

## 追加調査

**Minutes of Discussions  
on the Supplemental Field Survey on the Project for  
Rehabilitation of Monrovia Power System  
in the Republic of Liberia**

In response to the request from the Government of the Republic of Liberia, the Japan International Cooperation Agency (hereinafter referred to as "JICA"), in consultation with the Government of Japan, decided to conduct a Supplemental Field Survey (hereinafter referred to as "the Survey") on the Project for Rehabilitation of Monrovia Power System (hereinafter referred to as "the Project").

JICA sent to the Republic of Liberia a Supplemental Field Survey Team (hereinafter referred to as "the Team"), headed by Mr. Kyoji FUJII, Chief Consultant, Yachiyo Engineering Co., Ltd. The Team is scheduled to stay in the country from August 7th to 10th, 2012.

The Team held discussions with the officials of concerned authorities in Liberia (hereinafter referred to as "the Liberian side"). In the course of the discussions, both sides have confirmed the main items described in the sheets attached hereto.

Monrovia, August 10th, 2012

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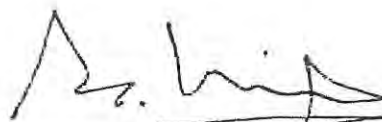
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Mr. Kyoji Fujii  
Chief Consultant  
JICA Preparatory Survey Team  
Yachiyo Engineering Co., Ltd.



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Hon. Patrick Sendolo  
Minister  
Ministry of Lands, Mines and Energy



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Mr. Shahid Mohammed 08/2012  
Chief Executive Officer  
Liberia Electricity Corporation

## ATTACHMENT

### 1. Revision of requested components from the Liberian side

The following (1) to (3) are the final items requested from the Liberian side confirmed on the minutes of discussions signed on January 26<sup>th</sup>, 2012.

- (1) Installation of 2x5 MW HFO-fired medium speed diesel generators and construction of new power house in existing Bushrod Power Plant
- (2) Construction of new substation in existing Bushrod Power Plant to include the following items
  - One (1) 15 MVA 22/66 kV transformer
  - Six (6) 22 kV switchgear
- (3) Supply of maintenance vehicles
  - Five (5) special purpose/dedicated crew trucks/lorries
  - One (1) bucket truck
  - One (1) pole construction truck
  - Two (2) 2.9 ton crane trucks

After the signing of the minutes of discussions, the Liberian side revised its Electric Master Plan (EMP) in June 2012 so as to incorporate the latest progress of power development and the commitment of donor assistance into the plan. In light of the change in the EMP, the Liberian side requested the Japanese side to delete the above item (2), i.e., construction of new substation in existing Bushrod Power Plant including one (1) 15 MVA 22/66 kV transformer and six (6) 22 kV switchgears from its final request. The Liberian side also requested the Japanese side to change the step up voltage of 2x5MW diesel generators from 66/6.6kV to 66/22kV in accordance with the EMP. The Team confirmed the technical appropriateness of the requests from the Liberian side and accepted them. The revised scope and design of the Project is shown in Annex-1. The change in the scope and design will be incorporated into the outline design of the Project. The revision leads the delay in forthcoming cabinet approval, etc. at least 2 months. Liberian side agreed that.

### 2. Schedule of other donor's assistance

The above mentioned revision of scope necessitates the procurement and installation of 66kV and 22kV substation facilities which other donor's assistance is expected. The Liberian side shall complete such substation works by the end of September 2014.

### 3. Installation area for new diesel generators

The Liberian side shall take necessary measures to prevent interference of installation areas for new 66/22kV substation facilities (other donor) and 2x5MW diesel generators under Japan's grant aid.

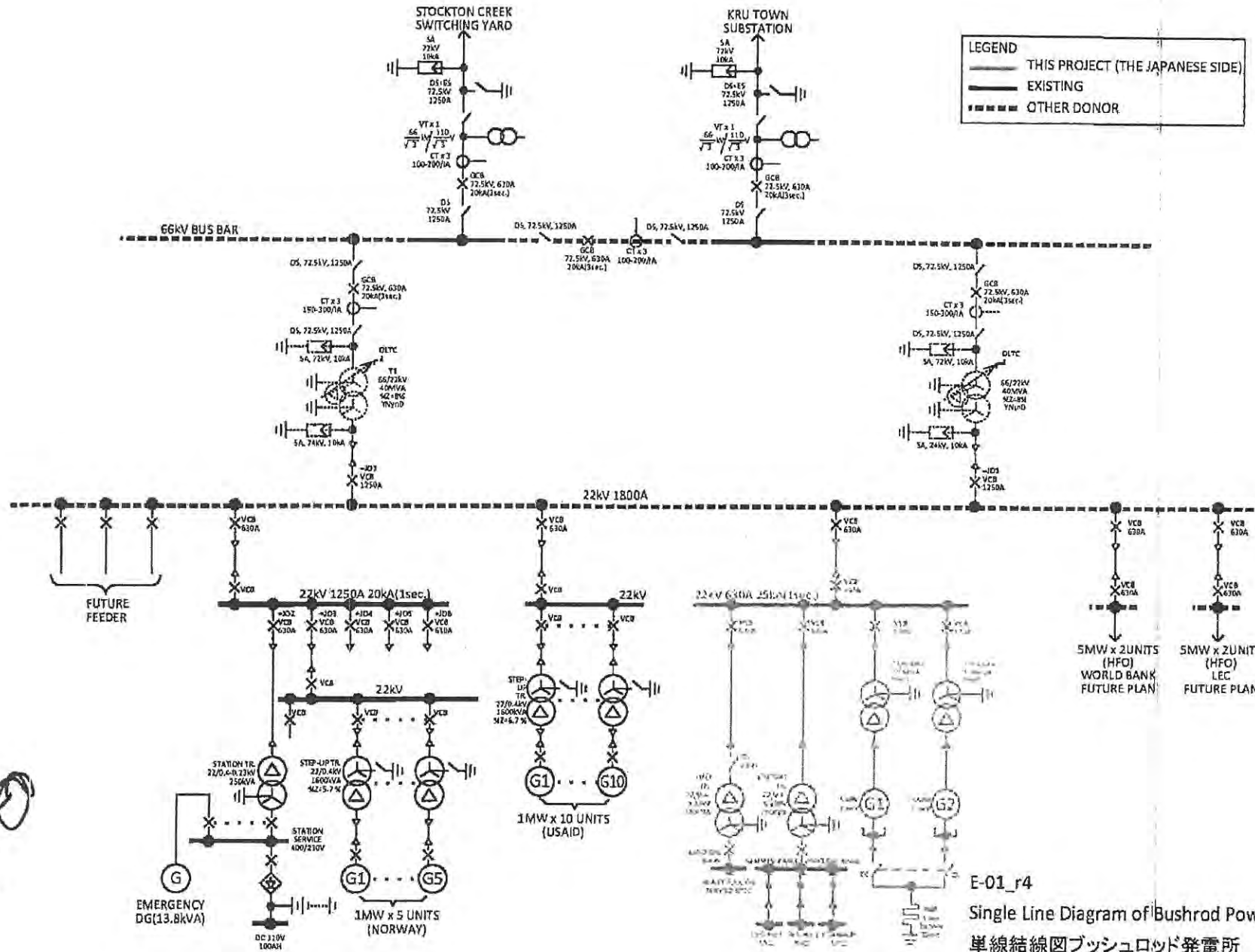
### 4. Environmental and social considerations

The Liberian side commenced the Environment Impact Assessment for new heavy fuel oil fired diesel generating plants which are to be financed by the Liberian government, the World Bank and the government of Japan and will be completed by April, 2013.

(End)

Annex-1 Single line diagram of Bushrod power station

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E-01\_r4

Single Line Diagram of Bushrod Power Station  
 単線結線図ブッシュロッド発電所

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## DBD 調査

**Minutes of Discussions  
on the Preparatory Survey on the Project for  
Rehabilitation of Monrovia Power System  
in the Republic of Liberia  
(Explanation on Draft Final Report)**

In response to the request from the Government of the Republic of Liberia, the Japan International Cooperation Agency (hereinafter referred to as "JICA"), in consultation with the Government of Japan, decided to conduct a Preparatory Survey (hereinafter referred to as "the Survey") on the Project for Rehabilitation of Monrovia Power System (hereinafter referred to as "the Project").

JICA conducted a first field survey from September 14th to 28th, 2011. Second field survey was conducted from January 10th to February 5th, 2012. Supplemental survey was conducted from August 7th to 10th, 2012. Through discussions, field surveys and the result of technical examination in Japan, JICA prepared a Draft Final Report of the Survey.

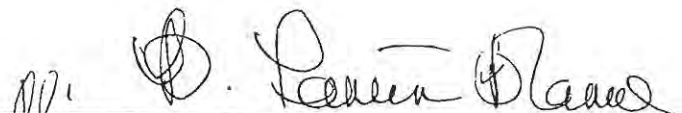
In order to explain and to consult with the officials of concerned authorities in Liberia (hereinafter referred to as "the Liberian side") on the contents of the Draft Final Report, JICA dispatched to Liberia the Preparatory Survey Team for Draft Final Report Explanation (hereinafter referred to as "the Team"), which is headed by Mr. Fuyuki SAGARA, Deputy Resident Representative, JICA Ghana Office. The Team is scheduled to stay in Liberia from October 16th to 26th, 2012.

The Team held discussions with the Liberian side. As a result of the discussions, both sides have confirmed the main items described in the sheets attached hereto.

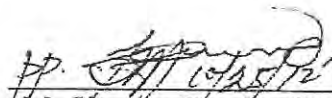
Monrovia, October 25th, 2012



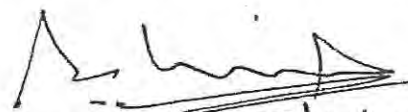
Mr. Fuyuki SAGARA  
Leader  
Preparatory Survey Team  
Japan International Cooperation Agency



Mr. Patrick Sendolo  
Minister  
Ministry of Lands, Mines and Energy



Mr. Yaneon-Dargbe Nimley  
Assistant Minister for Economic Cooperation  
and Integration  
Ministry of Planning and Economic Affairs



Mr. Shahid Mohammed  
Chief Executive Officer  
Liberia Electricity Corporation

## ATTACHMENT

### 1. Objective of the Project

The objective of the Project is to ensure the continuous supply of electric power to most part of Monrovia.

### 2. Project Site

The Project site is located in Monrovia City as shown in Annex-1.

### 3. Contents of the Draft Final Report

The Liberian side agreed and accepted in principle the contents of the Draft Final Report and the Draft Technical Specifications of the Survey explained by the Team.

### 4. Responsible and Implementing Organization

- (1) The responsible ministry is the Ministry of Lands, Mines and Energy (MLME).
- (2) The implementing organization is the Liberia Electricity Corporation (LEC).
- (3) The Organization Structure of LEC is shown in Annex-2.

### 5. Components of the Project

The following are selected as the Project Components.

- (1) Installation of 2x5 MW Heavy Fuel Oil (HFO)-fired medium speed diesel generators
- (2) Construction of new power house in existing Bushrod Power Plant
- (3) Supply of maintenance vehicles
  - Five (5) special purpose/dedicated crew trucks/lorries
  - One (1) bucket truck
  - One (1) pole construction truck
  - Two (2) 2.9 ton crane trucks

### 6. Confidentiality of the Project

#### (1) Project Cost

The Team explained the estimated cost of the Project as described in Annex-3. The Liberian side also agreed that the cost for the Project contains procurement cost of equipment, construction cost of facility, transportation cost up to the Project site, installation cost and the Consultant fees.

The Liberian side agreed that the cost for the Project should not exceed the amount agreed on the Exchange of Notes (E/N) to be signed between the governments. The Liberian side understood that the estimated cost for the Project attached as Annex-3 is not the final and is subject to change as a result of the detailed design to be implemented after the E/N.

#### (2) Detailed specifications of the Facilities and Equipment

Both sides agreed that all the information related to the Project including the estimated cost, detailed drawings and specifications of the facilities and equipment, and other technical information shall not be disclosed to any outside parties (i.e. outside of JICA and the Liberian side) before the conclusion of all contract(s) for the Project.

### 7. Possibility of Change in Scope, Schedule and Cost of the Project

The Team stressed that the scope, the schedule, and the cost for the Project are tentative and subject to change due to the domestic circumstances in Japan and in Liberia. The Liberian side understood it.



## 8. Japan's Grant Aid Scheme

- (1) JICA confirmed that the Liberian side understood Japan's Grant Aid Scheme explained by the Team as described in Annex-4 and 5.
- (2) The Liberian side will take the necessary measures, as described in Annex-6, for smooth implementation of the Project as prerequisites for the Japan's Grant Aid to be implemented.

## 9. Other Relevant Issues

### (1) Coordination among relevant projects

The Team requested the Liberian side to ensure coordination among following projects for smooth implementation of the Project.

- a) The project by World Bank, which is to rehabilitate HFO storage facilities and to install 10MW HFO-fired generator in Bushrod power plant.
- b) The project by LEC own fund, which is to install 10MW HFO-fired generator in Bushrod power plant.
- c) The project by private company, which is to rehabilitate HFO unloading and transfer facilities.
- d) The project by Norway, which is to procure and to install 66kV and 22kV substation facilities by the end of January 2014.

The Liberian side realized that it is critical to implement the project by Norway on schedule for the Project. The Liberian side accepted to provide the Team with information regarding the construction schedule, commissioning date and specification of equipment of the above projects. The Team and the Liberian side agreed the facility plan of each 10MW generator in Bushrod power plant as Annex-7.

### (2) Operation and Maintenance Cost

The Team emphasized it is essential that the Liberian side ensures to constantly secure the necessary budget for operation and maintenance including major overhauls, of equipment to be procured under the project, to ensure long-term stable power supply. The Liberian side has fully understood and shared the same view.

### (3) Customs and Tax exemption

The Liberian side understood that it shall be fully responsible on exemption of taxes, custom duties and any other levies imposed in the Republic of Liberia, in case the Project is implemented.

### (4) Operation and Maintenance system of new facilities

The Team emphasized that the allocation of enough number of qualified engineers and skilled technicians for operating and maintaining the new facilities is a prerequisite to implement the Project. The Liberian side understood the prerequisite.

### (5) Counterpart Personnel

The Team requested the Liberian side that the necessary number of counterpart personnel shall be assigned to the Team and the necessary arrangements with related organizations be made during implementing stage in Liberia. The Liberian side has agreed to follow the request.

### (6) Environmental and Social Considerations

- a) The Team requested the Liberian side to conduct the required environmental procedures, and obtain approval on environmental clearance for implementation of the Project.
- b) The Liberian side agreed to comply with the JICA Guidelines for Environmental and Social Considerations (hereinafter referred to as "JICA Guidelines") as well as laws and regulations in Liberia, and was requested to prepare Environmental Checklist and Monitoring Form which are designated by JICA Guidelines for an outline design.
- c) The Liberian side agreed to complete the Environment Impact Assessment for new heavy fuel oil fired diesel generating plants which are to be financed by the Liberian government, the World Bank and the government of Japan will be completed by April,



2013.

(End)

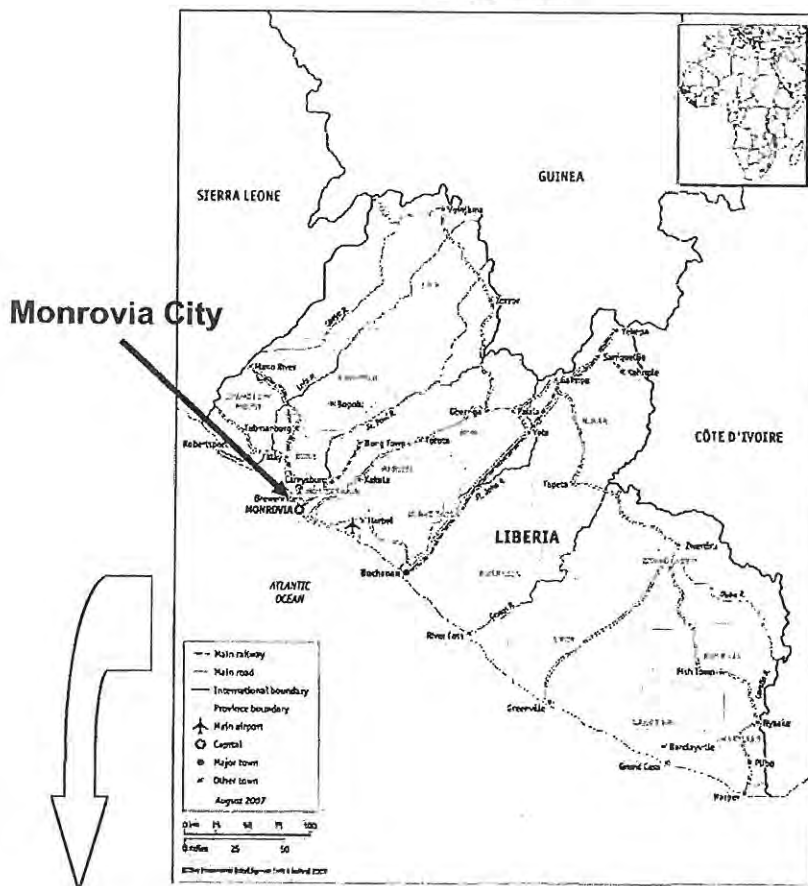
- Annex-1 Project Site
- Annex-2 Organization Chart of LEC
- Annex-3 Estimated Project Cost (Confidential)
- Annex-4 Japan's Grant Aid
- Annex-5 Flow Chart of Japan's Grant Aid Procedures
- Annex-6 Major Undertakings to be taken by Each Government
- Annex-7 Facility plan in Bushrod power plant

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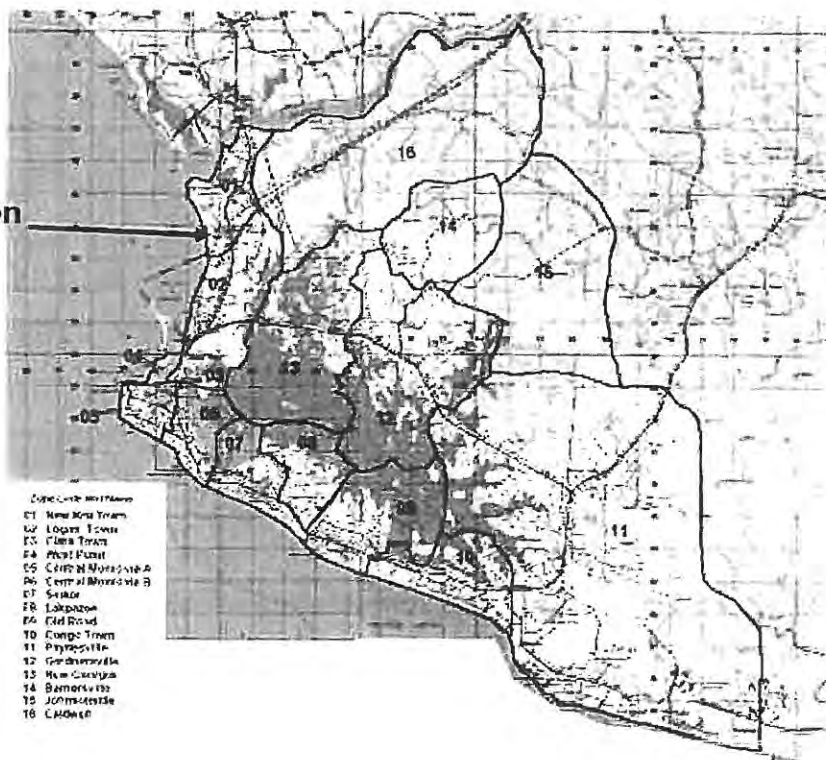
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Project Site



Bush rod Power Station

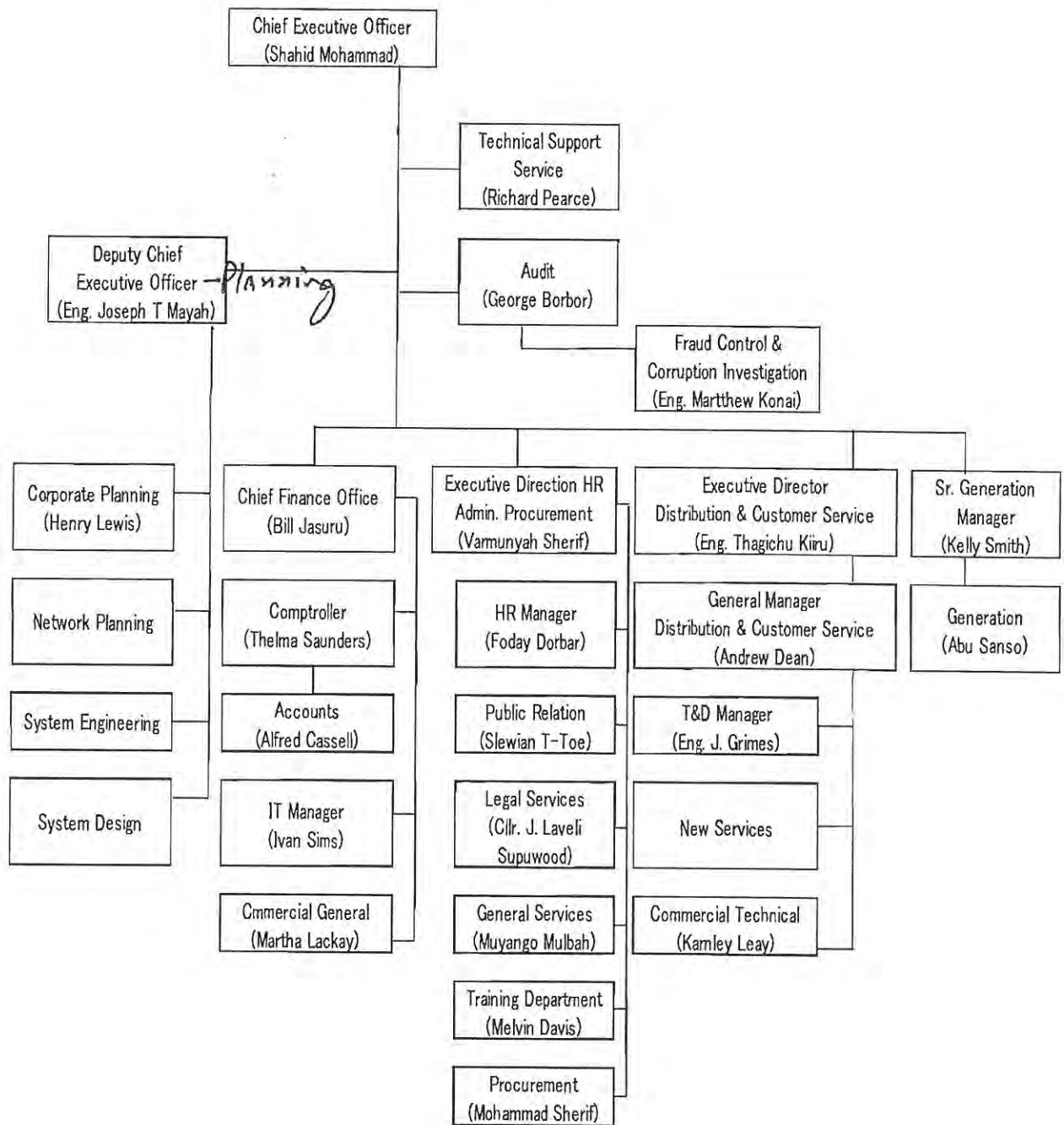


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Organization Chart of LEC



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(Confidential)  
Estimated Project Cost

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## Japan's Grant Aid

The Government of Japan (hereinafter referred to as "the GOJ") is implementing the organizational reforms to improve the quality of ODA operations, and as a part of this realignment, a new JICA law was entered into effect on October 1, 2008. Based on this law and the decision of the GOJ, JICA has become the executing agency of the Grant Aid for General Projects, for Fisheries and for Cultural Cooperation, etc.

The Grant Aid is non-reimbursable fund provided to a recipient country to procure the facilities, equipment and services (engineering services and transportation of the products, etc.) for its economic and social development in accordance with the relevant laws and regulations of Japan. The Grant Aid is not supplied through the donation of materials as such.

### 1. Grant Aid Procedures

The Japanese Grant Aid is supplied through following procedures :

- Preparatory Survey
  - The Survey conducted by JICA
- Appraisal & Approval
  - Appraisal by the GOJ and JICA, and Approval by the Japanese Cabinet
- Authority for Determining Implementation
  - The Notes exchanged between the GOJ and a recipient country
- Grant Agreement (hereinafter referred to as "the G/A")
  - Agreement concluded between JICA and a recipient country
- Implementation
  - Implementation of the Project on the basis of the G/A

### 2. Preparatory Survey

#### (1) Contents of the Survey

The aim of the preparatory Survey is to provide a basic document necessary for the appraisal of the Project made by the GOJ and JICA. The contents of the Survey are as follows:

- Confirmation of the background, objectives, and benefits of the Project and also institutional capacity of relevant agencies of the recipient country necessary for the implementation of the Project.
- Evaluation of the appropriateness of the Project to be implemented under the Grant Aid Scheme from a technical, financial, social and economic point of view.
- Confirmation of items agreed between both parties concerning the basic concept of the Project.
- Preparation of a basic design of the Project.

- Estimation of costs of the Project.

The contents of the original request by the recipient country are not necessarily approved in their initial form as the contents of the Grant Aid project. The Basic Design of the Project is confirmed based on the guidelines of the Japan's Grant Aid scheme.

JICA requests the Government of the recipient country to take whatever measures necessary to achieve its self-reliance in the implementation of the Project. Such measures must be guaranteed even though they may fall outside of the jurisdiction of the organization of the recipient country which actually implements the Project. Therefore, the implementation of the Project is confirmed by all relevant organizations of the recipient country based on the Minutes of Discussions.

#### (2) Selection of Consultants

For smooth implementation of the Survey, JICA employs (a) registered consulting firm(s). JICA selects (a) firm(s) based on proposals submitted by interested firms.

#### (3) Result of the Survey

JICA reviews the Report on the results of the Survey and recommends the GOJ to appraise the implementation of the Project after confirming the appropriateness of the Project.

### 3. Japan's Grant Aid Scheme

#### (1) The E/N and the G/A

After the Project is approved by the Cabinet of Japan, the Exchange of Notes (hereinafter referred to as "the E/N") will be signed between the GOJ and the Government of the recipient country to make a pledge for assistance, which is followed by the conclusion of the G/A between JICA and the Government of the recipient country to define the necessary articles to implement the Project, such as payment conditions, responsibilities of the Government of the recipient country, and procurement conditions.

#### (2) Selection of Consultants

In order to maintain technical consistency, the consulting firm(s) which conducted the Survey will be recommended by JICA to the recipient country to continue to work on the Project's implementation after the E/N and G/A.

#### (3) Eligible source country

Under the Japanese Grant Aid, in principle, Japanese products and services including transport or those of the recipient country are to be purchased. When JICA and the Government of the recipient country or its designated authority deem it necessary, the Grant Aid may be used for the purchase of the products or services of a third country. However, the prime contractors, namely, constructing and procurement firms, and the prime consulting firm are limited to "Japanese nationals".



(4) Necessity of "Verification"

The Government of the recipient country or its designated authority will conclude contracts denominated in Japanese yen with Japanese nationals. Those contracts shall be verified by JICA. This "Verification" is deemed necessary to fulfill accountability to Japanese taxpayers.

(5) Major undertakings to be taken by the Government of the Recipient Country

In the implementation of the Grant Aid Project, the recipient country is required to undertake such necessary measures as Annex-6.

(6) "Proper Use"

The Government of the recipient country is required to maintain and use properly and effectively the facilities constructed and the equipment purchased under the Grant Aid, to assign staff necessary for this operation and maintenance and to bear all the expenses other than those covered by the Grant Aid.

(7) "Export and Re-export"

The products purchased under the Grant Aid should not be exported or re-exported from the recipient country.

(8) Banking Arrangements (B/A)

a) The Government of the recipient country or its designated authority should open an account under the name of the Government of the recipient country in a bank in Japan (hereinafter referred to as "the Bank"). JICA will execute the Grant Aid by making payments in Japanese yen to cover the obligations incurred by the Government of the recipient country or its designated authority under the Verified Contracts.

b) The payments will be made when payment requests are presented by the Bank to JICA under an Authorization to Pay (A/P) issued by the Government of the recipient country or its designated authority.

(9) Authorization to Pay (A/P)

The Government of the recipient country should bear an advising commission of an Authorization to Pay and payment commissions paid to the Bank.

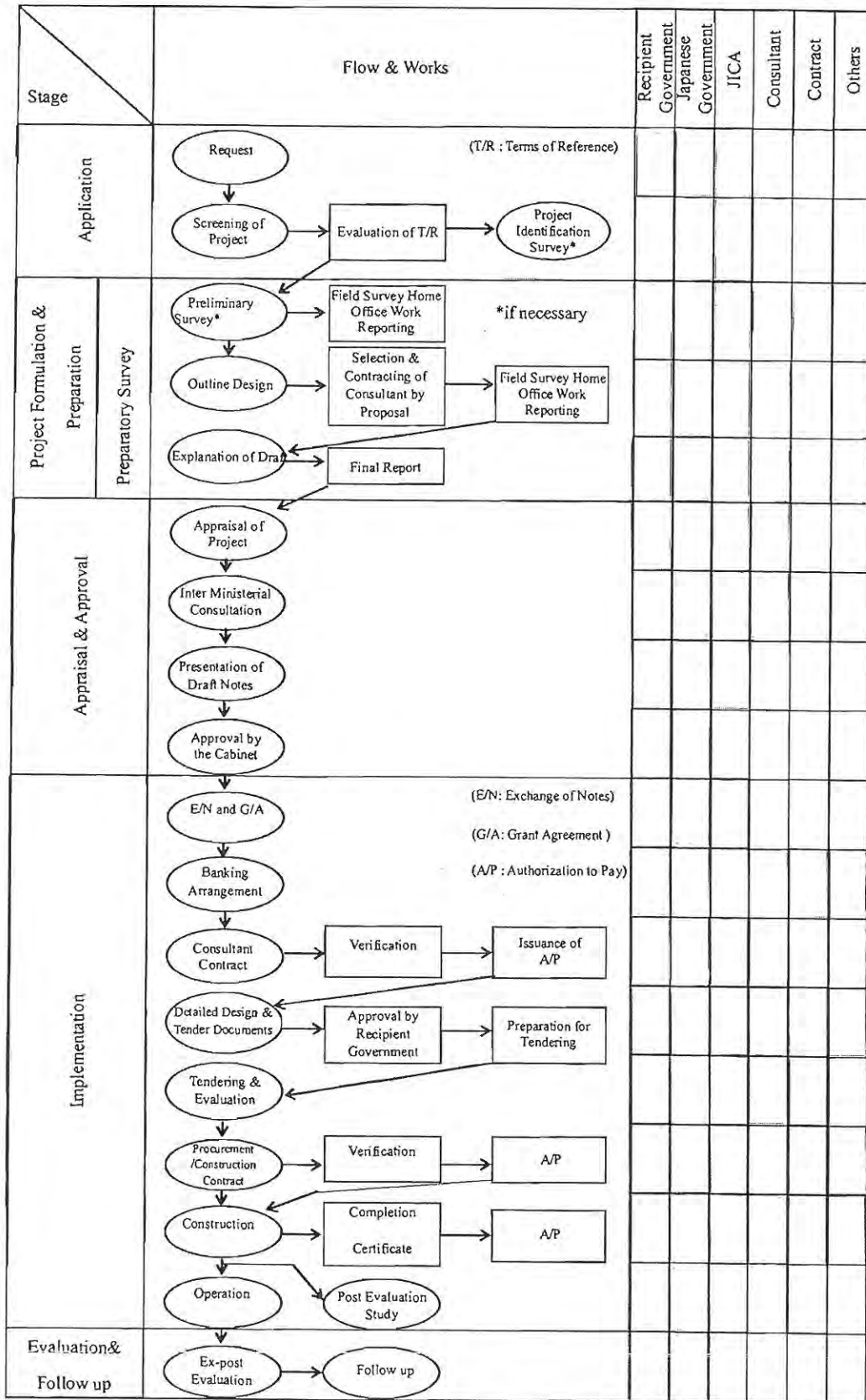
(10) Social and Environmental Considerations

A recipient country must carefully consider social and environmental impacts by the Project and must comply with the environmental regulations of the recipient country and JICA socio-environmental guidelines.

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**Flow Chart of Japan's Grant Aid Procedures**



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## Major undertakings to be taken by each Government

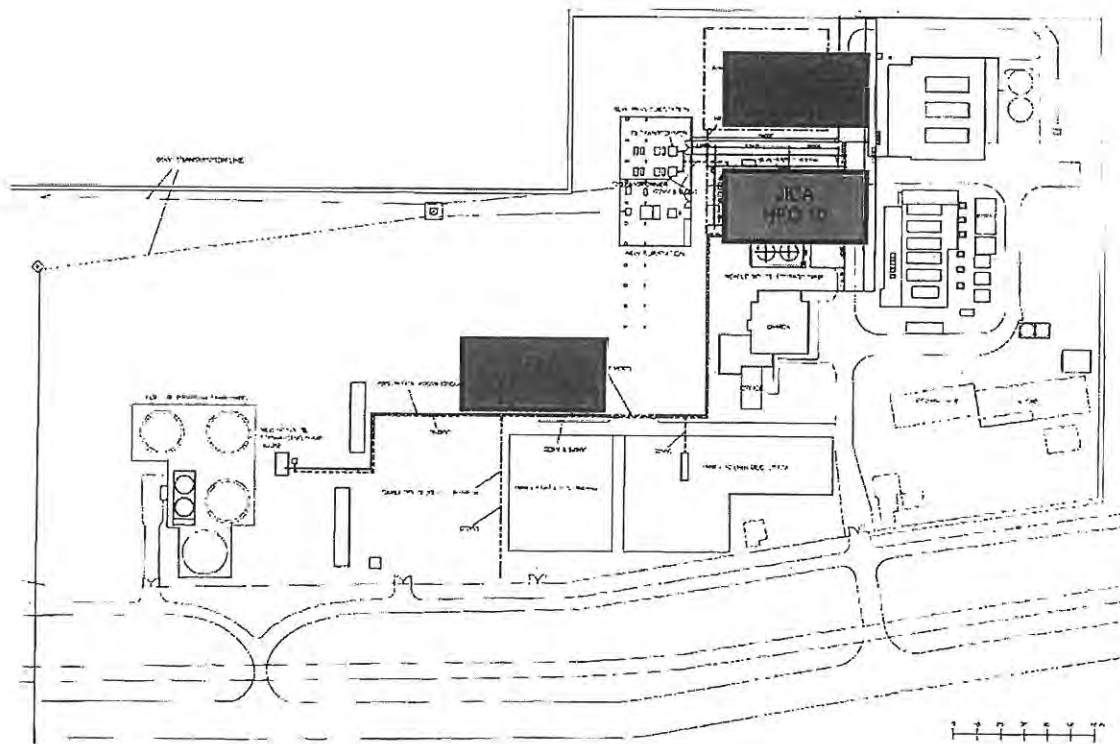
No.	Items	To be covered by Grant Aid	To be covered by Recipient Side
1	to secure [a lot] /[lots] of land necessary for the implementation of the Project and to clear the [site]/[sites];		•
2	To construct the following facilities		
	1) The building	•	
	2) The gates and fences in and around the site		•
	3) The parking lot	•	
	4) The road within the site	•	
	5) The road outside the site		•
3	To provide facilities for distribution of electricity, water supply and drainage and other incidental facilities necessary for the implementation of the Project outside the [site]/[sites]		
	1) Electricity		
	a. The distributing power line to the site		•
	b. The drop wiring and internal wiring within the site	•	
	c. The main circuit breaker and transformer	•	
	2) Water Supply		
	a. The city water distribution main to the site		•
	b. The supply system within the site (receiving and elevated tanks)	•	
	3) Drainage		
	a. The city drainage main (for storm sewer and others to the site)		•
	b. The drainage system (for toilet sewer, common waste, storm drainage and others) within the site	•	
	4) Gas Supply		
	a. The city gas main to the site		•
	b. The gas supply system within the site	•	
	5) Telephone System		
	a. The telephone trunk line to the main distribution frame/panel (MDF) of the building		•
	b. The MDF and the extension after the frame/panel	•	
	6) Furniture and Equipment		
	a. General furniture		•
	b. Project equipment	•	
4	To ensure prompt unloading and customs clearance of the products at ports of disembarkation in the recipient country and to assist internal transportation of the products		
	1) Marine (Air) transportation of the Products from Japan to the recipient country	•	
	2) Tax exemption and custom clearance of the Products at the port of disembarkation		•
	3) Internal transportation from the port of disembarkation to the project site	•	
5	To ensure that customs duties, internal taxes and other fiscal levies which may be imposed in the recipient country with respect to the purchase of the products and the services [ be exempted] / [be borne by the Authority without using the Grant]		•
6	To accord Japanese nationals whose services may be required in connection with the supply of the products and the services such facilities as may be necessary for their entry into the recipient country and stay therein for the performance of their work		•
7	To ensure that [the Facilities and the products]/[the Facilities]/ [the products] be maintained and used properly and effectively for the implementation of the Project		•
8	To bear all the expenses, other than those covered by the Grant, necessary for the implementation of the Project		•
9	To bear the following commissions paid to the Japanese bank for banking services based upon the B/A		
	1) Advising commission of A/P		•
	2) Payment commission		•
10	To give due environmental and social consideration in the implementation of the Project.		•

\*1 B/A : Banking Arrangement, A/P : Authorization to pay) \*2 If the environmental screening category is C, No. 10 is unnecessary

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Facility plan in Bushrod power plant



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添付資料 A-5 測量・土質調査報告書

**TOPOGRAPHIC SURVEY**

**FOR THE**

**REHABILITATION OF MONROVIA POWER STATION**

**IN THE**

**REPUBLIC OF LIBERIA.**

*FINAL REPORT*

**PREPARED BY:**

BEZALEEL + TURNKEY CONTRACTORS INC.  
77, CAREY STREET  
MONROVIA,  
LIBERIA.

**CLIENT:**

YACHIYO ENGINEERING CO. LTD.

May, 2012



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Appendix A: Survey Layout Plan

## REPORT OF TOPOGRAPHICAL SURVEY

### 1.0 INTRODUCTION

The topographical survey of the site covered was 1.218399 acres. The fieldwork commenced on 23.Feb.2012 and completed on 25.Feb.2012. The Topographical survey of the area covered, is as under: The site survey of the proposed Rehabilitation of Monrovia Power Station was carried out on the basis of the boundaries shown by Yachiyo Engineering Co. Ltd.

### 2.0 METHODOLOGY

The survey team comprised of:

1. Engineering Surveyor
2. Assistant Surveyor
3. Field Assistants.

Instruments used:

1. Garmin GPS-60
2. Compass
3. Nikon DTM 322 Total
4. Station
5. Tripod
6. Prism
7. Prism Pole

The survey team using the **Garmin GPS-60** to operate satellite coordinates (**WGS-UTM-84,29° N -Datum**) transferred the station points B1, B2 and B3. After determining this, the total station was centered to start work.

The survey team used Transvers method to shoot all terrain points from ground, to determine ground Levels (Datum), the horizontal (North) and Vertical (East) angle coordinates was also determined.

### 3.0 ANALYSIS

After the shooting process, all data downloaded from the instrument was carried out using **Trimble Transfer Software** which is in **DAT** format. These data is later transferred to **Microsoft Excel** and converted to **EXL** file and then downloaded to a survey software for drafting of the final drawing, Printing was done using the **HP 1280** for the A3 size sheet of this work.

The list of Station Points, GPS Coordinates and Bore Hole Coordinates are enlisted below.

STATION POINTS				
SL.NO	POINTS	NORTHING	EASTING	ELEVATION
1	S1	703601.000	302204.000	100.000
2	S2	704234.800	303330.000	100.306
3	S3	704362.300	297645.800	99.982
4	S4	697498.100	301310.560	99.745
5	S5	698793.400	295509.160	99.434
6	S6	704751.900	298365.400	99.702

GPS COORDINATES				
SL.NO	POINTS	NORTHING	EASTING	ELEVATION
1	S1	703601.000	302204.000	14.000 M
2	GROUND LEVEL OF S1	703601.000	302204.000	13.725 M
3	CON.PAD			13.825M
4	TANK AREA 1	703374.000	302286.000	13.825 M
5	TANK AREA 2	704654.490	303076.888	13.860 M

BORE HOLE COORDINATES				
SL.NO	POINTS	NORTHING	EASTING	ELEVATION
1	B1	701513.300	298823.700	99.256
2	B2	699791.500	299483.300	99.239
3	B3	699308.500	296933.900	99.296

# ***ATTACHMENT***

**SOIL INVESTIGATION WORKS**  
**FOR THE**  
**REHABILITATION OF MONROVIA POWER STATION**  
**IN THE**  
**REPUBLIC OF LIBERIA.**

*FINAL REPORT*

**PREPARED BY:**

**BEZALEEL + TURNKEY CONTRACTORS INC.  
77, CAREY STREET  
MONROVIA,  
LIBERIA.**

**CLIENT:**

**YACHIYO ENGINEERING CO. LTD.**

*May, 2012*



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- Appendix B: SPT Logging.
- Appendix C: Particle Size Distribution Curve.
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Table 5:	Settlement Analysis Result
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## **PLATES**

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Figure 1:	Layout of Boring Locations
Figure 2:	Soil Profile (1 – 2)
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### EXECUTIVE SUMMARY

The depth of the sub soil formation explored is up to the depth of 30m in all the 3No test bores. These were drilled by conducting Standard Penetration Test (SPT) at every 1.5m intervals up to maximum depth of 30m below the existing ground level. The samples obtained at different depths were also tested in the laboratory in order to determine the geotechnical properties of the subsoil at the various boring locations.

Based on the results obtained the sub soils of the various locations and their SPT N value are as presented below.

**Table A1: SPT N<sub>30</sub> Value**

Depth (m)	SPT N <sub>30</sub> VALUE			Lithology
	BH 1	BH 2	BH 3	
0.0-0.6	4	4	2	Fill material and organic soil
1.5-2.1	11	11	9	Fine sand
3.0-3.6	24	16	14	Fine sand
4.5-5.1	29	25	23	Fine sand
6.0-6.6	16	17	19	Coarse sand
7.5-8.1	32	23	27	Coarse sand
9.0-9.6	12	23	23	Fine sand and clay
10.5-11.1	48	39	37	Fine sand and coarse sand
12.0-12.6	80	40	42	Fine sand and coarse sand
13.5-14.1	62	40	37	Fine sand and coarse sand
15.0-15.6	60	36	34	Fine sand
16.5-17.1	72	39	37	Fine sand
18.0-18.6	50	45	46	Fine sand
19.5-20.1	49	22	39	Fine sand, coarse sand and clay
21.0-21.6	53	46	44	Fine sand and coarse sand
22.5-23.1	58	44	42	Fine sand and coarse sand
24.0-24.6	39	52	44	Fine sand
25.5-26.1	51	39	45	Fine sand
27.0-27.6	54	45	47	Fine sand
28.5-29.1	67	57	55	Very dense Sand
30.0-30.6	80	54	54	Very dense Sand
	EB	EB	EB	Very dense Sand

\* EB - End of Boring.

The materials encountered at site within the explored depths of 0.0-30.0 are predominantly sands and clay; therefore considering the nature of the subsoil at the boring locations at a depth of between 1.0-.3.0m the foundations of the various structures are recommended as follows;

#### **Transformer Base and Other Installations**

The foundation of the structures and plants should be **CELLULAR RAFT FOUNDATION** at depth of **2.0 – 2.50m** below the existing ground level; considering allowable bearing capacity values of 90 - 240kN/m<sup>2</sup> at that depth.

Alternatively depending on the loading combinations of the structures **DRIVEN PILES OR BORED PILES** which could be **CAST IN PLACE PILES** at depth of **15 - 20m** from the existing ground level could be adopted.

#### **Non Load Bearing Structures**

Considering the bearing capacity values of 90 - 110kN/m<sup>2</sup> at depth of 1.50-2.0m, the foundation of the building should be **GROUND BEAMS** at depth of **1.5m** below the existing ground level. Due to the depth of water table level observed at the excavated depth of about 2.20 – 2.30m, **TANKING MATERIAL** should be utilized at the hardcore level (DPC – damp proof course) to prevent the ingress of water at the foundation base.

As result of the high ground water observed at the depth of 2.20 – 2.30m provision should be made to dewater the site to a safe level to allow for ease of foundation construction. Adequate drainage and pumping methods should be provided around the site to drain away the water during and after construction.

## **1.0 INTRODUCTION**

### **GENERAL**

**1.1** The report of the Geotechnical foundation investigation conducted for the Proposed Construction of New Power House and New Substation at Bushrod Island Power Station, Monrovia, Liberia, is presented herein.

Reference your offer to carry out Geotechnical investigations at the above-named site. We mobilized to site on 7th March, 2012 for the field work.

### **SCOPE OF WORK FOR THE INVESTIGATIONS**

**1.2** The objectives of the investigations were as follows:

- i. To Conduct Standard Penetration Tests (SPT) at every 1.5m depth intervals, to the depth of 30m at 3Nos test bores;
- ii. Evaluate the bearing capacity of soils for foundation of structures;
- iii. To ascertain the depth to bed rock and water table level for design purpose;
- iv. Obtain open tube of 50 x 350mm long undisturbed samples and split spoon samples from boreholes for laboratory analyses;
- v. Evaluate by conducting laboratory tests the physical properties and strength of the soils obtained for both disturbed and undisturbed samples from the test bores.

**1.3** The field work commenced on 11th March, 2012 and it involved rotary drilling as well as sampling materials. A total of 3Nos test bores were drilled up to depths of 30m.

Samples were obtained at different depths in the 3Nos test bores. The samples were carefully identified, preserved and taken for further laboratory tests and analyses.

Table 1 shows the coordinates of the boring locations.

**Table 1: Coordinates of Test Locations**

S/No.	Borehole No.	Coordinates
1	BH1	E: 298823.700 N: 701513.300
2	BH 2	E: 299483.300 N: 699791.500
3	BH 3	E: 296933.900 N: 699308.500

## **2.0 GEOMORPHOLOGY**

### **2.1 General Geology**

The geology of the project is of the younger sedimentary basins. Along the Atlantic Ocean, the coastline is characterized by lagoons, mangrove swamps, and river-deposited sandbars. It is of the Quaternary age and Neogene – Mesozoic age comprising of sands and clay.

#### **Climate**

Liberia is known for its sustained heat and heavy rainfall. Because the republic lies south of the Tropic of Cancer and only a few degrees north of the equator, the days vary little in length. The tropical solar radiation is intense and the radiation is uniform across the country. Temperatures remain warm throughout the country, and there is little change in temperature between seasons.

### **2.2 Topography**

The topography of the area is of a relatively flat terrain and it falls within built up area.

## **3.0 GEOTECHNICAL INVESTIGATIONS:**

### **3.1 Field Work**

Three (3Nos) deep boreholes were drilled using the rotary drilling rig with HW (4”) casing in the overburden.

The test borings were drilled to depths of 30m using the wet drilling technique. In each test bore Standard Penetration Tests (SPT) was conducted at 1.5m interval.

The sampling procedure consisted of driving a standard split spoon as set forth in ASTM D1586-1990 and BS 5930. This was by repeated blows of hammer of 63.5kg weight falling through 760mm height. The relationship between the penetration resistance (N - value) and depth are shown in Appendix B.

Samples recovered from the borings as outlined above were visually classified and geologically logged. After these, they were taken to the laboratory for determination of the parameters outlined in section 5.0.

The layout of boring locations and soil profile are shown in Figure 1 - 3.





Plate A: Position of Rig at Test Location.



Plate B: Drilling Process at Test Location.

#### **4.0 SUBSOIL AND GROUNDWATER CONDITION**

4.1 The Stratigraphies of the subsurface deposits as observed from the logs of test bores performed at this site exhibited similarities both in nature and in strength characteristics from the beginning of the boreholes till their termination. A generalised description for the site can thus be as given below;

##### **Abstract of Findings**

The materials proved at all the test borings include fine sand, coarse sand, clay and dense sand. These were observed within total explored depth of 0.05 - 30m in all the 3Nos test bores. The bearing capacity of the formation explored range between 20 - 800kN/m<sup>2</sup>.

##### **Stratigraphy**

###### **Fine Sand**

These are strata of fine grained brown sandy material observed between 0.05 - 27.0m.

###### **Coarse Sand**

Layers of medium grained sandy material observed between 6.0 - 21.0m.

###### **Clay**

These are stiff medium consolidated clayey material with high plasticity as proved at depth of 9.0 and 20m.

###### **Dense Sand**

Layers of dense compacted sandy material occurring at different layers proved between 10.0 – 30.0m with good bearing pressures.

#### **4.2 Ground Water Table**

The groundwater level in all the test boring locations were observed to be at depth of 2.20 – 2.30m as at the time this investigation was carried out.

The phreatic surfaces were observed from all the borings and were taken twenty-four hours later (static). These values are recorded in each boring logs and are shown in Table 2 below.

**Table 2: Observed Water Table Level**

<b>S/No</b>	<b>Boring Location</b>	<b>Static Water Table Level (m)</b>
1	BH 1	2.30
2	BH 2	2.20
3	BH 3	2.30

## **5.0 LABORATORY TESTING.**

**5.1** Laboratory classification tests and other tests to determine geotechnical parameters were carried out on the undisturbed and disturbed samples obtained from the boreholes to improve on the field identification and classification. The tests were conducted in accordance with the relevant British Standard as Specified in BS 1377 (1990). The tests carried out include:

- \* Moisture Content Determination
- \* Atterberg Limit Tests
- \* Particle Size Distribution Tests.
- \* PH Value of Water in Soils.
- \* Sulphate Content of Water in Soils.
- \* British Standard Compaction Test.
- \* Undrained Triaxial Compression Test.
- \* Specific Gravity Test.
- \* Consolidation (Oedometer) Test.
- \* Bulk Density Test

**5.2** The Geotechnical properties of the soils encountered at the various strata formation of the overburden were obtained from the tests conducted in laboratory. The summary of the results are given below.

<b>Property</b>	<b>Min.</b>	<b>Max.</b>
Natural Moisture Content (%)	4	36
Liquid Limit (%)	32	34
Plastic Limit (%)	16	17
Plasticity Index (%)	16	17
Passing # 200 Sieve (%)	0.53	50.89
Bulk density (kN/m <sup>3</sup> )	15.68	18.26
Apparent Cohesion (kN/m <sup>2</sup> )	0	28
Angle of Internal Friction (Ø)	16	31
Coefficient at compressibility (m <sup>2</sup> /kN)	3.84 x10 <sup>-4</sup>	3.86 x10 <sup>-3</sup>
Specific Gravity	2.59	2.75

The detailed laboratory tests results are presented in laboratory result sheet.

### 5.3. Chemical Test Result

The chemical test results are shown in Table 3. These results indicate sulphate and chloride content of between 171.21 - 187.08mg/l and 285.03 – 292.45mg/l respectively with pH values ranging from 6.63 - 6.71. The PH value is considered slightly acidic while the sulphate and chloride content is considered moderate, within limit.

**Table 3: Results of Chemical Tests**

S/N	Boring Location	Chemical Results			Remarks
		PH Value	Sulphate content (mg/l)	Chloride content (mg/l)	
1	BH 1	6.71	185.63	285.03	Slightly acidic soil with moderate sulphate and chloride content
2	BH 2	6.67	171.21	292.45	Slightly acidic soil with moderate sulphate and chloride content
3	BH 3	6.63	187.08	287.72	Slightly acidic soil with moderate sulphate and chloride content

## **6.0 BEARING CAPACITY VALUES**

**6.1** The allowable bearing pressure imposed by a foundation is a function of characteristics of the shear strength of the soil as well as the depth and dimension of the foundation. The bearing capacities for selected boring locations were calculated from the laboratory shear strength tests conducted on soil samples for a typical boring location for depth between 1.5-3.0m is as shown below;

### ***BH3@2.0m***

$$Q_{\text{Ultimate}} = CN_c + \gamma D (N_q - 1) + \frac{1}{2} \gamma B N_\gamma.$$

Where  $C = 2\text{kN/m}^2$ ,  $\phi = 26^\circ$ ,  $\gamma = 16.87\text{kN/m}^3$ ,  $B = 1.0\text{m}$ ,  $D = 2.0\text{m}$ .

The Bearing capacity coefficients; (shallow foundations)

$$N_c = 27.09, N_q = 14.21, N_\gamma = 9.84.$$

$$\begin{aligned} \text{Therefore, } q_{(\text{Ult.})} &= 2 \times 27.09 + 6.87 \times 2.0 \times 13.21 + 0.5 \times 6.87 \times 1 \times 9.84 \\ &= 54.18 + 181.51 + 33.80 \\ &= \underline{\underline{296.49\text{kN/m}^2}} \end{aligned}$$

$$\text{Factor of safety} = 3.0$$

$$Q (\text{allowable}) = \underline{\underline{89.83\text{kN/m}^2}}$$

**Note:** Cohesion is only  $2\text{kN/m}^2$  which shows presence of silt in the sand and silt has a small degree of cohesion.



6.2 The bearing capacity of soil at the various depths is based on the standard penetration Tests (SPT) as a function of penetration resistance, which is the undrained shear strength in  $\text{kN/m}^2$ . The values are as shown in the table 4 below.

**Table 4: Bearing Capacity Values**

Depth (m)	Bearing Capacity Values ( $\text{kN/m}^2$ )		
	BH1	BH2	BH3
0.0-0.6	40	40	20
1.5-2.1	110	110	90
3.0-3.6	240	160	140
4.5-5.1	290	250	230
6.0-6.6	160	170	190
7.5-8.1	320	230	270
9.0-9.6	120	230	230
10.5-11.1	480	390	270
12.0-12.6	800	400	420
13.5-14.1	620	400	370
15.0-15.6	600	360	340
16.5-17.1	720	390	370
18.0-18.6	500	450	460
19.5-20.1	490	220	390
21.0-21.6	530	460	440
22.5-23.1	580	440	420
24.0-24.6	390	520	440
25.5-26.1	510	390	450
27.0-27.6	540	450	470
28.5-29.1	670	570	550
30.0-30.6	800	540	540
	EB	EB	EB

\* EB - End of Boring.

### 7.0. SETTLEMENT OF FOUNDATION BY MEYEHORF'S METHOD

This method is used to estimate the settlement of a footing on soil and is given by the relationship.

$$\rho = \frac{\Delta P \times B}{2 Cr}$$

Where  $\rho$  - Settlement

$\Delta P$  - The net foundation pressure increase which is simply the foundation loading less the value of vertical effective stress at foundation level ( $\delta v$ )

B - The least dimension of the footing

Cr - The average value of SPT over a depth below the footing equal to B

$$Cr = 400 \times N \text{ (kN/m}^2\text{)}$$

**At 1.50m**

$$\begin{aligned} \Delta P &= 100 - (6.47 \times 1.5) \\ &= 90.30 \text{ kN/m}^2 \end{aligned}$$

$$B = 2.0 \text{ m}$$

$$Cr = 400 \times 10 = 4,000 \text{ kN/m}^2$$

$$\rho = \frac{90.30 \times 2}{4,000 \times 2} = \frac{180.60}{8,000}$$

$$\rho = 22.57 \text{ mm}$$

**at 3.0m**

$$\begin{aligned} \Delta P &= 180 - (6.46 \times 3.0) \\ &= 160.62 \text{ kN/m}^2 \end{aligned}$$

$$Cr = 400 \times 18 = 7,200 \text{ kN/m}^2$$

$$\rho = \frac{160.62 \times 2}{7,200 \times 2} = \frac{321.24}{14,400}$$

$$\rho = 22.31 \text{ mm}$$

Settlement analysis for each strata of soils at various depth, are as contained in Table 5 below;

**Table 5: Settlement Analysis Result**

Depth of layer Below Ground(m)	Net Foundation Pressure $\Delta P$ (kN/m <sup>2</sup> )	The Average value of SPT Cr (kN/m <sup>2</sup> )	Settlement (mm)
1.5	90.30	4000	22.57
3.0	160.62	7200	22.31

The average immediate settlement at 3.0m is 22.31mm and it decreases with depth depending on imposed load.

## 8.0 SAFE LOAD CAPACITY OF PILES

The predominant materials are sand overburden, which are highly permeable such that pore pressures induced in these soils by the applied loads are dissipated rapidly. The total pile carrying capacity is a function of the frictional resistance and end bearing resistance.

The Total Pile capacity = SF + ER (Skin Friction + End Resistance)

$$q_s = K_s \gamma_{vo} \tan \delta$$

Where,

$$q_s = \text{Friction resistance}$$

$$K_s = \text{Coefficient of horizontal soil stress}$$

$$\gamma_{vo} = \text{Average effective overburden pressure } (\gamma_s - \gamma_w)$$

$$\delta = \text{Angle of wall friction}$$

And

$$q_b = N_q \gamma_{vo} A_b$$

$$q_b = \text{base resistance}$$

$$N_q = \text{bearing capacity friction}$$

$$\delta_{vo} = \text{effective overburden pressure at length of the soil layer}$$

$$A_b = \text{Area of base of pile (based on diameter of pile)}$$

### BH1

$$q_s = K_s \delta_{vo} \tan \delta$$

$$K_s = 1, \text{ for Bored and cast in Place Piles (after Kulhawy); } \gamma_{vo} \text{ (average)} = 16.73 \text{ kN/m}^3;$$

$$\delta = 1 \times \delta, \text{ for cast in place piles, } \delta = 27^\circ, \tan \delta = 0.510$$

$$\text{Depth (h)} = 15 \text{ m, Area} = 0.283 \text{ m}^2 \text{ (} \delta = 600 \text{ mm)}$$

$$q_s = 1 \times (16.73 - 10) \times 15 \times 0.510$$

$$= 51.49 \text{ kN/m}^2$$

$$\text{Pile capacity due to friction (SF)} = \text{Frictional Resistance } (q_s) \times \text{Contact Area } (2\pi rL)$$

$$= 51.49 \times 2\pi rL$$

$$= 51.49 \times 2 \times 3.142 \times 0.3 \times 15$$

$$= 1,455.88 \text{ kN}$$

$$\text{End Resistance (ER)} = 600 \text{ kN/m}^2$$

$$\text{Cross sectional Area (CA)} = 0.283 \text{ m}^2 \text{ (} d = 0.6 \text{ m)}$$

$$\text{Pile capacity due to end resistance (ER} \times \text{CA)} = 600 \times 0.283 = 169.80 \text{ kN}$$

$$\text{Total pile capacity (SF} + \text{ER)} = 1455.88 + 169.80$$

$$= 1625.68 \text{ kN}$$

$$\text{Safe pile capacity} = 1625.88/3 = 542 \text{ kN}$$



The diameter of the pile is considered for 600mm and 1000mm.

**Table 6a: Safe Load Capacity for Pile (600mm Diameter)**

Boring No.	$K_s$	$\gamma_b$	Depth of boring (m)	Tan $\phi$	Pi ( $\pi$ )	Pile Diameter (m)	Pile length (m)	Skin friction (KN)	$A_b$ ( $m^2$ )	End Resistance ( $KN/m^2$ )	Total Pile Capacity (KN)	Safe Pile Capacity FOS=3.0 (KN)
BH 1	1.0	6.73	15	0.510	3.142	0.6	15	1455.88	0.283	600	1625.68	542
BH 2	1.0	6.45	15	0.554	3.142	0.6	15	1515.69	0.283	360	1617.57	539
BH 3	1.0	6.64	15	0.532	3.142	0.6	15	1498.37	0.283	340	1594.59	531

FOS=Factor of Safety

**Table 6b: Safe Load Capacity for Pile (1000mm Diameter)**

Boring No.	$K_s$	$\gamma_b$	Depth of boring (m)	Tan $\phi$	Pi ( $\pi$ )	Pile Diameter (m)	Pile length (m)	Skin friction (KN)	$A_b$ ( $m^2$ )	End Resistance ( $KN/m^2$ )	Total Pile Capacity (KN)	Safe Pile Capacity FOS=3.0 (KN)
BH 1	1.0	6.73	15	0.510	3.142	1.0	15	2426.46	0.785	600	2897.47	966
BH 2	1.0	6.45	15	0.554	3.142	1.0	15	2526.14	0.785	360	2808.74	936
BH 3	1.0	6.64	15	0.532	3.142	1.0	15	2497.29	0.785	340	2764.19	921

FOS=Factor of Safety

## 9.0 FOUNDATION DISCUSSION AND RECOMMENDATIONS

### 9.1 DISCUSSION

The total depth explored in the entire 3 No test bores is 30.0m. These consist of sands and clay, subsoil, these were observed between 0.05 – 30.0m with bearing pressure of 20 – 800kN/m<sup>2</sup>.

The ground water levels were observed to at depth of 2.20 – 2.30m.

The standard penetration test (SPT) revealed that the subsoil at the site has average bearing pressure at the shallow depth but was observe to be varying with depth and strata formation as shown in Appendix B.

### 9.2 RECOMMENDATIONS

- \* The recommendations as contained in this report are based on careful correlation and interpretation of the results of the field results and analyses.
- \* The settlement at 3.0m is between 22.31mm and it decreases with depth based on the imposed load on the foundation;
- \* The materials encountered at site within the explored depths of 0.0-30.0 are predominantly sands and clay; therefore considering the nature of the subsoil at the boring locations at a depth of between 1.0-.3.0m the foundations of the various structures are recommended as follows;

#### **Transformer Base and Other Installations**

The foundation of the structures and plants should be **CELLULAR RAFT FOUNDATION** at depth of **2.0 – 2.50m** below the existing ground level; considering ultimate bearing capacity values of 90 - 240kN/m<sup>2</sup> at that depth.

Alternatively depending on the loading combinations of the structures **DRIVEN PILES OR BORED PILES** which could be **CAST IN PLACE PILES** at depth of **15 - 20m** from the existing ground level could be adopted.

#### **Non Load Bearing Structures**

Considering the bearing capacity values of 90 - 110kN/m<sup>2</sup> at depth of 1.50m, the foundation of the building should be **GROUND BEAMS** at depth of **1.5m** below the existing ground level.

- \* Due to the depth of water table level observed at the depth of about 2.20 – 2.30m, **TANKING MATERIAL** should be utilized at the hardcore level (DPC) to prevent the ingress of water at the foundation base.

As result of the high ground water observed at the depth of 2.20 – 2.30m provision should be made to dewater the site to a safe level to allow for ease of foundation construction. Adequate drainage and pumping methods should be provided around the site to drain away the water during

and after construction.

- \* The chemical tests on the water in soil samples confirmed the sulphate and chloride content of between 171.21 – 187.08g/l and 285.03 – 292.45mg/l respectively with pH values from 6.63 – 6.71 which is considered slightly acidic with moderate sulphate and chloride content. Therefore, Ordinary Portland Cement with cement content not less than 370kg/m<sup>3</sup> and maximum water cement-ratio of 0.40 could be used.

**Table 7: Summary of Foundation Recommendations**

Locations	Recommendations	Bearing Capacity Values (KN/m <sup>2</sup> )
Transformer Base and Other Installations	<b>CELLULAR RAFT FOUNDATION</b> at depth of <b>2.0 - 2.50m</b> below existing ground level. Alternatively depending on the loading combinations of the structures <b>DRIVEN PILES</b> or <b>BORED PILES</b> which could be <b>CAST IN PLACE PILES</b> at depth of <b>15 - 20m</b>	90 – 240kN/m <sup>2</sup> at depth of 2.0 - 3.0m
Non Load Bearing Structures	<b>GROUND BEAMS</b> at depth of <b>1.5m</b> below existing ground level	90 – 110kN/m <sup>2</sup> at depth of 1.5 - 2.0m

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