No.

Papua New Guinea

Baseline Data Collection Survey in Power Sector

FINAL REPORT

June 2010

JAPAN INTERNATIONAL COOPERATION AGENCY

NIPPON KOEI CO., LTD.

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Japan International Cooperation Agency

Papua New Guinea

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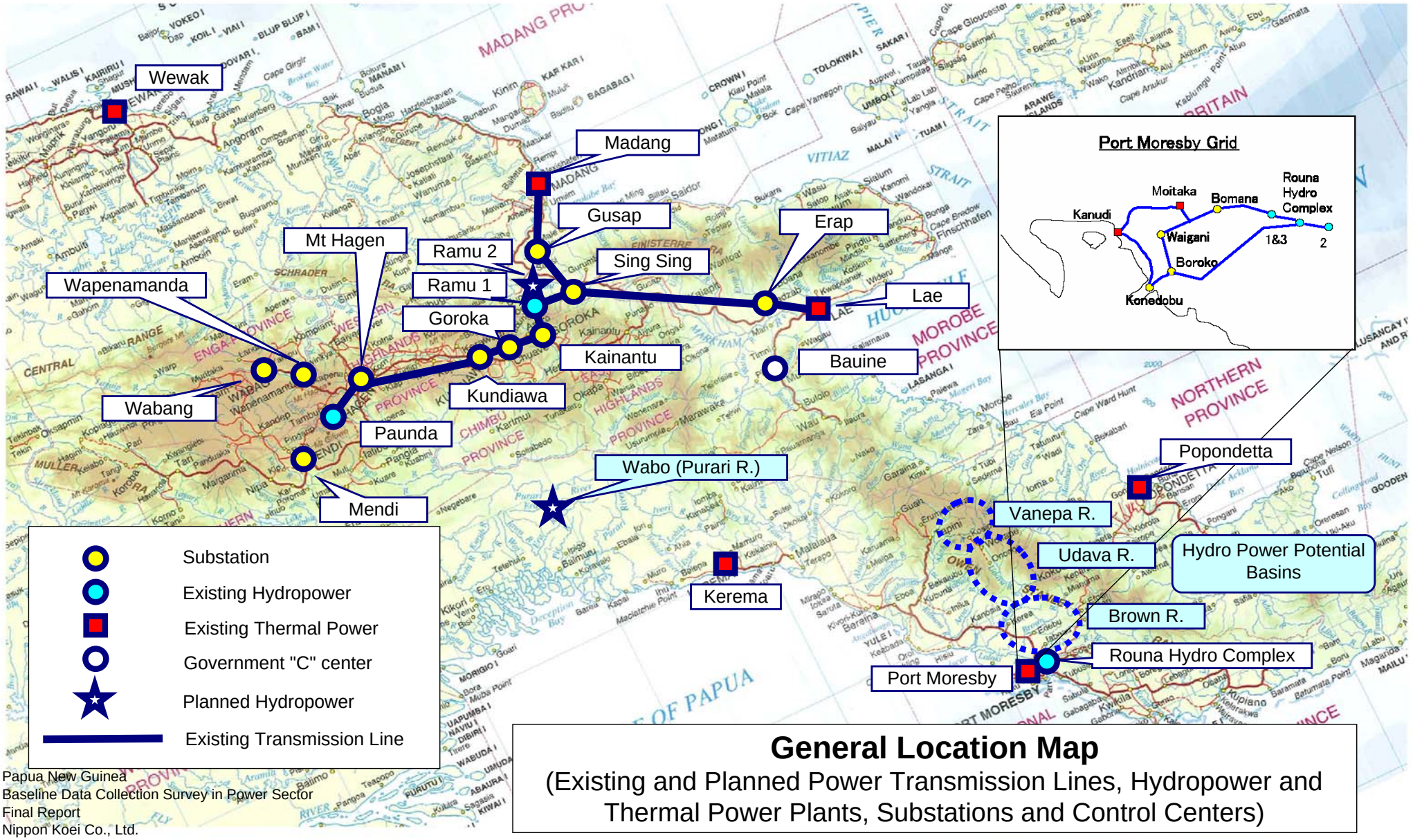
Figure-1



General Location Map

(Existing and Planned Power Transmission Lines, Hydropower and Thermal Power Plants, Substations and Control Centers)

Papua New Guinea
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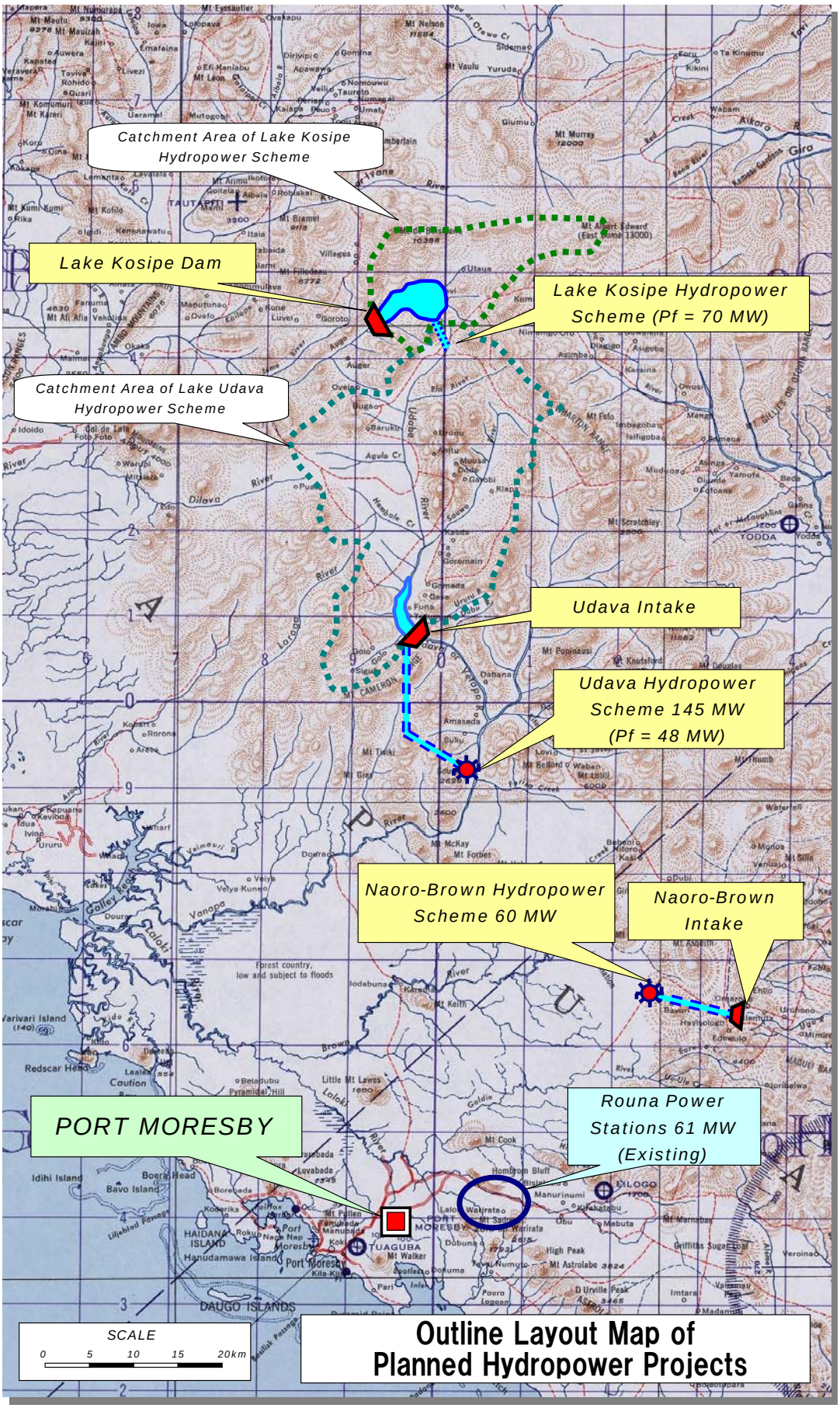
Catchment Area of Lake Kosipe Hydropower Scheme
Lake Kosipe Dam
Lake Kosipe Hydropower Scheme (Pf = 70 MW)
Catchment Area of Lake Udava Hydropower Scheme
Udava Intake
Udava Hydropower Scheme 145 MW (Pf = 48 MW)
Naoro-Brown Hydropower Scheme 60 MW
Naoro-Brown Intake
Rouna Power Stations 61 MW (Existing)
PORT MORESBY
SCALE
0 5 10 15 20km
Outline Layout Map of Planned Hydropower Projects

Figure-2

Papua New Guinea
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Abbreviations

Abbreviations	English
ADB	Asian Development Bank
BCM	Billion Cubic Meter
CSOs	Community Service Obligations
DEC	Department of Environment and Conservation
DNPM	Department of National Planning and Monitoring
DPE	Department of Petroleum & Energy
DSE	Department of State Enterprise
EIP	Electricity Industry Policy
EIR	Environmental Inception Report
EIS	Environment Impact Statement
EMC	Electricity Management Committee
EP	Energy Policy
ETF	Electricity Trust Fund
F/S, FS	Feasibility Study
FGDs	Focus Group Discussions
GDP	Gross Domestic Product
GWh	Giga Watt Hour
HFO	Heavy Fuel Oil
ICCC	Independent Consumer & Competition Commission
ICDC	Industrial Centers Development Corporation
ILG	Incorporated Land Group
IMF	International Monetary Fund
IPA	Investment Promotion Authority
IPBC	Independent Public Business Corporation
IPP	Independent Power Producer
JICA	Japan International Cooperation Agency
K/PNGK	Kina
kVA	Kilo Volt Ampere
kWh	Kilo Watt Hour
LLG	Local Level Government
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LV	Low Voltage
MTDS	Medium Term Development Strategy
MV	Medium Voltage
MVA	Mega Volt Ampere
MW	Mega Watt
MWh	Mega Watt Hour
NADP	National Agriculture Development Plan
NARI	National Agriculture Research Institute
NCD	National Capital District
NEP	National Energy Policy
NISIT	National Institute of Standards and Industrial Technology
NSO	National Statistics Office
OLPLLG	Organic Law on Provincial and Local Level Governments
OTML	Ok Tedi Mine Limited
PNG	Papua New Guinea

PNG Dams	PNG Dams Ltd
PNGFA	Papua New Guinea Forest Authority
PNGSDP	PNG Sustainable Development Program
PNGSEL	PNG Sustainable Energy Limited
PNGTPA	Papua New Guinea Tourism Promotion Authority
POM	Port Moresby
PPL	PNG Power Limited
PPP	Public Private Partnership
PSDP	Papua New Guinea: Power Sector Development Pan
REP	Rural Electricity Policy
SBDC	Small Business Development Corporation
SME	Small to Medium Enterprises
TFP	Total Factor Productivity
TOR	Terms of Reference
TPA	Tourism Promotion Authority
TYPDP 2009	National & Provincial 10 Year Power Development Plan 2009-2018 by PPL
WMA	Wildlife Management Area
WTP	Willingness to Pay

Exchange Rate
USD1 = Kina 2.678, JPY10 = Kina 0.2847
As of April 30, 2010

SUMMARY

1. Background

The economy in the Papua New Guinea (PNG) has been growing at over 6% during 2007 to 2008 period. The National and Provincial Ten Year Development Plan 2009-2018 estimated the forecast energy sales would increase from 801.4 GWh in 2009 to 1,139.6 GWh in 2018 at an average growth rate of 4.13 % per annum, and the corresponding aggregate maximum demand would increase from 182.33 MW in 2009 to 256.18 MW in 2018. The electric power demand-supply balance would further worsen in the urban areas in particular in the capital city, Port Moresby and the second largest city, Lae. The electric power supply has been in unstable in Port Moresby due to mainly capacity shortage of electric power generation facilities and partly due to unreliable operation and maintenance of the existing power generation facilities. The power supply in Lae is unstable due to mainly unreliable transmission and distribution systems and partly due to unreliable operation and maintenance of the existing power generation facilities. The National Energy Policy (2006) set an objective to expand supply of sufficient power to sustain the economic growth and expansion of the use of renewable energy.

2. Objective of Survey

The objective of the Survey is:

(1) To study the possibility of cooperation in the hydropower development that will supply electricity to the Port Moresby grid and the Ramu grid taking into consideration the effect of the cooperation to the power sector of PNG and its possibility of implementation; and

(2) To collect basic information towards specific cooperation, focusing on the hydropower development for supply to the Port Moresby grid and Ramu grid on the basis of the study results of ADB.

3. Survey Schedule

The Survey Team executed site reconnaissance, inspection and interview of the Port Moresby grid and the Ramu grid in PNG from April 14 to May 15, 2010 including inspection of potential hydropower project sites.

4. PNG Power Policy

Since 2008 three fundamental policies in the PNG Power Sector have been studied by the Energy Division of the Department of Petroleum and Energy. They are the Draft Electricity Industry Policy, the Draft Energy Policy and the Draft Rural Electrification Policy. Another relevant policy currently being developed by the Government relates to public-private partnerships (PPPs). The Electricity Industry Policy (EIP, August 2009) will be issued within

2010. The regulator of electricity supply is Independent Consumer and Competition Commission (ICCC) based on ICCC Act 2002. Its regulatory function is composed of the technical regulation and the economic regulation such as tariff system. Since 2002 ICCC has transferred the function of technical regulation to PPL, but it will be transferred to the Department of Petroleum and Energy by phasing process. ICCC takes charge of the economic regulation. The electric power generation market will be opened to private sector.

The main issues brought to the forefront in the EIP (August 2009) include:

(a) Promotion of competition and development of an enabling third party access regime,
(b) An emphasis on rural electrification,
(c) Developing regulations for third party access, as well as a commitment to price cap regulation,
(d) The continued policy of providing subsidies to the power sector,
(e) The exclusivity provisions granted to PPL in EIP, and
(f) Accessibility to the grid by third parties.

5. Present Conditions and Issues in Port Moresby Grid

The Port Moresby grid clears the N-1 criteria which is widely applied to assess the supply reliability of the transmission system and is assessed as reliable. However, new construction of substations is necessary to share the increasing demand of the existing substations and to augment caring capacity of the existing transmission lines. Construction of new substations is necessary for reducing the load of the Boroko and Konedobu substations and loss reduction of the distribution system. Input of hydropower is pressing needs to meet the high power demand growth since 2008 in line with the renewable energy policy.

6. Present Conditions and Issues in Ramu Grid

The Ramu grid is in initial stage for forming of transmission system with three single circuit radial lines from the Ramu substation, and it does not fulfill N-1 criteria for assessing power supply reliability. It is judged that stable and continuous power supply over the lines is difficult due to its line configuration and lack of one-phase re-closing system. Especially power supply from Ramu to Lae which is the largest demand center of the grid and shares about 2/3rd of the total demand is serious. Urgent countermeasures are necessary to improve the power supply reliability of the transmission system. For increasing its reliability, addition of the second circuit line, upgrading line protection system including re-closing system, upgrading communication system, etc. are required. Development of hydropower is also necessary to meet the future power demand growth.

7. Needs of Cooperation for Priority Projects

The following priority projects are recommended as promising for cooperation needs:

1. Port Moresby Grid
    i. Inspection of Stability of Sirinumu Dam and Saddle Dams (water source of Rouna Hydropower Stations)
    ii. Naoro-Brown Hydropower (60 MW) or Udava Hydropower (58-145 MW)
    iii. Lake Kosipe Hydropower (30 MW)
    iv. Rehabilitation of Rouna 1 Hydropower Station (8MW)
2. Ramu Grid
    i. Master Plan on Extension and Rehabilitation of Ramu Grid
        a. Construction of 1 cct 132 kV transmission line (Sing Sing – Erap - Taraka), or construction of 2 cct 220 kV design transmission lines (start operation by 132 kV)
        b.Extension and rehabilitation of other related transmissions and distribution systems
    ii. Capacity strengthening of operation, maintenance & management
    iii. Ramu 2 Hydro (60-240 MW)
3. Others
    i. Wabo Hydropower (1,800 MW)

Inspection of the safety of water leakages from the saddle dams of the Sirinumu reservoir is urgent. The potential risk information of saddle dam failure shall be shared among the donors, and relevant experts shall be dispatched as soon as possible to evaluate the conditions urgently. The on-going feasibility study would justify Naoro-Brown Hydropower being superior to Udava Hydropower. Rehabilitation of Rouna 1 Power Station would be able to be implement by PPL own fund.

The top priority issue of the Ramu grid is extension and rehabilitation of the 132 kV transmission line and related transmissions and distribution systems. The sustainable and stable power supply of the grid would not be achieved by the provision of new hydropower plants only unless reliability of the existing Ramu grid is fundamentally improved by the extension and overall rehabilitation. A comprehensive master plan is necessary to study and to plan overall measures, and to prepare a concrete implementation plan. Investment efficiency of Ramu 2 Hydropower is high.

Capacity strengthening of operation, maintenance and management of Port Moresby and Ramu grids is also required. Review of Wabo Hydropower is stared as a private investment project. The World Bank recommended that it is appropriate for the PNG Government to be involved in such a large scale project from an early stage through a role in the social and environmental studies. This project will also be involved in the national and regional development policy, land acquisition issues and creation of employment.

8. Preliminary Geotechnical Assessment of Priority Hydropower Projects

Naoro-Brown Hydropower, Udava Hydropower, Lake Kosipe Hydropower and Ramu No.2 Hydropower are located in the Mobile Belt, and Wabo Hydropower is in the Platform. Though these topography and geology is fairly stable as foundations of hydropower projects, respective project sites require careful consideration of specific geotechnical engineering to some extent. Those matters are basically technically viable.

9. Environmental and Social Considerations

Under the Environmental Act 2000(amended 2002), the implementer on the prescribed projects is required to submit Environmental Impact Statement (EIS) to Department of Environment and Conservation (DEC) to obtain the due Environmental Permit before its implementation. The prescribed projects are stipulated in the Environment (Prescribed Activities) Regulation 2002. Based on the classification in the regulation, when the person who intends an activities of (a) a level 2 or level 3 activity; or (b) a change in process, or expansion of works or plant in relation to an existing activity such that a level 2 or level 3 activity is carried out, the process on the Environmental Permit is required. The prospective priority hydropower projects and the transmission line extension project are all subject to EIS and Environmental Permit.

PNG's rich biodiversity in fauna and flora is well known in the world. However, biodiversity studies have still in progress. Known species are approximately 26 thousands (IUCN 2008). However, it was estimated about 400,000 or 700,000 species in total as mentioned what PNG has more than 5 % of the world species in the 1% of area in the world. Special care is pre-condition to the natural environment.

In general, there are two types of land acquisition process related to the public works in Papua New Guinea. Those are; 1) Compulsory Acquisition process and 2) Outright Acquisition process (Agreed Land Acquisition). Those acquisitions are regulated by the Land Act 1996 and the compensation is made to the land owner on both cases. PPL applies the Outright Acquisition in principle for the hydro power development. Impacts on the livelihood and living conditions of residents are to be carefully studied in the study of social considerations because information of the customary land use is very limited. It is generally takes time in the acquisition process of the customary land.

CHAPTER 1

INTRODUCTION

1.1 Background

The economy in the Papua New Guinea (PNG) has been growing at over 6% during 2007 to 2008 period. The National and Provincial Ten Year Development Plan 2009-2018 (PNG Power Ltd., November 2009) estimated the forecast energy sales are expected to increase from 801.4 GWh in 2009 to 1,139.6 GWh in 2018 at an average growth rate of 4.13 % per annum. The corresponding aggregate maximum demand is forecasted to increase from 182.33 MW in 2009 to 256.18 MW in 2018. The electric power demand-supply balance would further worsen in the urban areas in particular in the capital city, Port Moresby and the second largest city, Lae. It is reported that the electric power supply has been in unstable both in Port Moresby and Lae due to mainly capacity shortage of electric power generation facilities and partly due to unreliable operation and maintenance of the existing power generation facilities, and transmission and distribution systems.

The National Energy Policy (NEP 2006) set an objective to expand supply of sufficient power to sustain the economic growth and expansion of the use of renewable energy. The Government of PNG with donor agencies has pursued development of electric power generation projects and transmission and distribution facilities. ADB has been supporting in preparing the Power Sector Development Plan and its implementation since 2007. The JICA Survey is envisaged to identify the need of technical and financial cooperation including development of hydropower resources for the two principal power grids in PNG, the Port Moresby system and the Ramu system out of the systems of the national capital district and central province, the Ramu system, the Gazelle system, Western province system, and the other systems for other provinces and isolated systems.

1.2 Objective of Survey

The objective of the Survey is two fold:

(1) To study the possibility of cooperation in the hydropower development that will supply electricity to the Port Moresby Grid and the Ramu Grid taking into consideration the effect of the cooperation to the power sector of PNG and its possibility of implementation; and

(2) To collect basic information towards specific cooperation, focusing on the hydropower

development for supply to the Port Moresby Grid and Ramu Grid on the basis of the study results of ADB.

The Terms of Reference of the Survey coves:

1. Explanation and discussion on the Inception Report,
2. Analyses of present situation of the power sector,
3. Confirmation of cooperation needs,
4. Selection of possible cooperation domain, and study on cooperation approaches, and
5. Preparation of Draft Final Report, submission and explanation to JICA PNG office and the relevant agencies and entities of the Government of Papua New Guinea which contributed to the Survey.

Compilation and analysis of the collected information and data has been made from the three aspects: i) Extension and rehabilitation of the existing facilities (power generation facilities, transmission and distribution facilities), ii) New hydropower development, and iii) Capacity strengthening of the operation, maintenance and management of the relevant facilities.

1.3 Organizations Supported the Survey

Department of National Planning and Monitoring (DNPD) of the Government of Papua New Guinea (GoP), the Independent Public Business Corporation (IPBC) and the PNG Power Limited (PPL) supported the Survey. In particular, PPL provided its extensive support and contributed to collecting information, data and reports, inspection and interview survey of the existing facilities, reconnaissance to the planned hydropower sites, and provision of an office space in its head office in Port Moresby.

1.4 Survey Schedule

The Survey Team executed the survey composed of site reconnaissance, inspection and interview of the Port Moresby Grid and the Ramu Grid in Papua New Guinea from April 14 to May 15, 2010. The Survey also covered site inspection of potential hydropower project sites, Naoro-Brown Hydro Scheme and Wabo Power Project. The Survey Team received excellent support and cooperation, and a number of information, data and reports from the organizations and personnel concerned. The itinerary of the Survey Team is presented in Table 1.1. The composition of the survey members is listed below.

Title	Name	Organization
Team Leader/ Hydropower Planning	Yukihiro MIZUTANI	Nippon Koei Co., Ltd.
Grid Planning	Yoshiaki MIYAGAWA	Nippon Koei Co., Ltd.
Engineering Geology/Foundation	Masatoshi ETO	Nippon Koei Co., Ltd.
Environmental and Social Considerations	Kazuo IIYAMA	Nippon Koei Co., Ltd.
Coordinator	Tetsuhiro SASAKI	Nippon Koei Co., Ltd.

A full list of people met is attached as Appendix 1.

Table 1.1 The Itinerary of the Survey

			Commond Schedule	Individual Schedule
14-Apr	Wed	1	Start of Field Survey	1st Batch: Leave Narita (Mizutani& Miyagawa)
15-Apr	Thu	2	Arrival at POM	1st Batch: Arrive at POM (Mizutani& Miyagawa) JICA/IPBC courtesy call & interview (Mizutani& Miyagawa)
16-Apr	Fri	3		DNPM/ADB/PPL courtesy call & interview (Mizutani& Miyagawa)
17-Apr	Sat	4		2nd Batch: Leave Narita (Eto & Iiyama), Leave Manila (Sasaki)
18-Apr	Sun	5		2nd Batch: Arrive at POM (Eto, Iiyama & Sasaki)
19-Apr	Mon	6		Set up of Survey Team Office in PPL
20-Apr	Tue	7		
21-Apr	Wed	8	Survey & Data Collection for	Site survey of Wabo Hydropower Site (Mizutani & Eto)
22-Apr	Thu	9	Port Moresby System	
23-Apr	Fri	10		Site survey of Powerstations and Substations in Port Moresby
24-Apr	Sat	11		
25-Apr	Sun	12		Site survey of Naoro-Brown Hydropower Site (Mizutani, Miyagawa, Eto, Iiyama, Sasaki)
26-Apr	Mon	13		
27-Apr	Tue	14		Move from POM to Lae, Courtesy call and interview to related agencies in Lae, Site survey of Milfold Thermal Powerstation (Mizutani, Miyagawa, Eto, Iiyama, Sasaki)
28-Apr	Wed	15		Site survey and interview to Yonki Dam, Ramu Hydropower Stations (Mizutani, Miyagawa, Eto, Iiyama, Sasaki), Move from Ramu to Lae
29-Apr	Thu	16	Survey & Data Collection for Ramu System and Lae areas	Site survey, interview, operation record collection and visit to workshop, parts factory for Ramu Powerstations, Move from Ramu to Lae, Site survey and interview to Taiheiyo Cement Mizutani , Miyagawa, Sasaki) Move from Lae to POM (Eto, Iiyama)
30-Apr	Fri	17		Discussion with Related agencies in Lae, Data collection of powerstation operation records (Miyagawa) Move from Lae to POM (Mizutani, Sasaki)
1-May	Sat	18		Move from Lae to POM (Miyagawa)
2-May	Sun	19		
3-May	Mon	20		
4-May	Tue	21		Site survey of Rouna Hydropowr Station, Interview on operation and maintenance of the power station (Mizutani, Miyagawa, Eto, Iiyama,
5-May	Wed	22		
6-May	Thu	23	Survey & Data Collection for	
7-May	Fri	24	Port Moresby System	
8-May	Sat	25		
9-May	Sun	26		
10-May	Mon	27		Preparation of Draft Final Report (Draft)
11-May	Tue	28		
12-May	Wed	29		Preparation of presentation material
13-May	Thu	30		Survey result report to PPL/JICA/DNPM/IPBC/PNG EDL/OE/HTC (Mizutani, Miyagawa, Eto, Iiyama, Sasaki) Courtesy call and interview to DNPM (Mizutani, Miyagawa)
14-May	Fri	31		Report to Embassy of Japan (Mizutani, Miyagawa, Eto, Iiyama, Sasaki) Discussion with JICA/ADB (Mizutani, Iiyama) Discussion with IPBC/DPEnt (Sasaki)
15-May	Sat	32	Completion of Field Survey	Closure of an office at PPL, Move from POM to Narita (Mizutani, Miyagawa, Eto, Iiyama)
16-May	Sun	33		
17-May	Mon	34		Report and Discussion with DPE/Embassy of Japan (Sasaki)
18-May	Tue	35	Additional Field Survey	Report and Discussion with DNPM/JICA, DEC (Sasaki)
19-May	Wed	36		Coutesy call and interview to PPL CEO, DNPM (Sasaki), Move from POM to Narita (Sasaki)

Abbreviation List	
POM	Port Moresby
JICA	Japan International Cooperation Agency
ADB	Asian Development Bank
IPBC	Independent Public Business Corporation
DNPM	Department of National Planning and Monitoring
PPL	PNG Power Ltd.
PNG EDL	PNG Energy Development Ltd.
OE	Origin Energy Ltd.
HTC	Hydro Tasmania Consulting
DPEnt	Department of Public Enterprise
DPE	Department of Petroleum and Energy
DEC	Department of Environment and Conservation

CHAPTER 2

POWER SECTOR

2.1 PNG Power Policy and Strategy

2.1.1 Policy Development

Since 2008 three fundamental policies in the PNG Power Sector have been studied by the Energy Division of the Department of Petroleum and Energy (ED-DPE) and discussed within the Government and concerned stakeholders. They are the Draft Electricity Industry Policy (EIP), the Draft Energy Policy (EP) and the Draft Rural Electrification Policy (REP)[1]. Another relevant policy currently being developed by the Government relates to public-private partnerships (PPPs).

2.1.2 Energy Industry Policy

The first Electricity Industry Policy (EIP) issued in July 2008 was revised as the August 2009 version and its public consultation was completed. The 2009 draft is waiting for the approval of the Cabinet as of mid May 2010, and it will be issued within 2010. At present the regulator of electricity supply is ICCC (Independent Consumer and Competition Commission) based on ICCC Act 2002. Its regulatory function is composed of the technical regulation and the economic regulation such as tariff system. Since 2002 ICCC has transferred the function of technical regulation to PPL, but it will be transferred to the Department of Petroleum and Energy (DPE) by phasing process based on the new EIP. Since PNGSEL (PNG Sustainable Energy Ltd.) joined this industry PPL can not play the role based on competition principle and accountability of the Government. The present compromised arrangement by PPL will continue for the time being. ICCC takes charge of the economic regulation as it was. The electric power generation market will be opened to private sector as it is.

The main issues brought to the forefront in the EIP (August 2009) include:

(a) Promotion of competition and development of an enabling third party access regime.

(b) An emphasis on rural electrification, including:

- The setting of long-term electrification targets

[1] Policies and projects of the PNG Government tend to be proceeded based on the draft policy documents because it takes time to get approval of the policy documents by the Cabinet. The draft documents provide basis of future course of actions of the Government.

- Establishment of an Electricity Trust Fund (ETF) for rural electrification purposes to be funded by the Government
- A policy of country-wide uniform tariffs for PPL

(c) Strengthening of the regulatory regime, with a role provided to the present regulator (the ICCC) of developing regulations for third party access, as well as a commitment to price cap regulation.

(d) Formation of an Electricity Management Committee (EMC) to oversee implementation of the EIP, and manage the rural electrification public tender process.

(e) Possible revision of the EIP's provisions in the year 2012.

A number of issues and concerns on the EIP have been raised as it has circulated among stakeholders, the main ones being:

(a) The continued policy of providing subsidies to the power sector

(b) The exclusivity provisions granted to PPL in the policy

(c) Accessibility to the grid by third parties

(Refer to further details in Draft Electricity Industry Policy (August 2009) and PP 1-6, Appendix L: Policy Analysis, PSDP April 2009.)

2.1.3 Energy Policy

The Draft Energy Policy (EP) covers of the energy potential (oil, gas, hydroelectricity and other renewable energy) of the country and the efforts for development and economic exploitation of these resources.

PNG's current known recoverable oil and gas reserve stand at nearly 230 million barrels and about 15 trillion cubic feet (397 BCM) of gas as of mid 2005. The oil and gas sub-sector has been a major export revenue earner, amounting to as much as 30 percent of PNG's export revenue between 1993 and 2001. In 2004 the oil refinery at Napanapa began production of refined oil. A proposal to construct a gas pipeline to Australia was cancelled due to increased capital costs. However, commercialization of the gas resources shifted from piping gas to shipping LNG to established markets.

Besides hydropower potential that has been estimated at about 15,000 MW, there are other renewable energy resources such as geothermal energy, wind energy, solar energy, biomass energy and marine energy. However, despite the availability of potential energy resources, 90 percent of the country's population is without any access to electricity. Considering this situation and keeping in view the objectives of Government's Medium Term Development

Strategy (2005-2010), the EP has tried to spell out the vision, goals and principles for sustainable development of energy sector in the country.

The policy puts forward the well conceived vision at the outset aimed at welfare of PNG's citizens through sustainable development of the energy sector in the country as follows: "Improve quality of life and provide sustainable national development through a robust and vibrant energy sector". The stated goal of the draft energy policy is to ensure that ownership of energy resources is vested with the resource owners and that their development must be accessible, reliable, affordable, efficient and environment friendly for the benefit of communities, industries and trade, and other development activities. The EP hinges on three basic premises of sustainable development, i.e. social, economic and environmental sustainability.

The EP also includes:

(a) Principles for attaining the social sustainability encompassing ownership of energy resources vested its owners,
(b) The economic agenda for the technical and financial development assistance from international and domestic development partners including the privates sector,
(c) The environmental agenda,
(d) Detailed discussion on the way to complement other national policies and programs,
(e) The implementation arrangements with emphasis on capacity building,

(Refer to further details in PP 6-8, Appendix L: Policy Analysis, PSDP April 2009.)

2.1.4 Rural Electrification Policy

The Draft Rural Electricity Policy (REP) encapsulates the need for up scaling rural electrification through development of renewable energy resources. In a background note to the policy, the availability of renewable energy resources in the country, such as solar, hydro, wind, marine, biomass, geothermal and bio energy has been identified. In response to the increasing importance of renewable energy resources and technological advancements in this field, the Government of Papua New Guinea has proposed the development of Long Term Goal of Renewable Energy Supply with an Action Plan (2008-2027). This plan aims to implement relevant components of the rural electrification policy.

With a vision to enhance livelihood of rural population through sustainable provision of electricity, the goal of REP is to increase the coverage of Papua New Guinea's rural population to have access to affordable, sustainable, safe, robust and reliable electricity by utilizing appropriate renewable energy technologies and grid extension options.

The REP also includes:

(a) An overview of the rural electrification with a record on the history and performance of "C" Centers,

(b) Government's plan in order to carry out its obligations and electricity services to the majority of the population residing in the rural areas,

(c) A number of strategies.

(Refer to further details in PP 8-9, Appendix L: Policy Analysis, PSDP April 2009.)

2.2 Power Sector Organizations

An organization chart of the Power Sector of Papua New Guinea is presented below.

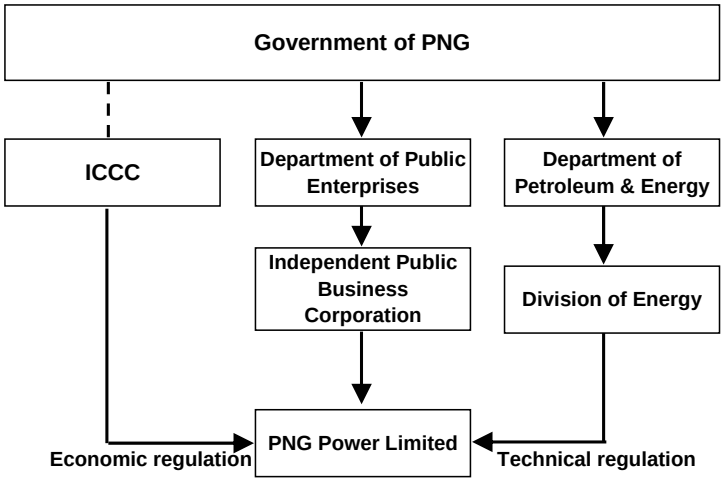


Figure 2.2.1 Organization of the Power Sector of Papua New Guinea

(Source: JICA Survey Team)

The Independent Public Business Corporation (IPBC) is under supervision of the Department of State Enterprises (DSE) of the Government of Papua New Guinea (GoP). The IPBC was established under the Law of Independent Public Business Corporation promulgated in 2002 in accordance with the privatization policy of the GoP. The IPBC is responsible for management of its assets and for their privatization if it is appropriate. The Independent Consumer & Competition Commission (ICCC) is responsible for review, adjustments and regulation of the power tariff. The PNG Power Limited (PPL) has a concession/permission to exclusively manage generation, transmission, and distribution of electricity for the capital city Port Moresby and the towns in the 19 Provinces. PPL is a power company of which the equity is held by the Government of Papua New Guinea where IPBC holds 100% share of its stocks. The PPL collects the tariff in accordance with the tariff system. PPL takes charge of the technical regulation[2] since it was entrusted by ICCC in 2001.

[2] The technical regulation will enforce all regulatory provisions governing the works and operations in generation, transmission, and distribution of electricity. This will entail ensuring compliance with standards in generation and network assets. Refer to Section

Department of National Planning and Monitoring (DNPD) regulate the international aid program from other countries and financing agencies.

PPL executes operation and maintenance of the generation, transmission and distribution facilities at present, but operation and maintenance of the water source, dams and reservoirs was transferred to the independent corporation, PNG Dams Ltd (PNG Dams). PNG Dams was incorporated by the NEC in July 2002 and the Sirinimu Dam, Yonki Dam and related assets and liabilities were transferred from ELCOM to PNG Dams. Currently there is an agreement between PPL and PNG Dams whereby in return for the supply of water from the dams, PPL agrees to pay PNG Dams sufficient to cover its corporate costs and also undertake all operation and maintenance responsibility for the dams and meet these costs.

4.2.1, Electricity Industry Policy, July 2008, Independent State of Papua New Guinea.

CHAPTER 3
PRESENT SITUATION OF POWER SUPPLY

3.1 General

The maximum power supply system in the country is the Port Moresby grid which covers the capital Port Moresby and its surrounding areas of parts of the Central Province. PPL is currently responsible for operation of 29 power supply systems (Centers) at various centers which covers area having high population density (urban areas). Three of these systems are medium hydro based with generating capacity in excess of 10MW and these are Port Moresby, Ramu and Gazelle Peninsula systems. The remaining 17 systems are thermal (diesel) based with the exception of three which have mini hydro schemes supplemented diesel power plants. The Ramu system consists of 10 power supply Centers. All systems are independently isolated from each other including Port Moresby, Ramu and Gazelle grids.

The three systems, i.e. Port Moresby, Ramu and Gazelle, have high voltage transmission lines of 132kV and 66kV. The other systems are served through MV lines of 33kV, 22kV and/or 11kV, and low voltage lines.

In addition to the above PPL's power supply systems, there are many captive power plants owned by private mining companies, sugar factories, factories, etc. for their own use and/or stand-by.

3.2 Power Generating Plants

3.2.1 Whole of PNG

In accordance with the information of the National and Provincial 10 Year Power Development Plan 2009-2018 (hereinafter called as TYPDP2009), total installed capacity of which facilities are owned and operated by PPL is 315MW. The capacity of the hydropower plants in total is 168MW, which shares 53% of the total and thermal power plants is 148MW. In addition to the power plants owned by PPL, there are many captive plants owned and operated by private mining companies, sugar factories, manufactures for their own use and/or stand-by. And its total capacity of the plant is estimated around 280MW to 300MW. Hydropower plants of about 160MW which is similar to the installed capacity of PPL.

The largest power supply system of the private companies is owned and operated by OTML mine in Western Province, which consists of hydropower plants of 60MW and thermal power plants of 54MW. Geothermal power plants have been developed by Lihir Gold Mine on Lihir Island, New Ireland Province with 53MW.

3.2.2 Port Moresby Grid

Port Moresby is supplied from the Rouna hydropower complex which has an installed capacity of 68.5MW in total and consists of a power plant located at the toe of the Sirinumu dam, Rouna No.1, Rouna No.2, Rouna No.3 and Rouna No.4 power plant. The Kanudi power station (IPP) provides further base power. Supplementary and emergency power is supplied by Moitaka thermal power station which has one gas turbine of 20MW rated and four medium speed heavy fuel oil diesel generators rated 7.5MW and 8MW. All hydropower stations except for Rouna No.2 which is a under ground type, are constructed on the ground. Kanudi power plant has two low speed heavy fuel oil diesel generators rated 12MW. The plant has been constructed by Korean contractor under BOT contract and operated since January 1999 with 15 years' concession period.

The details of the generating plants for Port Moresby grid are given in Table 3.2.1. In addition to the table, gas turbines having 2x15MW are under construction at Kanudi power station.

Table 3.2.1 Generating Power Plants of Port Moresby Grid

Power Plants	Type	Capacity (MW)				Name Manu.	Year Commis	Remarks
		Nos.	Unit Cap	Total Rating	Actual			
Rouna No.1	Hydro #3	1	1.00	1.00	0.85	Vobing	1957	
	Hydro #4	1	2.50	2.50	2.13	Vobing	1961	
Rouna No.2	#1,#4&#5	3	8.00	24.00	24.00	Andritz Vatech	2007-9	Upgraded
	Hydro #2&3	2	6.00	12.00	10.00	Voest Alpine	1969	#3: 4MW
Rouna No.3	Hydro #1&2	2	6.00	12.00	12.00	Vobing	1975	
Rouna No.4	Hydro #1	1	6.60	6.60	-	Ebara	1986	Under repair
	Hydro #2	1	6.60	6.60	5.74	Ebara	1986	
Sirinumu	Hydro	1	1.50	1.50	1.50	Andriz	1973	
Moitaka GT	G. Turbine	1	20.00	20.00	13.80		1982	
Moitaka DG	DG, HFO	2	7.50	15.00	12.70	HZ-Sulzer	1985	
Moitaka DG	DG, HFO	2	8.00	16.00	14.00	Mirrlees-Blkstone	1990	
Kanudi DG	DG, HFO	2	13.20	26.40	24.00	Man BMW	1997	
Total				143.60	120.72			

(Source: PPL's 10 Year Plan 2009 and interview at site)

The Rouna No.1 power plant is the oldest and started its operation in 1955 and the 4th unit has been added including new construction of additional penstock in 1959. The old penstock was broken and removed already from the site. As a result of the removal of the broken penstock, No.3 and No.4 units only are operated with the penstock constructed in 1959 at present. PPL has a plan that the No.1 and No.2 units will be replaced with a unit having its rated output of 8MW, including new construction of a penstock.

Rouna No.2 power plant having 5x6.0MW rated put into operation in 1965, and No.1, No.4 and No.5 units have been upgraded from the original rated output of 6MW to 8MW between 2007 and 2009. The governor control system of No.2 unit was also replaced at the time. The No.3 unit is presently operated less than 4MW under normal operation conditions to keep temperature of the upper bearing within the allowable range. Cooling water is taken from the

penstock. However, it is required to clean the filter once per week during heavy rainy season, because the water contains mud and rubbish. For other power plants, there is no such trouble, because ground water is used as cooling water.

Re-winding of coils of rotor and stator of No.2 unit of Rouna No.3 had been done at the factory in Australia and the works of re-assembling and testing had been completed in March 2010. Re-winding of rotor of No.1 unit of Rouna No.4 has also been done at the factory in New Zealand and it is now on its way by sea transportation to PNG.

Comparatively small scale repairing works of water turbine, generator, auxiliary equipment, control system, etc. have been made at repair shop provided in the power station site and/or local repair works. However, large scale repairing of machines like re-winding of generator coils, repair of runner (cavitation), etc. have been done at the manufacture's factory and/or overseas repair works. In case of the re-winding of rotor and stator of the above-mentioned Rouna No.3, eight (8) months was needed.

3.2.3 Ramu Grid

Ramu Grid has hydropower stations at Ramu (5x15MW, underground powerhouse) and Pauanda (2x6MW), and serves Lae（Morobe）, Madang (Madang), Goroka (Eastern Highlands), Kainatu (Eastern Highlands), Mount Hargen (Western Highlands), Kundiawa (Chimbu), Yonki (Eastern Highlands), Mendi (Southern Highlands) and Wabag/Wapennamanda (Enga). Those hydropower stations are major supply sources of Ramu grid and diesel generators at Lae, Madang, Mendi and Wabag supply supplementary energy during transmission line outages. Power is also purchased from Baiune hydropower station which is owned by Forest Product Ltd. when required and varies between 1 to 2MW depending on availability. The details of generating plants for Ramu grid are given in Table 3.2.2.

The No.2 unit of Pauanda has stopped its operation due to the damage of the intake structure. Cooling water for all units of Ramu hydropower station is taken from penstocks. The filters of cooling water supply system of all units are needed to be cleaned with a frequency of once per week during rainy season, because cooling water contains not only mud but also many fine vegetable rubbish. Even frequent filter clearing has been made, the output of machine is sometimes suppressed due to the high temperature of the generator coils. The team inspected rubbish taken from the filters. Rubbish contains many vegetable shreds like ears of pampas grass. It is urgently required to rehabilitate the cooling water supply systems, especially for No1, No.2 and No.3 units. At present these units are operated at 80% of the rated output as maximum.

Table 3.2.2 Generating Power Plants of Ramu Grid

Power Plants	Type	Capacity (MW)				Name of Manufact.	Year Commis.	Remarks
		Nos.	Unit Cap	Total Rating	Actual			
Pauanda	Hydro-#1	1	6.00	6.00	5.00	n.a	1983	
	Hydro-#2	1	6.00	6.00	-	n.a	1983	Not in service
Ramu	Hydro-#1	1	15.00	15.00	12.00	Litostroj	1976	1991: Runner
	Hydro-#2	1	15.00	15.00	12.00	Litostroj	1976	replaced
	Hydro-#3	1	15.00	15.00	12.00	Litostroj	1976	
	Hydro-#4	1	15.00	15.00	-	Boving	1990	Under repair
	Hydro-#5	1	15.00	15.00	12.00	Boving	1990	
Madang DG	#1	1	0.50	0.50	0.40		1959	
	#2 & #4	2	1.50	3.00	2.40		1971/72	
	#3	1	1.34	1.34	1.20		1968	
	#5 & #6	2	3.30	6.60	5.40		1980/08	
Milford DG	#1&#2	2	0.70	1.40	0.50		1959	Not in service
	#3-#6	3	3.00	9.00	-		1971/79	Not in service
	#7-#12	6	3.00	18.00	10.00			3: not in sevice
	#13	1	1.50	1.50	1.20		2009	Contener type
Taraka DG	#1 - #9	9	1.20	10.80	9.00		2009	Contener type
Mendi	#1	2	0.25	0.50	0.40		1979	Southern H.lands
	#2	1	0.30	0.30	0.20			
Wabag	#1	1	0.30	0.30	0.30	Catapillar	n.a	Enga Prov.
	#2	1	0.23	0.23	0.23	Catapillar	n.a	
	#3	1	0.63	0.63	0.62	Detroit	n.a	Owner: EPG
Total of Ramu Grid				135.10	79.85			

(Source: TYPDP2009 and interview at site)

In the interview with the staff of Ramu power station, they indicated that runner cavitation is heavily occurred. Presently No.4 unit is not in service, because its runner has been sent to Thailand for cavitation repair. Operation records of all generating units for one week from April 4 to April 11, 2010 have been received at site. Even, it is the short time operation records, it is considered to be one of causes of cavitation that most of all machines are under low output operation in a very long time.

In general, advantages of a turbine of Francis type are its simple mechanism and then cheaper cost in comparison with other type of turbines. However, it has a disadvantage of which the range with high efficiency is narrow in comparison with other type of turbine. A Francis turbine is usually designed with maximum efficiency point in 80% to 95% of its rated output and its efficiency is remarkably goes down in the low output range. It is recommended to operate the machines with higher output range as much as possible. For reference, Table 3.2.3 shows the actual records under 4 units operation of April 7, 2010 and its plant factors, and output and its plant factors under 3 units operation.

Table 3.2.3 Operation Records of Ramu Power Plant and its Plant Factor

	Actual Output (MW) and its Plant Factor (%)								Total	3 Units Oper	
	G1	(%)	G2	(%)	G3	(%)	G5	(%)	MW	MW	(%)
16:00	7.0	(47)	10.1	(67)	7.7	(51)	8.8	(59)	33.6	11.2	(75)
17:00	8.6	(57)	9.9	(66)	7.8	(52)	9.0	(60)	35.3	11.8	(78)
18:00	2.4	(16)	7.7	(51)	9.7	(65)	10.3	(69)	30.1	10.0	(67)
19:00	9.0	(60)	8.5	(57)	8.8	(59)	8.8	(59)	35.1	11.7	(78)
20:00	7.0	(47)	8.4	(56)	9.5	(63)	9.3	(62)	34.2	11.4	(76)
21:00	6.7	(45)	8.4	(56)	9.4	(63)	9.3	(62)	33.8	11.3	(75)

(Source: Log sheets of Ramu network control center)
Remarks: Operation records of Apr. 7, 2010

3.3 Transmission and Distribution Facilities

3.3.1 Whole of PNG

Presently only three transmission line systems owned by PPL are existing, namely Port Moresby, Ramu and Gazelle transmission system. The Port Moresby and Gazelle system have 66kV lines only. The Ramu system consists of 66kV and 132kV which has been upgraded from 66kV. Other than PPL systems, OTML mine company has owned and operated 132kV transmission system for transmitting electric power generated by hydropower plants to the demand centers. However, other systems are not clear.

The medium distribution line voltages of PPL are 33kV, 22kV and 11kV, and low voltage 415/240V. The 33kV lines have been initially constructed as a transmission line and most of the lines are presently used as a distribution line with extension of the power supply system[1]. PPL has no intension to extend more those 33kV lines.

3.3.2 Port Moresby Grid

Electric power generated by the Rouna complex is sent to Port Moresby through 3 circuits of 66kV transmission lines and one 33kV feeder. The 33kV feeder was originally constructed for the transmission line for Rouna No.1 hydropower plant and presently used as a part of the distribution system. A double circuit 66kV transmission is used for transmitting electric power generated at Rouna No.2 and Rouna No.4 plants to Boroko substation which is a main substation of Port Moresby grid, a single circuit 66kV line is provided from Rouna No.2 plant to Moitaka power plant via Bomana substation.

Details of transmission lines are given in Table 3.3.1, and one-line diagram of Port Moresby grid is given on Figure 3.3.1. From the Figure 3.3.1, it is understood that almost all transmission system are cleared the N-1 criteria which is widely applied to assess the supply reliability of the transmission system. There is no bottle neck for supplying electricity in the area at present. However, new construction of substation which will share the demand of the

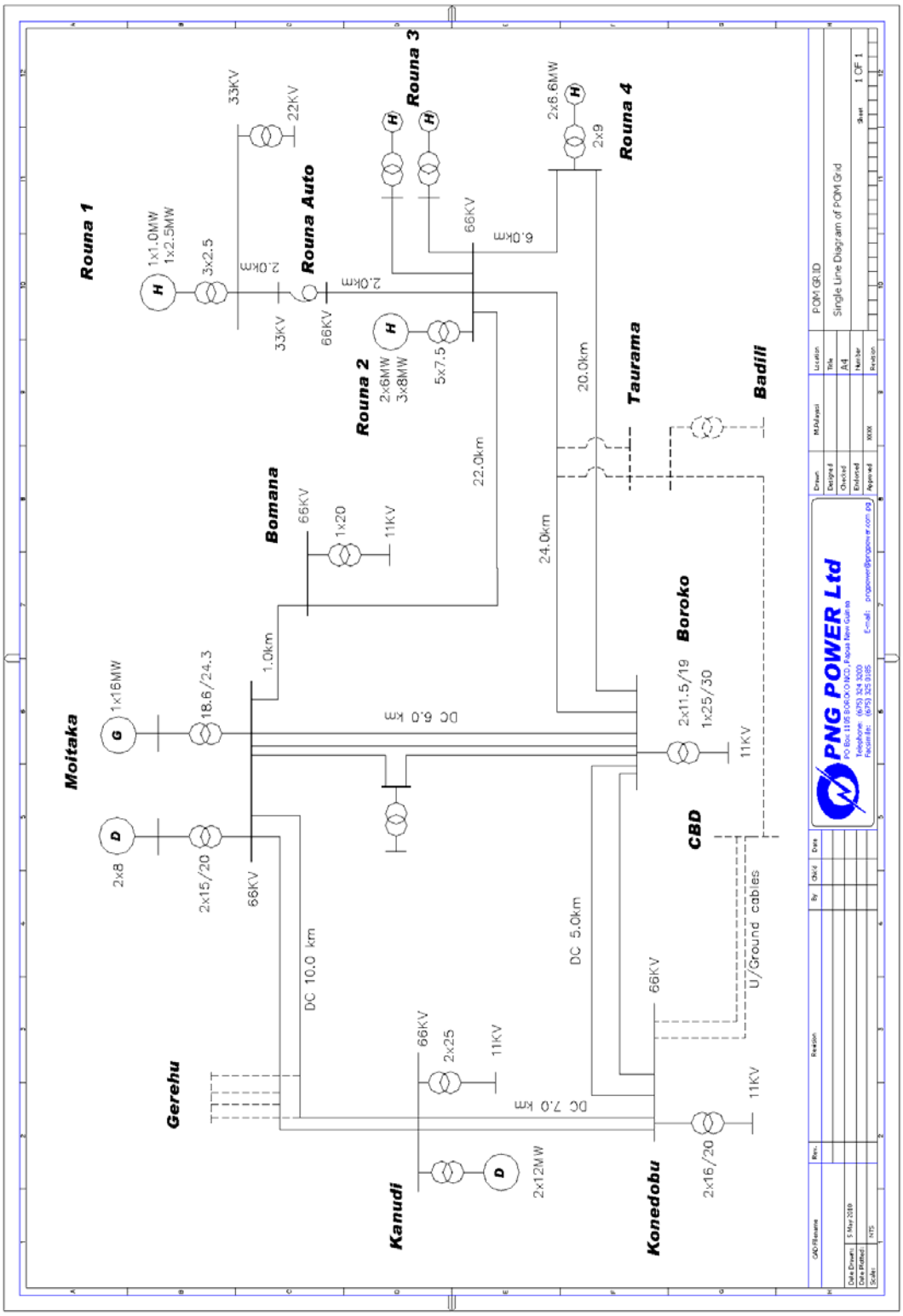
[1] There is still a possibility to extend 33 kV lines as transmission line from the view point of economic viability.

existing substations in accompanying demand increase of the area and augmentation of caring capacity of the existing transmission lines .

Table 3.3.1 Existing Transmission Lines of Port Moresby Grid

	Line Section		Volt	CCT	Length	CCT・km	Conductor		G.W
	From	To	(kV)		(km)		Type	MVA	Type
1)	Rouna 3	Rouna 2	66	2	6	12	Cu 6/3.75	46	3/4.43
2)	Rouna 2	Boroko	66	1	24	24	Opal	34	7/2.75
3)	Rouna 2	Rouna 4	66	1	6	6	Opal	34	7/2.75
4)	Rouna 4	Boroko	66	1	20	20	Opal	34	7/2.75
5)	Rouna 2	Bomana	66	1	22	22	Waxwing	30	7/2.75
6)	Bomana	Moitaka	66	1	1	1	Waxwing	30	7/2.75
7)	Moitaka	Boroko	66	1	6	6	Waxwing	120	7/2.75
8)	Moitaka	Boroko	66	2	6	12	Mango	120	7/2.75
9)	Moitaka	Kanudi	66	2	10	20	Mango	68	7/2.75
10)	Kanudi	Konedobu	66	2	7	14	Mango	68	7/2.75
11)	Boroko	Konedobu	66	2	5	10	Cu 7/2.64	46	3/4.43
12)	Rouna 2	Rouna Auto	66	1	2	2	Cu 7/2.64	23	3/4.43
13)	Rouna Auto	Rouna 1	33	1	2	2	Cu 7/1.04	11.4	
14)	Warangi in-comming		66	2	1	2	Mango	120	7/2.75
	Total					153			
(Source: PPL)									

There are five substations on the Port Moresby grid provided with 11 units of step-down transformers having total capacity of 227MVA. In addition to such substation transformers, there are 22 step-up transformers having installed capacity of 252MVA at power plants. Their details are given in Table 3.3.2. The existing transformer capacity has enough allowance in comparison with the present maximum peak demand. At present new construction of substations is planned in TYPDP2009. For example, CBD GIS substation is planned for reducing the load of the Boroko and Konedobu substations and the loss reduction of distribution system.



(Source: PPL)

Figure 3.3.1 One-Line Diagram of Port Moresby Grid

Table 3.3.2 Existing Transformers of Port Moresby Grid

A: Zone Transformers								
	Name of	Voltage	Nos.	Unit (MVA)		Install.	Cooling	Manufact.
	Substation	Ratio		Natural	Forced	Capacity		Name
1)	Boroko	66/11	2	11.5	19	38	ONAN/OFAF	Tyree
		66/11	1	25	30	30	ONAN/ONAF	Tyree
2)	Konedobu	66/11	1	15	20	20	ONAN/ONAF	Crompton
		66/11	1	10	14	14	ONAN/ONAF	Hyundai
		66/11	1	20	25	25	ONAN/ONAF	ABB
3)	Waigani	66/11	1	15	20	20	ONAN/ONAF	
		66/11	1	15	20	20	ONAN/ONAF	
4)	Bomana	66/11	1	10	15	15	ONAN/ONAF	Hyundai
5)	Kanudi	66/11	1	15	20	20	ONAN/ONAF	Crompton
		66/11	1	20	25	25	ONAN/ONAF	
	Total Capacity (MVA)		11			227		
B: Generation Transformers								
1)	Rouna 1	3.3/33	3	2.5		7.5	ONAN	
		33/22	2	2.0		4.0	ONAN	
2)	Rouna 2	11/66	2	7.5		15.0	ONAN	
		11/66	3	10.0		30.0	ONAN	
3)	Rouna 3	11/66	2	7.5		15.0	ONAN	
4)	Rouna 4	11/66	2	9.1		18.2	ONAN	
5)	Rouna Auto	33/66	2	5.0		10.0	ONAN	
6)	Sirinumu	6.6/22	1	2.0		2.0	ONAN	
7)	Moitaka 5&6	11/66	1	15.0	25.0	25.0	ONAN/OFAF	
	Moitaka GT.2	11/66	1	19.5	25.5	25.5	ONAN/OFAF	
	Moitaka 3&4	11/66	1	20.0		20.0		
9)	Kanudi	11/66	2	20.0	40.0	80.0	ONAN/OFAF	
Total			22			252.2		
(Source: TYPDP2009)								

As for the distribution system of Port Moresby grid, total length of MV lines is 444kM, and its details are 22kV: 145km, 11kV: 289km and SWER (Single Wire Earth Return): 10km. The length of low voltage lines of 415/240V is 334km including single phase lines. Number of units of distribution transformers is 582 units including transformers of 51 units for the bulk supply customers and its total capacity is 165MVA. Details information on the distribution systems except Port Moresby is limited.

3.3.3 Ramu Grid

Three single circuit radial transmission lines are extended from the Ramu switching station to Lae (Morobe), Madang and Highland areas. Ramu – Lae transmission line was upgraded from 66kV to 132kV in 2009. However, the remaining part of the transmission system is still remained at 66kV. For the township of Kainatu, Goroka, Kundiawa, and Mount Hargen are connected by 66kV and interconnected with Pauanda hydropower plant. In addition to the

township connected by 66kV lines, Wabag (Enga) and Mendi (Southern Highland) are served from Pauanda power plant through 22kV lines.

One-line diagram of Ramu grid is given on Figure 3.3.2 and details of transmission lines are in Table 3.3.3.

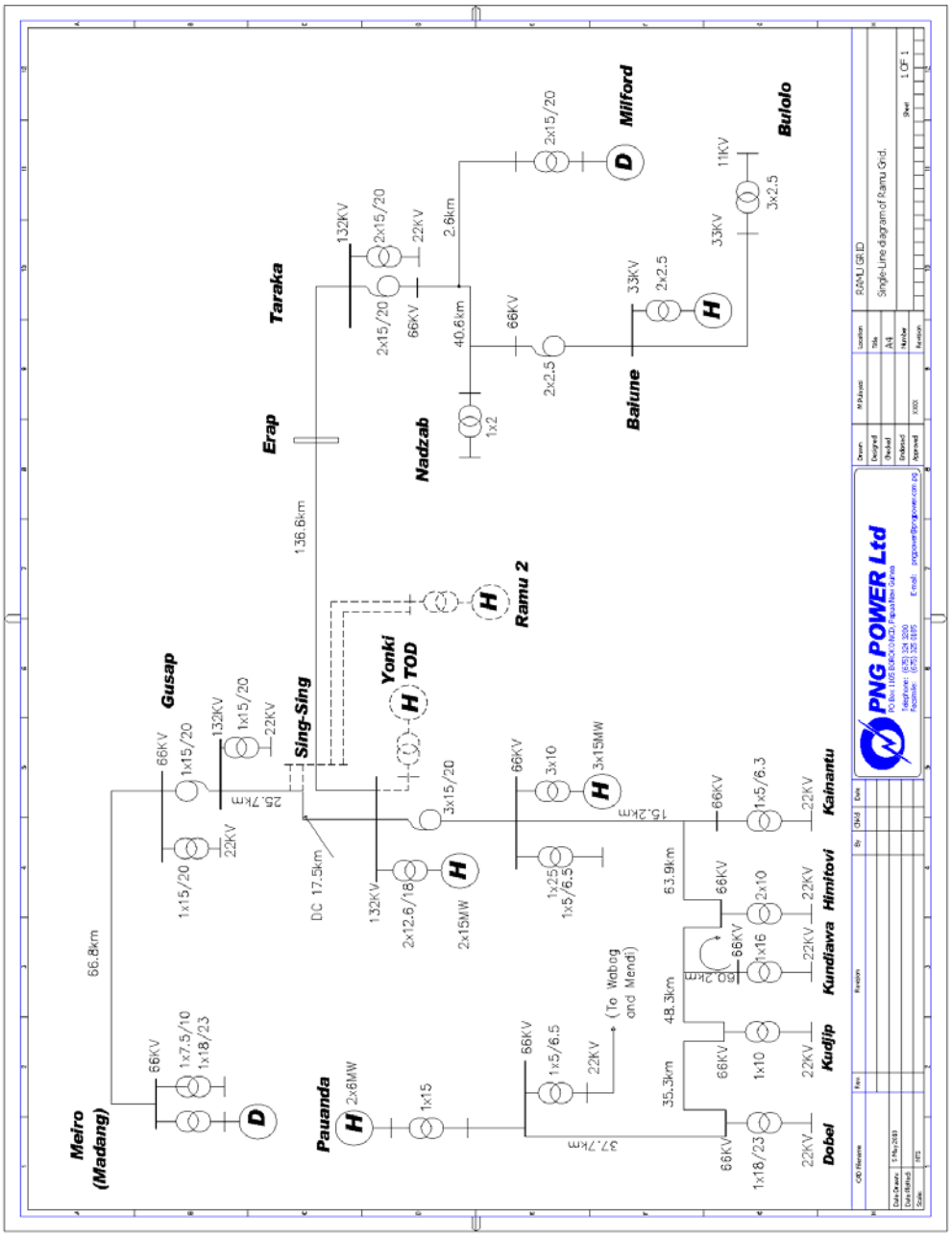
Table 3.3.3 Existing Transmission Lines of Ramu Grid

	Line Section		Voltage	Circuit	Length	CCT·km	Conductor		G.W
	From	To	(kV)		(km)		Type	MVA	Type
1)	Ramu	Sing Sing	132	1	17.3	17.3	Panther	100	19/2.03
2)	Sing Sing	Taraka	132	1	136.6	136.6	Deer	100	19/2.03
3)	Taraka	Milford T	66	1	4.6	4.6	Camel	45	7/2.64
4)	Milford T	Millford	66	1	2.6	2.6	Tiger	45	7/2.64
	Taraka	Milford T	66	1	4.6	4.6		23	
	Milford T	Nadzab			36.0			23	
6)	Ramu	Sing Sing	132	1	17.5	17.5	Panther	100	19/2.03
7)	Sing Sing	Gusap	132	1	25.7	25.7	Tiger	75	19/2.03
8)	Gusap	Meiro	66	1	66.8	66.8	Tiger	37.5	19/2.03
9)	Ramu	Kainantu	66	1	15.2	15.2	Dog	31	7/2.64
10)	Kainantu	Himitovi	66	1	63.9	63.9	Dog	31	7/2.64
11)	Himitovi	Kundiawa	66	1	60.2	60.2	Dog	31	7/2.64
12)	Kundiawa	Kudjip	66	1	48.3	48.3	Dog	31	7/2.64
13)	Kudjip	Dobel	66	1	35.3	35.3	Dog	31	7/2.64
14)	Dobel	Pauanda	66	1	37.7	37.7	Dog	31	7/2.64
	Total					536.3			
(Source: PPL and PNG Ramu Transmission System Study by PB Power, Aug 2006)									

The Ramu grid is still in initial stage for forming of transmission system with three radial lines from the Ramu power station. N-1 criteria for assessing supply reliability of transmission system are not applicable. And length of most of transmission line is rather long (Ramu-Lae: 154km, Ramu-Madang: 110km, Ramu-Mt. Hargen-Pauanda: 260km). In addition to such line configuration, one-phase re-closing system is not applied to minimize the line-outages due to one-line-ground faults. Therefore, it is judged that stable and continuous power supply over the lines seems to be difficult. Large part of the one-line-ground faults of transmission lines is caused by means of touching of conductors and branches of trees.

As explained in Clause 3.2.3, the operation records obtained during site survey includes the reading records of watt-meter on the 132kV line at Taraka substation in Lae. The long time shut-down of the Ramu – Lae 132kV transmission line from 19:00 to 22:30 on 10th April 2010 is observed in only 1-week operation records[2]. The Ramu grid has no facilities to trace the operation of power system like the Port Moresby grid. Therefore, it is indispensable to input the operation records given in the form of hard copies to the computer for analyzing.

[2] It is reported that long time shutdown occurs chronically, however, actual records were obtained only for 10th April, 2010.



(Source: PPL)

Figure 3.3.2 One-Line Diagram of Ramu Grid

Ramu grid is configured by 66 kV and 132 kV transmission line and has 13 substations. In those substations, there are 8 units of auto-transformers having total capacity of 125MVA and 19 units of step-down transformers having total capacity 214MVA. In addition to such

substation transformers, there are 8units of step-up transformers having installed capacity of 135MVA at power plants. The existing transformer capacity has enough allowance in comparison with the present maximum peak demand.

Table 3.3.4 Existing Transformers of Ramu Grid

A: Zone Transformers								
	Name of Substation	Voltage Ratio	Nos.	Unit Capacity (MW) Natural	Unit Capacity (MW) Forced	Install. Capacity	Cooling	Manufact. Name
Auto Transformers								
1)	Taraka	132/66	2	15	20	40	ONAN/ONAF	
2)	Gusap	132/66	1	15	20	20	ONAN/ONAF	
3)	Ramu S. Yard	132/66	3	15	20	60	ONAN/ONAF	
4)	Baiune Auto	66/33	2	2.5		5	ONAN	
	Total		8			125		
Step-downe Transformers								
1)	Milford	66/11	2	15	20	40	ONAN/ONAF	
2)	Taraka	132/11	2	15	20	40	ONAN/ONAF	
3)	Nadzap	66/11	2	1		2	ONAN	
4)	Walium	66/11	1	1		1	ONAN	
5)	Meiro	66/11	1	18	23	23	ONAN/ONAF	
6)	Gusap	66/22	1	5	6.3	6	ONAN/ONAF	
		132/22	1	15	20	20	ONAN/ONAF	
7)	Ramu S. Yard	66/22	1	2.5		3	ONAN	
		66/22	1	5	6.5	7	ONAN/ONAF	
8)	Kainantu	66/22	1	5	6.3	6	ONAN/ONAF	
9)	Himitovi	66/22	2	10		20	ONAN	
10)	Kundiawa	66/22	1	5	6.3	6	ONAN/ONAF	
11)	Kudjip	66/22	1	10		10	ONAN	
12)	Dobel	66/22	1	18	23	23	ONAN/ONAF	
13)	Pauanda	66/22	1	5	6.7	7	ONAN/ONAF	
	Total		19			213.6		
B: Generation Transformers								
1)	Ramu 1	11/66	3		17	51	OFAF	
		11/132	2	12.6	18	36	ONAF	
2)	Pauanda	6.6/66	1		15	15	ONAF	
3)	Meiro	11/66	1	7.5	10	10	ONAN/ONAF	
		11/66	1	18	23	23	ONAN/ONAF	
	Total		8			135		

(Source: PPL)

3.4 Power and Energy Supply

3.4.1 Whole of PNG

In 2009, total electric energy supply of PNG under PPL is 896.2GWh including purchased energy. Energy generated by hydropower plants is the largest at 589.9GWh, and shares 65.8% of the total. Supply energy from thermal power plants owned by PPL is 156.4GWh (17.5%), and purchased energy is 149.9GWh (16.7%). As explained in Clause 3.2.2, almost all of the purchased energy is supplied from IPP (Kanudi power plant) of the Port Moresby grid.

Actual annual generated and purchased energy of PNG from 2000 to 2009 are given in Table 3.4.1.

Table 3.4.1 Annual Generated and Purchased Energy of Whole PNG (MWh)

											Increase rate	
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2000-09	2004-09
Hydro	541.6	546.6	512.5	506.8	471.7	510.2	522.4	535.2	548.7	589.9	0.95%	4.57%
Thermal	113.3	118.3	111.7	107.6	114.0	111.3	119.3	130.7	144.6	156.4	3.65%	6.52%
PPL Genration	654.8	664.9	624.2	614.4	585.8	621.5	641.7	665.9	693.3	746.3	1.46%	4.96%
Purchase	141.5	105.1	155.8	156.2	171.4	156.0	142.3	152.0	156.4	149.9	0.65%	-2.65%
System Total	796.3	770.0	780.0	770.6	757.2	777.5	784.0	817.9	849.7	896.2	1.32%	3.43%

(Source: Netwok Contrl Division of PPL)

As shown in the table, annual energy is gradually decreased toward 2004, and after 2005 it is continuously increased every year up to 2009. In other words, averaged annual increase rate between 2000 and 2009 is very low rate of 1.3%, but stable increase is observed between 2004 and 2009 with averaged annual increase rate of 3.4%.

In same year of 2009, annual supply energy to the Port Moresby grid is 441.1GWh which is 49.2% of whole PNG, and the Ramu grid is 327.9GWh (36.6% of the total), and energy of 769.0GWh is supplied to both the Port Moresby and Ramu grids. However, annual energy supply to the remaining 15 power supply system shares only 14.2% of the total.

Annual energy supply in 2004 is the lowest. It is considered to be caused not only decrease of the demand, but also big deduction of energy generated by hydropower (12.9% decrease against 2000) due to much decreasing of rainfall, namely effect of “Load Sharing” and/or “Load Shedding” which are taken as countermeasure during peak time of the day under the deficit of power supply capacity.

The results of the calculation based on the actual annual maximum power demand of each supply system obtained from Network Control Center are given in Table 3.4.2. The Port Moresby grid occupies about half (51.2%) of the whole maximum demand in 2009, the Ramu grid accounts for 33.5% next, and the maximum total demand of the remaining systems is 15.3%.

Table 3.4.2 Peak Demand (MW)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Inc.Rate
PNG Total	146.8	149.2	151.8	150.4	151.8	153.7	153.4	160.3	167.3	173.5	1.9%
Port Moresby	77.1	75.7	76.6	76.1	77.0	79.3	77.3	78.5	84.8	88.8	1.6%
Ramu	49.4	52.6	55.1	54.3	54.5	52.5	54.2	58.6	58.1	58.1	1.8%
Others	20.3	20.9	20.1	20.0	20.3	21.9	21.9	23.2	24.4	26.6	3.0%

(Source: Network Control Center of PPL)

3.4.2 Port Moresby Grid

In 2009, total annual electric energy supply of Port Moresby grid is 441.1GWh including purchased energy. Energy generated by hydropower plants is 256.3GWh, and shares 58.1% of the total. Supply energy from thermal power plants is 39.2GWh (8.9%), and purchased energy is 145.6GWh (33.0%). The share of energy generated by hydropower plants is smaller than that of whole PNG. It is caused by extremely high share of hydropower of Ramu grid. The purchased

energy is supplied by IPP above-mentioned in Clause 3.2.2.

Actual annual generated and purchased energy of Port Moresby grid from 2000 to 2009 are given in Table 3.4.3.

Table 3.4.3 Annual Generated and Purchased Energy of Port Moresby Grid (GWh)

											Increase rate	
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2000-09	2004-09
Hydro	222.8	230.6	192.2	196.4	172.8	203.9	214.7	196.0	215.5	256.3	1.57%	8.21%
Thermal	37.5	47.3	39.2	33.1	38.3	29.0	31.0	44.9	50.4	39.2	0.49%	0.42%
PPL Genration	260.3	277.9	231.4	229.5	211.2	232.9	245.7	240.9	266.0	295.5	1.42%	6.95%
Purchase	137.9	103.0	154.6	156.2	171.4	156.0	142.3	152.0	152.1	145.6	0.60%	-3.22%
System Total	398.2	381.0	386.0	385.8	382.6	388.9	388.0	392.9	418.1	441.1	1.14%	2.89%

(Source: Netwok Contrl Division of PPL)

For the Port Moresby grid, the system control center in the building headquarter of PPL is conducting load dispatching of the system and operation/control of the substations. In addition, the computer of the center also traces actual operation and records every 30 minutes. This survey team obtained the operation records for one week from 18th to 25th April 2010. Situation of sharing of load of Port Moresby grid by generation type is shown on Figure 3.4.1 which is the typical daily load on 21st April 2010 (Wed). And the typical load curves of 18th April 2010 (Sun) and 21st April 2010 (Wed) are given on Figure 3.4.2

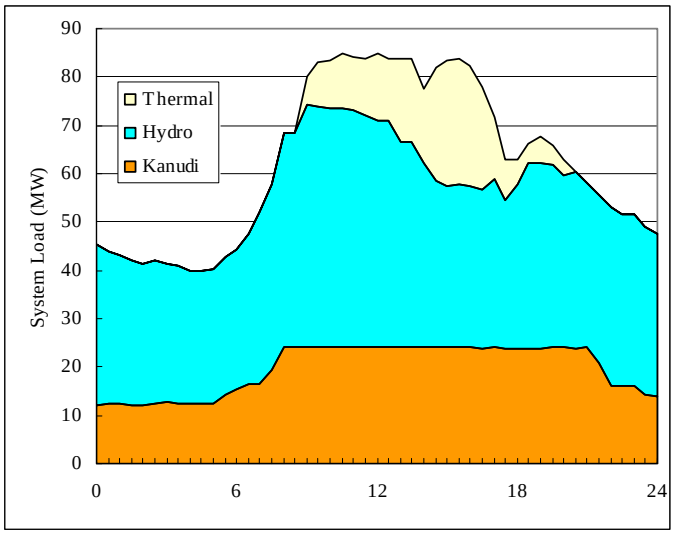


Figure 3.4.1 Typical Daily Generation by Type of Port Moresby Grid

As shown in Figure 3.4.2, the daily load curve of Port Moresby grid is Day-Time peak and is very rare in comparison with the daily load curves of other under developing countries. As given in Table 3.6.1 below, the sold energy of the general demand is largest and shares 59.0% of the total in 2009, followed by industrial demand of 22.3%. In under developing countries, domestic demand generally shares the biggest part of total energy consumption, however domestic demand of Port Moresby shares only 18.3% of the total. The figure on Sunday clearly

reveals, i.e. the drop of load in day-time is much bigger than that of night-time. However, it still maintains a type of day-time peak on Sunday.

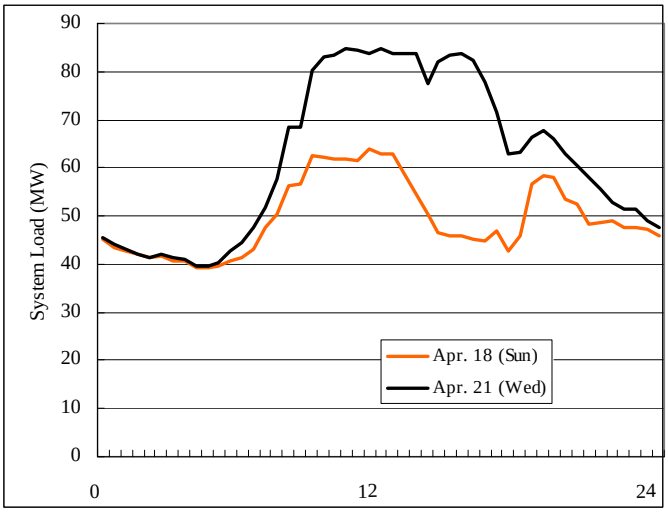


Figure 3.4.2 Typical Daily Load Curves of Port Moresby Grid

Monthly generated energy records by hydropower plants from 2000 to 2009 are given in Table 3.4.4. As shown in the table, it is understood that abnormal drought badly hit PNG in 2004 and energy generated by hydropower plants was much decreased, and such situation continued from April 2004 to February 2005. In 2009, PNG enjoyed rich rainfall for power generation and such whether condition seems to be continued to the present (May 2010). The weather of PNG is roughly divided into two seasons, namely wet and dry seasons. However, the difference of the generated energy in the both seasons seems to be smaller than that of south-east Asian countries.

As shown in Table 3.4.2, the annual maximum power demand of Port Moresby is recorded at 88.8MW in 2009. The Table 3.2.1 shows that the total power generation capacity is 143.6MW, its effective output is 121.0MW. However, the total effective output of IPP and hydro power plants is 80.2MW which is lower than the peak demand. Therefore, the supplement aged gas turbine and diesel power plants are needed to be daily operated.

Table 3.4.4 Monthly Generation by Hydro of Port Moresby Grid (GWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	20.49	22.45	17.75	15.42	15.56	17.21	16.24	17.27	20.63	20.00	20.47	19.33
2001	21.82	18.91	22.95	21.78	21.99	20.81	20.38	12.04	16.35	18.40	18.58	16.59
2002	17.93	16.87	18.76	18.12	18.58	14.68	14.96	14.16	14.43	13.73	14.34	15.64
2003	16.27	16.65	18.15	17.02	17.94	15.48	15.27	15.89	14.32	17.08	14.56	17.78
2004	17.65	16.91	19.35	15.09	15.23	13.04	11.93	11.85	13.97	11.75	11.79	14.25
2005	15.74	14.28	19.87	19.03	16.79	15.92	17.27	15.32	15.29	17.06	17.99	19.36
2006	21.36	17.83	19.03	18.68	18.66	18.72	15.65	15.56	17.80	15.92	18.05	17.47
2007	17.57	16.12	20.34	17.18	17.81	15.66	15.07	14.98	14.94	16.43	13.61	16.25
2008	16.97	17.03	18.85	17.70	17.44	15.65	13.79	16.09	18.29	22.62	24.47	16.66
2009	23.26	19.88	23.47	23.35	23.54	23.53	20.85	20.12	17.55	19.19	20.23	21.37
Ave	18.91	17.69	19.85	18.34	18.35	17.07	16.14	15.33	16.35	17.22	17.41	17.47
Max	23.26	22.45	23.47	23.35	23.54	23.53	20.85	20.12	20.63	22.62	24.47	21.37
Min	15.74	14.28	17.75	15.09	15.23	13.04	11.93	11.85	13.97	11.75	11.79	14.25

(Source: Network Control Center of PPL)

3.4.3 Ramu Grid

In 2009, total annual electric energy supply of Ramu grid is 327.9GWh. Energy generated by hydropower plants is 294.0GWh, and shares big portion of total generation i.e. 89.7% of the total. Supply energy from thermal power plants is 29.6GWh (9.0%), and purchased energy is only 4.3GWh (1.3%). The share of hydropower generation is extremely big, and it is caused that the installed capacity of hydropower plant has margin against the system demand. On the other hand, the share of thermal power plant is similar to that of Port Moresby grid. It is considered to be caused that emergency operation time is increased due to less reliability of the transmission system.

Actual annual generated and purchased energy of Port Moresby grid from 2000 to 2009 are given in Table 3.4.5.

Table 3.4.5 Annual Generated and Purchased Energy of Ramu Grid (GWh)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2000-09	2004-09
Hydro	288.3	283.6	288.4	277.7	266.6	274.1	281.3	304.1	299.1	294.0	0.22%	1.98%
Thermal	2.9	1.7	1.3	2.7	4.4	5.3	3.1	3.7	7.1	29.6	29.62%	46.31%
PPL Genration	291.2	285.3	289.7	280.5	271.0	279.3	284.4	307.8	306.1	323.6	1.18%	3.61%
Purchase	1.2	1.4	1.2	0.0	0.0	0.0	0.0	0.0	4.2	4.3	15.83%	-
System Total	292.4	286.6	290.9	280.5	271.0	279.3	284.4	307.8	310.3	327.9	1.28%	3.89%

(Source: Network Control Center of PPL)

The load dispatching of the Ramu grid is made from the control room of Ramu hydropower station through telephone line due to the imperfection of communication system. However, power output of each unit of Ramu power plant, received power over transmission line at Taraka (Lae), Himitovi (Goroka) and Meiro (Madang) substations, power output of Pauanda hydropower plant, Milford diesel power plant (Lae) and Madang diesel power plant are recorded every 30 minutes in log sheets at Ramu control center. In this survey, operation records

of 1 week from 4th April to 11th April 2010 are collected.

Situation of sharing of load of Ramu grid by generation type is shown on Figure 3.4.3 which is the typical daily load on 8th April 2010 (Thu). And the typical load curves of Ramu and Lae systems on 4th April 2010 (Sun) and 8th April 2010 (Wed) are given on Figure 3.4.4. Figure 3.4.4 shows that daily load curve of week day is Day-Time peak and it changes to Night-Time peak on Sunday. The sharp drop of demand is observed in day time of the daily load curve and it is abnormal due to some kind of faults in comparison with ones of other week days. However, certain cause is not clear from the obtained daily operation records.

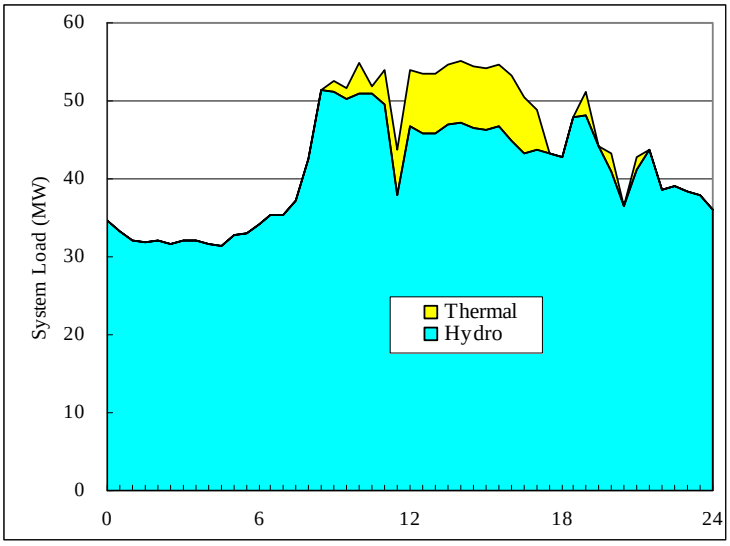


Figure 3.4.3 Typical Daily Generation by Type of Ramu Grid

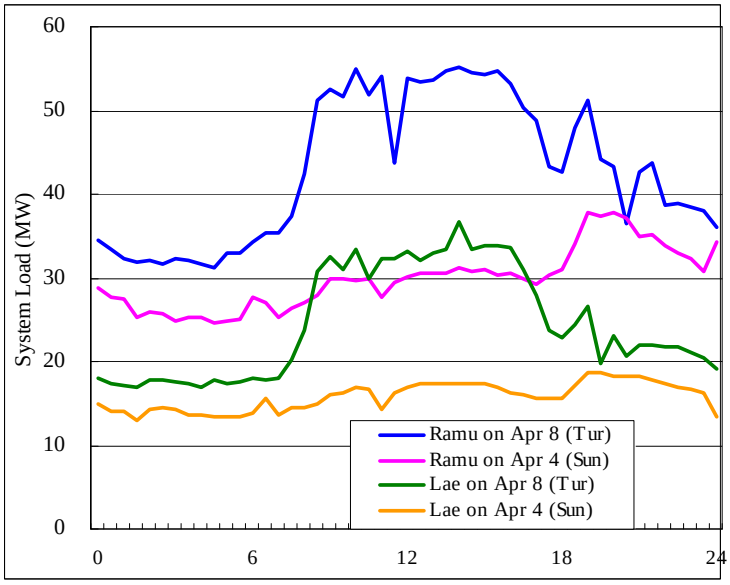


Figure 3.4.4 Daily Load Curves of Ramu Grid and Lae Center

Monthly generated energy by hydropower plants is given in Table 3.4.6. As shown in the table, it is understood that energy generated by hydropower plants was influenced by abnormal drought whether conditions similar to Port Moresby grid, but less effect.

Table 3.4.6 Monthly Generation by Hydro of Ramu Grid (GWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	23.27	23.15	25.43	23.65	25.18	24.20	23.53	23.64	23.59	24.90	24.25	23.54
2001	23.44	22.06	24.94	23.23	24.74	23.26	23.33	24.39	23.39	24.40	23.91	22.54
2002	23.67	23.14	23.90	23.29	25.22	22.97	23.64	23.59	26.50	26.35	23.52	22.61
2003	23.04	23.93	22.75	23.35	24.62	22.90	24.03	23.28	22.27	24.21	21.06	22.30
2004	21.82	21.27	23.54	21.52	23.49	21.99	21.22	22.26	22.14	22.69	22.08	22.56
2005	21.12	21.96	24.00	23.18	23.96	22.05	23.14	22.93	22.81	23.54	22.87	22.51
2006	23.22	19.57	24.32	23.36	25.25	23.78	23.38	22.77	22.98	24.43	24.23	23.98
2007	24.51	23.78	25.89	24.93	27.33	25.60	25.37	27.55	26.25	25.14	24.08	23.70
2008	24.38	23.52	25.34	25.51	26.48	24.57	24.81	24.14	23.82	25.59	25.42	25.48
2009	25.36	23.33	24.56	25.37	24.11	24.75	24.84	23.87	25.04	23.36	25.15	24.25
Aver	23.38	22.57	24.47	23.74	25.04	23.61	23.73	23.84	23.88	24.46	23.66	23.35
Max	25.36	23.93	25.89	25.51	27.33	25.60	25.37	27.55	26.50	26.35	25.42	25.48
Min	21.12	19.57	22.75	21.52	23.49	21.99	21.22	22.26	22.14	22.69	21.06	22.30

(Source: Network Control Center of PPL)

As shown in Table 3.4.2, the annual maximum demand of 2009 is 58.1MW. Table 3.2.2 shows that the total power generation capacity 135.1MW and its effective output is 80.0MW. Reserve margin is approximately 38% of high value. However, the effective output of hydropower plant is 53.0MW, then the supplement aged and small scaled diesel plants is required to be operated daily.

3.5 Tariff Structure and Electric Tariff

3.5.1 Tariff Structure

The tariff structure of PPL is very simple, which consists of Domestic, General, Industrial and Public Lighting categories[3]. In accordance with the tariff table announced by PPL and interview with related staff of PPL, the definitions of tariff groups are as follow.

(1) Domestic Customers: A customer is a Domestic Customer in respect of premises if that Customer consumes or intends to consume electricity supplied to those premises principally for domestic or household purposes and that Customer is not a General or an Industrial Customer in respect of those premises.

(2) General Supply Customers: A Customer is a General Customer in respect of premises if that Customer has a maximum demand for electricity of less than 200kVA at the premises, but who does not consumer or intend to consume that electricity principally for domestic or household purposes. However, in case of residential apartments, if it makes bulk supply contract with PPL, it classified as the general customer when the maximum demand is less than 200kVA. In case of residential customers with small shop or office, two energy meters

[3] There is another tariff for power transfer supply, however, such tariff system seems to be applied depending on the contract conditions of respective users.

will be provided for the individual purposes.

(3) Industrial Customers: A Customer is an Industrial Customer in respect of premises if that Customer has a maximum demand for electricity of more than 200kVA at the premises, irrespective of the purpose for which electricity is or to be used, and such demand to be determined by a demand meter connected to that premise over any period of 12 consecutive months in that period of two years before the date of calculation or if electricity has been supplied for a limited period, as estimated by the Regulator on application by either party. For that purposes, two meters, i.e. energy and capacity meters, are provided.

(4) Streetlights: A person, City Authority of Provincial Government who is responsible for providing streetlights is deemed to be a customer for the purpose of applying the prescribed streetlight rate and charges. The annual streetlight charges and the rate applying to metered streetlights are based on the General Supply Rate. In the interview with PPL's staff, annual electric charge will be calculated on the basis of customer's application such as number, type, capacity, etc. of street lights.

In addition to the above tariff categories, the domestic and general supply customers are consisted of two groups, i.e. "Credit" and "Easipay" tariff groups and they have different electricity rates.

Electric charge collecting system of the "Credit" is widely applied in the world, which has the process of monthly meter reading, issuing of bill and paying by customer. In other words, it is a system of "Use First" and "Pay Later". Electric charge collecting system of the "Easipay" is same method applied to mobile phone, namely "Pay First" and "Use Later".

Electricity tariff of "Credit" has a special tariff taking low-income customers into consideration. In other words, as shown in Table 3.5.1, low price with 60% of normal tariff of "Credit" is applied to the consumption up to 30kWh/month. There is no such special consideration for "Easipay" customers, but electric rate of 82% of the normal tariff of "Credit" is commonly applied for all consumption of energy.

For arrears of electric charges of "Credit" customers, as well as other countries, if the claimed electric charges are not paid up to the date of next meter reading, the power supply will be stopped at the time. On other hand, "Easipay" is automatically stopped its power supply at the time finishing the charged amount.

3.5.2 Electric Tariff

ICCC has approved a 2.7% reduction in tariffs and charges for 2010 except for the scheduled services. Table 3.5.1 is the tariff schedule indicating the current and new rates applied from 1st January 2010.

Table 3.5.1 Current and New Electricity Tariff Table

	Tariff Categories	Unit	Old Tariffs (2009)	New Tariffs applied from 1st Jan 2010
A	**Industrial Customers (Credit Meters)**			
	All energy	Toea/kWh	49.71	48.32
	Demand charge	Kina/kVA/month	60.57	58.87
	Minimum demand	kVA/month	200	200
B	**General Supply Customers (GS)**			
B.1	**Credit Meters**			
	All energy	Toea/kWh	77.51	75.34
	Minimum charge	Kina/month	18	18
B.2	**Easipay**			
	All energy	Toea/kWh	75.61	73.48
	Minimum charge	Kina/receipt	50	50
	Easipay Emergency Receipt-GS	Kina/receipt	50	50
	Easipay Emergency Service Fee-GS	Kina/receipt	11	11
C	**Domestic Customers (DC)**			
C.1	**Credit Meters**			
	First 30kWh/month	Toea/kWh	39.16	38.07
	Balance	Toea/kWh	66.56	64.69
	Minimum charge	Kina/month	12	12
C.2	**Easipay**			
	All energy	Toea/kWh	54.73	53.19
	Minimum charge	Kina/receipt	10	10
	Easipay Emergency Receipt-DC	Kina/receipt	10	10
	Easipay Emergency Service Fee-DC	Kina/receipt	10	10
D	**Public Lighting Customers**			
	Metered streetlights-All energy		77.51	75.34
	Tariff by type of fitting is also indicated in the authrised tariff table.			
In addition to the above, prices for Schedule Services are indicated as follow.				
1) Provision of temporary supply				
	Minimum account charge	Kina/month	14	15
	Temporary supply connection fee	Kina	80	85
2) New connection where service line available				
	Normal hours	Kina	39	42
	After hours	Kina	80	85
3) Reconnection of change of customers (excluding defaulting customers)				
	Normal hours	Kina	39	42
	After hours	Kina	80	85
4) Reconnection for defaulting customers				
	Normal hours	Kina	80	85
	After hours	Kina	158	169
5) Intermediate meter reading		Kina	25	27
6) Metering & service fee (single ohase)		Kina	130	139
7) Metering & service fee three ohase)		Kina	386	413
8) Meter testing		Kina	103	110
(Source: PPL)				

3.6 Demand

The sold energy by customer groups and number of customers of all centers are shown in TYPDP2009, but not complete and not include revenue. In addition, there are some differences in comparison with the information from 2003 to 2009 obtained from Revenue & Customer Services division.

In this study, the monthly sales data from 2003 to 2009 obtained from Revenue & Customer Services division will be used and explained hereunder, because of necessity of analysis of electricity rate. However, for the Public Lighting, it is noted that only revenue is recorded in the monthly sales data.

3.6.1 Sold Energy

Sold energy of whole PNG by tariff categories is given in Table 3.6.1. As explained in the remarks of the table, sold energy of public lighting from 2003 to 2008 has been taken from TYPDP2009 and sold energy of 2009 is estimated by using actual unit price K0.479/kWh (2007), because no information in the collected monthly data from Revenue & Customer Services Dep.

Table 3.6.1 Actual Energy Sales of Whole PNG 2000-2009 (MWh)

	Domestic			General Supply			Industrial	Public Lighting	Total
	Credit	Easipay	Total	Credit	Easipay	Total			
2003	74,341	47,709	122,050	455,379	0	455,379	61,946	2,874	642,250
2004	70,972	49,170	120,142	437,999	0	437,999	72,851	2,453	633,445
2005	62,202	55,937	118,139	422,558	0	422,558	87,240	1,623	627,937
2006	50,080	67,860	117,940	404,592	12,033	416,625	112,938	1,930	649,433
2007	41,710	82,251	123,961	398,557	12,165	410,722	139,015	2,045	675,744
2008	35,482	94,650	130,131	401,894	18,562	420,456	143,307	2,735	696,629
2009	34,442	94,140	128,581	394,953	20,433	415,386	156,665	**2,855**	703,488

(Source: Revenue & Customer Service of PPL)

Remarks:

(1) Public Lighting: Only revenue is recorded. Therefore, sold energy are taken from TYPDP2009 except for 2009, which is estimated from the past unit rate.

From the above table and Table 3.4.1, the estimated transmission and distribution losses of whole PNG are still in high level between 19.5% (2004) and 27.4% (2009).

Only for reference, actual sold energy of Port Moresby and Ramu grids which are taken from TYPDP2009 are given in Table 3.6.2 and Table 3.6.3.

Table 3.6.2 Actual Energy Sales of POM Grid 2000-2009 (MWh)

Year	Domestic			General			Industrial	Street Lighting	Total Sales	Growth Rate
	Credit	Easipay	Total	Supply	Easipay	Total				
1999	19,627	39,197	58,824	227,242	0	227,242	37,106	2,376	325,548	3.2%
2000	20,134	43,347	63,481	252,371	0	252,371	43,996	2,919	362,767	11.4%
2001	16,627	45,996	62,623	220,025	0	220,025	37,425	1,400	321,473	-11.4%
2002	17,207	46,760	63,967	222,178	1,500	223,678	38,046	1,118	326,809	1.7%
2003	16,581	47,018	63,599	220,998	3,298	224,296	24,095	1,357	313,347	-4.1%
2004	16,215	49,524	65,739	227,301	3,183	230,484	25,545	861	322,629	3.0%
2005	5,885	49,676	55,561	206,453	2,214	208,667	39,022	783	304,033	-5.8%
2006	4,214	60,018	64,232	190,474	11,340	201,814	59,279	970	326,295	7.3%
2007	2,026	60,394	62,420	190,391	11,440	201,831	57,274	971	322,496	-1.2%
2008	3,443	63,494	66,937	228,497	12,580	241,077	68,096	1,068	377,178	17.0%
2009	4,999	67,643	72,642	189,552	13,531	203,083	68,022	0	343,747	-8.9%

(Source: TYPDP2009 and PPL)

Table 3.6.3 Actual Energy Sales of Ramu Grid 2000-2009 (MWh)

Year	Domestic			General			Industrial	Street Lighting	Total Sales	Growth Rate
	Supply	Easipay	Total	Supply	Easipay	Total				
1999	39,688		39,688	152,541		152,541	45,878	1,507	239,614	6.2%
2000	38,476		38476	152,504		152504	43,416	1,869	236,265	-1.4%
2001	37,539		37,539	155,411		155,411	44,482	2,520	239,952	1.6%
2002	36,162		36,162	146,168		146,168	46,741	1,373	230,444	-4.0%
2003	34,986		34,986	145,372		145,372	46,505	1,048	227,911	-1.1%
2004	32,855		32,855	139,803		139,803	37,796	1,122	211,576	-7.2%
2005	36,954	343	37,297	135,458		135,458	39,303	594	212,652	0.5%
2006	35,372	427	35,799	147,731		147,731	41,826	763	226,119	6.3%
2007	33,181	459	33,640	168,374		168,374	41,967	892	244,873	8.3%
2008	35,640	2,379	38,019	176,631		176,631	60,658	1,491	276,799	13.0%
2009	13,046	27,409	40,455	132,599	5,416	138,015	69,578	0	248,048	-10.4%

(Source: TYPDP2009 and PPL)

3.6.2 Number of Customers

Actual number of customers by tariff categories is given in Table 3.6.4. As shown in table, the share of “Easipay” has reached to 79% of the total domestic customers and 30% of the general customers in 2009.

Table 3.6.4 Number of Customers by Tariff Categories

Year	Domestic			General Supply			Industrial	Public Lighting	Total
	Credit	Easipay	Total	Credit	Easipay	Total			
2003	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
2004	36,020	27,121	63,141	11,147	0	11,147	38	n.a	74,326
2005	34,471	41,252	75,723	10,789	0	10,789	49	n.a	86,561
2006	26,190	43,790	69,980	9,541	1,941	11,482	61	n.a	81,523
2007	23,856	50,963	74,819	9,278	2,891	12,169	70	n.a	87,058
2008	19,219	58,795	78,014	8,053	3,337	11,390	84	n.a	89,488
2009	15,779	58,795	74,574	7,633	3,337	10,970	84	n.a	85,628

(Source: Revenue & Customer Service of PPL)

Remarks: Number of customers of December of each year is used.

As explained in Clause 3.5.1, electricity tariff "Credit" of domestic customers has a special rate for applying to low-income group. Table 3.6.5 shows the actual condition of the past four years, because the sold energy of the minimum rate of "Credit" (Block-1) are recorded since 2006. As shown in the table, there are many customers whom energy consumption is less than 30kWh/month (estimated at 15 to 20% of total customers of "Credit") up to 2008. However, it is said that such customers have been decreased to the level of 1%, because averaged monthly energy consumption in 2009 has remarkably increased to around 30kWh. In other words, the current most of "Credit" customers consume electricity more than 30kWh/month.

Table 3.6.5 Consumption of Domestic Customers applied Minimum Rate

Year	Nos of Customer	Credit Block-1 (kWh)	Unit Consump (kWh/Month)
2006	29,321	7,832,409	22.26
2007	25,396	6,782,007	24.28
2008	19,950	6,137,691	25.64
2009	17,569	6,257,285	29.68

(Source: PPL)

3.6.3 Revenue

Actual revenue by tariff categories in the past seven years is given in Table 3.6.6. Industrial demand includes a capacity charge (Kina/kVA) which is charged based on the maximum demand meter reading.

Table 3.6.6 Revenue by Customer Categories

Year	Domestic			General Supply			Industrial	Public	Total
	Credit	Easipay	Total	Credit	Easipay	Total		Lighting	
2003	23,601	15,227	38,827	196,331	0	196,331	19,894	535	255,588
2004	27,621	18,713	46,334	223,437	0	223,437	27,155	630	297,556
2005	26,410	24,490	50,901	238,626	0	238,626	35,803	766	326,096
2006	23,607	29,175	52,782	252,749	6,970	259,719	55,344	924	368,768
2007	20,666	36,398	57,064	252,671	6,719	259,390	68,199	979	385,632
2008	19,304	45,273	64,576	272,230	11,226	283,455	86,132	1,274	435,437
2009	21,303	51,523	72,825	302,615	15,449	318,064	108,565	1,368	500,823

(Source: Revenue & Customer Service of PPL)

Unit electric charge per kWh is given in Table 3.6.7, which is worked out from Table 3.6.1 and Table 3.6.6. As shown in the table, the averaged unit charge of all categories in 2009 is T71.2/kWh (28.5 US cent) which is in rather higher level in comparison with other countries. The highest unit charge among customer groups is T76.6/kWh (30.6 cent) of industrial customers and follows T69.3/kWh (27.7 cent) of general supply customers and T56.6/kWh (22.6 cent) of domestic customers. The unit charge of “Easipay” of domestic customer group is the lowest. In 2009, annual electric charge paid by domestic customers is K1,350 (US$540) for the customers of “Credit” which is broken-down K174 (US$70) of Block-1 (monthly consumption less than 30kWh) and K1,175 (US$470) of Block-2 (consumption more than 30kWh), K876 (US$350) of “Easipay” and K977 (US$391) of average in total.

Table 3.6.7 Unit Energy Charge paid by Customers

Year	Domestic			General Supply			Industrial	Public Lighting	Total
	Credit	Easipay	Total	Credit	Easipay	Total			
2003	31.7	31.9	31.8	43.1		43.1	32.1	18.6	39.8
2004	38.9	38.1	38.6	51.0		51.0	37.3	25.7	47.0
2005	42.5	43.8	43.1	56.5		56.5	41.0	47.2	51.9
2006	47.1	43.0	44.8	62.5	57.9	62.3	49.0	47.9	56.8
2007	49.5	44.3	46.0	63.4	55.2	63.2	49.1	47.9	57.1
2008	54.4	47.8	49.6	67.7	60.5	67.4	60.1	46.6	62.5
2009	61.9	54.7	56.6	76.6	75.6	76.6	69.3	47.9	71.2

(Source: by Survey Team)

3.7 Issues of the Existing Power Supply Facilities and Major Development Plans of TYPDP2009

3.7.1 Issues of the Existing Power Supply Facilities

The results of survey have been mentioned in the above related titles. The power facilities needed emergency countermeasure and/or renewal are explained hereunder.

Common Issues for the Both Port Moresby and Ramu Grid

(1) **Cooling Water Supply System of Underground Hydropower Stations**: Ramu and Rouna No.2 hydropower stations are underground type. Water for cooling generator coils and/or bearings is taken from the penstock. The filters of cooling water supply system of all units are needed to be cleaned with a frequency of once per week during rainy season, because cooling water contains not only mud but also many fine vegetable rubbish. Especially, conditions of Ramu power station are more serious and all units are operated under the limitation of maximum output less than 80% of the rated output. Therefore, urgent countermeasures should be taken. The team recommends that the existing water supply system should be changed to “Closed Circuit Cooling Water Supply System”.

(2) **Training of Maintenance Staff**: Duration time of outage of generating unit is very long, because rather big scale of repairing works of machine such as re-wiring of generator coils, repairing cavitation of runner, etc. have been made at the manufacturer and/or repair shop of overseas. To reduce such outage duration time for repair, training of maintenance staff are needed for re-wiring of generator coils, repair cavitation of small scale, etc. In this connection, it is noted that spare parts and materials required for such repairing works should be procured periodically.

(3) **Over-hall of Generating Facilities:** In accordance with the results of interview with operation/maintenance staff at hydropower station, most all repairing works were done when some troubles occurred and no scheduled over-hall was made up to now. Then, the team recommends that over-hall works of generating units of some hydropower station should be done together with maintenance staff of PPL for transferring technologies in all

process of over-haling such as dismantling, inspecting, re-assembling, adjusting, testing, etc.

Port Moresby Grid

There is no special issue other than cooling water supply system of Rouna No.2 power station and repairing works of generating facilities explained above.

Ramu Grid

(1) **Rehabilitation of Transmission System:** The Ramu grid is still in initial stage for forming of transmission system with three single circuit radial lines from the Ramu substation. N-1 criteria for assessing supply reliability of transmission system are not applicable to the system. And length of most of transmission line is rather long. In addition to such line configuration, one-phase re-closing system is not applied to minimize the line-outages due to one-line-ground faults. Therefore, it is judged that stable and continuous power supply over the lines seems to be difficult. Especially, the situation of power supply from Ramu to Lae which is the largest demand center of the grid and shares about 2/3 of the total demand is serious. Urgent countermeasure should be taken for increasing the power supply reliability of the transmission system. For increasing its reliability, addition of the second circuit line, upgrading line protection system including re-closing system, upgrading communication system, etc. are required.

To solve the abovementioned issues through comprehensive manner, it is proposed to conduct a master plan study related to upgrading and expansion of Ramu transmission system. Target areas of the maser plan study are transmission facilities, substation, distribution facilities of Morobe, Madang, Eastern Highlands, Western Highlands, Chimbu Southern Highlands and Enga provinces, which is covered by Ramu transmission system.

(2) **Augmentation of Power Supply Capacity in Lae Area:** Power supply from Ramu to Lae which is the largest demand center is not stable as explained above. Augmentation of generating plants in the Lae area is urgently required, since the above rehabilitation works of transmission system will take rather long time.

3.7.2 Development Plans of TYPDP2009 except for Hydropower Development

The major development plans of TYPDP will be explained hereunder, but excluding hydropower development.

Port Moresby Grid

(1) **Construction of Gas Turbine Power Plant:** Two gas turbine generating plant of 15MW are under construction in the yard of Kanudi power station.

(2) **Construction of CBD GIS Substation and Konedobu – CBD 66kV Underground Power Cable Lines:** The purposes of the project are to shift loads of the existing Konedobu and Goroko substations to the new substation and to reduce the distribution losses. It is the first GIS substation in PNG. All existing substations are interconnected with overhead transmission lines. Augmentation of those transmission lines will be required in future, because of its rather small power carrying capacity. In that time, undergrounded transmission lines are surely become necessary, because the difficulty of land acquisition for the line route. The team collected an Application Form for Japanese Grant Aid for this project, but there is no description in TYPDP2009.

(3) **Construction of Taurama Substation:** The purposes of the project are to shift loads of the existing Goroko substations to the new substation and to reduce the distribution losses. This plan should be considered together with the above-mentioned construction plan of CBD GIS substation on the basis of concrete rehabilitation master plan. For that purpose, a master plan for rehabilitation and extension plan of the Port Moresby grid is required.

Ramu Grid

In TYPDP2009, rehabilitation and extension plans include only upgrading the existing 66kV lines to 132kV, replacement/augmentation of transformers, new construction of substations for new big customers, etc., but there is no plan for upgrading power supply reliability of the system. As a result of such development plan, even Ramu-2 hydropower plant is developed, appearance of power balance only seems to become better, and stability and reliability of power supply of the grid remained unchanged.

CHAPTER 4
PRIORY POWER DEVELOPMNNT AND REHABILITATION PROJECTS

4.1 Power Generation Plan in Ten Year Development Plan

The power generation plan of the National and Provincial Ten Year Power Development Plan 2009-2018, November 2009, prepared by PNG Power Ltd (TYPDP 2009-2018) is summarized as follows:

i) TYPDP 2009-2018 provides plans to add/or replace aging plants according to the loss of load expectancy (LOLE) and the expected un-served energy (EUE) criteria and system requirements.

ii) Load growth in Port Moresby indicates that further thermal capacity of 12 MW will be required in 2011 and 8MW in 2012. Development options that need to be considered are independent power producers (IPPs) with gas resource development or Vanapa/Brown River Hydro base generation.

iii) Ramu generation expansion is influenced by the development of major mining loads. Commencement of the Ramu Nickel Mine along with Hidden Valley Gold Mine will advance commissioning of Yonki Toe-of Dam to 2010 and the further development of Ramu 2. Studies are processing on the next Phase (Ramu 2) of Ramu River development and possible utilization of natural gas resources.

iv) The diesel power station at Takara (1x12 MW), Lae and another 10 diesel units are planned for installation in 2010 in Kerema, Alotau, Wewak, Kanieng, etc.

v) Due to the high cost of fossil oil, 7 hydro schemes are considered as major developments in generation planning from 2014 to 2018.

The high speed diesel power station at Takara (1x12 MW) was commissioned in late 2009 and in operation now, but it will be operated short term bases. The Yonki Toe-of Dam (2x9MW) is still under construction of its foundation works and its planned commissioning date within 2010 is not confirmed yet. A part of The Papua New Guinea: Power Sector Development Plan (PSDP 2009)[1] does not coincide with TYPDP 2009-2018 in particular the hydropower development plan after 2010 for the Port Moresby system.

[1] DPE, ADB TA 4932-PNG, Final report, April 2009

4.2 Generation Plan for Port Moresby System

4.2.1 New Hydropower Development for POM System

Since the Laloki River (Rauna Scheme) was fully developed, the Port Moresby system (POM), which serves for the national capital district (NCD) and central province will increasingly rely on thermal generation prior to any additional major hydro energy sources up to the end of the decade to meet the shortfall in capacity and energy requirements over the short to mid term period. In the long term, POM will require a major power source development.

Table 4.2.1 Generation Plan Summary for POM

	TYPDP 2009-2018	PSDP 2009
2009	Refurnished 20 MW Gas Turbine at Moitaka, Energy Efficiency-Commence Clean Development Mechanism(CDM) and SSM Development	
2010	Install 2 x 15 MW Gas Turbine at Kanudi	ditto
2015	Vanapa or Naoro-Brown River Hydro base generation	Udava Hydro 58 MW
2017	Major power source development	
2018		Udava Hydro + 29 MW (total 87 MW)
2019		Thermal 40 MW
2021		Udava Hydro + 29 MW (total 116 MW)
2022		Lake Kosipe 30 MW
2023		Udava Hydro + 29 MW (total 145 MW)

(Source: Prepared by JICA Survey Team from TYPDP2009-2018 and PSDP 2009)

To enable a clear choice to be made between the interconnection with the Ramu system and the development of the major hydro additional studies are required on the Vanapa and Brown Rivers for hydro schemes to be selected for detailed engineering studies and for comparison with the interconnection option. The studies also need to proceed on other supply options such as natural gas.

PSDP 2009 concluded that the Port Moresby - Ram inter connection was not economically viable for the foreseeable future and dropped it as non-viable option with reference to a pre-feasibility study (Section 5.4, p36).

Until 2014, no other generation alternatives are available to POM to meet the projected demand. Adding 145 MW generating capacity from the Udava hydro has been found to be economic in comparison to a thermal alternative comprising gas-based generation from a combined cycle plant. Initial installed capacity in 2015 would be 58 MW, followed by successive 29 MW in 2018, 2021 and 2023. The associated economic internal rate of return (EIRR) for this project is 14.3%. Additional thermal capacity of 40 MW over 2019-21 will be required before Lake Kosipe in Vanapa River system. Lake Kosipe becomes feasible if commissioned after 2022 with its EIRR of 12.4% (Section 5.2, p32).

Possible hydro developments on the Angabanga and Brown Rivers have been eliminated as

candidate plants because of its higher cost and lower output than the Vanapa schemes. The Lower Brown alternatives have yielded an EIRR of only 7.9% (Section 5.2, p32).

It has been estimated that the 145 MW Udava hydropower facilities would have a production cost of US$ 0.069/kWh. The combined cycle facilities would have a production cost US$ 0.096/kWh, assuming a capacity factor of 80%. Diesel production would cost US$ 0.197/kWh assuming a fuel price of K 2.0 per liter (about US$ 0.8), a specific consumption rate 0.24 liters/kWh and an installed capacity cost of US$ 800/kWh. It is also noted that the LNG venture might consider the option of purchasing low-cost hydropower for at least part of its LNG production process, as opposed to using precious natural gas. If this happens to be feasible, then all the Vanapa basin could be developed to its full potential on a fast-track basis (Section 5.2, p32).

PPL commenced the feasibility study for the Naoro-Brown Hydropower Scheme (about 60 MW) in January 2010 to examine its technical and financial viability as an option to the POM hydropower schemes. PPL envisages it high viability considering its advantages of shorter access and transmission distance, and acclaim of land owners in the project area. The preliminary study done by the Survey Team by use of available maps indicates that Naoro-Brown Hydropower is in favor of topography with efficient water head of 45 m/km, head of about 500 m by a 11 km long pressure pipe. The drainage area of about 279 km^2 is small but increase of water quantity is technically possible by diverting water from the nearby river stretches.

The location of the Vanapa River, the Udava River and the Brown River are shown in the General Location Map. Project locations of the Lake Kosipe Hydropower, the Udava Hydropower and the Naoro-Brown Hydropower are shown in Outline Location Map of Planned Hydropower Project. The project layout of the hydropower projects related with POM Grid is shown in Figure 4.1. The schematic profiles of Naoro-Brown Hydro, Udava Hydro and Lake Kosipe Hydro are shown in Figures 5.3, 5.4 and 5.5 respectively.

4.2.2 Rehabilitation of Rouna Hydropower System

(1) Rehabilitation of Rouna 1 Power Station

Re-installation of generator unit 1 (1 MW) and unit 2 (1MW) of Rouna 1 power station and its penstock is proposed by PPL. One 8 MW unit is planned to be replaced with the former unit 1 and unit 2 (refer to Figure 3.3.1 One-Line Diagram of Port Moresby Grid).

(2) Inspection of Stability of Sirinumu Dam and Saddle Dams

Technical inspection of the stability of the three saddle dams (A, B and C) out of the Sirinumu main dam[2] and 7 fill type saddle dams is urgently necessary. It is reported that leakage water through the three saddle dams, in particular of the saddle dam A increased. The leakage quantity from the back erosion on the downstream surface of the natural saddle was about 100 liters/s [3],

[2] The Sirinumu dam with steel and concrete surfacing was constructed in two phases: Phase 1 completed in 1963 and Phase 2 completed in 1973. Thirty seven years has passed since the completion of Phase 2.

[3] Sirinumu Dam and Saddle Dams Comprehensive Safety Assessment 2005, PNG Power Ltd, Tasumania Hydro Consulting

and its quantity has increased significantly recently[4]. If one of these dams collapsed some of the substations and transmission lines of the Roua System would be damaged, and its adverse effect to Port Moresby would be significant. The electric supply to Port Moresby would be stopped and population of about 200, 000 would be affected by the wave of water from the reservoir, gross volume of about 340 million m^3. These dams have been owned and operate by an independent corporation, PNG Dams Ltd instead of PPL[5]. The Survey Team evaluates that there is a risk of failure of these saddle dam as pointed out by PPL because increase of leakage water might be a sign of progressive back erosion though the Survey Team did not execute site inspection at all. It is recommended to dispatch an expert team of fill dam and geotechnical engineering as soon as possible to inspect and to assess the cause of leakage water from the Saddle dams A, B and C considering the nature of socio economic risk of Port Moresby.

4.3 Generation Plan for Ramu System

4.3.1 New Hydropower Development for Ramu System

Development of hydropower generation will continue to be a high priority. However, other indigenous resources such as natural gas, other renewable sources and fuel oil are being considered as strategic options. Lae system will continue to rely on thermal backup generation to meet both the shortfalls in capacity and energy requirements over the short to medium term period until the second 132 kV line is built. There is approximately 100 MW hydro potential on Ramu River yet to be developed. There is a need for feasibility study to determine the cost effective power supply for the Province. Other renewable such as gas-based generation, wind, sea wave and solar power are possible source of power. The Feasibility Study on Ramu 26has been under review by PPL now. The long section of Ramu 2 Hydro is shown in Figure 5.6.

Table 4.3.1 Generation Plan Summary for Ramu System

	TYPDP 2009-2018	PSDP 2009
2009	Energy Efficiency - Clean Development Mechanism(CDM) and SSM Development	
2010	Complete temporarily 12 MW Taraka Power Station	Ramu Nickel backup diesel 95 MW by MOA
2012		Ramu 2 - Phase 1 60 MW
2016	Complete study into Malahang proposed power plants	
2017	Major power source development	

[4] It is reported that the leakage quantity of the Saddle dam A was about 200 liter/s when it was estimated approximately by measuring flow velocity and flow area in 2008. Rehabilitation of the monitoring weir, leakage monitoring and etc were recommended in the repot of 2005, but those were not materialized.

[5] The PPL civil engineer in charge reported that PNG Dams Ltd owns the dam but it does not conduct its operation and maintenance in reality. He also pointed out that the number of civil engineer in PPL was only two as of May 2010, and available resources are not sufficient to conduct the O&M of the dam facilities.

[6] Final Feasibility Report, Ramu 2 Hydropower Scheme, RB in association with URS, 2006

2020		Thermal 20 MW for peaking

(Source: Prepared by JICA Survey Team from TYPDP2009-2018 and PSDP 2009)

4.4 Other Potential Hydropower Development Projects

4.4.1 Wabo Power Project

The Wabo Hydropower Project[7] Site is located at about 200 km from the estuary of the Purari River. The drainage area of the Wabo dam site covers 26,300 km2 of the whole Purari River Basin, 33,000 km2. The mean annual rainfall is 8,000 mm in the drainage area, and the mean discharge at the dam site is 2,500 m3.

At the optimum scale of development the firm energy available (the guaranteed minimum in a drought year) is 11, 825 GWh/annum, but most of the time a considerably greater output is available. A maximum output of 1,800 MW was adopted (5 x 360 MW generating unit and one 360 MW standby unit), which will be able to supply the expected industrial load except during draught periods. During such period it would be necessary to restrict consumption to a peak demand of 1, 500 MW, or to supplement the Wabo supply from another source. The average secondary or non-firm energy output, but not accounted for in selecting the optimum scheme, 3,130 GWh/annum.

At 1976 price levels the estimated capital cost of the Wabo hydroelectric development including transmission to the port is US$ 900 million to the Gulf or US$ 1,020 million to Hall Sound. The corresponding financial power cost are 10.6 US$ mills/kWh and 12.1 US$ mills/kWh respectively, assuming an interest rate of 8%, a loan period of 30 years, and a 5-year load growth period. The installed capital cost is US$ 568/kW for the case of Hall Sound.

The firm energy output could be increased to 14,200 GWh/annum by the installation of at the industrial site of seven 60 MW gas turbine which would need to be operated only during the period of an extreme but very infrequent drought. As an alternative firming source, a hydroelectric scheme in the Aure River was more expensive in the 1970th.

The main dam is rock fill type with 160 m high and volume of 15.9 million m3. The total volume of the 5 fill type saddle dams is 7.8 million m3. The total length of the 500 kV 2 cct transmission lines to Hall Sound is about 300 km.

Technical and economic features of the Wabo Power Project are presented in Appendix II.

[7] Purari River Basin Power Project Feasibility Report, Volume 1 to 8, Government of Australia, Government of Japan, Government of Papua New Guinea, December 1977

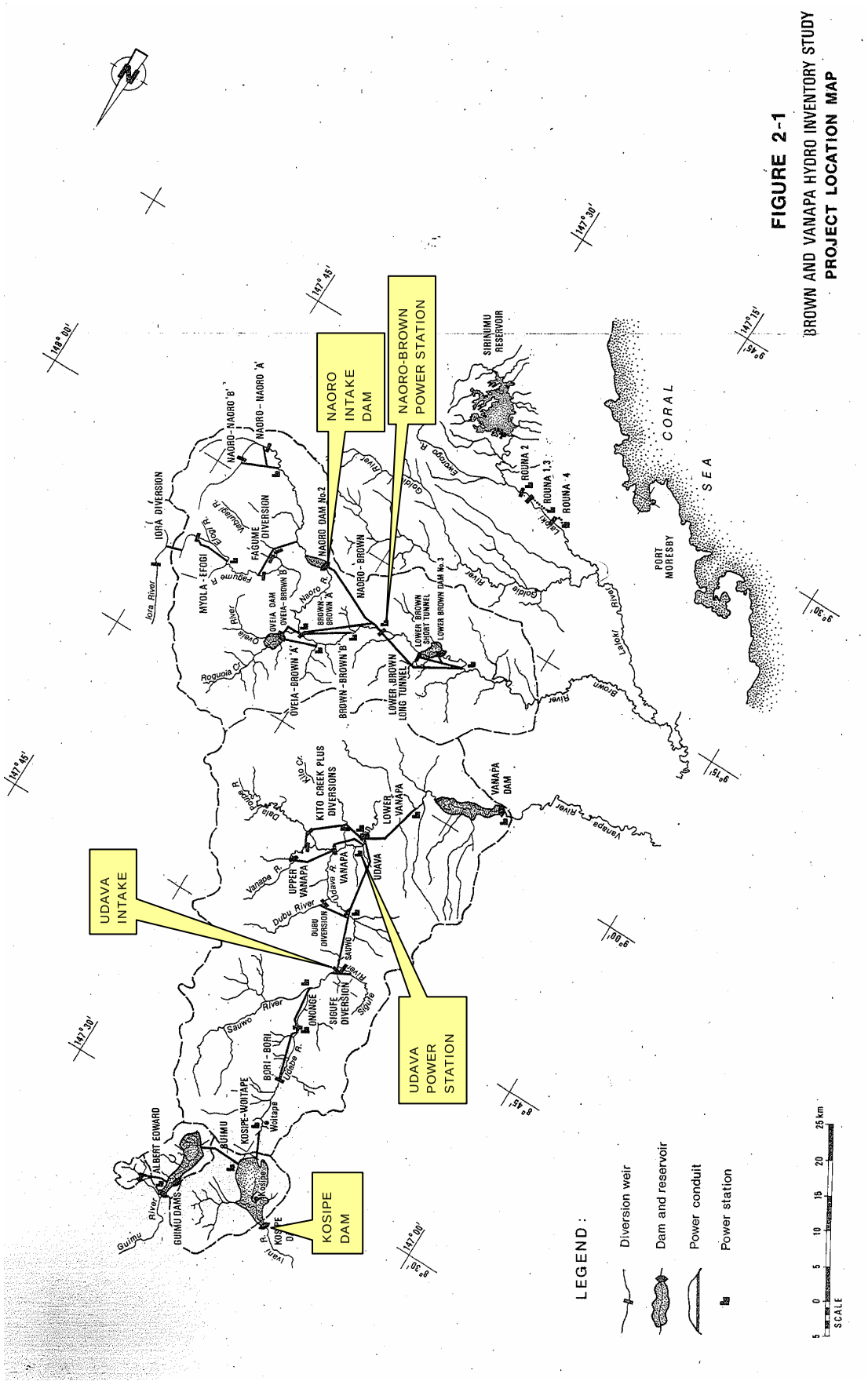


Figure 4.1 General Plan of Hydro Power Scheme in Port Moresby Grid

(Brown and Vanapa Inventory Study, Monenco 1989)

CHAPTER 5
ENGINEERING GEOLOGY AND FOUNDATIONS

5.1 General Geology

5.1.1 Three Major Tectonic Elements

Geology of the mainland of PNG is composed of three geo-tectonic elements. That is (1) Platform, (2) Mobile Belt, (3) Oceanic Crust-Island Arcs, which is bordered by major faults as below. (1/2,500,000 Geology of Papua New Guinea, 1976)

- Boundary of Platform/Mobile Belt: Lagaip Fault Zone – Aure Trough
- Boundary of Mobile Belt/ Oceanic Crust-Island Arcs ; Ramu- Markham Fault Zone and Owen-Stanley Fault

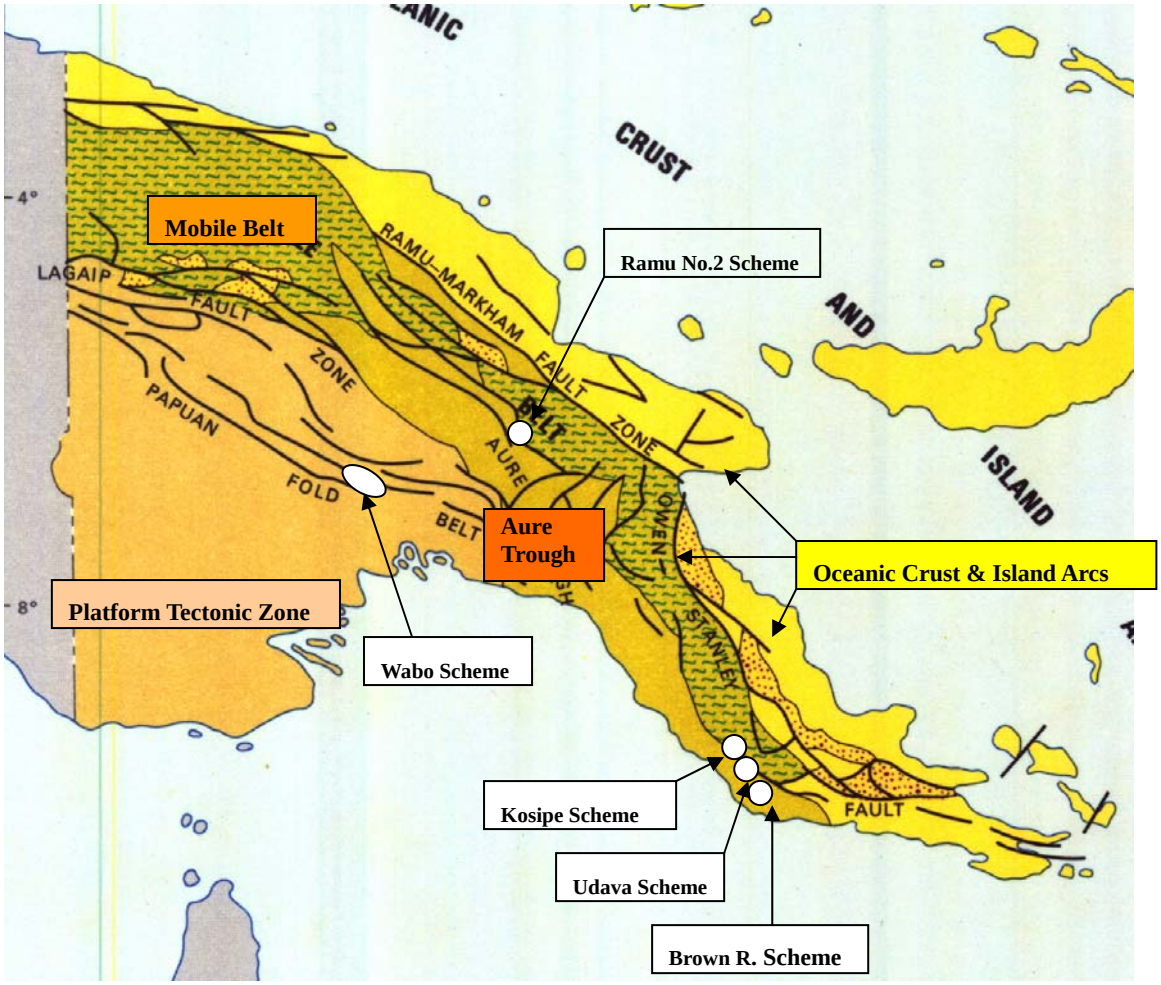


Figure 5.1 Major Geo-Tectonic Elements and Hydro Power Project Sites
(Citation from 1/2,500,000 Geology of Papua New Guinea ; 1976)

5.1.2 Rocks in the Platform and Mobile Zone and Engineering Feature

Oceanic Crust-Island Arcs is active zone in geo-tectonically where ultra basic plutonic rocks, volcanic rocks are mainly produced under the process of New Guinea Mountain Building.

Brown River, Udava, Kosipe in Port Moresby Grid and Ramu No.2 Project in Ramu Grid are located in the "Mobile Belt" and Wabo Project is situated in the "Platform".

Geological setting and engineering features in the Platform and Mobile Belt is summarized below.

(1) Platform

1) Rocks in the Platform

The platform is developed wide area around 160,000km^2 in the south-western part of the mainland of PNG which is marked by Lagaip Fault Zone in the northern end and bordered by the Aure Trough in the eastern end.

The major geology of the Platform is composed of shallow marine and non-marine sediments which deposited from Mesozoic to Tertiary and volcanic rocks of Tertiary and Quaternary.

Mesozoic sediments are covered by younger layers in the southern area and it outcrops in the northern limited part where is faulted and folded zone under tectonic movement of New Guinea Mountain Building.

Wide swamp area is formed in the southern most part under gentle river flow.

Young Tertiary sedimentary rocks are outcropped in the Wabo Project area which is composed of half consolidated alternation of sandstone/siltstone/mudstone and bedded limestone.

2) General Engineering Features of Sedimentary Rocks

Tertiary sediment rocks; sandstone, siltstone and mudstone in the Platform is generally soft and week which compressive strength is estimated under 100kgf/cm^2. Furthermore, they are prone to be broken by fluctuation of water content which is required careful treatment in concrete structures and soil works such as foundation excavation or slope cutting.

Weathering depth is not so deep that is estimated around 10m in ridge and 1 to 2 meters in lower part in slopes. Weathered soils are flow down by surface slip forming thick talus deposit.

Many small scale landslides are occurring in the reservoir area. And, a big scale landslide may happen in an area where planar structure is regulated by faults.

Limestone is the unwelcome layer for reservoir area which is developing many caves.

(2) Mobile Belt with Aure Trough

1) Rocks in Mobile Zone

The Mobile Belt with Aure Trough is developing NW direction with 50-100km width. This zone has been made up by New Guinea Mountain Building which started from late Mesozoic (Around 200Ma before).

The Mobile Belt is the core of main island of PNG which consists of various types of rocks as below.

A) Plutonic Rocks：Diorite, Granodiorite, Gabbro

B) Metamorphic Rocks : Green schist, Phyllite; Rocks forming core of the mainland of PNG (Late Cretaceous)

C) Sedimentary Rocks：Sandston, Mudstone, Tuff, Limestone (often metamorphosed)

D) Volcanic Rocks：Basalt lava and Andesite lava, Volcanic Ash(Mesozoic – Quaternary)

General distribution trend is NW-SE sandwiched by Lagaip Fault Zone – Aure Trough and Ramu- Markham Fault Zone and Owen-Stanley Fault

2) General Engineering Feature of Rocks

Metamorphic and plutonic rocks in the Mobile Belt are generally hard and compact which have strong property. It seems that compressive strength of metamorphic rocks and volcanic rocks may show 500 – 1,000kgf/cm^2 and plutonic rocks are over 1,000kgf/cm^2. Sedimentary rocks are mostly metamorphosed to be sound and hard. Weathering is not so severe but weathered depth in ridge, fractured zone and volcanic rocks is rather deep. So, generally, geological condition is suitable to implement facilities for hydro power project.

But, following geological phenomena shall be considered for planning and implementing hydro power facilities.

- Faults parallel and oblique to “Owen- Stanley Fault” are widely developed in the mobile belt.
- Small to large scale landslides are prone to occur related with faults, fold, and joints of rocks
- Cavity and pipe holes are generally formed in limestone. And high permeable cool joints are often developed in andesite and basalt lava. It is recommended to avoid these rock types for intake reservoir.

(3) Seismic Risk

Papua New Guinea is situated in the Circum-Pacific seismic belt and most seismic area in the world. Papua New Guinea has been classified into four seismic zones on the basis of the recurrence intervals of earthquake shocks of certain intensities. As shown in figure 5.2, four seismic Risk Zone is classified. Seismic Risk Zones are almost corresponding to geo-tectonic three elements; Oceanic Crust-Island Arcs: High Risk zone, Mobile Belt; Medium Risk., Low Risk Zone: Southern part of Platform .Very High Risk Zone is northern part of Solomon Sea.

Hydro power schemes in Port Moresby Grid, Ram Grid and Wabo project site is situated in the Medium Risk zone. It is necessary to careful consideration on seismic risk of each project site, but all hydropower project sites are situated in medium seismic risk zone in PNG where maximum seismic acceleration is expected 0.2 to 0.25 g.

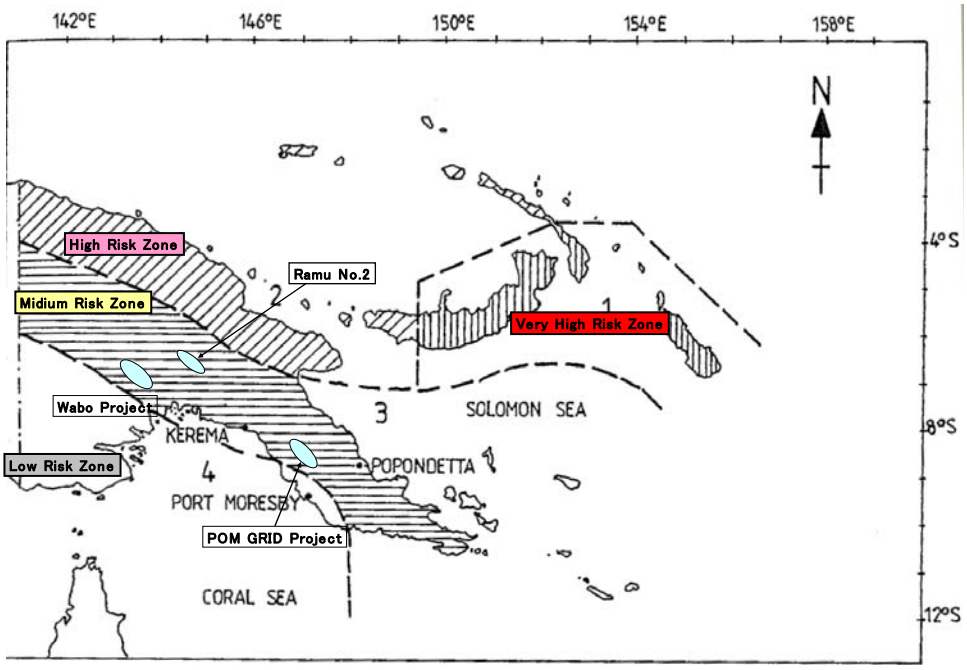


Figure 5.2 Zoning Map on Seismic Risk in PNG
(Source: Stage 1 Investigation of Hydro Power Alternatives, Vol. 3)

5.2. Assessment of Engineering Geology and Foundation of Priority Project

5.2.1 Port Moresby Grid

(1) Previous Study

Several Geological investigations and studies had been carried out for the priority Hydropower Schemes; Naoro – Brown, Udava and Lake Kosipe project.

- 1979; Engineering Geological Feasibility Study of the Proposed Vanapa Hydro- electric Scheme, Geological Survey of PNG
- 1980; Vanapa Hydro Electric Complex Feasibility Study; ELCOM
- 1982; Engineering Geological Feasibility Study of the Naoro-Brown River Hydro-electric Scheme, Geological Survey of PNG
- 1982: Stage 1 – Investigation of Hydro Power Alternatives, GIBB
- 2009: Power Sector Development Plan Draft Final, Appendix H: Pre-Feasibility Study Udava Hydropower Development Plan, ADB
- 2009: Power Sector Development Plan Draft Final, Appendix I: Pre-Feasibility Study Lake Kosipe Hydropower Development Plan, ADB

The study team reviewed previous studies on hydro power scheme in Port Moresby Grid and assessed geological condition of each site focused on geological phenomena which may give important influence to promote the project.

(2) Regional Geology

1) Geological unit and rock types in the project area

Priority Hydropower Schemes; Naoro－Brown, Udava, Lake Kosipe, are situated on the south flank of Owen -Stanley Range which forms the core of main island of PNG. This area is a part of "Mobile Belt" in geo-tectonically where various rocks have been produced in the process of New Guinea Mountain Building.

Geological units and rock types in the project area are shown in table 5.1.

Most old geological units are Kagi Metamorphics (Jurassic? to Cretaceous) which developing widely in the project area. These oldest rocks had been intruded by dyke rocks and overlain by younger sedimentary rocks or volcanic rocks. (Refer to 1/250,000 geological map: Port Moresby-Karo-Aroa and Stage-1 Investigation of Hydro Power Alternatives, 1982)

Table 5.1 Geological Unit of Project Area

Geological Age	Geological Unit	Rock Type/Engineering Feature
Holocene (0.01 Ma to present)	Alluvium	River deposits; gravel, sand silt, clay Talus deposit; Boulder, gravel, silt, clay
	Colluvium	Terrace/lake deposit; gravel, sand silt, clay
Pleistocene (1.64 to 0.01 Ma)	Efogi Volcanics	Porphilitic, vesicular basalt and andesite/often permeable
Pliocene (5.2 to 1.6Ma)	Astrolabe Agglomerate	Basalt and minor andesite agglomerate, tuff,lava breccia, partly reworked; occur in Vanapa river/variable engineering feature, often permeable.
	Mt. Davidson Volcanics	Basalt and minor andesite agglomerate, tuff, lava breccia, partly reworked/variable engineering feature, often permeable.
Miocene (23 to 5Ma)	Oveira Diorite	Diorite, monzonite/hard and sound/variable engineering feature; sound to loose
	Talma volcanics	Basalt and andesite pyroclastic, lava, volcanic sandstone/variable engineering feature, (distributing north-western part of Vanapa river)
Early Cretaceous (141Ma) to late Eocene (35Ma)	Kemp Welch Beds	Shale, slate, sandstone, greywacke, conglomerate, limestone and intebeded volcanics
Jurassic?(208Ma) to Cretaceous(65Ma)	Kagi Metamorphics	Slate, Phyllite, Quazite/having compact schistosity, generally sound and strong

(Source: JICA Survey Team)

Among geological units shown above, the Kagi Metamorphics is distributing dominantly in the project area and partly encountered with Quaternary volcanic deposits and recent superficial deposits,

2) Geological Structure

The Kagi metamorphics is developing from SE to NW parallel to the Owen Stanley Range.
From late Oligocene (around 30 Ma before present) to Quaternary(around 1Ma), intermittent up lift of eastern Papuan landmass gave rise to a dip slip fault pattern trending north- west to east-west on the southern fall of the Owen Stanley Range. This faulting provides the major structure in the project area. Geological map of "Port Moresby-Karo-Aroa" suggests three direction of fault in the project area: north-west to south-east, north to south and northeast-south to south-west.

3) Engineering Features of Foundation

The Kagi Metamorphic rocks: having fissility but generally hard and compact except fractured parts by faulting and suitable for foundation of structures. It is not adequate for concrete materials.

Intrusive rocks: hard and sound, suitable for foundation of structures and concrete materials.

Volcanic rocks of Quaternary: it composed of lava and pyroclastic rocks which show variable rock feature. Lava is generally hard and sound, but often permeable due to development of cool joints. Pyroclastic rocks are generally soft but suitable for foundation of structures.

Weathering: Lower part of slope is fresh and weathering becomes deep gently to a ridge. But, fault or fracture zone is weathered deeply. Ridge/slope composed of volcanic rocks is generally weathered deeply.

(3) Assessment of Engineering Geology and Foundation

Reviewing previous study above, geology and foundation for each priority project sites is compiled and assessed from view points of geotechnical aspect and matters which may have technical viability for project implementation as below.

A) Suitability of dam foundation
B) Reservoir water tightness
C) Big landslide in the vicinity of important facility
D) Weathering grade of slopes
E) Foundation of facilities
F) Construction materials

Review and geotechnical assessment on Naoro-Brown, Udava and Lake Kosipe project are shown in Table 5.2, 5.3 and 5.4.

1) Naoro-Brown Project

This project involves the diversion of water from the Naoro Valley upstream of Madingo by low pressure tunnel and surface penstocks to power station on the Brown River approximately 10km to the west. (Figure 5.3)

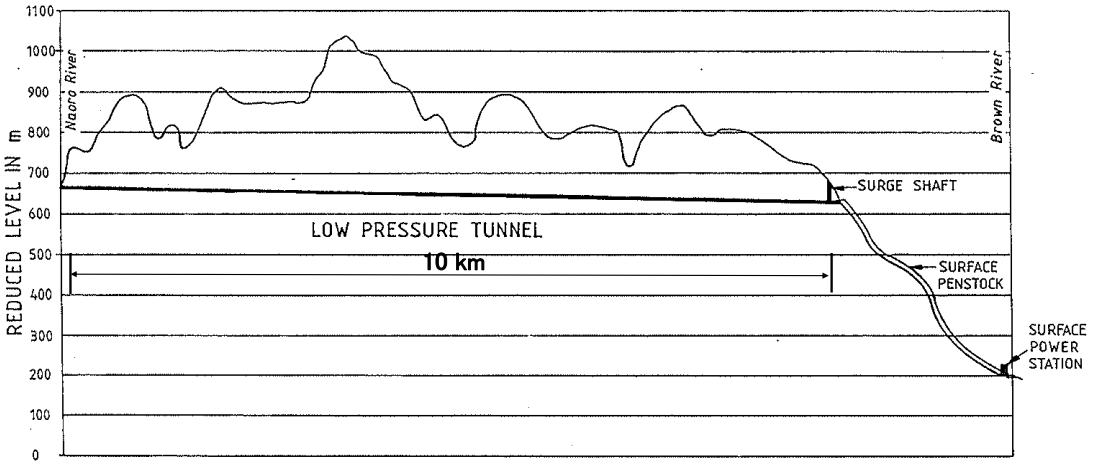


Figure 5.3 Schematic Profile of Naoro Brown Project
(Stage 1- Investigation of Hydro Power Alternatives, Gibb, 1983)

As compiled in Table 5.2, foundation of each facility is suitable for construction. But, it is

important to clarify the mechanism of water loss from reservoir area and suitable weir site shall be selected by geological investigation in next stage.

Basalt and river bed deposits are expected for concrete material.

Table 5.2 Geotechnical Assessment of Naoro-Brown project

Assessment Foundation of Facility	Foundation Condition/Engineering Assessment
A) Intake Weir Site	● Left bank/river bed: metasiltstone ● Basalt lava is out cropped in the upper part of the right bank ● Foundation is suitable for low weir site. ● But it is necessary grouting to control seepage especially for the contact of metasiltstone/basalt in the right bank
B) Reservoir water tightness	● Water loss which is estimated almost 30% of low flow was found by Water Resources Bureau. It is suspected that water is flow out through basalt layer (perhaps Efogi volcanics). ● Phenomina should be clarified to consider suitable site selection and treatment.
C) Low pressure tunnel	● Geology is mainly metamorphic rocks; phyllite, schist, metasiltstone and metavolcanics and partly encountered by the Oveira diorite. ● The tunnel will pass through rather stable geological condition. In some sections (up to 20%), encountered with fracture zone which can be supported careful tunneling and concrete lining.
D) Surface Penstock	● Geology of penstock is weathered schist which depth is estimated up to30m and average 10 to 20m. ● The penstock could be founded on moderately weathered schist.
E) Power House	● Geology of power house is schist overlain by terrace deposits. ● Around 10-15m excavation will be necessary to the stable foundation

(Source: JICA Survey Team)

2) Udava Project

This project involves a weir on the Udava River some 1.5 km downstream of the confluence with the Golo river, a 10km headrace tunnel and a surface penstock and a power station on the Vanapa River, near Noba creak.

The Kagi metamorphic rocks are distributed in all facility sites; weir site, low pressure tunnel, penstock and power house. Weathering depth in the penstock slope is up to 20m. But, foundation condition is expected good condition in all facility sites.

Quartzite and dyke rocks are available for concrete aggregate.

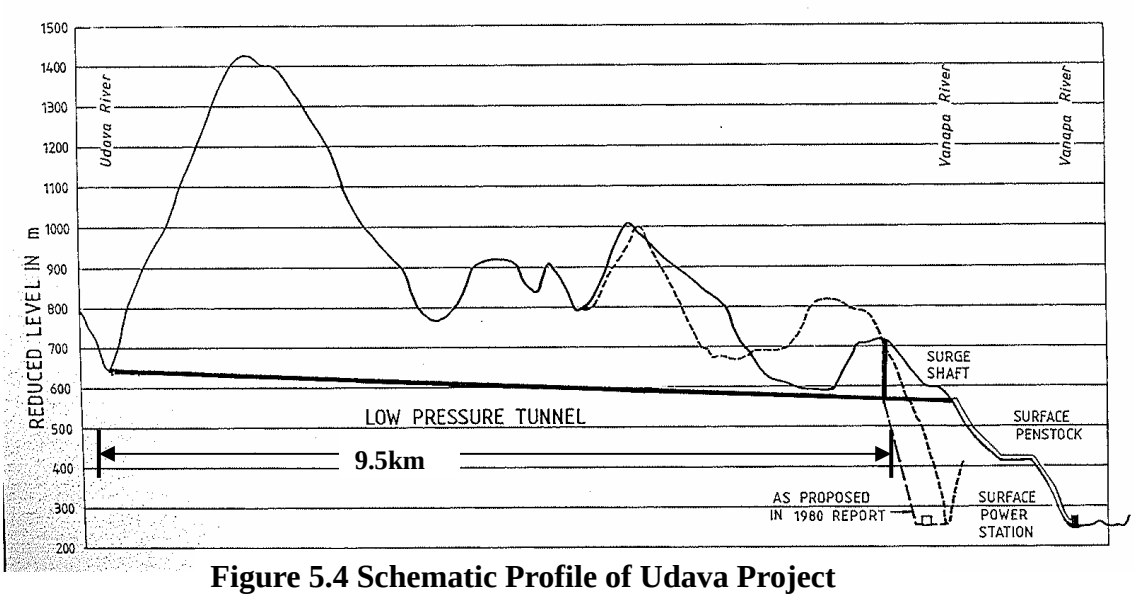


Figure 5.4 Schematic Profile of Udava Project
(Stage 1- Investigation of Hydro Power Alternatives, Gibb, 1983)

Table 5.3 Geotechnical Assessment of Udava Hydro

Assessment Item	Foundation Condition/Engineering Assessment
A) Weir site	● Foundation comprised of quartzite and dyke rock which are hard and sound. ● Dam foundation is good condition.
B) Reservoir water tightness	● No problem in the upstream of weir site
C)) Low pressure tunnel	● Geology of tunnel is mostly Kagi metamorphic rocks and dyke rocks which is hard and sound. ● In some section, tunnel will encounter with faults
D) Penstock	● Geology of penstock is also Kagi metamorphic rocks which is hard and sound in fresh rock. Weathered zone is estimated up to 20m ● Stripping for the penstock will stabilize the slope above the power station.
E) Power House	● The power house would be founded on fresh or slightly weathered quartzite with stripping depth less than 5m

(Source: JICA Survey Team)

3) Kosipe Dam Project

Kosipe Dam project is sited where the Ivani River leaves the Kosipe Swamp and start to cut into interbedded schist and phyllite of the Kagi metamorphic.

Geology and foundation of dam site, diversion tunnel, spillway is sound metamorphic rocks. So, common construction method can be applied for these facilities.

Deeply weathered volcanic rocks are underlain in the route from conduit-penstock-power station. So, it is advisable suitable construction shall be considered for these facilities according to the result of detailed geological investigation.

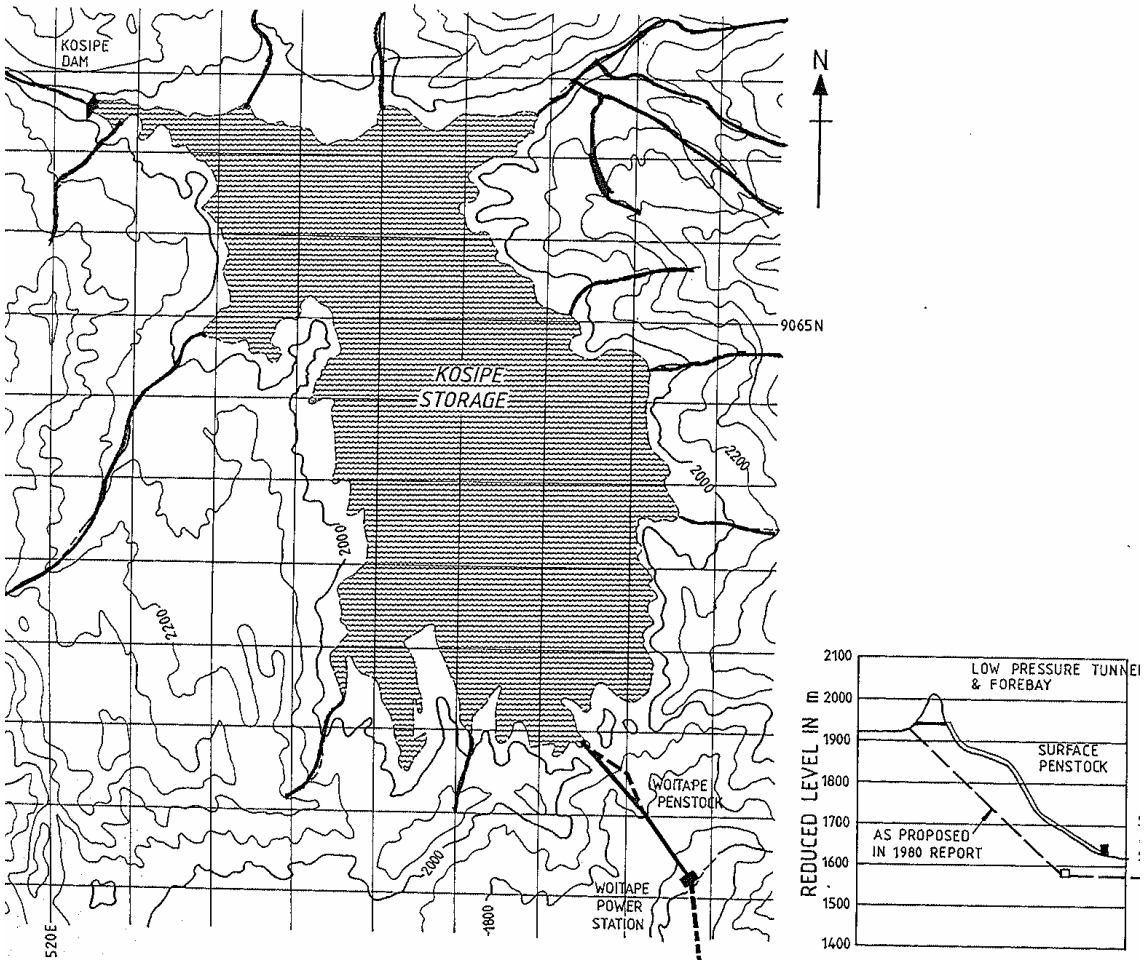


Figure 5.5 Schematic Plan of Kosipe Project
(Stage 1- Investigation of Hydro Power Alternatives, Gibb, 1983)

Table 5.4 Geotechnical Assessment of Kosipe Hydro

Assessment Item	Foundation Condition/Engineering Assessment
(A) Dam Site	● Sound rock is exposed along the river in the vicinity of the dam site. Weathering both bank would be up to 20m. ● Suitable for a fill type dam
B) Reservoir water tightness	● Kosipe swamp is underlain by lake deposit at least 20m thickness. ● But, thin ridge exists in the southern end where is deeply weathered. ● Some treatment will be necessary for the thin ridge in southern end.
C) Diversion tunnel	● Geology of diversion tunnel is quartz mica schist and phyllite. ● Common tunneling method can be applicable considering rock condition
D) Spillway	● Foundation of spillway is phyllite and schist which dipping up stream. But, joints rich. ● Concrete lining will be necessary.
E) Power conduit	● The ridge is underlain by deeply weathered andesite lava and tuff to well.

	● It is considered tunnel is suitable condition rather than surface channel where stability of the slope is required.
F) Penstock	● Foundation of penstock is deeply weathered volcanic rocks. Stripping to foundation would be up to 20m. ● Under ground penstock is advisable to get into metasediments which underlie the volcanics.
F) Construction materials	● Concrete aggregate: Quartzite is suitable ● Core material: Weathered materials ● Rock material: Metamorphic rocks

(Source: JICA Survey Team)

5.2.2 Ramu Grid

Priority hydropower project site in Ramu Grid is Ramu No.2 Hydro Power Scheme. Following four studies had been implemented for this project.

- 1973: Report, Ramu 2 Project Preliminary Layout and Cost Estimate, December; Australian Department of Works
- 1975: Preliminary geological investigation of proposed Ramu-2 hydro-electric project, Geological Survey of Papua New Guinea.
- 1983: Ramu System Hydro Investigation Study. Stage 1 – Investigation of hydro power alternative, Gibb Australia, Merz & Mclellan & partners, and Willing and Partners Pty Ltd.
- 2006; Final Feasibility Report, Ramu 2 Hydropower Scheme, PB in association with URS

Engineering geology and foundation of the project site is evaluated referring mainly the latest feasibility study, 2006 in which including important information and findings of former studies.

(1) Geology of Ramu 2 Project Area

Ramu 2 project is located in "Mobile Zone" Geo-tectonically. Project area is composed mainly of Omaura Greywake (Oligocene) and Akuna Igneous Complex (Miocene) which is intruded into the Omaura Greywack. These base rocks are covered by Terrace Alluvium, River Alluvium, Colluvium and Talus deposits

<u>The Omaura Greywacke</u>

The Omaura Gretwack is thick marine sedimentary rocks which consist of a basal conglomerate and alternation of sandstone, siltstone, shale and marble. The greywacke is outcropped in the intake area and at the down stream end of the project site. Thie Omaura Greywacke is so sound that the powerhouse of Ram No.1 has been constructed without lining.

<u>The Akuna Intrusive Complex</u>

The Akuna Intrusive Complex is an intruded rock to the Omaura Greywacke. Within the project area rock type of this Intrusive Complex is dominated by granodiorite including dolerite/gabbro and diorite partly.

This granodiorite shows blocky rock which is generally very hard and sound in fresh outcrop.

Interpretation of air photos by Gibson identified three set of longer lineament in the vicinity of intake area. They may suggest small fault or joint rich zone in the rock mass. But, no major fault has been found.

Shallow slip is occurring on the steep slopes formed in the weathered rocks in the project area. But, no major landslides has found in the project area.

(2) Assessment of Engineering Geology and Foundation

A series of facility to generate power; intake weir, tunnel intake, headrace tunnel, surge chamber, surface penstock, power station and tail race channel has been planned in the feasibility study in 2006.

Final Feasibility Report, Ramu 2 Hydropower Scheme, December 2006, PB in association with URS is used as reference to assess engineering geology and foundation of project area.

1) Intake weir

Intake weir which is around 30m height is located near to marble and diorite where rock is present along the river at current site. In the left bank, thick colluviums or landslide debris may be overlying and the alluvium is up to 10m in thickness.

It is considered most important issue of the weir site is whether holes are developing or not in the marble in higher part of the pond. It should be clarified before design stage.

2) Tunnel intake

Tunnel intake site is also located near the boundary of marble and granodiorite. Up to 10m of colluvium and alluvium may need to be stripped to expose foundation rock. And, stripped rock will be required to protect with rock bolts.

3) Headrace tunnel

The head race tunnel is 7399m in length with diameter of 5m.

Geology of headrace tunnel is mostly granodiorite except 150m section of intake side and a short section from 5900 to 6300 where is greywacke zone. The tunnel may encounter with poor geological condition in 150m section of intake side or joint rich section. But, it is judged geological condition is generally sound.

4) Surge chamber

The surge chamber is situated sound ridge of 1035m elevation. A single conventional cylinder type surge chamber has been planned. The surge chamber will be 60m deep with 14m diameter.

Geology of the surge chamber site is greywacke group. Weathering depth is estimated up to 60m by the seismic exploration implemented in 1975. So, surge chamber will be excavated into weathered, poor quality rocks which require heavy support during construction.

5) Surface penstock

The surface penstocks of 900m length will be aligned along a slope of 20 degrees.

Weathered greywacke is scattered on the slope and slightly moderately weathered rock may be present close to the ground surface in places. The depth to reasonable quality rock will determine the foundation design for the pedestal blocks and anchor blocks.

6) Power station

Conventional surface structure power station is planned on terrace that lies 7-8m above the surrounding land.

The foundation of the power house will be on weathered greywacke. A careful excavation and protection measure for weak layers is necessary.

7) Tail race channel

The tailrace channel will be constructed through swampy ground. Greywacke rock may be

expected in the deepest cut sections near the power house.

Alluvial in the Ram river bed and terrace is mainly sand and fan alluvium exposed near the power house is mainly gravel.

8) Concrete Aggregate

It is expected that a source of suitable gravels could be developed in the Ramu- Markham valley. And, construction disposals can be utilized for concrete aggregate.

As compiled above, no significant issues on geological aspect which will adversely affect the technical viability of the Ramu 2 project have been identified.

Limestone bed in the reservoir and weathered condition of the slope from surge chamber to power house shall be checked carefully by geological survey. Suitable structures can be designed and implemented considering the result of detailed geological survey.

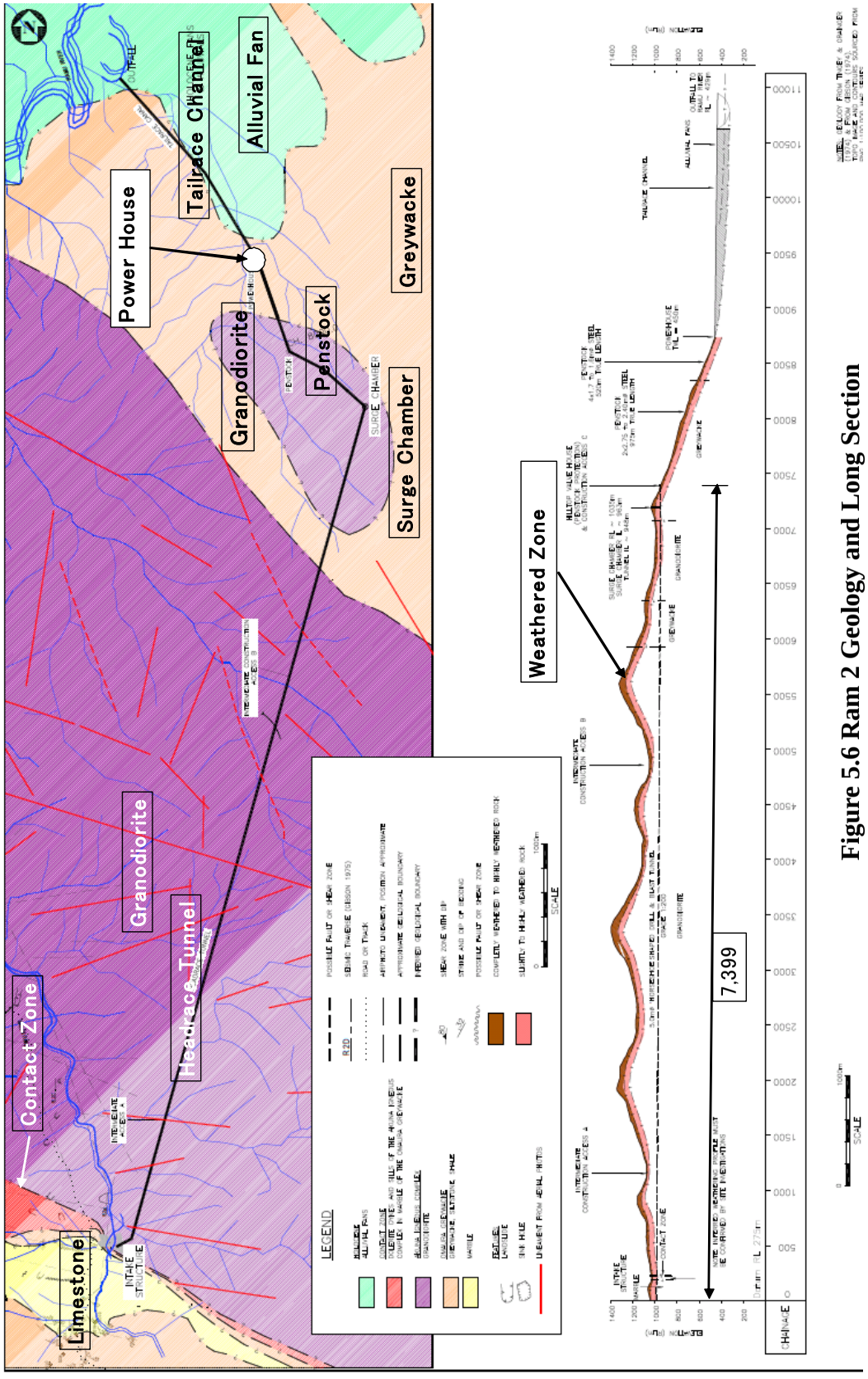


Figure 5.6 Ram 2 Geology and Long Section
(Final Feasibility Report, Ramu 2 Hydropower Scheme, 2006, PB in association with URS)

5.2.3 Wabo Hydro Power Project Site

Three geological investigations had been done as below with report on the result.

A) 1960: First Investigation; Commonwealth Aluminum Corporation Pty, Ltd,

Result of 30 holes around 1,600m is reported in the document below. (not collected in this study)

- Report on site investigation for proposed Wabo Dam, Purari River, Pupua; George Wimpey & Co, Limited, Hayes, UK. , December 1960 Wabo Dam Project;
- Report on further geological investigations, Wabo Dam Project; Miles, Keith R., January 1960

B) 1973: Second Investigation; Nippon Koei Co, Ltd.

6hole, around 370m of drilling had been carried out in the dam site.

- The lower basin development of the Purari River – Preliminary Report, September 1975, Nippon Koei co, Ltd.

C) Third Investigation: Japan／Australia/PNG Joint JICA Study

- 1977: Purari River Wabo Power Project Feasibility Report, SMEC & NK et al.

(1) Geology of Wabo Hydro Power Project Site

The third geological survey for Wabo Hydro Power Project implemented by Joint Study among Japan/Australia/Papua New Guinea is comprehensive investigation to plan hydro power facilities which is including former investigation result.

Geological condition is summarized below based on third geological investigation.

(1) Geological Layers and Rocks in the Project Area

Wabo Project area situates in the geo-tectonic unit of “Platform”. Geology of this area is consist of sedimentary rocks of Cretaceous (sandstone/siltstone/mudstone), limestone of late Paleogene to early Neogene Tertiary, sedimentary rocks of Neogene Tertiary（sandstone, siltstone, mudstone）and Quaternary deposits of tuff, terrace deposit and river deposit.

Geological map of reservoir was made based on existing 1/250,000 geological map, photo interpretation and observation of limited out crops observation. Figure 5.7 shows a geological map of reservoir area, and geological layer and rocks are described in table5.5

Table 5.5 Geological Bed and Rocks in Wabo Project Area

Name of Beds	Geological Age	Rock Type
Terrace/River Deposit	Holocene	Gravel/sand/clay
Duau Volcanics,Tuff	Holocene	Tuff
Era Beds	Plio-Pleistocene	Sandstone/siltstone/mudstone
Orubadi Bed/Aure Beds	Miocene-Pliocene	Sandstone/siltstone/mudstone and limestone
Darai Limestone	Oligocene-Miocene	Limestone
Cretaceous	Cretaceous	Sandstone/siltstone/mudstone

(Source: JICA Survey Team)

The youngest Era beds are outcropped widely from east to west in the project area. And older beds is appears northern and southern area which shows syncline structure in the reservoir area. Three geological beds occur in the main dam site; the Aure Beds, Orubadi Beds and Era Beds. Aure and Orubadi Beds contain little sandstone and comprise the relatively low-lying area of the saddle dam site. The base of these beds is marked by the first thick bed of sandstone and is followed by a succession of thick sandstone beds alternating with siltstone and mudstone.

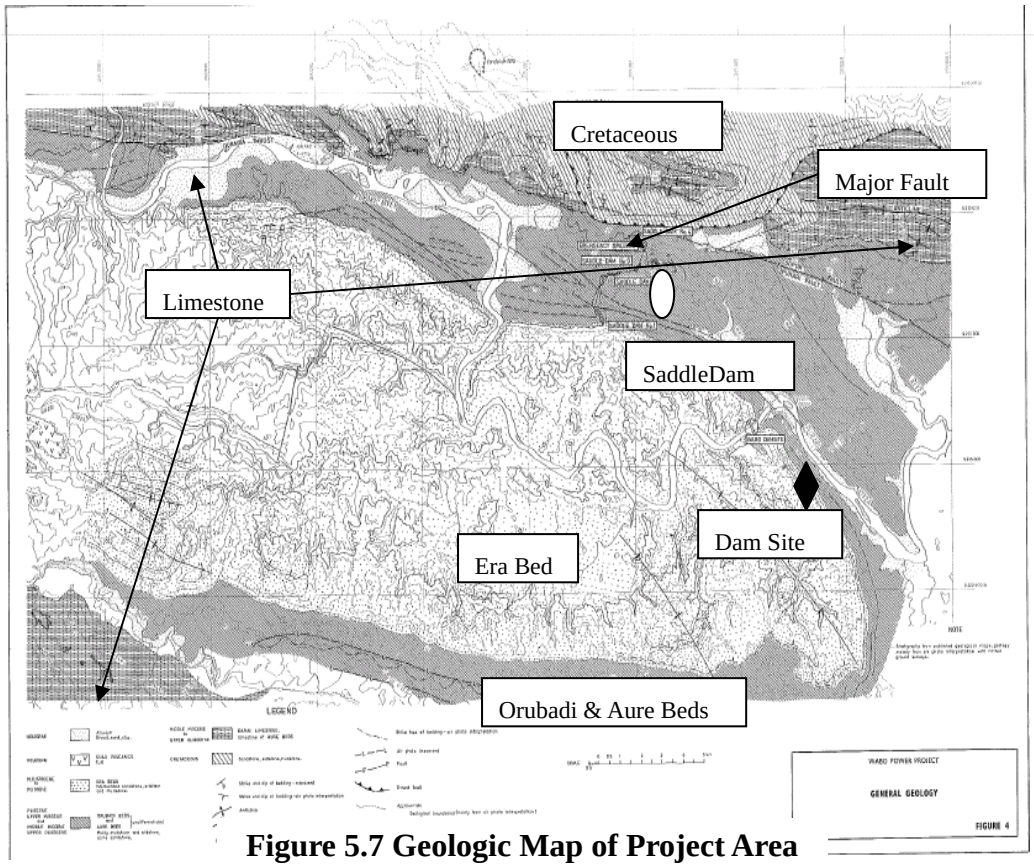


Figure 5.7 Geologic Map of Project Area

(Purari River Wabo Power Project Feasibility Study)

Immediately north of the saddle dam site, a major thrust in this area is believed to exist. And at least nine fault zones were identified which containing from 2m to 3m of crushed mudstone within the length of the saddle dam site.

Deposits of slide debris and talus, locally in excess of 20m in thickness, occur in the saddle dam area, downstream half of the main dam site, power station area and along the spillway .

(2) Assessment of Engineering Geology

A centre core fill type is selected for main dam. As dam height is required 160m to generate 11,825GMWh in a year, five saddle dam is necessary to keep reservoir.

Geological investigation for this feasibility study was carried out to collect enough information on geology and foundation to plan hydro power facilities. This study shows dam foundation is suitable for 160 height rock fill dam and other facilities are designed considering foundation condition of each site.

Outline of geological/foundation condition of each facilities and issues are as below.

Additional survey is necessary for some issues on foundation. But, there is no fatal defect from geotechnical view point which will affect adversely to implement the project.

Main Dam Site: Suitable for 160m height rock fill dam

- Dam foundation is alternation of sandstone, siltstone and mudstone of Orubadi Beds and Era Beds which is prone to slaking,
- . No distinct fault is found in the vicinity of the dam site. But, many shearing is observed in the mudstone and siltstone in the downstream, especially power station area,
- Detritus occur around 20 m thickness in the down stream half of the site
- River deposit is up to 27 m thick along river channel,
- Earth quake factor of 0.12g has been given for preliminary design

Reservoir: No fatal issue

- Limestone occurs in the northern part of the reservoir but does not extend continuously into any adjacent catchments and therefore causes no potential leakage problem,
- Landslides occur frequently in the reservoir area. The largest landslide in the reservoir area would have little effect on the loss of storage capacity and, being remote from the dam sate, would not generate wave action to damage the dam.

Saddle Dam: Suitable for Earth/Rock fill dam foundation. But detailed study on treatment for fault and landslide is required

- Bed rock is mudstone and siltstone with sandstone comprising less than 10%,
- Average stripping depth to sound foundation will be roughly 4m except for several landslide areas where up to 17m stripping will be required,
- Additional investigation is necessary to make plan of foundation treatment.

Intake structure: Located in sound rock

- Located in a prominent ridge where can be founded sound sandstone bed and steep batters may be adapted.

Penstock: The penstock can be implemented to be found on bedrocks.

- In this area, two fairly thick sandstone beds exist in the upper section of penstock bench, but there are only a few thin beds along the sloping section of the bench

Power Station: Further study on foundation is required

- In this area, slide debris is at least 15m thick. And mudstone bed under thick overlain is weakened by faulting and shearing. The bearing capacity of the faulted mudstone and siltstone has not been conclusively determined and should be further studied in the design stage

Spillway: Similar condition to that of the intake structure and penstock bench

- The large crest structure will be located in a prominent ridge containing thick sandstone beds with only a veneer of soil and weathered rock.

Diversion Tunnel: Careful designing and tunnelling is required

- Large diameter of diversion tunnels pass the weak beds. So, great care is necessary to ensure that the tunnels are adequately support during construction.

PPL is going to implement additional geological investigation from May 2010 in the project area to clarify issues of foundation to ensure the feasibility.

References for Chapter 5

<Port Moresby Grid>

1. 1/2,500,000 Geology of Papua New Guinea ; 1976)
2. 1980; Vanapa Hydro Electric Complex Feasibility Study; ELCOM
3. 1982; Engineering Geological Feasibility Study of the Naoro-Brown River Hydro-electric Scheme, Geological Survey of PNG
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7. 1973: Report, Ramu 2 Project Preliminary Layout and Cost Estimate, December; Australian Department of Works
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11. The lower basin development of the Purari River – Preliminary Report, September 1975, Nippon Koei co, Ltd.
12. 1977: Purari River Wabo Power Project Feasibility Report, SMEC & NK et al.

CHAPTER 6

ENVIRONMENTAL AND SOCIAL CONSIDERATION

6.1 Baseline Features of Natural Resources and Socioeconomic Conditions

The Independent Country of Papua New Guinea is well known as the country has ecologically and culturally very unique feature in the Oceania. The brief feature of the country related to natural resources and socioeconomic condition is described bellow.

Table 6.1.1 Overview of the Environmental condition in PNG

Geomorphology	The country consists eastern part of the main land of new guinea island which is the 2nd largest island in the world, and more than 600 of various scale of the islands. The country area is 452,860 km^2 and major feature of the mainland is undulating mountainous associated with coastal lowlands and foothills. The country is geographically classified 4 regions 1) Southern, 2) Momase, 3) Highlands and 4) Island and divided 20 provinces (including National Capital District). The annual rainfalls are varied approximately 2,500-3,000 mm in general. However, some districts have annual rainfall of more than 9,000 mm. Papua New Guinea is located on the “Ring of Fire” in the Pacific Ocean and is geologically active. Soils range from old alluvium deposits to newly formed soils as a result of recent volcanism.
Biological feature	PNG has world widely well known high biodiversity in fauna and flora. However, those studies have still in progress. Known species are approximately 26 thousands (IUCN 2008). However, it was estimated sometime 400,000 or 700,000 species in total as mentioned what PNG has more than 5 % of world species in the 1% of area in the world. Vegetation are classified as (1) Coastal and oceanic areas (2) Deltaic plains (3) Lowland forest areas(4) Lower mountain forest areas (5) Upper mountain forest areas (6) Grasslands. Forests cover approximately 300 thousand km^2 (291,600 km^2 in 2007 WB) of a total land area(68%) of about 452,860 km^2. Fifty seven (57) areas including 1 Conservation Area,16 National Parks and 40 Wildlife Management Areas are protected. Those area are extended approximately

	3% of the total land area. Having 3,120,000 km^2 of Sea area and 17,110 km^2 of coastal line, the diverted marine ecologies from tidal wetlands and estuaries to deep ocean basins are contained.
Social environment feature	Total population in the country is estimated approximately 7 million in 2010 (National Statistic Office). Majority of total population in PNG (more than 80%) are living in the rural area(at the time of PNG National Census 2000) and having subsistence livelihood based on agriculture, animal husbandry, and fishery. The population growth rate was approximately 3.2% annual at the latest census (2000). The distribution of the population is varied from the region and 38% of total population living in interior highlands region, 28% in the north coast region, 20 % in the south coast region, and 14 % in the Islands region. Also, the population density is varied ranging from 2 persons /km^2 in Western Province to 52 persons /km^2 in Western Highland Province. Approximately 13% of the total land area(60,235km^2) are classified as Arable land (ADB 2009) and the lands are used for mainly cultivation of coffee, cocoa, coconut, palm oil, tea, rubber, sweet potatoes, fruit vegetables and livestock. The main industries consist of coconut oil, palm oil, plywood, wood chip, mining, crude oil production, construction and tourism. The combine of manufacturing, construction, Mining, Quarrying, and Petroleum sectors contributed 37.9 percent of the GDP in 2007, followed by the Agriculture, Forestry, and Fishing (37.1%) and the other sectors (25%) (ADB 2009).

(Source: ADB (2009) Papua New Guinea: Power Sector Development Plan, National Statistic Office in PNG(2010), IUCN(2008))

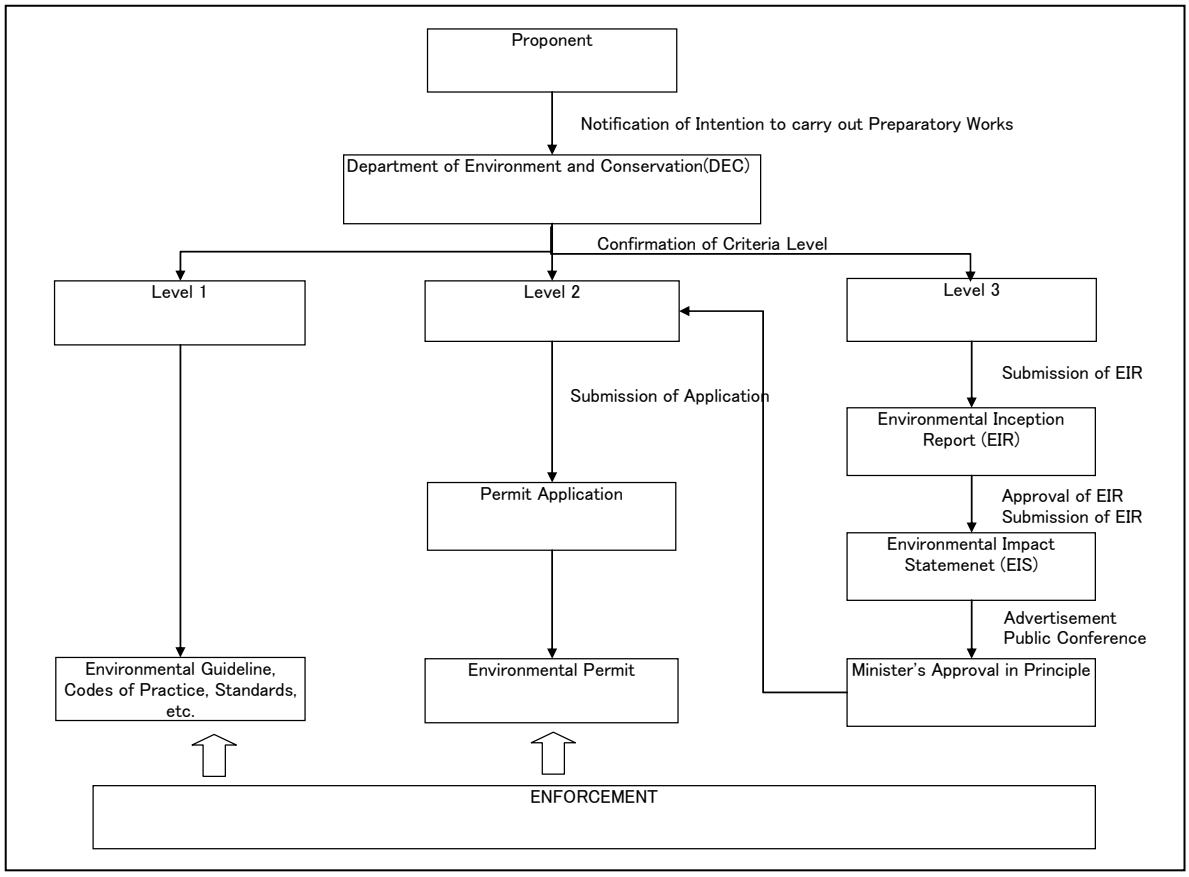
6.2 Environmental Laws, Regulations, Guidelines

6.2.1 Legislation related to Environmental Impact Assessment

Under the law, Environmental Act 2000(amended 2002), the implementer on the prescribed projects is required to submit Environmental Impact Statement (EIS) to obligatory obtain the Environmental Permit before its implementation. The prescribed projects are provided in the Environment (Prescribed Activities) Regulation 2002. Based on the classification in the Regulation, when the person who intends an activities of (a) a level 2 or level 3 activity; or (b) a

change in process, or expansion of works or plant in relation to an existing activity such that a level 2 or level 3 activity is carried out, the process on the Environmental Permit is required.

Process of the Environmental study on the Permit in the Papua New Guinea is following;



(Source: Department of Environment and Conservation)

Figure 6.2.1 Procedure of Environmental Study in PNG

The proponents for the projects should register the intention to carry out preparatory work to the Department of Environment and Conservation(DEC), at least one month prior to the preparation works. After confirmation of the Categories in Levels1-3 by the department, proponent should submit Environmental Inception Report (EIR) which shows listing the issues to be covered by the Environmental Impact Statement. After approval of the EIR, the proponent can submit Environmental Impact Statement (EIS) based on the environmental impact assessment following the issue on the approval at EIR. When the EIS is approved by the Minister, finally application of the Environmental Permit can be processed. This environmental assessment procedure is described in the section 51, (1) in Environmental Act 2000 as showing bellow.

Section 51, (1) in Environmental Act 2000

(1) An environmental impact assessment shall involve the following:-
(a) submission of an inception report in accordance with Section 52 setting out the issues to be covered in the environmental impact statement;
(b) submission of an environmental impact statement in accordance with Section 53 setting out the physical and social environmental impacts which are likely to result from the carrying out of the activity
(c) assessment and public review of the environmental impact statement in accordance with Sections 54 and 55;
(d) acceptance of the environmental impact statement by the Director in accordance with Section 56;
(e) referral of the environmental impact statement, assessment report and other material to the Council in accordance with Section 57;
(f) recommendation by the Council to the Minister in accordance with Section 58;
(g) where the Minister has received a recommendation from the Council under Section 59 – an approval in principle by the Minister.

(Source: Environmental Act 2000)

As showing the figure above, in the Act, an information disclosure is also provided. After receiving the Environmental Impact Statement, the director of the Environment may give a direction to proponent to make a public presentation to persons who are likely to be affected by the carrying out of the activity.

The contents of the Environmental Impact Statement is guided in the Guideline for Conduct of Environmental Impact Assessment & Preparation of Environmental Impact Statement(DEC Publication: GL-Env/02/2004). The required items in the contents are showing bellows;

CONTENT OF THE ENVIRONMENTAL IMPACT STATEMENT

1. Executive Summary or Overview of Proposal
2. Purpose of The Development
3. Viability of The Project
4. Description of The Proposed Development Activity
5. Development Timetable
6. Characteristics of The Receiving Environment
   - Available Environmental Studies & Investigations
   - Physical Environment
   - Biological Environment
   - Social Environment
7. Waste Minimization, Cleaner Production and Energy Balance
8. Environmental Management, Monitoring and Reporting
9. Other Statutory Decisions.
10. Confidential Information.
11. References.
12. Acknowledgements.
13. Study Team.

(Source: Guideline for Conduct of Environmental Impact Assessment & Preparation of Environmental Impact Statement(DEC Publication: GL-Env/02/2004))

6.3 Legislation and Procedures for Environmental Study on Hydropower Development

Hydropower projects in Papua New Guinea having an installed capacity exceeding 2 MW will be required for Environment Impact Assessment according to the Environment (Prescribed

Activities) Regulation 2002, No.30 of 2002.

The Schedule 1 and Schedule 2 of the regulation list the activities which are required Environmental Impact Assessment process, namely Environmental Impact Statement, as activities of Level 2 and 3 provided by Environmental Act 2000. The relevant activities likely occur related to hydropower development shows below (extracted from the regulation).

SCHEDULE 1: LEVEL 2 ACTIVITIES

CATEGORY B

Sub-Category 10: Energy production

10.1 Operation of hydroelectric plants with a capacity of more than 2 Megawatts (MW).

Sub-Category 12: Infrastructure

12.6 Construction of electricity transmission lines or pipelines greater than 10 km in length.

Sub-Category 13: Other activities

13.1 Damming or diversion of rivers or streams.

(Source: Schedule-1, Environment (Prescribed Activities) Regulation 2002)

SCHEDULE 2: LEVEL 3 ACTIVITIES

Sub-Category 14: General

14.1 Activities involving investment of a capital cost of more than K50 million, except where such investment is made in pursuing an activity otherwise dealt with in this Regulation in which case that category of activity will apply to the investment.

14.2 Activities involving the generation of a volume of liquid waste of more than 7,000,000 m^3 per year (approximately 20 million liters per day).

14.3 Activities that will involve the discharge, emission or deposit of hazardous contaminants, except where such discharge, emission or deposit is ancillary or incidental to, or associated with, any other activity in this Regulation in which case that category of activity will apply to the discharge, emission or deposit.

14.4 Activities that may result in a significant risk of serious or material environmental harm within Wildlife Management Areas, Conservation Areas, National Parks and Protected Areas or any area declared to be protected under the provisions of an International Treaty to which Papua New Guinea is a party and which has been ratified by the Parliament of the Independent State of Papua New Guinea.

Sub-Category 16: Forest harvesting and land clearance

16.2 Any large scale clearing carried out under section 90 (a), (b), (c) or (d) of the Forest Act.

Sub-Category 19: Infrastructure construction

19.1 Construction of major hydropower schemes or water supply reservoirs inundating an area greater than 5 km^2.

19.3 Infrastructure construction that requires the reclamation of more than 5 hectares of land below the high water mark.

(Source: Schedule-2, Environment (Prescribed Activities) Regulation 2002)

6.4 Legislation and Legal Procedure for Land Acquisition for Development

(1) Land tenure system in PNG

The land system in Papua New Guinea is classified into two: one is Alienated Land that is managed by the Government, and the other is Customary Land that belongs to residents, a citizen or a group of citizens, who are regulated by custom. Alienated Land includes unused land in urban areas, undeveloped land, rent land, land with ownership for indefinite period, private land, and shares about 3% of the country total. The rest of 97% is Customary Land and not managed with written document. The land acquisition of the Customary Land is described bellow.

(2) Land acquisition for hydropower development

In general, there are two (2) types of land acquisition process related to the public works in Papua New Guinea.

Those are; 1) Compulsory Acquisition process and 2) Outright Acquisition process (Agreed Land Acquisition). Those acquisitions are provided in the Land Act 1996 and the compensation is made to the land owner on both cases. In most case of hydro power development mainly conducted by PPL, the Outright Acquisition is applied.

Recent case related to hydro power development by PPL, land acquisition was taken at the power transmission line construction between Erap (Huon district) and Hidden Valley (Bulolo district) in the Ramu system. The lands for the towers of transmission line for approximately 175km of distance were acquired by the power limited company. And it took around 1 year and 6 months for the negotiation.

(3) Identification of the Land owners

In case of the hydropower development by PPL, once exact location of the project site is selected, the land officer of the company starts the land acquisition process. Normally it is started at Identification of owner (owner group, individual) and Identification of boundary, and the negotiation is launched afterward. Within the process, when the problems on the land tenure between owners happen, the matter is left the mediation of third party (mediation by the village and land courts) following the procedure of Land Disputes Settlement Act 1975.

(4) Establishment of the Incorporated Land Group:

Because the negotiation on the land is only applied with the Incorporated Land Group as the representative of the land owners, the Group should be organized at the acquisition process. As mentioned in the legislation, this process is regulated by the Incorporated Land Group Act.

(5) Registration of ILGs

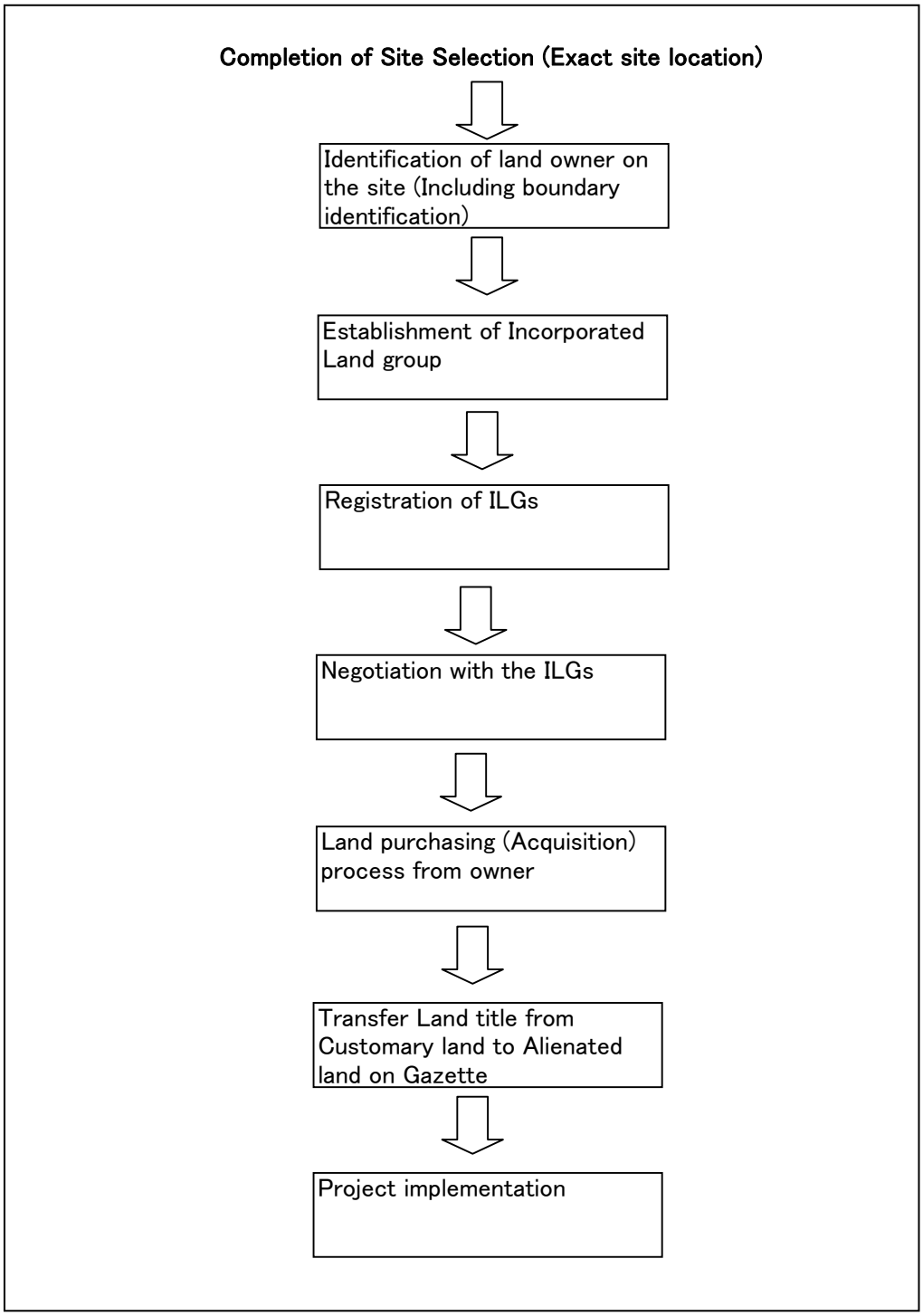
The ILG is a registered body for the land under the Land Registration Act. The ILG negotiates with the investors and a sublease is signed between the ILG and the investor. The Land Department plays no role in the process. Disputes are settled in civil court.

(6) Purchasing the land

In case of the hydropower development by PPL, the monetary compensation is normally applied the price on the land are negotiated already above mentioned process. (This should follow the Valuation Act 1967).

(7) Transferring Land title

After the acquisition of the land, the land tile is transferred from Customary Land to State Land in case of the hydropower development by PPL. The land transfer will be announced on the gazette. Once the gazettal takes place the land becomes the property of the state and is free of all claims by any individual or group that had an interest in the land. No further payments or actions by the purchaser can be demanded by the former owners. The provision for assessing and paying compensation is set out in the Land Act.



(Source: PNG Power Ltd., ADB(2009) Papua New Guinea: Power Sector Development Plan, Manning & Hughes (2008) Acquiring land for public purposes in Papua New Guinea and Vanuatu)

Figure 6.4.1 Land Acquisition Process in PNG

6.5 Requirement of Study and Assessment of Environmental and Social Consideration

6.5.1 Present situation on the proposed area

(1) Areas currently covered by Port Moresby Grid System and Ramu Grid System

The Areas where the Port Moresby Grid System and Ramu Grid System cover, are mainly focused in this report. The provinces which are fallen into those systems are followings;

Grid systems	Provinces
Port Moresby Grid System	The area surrounding Port Moresby City including 2 provinces; National Capital District Central Province
Ramu Grid System	The area surrounding Lae City including 7 provinces; Morobe Province Madang Province Eastern Highland Province Chimbu Province Western Highland Province Southern Highland Province Enga Province

(Source: PNG Power Ltd.)

(2)Social Condition

(a) Social administrative structure

The country is divided 4 Regions, 1) Southern, 2) Momase, 3) Highlands and 4)Island and those corresponding to the geological feature in the country. Administratively, also there are regional offices in each region. Under those regions, the country consists 20 provinces (19 provinces and 1 National Capital District). The provinces consists districts and also Local Level Governments (LLGs) under the districts. Those LLGs consist many words. In Papua New Guinea , there are, 89 districts, 313 local-level governments and 6,131 wards, the challenges for policy makers and service delivery agencies are substantial(NRI 2010).

(b) Population

The present population of the Papua New Guinea is projected approximately 7 million. At the annual growth rate at the census in 2000 shows 3.2% in total. (National Statistic Office). The census survey is conducted every 10 years and the new census survey is planned to be held on the July, 2010. The result may be available 1 to 2 years after the survey.

Table 6.5.1 Population in PNG

	1990	2000	Growth rate (%)	2010 (projection)
PNG	3,761,954	5,190,786	3.2	7,112,628
Province				
Western	110,420	153,304	3.3	2,12,107.8
Gulf	68,737	106,898	4.4	164,427.5
Central	141,195	183,983	2.6	237,821.6
NCD	195,570	254,158	2.6	328,531.8
Mile Bay	158,780	210,412	2.8	277,333.1
Northern	96,491	133,065	3.2	182,331.1
SHP	317,437	546,265	5.4	924,292.6
Enga	235,561	295,031	2.3	370,359.9
WHP	336,178	440,025	2.7	574,356.8
Chimbu	183,849	259,703	3.5	366,336.7
EHP	300,648	432,972	3.6	616,676.5
Morobe	380,117	539,404	3.5	611,833.1
Madang	253,195	365,106	3.7	525,057.1
ESP	254,371	343,181	3.0	461,206.6
WSP	139,917	185,741	2.8	244,815.5
Manus	32,480	43,387	2.8	57,186.14
NIP	86,999	118,350	3.1	160,603.5
ENBP	185,459	220,133	1.7	260,552.2
WNBP	130,190	184,508	3.5	260,266.8
NSP	154,000	175,160	1.3	199,310.1

(Source: National Statistic Office - using exponential growth assuming the rates are steady (2010). Based on the census data in 2000.)

(c) Socio-Economic Indicators

Basic information on the country is shown below;

Table 6.5.2 Socio-Economic Indicators

Indicators	Data	Ref.
Population	5.1 million at 2000(Average annual growth rate : 3.2 %) Approximately 7 million on the projection at 2010.	JICA Country Profile 2002, National Statistical Office
Ethnic Groups	Papua and Melanesia tribes falling under Melanesia	JICA Country Profile 2002
Religion	Christianity is predominant, as and traditional religions	JICA Country Profile 2002
Literacy	Total Pop. 58 %; (adult over 15 years) at estimation of 2008	2008 World Bank Papua New guinea at glance, 2009
Urban Population	13 % (Urban : Rural = 675,403:4,496,165) at 2000	2000 Census National Report
Life Expectancy	63.1 years; females: 65.3 years; males: 61.1 years at 2000	JICA Country Profile 2002
Child Mortality	58.21 (Mortality of children under five years old against	JICA Country Profile

	1,000 birth)	2002
GDP	8.1 billion US$ at 2008 World Bank's estimation	World Bank(2009) Papua New Guinea at a glance
GDP Composition	Agriculture:34% Industry: 48% Services: 18 % at 2008 World Bank's estimation	World Bank(2009) Papua New Guinea at a glance
Industry	Food processing, timber, plywood production, wood chip production, mining of gold, silver and cooper, oil palm processing, crude oil production, construction, tourism, copra crushing	JICA Country Profile 2002
Natural Resources	Gold, copper, silver, petroleum, timber, coffee, cocoa, copra, raw rubber, tuna, palm oil, marine resources	JICA Country Profile 2002
Access to the Safe Water *1	Urban areas: 84 % Rural areas: 17 % in 1980-1995	JICA Country Profile 2002
Access to the Sanitation *2	Urban areas: 95 % Rural areas: 12 % in 1980-1995	JICA Country Profile 2002
Human Development Indicators (HDI)	0.541(148th in the world, GNP per capita was 138th at 2008 in HDR 2009)	UNDP

Note: *1: Access to Safe Water is the percentage of the population with reasonable access to an adequate amount of safe water including treated surface water and untreated but uncontaminated water, such as from springs, sanitary wells and protected boreholes.
*2: Access to Sanitation is the percentage of the population with reasonable access the pit latrine, flush toilet with sewage, septic tanks and other suitable facilities to dispose and prevent human from contact with excreta.
(Source: JICA Country profile 2002, National Statistic Office, World Bank(2009) Papua New Guinea at a glance)

(d) Land use

The land use in the country presented bellows. Approximately 30% of the total area was used for the agricultural production purpose at the time of 1990. Land use in the customary land should be considered at the socio-economic research associate with the project planning.

Table 6.5.3 Land use of the provinces

Province	Total area (km^2)	Population 1990	Persons per km^2 1990	Total cultivated land (%)	Total used land (%)	% change
Western	97,065	110,420	1	8.0	10.0	2.0
Gulf	33,847	68,122	2	11.0	12.0	1.0
Central	29,954	141,241	5	21.0	30.0	9.0
Milne Bay	14,125	158,700	11	40.0	47.0	7.0
Oro	22,510	96,239	4	19.0	22.0	3.0
Southern Highlands	25,698	317,184	12	27.0	29.0	2.0
Enga	11,839	235,561	20	31.0	37.0	7.0
Western Highlands	8,897	333,828	38	50.0	55.0	5.0
Chimbu	6,022	186,114	31	42.0	43.0	1.0
Eastern Highlands	11,006	300,515	27	50.0	53.0	3.0
Morobe	33,525	377,563	11	36.0	43.0	7.0

Madang	28,732	256,370	9	56.0	64.0	8.0
East Sepik	43,720	255,012	6	20.0	37.0	17.0
West Sepik	36,010	140,051	4	23.0	26.0	3.0
Manus	2,098	32,840	16	83.0	84.0	1.0
New Ireland	9,615	86 999	9	47.0	47.0	0.5
East New Britain	15,109	185 024	12	25.0	25.0	-
West New Britain	20,753	130,625	6	27.0	31.0	4.0
North Solomons	9,329	155,000	17	55.0	55.0	-
Total	**459,854**	**3,567,408**		**25.0**	**30.0**	**5.0**

(Source: Saunders, J. 1993. Agricultural Land Use of Papua New Guinea: Explanatory Notes to Map. PNGRIS Publication No. 1. AIDAB, Canberra. in Graham Sem(1996), 4. Land-use change and population in Papua New Guinea, Population, land management, and environmental change, UNDP.)

(e) Condition of the Relevant Provinces

Social condition of the Provincial levels are described in the National Research Institute(2010), Papua New Guinea District and Provincial Profiles. The general feature in the proposed areas, Port Moresby Grid and Ramu Grid systems are shown bellows;

Table 6.5.4 Baseline information on the provinces in Port Moresby Grid System

Name of Province	Description
National Capital District	The NCD is the administrative unit that encompasses the national capital of Papua New Guinea, Port Moresby. While the administration of NCD is quite different to the Provincial Governments, for electoral purposes, is classified as the equivalent of a province, in that it has a Provincial Member, who becomes the Governor of the district. The National Capital District Commission (NCDC) is the administrative authority and operates under the National Capital District Commission Act for the purpose of providing municipal services to the entire city. Provincial headquarters: Port Moresby Number of LLGs: n/a Number of wards: 12 Population Total 254,158 Area (km²):240 Literacy rate (%) Total90.7%(Male:Female=92.3:88.7) Economic Activity(agricultural activities of citizen households%) Food crops 14.4% Betel nut 8.1 % Coconut 6.1 % Fishing 4.3 % Livestock 2.2 % Electricity customers 41,766
Central Province	Central Province occupies the southern side of the Owen Stanley Ranges and the area of coast from Bereina in the north to Gaire Village in the south.

	People living near Bereina can earn a high income from the sale of food and betel nut, while those in reasonable proximity to Port Moresby can earn moderate incomes selling food and other goods at markets. People in the more remote areas of Goilala and Abau have low potential environments and earn low incomes. Many people commute to earn non-agricultural wage incomes in and around Port Moresby. A road runs along the length of the province, and areas around Port Moresby are also well served by roads. Another road leads up to the Sogeri Plateau and the start of the Kokoda Track. However, Goilala district and the east of Abau district have very few roads. Provincial headquarters: Port Moresby Number of districts: 4 districts(Abau, Goilala, Kairuku- Hiri, Rigo) Number of LLGs: 13 Number of wards: 205 Total population : 183,983 Area (km²) 29,998 Literacy rate (%)Total72.1%(Male :Female=75.4 :68.6) Economic Activity(Top agricultural activities of citizen households) Food crops 75.3 % Betel nut 57.0 % Coconut 53.0 % Fishing 36.3 % Livestock 34.7 % Electricity customers 3,182

(Source: The National Research Institute(2010),Papua New Guinea District and Provincial Profiles(data based on the National Census 2000))

Table 6.5.5 Baseline information on the provinces in Ramu Grid System

Name of Province	Description
Morobe Province	Morobe Province stretches from the Sarawaget Range in the north along the Huon Peninsula to the east and through the Markham Valley in the centre of the province. The Bulolo and Watut Valleys run north-south, with the Ekuti and Owen Stanley Ranges in the south. High agricultural incomes from the sale of betel nut and fresh food can be earned by those living in the Markham and Watut Valleys. More moderate incomes can be earned from fish, food, coconut and betel nut in the coastal areas around Lae. More remote areas earn very low incomes. Other sources of income are also available from mining near Wau, forestry near Bulolo and cattle in the Markham Valley. The Highlands Highway and a road between Lae and Wau provide reasonable road access in the province. Roads along the Huon Peninsula do not connect to Lae,. The very north of the province in Kabwum Distict and south of the province, around Garaina are very remote. Provincial headquarters: Lae Number of districts: 9 - Bulolo, Finschhafen, Huon Gulf, Kabwum, Lae, Markham, Menyamya, Nawae, Tewai Siassi Number of LLGs: 33 Number of wards: 547

	Population Total :539,404 Area (km²) :33,705 Literacy rate (%)Total 63.6%(Male :Female=69.5 57.3) Economic Activity(Top agricultural activities of citizen households) Food crops 69.2% Betel nut 59.4 % Coffee 45.7 % Coconut 36.9 % Livestock 34.5% Electricity customers 12,136
Madang Province	Madang Province runs along the coast from the head of the Ramu River south to Saidor. Going inland, it covers the Ruboni, Adelbert, Schrader, Bismarck and Finisterre Ranges, and the Ramu, Sogeram and Golgol Valleys. High incomes can be earned on Karkar Island and along the coast from the sale of cocoa, betel nut, copra and food. The rest of the province has less access to markets and therefore earns mostly low incomes. Some wage-earning opportunities are also available in the town of Madang, with Ramu Sugar and with expanding mining and forestry operations. Roads travel along the coast of the province from Bogia to Saidor, as well as within the Golgol Valley near Madang Town. A road also runs inland to Josephstaal and through the Ramu Valley towards Lae. Areas in the very west of the province, such as Simbai, are very remote. Water transport is also common along the coast and particularly to the islands. Provincial headquarters: Madang Number of districts: 6 - Bogia, Madang, Middle Ramu, Rai Coast, Sumkar, Usino Bundi Number of LLGs: 19 Number of wards: 451 Population Total : 365,106 Area (km²) :28,886 Literacy rate (%)Total55.2%(Male Female=61.2%: 48.8%) Economic Activity(Top agricultural activities of citizen households%) Food crops 76.3 % Betel nut 70.7 % Coconut 58.6 % Cocoa 39.7 % Livestock 39.3 % Electricity customers 3,297
Eastern Highland Province	Eastern Highlands Province includes the Bismark Range and Upper Ramu Valley in the north of the province. It also covers the Asaro, Benabena and Dunantina Valleys, all of which are very agriculturally productive. However, the south of the province, especially near Marawaka, is mountainous and remote. The area around Henganofi provides very good agricultural income from the sale of coffee, food, tobacco and firewood, and most of the north of the province can earn moderate incomes. However, there are very few income-earning opportunities for those in the south of Obura Wonenara, Okapa and Lufa. The Highlands Highway and a network of smaller roads cover the north of the province. Limited and deteriorated roads travel through Lufa and Okapa District, while Obura Wonenara has very limited roads, especially in the remote areas in the south. Provincial headquarters: Goroka Number of districts: 8 - Daulo, Goroka, Henganofi, Kainantu, Lufa, Obura Wonenara, Okapa, Unggai Bena

	Number of LLGs: 24 Number of wards: 261 Population Total 432972 (Male(%):Female(%)=51.5 48.5) Area (km²) 11,157 Literacy rate (%)Total 43.9%(Male: Female=51.0 36.5) Economic Activity(Top agricultural activities of citizen households) Coffee 88.4 (%) Food crops 76.7 (%) Livestock 47.8 (%) Betel nut 13.5 (%) Poultry 12.5 (%) Electricity customers 5,445
Chimbu Province	Chimbu Province includes the highest mountain in PNG, Mt. Wilhelm, in the Wilhelm Range in the north. The densely settled Wahgi Valley is in the west of the province, and the lowlands near Karimui, and the Purari Valley are in the south. There are pockets of agricultural activity in the north which earn high incomes from the sale of coffee and food. However, the rest of the province earns relatively low incomes. Some income earning opportunities are also available along the Highlands Highway running PMVs and tradestores. A network of roads, including the Highlands Highway, covers most of the northern areas of Simbu Province. The Wahgi River Gorge divides the province south of Kundiawa. The small township of Karimui, in the centre of Karimui Nomane District is not linked by road to anywhere else in the province. A mostly impassable road also leads north to Usino in Madang. Provincial headquarters: Kundiawa Number of districts: 6 - Chuave, Gumine, Karimui Nomane, Kerowagi, Kundiawa, Sinasina Yonggamugl Number of LLGs: 20 Number of wards: 308 Population Total 259,703 (Male(%):Female(%)=52.0 48.0) Area (km²) 6,112 Literacy rate Total 41.8 %(Male :Female =48.7 :34.5) Economic Activity(Top agricultural activities of citizen households) Coffee 87.8 (%) Food crops 81.2(%) Livestock 72.8 (%) Poultry 25.6 (%) Betel nut 3.3 (%) Electricity customers 1,721
Western Highland Province	Western Highlands Province covers the Jimi, Wahgi, Baiyer, Lai, Kaugel and Nebilyer Valleys. It also includes the Hagen Range, the Kubor Range and the mountains of the Sepik-Wahgi Divide which run through the entire province. Western Highlands Province has some of the most productive smallholder agriculture and coffee plantations in PNG. People in the Wahgi, Baiyer and Nebilyer Valleys earn high incomes from the sale of coffee and food. However, the more remote lower Jimi Valley and Mera area earn much lower incomes. Wage employment is also available in the township of Mt Hagen. The Highlands Highway runs through the Wahgi and Nebilyer Valleys. Other smaller road networks travel through the Tambul Nebilyer, Baiyer Mul and Jimi Districts. However, people in the far north, in the lower Jimi Valley and far south near Mera are isolated from service centers. Provincial headquarters: Mt. Hagen Number of districts: 7 - Anglimp South Wahgi, Baiyer Mul , Dei, Hagen, Jimi, North Wahgi, Tambul Nebilyer

	Number of LLGs: 15 Number of wards: 479 Population Total 440,025 (Male(%):Female(%)=51.1 :48.9) Area (km²) 9,097 Literacy rate Total 38.4%(Male :Female=44.1 32.6) Economic Activity(Top agricultural activities of citizen households) Food crops 77.7 (%) Coffee 77.0 (%) Livestock 63.6 (%) Poultry 23.7 (%) Betel nut 5.9 (%) Electricity customers 6,175
Southern Highland Province	Southern Highlands Province covers the Central Range and Lagaip Valley in the north. The Tagari Valley runs through the centre. The south of the province includes limestone plateaux, Lake Kutubu and the Hegigio, Mubi and Digimu Valleys as well as the dormant volcano, Mt. Bosavi. Incomes for most of Southern Highlands Province are low, earned from the sale of coffee, food and firewood. Small pockets of high incomes are earned from oil and gas operations; however this is limited to the areas near these concerns. Incomes of this kind may increase with the proposed Liquefied Natural Gas Project. The Highlands Highway runs through the province from Imbonggu to Kopiago, and other roads go to Komo, Erave and Pangia. Remote areas in Komo Margarima and Nipa Kutubu, especially near Mt. Bosavi require more than a day's travel to reach a service centre. Provincial headquarters: Mendi Number of districts: 8 – Ialibu Pangia, Imbonggu, Kagua Erave, Komo Margarima, Koroba Lake Kopiago, Mendi, Nipa Kutubu, Tari Pori Number of LLGs: 32 Number of wards: 729 Population Total 546,265 (Male(%) :Female(%)=51.0 49.0) Area (km²) 25,587 Literacy rate (%)Total 36.5 %(Male Female=40.6%: 32.2%) Economic Activity(Top agricultural activities of citizen households) Food crops 78.0 % Livestock 62.2 % Coffee 50.3 % Poultry 15.4 % Fishing 4.9 % Electricity customers 1,131
Enga Province	Enga Province shares a northern border with East Sepik Province. The Central Range runs through the north of the province, with two river valleys, the Lagaip and the Lai supporting high population densities. The Lagaip River runs south to join the Fly River while the Lai joins the Sepik River in the north. Agriculture provides only a low to moderate source of income for the province, earned from the sale of coffee, food and firewood. Cultivated areas are very prone to both drought and frost, which can seriously affect food security. Some royalties and wage employment can be earned at the Porgera Goldmine. A branch of the Highlands Highway runs from Mt. Hagen up to Wapenamanda and Wabag and the Porgera Goldmine. Another road

	connects Kandep with Southern Highlands Province. Those living in the north of the province are very remote and require more than a day's travel to reach a service centre. Provincial headquarters: Wabag Number of districts: 5 - Kandep, Kompiam-Ambum, Lagaip-Porgera, Wabag, Wapenamanda Number of LLGs: 15 Number of wards: 334 Population Total 295,031 (Male(%):Female(%)=51.9 48.1) Area (km²) 11,704 Literacy rate (%)Total 35.0% (Male :Female=40.2 :29.5) Economic Activity(Top agricultural activities of citizen households) Food crops 79.8 % Livestock 70.1 % Coffee 36.9 % Poultry 20.2 % Betel nut 6.7 % Electricity customers 1,396

(Source: The National Research Institute(2010),Papua New Guinea District and Provincial Profiles(data based on the National Census 2000))

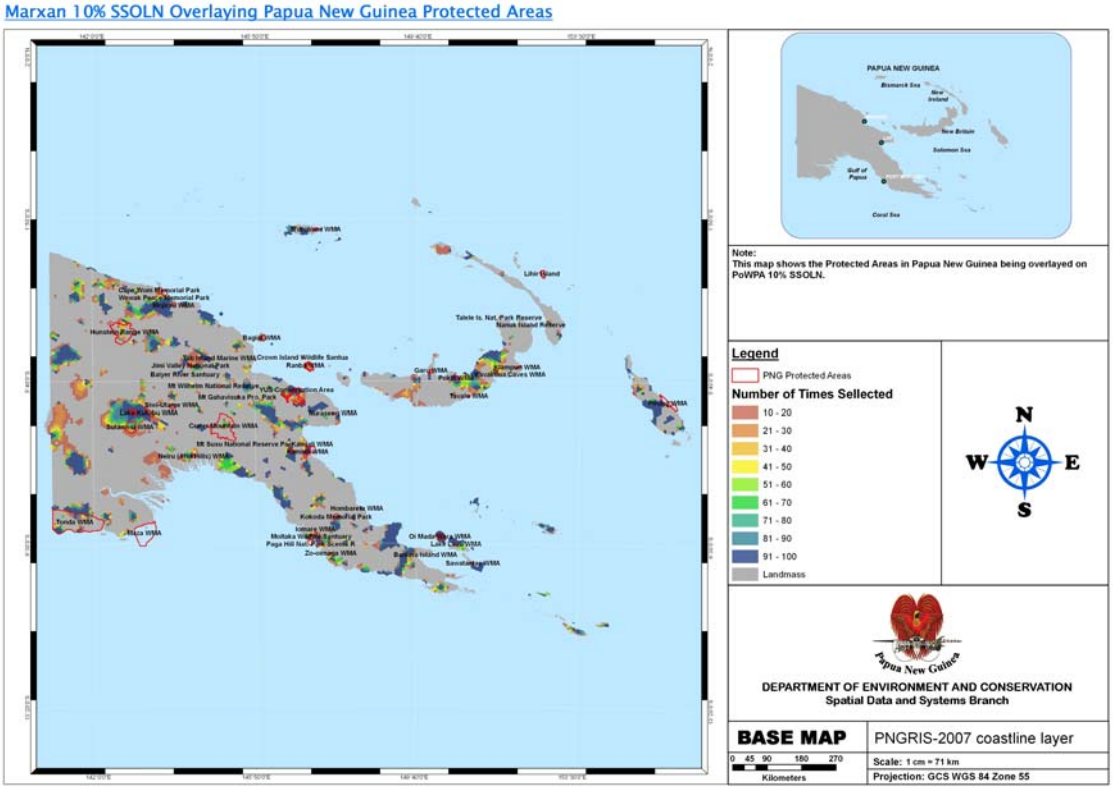
(2) Natural Environment

(a) Protected Areas

According to the Department of Environment and Conservation(DEC), currently 57 protected areas(Including 1 Conservation Area, 16 National Parks and 40 Wildlife Management Areas) are existed at the moment, 2010 in the PNG. National Parks are provided by National Park Act, and the Conservation areas by Conservation Area Act, Wildlife Management Area by Fauna (Protection and Control) Act respectively. For the National park, area protected as a state land as Alienated Land or lease under the agreement with the landowner. Wildlife Management Area, Conservation area are managed by local people as their property as in a Customary Land.

Besides the national legislations which provide those protected area, the government of PNG also joins the international conventions for protecting natural environment such as (a) The Convention on International Trade in Endangered Species of flora and fauna (CITES), (b) Biodiversity Convention, (c) Ramsar Convention, and (d) Convention Concerning the Protection of World Cultural and Natural Heritage. The areas under protected those categories also should be considered to avoid the impact on the projects.

The locations of the areas are identified by DEC as followings.



(Source: Department of Environment and Conservation)

Figure 6.5.1 Protected Area in PNG

Table 6.5.6 Protected area in the provinces where the Port Moresby Grid System fallen into

Name of Province	Protected areas
National Capital District	Moitaka Wildlife Santuary、 Paga Hill Nat. Park Scenic R、
Central Province	Iomare WMA Zo-oimaga WMA Variarata Nat. Park Namanatabu Reserve Horse Shoe Reef PA

(Source: Department of Environment and Conservation)

Table 6.5.7 Protected area in the provinces where the Ramu Grid System fallen into

Name of Province	Protected areas
Morobe Province	Kamiali WMA, Mc Adams National Park, Mt Kaindi WMA, Mt Susu National Reserve Park, Nuraseng WMA, YUS Conservation Area(proposed)
Madang Province	Crown Island Wildlife Sanctuary,

	Ranba WMA + Sanctuary, Bagiai WMA, Balek Wildlife Sanctuary, Sinub Island, Laugum Island, Tab Island, Tabad Island, Kau Wildlife Area, Wiad(proposed)
Eastern Highland Province	Crater Mountain WMA, Mt Gahavisuk, a Pro. Park,
Chimbu Province	Crater Mountain WMA
Western Highland Province	Jimi Valley National Park, Mt Wilhelm National Reserve, Baiyer River Sanctuary, **Ramsar Site:** Tonda Wildlife Management Area 16-Mar-93 (Western Province) **World Heritage：** Kuk Early Agricultural Site(Cultural)
Southern Highland Province	Lake Kutubu WMA, Siwi-Utame WMA, Sulamesi - Mt Bosavi(proposed), Libano-Hose(proposed), Libano-Arisai(proposed) **Ramsar Site**: Lake Kutubu 25-Sep-98 (Southern Highland)
Enga Province	-

(Source: Department of Environment and Conservation, UNESCO(2010) http://whc.unesco.org/en/list/887, Ramsar sites information service(www.ramsar.wetlands.org))

(b) Ecosystem

Current study in the biodiversities, both plants and animals, are not easily available in the country.

Biodiversity study in the country has been conducted as a part of the Oceania region in IUCN. The assessment was conducted through the sampling study in entire islands in the region. At the research on the IUCN, one of the five assessed species (1/5 species) were found as endemic species. Also, it assumed approximately 16 % of the total species (373 species among total assessed 2,316 species) are in the status of threatened as Critical endangered, Endangered and vulnerable.

Table 6.5.8 The Known Species in PNG

Categories	Total Plants	Birds	Mammals	Reptiles	Amphibians	Total Fish	Total Invertebrates	Totals
species	18,894	719	271	227	266	3,060	2,881	26,318

(Source: "The Pacific islands: An analysis of the status of species as listed on the 2008 IUCN Red List of Threatened Species™")

(c) Forest

Decrease of the natural forest in Papua New Guinea is also one of the world-widely concerned. The current situation on the forest resources shown bellows;

Table 6.5.9 Forest Area in PNG

FRA 2005 categories	Area (1000 hectares)		
	1990	2000	2005
Forest area (thousands ha)	31,523	30,132	29,437
Other Wooded land	4,474	4,474	4,474
Forest and other wooded land	35,997	34,606	33,911
Other land	9,289	10,680	11,375
...of which with tree cover	-	-	-
Total land area	45,286	45,286	45,286
Inland water bodies	998	998	998
Total area of country	46,284	46,284	46,284

(Source: FAO, Global Forest Resources Assessment 2005, Papua New Guinea Forest Authority((http://www.forestry.gov.pg/))

Table 6.5.10 Characteristics of forest and other wooded land

FRA 2005 categories	Area (1000 hectares)		
	Forest		
	1990	2000	2005
Primary	29,210	26,462	25,211
Modified natural	2,250	3,588	4,134
Semi-natural	-	-	-
Productive plantation	63	82	92
Protective plantation	-	-	-
Total	31,523	30,132	29432

(Source: FAO, Global Forest Resources Assessment 2005.)

(d) Critical area because of short of information related to biodiversity.

The huge biological diversities on the natural resources are concerned in the many literatures. However, the detail feature has not been clear yet and still the studies on the field are recognized very limited. According to J.F. Swartzendruber (1993), Papua New Guinea; Conservation Needs Assessment, Synopsis Report, published by Department of Environment and Conservation, several biological important area in PNG are presented.

Those are;

1) A map of 16 biologically unknown areas that merit immediate survey and study (Figure

6.5.2);

Among 16 areas, 10 areas are located in the main land of Papua New Guinea. The further hydropower development on the main lands which are currently proposed in the PPL, those biodiversity features should be considered.

2) A map of 30 marine and coastal high biodiversity areas and 5 watersheds critical to the health of those marine and coastal areas(Figure 6.5.3);

Among 5 of critical watersheds, 4 watersheds are located in the main land of the New Guinea Islands. Those are ;

Table 6.5.11 Critical Watershed in terms of Biodiversity in Main Land in PNG

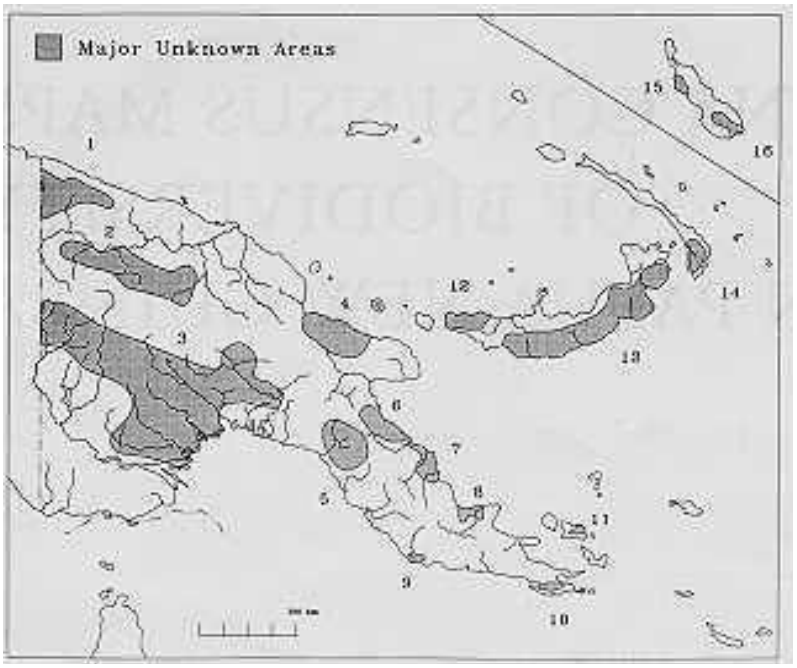
Code.	Name	Description
W1.	Sepik/Fly Drainages.	These comprise the two largest drainages in Papua New Guinea. The Fly is of critical importance to the health of the Gulf of Papua.
W2.	Morobe/Waria Watershed.	Important upland drainages that affect coastal islands and reef of Morobe.
W3.	Vanapa/Brown.	A river system that drains into an important mangrove system.
W4.	Musa/Topographers.	Another small but important watershed that affects the marine systems around Tufi.

(Source: J.F. Swartzendruber (1993), Papua New Guinea; Conservation Needs Assessment)

On the further hydropower development, those natural environments are should be considered.

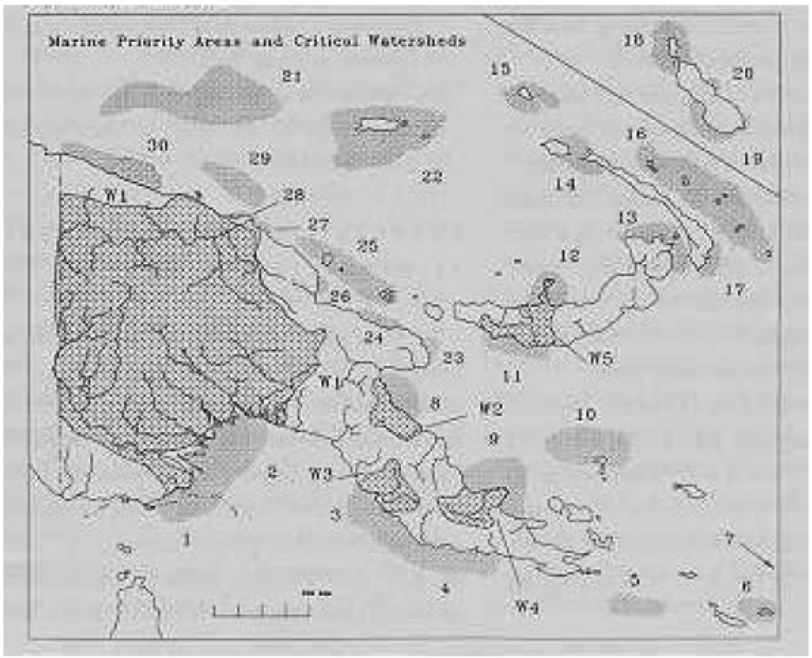
3) A map of 42 terrestrial high biodiversity areas and 13 important wetland habitats.

Among 42 terrestrial high diversity areas, approximately 1/4th are located in the mainland. Most projects of PPL at the time, which are required urgent implementation, are planed in the mainland. These areas should be considered on the planning of further hydropower development (Figure 6.5.4).



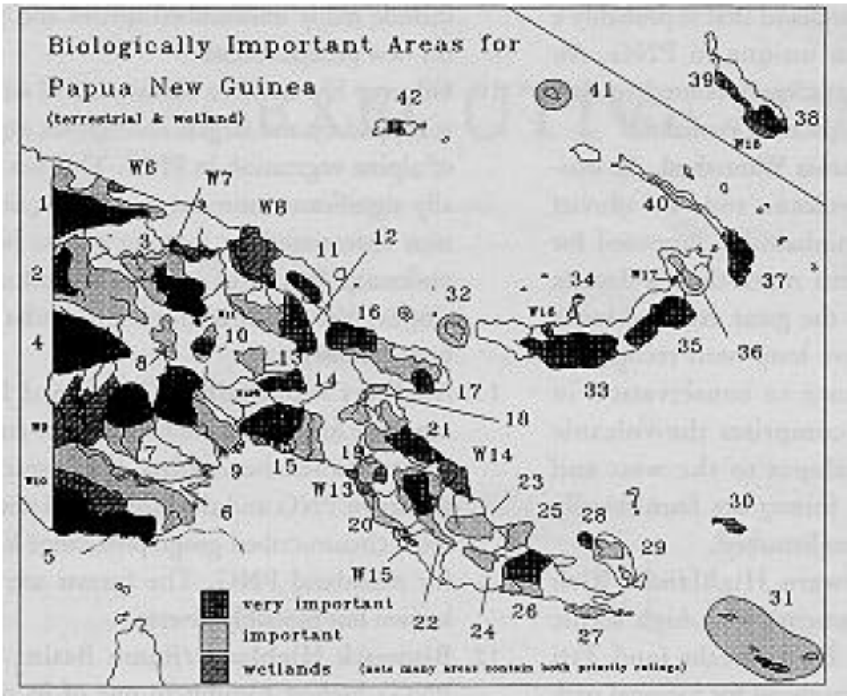
(Source: J.F. Swartzendruber (1993), Papua New Guinea; Conservation Needs Assessment, Synopsis Report, published by Department of Environment and Conservation. (Synthesis Map #1))

Figure 6.5.2 Biologically unknown areas in PNG



(Source: J.F. Swartzendruber (1993), Papua New Guinea; Conservation Needs Assessment, Synopsis Report, published by Department of Environment and Conservation.(Synthesis map #2))

Figure 6.5.3 Biologically critical coastal areas and watersheds in PNG due to high biodiversity



Source: J.F. Swartzendruber (1993), Papua New Guinea; Conservation Needs Assessment, Synopsis Report, published by Department of Environment and Conservation.

Figure 6.5.4 High biodiversity areas and 13 important wetland habitats in PNG

6.5.2 Required Study

Related to the hydropower development in the PNG, following study might be considered at the time of further development. Also, the present situation of the environment study at currently proposed projects are shown in Table 6-14.

Table 6.5.12 Environmental Items expected in Hydropower development project

Categories	Environmental Items	Description
1Permits and Explanation	(1) EIA and Environmental Permits	(1) Under the law, Environmental Act 2000(amended 2002), the implementer on the prescribed projects is required to submit Environmental Impact Statement(EIS) to obtain the Environmental Permit before its implementation. -For the Improvement of the existing power facilities, the process on the EA may be varied depending on the scale; The expansion of the area may require the permit. In case of newly constructing hydropower station in Ramu system(18MW), past permit was amended because no any expansion of area was required. -Present situation of environmental studies related to the proposed projects: There are no particular studies related to those. some environmental study is involved in a feasibility study in Ramu 2 power station at Ramu Grid, Naoro-Brown power station at Port Moresby Grid systems. Also, the agreement of the villagers were confirmed closing MOU between PNG power and them before the feasibility study(March 2010, Brown river)
	(2) Explanation to the	(2)In the Environmental Act 2000, the information disclosure is

	Public	provided at the process of evaluation by DEC.
2 Mitigation Measures	(1)Air Quality (2)Water Quality (3)Wastes (4)Soil Contamination (5)Noise and Vibration (6)Subsidence (7)Odor	Existing Standard for the environmental items should be considered related to project activities i.e; during the construction and at the operation stages.
3 Natural Environment	(1)Protected Areas (2) Ecosystem (3) Hydrology (4)Topography and Geology	(1) Protected area is categorized under The law National Park Act, Wildlife Management Area Act, Conservation Area Act. 57 protected areas in total and those are 16 National Parks, 40 Wildlife Management areas and 1 conservation area. There are 2 Ramsar sites in PNG. One world heritage. (2) Ecological feature in the country is still scientifically unknown and should be considered at the environmental study. (3) Hydrological feature should be considered to minimize impact. (3) Information on the land use in the customary land is limited and those should be considered in the compensation procedure.
4 Social Environment	(1) Resettlement (2) Living and Livelihood (3) Heritage (4) Landscape (5) Ethnic Minorities and Indigenous Peoples	(1)In case of the hydropower development, the land acquisition is required. The acquisition can be agreement acquisition based on the monetary compensation under negotiation with the ILGs as a representative of landowners. (2)If the project will be involved the Indigenous peoples, directly /indirectly, their impact should be considered referring WB safe guard policy（Customary lands：97%, Alienated lands：3%）.
5 Others	(1) Impact during the construction (2) Monitoring	Dispute between land owners commonly happen during identification of owners and boundary of the lands. It causes the delay on the projects. -Monitoring method after the implementation should be considered adequately.

(Source: Study team based on the information by PPL, Items are referred JBIC Guidelines for Confirmation of Environmental and Social Considerations(April,2002))

Table 6.5.13 Currently planned Project in the hydropower development in PNG

Name of Project	Description	Situation of Environment study (at April2010)
Udava Hydro Project	The project was studied its feasibility among the Papua New Guinea: Power Sector Development Plan(ADB,2009) Over the longer-term, production from the Udava project will be enhanced by additional hydro facilities plants constructed upstream, such as the Lake Kosipe inter-basin transfer and the Dubu Diversion. Hence, the Udava project can be constructed in a number of stages: (a) Stage A: Run-of-river prior to the construction of Kosipe Dam (b) Stage B: Upgrading of the power station to utilize the firm flow after completion of Kosipe Dam (c) Stage C: Diversion of the Dubu River before or after Kosipe development The major project components of the Udava Project are as follows: (a) Intake/ dam structure	The preliminary environmental study was conducted accompanied with the feasibility study completed in April 2009. -Further environmental study is not conducted. -No any action on the land acquisition.

	- Full supply level 635 m - Weir/dam height 15 m - Crest length 90 m - Storage capacity 0.4 mcm (b) Headrace tunnel -Low pressure tunnel - 10,200 m in length and 2.55 to 3.90 m in diameter -High pressure tunnel - 700 m in length and 2.35 to 3.40 m in diameter -Surge shaft - 140 m in length and 4.0 to 12.0 m diameter -Penstock - 1500 m in length and 1.1 m diameter, multiple penstocks feeding turbine/generators of 29 MW – 35 MW each (c) Power plant - Installed capacity 70 – 180 MW (d) Transmission Line - Power from the Udava to existing Moitaka substation in Port Moresby at 220 kV ;. approx. 65 km in total length (30 km requiring helicopter support). (e) Access Roads - Hiritano Highway near the Vanapa River bridge. About 92 km of new road to connect to the existing road, (Onange Mission to Kosipe Mission)	
Vanapa Hydro Project (Lake Kosipe)	The project was proposed as a part of the the Papua New Guinea: Power Sector Development Plan(ADB,2009). The major components of the project are: (a) A rock fill dam to impound water in the natural swamp at the head of the Ivane River (b) A 0.5 km headrace low-pressure tunnel and 1.9 km long surface penstock, and a surface power station 2 km upstream of Woitape Village, developing a gross head between 320 and 330 m.	The preliminary environmental study was conducted accompanied with the feasibility study completed in April 2009. -Further environmental study is not conducted. -No any action on the land acquisition.
Rouna rehabilitation(at proposal)	The project was proposed in the report on preparatory study on Climate change program in Oceania region(JICA,2009) as a possible project in the country. There area 1 hydropower station at the Sirinumu Dam and 4 hydropower stations at drown stream on it namely Rouna2, Rouna3, Rouna1 and Rouna4. Rouna2, 3 and 4 had been rehabilitated, although the Rouna4 is still not fully operated. Only Rouna 1 may require further rehabilitation on its flume line.	The project was already conducted its most parts. The activities were only limited the replacement/rehabilitation of existing facility, any environmental study was conducted.
Naoro-Brown river project	The primary project design was established late 1980s and currently this feasibility is been confirming with the PLL's own budget. Feasibility Study including some aspect of environment is currently conducted. The Memorandum of Understanding (MOU) between	Naoro Brown Detailed Feasibility Study is currently conducted by PPL's own budget until Oct, 2010. Some environmental study is involved. However, the contents of the study are not confirmed.

	PNG power with Landowners, i.e., Incorporated Land Groups (ILGs) was closed prior to the feasibility study, on March 2010. Underground facilities with the run-off type water intakes are currently studied. Primary forest, land acquisition associated with underground facility may be involved.	
Ramu 2 project	The primary project design was established at late 1980s and currently The basic design is the run-off type. Currently Hydro Tasmania is conducting feasibility study.	Currently a pre-feasibility study is conducted. Some environmental aspects are studied. However, the contents of the study are not confirmed. Environmental Plan at the previous construction of Yonki Dam was kept in PPL.
Other Area		
6 small hydro power project	Currently the feasibility studies on the projects are conducted thorough ADB. Those are; 1). Divune(Oro Province, Southern Region) 2). Ramazou (Bougainville, Island Region) 3). Gumini (Milne Bay, Southern Region) 4). Sogeran (East Sepik, Momase Region) 5). Ru Creek 2 (West New Britain, Island Region) 6). Kimada (New Lreland, Island Region)	Some of those projects, environmental study is also conducted. Draft report of preliminary environmental report on the Ramazou was prepared.
Wabo hydro power project	Currently the feasibility studies on the projects are conducted by Western Power contracting Australian consultant, Hydro Tasmania. The area is located in Gulf province.	Some environmental report may exist. However, no any information on the report is kept in PPL.

(Source: PNG Power Ltd, ADB(2009) Papua New Guinea: Power Sector Development Plan)

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