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STATUS SUMMARY REPORT ON RESOLUTION OF ISSUES RAISED BY THE 1978 IAEA SAFETY MISSION TO THE PHILIPPINES

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ABSTRACT

The 1978 IAEA Safety Mission raised several issues concerning the siting of PNPP-1. These issues involve the safe shutdown earthquake, the threat of volcanism and foundation engineering. The Philippine Atomic Energy Commission (PAEC) has required the Applicant to address these issues. The Applicant has provided responses to several issues and is addressing the others. PAEC has reviewed these responses and established additional requirements. In reaching these positions PAEC has utilized qualified local consultants. Where local consultants lack the necessary experience and expertise, IAEA assistance is being sought.

It is concluded that while the work is progressing less rapidly than was recommended, PAEC is acting in a responsible manner to ensure the safety of the plant.

- N o t e -

This report is based on the author's own expertise and does not engage the IAEA in any way nor imply any commitment on the part of the IAEA.

1284 064

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BACKGROUND

The first Philippine Nuclear Power Plant (PNPP-1) is a 621 MWe Westinghouse 2-loop PWR. It uses Krsko, Yugoslavia plant as a reference design and is in the line of development including KoRi, Angra-1, Kewaunee Prairie Island, Point Beach, etc. The plant is being constructed on a "turnkey" basis by Westinghouse International Projects, Co. (WIPCO). An extensive site investigation was performed by the owner, National Power Corporation (NPC) and its consultant, EBASCO Services, Inc. A Preliminary Safety Analysis Report (PSAR) was prepared in accordance with the US Nuclear Regulatory Commission (NRC) "standard format" and submitted to the Philippine Atomic Energy Commission (PAEC) in July 1977. Seven volumes of the PSAR are devoted to the site study.

Review of the PSAR by an IAEA Safety Mission in July 1977 and by the PAEC Staff indicated that this appeared to be the most comprehensive site investigation and PSAR ever provided in a developing country. These reviews also resulted in a number of questions and requirements for further investigations. Pending resolution of these issues (and completion of the Environmental Report*) the issuance of the Construction Permit was delayed, with construction work continuing on the authority

*PNPP-1 is designed to comply with US requirements as per 10 CFR 50 Appendix I. Due to changes in Philippine law, the Environmental Report is no longer a factor in PAEC licensing action. The ER will be reviewed in accordance with PD 1151. Two "phases" (7 volumes) of the ER have been submitted; the remaining "phase", due in Sept. 1979, will include consideration of chemicals, biocides, and sanitary wastes along with the cost-benefit analysis.

1284 065

UNCLASSIFIED

of a limited work authorization (LWA) issued 3 October 1977. (The integrity pressure test of the containment vessel was completed 5 March 1979.)

In recognition of the importance of the site-related issues, PAEC requested the assistance of an IAEA Safety Mission that would concentrate on the geotechnical considerations. The mission was sought in the fall of 1977 but actually reached the Philippines in May 1978. The EBASCO and WIPCO experts were not present for discussions with the Mission in May so the Mission was re-convened in Vienna in July 1978. Based on the information in the PSAR and supplementary materials (Table 1) as well as the discussions with EBASCO, WIPCO and NPC experts, the mission concluded that certain additional efforts were needed. The Applicant (NPC) was directed by PAEC to perform the necessary investigations and respond to the issues raised in six areas. This work is in progress. Each of the Mission's concerns and the status of the associated investigations are discussed in the following paragraphs.

VIBRATORY GROUND MOTION AND SURFACE FAULTING.

Two of the mission's concerns were in this area. They will be discussed separately. The Mission's first conclusion was:

1. "The Safe Shutdown Earthquake should be re-evaluated considering a possibly higher magnitude random shallow earthquake postulated to occur beneath the site and a high magnitude earthquake postulated to occur on the subducting slabs beneath the site at its closest approach to the site. A third event postulated to occur in a zone of possible offshore faulting, is judged to be of lower risk level so long as these two earthquakes are reconsidered."

TABLE 1

REFERENCE MATERIALS PROVIDED TO THE IAEA SAFETY MISSION ON GEOLOGIC HAZARDS AND GEOTECHNICAL ASPECTS OF PNPP-1.

1. PNPP-1 Preliminary Safety Analysis Report (especially Chapters 2 & 3 on Site Characteristics and on Design of Structures, Components, Equipment and Systems; 8 volumes) July 1977.
2. PNPP-1 PSAR Amendment No. 3 and Amendment 3 Information Sheet. (Undated but prepared in 1978)
3. Site Confirmation Report, January 1976.
4. Engineering Report No. 1, February 1976.
5. Addendum to Engineering Report No. 1, no date.
6. Engineering Report No. 2, April 1976.
7. Addendum to Engineering Report No. 2, Vibratory Ground Motion, May 1976.
8. Engineering Report No. 3, (2 volumes), September 1976.
9. Engineering Report No. 4, February 1977.
10. Engineering Report No. 5, May 1978.
11. Responses to PAEC Letter Dated 20 December 1976, no date.
12. Responses to PAEC Letter Dated 21 May 1977, no date (unbound).
13. Geologic Hazards of PNPP Unit 1, July 1977.
14. PNPP-1 Volcanic-Seismic Surveillance Program, no date.
15. Seismic Risk Analysis for PNPP-1, no date.
16. Geology of Unit 1 Excavation, February 1978.
17. Seismic Analysis of PNPP-1, WCAP-9187, February 1978.
18. PNPP-1 Additional Safety Related Data, 30 June 1978.
19. Biographical Data of Personnel, no date, unbound.

POOR ORIGINAL

1.a. Random Earthquake

The Applicant followed US NRC criteria. Every earthquake in the province with magnitude exceeding 4.5 and with known location was associated with a tectonic feature. It was thus concluded that the random earthquake at the site, used to determine the SSE, should be of magnitude 4.5.

The Mission recognized the seismological work as state-of-the-art and consistant with US practices, but felt this was not sufficiently conservative. Specifically, the Mission proposed that the West Luzon Trough be considered inactive and that the two earthquakes of magnitude 6.25 associated with the Trough be considered floating earthquakes. The Mission also recommended that the issue be further investigated by (1) preparing a complete epicenter map, (2) providing a composite earthquake catalog, (3) considering relocation of the epicenters of earthquakes of interest or, alternately, (4) selecting and evaluating a new random earthquake with magnitude in the range of 6.0 and depth less than 30 km, (5) developing a strong technical basis for this choice and (6) thoroughly studying the duration and high frequency content of this earthquake as they affect the shape of the design response spectra.

The Applicant chose the first approach. The composite catalog (item 1) and the composite map (item 2) have been prepared.[9] Seven earthquakes were relocated,[9] including those cited by the Mission. The Applicant finds no basis for selecting a higher magnitude for the random earthquake.[9]

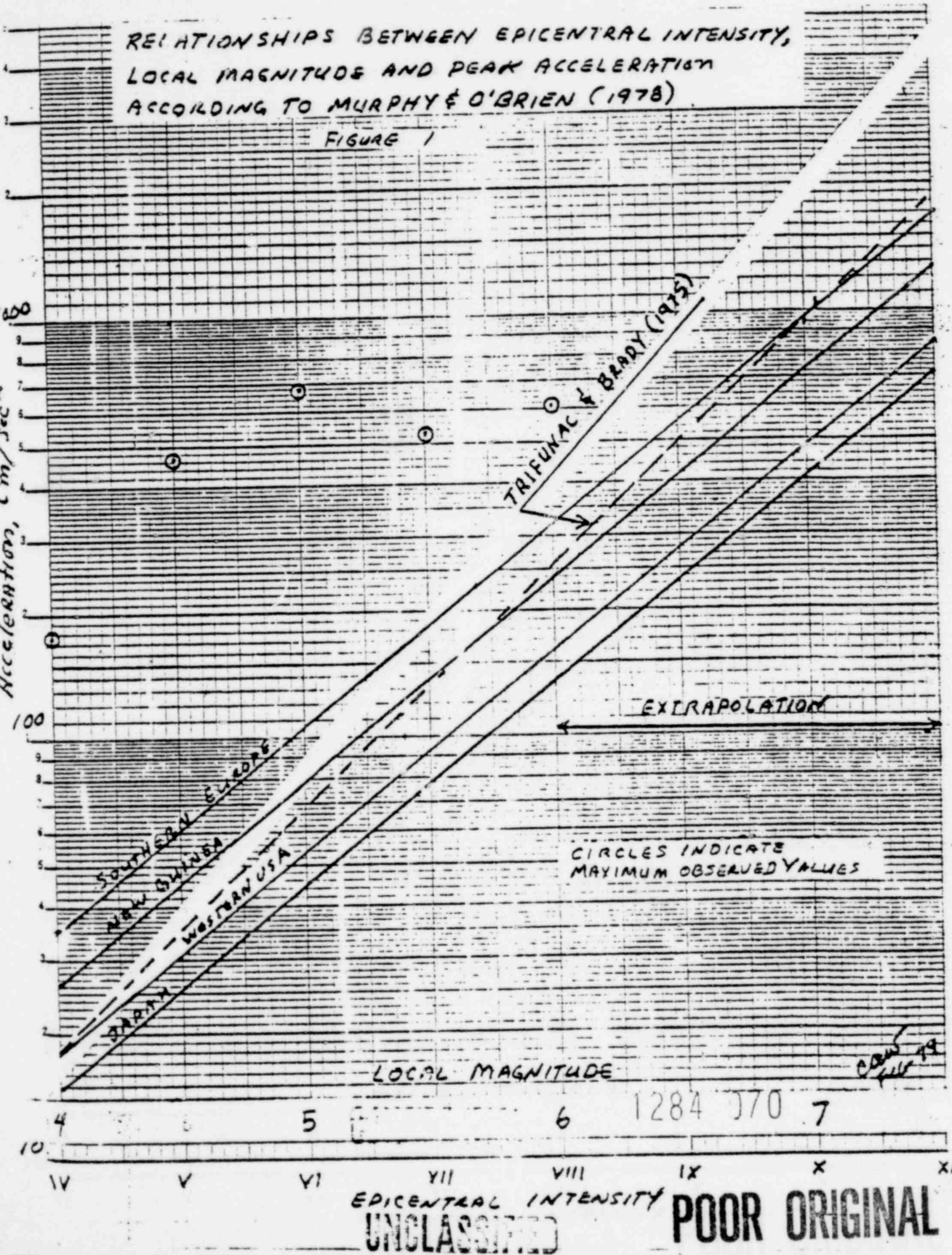
PAEC finds the Applicant's methods and conclusions consistant with NRC criteria.[1] Further, PAEC has reviewed the data and confirmed that at

1284 068

least all "strong" earthquakes (6 or greater magnitude) in the province are associated with tectonic structures other than the trough, see Appendix B. PAEC notes that a shallow earthquake of local magnitude 6 in the States corresponds to an epicentral intensity of VIII on the Modified Mercalli (MM) scale; see Murphy and O'Brien[2], for example. The associated peak acceleration would be about 0.16 g in the Western USA and slightly less in Japan; the more conservative Trifunac and Brady relationship yields 0.25 g (see Figure 1). As stated by Rood et al[3], US NRC requirements are met by a peak acceleration of 0.25 g where the random earthquake intensity is MM VIII. Thus, the present PNPP-1 design value of 0.4 g appears sufficiently conservative to accommodate any reasonable uncertainty in the random earthquake.

1.b. Earthquake on the Subducting Slab

The Applicant again followed US NRC criteria. The largest historical earthquake associated with each fault was determined. Using published length-magnitude relationships, and taking the rupture length as 40% of the fault length as recommended by Denton[4], a "maximum" magnitude was calculated for each tectonic structure. The use of a 50% rupture length as suggested by Mark[5] would not significantly change the results. In every case, the calculated magnitude exceeded or equaled the largest historic magnitude. Each of these "maximum" events was assumed to occur near the earth's surface at the fault's closest approach to the site. Seven published relationships between magnitude, distance and peak acceleration were used (Appendix A) and the largest calculated


RELATIONSHIPS BETWEEN EPICENTRAL INTENSITY, LOCAL MAGNITUDE AND PEAK ACCELERATION ACCORDING TO MURPHY & O'BRIEN (1978)
FIGURE 1
Acceleration, cm/sec²
1000
100
10
TRIFUNAC & BRADY (1975)
EXTRAPOLATION
SOUTHERN EUROPE
NEW GUINEA
WESTERN USA
JAPAN
CIRCLES INDICATE MAXIMUM OBSERVED VALUES
LOCAL MAGNITUDE
4
5
6
7
IV
V
VI
VII
VIII
IX
X
XI
EPICENTRAL INTENSITY

1284 070

acceleration was assumed in each case. After questions were raised concerning the methods used in preparation of the PSAR, both magnitudes and accelerations were re-calculated using more recently published relationships, and the PSAR values were confirmed. See Table 2.

Again, the Mission was concerned that the approaches used were not sufficiently conservative. Slightly higher magnitudes were suggested for each of the tectonic structures. In themselves, these magnitude changes would make no significant differences; the largest increase suggested is from 7.4 to 7.8 for the San Antonio Fracture Zone and this would increase the calculated peak acceleration to only 0.36 g. However, the major concern is with the location of these events; the Mission recommends placing the Manila Trench earthquake at the top of the subducting slab directly beneath the site. Specifically, they recommend a magnitude 8 event at a depth of 50 to 70 km beneath the site. Again, this new assumption would in itself, impose no new requirements because the applicable magnitude-distance-acceleration relationships yield peak accelerations less than 0.4 g. The Katayama[6] formulation, for example, gives 0.21 g for 70 km and 0.31 g for 50 km. The problem arises from the paucity of acceleration data near epicenters and the need to consider near field effects. The Mission recommends the use of "some type of scaling approach".

The Applicant has submitted material which contends that no technical justification can be found for considering the top of the slab to be less than 70 km below the site.[9] The largest earthquake

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TABLE 2

FNPP-1 EARTHQUAKE DATA SUMMARY

	Length km	Distance to site, km	Magnitude Historic	Magnitude Calculated	Calculated Acceleration*, g
Manila Trench	500	100	6.75	7.9	.35
West Luzon Trough	220	35	<6.0	7.55	.35
San Antonio FZ	160	32	5.75	7.4	.34
Manila Bay FZ	125	30	6.25	7.35	.34
Iba Fractures Zone	100	60	5.7	7.3	.23
Taal Fracture Zone	1000	125	5.5	8.2	.2
Philippine Fault	1500	160	7.8	8.4	.18
Verde Island Passage	350	95	7.8	7.8	.16
Philippine Trench	900	650	8.3	8.3	.02

*Maximum acceleration at the site calculated from historic earthquakes is .12 g.

1284 072

UNCLASSIFIED

in the trench slab was magnitude 6.75 so assuming anything higher than 7.0 directly beneath the site would be inappropriate[9]. Also calculations were reported scaling 16 response spectra from 11 earthquakes that may correspond to the PNPP-1 situation.[9] These calculations indicate that the 0.4 g design value might be exceeded with an earthquake of magnitude 8 at 50 km depth but not for a magnitude 7 event at 70 km. Some of the scaled spectra fell within the design criteria in both cases but scaling the spectrum obtained at Olympia Station from the earthquake at Puget Sound 29 April 1965 to magnitude 8.0 at 50 km suggests a design requirement of 2. g.

PAEC has concluded that (1) there is justification for assuming that the slab is at least 70 km beneath the site, and (2) it is sufficiently conservative to postulate a magnitude 7.0 event directly beneath the site. Thus, the present design basis is found to be acceptable.

1.c. Off-Shore (Shore-Parallel) Faulting.

PAEC reviewers noticed in the PSAR figures, indications of a possible fault running parallel to the shoreline off Napot Point. The Applicant has provided documentation contending that (1) the indications are slump features, not a tectonic fault and (2) even if there were a tectonic fault in the indicated location, it would necessarily be too short to produce a strong enough earthquake to increase the Safe Shutdown Earthquake (SSE). The Mission considered the data obtained with the single-channel system to be of too low quality to conclusively preclude the existence of the possible fault.

1284 073

PAEC has concluded that no further work in this area is required because the acceleration that a maximum earthquake on this possible fault would produce would be less than the present SSE value.

The Mission's <u>second conclusion</u> was:

2. "Additional investigation and analyses are required to resolve concern with evidence for a shore normal fault running parallel to and immediately south of the Napot Point Peninsula."

The topography immediately south of the site, as revealed by the Marine Geological Survey, SLAR, Landsat data, etc. caused concern on the part of both PAEC reviewers and the Mission about a possible tectonic fault. Such a fault within a km of the site could affect the SSE.

The Applicant has responded to PAEC requirements by digging appropriate trenches and mapping the area utilizing road cuts, etc. The trenches have been investigated by PAEC consultants. The final report, which concludes that no capable fault exists, was submitted recently. It is being reviewed by PAEC and its consultants. To ensure an adequate basis for judgements, PAEC has required an additional seismic survey of the area.

<u>VOLCANISM</u>

Three of the Mission's concerns were in this area and they are discussed separately in the paragraphs following the background information

1284 074

Background

Volcanism has received little attention in past nuclear siting studies, in part at least because of the relatively low volcanic activity in the continental USA. Recently, volcanic hazards have been considered for the Pebble Springs and the Skaget plants in the States. Of course, Japan has considerable volcanic activity. Philippine volcanic activity is high (Table 3); only Indonesia and Italy have experienced more volcanic disasters. Nash, for example, lists 17 disastrous volcanic eruptions in the Philippines since 1591[(7)]. These disasters are all associated with 3 volcanoes; (Taal, Mayon and Hibok-Hibok), but other Philippine volcanoes are considered active. Taal, little more than 60 miles away, is the active volcano closest to the site (Table 4). Mt. Pinatubo is considered inactive because it has not erupted in historic times. However, it did erupt some 635 years ago so it cannot be ignored; Pinatubo is little more than 35 miles from the site. All these volcanoes could affect the site by causing heavy ash fall.

The principal concerns about volcanic activity are associated with [illegible] inactive but nearby peaks; Natib and Mariveles. Mariveles is about 12 miles from the site and so presents the possibility of very heavy ash-fall. Natib's closest crater is less than 6 miles from the site and it is conceivable that a new fissure on the western slope could threaten the site with glowing avalanche, etc. Natib last erupted about 67,000 years ago and is considered by some to be extinct. For comparison, in the US, only those volcanoes which had erupted in the last 15,000 years were considered in the evaluation of Pebble Springs and of Skaget.

1284 075

TABLE 3

WORLD VOLCANO DISTRIBUTION

Eastern Pacific Islands*	45%
Western Americas	17%
Indonesia	14%
Atlantic Islands	13%
Continental** & Mediterranean	7%
Central Pacific Islands	3%
Indian Ocean Islands	1%

*Including the Philippines

**Principally the East African Rift Valley

1284 076

TABLE 4

VOLCANOES IN THE PNPP-1 AREA

NAME	KM FROM SITE	COMMENT
WESTERN ZONE (Theoleitic) Activity 0.6 to 7 Mybp		
Mt. Natib Calderia	9	youngest west flank deposit 600,000 years.
Mt. Santa Rita	22	
Mt. Namiranlac	32.5	
Mt. Balakibok	33	
Mt. Subic	33.6	
CENTRAL ZONE (Calc-Alkalic) Activity 600 ybp to 7 Mybp		
Mt. Natib, East Vent	14	Pyroclastic deposit (7.5 km^3) about 67,000 ybp
Mt. Mariveles	21	190,000 ybp lava, more recent activity older than last Natib eruption
Mt. Samat	21.5	
Mt. Limay	23.5	
Mariveles Harbor	28	
Orion	29	
Corregidor	39	
Mt. Pinatubo	57	Pyroclastic flow 600 ybp; 7.5 km^3 terphra
Cavite-Batangas Highlands	60	
Mt. Cariliao	75	
Mt. Batulao	84	
EASTERN ZONE (Shoshonitic) Active 0 to 2 Mybp		
Mt. Arayat	79	
Taal	101	active; most destructive recent eruptions (MDRE) 1754, 1911, 1965
Camotes Mt.	105	
Mt. Makiling	110	
Mt. Mapinggon	116	
Mt. Nagcarlang	124	
Mt. Malepunyo	126	
Mt. Atimbia	126	
Mt. San Cristobal	136	considered active, associated with Balungao
Mt. Bangcay	136	
Mt. Cuyapo	136	
Mt. Banahao	142	no activity since 1909, MDRE: 1730, 1743, 1909
Mt Balungao	143	
Mt. Amorong	144	
DISTANT ACTIVE VOLCANOES		
Mt. Mayon	407	active, MDRE 1968, 1928, 1914, 1897, etc.
Mt. Bulusan	471	Erupted 1978
Hibok-Hibok	507	Destructive eruptions 1950 & 1951; 84 & 248 killed.

1284 077

The Applicant performed investigations (later said by the Mission to be extensive, in-depth, and state-of-the-art) and obtained review and counsel from some of the world's most eminent volcanologists. The conclusions reached were that during the life of the plant, eruption in the Philippines are virtually certain and that the expulsion of a large quantity of ejecta is not highly improbable. Thus, the plant is designed to withstand a limited amount of ash fall. An eruption on the Bataan peninsula, on the other hand, is considered highly improbable. Furthermore, historic trends and geochemical considerations indicate that even if Natib were to erupt, the eruption would occur at the summit areas or on the eastern side so the plant would not be threatened by glowing avalanche and the like. The youngest volcanic deposit on the western flank is 600,000 years old. The Applicant proposed a volcano monitoring system to ensure adequate warning should Natib again become active.

The Mission's <u>third conclusion</u> was:

3. "The eruption of Mt. Natib is a credible event which should be taken into account. This requires consideration of excessive ash fall, glowing avalanche, and gas accumulation as well as laharic slides."

The Mission recognized the high quality of the work that had been done but concluded first that there remained considerable uncertainty about renewal of volcanic activity at Natib and second, that an eruption on the western slope could not be deemed incredible.

1284 078

The Applicant has provided additional information on the volcanic threats. Clearly local topography protects the site from most of these threats unless a new fissure develops and a flank eruption occurs, essentially at the site. The Applicant deems such an eruption incredible. Even if an eruption were to occur at or near the summit nearest the site, gravity would channel flows away from the site, protecting the plant from pyroclastic flows, laharic flows, and lava flows. The plant is considered safe from direct impact of ejected missiles by reason of first, distance and second, the absence of a volcanic dome at Natib. Volcanic shock waves and earthquakes would be far smaller than the design bases. The amount of ground tilt considered credible at this distance from the summit should pose no threat to the site. These phenomena should not directly damage the plant but could isolate the site, according to the Applicant's evaluations.

Direct volcanic threats to the plant are provided by ashfall and gases. The Applicant has estimated that dangerous levels of gases at the site would be limited to 3 hours or less. The ash fall estimates are that a Katmai-like eruption (Table 5) at Natib would result in between 4 and 22 feet of ash at the site while an eruption at Pinatubo would produce 0.1 to 4 feet of ash at Napot Point (Figure 2). WIPCO has shown that 10 inches of ash fall at the site would be acceptable.

PAEC has directed the Applicant to extend the investigation of both ash fall and volcanic gases. The threat of volcanic gases was emphasized by the recent disaster in Indonesia. The Applicant has been directed to provide the available information on kinds and amounts of gases which might

TABLE 5

QUANTITY OF EJECTA AND ENERGY RELEASES FROM SOME MAJOR VOLCANO ERUPTIONS

DATE	LOCATION	VOLUME, km^3	ENERGY, MT**
7000 ybp	Mazama, Oregon	63.	
1932	Quizapu, Chile	20.	
1912	Katmai*, Alaska	20.	
1815	Tambora,*** Indonesia	20.	20,000
1835	Cosiguina, Nicaragua	8.3	24
1902	Santa Maria, Guatemala	5.5	
1883	Krokatoa, Indonesia	5.	240
1964	Shiveluch, Kamchatka	1.5	
1958	Bezymianny, Kamchatka	1.	570
1929	Komagatake, Japan	1.	
1888	Bandaisan, Japan	1.	
1669	Etna, Italy	0.76	
1911	Taal, Philippines	0.5	
1947-48	Hekla, Iceland	0.4	
1902	Peleé, Martinique	0.1	
1919	Kelud, Java	0.1	
1843	Guntur, Java	0.008	1.6
1968	Mayon, Philippines	0.004	
1898	Una Una, Celebes Island	0.002	0.43

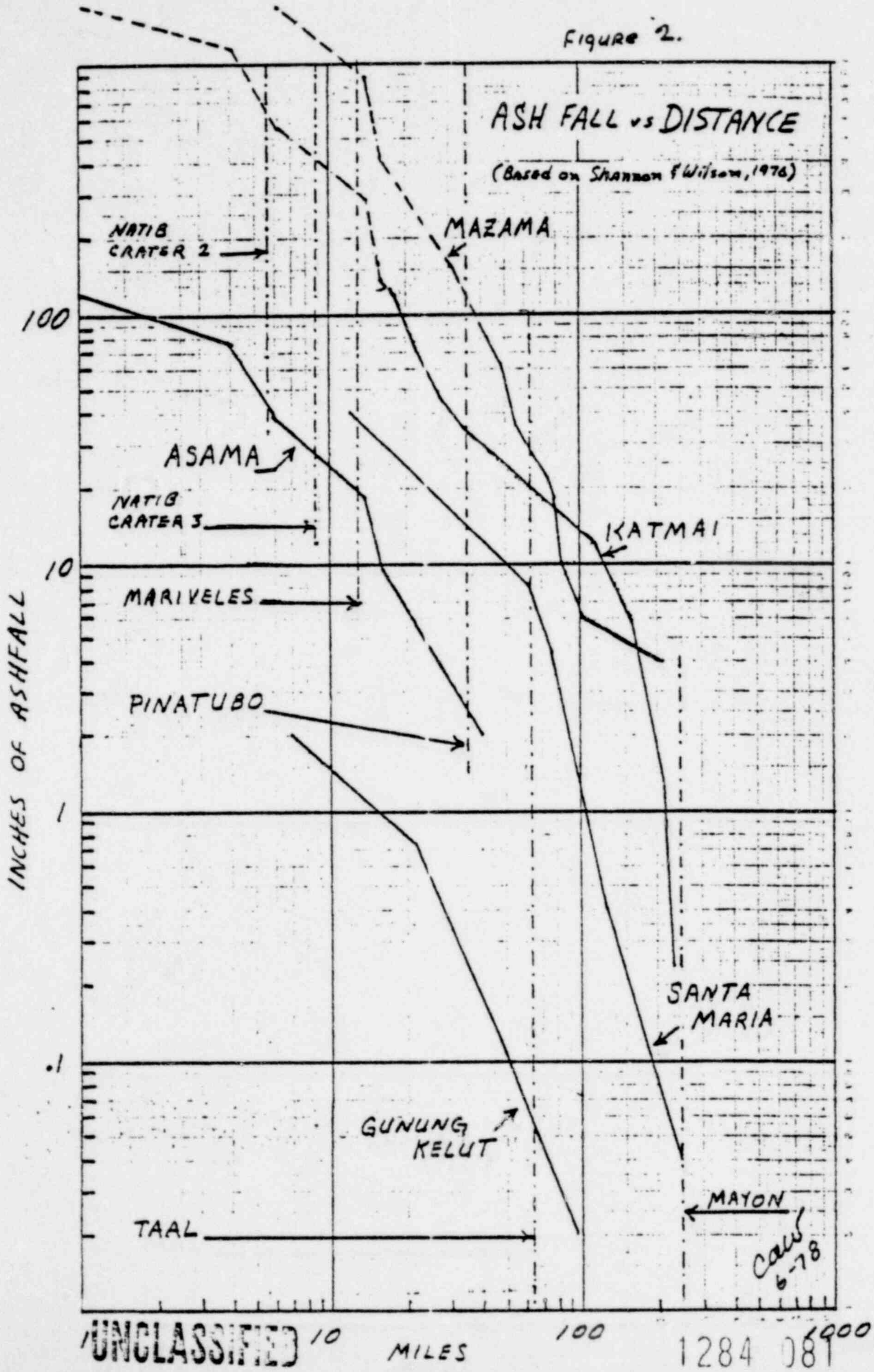
* or Mt. Novarupta

** Megatons TNT; 1 MT = 4.2×10^{22} ergs

*** The volume of ejecta from Tambora also has been given as 40 km^3 and the PSAR in one place mentions 20 $miles^3$.

1284 080

Figure 2.


ASH FALL vs DISTANCE
(Based on Shannon & Wilson, 1976)
NATIB CRATER 2
MAZAMA
100
ASAMA
NATIB CRATER 3
KATMAI
10
MARIVELES
PINATUBO
INCHES OF ASHFALL
1
SANTA MARIA
.1
GUNUNG KELUT
MAYON
TAAL
CAW 6-78
1
10
100
1000
MILES

be emitted in a major eruption. Also calcualtions are required of concentrations and integrated exposures at the site from eruptions at Natib, Pinatubo and Taal.

PAEC cannot accept the position that an eruption on the western slope of Natib is "incredible". The distance involved seem too small to justify the implied large difference in probabilities for western and eastern slope eruptions. Therefore, the Applicant has been directed to calculate probabilities for (1) a western slope eruption and (2) a western slope eruption without adequate advance warning. Further, the Applicant has been directed to evaluate the consequences of an eruption such as the 1911 eruption of Taal, if the eruption were to occur on the western slope of Natib; this ev luation should include a determination of the eruption locations from which the "base surge" would not reach the plant.

PAEC has directed the Applicant to include in its August 1970 report assurance that the plant is designed to be safe despite (1) an ash fall of 4 feet in 60 hours without prior warning and (2) A 22-foot ash fall after shutdown following an advance warning. (Note: the first condition corresponds to maximum ash fall from a Katmai-type eruption at Pinatubo and the second condition corresponds to maximum ashfall from such an eruption at Natib).

The Mission's <u>fourth conclusion</u> was:

4. "The immediate installation of a sophisticated and well maintained volcano surveillance system in combination with well defined base line criteria and subsequential procedures and action plan concerning the operation and/or shutdown of the plant is strongly recommended."

This recommendation reflects the importance placed by the Mission on the volcano surveillance system. This feeling is shared by PAEC and the Applicant is responding appropriately. A plan has been developed and is being implemented. According to the schedule, the system will be in operation by 1 September 1979.

The Mission's <u>fifth conclusion</u> was:

5. "One possible solution to mitigate against a radioactive release in the event of an eruption of Mt. Natib is the removal of the fuel to an off-site storage location upon advance warning of a surveillance system. The Mission believes that this alternative as well as other possible alternatives, deserve consideration in developing the procedures and action plan mentioned above."

This statement indicates the Mission's concern that the detection of volcanic activity at Natib would serve little purpose unless proper procedures for responding to these warnings were developed and implemented. PAEC agrees and has required the Applicant to develop and justify appropriate procedures, including consideration of fuel removal.

The Applicant has not completed work in this area. The schedule calls for these procedures and their justification to be submitted for PAEC review in August 1979.

1284 083

FOUNDATION ENGINEERING

Sixth conclusion:

6 "The geotechnical investigation conducted by the Applicant is acceptable for the particular soil foundation characteristics. The site appears adequate from a static foundation engineering point of view. Topographical and local effects on vibratory ground motion, design response spectra, natural slope stability and cut slope stability should be properly investigated; soil-structure interaction should also be revised accordingly if appropriate. Clarification is needed with respect to the shear moduli and "strain softening" soil characteristics used in the dynamic analysis presented to date."

The concern about topographical and local effects result from the fact that the Napot Point site differs significantly (perhaps more than other real sites) from the "infinite plane" presumed in postulating a free field acceleration and spectrum. The site is a small peninsula rising rather sharply from the sea floor. On the landward side is a significant mountain. WIPCO agreed to perform analyses to evaluate these phenomena if so directed by the Applicant.

The Mission seriously questioned the shear modulus-strain function experimentally obtained by EBASCO and used by WIPCO in WCAP-9187. The issue is the reduction in the modulus at high strain. In Vienna, WIPCO contended, and agreed to verify, that the dynamic strains do not exceed about 10^{-4}. The variation in shear modulus at such low strains is so small that an error in the function would be unimportant.

6.a. Topographical and Local Effects

In response to PAEC questions, the Applicant has reported that WIPCO finds the requested analyses to be beyond the state-of-the-art. Therefore, the Applicant is unable to supply the requested information.

PAEC then directed the Applicant to provide a report justifying the methods used, considering the inability to handle topographical and local effects. The Applicant has not yet provided this report. However, WIPCO has indicated that the methods used meet US NRC criteria, including the regulatory guides and the Standard Review Plan. WIPCO comments also indicate that the methods include conservatism to compensate for these limitations in the analysis.

Although PAEC cannot make a judgement until the full report is reviewed, satisfactory resolution seems probable.

6.b. Initial Shear Moduli and "Strain-Softening"

The Applicant has performed the re-evaluation and, as a result, has revoked the soft soil case (of WCAP-9187) and has added, a new parametric case of soil modulus. The strains were found to be less than $2. \times 10^{-4}$; thus, the modulus remains in the flat region.

PAEC has reviewed this response internally and feels that it is adequate. Recognizing its limited capability in this area, however, PAEC is submitting the report to IAEA for further review.

1284 085

6.c. Cut and Natural Slope Stability

The slope stability question has been evaluated by the Applicant's consultant, EBASCO. PAEC Staff has reviewed and found the result acceptable based on the present SSE. However, in this area also, PAEC is seeking IAEA support to ensure adequate review.

COMMENT AND CONCLUSION

The work has progressed more slowly than was recommended. The cause of this delay has not been fully established. Field investigations, of course, require time to plan and execute. I suspect also that difficulty in the reorganization of NPC has been an important factor.

Responses received and reviewed to date have varied greatly in quality. This suggests communication problems. To improve communications, frequent staff-level meetings between PAEC and NPC have been arranged.

An important factor in the PNPP-1 situation is the ability and willingness of PAEC to act to ensure the safety of the plant. An example is the recent PAEC order stopping work in one area until PAEC is convinced that adequate provisions have been made for the repair of defective concrete therein. PAEC inspection teams are now at the site every second week and the frequency is expected to be increased to every week. One full audit of the subcontractors has been performed and others are planned. Several members of the regulatory staff have foreign education (to the Ph.D. level) and training (on-the-job quality assurance, for example). The Philippine regulatory situation is vastly superior to that in many other developing countries.

While geotechnical problems are more difficult in the Philippines than in many other areas, there is evidence that appropriate precautions are being taken. It is noteworthy that the site selected appears to be the best possible on Luzon and that exceptionally thorough site investigations have been conducted. USA criteria* have been used and conscientious efforts are being made to resolve the issues raised by the 1978 IAEA Safety Mission. Generally, my recommendations have been well received and additional IAEA assistance is being sought. In total, the situation is encouraging.

It is recommended that IAEA make special efforts to provide the technical assistance that is needed in the Philippines. This will provide a high degree of assurance that PNPP-1 will constitute no undue hazard to the public.

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*US criteria are more detailed and explicit than the IAEA (draft) guides in these areas.

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EXPRESSION USED IN EVALUATING PNPP-1 SSE MAGNITUDE AND ACCELERATION

Magnitude as a Function of Rupture Length

Tocher(1) : $M = 0.98 \, Log_{10} L + 5.65$ ... $M > 6.5$

Iida(2) : $M = 0.76 \, Log_{10} L + 6.07$

Press(3) : $M = 1.06 \, Log_{10} L + 5.53$ ... $M > 6$

Wyss & Brune(4) : $M = 1.9 \, Log_{10} L + 2.8$

Housner(5): $M = 1.15 \, Log_{10} L + 5.1$ ... $M > 6.5$

Slemmons(16) : $M = 1.182 \, Log_{10} L + 5.152$ ... world wide data

NOTE: The use of the most conservative of the Slemmons functions in each case would not increase the magnitude postulated in the PNPP-1 PSAR.

Earthquake magnitude is M and L is rupture length in km. For PNPP-1 each of these expressions was tried and the one giving the highest magnitude for each specific fault was used.

Acceleration-Distance-Magnitude Relationship

1. Gutenberg & Richter(6) : $Log_{10} a_o = -5.1 + 0.81M - 0.027M^2$
2. Blume(7) : $Log_{10} a_o = -(\bar{b} + 3) + 0.81 M - 0.027 M^2$

   $a = a_o [1 + (D/H)^2]^{-1}$
3. Kani(9) : $a_r = (1/T) \, 10^B$

   $B = 0.16 M - [1.66 + 3.6/R] Log_{10} R + 0.167 -$,3/R
4. Milne & Devenport(10) : $a = (.0069 \, e^{1.64 M})/(1.1 \, e^{1.1 M} + D^2)$
5. Esteva(11) : $a = (1.25 \, e^{0.8 M})/(R + 25)^2$
6. Cloud & Perez(12) : $Log_{10} a = 3.5 - 2 \, Log_{10} (0.62D + 80)$ ... $M \geq 7.0$
7. Schnabel & Seed(13) : curves given (Figure A..)
8. Donovan(14): $a = 1.1 \, e^{0.5 M} (R + 25)^{-1.32}$
9. Okamoto(15): $Log_{10} a = -0.185 + \frac{0.62D + 25}{63} (-7.6041 + 1.744 M - 0.1036 M^2)$

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10. Kat... (17) : Log_{10} a = 0.411 M - 0.6832 - 1.637 Log_{10} (R + 30)

a_o = peak epicentral acceleration, g

a = peak acceleration, g

M = magnitude

$\bar{b}$ = site factor

D = epicentral distance, km

H = focal depth, km

a_r = baserock peak acceleration, g

T = predominant period

R = distance to hypocenter, km

For PNPP-1, functions 3, 4, 5, 6, 7, 8, 9 and 10 were tried and in each case the function used was that which gave the largest acceleration.

In Amendment 3 to the PSAR, the method of Umemura et. al. was considered and found to give acceleration values lower than those previously presented in the PSAR. The peak acceleration (in cm/sec^2) was found to average 11 times the maximum velocity (V_{max}, cm/sec) with a standard deviation of 1.8. Thus the mean plus one standard deviation acceleration is given by*:

11. Umemura(18): $a = 12.5\ V_{max}/980$

$V_{max} = 10^c$

$C = 0.61\ M - (1.66 + 3.6/R)Log_{10}\ R - 0.631 - 1.83/R$

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*What appeared to be an error in the PSAR formulative has been corrected so the equations are consistant with the graph in the PSAR amendment, Figure A2.

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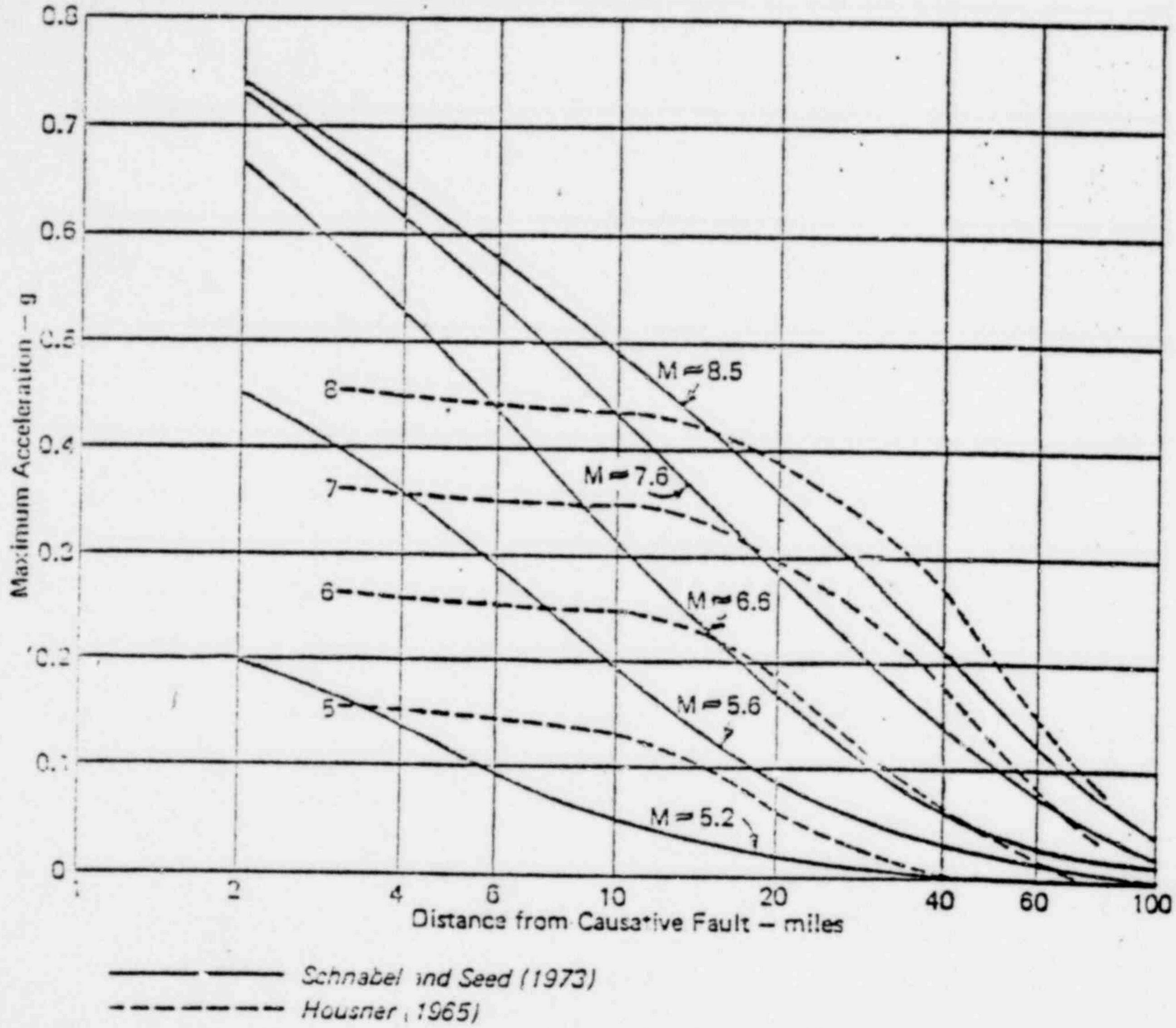
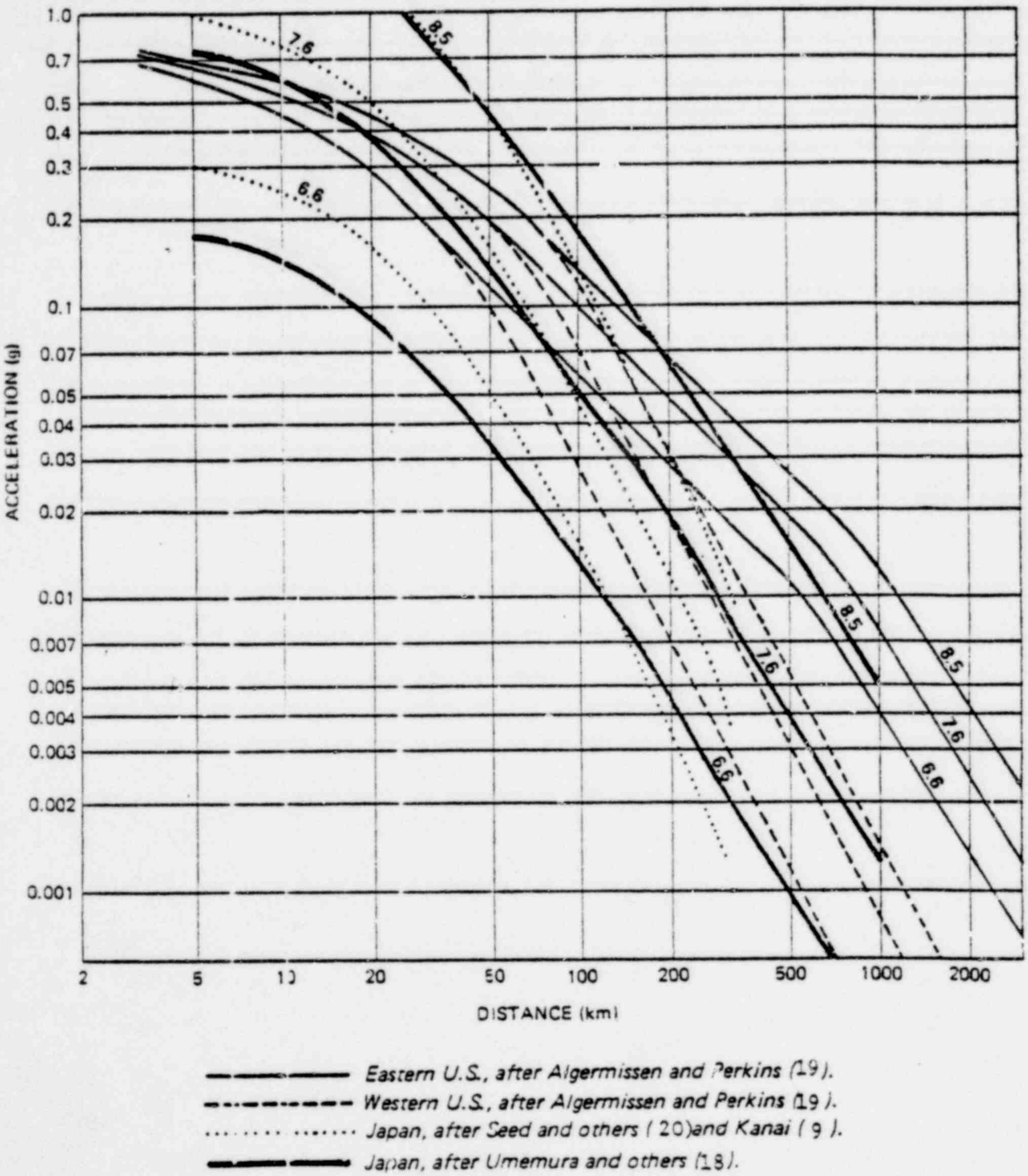

0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Maximum Acceleration – g
M = 8.5
M = 7.6
M = 6.6
M = 5.6
M = 5.2
8
7
6
5
1
2
4
6
10
20
40
60
100
Distance from Causative Fault – miles
Schnabel and Seed (1973)
Housner (1965)

1284 091

Figure A2



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PSAR FIGURE 2.5.L–2

ACCELERATION ATTENUATION CURVES BASED ON U.S. AND JAPANESE DATA

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1284 093

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* Largely as given in the PNPP-1 PSAR and supplementary materials.

EARTHQUAKE ACTIVITY IN THE SITE REGION

The Central Luzon Tectonic Province is bounded by the Philippine Fault, the Taal Fracture Zone and the Manila Trench. Appendix C lists the province' high intensity events and the text gives the maximum historic magnitude for each fault. This Appendix lists the strong earthquakes, magnitude 6 or more, in the province and the region around it (Table B1).

This Table was compared to the PAGASA (Philippine Weather Bureau) catalog. Some minor differences were noted but generally the agreement was good. One event was added to the Table which was not positively identified in the NPC/EBASCO composite catalog. This event's occurrence seems well established because it reportedly wrecked a sub-standard apartment building, thereby killing some 300 people in Manila. This event is of no special significance in the PNPP-1 evaluation. Three other earthquakes listed in PSAR Table 2.5 F-3 as having magnitudes greater than 6.0 were not so listed in the composite catalog and were not included in Table B1; these are events 212, 253 and 538 with magnitudes 6.75, 6.5 and 6.5 located in TFZ, CEZ, and NLEZ, respectively. The "structure" listed was not provided by the Applicant but is my own assessment.

A map (Figure B1) is included which shows the approximate location of each of the major tectonic structures. Several events are associated with the Manila Trench even though the epicenters is many kilometers from the Trench. This is appropriate because the Trench is produced by a slab which subducts at about 45 degrees and underlies the Province. Thus, event 183 is associated with the Trench even though its epicenter is in the West Luzon Trough and some 50 km from the Trench. Event 183 occurred at a depth of 100 km and so was in the slab associated with the Manila Trench.

1284 095

Table B1

STRONG EARTHQUAKES IN THE PNPP-1 SITE REGION
(From the NPC/EBASCO Composite Catalog, 1
through 1977, Magnitude 6, Latitude 12 to
17 N, Longitude 118 to 123 E)

Date	Degrees North	Degrees East	Depth, km	Structure	Catalog Number	Magnitude Body Wave	Magnitude Local
15 June 1928	12.5	121.5	-	SMEZ	10	-	7.0
25 May 1925	12.5	122.5	-	SMEZ	18	-	6.25
5 Feb. 1970	12.6	122.1	11	SMEZ	25	6.0	6.5
[illegible] July 1931	12.0	123.0	-	SMEZ	30	-	6.5
5 Nov. 1941	12.5	123.0	-	SMEZ	31	-	6.9
[illegible] Oct. 1956	13.6	120.6	115	VIP	34	-	6.25*
[illegible] June 1964	13.6	120.3	56	VIP	51	6.5	-*
[illegible] April 1972	13.4	120.3	50	VIP	89	6.2	7.3(b)*
20 Sept 1933	13.0	121.0	100	SMEZ	150	-	6.5
20 May 1936	13.5	121.5	160	VIP	151	-	6.0 *
6 May 1939	13.5	121.25	110	VIP	152	-	6.5 *
8 April 1942	13.5	121.0	25	VIP	153	-	7.8 *
7 Feb 1935	13.5	122.75	-	PF	168	-	6.0 *
17 March 1973	13.4	122.8	33	PF	175	5.6	7.5(c)*
21 March 191[illegible]	13.0	123.0	50	PF	182	-	6.5 *
18 July 1932	14.0	120.0	100	MT(s)	183	-	6.0 *
[illegible] June 1933	13.6	120.4	76	VIP/MT(s)	184	-	6.25(f)*
[illegible] Nov 1934	13.8	120.6	79	VIP/MT(s)	185	-	6.25(f)*
[illegible] March 1940	14.5	120.0	200	MT(s)	186	-	6.75*
20 Aug 1937	14.5	121.5	-	TFZ/PF	209	-	7.5 *
[illegible] Dec 1919	14.0	122.0	25	PF	220	-	7.8 *
9 Sept. 1941	14.0	123.0	-	?	229	-	6.75
[illegible] March 1933	15.5	120.0	120	IFZ	231	-	6.5 *
[illegible] July 1959	15.5	120.5	150	MT(s)	235	-	6.63*
[illegible] May 1963	15.7	120.1	89	MT(s)	240	6.3	-*
[illegible] April 1970	15.7	121.7	36	CEZ	283	6.4	7.5(a)
[illegible] April 1970	15.4	121.8	33	CEZ	315	5.7	6.3
[illegible] April 1970	15.1	122.1	24	BEC	373	5.9	7.0
15 April 1970	15.1	122.7	12	BEC	350	5.6	6.0
13 April 1977	16.0	120.5	140	MT(s)/PF	408	-	6.25*(e)
[illegible] April 1927	16.0	120.5	140	MT(s)/PF	409	-	6.75*(e)
[illegible] April 1927	16.0	120.0	100	MT(s)	410	-	6.75*
[illegible] Aug 193[illegible]	16.5	120.5	-	NLEZ	411	-	6.25
[illegible] Nov 195[illegible]	16.0	121.0	-	NLEZ	424	-	6.0
[illegible]6 Feb 196[illegible]	16.1	121.6	32	NLEZ/CEZ	427	-	6.1
22 May 1972	16.6	122.3	34	CEZ	470	5.7	6.9
13 May 1975	16.2	122.2	64	CEZ	493	4.8	6.5
18 March 1977	16.8	122.3	37	CEZ	494	6.2	7.0
21 July 1977	16.9	122.4	33	CEZ	533	6.1	6.8
5 Aug 1928	16.0	119.5	-	MT	602	-	6.25*
[illegible] Aug 1968	16.5	122.3	-	CEZ	(d)	-	7.3

1284 096

* These 22 events were within, or on structures bounding the Central Luzon Tectonic Province.

(a) PAGASA lists this as 6.4

(b) PAGASA does not list a local magnitude

(c) PAGASA lists this as 7.0

(d) From the PAGASA list; may correspond to event 445 or 450 in the NPC/EBASCO catalog, both of 5.9 body wave magnitude

(e) PAGASA lists both of these as 6.5 magnitude

(f) These events have been relocated (at the IAEA Mission's suggestion) from 14 N by 120 E and unknown depth.

SMEZ : South Mindoro Earthquake Zone

VIP : Verde Island Passage

PF : Philippine Fault

WLT : West Luzon Trough

MT : Manila Trench; (s) indicates the associated slab

TFZ : Taal Fracture Zone

? : Undetermined, remote from CLT Province

IFZ : Iba Fracture Zone

CEZ : Casiguran Earthquake Zone

BEZ : Baler Earthquake Zone

NLEZ : North Luzon Earthquake Zone

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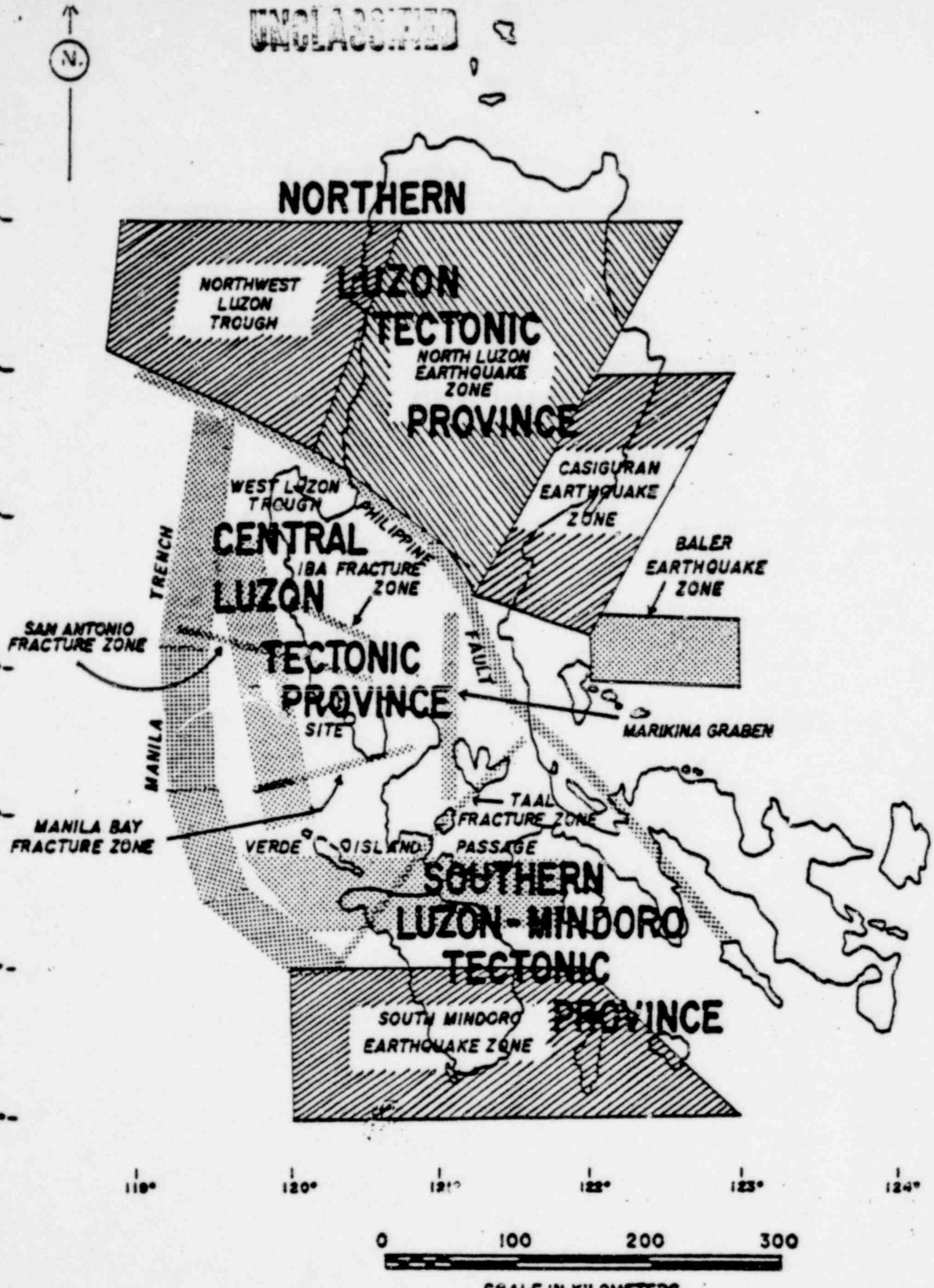

FIGURE B1

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APPENDIX C

DISCUSSION OF THE PAEC REQUIREMENTS

In response to the IAEA Safety Mission recommendations, PAEC has established additional requirement for PNPP-1. These requirements are intended to ensure the safety of the plant and to complete the public record. The requirements are stated and discussed briefly in the body of this report. This appendix provides further discussion and clarification of the requirements.

1. Random Earthquake

Earthquakes sometimes occur where there is no known causitive structure. The location of such "random" or "floating" earthquakes cannot yet be reliably predicted. For nuclear plant design purposes, it is assumed that the most severe historic random earthquake in the tectonic province will occur directly beneath the site. With this approach, random earthquakes have become the controlling events for several nuclear plants in less seismically active parts of the U.S.

Random earthquake considerations might not be expected to dominate PNPP-1 design because of the proximity of known faults. Actually the Applicant's selection of a 0.4 g design basis was not influenced by a random earthquake. All earthquakes with known epicentral location and magnitude exceeding 4.5 were associated with tectonic structures so the random earthquake magnitude was taken as 4.5. Earthquakes with magnitudes between 4 and 5 are considered "feeble shocks" where damage is not usually reported. Such an event is not a factor in the PNPP-1 design.

While the approach used was reasonable, I was concerned about (1) the use of such a mild random event for a seismically active area while much stronger random earthquakes are being used in relatively inactive areas in the U.S;

  1284 099

(2) the failure to consider a number of high intensity historic events (Table C.1) because the epicenter locations were not known; and (3) the limited accuracy in locating earthquakes (the common uncertainty of 50 km exceeds the distance between known faults). Thus, further consideration of the random earthquake seamed appropriate.

Key considerations are (1) The random earthquake is mild because known faults are nearby. (2) The selection of a low-magnitude random earthquake did not result in a "soft" design. The historic high intensity events are readily accounted for by the structure underlying Manila and the proximity of active faults, particularly the Marikina Graben and the Manila Bay Fracture Zone (20 km) and the highly active Verde Island Passage (90 km). A measure of the soil amplification in Manila is provided by the 1968 event wherein defective construction combined with a magnitude 7.3 event some 250 km away to kill 300 people.

The Applicant has been asked to provide an assessment of the early high intensity events to complete the public record but this is not likely to alter the earthquake risk evaluation.

2. Earthquake on Subducting Slabs

Two slabs are said to underly the site. The slab associated with the Manila Trench is subducting. The slab associated with the West Luzon Trough is said to be no longer subducting. (A PAEC

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TABLE C.1

HIGH INTENSITY EARTHQUAKES IN THE CENTRAL LUZON TECTONIC PROVINCE
(From the PAGASA Catalog)

Date	Intensity*	Location	Remarks
21 June 1599	VIII	Manila	
1 Jan. 1601	IX	Manila	
30 Nov. 1645	X	Manila	600 killed
20 Aug. 1658	IX	Manila	Few killed
7 Dec. 1677	IX	Manila	2 or 3 killed
28 Feb. 1687	VIII	Luzon	
2 Feb. 1771	VIII	Manila	
Oct. 1796	VIII	Manila	
26 Oct. 1824	VIII	Manila	
18 Jan. 1830	IX	Manila	
16 Sept. 1852	IX	Manila	
13 July 1862	VIII	Manila	
3 June 1863	X	Manila	320 killed
1 Oct. 1869	VIII	Manila	
18 July 1880	X	Manila	20 killed
17 March 1892	X	Dagupan Area	
19 March 1931	VIII	Luzon-Ambulong	Magnitude 6.9
30 Aug. 1937	VIII	Alabat	M = 7.5 at 14.5°N & 121.5°E
2 Aug. 1968	?	Manila (300 killed)	M= 7.3 at 16.5°N & 122.3°E

*The original Rossi-Forel Scale of 10 intensities was used up to 1934. Thereafter the adapted Rossi-Forel Scale of 9 intensities was used. It Has been suggested that, on the original RF Scale, RF VIII corresponds to MM VII or VIII; RF IX corresponds to MM VIII or IX; and RF X corresponds to MM X through XII. The two most recent events in this list were considered in the previous analysis.

1284 101

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geologist, Mr. G. Santos, doubts the existence of this slab). It is agreed that both the Trench and the Trough are seismically active. However, the slab location is determined by the location of earthquake focal points so the slab associated with the Trough evidently is inactive.

The published relationships (Appendix A) between magnitude, distance and peak acceleration are in considerable disagreement. For present purposes the most important disagreement concerns the acceleration close to the event. Japanese results show great variation in acceleration with magnitude whereas American results show relatively little magnitude effect. (See Appendix A Figure 2). Even so, if the most conservative of these relationships (where focal depth is considered) is used in each case, the 0.4 g design basis is not exceeded by the "maximum" events on the slabs.

The problem of near field effects presents difficulties, largely because few data are available for accelerations near the epicenter. While Donovan and Bornstein[1] report accelerations within 5 km of the "energy center" and find this data consistent with their attenuation model, the issue seems open to question.

The Applicant has presented the results obtained for events beneath the site using a scaling approach (as recommended by the Mission). However, the approach used has not yet been fully explained nor justified. Justification is being required.

The Applicant contends that the depth of the slab associated with the Manila Trench is at least 70 km below the site. PAEC finds no basis for disagreeing but is requiring that the justification be more fully documented.

3. Evaluation of Poison Gases From Volcanoes

The poison gas hazard from volcanoes has been known at least since 70 AD when gases from Vesuvius killed Pliny the Elder. The recent disaster in Indonesia has focused attention on the problem. The gas hazard is discussed briefly in the PSAR but a more explicit quantitative evaluation is necessary.

PAEC specifically needs to know what volcanic releases might incapacitate (1) the control room personnel and (2) other site personnel. This requires consideration of historic releases of volcanic gases, the type and amount of gases which might be released and atmospheric transport processes. The Applicant should also consider precautionary measures which might be taken.

4. Natib Eruption Probabilities

The Applicant has estimated the probability of Natib erupting as about 3×10^{-5} pa but considers a western slope eruption to be "incredible".

1284 103

PAEC cannot accept the "incredible" assessment, particularly when the youngest deposits on Natib are only about 10 km from the western slope. It does seem reasonable that a western slope eruption is less likely than eruption at the summit or on the eastern slope. The fact that the youngest deposit on the western slope is ten times as old as the youngest eastern deposit is important; nevertheless, quantitative assessment of the risk is required.

The information available to PAEC indicates that in almost every case there are clearly recognizable warnings before a major volcanic eruption. Also an instrumentation system is being provided to enhance the likelihood of advance warning. Nevertheless, advance warning cannot be considered certain. Therefore, the calculation of the probability of an eruption without warning is required. The result obtained is of less interest than the basis for it, including such things as kind and frequency of observations made, equipment reliability, etc.

This calculation is intended not only to verify that the situation has been thoroughly evaluated and that the probability is acceptably low; it will also provide the basis for surveillance requirements and for regulatory actions.

5. Consequences of Eruption on Western Natib

The Applicant has argued that the site would not be directly in the path of nuee ardenta, etc. even if there were an eruption on the western slope of Natib. Topographic maps and physical inspections of the site area lead PAEC to agree that generally this assessment is valid. However, the evaluation has not been quantitative or objective. Therefore, the Applicant has been directed to provide a quantitative evaluation.

Flows of materials from an erupting volcano are complex. A simple drainage map of Natib may be a good starting point but it is not sufficient; a "Hawaiian" type eruption is not to be expected The flow pattern is strongly influenced by the eruption. Small eruptions produce little material that can flow. On the other hand, a "plinian" type eruption can be so destructive locally that flows are of little concern. Thus, to provide a basis for evaluating local topography, the 1911 eruption of Taal was selected as a model. This was one of the largest Philippine historic eruptions but it is not so violent as to mask local topographic effects.

6. Ash Fall Protection

Ash fall in significant quantities is not highly improbable at Napot Point. The Applicant's analysis is based on a Katmai-type eruption. It shows that such an event at Natib Crater 3 could produce 22 feet of ash fall at the site and that Pinatubo could produce up to 4 feet. These results are consistent with other work(2). Questionable statistical analyses are used to select a 1.3 feet as the design basis ash fall.

1284 105

PAEC concludes that (1) provisions must be made to protect against a meltdown even if Natib erupts and (2) the plant must be safe even if Pinatubo (or Taal, etc.) erupts without advance warning. Protection against a Natib eruption means protection against 22 feet of ash fall. This could be accomplished, for example, by removal of the fuel from the site. Another approach might be to transfer the fuel into the fuel storage pool, operate the pool cooling system as long as practicable and restart cooling after the eruption. Ideally, the plant would be designed so the fuel could be left in the reactor vessel. Whatever the approach selected, the design requirements must be identified as soon as practicable.

The volcano monitoring system will give warning only of impending eruptions of Natib and Mariveles. It would be impractical to respond to the almost daily signs of activity at Taal. Thus, the plant must be capable of withstanding the possible ash fall from Pinatubo, Taal, etc. without warning. This could amount to 4 feet of ash. There are various possible approaches. Ideally, the plant would continue to operate, having adequately protected the air intakes, cooling systems, etc. However, shutdown under certain conditions may be appropriate. The cooling systems must continue to operate after shutdown, the control room must remain habitable, etc. The situation must be evaluated and necessary features incorporated in the design as soon as practicable.

1284 106

7. Volcano Surveillance System and Program

The PNPP-1 site was selected and accepted on the grounds that (1) the likelihood of renewed volcanic activity at Natib or Mariveles is slight and (2) an appropriate surveillance program will be conducted to ensure adequate warning should a volcanic threat develop. There has been little disagreement on this issue.

8. Procedures for Response to Volcano Warning

The warning signs of renewed volcanism should precede any eruption of Natib or Mariveles by several months. This period of time will permit a variety of possible responses. To be effective, however, the "action levels" of the Warnings and the planned responses must be developed in advance. Simply shutting the reactor down for 90 days greatly reduces the potential radiological hazard by (1) virtually eliminating both the halogens and the noble gases[(3)] and (2) greatly reducing the residual heat rate (to perhaps 3 megawatts thermal). Meltdown remains possible, however, even after an extended shutdown period and additional precautionary measures will be necessary.

The most complete protection would be provided by complete removal of all fuel from the site. The Applicant has been directed to evaluate this possibility, but difficulties are evident so another approach may be preferred. Placing the fuel in the storage pool (with the refueling cavity flooded) may permit the cooling system to be deactivated safely for a period (perhaps a week) though heat removal must be restarted soon. These possibilities must be explored and a definite program established.

9. Foundation Engineering

PAEC has required the Applicant to address the Mission's concerns in this area. IAEA assistance will be requested in reviewing the final report when they are available.

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1284 108