improvement whenever necessary or provide an alternative foundation types;
- Provide "Excavation and Fill Guidelines"; and
- Water Pressures Test using Lugeon Procedures to determine the susceptibility of seepage through the bedrock.

VIII. SLOPE STABILIZATION

In connection with the susceptibility of the natural slope and cut slope to landslide, the observed slope stabilization being implemented on the site by the company consisted of the following:

- Shotcreting
- Rock Anchoring at design length and as per the soil condition
- Stone Masonry
- Ripraping
- Grass seeding with coconet

According to Civil Engr. Causing, the gradient of the slope and method of stabilization were determined by the Design Engineers in consideration of the soil properties. In addition, preparation for massive slope stabilization is on-going at the Powerhouse area (Photo 7) to ensure that construction of other facilities will progress on schedule.

IX. CONCLUSIONS AND RECOMMENDATIONS

In view of the foregoing observations and findings, presented below are the conclusions and recommendations for the project site:

1. The area is underlain Pre-Jurassic to Jurassic Halcon Metamorphics which is basically composed of amphibolites, metagabbro, gneisses, greenschists, phyllites, slates and marble.

2. The potential geologic hazards identified at the proposed are seismic hazard such as ground shaking and earthquake-induced landslide due to the presence of active faults in the region, the nearest of which is the Central Mindoro Fault, and also landslide due to highly fractured nature of rock in some natural slopes and cut slopes.

3. The company had already used the services of private company/individuals to conduct geotechnical studies/investigation for the project.

4. Slope stabilization measures are now being undertaken by the company to ensure the safety of the people and the stability of the power facilities at the site.

5. The on-going tunnel excavation must proceed with strict monitoring of the condition of the roof and wall materials of the tunnel as well as assessment of water seepages.

6. The company must strictly adopt the tunnel support systems like shotcrete and bolt rock system. Steel cribe with concrete lining is recommended along fault/shear zones. Also, the walls and roofs of the tunnel must be design to resist possible ground acceleration during an earthquake.

7. Slope stabilization measures should be strictly implemented especially near the inlet portal where potential debris slides may occur.

9. During the implementation stage of the project, the company must consider the findings and recommendations specified in all geotechnical investigation reports prepared by various geotechnical consultants for the proposed hydroelectric power plant.

ARNOLD A. VILLANUEVA

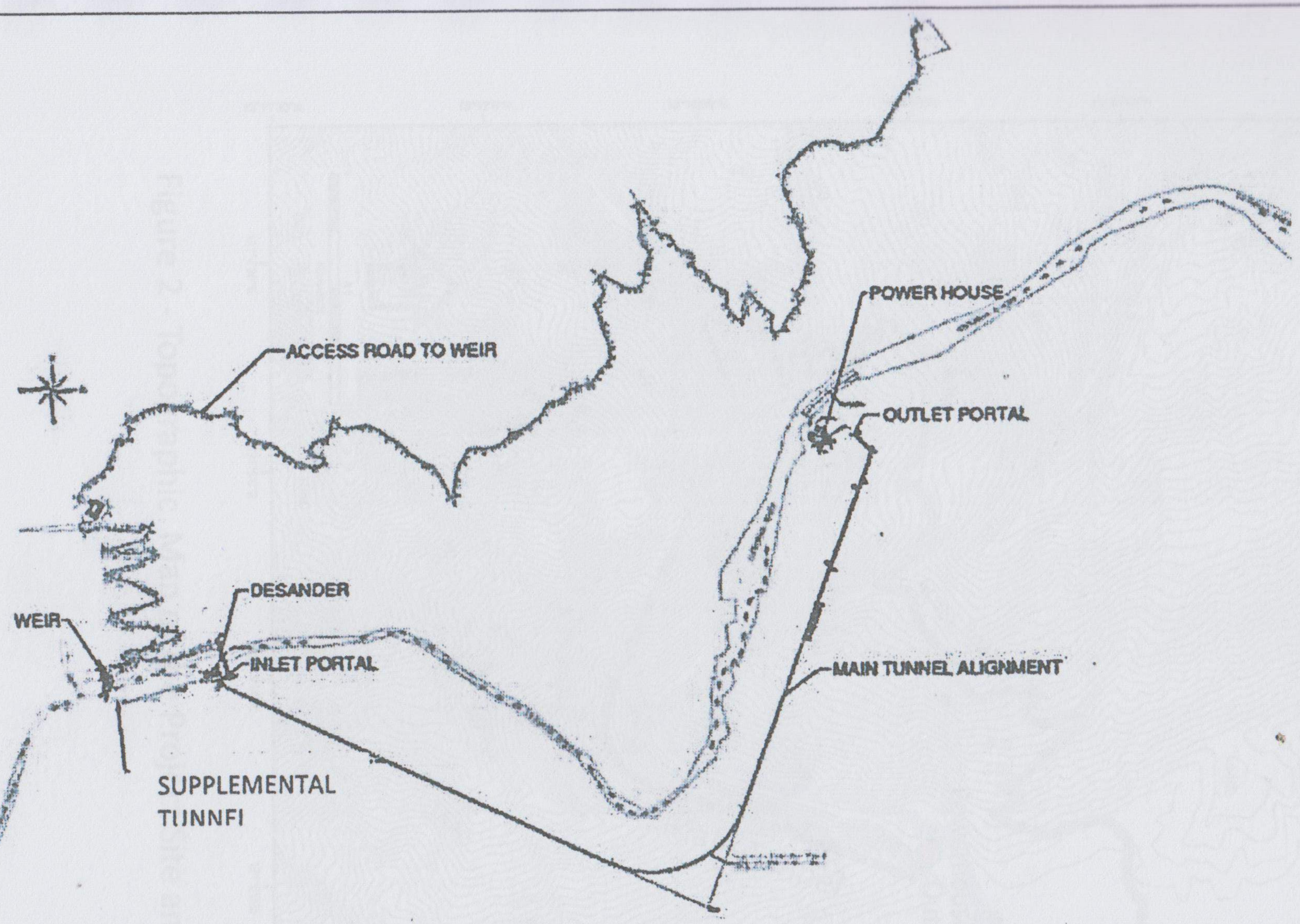


Figure 1 – Major Component Structure of the 8MW Catuiran Hydroelectirc Power Plant Project of Sta. Clara International Corporation in Brgy. Malvar, Naujan, Oriental Mindoro