1-INTRODUCTION

For safety reason of construction, the soil under foundation should be investigated.

The main objectives of the soils investigations showed that the Engineer's method define type of foundations (Strip footing, mat foundation, foundation piers, and foundation piles...).

On 09Th June 2001, ***Research And Design Enterprise of Soil Testing Laboratory*** has been awarded a contract to undertake the soil investigation for **New Power Plani Project,** located at **Khum Chreal, Siem Reap District, Siem Reap Province, Kingdom of Cambodia.**

The field works have been carried out from 09th to 10th June 2001 and laboratory testing from 12th to 18th June 2001.

This report presents the ground conditions, mechanic of the soils, results of Standard Penetration Test (SPT) and field log recording.

2- SCOPE OF WORK

The scope of work for investigation included the following:

2.1-FIELD WORK

All field works activities were supervised by:

- Mr. KONG Sangva - Engineer of Geology
- Mr. SIENG Peou -Master Engineer of Geology

Two boreholes of 120mm nominal diameter and 20 m depths with Standard Penetration Test (SPT) where carried by rotary auger machine model **УГВ-50М** (Russian equipment) with a maximum capacity 35m depths.

The positions of boreholes are shown in the location plan (Figure 1).

2.2-STANDARD PENETRATION TEST (SPT)

Standard Penetration Test was carried out **1.50m** intervals inside the boring hole. A standard split spoons of **50.8**mm diameter with a ball check valve on the top and harden steel cutter. A Standard spilt spoon was installed and drives into the soil by a **63.5**Kg, automatic drop hammer falling freely from a fixed height of **760**mm along a guide rod.

The blow counts defined for each 150mm penetration of the seating drive. Total penetration of the spoon is **450mm** and the numbers of blow N-value for last **300mm**. Penetration was recorded as the **N**- value of the soil stratum encountered which indicated the relative density of non-cohesive soil as well the consistency of the cohesive soil.

2.3-SAMPLING

-Undisturbed samples

Undisturbed samples were taken in the natural state of the soil from **firm to stiff clay** and **sandy clay** for testing undrained direct shear test, unconfined compression test, consolidation test...The undisturbed samples were taken by thin wall tube sampler.

-Disturbed samples

The disturbed samples were taken at a rate of 1.5m to 3m and all strata in the borehole. The disturbed samples were also collected in soft to stiff clay and sandy soil for laboratory testing.

3- LABORATORY TESTING PROGRAM

The Laboratory Testing Program Included:

-Natural water contents determination

-Density and dry density determination

-Atterberg limit tests of selected cohesive soil or sandy sieving pass 425 micrometers

-Sieves distribution Test

-Unconfined compression Test

-Specific gravity Gs

The testing-procedure was conducted in accordance with **ASTM** Standard and classified soil by **USCS** (Unified Soil Classification System).

Mr. **SIENG PEOU** (Master engineer of geology) prepared this present report.

Summary of testing results was presented in the table *characteristic of Soil Mechanic*.

4- RELATIVE DENSITY AND CONSISTENCY

The relationship between Standard Penetration Test result and consistency clay, silt soil (Cohesive soil) and relative density for sandy soil (non-cohesive soil) are shown in the table No 1 and 2.

RELATION BETWEEN S.P.T RESULTS and CONSISTENCY

for CLAY, SILT, CLAYEY-SILT and SILTY-CLAY

(COHESION SOILS)

Table 1

S.P.T N Value (blows/ 300mm)	CONSISTENCY
2 to 4	Soft
4 to 8	Medium
8 to 15	Stiff
15 to 30	Very Stiff
30 over	Hard

RELATION BETWEEN S.P.T RESULTS and RELATIVE DENSITY

for SAND and GRAVEL.

(COHESIONLESS SOIL)

Table 2

S.P.T N Value (blows/ 300mm)	RELATIVE DENSITY
Less than 4	Very loose
4 to 10	Loose
10 to 30	Medium dense
30 to 50	Dense
Over 50	Very dense

5- GROUND CONDITION AND SOIL PROPERTIES

Ground condition from the ground surface to 20m depths for this site consisted of filling process of geology was in 4th Era (Young alluvium) by Geologic Map of Cambodia showing location of litho-logic section.

The soil condition encountered on boreholes have been into strata as follows:

BOREHOLE No 1

Stratum No	Description of soil strata	N-value blows/300mm
1-	Farm Soil, encountered from top to 0.50m depth.	
2-	Yellow white loose silty FINE SAND, encountered from 0.50m to 2.50m.	N-5
3-	Yellow white loose clayey FINE SAND, encountered from 2.50m to 3.70m.	N-6
4-	White grey clayey silty medium dense MEDIUM SAND, encountered from 3.70m to 5.30m.	N-11
5-	White grey clayey silty loose COARSE SAND, encountered from 5.30m to 7.00m.	N-4
6-	White grey clayey silty loose FINE SAND, encountered from 7.00m to 9.80m.	N-5 N-6
7-	White grey medium dense clayey MEDIUM SAND, encountered from 9.80m to 12.80m.	N-13 N-10
8-	White grey medium dense clayey silty FINE SAND, encountered from 12.80m to 15.50m.	N-24 N-27
9-	White grey clayey medium dense FINE SAND, encountered from 15.50m to 20.00m.	N-19 N-23 N-30

BOREHOLE No 2

Stratum No	Description of soil strata	N-value blows/300mm
1-	Farm Soil encountered from top to 0.50m depth.	
2-	Yellow white very loose clayey silty MEDIUM SAND, encountered from 0.50m to 4.00m.	N-1 N-1
3-	White grey clayey medium dense MEDIUM SAND, encountered from 4.00m to 5.00m.	N-13
4-	White grey clayey silty loose MEDIUM SAND, encountered from 5.00m to 6.50m.	N-8
5-	White grey clayey loose FINE SAND, encountered from 6.50m to 11.50m.	N-7 N-6 N-5
6-	White grey medium dense clayey MEDIUM SAND, encountered from 11.50m to 12.60m.	N-13
7-	White grey clayey silty medium dense FINE SAND, encountered from 12.60m to 20.00m.	N-25 N-16 N-24 N-24 N-23

6-GROUND WATER CONDITION

The investigation of the ground water is one of importance for soil investigation, because the variation of the ground water level, the characteristic of soil mechanic can be change.

The ground water is divided into two kinds and two seasons:

6.1-Water strikes and Ground water level

-During boring activities, water is found at a greater depth (**Water strike**).

-But a few hours or 24 hours after the boring completed, water is stabilized at a higher level (**Ground water level**).

6.2-The ground water by season

The ground water varies according to the season:

-In dry season the ground water level is **decrease**.

-In rainy season the ground water level is **increase**.

Table No 3

Borehole No	Boring started date	Boring finished date	Water strike (m.)	Water level (m.)	Date measured
BH-1	09/06/2001	09/06/2001	3.00	0.50	10/06/2001
BH-2	10/06/2001	10/06/2001	1.00	0.50	10/06/2001

6.3-Ground Water analysis

Results of Ground Water analysis show in table No 4.

Table No 4

Item	Unit	Amount	Standard
		BH-1	
pH	-	5.07	6.5 to 8.5
SO4	mg/l	8.376	25 to 500
Cl	mg/l	1.403	25 to 350
Na	mg/l	2.989	150 to 200

7-CONCLUSION AND RECOMMENDATION

Based on the soil data from 2 boring holes, the following recommendation can be presented:

1-For this project ***pile foundation*** should be recommended.

2-The allowable bearing load for pile foundation was presented in the Table No 5.

TABLE No 5

Borehole No	Pile size	Pile depth	Pile length	End bearing capacity	End bearing load	Friction load	Allowable bearing Load
	(m^2)	(m)	(m)	(kN/m^2)	(KN)	(KN)	(KN)
BH-1	0.20x0.20	4.50	4.00	1100	44	10.56	54.56
BH-1	0.30X0.30	13.50	12.00	1834	165.11	62.10	227.21
BH-2	0.20x0.20	4.50	4.00	1300	52.0	4.0	56.0
BH-2	0.30x0.30	13.5	12.00	1881	169.34	56.19	225.53

Phnom Penh, June 20, 2001

Master engineer of Geology

Mr. SIENG PEOU

8- GENERRAL

The analysis and recommendation submitted in this report are based on available information. Since significant variations in soil conditions may occur between the boring, it is recommended that pile experienced soil engineer to assure that the bearing capacity conform to the design and specifications.

The suggestion and recommendation herein are based on available data obtained from limited specified soil information, the homogeneity of soil formation assumption, and equations involved in the calculation, which are believed to be reliable. However, such prediction or recommendations should be verified by full-scale test of investigation during construction period to obtain more precise reliable data. Construction method must be adopted to best suit the analysis method assumption .We do not make any representations as to its accuracy or completeness .Any, data or design criterion is only current solutions which are subjected to change or revise.

This report has been prepared in order to aid in the evaluation of the site conditions only, to assist the engineer in the design of the project, based on our understanding of the design details, criteria & utilization of the project as outlined herein. If our understanding of the design and utilization is not correct, we should be promptly informed of the correct data so that we may revise our recommendations as appropriate.

RESEARCH AND DESINGN ENTERPRISE

SOIL TESTING LABORATORY

FIELD BORING LOG

SITE : New Power Plan Siemreap(Phum Kna Khum Chreal)

EQUIPMENT rotary auger

SHEET 1

DATE : 09.06.2001

ELEVATION :

BOREHOLE N° 1

DEPTH (m)	SAMPLE N°	DIST SAMPLE	UNDIST SAMPLE	DESCRIPTION OF STRATA	DEPTH & THICK	LEGEND of SOIL	S.P.T (N) N/150mm No	N1	N2	BLOWS/300mm N	N values 10 20 30 40 50	Testing interval (M)	RECOVERY RATIO (MM)
				Farm Soil	0.50								
1					0.50								
2	1	D	-	Yellow white loose silty FINE SAND	2.00		1	1	4	5		1.5to1.45	350/450
3	2	D	-	Yellow white loose clayey FINE SAND	2.50 1.20		1	2	4	6		3.0to3.45	360/450
4					3.70								
5	3	D	-	White grey clayey silty medium dense MEDIUM SAND	1.60		2	5	6	11		4.5to4.95	300/450
6					5.30								
7	4	D	-	White grey clayey silty loose COARSE SAND	1.70		1	1	3	4		6.0to6.45	200/450
8	5	D	-	White grey clayey silty losse FINE SAND	7.00		1	2	3	5		7.5to7.95	40/450
9	6	D	-		2.80		2	3	3	6		9.0to9.45	140/450
10					9.80								
11	7	D	-	White grey medium dense clayey MEDIUM SAND	3.00		4	7	6	13		10.5to10.95	170/450
12	8	D	-				3	5	5	10		12to12.45	240/450
13					12.80								
14	9	D	-	White grey medium dense clayey silty FINE SAND	2.70		17	14	10	24		13.5to13.95	80/450
15	10	D	-				8	11	16	27		15to15.45	240/450
16	11	D	-	White grey clayey medium dense FINE SAND	15.50								
17							5	9	10	19		16.5to16.95	100/450
18	12	D	-		4.50		5	11	12	23		18.to18.45	90/450
19													
20	13	D	-		20.00		6	12	18	30		19.5to19.95	80/450

FIGURE 3

LEGEND

D- disturbed sample

U- Undisturbed sample.

W- water sample .

Ground water after boring 0.5m

W.S-water strike 3.0m

STARTED :09.06.2001

FINISHED :09.06.2001

N <2 very soft , 2<N <4 soft

4<N <8 medium , 8<N < 15 stiff

15<N < 30 very stiff , N>30 hard

0<N <4 very loose , 4<N<10 loose

10<N <30 medium dense

30<N <50 dense , N>50 very dense

RESEARCH AND DESINGN ENTERPRISE

SOIL TESTING LABORATORY

FIELD BORING LOG

SITE : New Power Plan Siemreap(Phum Kna Khum Chreal)

EQUIPMENT: rotary auger

SHEET: 1

DATE : 10.06.2001

ELEVATION :

BOREHOLE N° 2

DEPTH (m)	SAMPLE N°	DIST SAMPLE	UNDIST SAMPLE	DESCRIPTION OF STRATA	DEPTH & THICK	LEGEND of SOIL	S.P.T (N) N/150mm No	N1	N2	BLOWS/300mm N	N values (10 20 30 40 50)	Testing interval (M)	RECOVERY RATIO (MM)
				Farm Soil	0.50								
1					0.50								
	14	D	-				1	0.5	0.5	1		1.5to1.45	450/450
2				Yellow white very loose clayey silty MEDIUM SAND	3.50								
3							1	0.5	0.5	1		3.0to3.45	350/450
	15	D	-										
4					4.00								
	16	D	-	White grey clayey medium dense MEDIUM SAND	1.00		4	7	8	13		4.5to4.95	230/450
5					5.00								
	17	D	-	White grey clayey silty loose MEDIUM SAND	1.50		3	5	3	8		6.0to6.45	220/450
6					6.50								
7													
	18	D	-				2	3	4	7		7.5to7.95	120/450
8													
9	19	D	-	White grey clayey losse FINE SAND	5.00		2	3	3	6		9.0to9.45	90/450
10													
	20	D	-				2	2	3	5		10.5to10.95	130/450
11					11.50								
12	21	D	-	White grey medium dense clayey MEDIUM SAND	1.10		2	7	8	13		12to12.45	110/450
13					12.60								
	22	D	-				6	11	14	25		13.5to13.95	240/450
14													
15	23	D	-				4	6	10	16		15to15.45	110/450
16	24	D	-	White grey clayey silty medium dense FINE SAND	7.40								
17							4	10	14	24		16.5to16.95	100/450
	25	D	-										
18							6	10	14	24		18.to18.45	100/450
19													
	26	D	-				9	11	12	23		19.5to19.95	160/450
20					20.00								

FIGURE 4

LEGEND

D- disturbed sample

U- Undisturbed sample.

W- water sample .

Ground water after boring 0.5m

W.S-water strike 1.0m

STARTED :10.06.2001

FINISHED :10.06.2001

N <2 very soft , 2<N <4 soft

4<N <8 medium , 8<N < 15 stiff

15<N < 30 very stiff , N>30 hard

0<N <4 very loose , 4<N<10 loose

10<N <30 medium dense

30<N <50 dense , N>50 very dense

RESEARCH AND DESIGN ENTERPRISE
SOIL TESTING LABORATORY

Date 17/06/01
Sheet No 1

SUMMARY OF LABORATORY TESTING RESULTS

BOREHOLE No 1

Project name: New Power Plan Siem Reap.
Site: Siem Reap Province.

SAMPLE	DEPTH		DESCRIPTION OF STRATA	WATER CONTENT	ATTEBERG LIMIT		PLASTIC INDEX	LIQUITY INDEX	DENSITY OF SOIL		PARTICAL SIZE DISTRIBUTION			UNDRAINED SHEAR STRENGTH				SPECIFIC GRAVITY	SOIL CLASS	Void radio	CONSOLIDATION			SPT
														DIRECT SHEAR		UNCONFINED COMPRESSION	POCKET PENETRATION							
No	From	to		W	L.L	P.L	IP	IL	B.D	D.D	M&C	Sand	Gravel	C	ϕ	Qu/2	Qp/2	Gs		e	CV	MV	K	N-Value
	(M).			%	%	%	-	-	KN/m³	KN/m³	%	%	%	kN/m²	Degree.	kPa	kPa				m²/s	m²/MN	m/s	blows
-	0.00	0.50	Farm soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	0.50	2.50	loose silty fine sand	12.51	-	-	-	-	14.22	16.00	23.05	76.95	-	-	26	-	-	2.70	SM	0.90	-	-	-	5
2	2.50	3.70	Loose clayey fine sand	16.07	20.60	12.08	8.49	-	14.64	17.00	30.04	69.96	-	-	26	-	-	2.69	SC	0.83	-	-	-	6
3	3.70	5.30	Clayey silty medium dense	15.28	24.00	17.96	6.01	-	15.61	18.00	12.51	87.49	-	-	29	-	-	2.70	SM	0.73	-	-	-	11
			medium sand																SC					
4	5.30	7.00	Clayey silty loose coarse sand	17.70	20.40	15.73	4.71	-	13.59	16.00	13.79	86.21	-	-	26	-	-	2.70	SM	0.98	-	-	-	4
																			SC					
5	7.00	9.80	Clayey silty loose fine sand	16.34	19.90	14.20	5.66	-	13.75	16.00	27.60	72.40	-	-	26	-	-	2.70	SM	0.96	-	-	-	5
6																								6
7	9.80	12.80	Clayey medium dense medium	13.58	23.00	14.43	8.56	-	15.84	18.00	21.24	78.76	-	-	30	-	-	2.68	SC	0.69	-	-	-	13
8			sand																					10
9	12.80	15.50	Clayey silty medium dense	12.13	20.30	13.77	6.51	-	17.83	20.00	34.80	65.20	-	-	31	-	-	2.68	SM	0.50	-	-	-	24
10			fine sand																SC					27
11																								19
12	15.50	20.00	Clayey medium dense fine sand	16.91	29.50	16.93	12.58	-	16.25	19.00	34.54	65.46	-	-	32	-	-	2.69	SC	0.65	-	-	-	23
13																								30

GEOTECHNICAL ENGINEER

SIENG PEOU

RESEARCH AND DESIGN ENTERPRISE
SOIL TESTING LABORATORY

Date 17/06/01
Sheet No 1

SUMMARY OF LABORATORY TESTING RESULTS

BOREHOLE No 2

Project name: New Power Plan Siem Reap.
Site: Siem Reap Province.

SAMPLE No	DEPTH From (M).	DEPTH to (M).	DESCRIPTION OF STRATA	WATER CONTENT W %	ATTEBERG LIMIT L.L %	ATTEBERG LIMIT P.L %	PLASTIC INDEX IP -	LIQUITY INDEX IL -	DENSITY B.D KN/m³	DENSITY O.F SOIL D.D KN/m³	PARTICAL SIZE DISTRIBUTION M&C %	Sand %	Gravel %	UNDRAINED SHEAR STRENGTH DIRECT SHEAR C kN/m²	DIRECT SHEAR ϕ Degree.	UNCONFINED COMPRESSION Qu/2 kPa	POCKET PENETRATION Qp/2 kPa	SPECIFIC GRAVITY Gs	SOIL CLASS	Void radio e	CONSOLIDATION CV m²/s	CONSOLIDATION MV m²/MN	CONSOLIDATION K m/s	SPT N-Value blows
-	0.00	0.50	Farm soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	0.50	4.00	Very loose clayey silty	15.38	18.90	12.07	6.79	-	11.26	13.00	22.69	77.31	-	-	25	-	-	2.68	SM	1.37	-	-	-	1
15			medium sand																SC					1
16	4.00	5.00	Clayey medium dense medium sand	16.78	26.40	15.35	11.08	-	15.41	18.00	30.05	69.95	-	-	30	-	-	2.69	SC	0.74	-	-	-	13
17	5.00	6.50	Clayey silty loose medium sand	15.96	20.70	16.26	4.37	-	14.66	17.00	15.80	84.20	-	-	28	-	-	2.68	SM	0.83	-	-	-	8
																			SC					
18																								7
19	6.50	11.5	Clayey silty loose fine sand	14.91	21.60	12.10	9.44	-	14.79	17.00	30.69	69.31	-	-	27	-	-	2.70	SC	0.82	-	-	-	6
20																								5
21	11.50	12.6	Clayey medium dense medium sand	13.19	21.90	13.18	8.70	-	15.90	18.00	22.64	77.36	-	-	30	-	-	2.70	SC	0.70	-	-	-	13
22																								25
23																								16
24	12.60	20.0	Clayey silty medium dense	14.21	20.30	14.55	5.72	-	16.63	19.00	32.23	67.77	-	-	32	-	-	2.69	SM	0.61	-	-	-	24
25			fine sand																SC					24
26																								23

GEOTECHNICAL ENGINEER

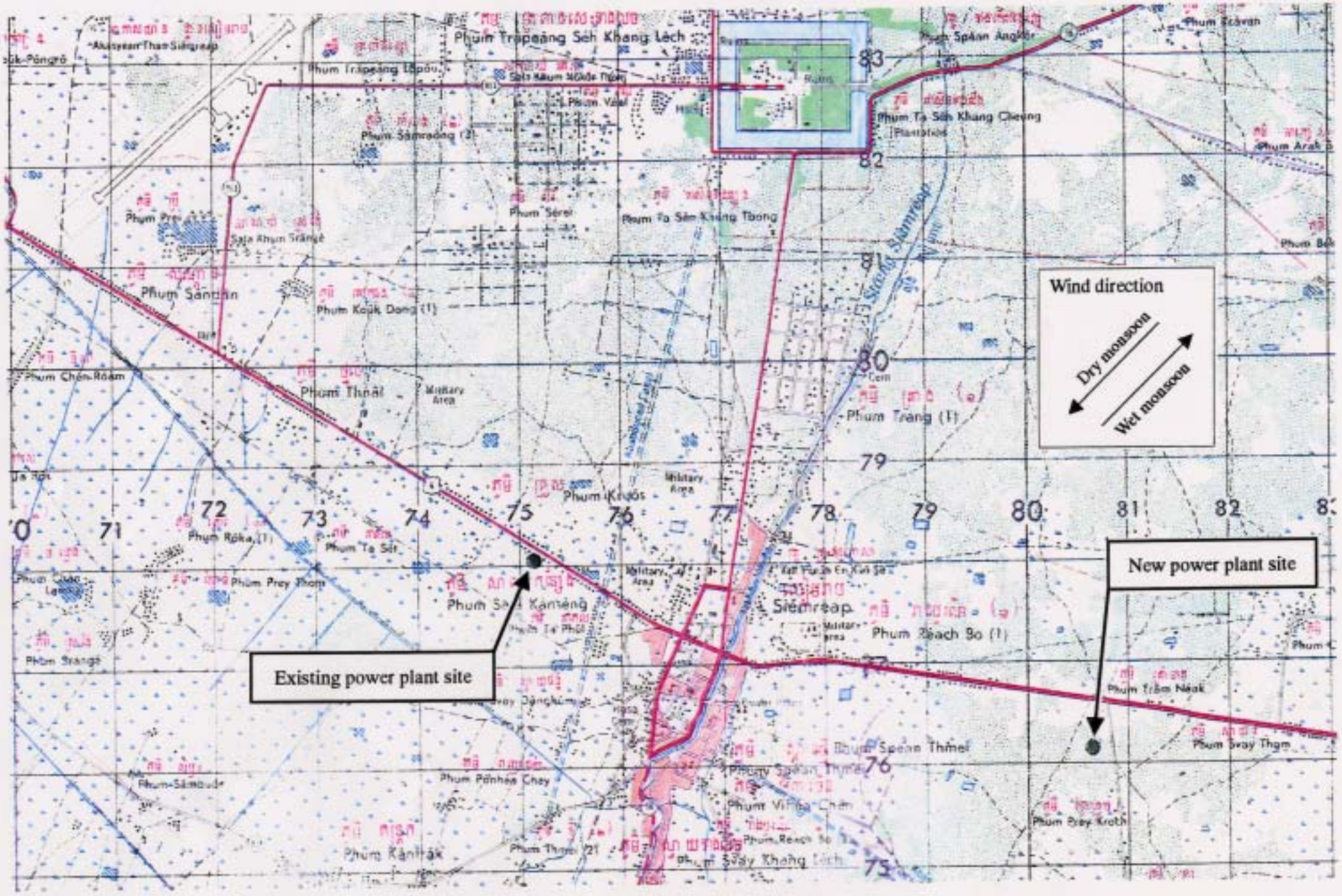
SIENG PEOU

BASIC DESIGN STUDY
ON
THE PROJECT FOR SIEM REAP GENERATING FACILITIES
IN
THE KINGDOM OF CAMBODIA

ENVIRONMENTAL STUDY REPORT

OCTOBER 2001

Location Map of the Project Site



CONTENTS

1. General

The Japan International Cooperation Agency (JICA) conducted, upon a request of the Government of Cambodia (GOC) to the Government of Japan (GOJ), a Master Plan Study on the Rehabilitation and Reconstruction of Electricity Supply in Phnom Penh and Siem Reap in 1993 and a Feasibility Study for the urgently required power generation and distribution facilities identified in the Master Plan.

On the basis of the study results, GOC requested grant aid from GOJ for the project for rehabilitation and upgrading of electricity supply facilities in Phnom Penh. The project was conducted under two grant aid projects from GOJ in 1995/1996 for the project phase-I and in 1999 for the project phase-II to be completed in 2002.

Besides GOC requested Grant Aid from GOJ for the Project for Siem Reap Generating Facilities in 2000.

In response to the official request, GOJ decided to conduct a Basic Design Study to examine the viability of the Project. JICA dispatched a Basic Design Study Team in May 2001 to Cambodia. The team surveyed the Project area, collected relevant data and information for the formation of the Basic Design and discussed technical aspects of the Project with the officials of authorities concerned.

1.1 Project Description

The Project for Siem Reap Generating Facilities (the Project) aims to construct;

i) a diesel power plant having total installed capacity 10.5 MW in Siem Reap with 3-units of 3,500 kW each, 2-units for regular operation and 1-unit for standby, and

ii) 22 kV underground transmission line of 1.2 km in length to connect the new diesel power plant with the existing Siem Reap distribution network.

The project site is located in the Developing Area specified in the Siem Reap City Plan prepared in 2000.

The power plant site is about 4 km east of Siem Reap city, the provincial capital of Siem Reap province, by road, which is close to the National Route No.6 that links Phnom Penh (285 km away) to Thailand (150 km away). And the most famous building Angkor Wat is 8 km northwest of the plant site.

The location map of the project site is given in the Appendix.

1.2 Rationale of the Environmental Study

The Project is not likely to cause significant impacts on the environment in and around the project area considering its development component, scale, and location. However, an Environmental Study will be required, because it has project components which may bring about adverse environmental impacts on the natural and social environment, such as installation of diesel engine unit.

Consequently, the Environmental Study (the Study) is conducted in an Initial Environmental

Impact Assessment level by focusing on one project component which might bring about adverse environmental impacts, namely the construction of a diesel power plant having total installed capacity 10.5 MW in Siem Reap

1.3 Objectives and Strategies

The principal objectives of the Study are to clarify environmental impacts caused by the diesel power plant construction in Siem Reap, to evaluate those magnitudes, and to propose countermeasures, if any. This result shall provide necessary data and information for formulation of environmentally sound project design and guide a way to cope with possible impacts for implementation of the Project.

To attain the objectives mentioned above, the following strategies are taken in the Study:

- to collect and review relevant data and documents related to environmental aspects of the Project including laws and regulations concerned in Cambodia,
- to carry out a field reconnaissance in the existing and potential project sites for checking environmental sensitivity of the Project,
- to evaluate the magnitude of impacts preliminarily and to prepare the study report.

1.4 National Policy on the Environment in Cambodia

The Government of Cambodia issued "The Law on Environmental Protection and Natural Resource Management" on January 1997.

The purposes of the law are:

- to protect [and] promote environmental quality and public health though the prevention, reduction, and control of pollution
- to assess the environmental impact of all proposed projects prior to the issuance of a decision by the Royal Government
- to ensure the rational and sustainable conservation, development, management, and use of the natural resources of the Kingdom of Cambodia
- to encourage and enable the pubic to participate in environmental protection and natural resource management
- to suppress any acts that cause harm to the environment

The environmental study is carried out based on the above Law.

2. Initial Environmental Study

2.1 Environmental Items to be Studied

Although a lot of environmental items could be picked up in accordance with the Law on Environmental Protection and Natural Resource Management for Project, most of them would not be necessary or not have significant impact due to the specific conditions of the Project in

Siem Reap.

The followings are the key points for selection of environmental items to be studied in Environmental Impact Assessment.

(1) Meteorology

The climate of the area is strongly monsoonal. The cooler dry northeast monsoon (November to March) follows after the southwest monsoon with higher winds, and humilities and most of year's rainfall. Daily mean temperatures at the Project site range from about 24 in December and January to 29 in April. Average annual rainfall is about 1400 mm.

(2) Topography and geology

The power plant site is on plains between Lake Tonle Sap (10 km to the south) and the national route No.6 some 400 m to the north.

The power plant site is located in the Development Area classified in the Siem Reap City Plan.

The plains undulate gently, ranging in elevation from 9-10 meters. The soil at and around the power plant site are alluvial silts, sand and clays deposited by flood waters from adjacent rivers an Lake Tonle Sap. Groundwater levels around the power plant site are generally high and fluctuate from close to the surface in the wet season to about 4 meter below in the dry season.

Necessary acreage of the diesel power plant would be about 19,685 m^3, with plant trees area of 20 m wide around the area. The land area of new power plant is an uncultivated field. No there are houses and other obstacles in the area. Thus, displacement of the local peoples and houses are not required for the project. This means that the environmental impacts related to the project location would not be significant, and the Project is not situated in an environmentally sensitive area.

Besides, the power plant site is at an enough distance from the main roads and houses in the vicinities. So, the environmental impacts during the construction stage could be in minimum, and no serious adverse effects are expected.

(3) Underground water

There is no permanent water supply system and body in the vicinity of the power plant site. The Project will provide a water supply system by means of a deep well pumping system in the power plant site.

Diesel power plant to be installed by the Project is a open type generator with a closed circulation radiator type cooling system. Consequently, little amount (200 - 300 litters/day) of water will be used for cooling purpose. All drainage water from the power plant should be corrected to the oil-water separator pit for processing to separate oil from water.

Therefore, water quality pollution and impact on the social environmental in the surrounding of the power plant will not be expected by the operation of the power plant.

(4) Flora and Fauna

There are rich fisheries in Lake Tonle Sap, but only very poor ones in the rice fields and irrigation canals around the Project area. The wildlife around the Project area has never been studied in detail. However, about 100 mammals and 400 bird species inhabit the general area. A number of these are on international endangered species list (17 species of endangered mammals and 24 species of endangered birds, none of which been recorded in the close vicinity of the Project area). There are no natural or near natural forests within 3 km of the Project area.

Considering the given conditions mentioned above and a general project feature, it is considered that the Project is not environmentally sensitive. The possible environmental impacts to be studied are eventually four items during the operation stage, namely;

i) Air pollution by NO_2,

ii) Air pollution by SO_2,

iii) Noise, and

iv) Vibration.

2.2 Results of Initial Environmental Examination

2.2.1 Air pollution by NO_2 and SO_2

A diesel power plant with total installed capacity of 10.5 MW (3,500 kW x 2 unit for regular operation and 1 unit for standby), will be installed in the area of the new power plant in Siem Reap. The future NO_2 and SO_2 concentration is predicted by Sutton's formula as shown in Table-1.

(1) Prediction of NO_2

Air quality standards of NO_2 concentration in Japan, USA and Cambodia shown below. The maximum ground concentration of NO_2 would appear at the point of 1,116 m apart from the pollution source as shown in Table-2 and summarized below.

(One hour mean value)

Air Quality Standards		Predicted Value
Japan	0.082-0.123 mg/m^3	0.0274 mg/m^3
USA	0.102 mg/m^3	
Cambodia	0.300 mg/m^3	

NO_2 concentration is expected to increase about 0.0274 mg/m^3 by the Project. The predicted NO_2 value would be fairly below compared with these standards. The background NO_2 level around the project site is considered as a natural condition because there are no large scale point sources of air pollution. Thus, no significant environmental impact on air quality would be expected by NO_2 emission from the power plant.

(2) Prediction of SO_2

Air quality standards of SO_2 concentration in Japan, USA and Cambodia shown below. The maximum ground concentration of SO_2 would appear at the point of 1,116 m apart from the pollution source as shown in Table-2 and summarized below.

(One hour mean value)

Air Quality Standards		Predicted Value
Japan	0.114 mg/m^3	0.0200 mg/m^3
USA	0.362 mg/m^3	
Cambodia	0.500 mg/m^3	

SO_2 concentration is expected to increase about 0.0200 mg/m^3 by the Project. The predicted SO_2 value would be fairly below compared with these standards. The background SO_2 level around the project site is considered as a natural condition because there are no large scale point sources of air pollution. Thus, no significant environmental impact on air quality would be expected by SO_2 emission from the power plant.

2.2.2 Noise caused by the Operation of Diesel Power Generator

(a) Prediction Point

Two prediction points of noise are set on a line from the noise source (newly installed power plant) to a boundary of the plant site (about 60 m in distance) and other is the nearest house (about 100 m in distance) as shown in Table-3.

(b) Noise Level of the Power Plant

According to the general specification of a diesel power plant with capacity of regular operation (3,500 kW x 2 units), its noise level is 97.9 dB compounded with exhaust gas outlet, intake air filter, and radiator at the adjacent place of a plant as shown in Table-3.

(c) Prediction Noise Level

The prediction noise level at the prediction points by the operation of power plant is shown in Table-3 and summarized below:

	Noise Level (dB(A))		
Noise Source	Plant Site	Site Boundary (60 m)	Nearest House (100m)
Power Plant	97.9dB(A)	54.3 dB(A)	49.9dB(A)

(d) Evaluation

The future noise level caused by the operation of the newly installed power plant is assessed about 54.3 dB(A) at the site boundary and 49.9 dB(A) at the nearest house. It should be noted that the actual future noise level could be less than those of predicted level, because the existence of administration office, oil tanks, plant tree area and ground undulation in the

project site will reduce the noise level.

Table-5 shows general criteria related to noise. The assessed noise level could be almost a background noise level in common residential area. Moreover, no facilities which require calm conditions such as school, hospitals, and libraries are situated around the power plant site.

Therefore, relatively low magnitude of impact would be expected by the operation of the installed power plant.

2.2.3 Vibration caused by the Operation of Diesel Power Generator

(a) Prediction point

Vibration basically considered an annoying source for human which has the same origin and characteristic as noise. Therefore, the prediction of vibration level caused by the newly installed power plant is conducted taking similar approach used for the noise level prediction. Thus, the prediction point of vibration is the nearest house the same as noise (about 100 m in distance from Power plant).

(b) Vibration level of the Power Plant

The prediction result of vibration level at the prediction points by the operation of power plants is show in Table-4 and summarized below:

Noise Source	Plant Site	Site Boundary	Nearest House (100m)
Power Plant	83.0dB(A)	25.2 dB(A)	39.1dB(A)

(c) Evaluation

Table-6 shows general criteria related to vibration. The vibration level at the prediction points is very low, and these vibration values would be negligible for the most person. Therefore, no serious impact is expected by the operation of the newly installed diesel power plant.

3. Conclusion and Recommendation

3.1 Conclusion

Displacement of the local peoples and houses in the project area are not required. Water quality pollution and impact on the social environmental in the surrounding of the power plant will not be expected by the operation of the power plant as discussed in Section 2.1.

Minimal impacts are predicted during the project construction, provided that good construction standards and procedure are adopted under the contractual guarantees with contractors.

Eventually, four environmental items, namely i) NO_2, ii) SO_2, iii) Noise, and iv) Vibration, are selected as the principal subjects to be studied carefully considering feature and location of the Project.

The Environmental Study of the selected four items revealed that relatively low magnitude of impacts would be expected and no significant impacts be caused by the Project. Moreover, no complaints related to the environment could be found through the inquiry survey to the local people who live around the existing plant. Therefore, the Project is judged acceptable and no mitigation measure is required from the environmental viewpoints, conclusively at this stage.

3.2 Recommendation

Since no actual data of air quality, noise, and vibration are available in this Study, the verification of prediction results is crucial. To monitor and check the assessed values surely contributes to improve an assessment method in accuracy and to strengthen an environmental management capability of EDC's staff.

Table – 1 Calculation of Pollution Intensity of NOx and SOx

A diesel power plant with 10.5 MW (3,500 kW x 2 units for regular operation and 1 unit for standby) will be installed in the area of the new power plant in Siem Reap

Output	: 3,500kW/unit
Fuel consumption	: 189 g/kWh (Heavy oil)
Sulfur content	: 2 %
Intensity of the pollution source (Nm^3/s)	: 22,500Nm^3／h（wet）、21,300Nm^3／h（dry）
Height of emission outlet	: GL+15m,750A(ID=753mm)

The future NOx and SOx concentration is predicted by following Sutton's formula;

$$C(X)= (2Q/(\pi \cdot C_y \cdot C_z \cdot U \cdot x^{2-n})) \exp(-He^2/(Cz^2 \cdot x^{2-n})) \cdot 10^6$$

where

C(X)	:	Ground surface concentration at a point of X (m) apart from the pollution source (ppm),
x	:	Distance of leeward direction (m),
Q	:	Intensity of the pollution source (m^3/s),
U	:	Wind velocity (m/s), (applied 6.0 m/s),
Cz, Cy, n	:	Sutton's concentration parameter, Cz=0.07, Cy=0.07/0.15, n=0.25
He	:	Effective height of emission outlet (m), (applied 32.6m)

He = Ho+0.65(Hm+Ht)

Hm = $0.795\sqrt{Q'} \cdot V／(1+2.58／V)$

Ht = $2.01\times10^{-3}\times Q'\times(T-288)\times(2.30\log(J)+1/J-1)$

J = $1／\sqrt{Q'} \cdot V \cdot (1460－296V／(T-288))+1$

Ho : Actual height of emission outlet(m), (15m)

Q' : Intensity of the pollution source (15℃1atm,m^3/s),

V : Ex.Gas Velocity

thus

V = $22,500\times1／3600\times(273+365)／273／(\pi／4\times0.753^2)$
= 32 [m/s]

Q' = $22500\times1／3600\times288／273$
= 6.59 [m^3/s]

J = $1／\sqrt{6.59 \cdot 32} \cdot (1460-296\times32／(273+365-288))+1$
= 98.7

Hm = $0.795\times\sqrt{6.59 \cdot 32}／(1+2.58/32)$
= 10.6 [m]

Ht = $2.01\times10^{-3}\times6.59\times(273+365-288)\times(2.30\log98.7+1／98.7-1)$

$= 16.6$ [m]

He $= 15+0.65\times(10.6+16.6)$

$= 32.6$ [m]

Q $= 500\times10^{-6}\times21{,}300\times1/3600\times288/273$

$= 3.12\times10^{-3}$ [m^3/s] (SOx)

Q $= 950\times10^{-6}\times21{,}300\times1/3600\times288/273$

$= 5.93\times10^{-3}$ [m^3/s] (NOx)

Max ground surface concentration is calculated as follows:

Cmax : Max ground surface concentration

$= 1.72\times Q''/He^2$ [ppm]

Xmax : Distance between at a point of max ground surface concentration and the pollution source

$= 20.8\times He^{1.143}$ [m]

thus

SOx : Cmax $= 1.72\times21{,}300\times500\times10^{-6}/32.6^2$

$= 0.0172$ [ppm] $= 0.0491$ [mg/m^3]

NOx : Cmax $= 1.72\times21{,}300\times950\times10^{-6}/32.6^2$

$= 0.0327$ [ppm] $= 0.0672$ [mg/m^3]

Xmax $= 20.8\times32.6^{1.143} = 1116$ [m]

Above ground surface concentration show 3 minutes mean concentration. So one (1) hour mean concentrations are shown below;

Cmax(SOx 1hour) $= 0.0200$[mg/m^3]at 15℃

Cmax(NOx 1hour) $= 0.0274$[mg/m^3]at 15℃

The result of prediction is indicated in Table.2.

Table 2 (1)

Distance	Ground surface concentration			
X	NOx		SOx	
m	ppm	mg/m^3	ppm	mg/m^3
100	0.0000	0.0000	0.0000	0.0000
200	0.0000	0.0000	0.0000	0.0000
300	0.0000	0.0001	0.0000	0.0001
400	0.0013	0.0026	0.0007	0.0019
500	0.0060	0.0124	0.0032	0.0091
600	0.0134	0.0276	0.0071	0.0202
700	0.0208	0.0426	0.0109	0.0312
800	0.0264	0.0542	0.0139	0.0397
900	0.0301	0.0617	0.0158	0.0452
1000	0.0320	0.0657	0.0168	0.0481
1100	0.0327	0.0671	0.0172	0.0491
1116	0.0327	0.0671	0.0172	0.0491
1200	0.0325	0.0667	0.0171	0.0488
1300	0.0317	0.0651	0.0167	0.0476
1400	0.0306	0.0628	0.0161	0.0459
1500	0.0293	0.0601	0.0154	0.0440
1600	0.0279	0.0572	0.0147	0.0419
1700	0.0264	0.0543	0.0139	0.0398
1800	0.0251	0.0515	0.0132	0.0377
1900	0.0237	0.0487	0.0125	0.0356
2000	0.0224	0.0460	0.0118	0.0337
2500	0.0171	0.0350	0.0090	0.0256
3000	0.0133	0.0272	0.0070	0.0199
3500	0.0106	0.0217	0.0056	0.0159
4000	0.0086	0.0177	0.0045	0.0129
5000	0.0060	0.0124	0.0032	0.0091
6000	0.0045	0.0092	0.0024	0.0067
7000	0.0035	0.0071	0.0018	0.0052
8000	0.0028	0.0057	0.0015	0.0041
9000	0.0023	0.0046	0.0012	0.0034
10000	0.0019	0.0039	0.0010	0.0028

Table2(2) The result of ground surface concentration prediction

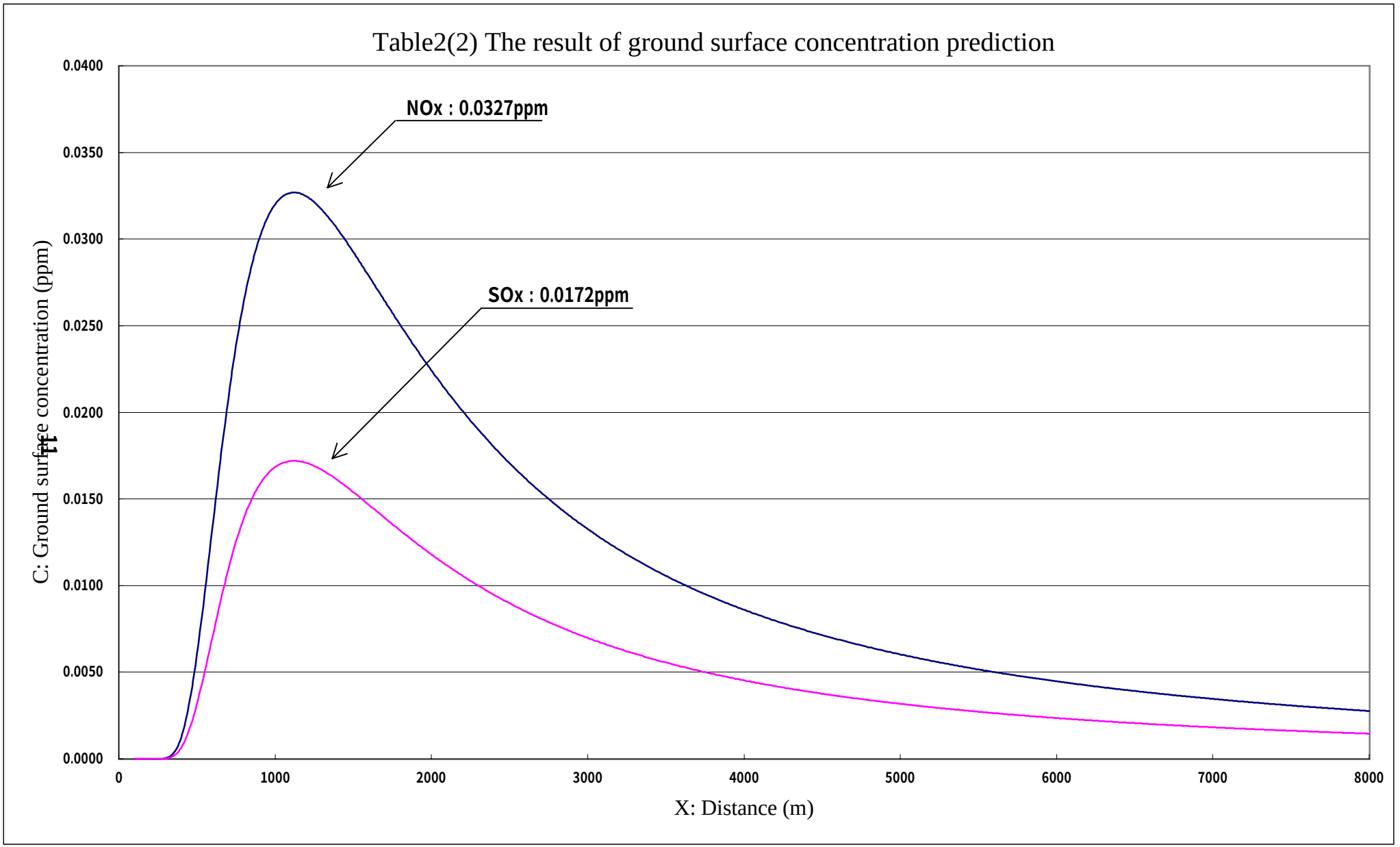


Table – 3 Calculation of Noise Level

According to the general specification of a diesel power plant with capacity of 3,500 kW, its noise level are shown below.

・Noise level at the power house :90dB(A)

・Noise level at Ex.Gas outlet :90dB(A)

・Noise level at Intake air filter :80dB(A)

・Noise level at Radiator :90dB(A)

The combined noise level of the above component is calculated below formula;

Lp =10log(Σ {10^(Li/10)})

$=10\log(10^{90/10}+10^{90/10}+10^{80/10}+10^{90/10})$

= 94.9 dB(A)

where

Lp : Compound noise level of above component (unit noise level)

Li : Noise level by above each component

Thus, the noise level of the regular operation (3,500 kW x 2 units) is estimated 97.9 dB by compounding the unit noise level at the power plant based on the following compound formula:

Lw =10log(Σ {10^(Lp/10)})

= 97.9 dB(A)

The noise levels at the selected prediction points of site boundary (60 m) and the nearest house (100 m) are assessed by the following logical formula of propagation;

L =Lw-20logR-8

L_{60} =54.3 dB(A) at the site boundary, and

L_{100} =49.9 dB(A) at the nearest house.

Where

L : Noise level at the selected prediction point

Lw : Noise level of the source (94.9dB(A))

R : distance from noise source to prediction point (100m)

Table – 4 Calculation of Vibration Level

According to the general specification of a diesel power plant with capacity of 3,500 kW, its init vibration level should be less 80 dB at the adjacent place of a plant. Thus the vibletion level of the pollution source is estimated 83 dB(A)by compounding the unit noise level for the regular operation (3,500 kW x 2 units) of the power plant based on the following compound formula..

VLo =10log(Σ {10^(Li/10)})

= 83.0 dB(A)

where

VLo : Compound unit noise level (noise level of power plant)

Li : Unit noise level

Since the vibration propagated though the ground as a medium, the following logical formula of propagation is applied for the prediction of the vibration level at the prediction points caused by the operation of power plant.

VL =VLo – 20log(R/Ro)^n – 8.7*(R – Ro)*2

VL_{60} = 39.1 dB(A)

VL_{100} = 25.2 dB(A)

Where:

VL : Vibration level at the prediction point of “R” m apart from the point of VLo (dB),

VLo : vibration level at the point of “Ro” m apart from the source (dB),

R : Distance from the point of VLo to ther source,

Ro : Distance from the point of VLo to its source (= 1 m)

n Damped coefficient of ground (= 0.8),

a Damped coefficient of ground friction (= 0.03).

Table – 5 Provisional Conservation Criteria Related to Noise

Noise	
Level (dB(A))	Description
80	Air craft on taking off or landing
75	Indoor of a noisy factory
70	Ringing telephone
65	Indoor or an action-movie theater
60	Indoor of a noisy office
55	Background level in a common residence area
50	Indoor of a school or calm office
45	Indoor of a library

Table – 6 Provisional Conservation Criteria Related to Vibration

Vibration	
Level (dB(A))	Description
>75	Quaking houses, clattering doors and windows
70	Tangible for most person and awaking from deep sleep
65	Tangible for most person and awaking from light sleep
60	Tangible for most person in walking but not awaking from deep sleep
55	Tangible only for person in standing but no influence to sleep
<50	Intangible for most person