Sri Lanka
Ceylon Electricity Board

Development Planning on Optimal Power Generation for Peak Demand in Sri Lanka

Final Report

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Japan International Cooperation Agency
Electric Power Development Co., Ltd.

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ABBREVIATION

Abbreviation	Formal Name
ADB	Asian Development Bank
ADCC	Auto Diesel Combined Cycle
ADGC	Auto Diesel Gas Turbine
AMI	Advanced Metering Infrastructure
BOD	Biochemical Oxygen Demand
BOI	Board of Investment
C/P	Counterpart
C_2F_6	Hexafluoroethane
CEA	Central Environment Authority
CEB	Ceylon Electricity Board
CF_4	Carbon Tetrafluoride
CFL	Compact Fluorescent Lamp
CFL	Compact Fluorescent Lamp
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
CPC	Ceylon Petroleum Corporation
CR	Critically Endangered
CST	Coal Steam Thermal
DFR	Draft Final Report
DG	Director General
DGM	Deputy General Manager
DO	Dissolved Oxygen
DSM	Demand Side Management
EIA	Environmental Impact Assessment
ELT	Economic Life Time
EMP	Environmental Management Plan
EN	Endangered
ENEPEP	Energy and Power Evaluation Program
EPL	Environmental Protection License
EPZZ	Export Processing Zones
EW	Extinct in the Wild
EX	Extinct
F/S	Feasibility Study
FAC	Fuel Adjustment Charge
FAO	Food and Agricultural Organization
FIT	Feed-in Tariff
FOB	Free on Board
GBM	Geological Survey and Mines Bureau
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GMT	Greenwich Mean Time

Abbreviation	Formal Name
GN	Grama Niladari
GSHAP	Global Seismic Hazard Assessment Program
GTW	Gas Turbine World
HC	Highland Complex
IAEA	International Atomic Energy Agency
IAS	Invasive Alien Species
IBAs	Important Bird Areas
IEA	International Energy Agency
IEE	Initial Environmental Evaluation
IPP	Independent Power Producer
IUCN	International Union for Conservation of Nature
JETRO	Japan External Trade Organization
JICA	Japan International Cooperation Agency
KC	Kadugannawa Complex
LAA	Land Acquisition Act
LC	Least Concern
LCLTGEP	Least Cost Long Term Generation Expansion Plan
LECO	Lanka Electricity Company
LED	Light Emitting Diode
LKR	Lanka Rupee
LNG	Liquid Natural Gas
LNG IGCC	LNG Integrated Gas Combined Cycle PP
LOLP	Loss of Load Probability
LTGEP	Long Term Generation Expansion Plan
LTTDP	Long Term Transmission Development Plan
LTTE	Liberation Tigers of Tamil Eelam
MAB	Man and the Biosphere
MOPE	Ministry of Power and Energy
MOU	Memorandum of Understandings
MPN	Most Probable Number
N/A	not applicable
N_2O	Dinitrogen Monoxide
NBRO	National Building Research Organization
NCSDP	National Committee on Seismic Design Parameters
NEA	National Environmental Act
NGO	Non-governmental Organization
NIRP	National Involuntary Resettlement Policy
NO_2	Nitrogen Dioxide
NO3-N	Nitrate Nitrogen
NTFPs	Non-timber forest products
O&M	Operation and Maintenance
PAA	Project Approving Agency
PD	Project Director
PGCIL	Power Grid Corporation of India Limited

Abbreviation	Formal Name
PI	Preliminary Information
PM10	Particulate Matter 10
PM2.5	Particulate Matter 2.5
PO4-P	Phosphate Phosphorous
PP	Power Plant
PP	Project Proponent
PPA	Power Purchase Agreement
PS	Power Station
PSPP	Pumped Storage Power Plant
PUCSL	Public Utilities Commission of Sri Lanka
QC	Wanni Complex
Rs	Rupee
SEA	Strategic Environmental Assessment
SEA	Sustainable Energy Authority
SFC	Static Frequency Converter
SHM	Stakeholders Meeting
SLS	Sri Lanka Standard
SLSC	Standard Least-Squares Criterion
SO	Sulfur Dioxide
SPPA	Standard Power Purchase Agreement
SS	Sub-Station
SYSIM	System Simulation Package
T/L	Transmission Line
TEC	Technical Evaluation Committee
TOR	Terms of Reference
UNESCO	United Nations Educational, Scientific and Cultural Organization
USD	United States Dollar
VC	Vijayan Complex
VU	Vulnerable
WEPA	Water Environment Partnership in Asia
WHO	World Health Organization

Chapter 1

Introduction

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Chapter 1 Introduction

1.1 Background of the Project

The change in the economic situation of Sri Lanka is shown in the Table 1.1-1. The Sri Lankan economy was under the influence of the worldwide financial crisis in 2008 originated from the Lehman Shock in the USA and its GDP was once reduced to growing rate of 3.5% by subsequent stagnation of the world economy, however, after the latter half of 2009, due to the restoration market after the end of the civil war, the mining and manufacturing businesses in Sri Lanka were rapidly booming and transportation and communication business became active, then in 2010 and 2011 the actual rate of growth of GDP achieved 8.0 % and 8.2 %, respectively. In 2012, though the economy came under the influence of the rolling blackouts due to abnormal drought happened in the latter half of the year and other adverse impact on the production activities in Sri Lanka, it showed firm growth and recorded a rate of growth of GDP of 6.3 % that is same level before the Lehman Shock, and it regain high level 7.3% in 2013.

Table 1.1-1 Annual Variation of Economic Indicator of Sri Lanka

	units	2007	2008	2009	2010	2011	2012	2013
Mid-Year Population	thousand	20,039	20,217	20,450	20,653	20,869	20,328	20,483
Growth of Population	%	1.2	1.1	1.1	1.0	1.0	0.9.	0.8
GDP at market price	billion Rs.	3,579	4,411	4,835	5,604	6,544	7,579	8,674
GDP per Capita	Rs.	178,845	218,167	236,445	271,346	313,576	372,814	423,467
Exchange Rate	Rs./USD	110.62	108.33	114.94	113.06	110.57	127.60	129.11
GDP per Capita	USD	1,617	2,014	2,057	2,400	2,836	2,922	3,280
GDP Real Growth	%	6.8	6.0	3.5	8.0	8.2	6.3	7.3

(Source: Annual Report 2012, Central Bank of Sri Lanka)

The trend of the situation in electric power supply and demand is shown in the Table 1.1-2.

Table 1.1-2 Annual Variation of Power Demand and Supply

Year	Generation (GWh)	Growth (%)	Demand （GWh）	Growth (%)	Peak Load (MW)	Growth (%)
2003	7,612	11.8	6,209	12.8	1,516	6.6
2004	8,043	5.7	6,781	9.2	1,563	3.1
2005	8,769	9.0	7,255	7.0	1,748	11.8
2006	9,389	7.1	7,832	8.0	1,893	8.3
2007	9,814	4.5	8,276	5.7	1,842	-2.7
2008	9,901	0.9	8,417	1.7	1,922	4.3
2009	9,882	-0.2	8,441	0.3	1,868	-2.8
2010	10,714	8.4	9,268	9.8	1,955	4.7
2011	11,528	7.6	10,023	8.1	2,163	10.6
2012	11,801	2.4	10,474	4.5	2,146	-0.8
2013	11,962	1.4	10,621	1.4	2,164	0.8
Ave.		4.6		5.5		3.6

(Source：LTGEP 2013-2032)

The electric energy generated in 2011 in Sri Lanka was 11,528GWh at generating end (except self-generation) and the net system energy demand was 10,023GWh, and their difference comes from station service power and transmission and distribution loss. Sri Lanka got hit by abnormal drought in 2012 and was forced to suffer from rolling blackouts, however, the electric energy generated in 11,801GWh and net system energy demand in 10,474 per annum were recorded with rate of increase in 2.4% and 4.5%, respectively. The average rate of increase of electric energy generated in last decade (2003 to 2013) is 4.6% and the same of net system energy demand is 5.5% under the steady economic circumstances. In regard to the annual maximum demand in Sri Lanka, the average rate of increase of electric energy generated in last decade is 3.6% and the same of annum in 2010, 2011 and 2012 are 4.7%, 10.6% and -0.8%, respectively. The depletion in 2012 is thought as the result from the abnormal drought.

According to the Annual Report 2012 of Central Bank of Sri Lanka, it anticipates that the improvement activities of infrastructure and the growth of tourism industry will make the growth rate of GDP continuously increase at around 8% (2014: 7.8%, 2015: 8.2%). The electric power demand is expected to keep on substantially increasing, accordingly.

The peak power demand in Sri Lanka prevails in the evening time up to 22 o'clock mainly by power demand for lighting and is also driven up by the improvement of the electrification rate. Hydro power plants that account approximately 40% of electric power generated in Sri Lanka may act as power generators for peak power demand under normal circumstances. However, in order to make up for the capacity degradation in power supply for peak power demand during dry season as evidenced in 2012 or to allow planned significant introduction of renewable energy by absorbing its power variation, CEB has planned the study of the development of pumped storage power plant as power generation for peak power demand as part of utilization of domestic energy, and requested technical assistance from Japanese Government.

To that end, JICA executed the Detailed Planning Survey for the Pumped Storage Power Generation in Sri Lanka. Through a series of discussion with Sri Lankan side, it became clear that the Study on the following items were required:

- Reliability of alternative power generation options for peak power demand and selection of optimal options
- Appropriateness of Pumped Storage Power Generation as peak power supply option
- Necessity of Pumped Storage Power Generation for intending expansion of Non-Conventional Renewable Energy
- Appropriate timing of development of Pumped Storage Power Plant in consideration of the development progress of coal -fired thermal power plants
- Suitable power mix of peak power demand under the circumstance that the study on LNG utilization project is ongoing

In consideration of the background of the Study, both of Sri Lankan side and JICA share the recognition that the Study on power generation for peak power demand is appropriate and change the title of the Study to "The Project for the Development Planning on Optimal Power Generation for Peak Power Demand in Sri Lanka". Consequently, the Study on pumped storage power plant was carried out after the selection of power generation options available in the Sri Lanka and confirmation that the pumped storage power plant is optimal power generation through the comparison study of options.

1.2 Purpose and Scope of Study

The Study aims at propounding optimal power generation for peak power demand in Sri Lanka that will contribute to development and improvement in Sri Lankan economy and living standard in a quick and efficient manner through stable supply of electricity and relief of peak power shortage and fluctuation in electric supply capacity according to season. In addition, through the joint study with Sri Lankan engineers, the Study will contribute to technology transfer and human resource development in the area of electric power development for peak power demand.

Specifically, the Study will be conducted in accordance with "Record of Discussion on the project for the Development Planning on Optimal Power Generation for Peak power Demand in Sri Lanka" confirmed between Sri Lankan Government and JICA in 2012. The following items are main scope of the Study:

- to practice electric power demand projection for 15-20 years after the year 2013 and to confirm the necessity of power generation for peak power demand by comparison with existing power development plan,
- to propose optimal power generation for peak power demand (including combination of options) after comprehensive study on economic efficiency, technical, topographical and environmental restriction, and impact on power system in Sri Lanka of options for peak power demand, such as pumped storage, gas combined cycle, new hydropower for peak demand, expansion of existing hydropower, electricity interchange with Indian network and so on,
- to list up around 10 potential pumped storage sites including study sites of CEB after confirmation that Pumped Storage is the most suitable for Sri Lanka as power generation for peak power demand, to select three prevailing site in accordance with the evaluation criteria to be established, and to select conclusively the most promising candidate site in consideration of aspects in environmental and social considerations and topographical and geological investigations.

The detail procedures will be shown in the Chapter 1.3 "Study Plan".

1.3 Study Plan

1.3.1 Study Procedure

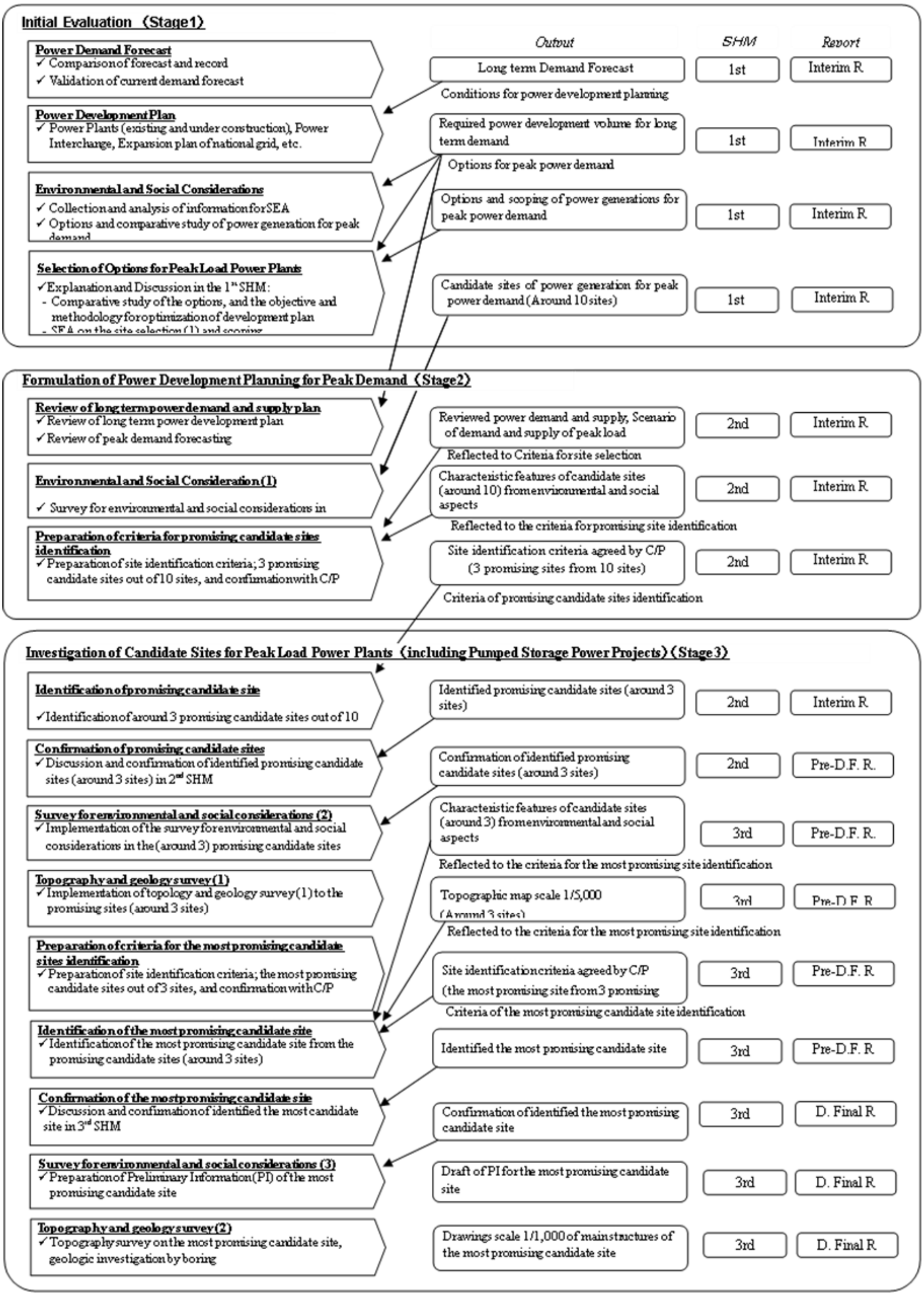
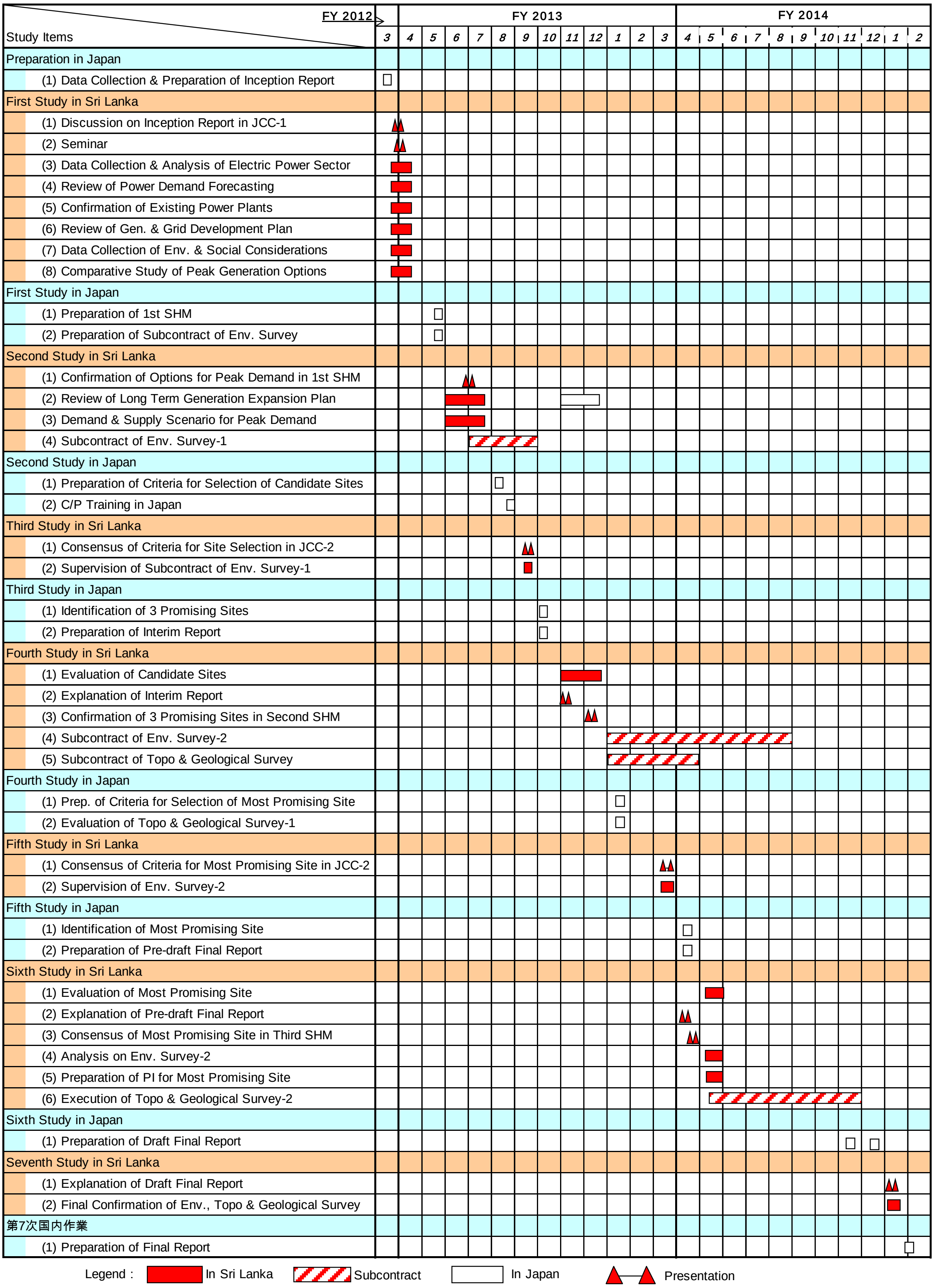


Figure 1.3.1-1 Work Contents and Output

1.3.2 Study Schedule and Study Items

Table 1.3.2-1 Study Schedule and Study Items



1.4 JICA Study Team Member and Work Description

Table 1.4-1 Work Description of Team Member

Name/Assignment	Principal Work Description
Katsu HAGIHARA Team Leader/Power Development Planning	- Decision of policy of works and overall coordination of works - Explanation, discussion and agreement with C/P and related parties - Contract of re-consignment at site - Compilation of reports - Selection of optimal power generation for peak power demand - Establishment of assessment criterion for project & assessment (all project) - Optimization of power generation for peak power demand - Selection of potential projects and promising project - Revision of long term generation expansion plan
Yasushi YOSHINO Sub-Leader/Hydropower Planning/Civil Engineering (A: Planning)	- Deputy to team leader's works - Overall management of technical issue - Optimization of power generation for peak power demand - Establishment of assessment criterion for pumped storage project & assessment - Selection of potential projects and promising project - Establishment of power development plan
Hiroshi WATABE (took over from) Shuichi YOSHIDA Hydropower Planning /Civil Engineer (B: Cost Estimation)	- Establishment of assessment criterion for pumped storage project & assessment - Selection of potential projects and promising project - Cost estimation of project and civil works
Madoka HARADA Geography & Geology	- Establishment of assessment criterion for pumped storage project & assessment (geography & geology) - Selection of potential projects and promising project - Sub-contract management (geography & geology)
Gaku MATSUOKA Hydrology & Meteorology	- Establishment of assessment criterion for pumped storage project & assessment (hydrology & meteorology) - Analysis and verification of hydrological and meteorological data
Hitoshi Furukoshi (took over from) Yasuhiro YOKOSAWA Power System Planning A （Power Demand Forecast）	- Confirmation of Power demand forecasting method - Power demand forecasting
Masahide KURACHI Power System Planning B (System Analysis)	- Study on existing power system and generation expansion plan - Establishment of assessment criterion for pumped storage project & assessment (system) - Study on impact of power generation for peak power demand - Power system analysis for potential projects
Takeo KIMURA Transmission Line Engineering	- Establishment of assessment criterion for pumped storage project & assessment (transmission line) - Study on route of transmission line for potential projects - Cost estimation of transmission line of potential projects

Name/Assignment	Principal Work Description
Kozo UTSUMI Electrical Engineering	- Establishment of assessment criterion for pumped storage project & assessment (electro-mechanical equipment) - Cost estimation of electro-mechanical equipment of potential projects and promising project
Hachiro IDA Economical & Financial Analysis	- Study on economic, energy and power sector policy - investigation of CEB's financial standing - Economical & financial analysis of potential projects (trial) - Economical & financial analysis of promising project - Study on financing method for promising project
Shunji USUI Environmental & Social Consideration A (Natural/GIS)	- Evaluation of potential projects and promising project from physical environmental point of view - Disclosure of information and organization of stakeholder meetings - Sub-contract management (physical environment)
Nobuki HAYASHI Environmental & Social Consideration B (Social)	- Evaluation of potential projects and promising project from social environmental point of view - Assistance of organization of stakeholder meeting - Sub-contract management (social consideration)

1.5 Counter Part

The Study was carried out with the collaboration with CEB counterparts as follows:

Table 1.5-1 Counter Part

Name	Position	Assignment for Study
Ms. Kamani Jayasekera	DGM (Tr. & Gen. Planning)	Leader/Power Development Planning
Mr. Buddhika Samarasekara	Chief Engineer (Gen. Planning)	Sub-Leader/ Planning, Transmission Line Engineering
Ms. Thushara de Silva	Chief Engineer (Gen. Development Studies)	Hydrology, Meteorology, Power Demand Forecast, Economical & Financial Analysis
Mr. Rohitha Gunawardena	Head of Environment	Cost Estimation, Environmental & Social Considerations
Dr. H.M. Wijekoon Banda	Chief Engineer (Trans. Planning)	System Analysis
Mr. Lathika Attanayaka	Electric Engineer (Gen. Planning)	Planning, Geography & Geology
Mr. Kelum Niranjan	Civil Engineer (Tr. Design & Environment)	Cost Estimation, Environmental & Social Considerations
Ms. Diyasha Hapuarachchi	Electric Engineer (Gen. Planning)	Hydrology & Meteorology, Economical & Financial Analysis
Mr. Dayan Yasuranga	Electric Engineer (Trans. Design)	Transmission Line Engineering
Mr. Randika Wijekoon	Electric Engineer (Gen Planning)	Electrical Engineering

1.6 List of Document Collected

Chapter	No.	title	source	year
Chapter 2	1	Long term Generation Expansion Plan 2013-2032	Ceylon Electricity Board	2013
	2	Sri Lanka Electricity Act (2009)	Sri Lankan gov.	2009
	3	Sri Lanka Electricity (AMENDMENT) Act	Sri Lankan gov.	2013
	4	National Energy Policy and Strategies of Sri Lanka	MINISTRY OF POWER AND ENERGY	2008
	5	General Policy Guidelines on the Electricity Industry for the Republic Utilities Commission of Sri Lanka	Sri Lankan gov.	
	6	Tariff Methodology	Public Utilities Commission of Sri Lanka	2011
	7	Consultation Paper on Setting Tariffs for the Period of 2011-2015	Public Utilities Commission of Sri Lanka	2010
	8	performance report of distribution licensees 2012	Public Utilities Commission of Sri Lanka	2013
	9	CEB Annual Report 2012	Ceylon Electricity Board	2013
	10	CEB Annual Report 2011	Ceylon Electricity Board	2012
	11	CEB Financial Statement 2012	Ceylon Electricity Board	2013
	12	Annual Report 2012	Ministry of Finance and Planning, Sri Lanka	2013
	13	Energy Diversification Enhancement Project, Phase IIA Feasibility Study for Introducing LNG to Sri Lanka	JICA	2014
Chapter 5	14	Long Term Transmission Development Plan 2013-2022	Ceylon Electricity Board	2013
	15	monthly peak demand 2011	Ceylon Electricity Board	2011
	16	CEB - generation data 2010 - 2012	Ceylon Electricity Board	2010-12
	17	Annual Report 2011, System Control and Operations	Ceylon Electricity Board	2012
	18	Monthly review, 2012/Dec, System Control and Operations	Ceylon Electricity Board	2013
Chapter 6	19	Environmental Act	CENTRAL ENVIRONMENTAL AUTHORITY	1980
	20	Environmental Guidelines for Road and Rail Development in Sri Lanka	CENTRAL ENVIRONMENTAL AUTHORITY	1997
	21	Environmental Guidelines for Agriculture Sector Projects in Sri Lanka	CENTRAL ENVIRONMENTAL AUTHORITY	1997
	22	Guidance for Implimenting the Environmental Impact Assessment (EIA) Process	CENTRAL ENVIRONMENTAL AUTHORITY	2006
	23	Forest management in Sri Lanka Fact sheet No.6	CENTRAL ENVIRONMENTAL AUTHORITY	2004
	24	SriLanka Environmental Issues in the Power Sector, Final Report	Economic Consulting Associates Ltd.	2010
	25	Biodiversity Conservation in Sri Lanka – A Framework for Action	Ministry of Forestry and Environment	1999
	26	Climate Change Secretariat	Ministry of Environment, Sri Lanka	web site
	27	Annual Report 2013	Central Bank of Sri Lanka	2014
	28	FAO Country Profiles: Sri Lanka	Food and Agriculture Organization of the United Nations	web site
	29	Birds of Sri Lanka	Deepal Warakagoda, Carol Inskipp, Tim Inskipp and Richard Grimmett	2012
	30	Conservation International (homepage)	Conservation International	web site
	31	Important Bird Areas in Asia: key sites for conservation	BirdLife International	2004
	32	The National Red List 2012 of Sri Lanka – Conservation Status of the Fauna and Flora	Ministry of Environment, Sri Lanka	2012
	33	The IUCN Red List of Threatened Species	International Union for Conservation of Nature and Natural Resources	2013
	34	The National Atlas of Sri Lanka – second edition	Survey Department, Sri Lanka	2007
	35	Progress Report 2011 and Action Plan 2012	Forest Department, Ministry of Environment	2012
	36	Sri Lanka Forestry Outlook Study	Food and Agriculture Organization of the United Nations	2009
	37	Ramsar Convention	ramsar@ramsar.org, etc.	web site
	38	UNESCO World Heritage Centre	UNESCO	web site
	39	UNESCO Biosphere Reserves	UNESCO	web site
	40	Fourth Country Report from Sri Lanka to the United Nations Convention on Biological Diversity	Sri Lankan gov.	2009
	41	Preliminary report-1, Census of Population and Housing 2011	Department of Census and Statistics Sri Lanka	2012
	42	Population & Housing Data 2012	Department of Census and Statistics Sri Lanka	2012
	43	JETRO Annual Report 2012	Japan External Trade Organization (JETRO)	2013
	44	Labour Force Survey Annual report 2011	Department of Census and Statistics Sri Lanka	2012
	45	Sri Lanka Labour Gazette Volume 63 No. 4	Ministry of Labour and Labour Relations	-
	45	The website of Ministry of Education in Sri Lanka	Ministry of Education in Sri Lanka	web site
	46	National Action Plan for Haritha Lanka Programme	Ministry of Environment and Natural Resources,	web site
	47	Mahinda Chintana, 10 year development framework	Sri Lankan gov.	2010
	48	Hand book on multilateral environment agreements 2008	Ministry of Environment & Natural Resources	2008
	49	Land acquisition and implementation of the national involuntary resettlement policy, A guide for public officials on Good practices first print 2013	Sri Lankan gov.	2013
	50	Environmental Norms 2011	Board of Investment of Sri Lanka	2011
	51	Water Environment Partnership in Asia (WEPA)	Water Environment Partnership in Asia (WEPA)	2012

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Chapter 2

Sri Lanka Power Sector Performance and Development Policy

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Chapter 2 Sri Lanka Power Sector Performance and Development Policy

2.1 Power Sector in Sri Lanka

2.1.1 Power Supply Performance

Sri Lankan economy has been growing steadily for the last two decades. The demand for electricity has also been constantly increasing, following economic growth. Characteristics of electricity demand and supply are explained hereunder;

- Electricity generation in 2012 increased moderately by 2.4% to 11,801 GWh compared with 11,528 GWh in 2011. Electricity sales increased by 4.5% to 10,474 GWh in 2012 compared to 10,023 GWh in 2011. The annual average growth rates for the last 10 years from 2003 to 2013 were 4.6% (generation) and 5.5% (sales) respectively.
- Power generation by private sector started in 1996 in the form of hired private power and self-generation. Purchase from private sector electricity was 307 GWh in 1996. Since then, the share of private sector generation has been increasing rapidly, and it was 48% (5,638 GWh) of total generation in 2012.
- The share of hydro power generation, excluding mini hydro, was 34.5% in three-year average from 2010 to 2012. It was more than 90% in early 1990's, but new additions of hydro power plants were limited only two, Kukule and Upper Kotmale, and large portion of increased power demand has been covered by CEB's thermals and IPP generation. The share of hydro power in 2012, excluding mini hydro was 23.5%, the lowest in history due to the extreme drought year. As more oil-based fuels (high cost generation) are used to meet the steady demand for electricity, the average cost of supply also pushed up accordingly.

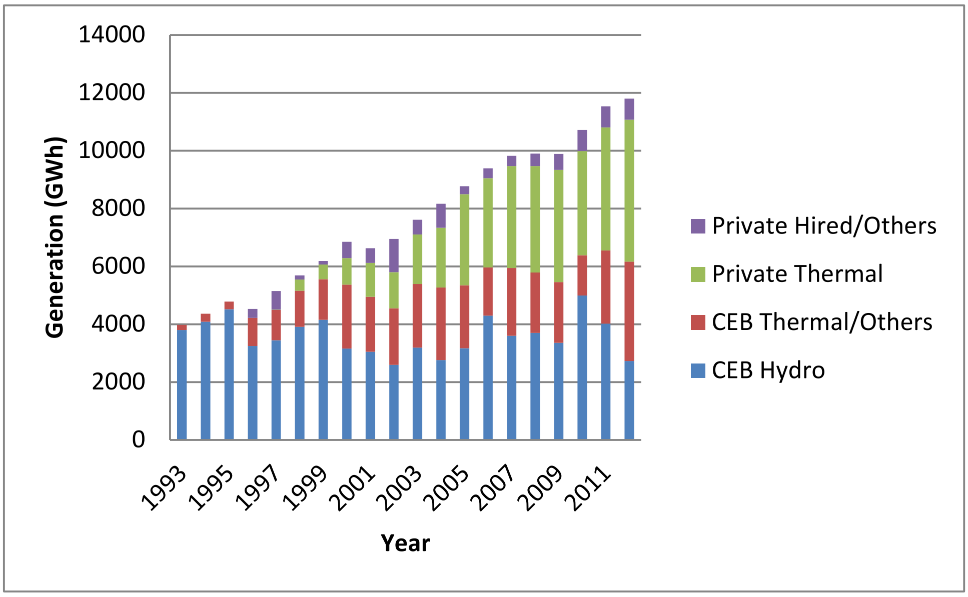

Figure 2.1.1-1 Sri Lanka: Share of Electricity Generation (1993-2012)

- In July 2011, the first coal power generation (300MW) commenced operations in Sri Lanka. Second and third same size coal power plants also started 2014. It is expected that adding coal power plants would bring unit generation cost to reasonably lower level.

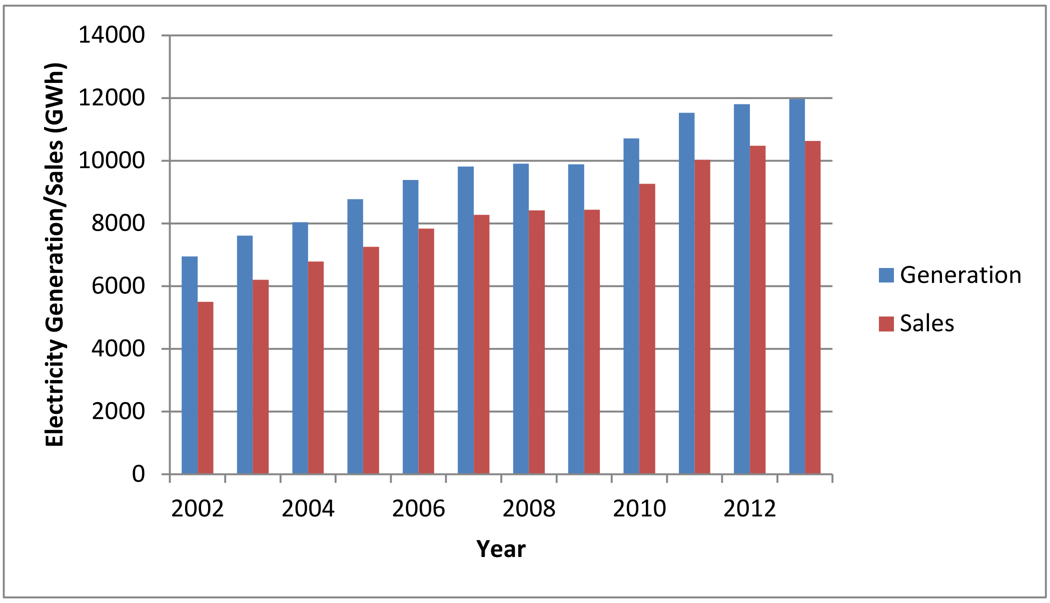

Figure 2.1.1-2 Sri Lanka: Electricity Generation and Sales (2002-2013)

- The annual average economic growth (GDP growth) from 2002 to 2012 was about 6%, the demand for electricity has correlation with this economic growth.

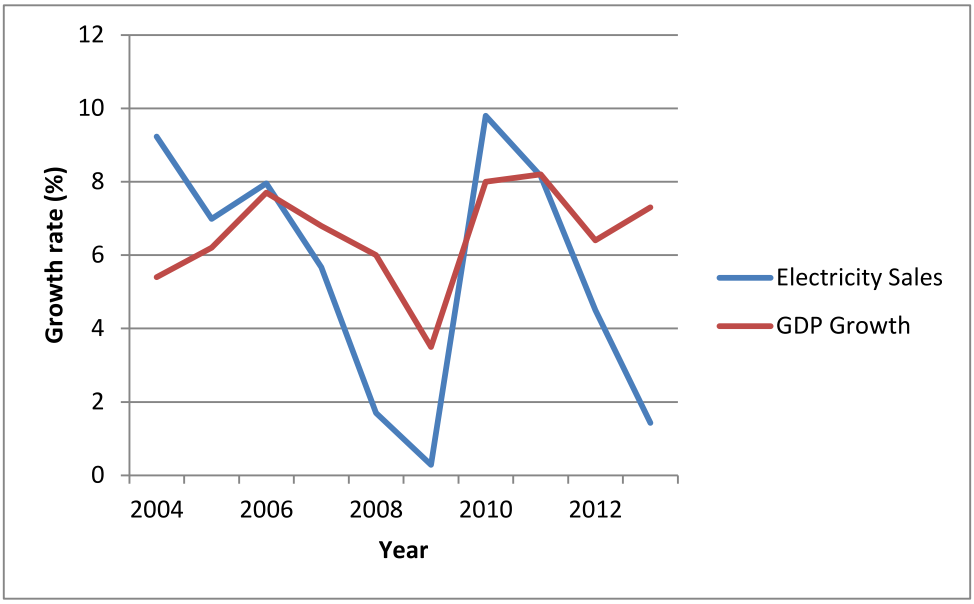

Figure 2.1.1-3 Sri Lanka: Electricity Sales and GDP Growth Rate (2002-2013)

- The maximum demand in 2012 was 2,146 MW. The historical record of peak demand was recorded as 2,163 MW on May 20th 2011. The annual average increase of peak demand was 3.6% in the last 10 years (2003-2013). The increasing rate is in downward trend, which was caused by (i) improvement (lowering) of load factor, and (ii) rate of transmission and distribution loss becomes lower.

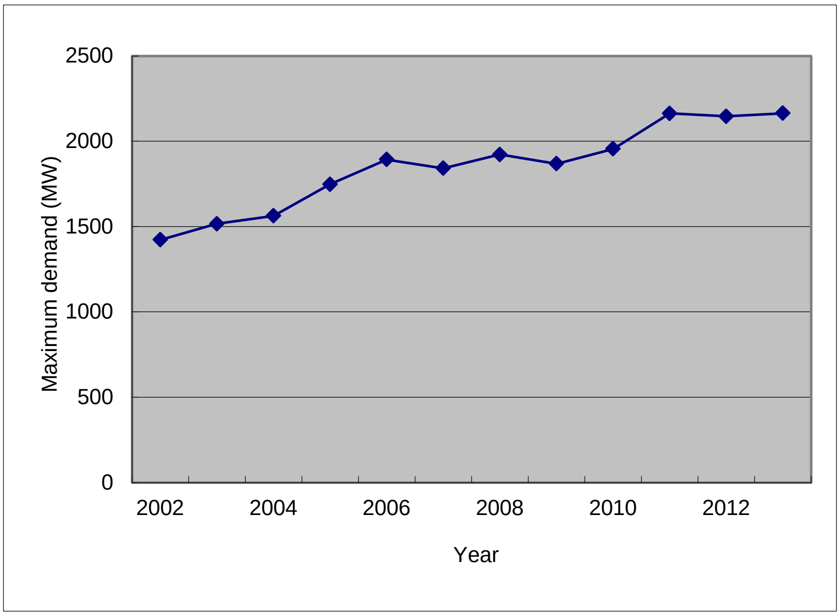

Figure 2.1.1-4 Sri Lanka: Maximum Electricity Demand (2002-2013)

- The household electrification rate was 67% inclusive of off-grid in 2003, and it increased to 94% in 2012. This electrification level is higher when compared with neighboring countries.
- Shares of electricity consumption by customer categories have not been changing drastically for the last 10 years. Consumption by CEB customers in 2012 was 39.5% by domestic customers, 36.2% by industry, and 24.3% by general purpose and hotel. Domestic sector always occupies about 40% for the last 10 years, industry decreased by 5% in the same period, which were taken by general purpose and hotel.
- Figure 2.1.1-5 shows the load factor excluding non-conventional renewable energy. Though the load factor has been showing improving trend (becoming flat), the gap between peck demand and that of off-peak becomes larger. It means that the slight improvement of load factor has been off-set by increases of energy demand and peak power.

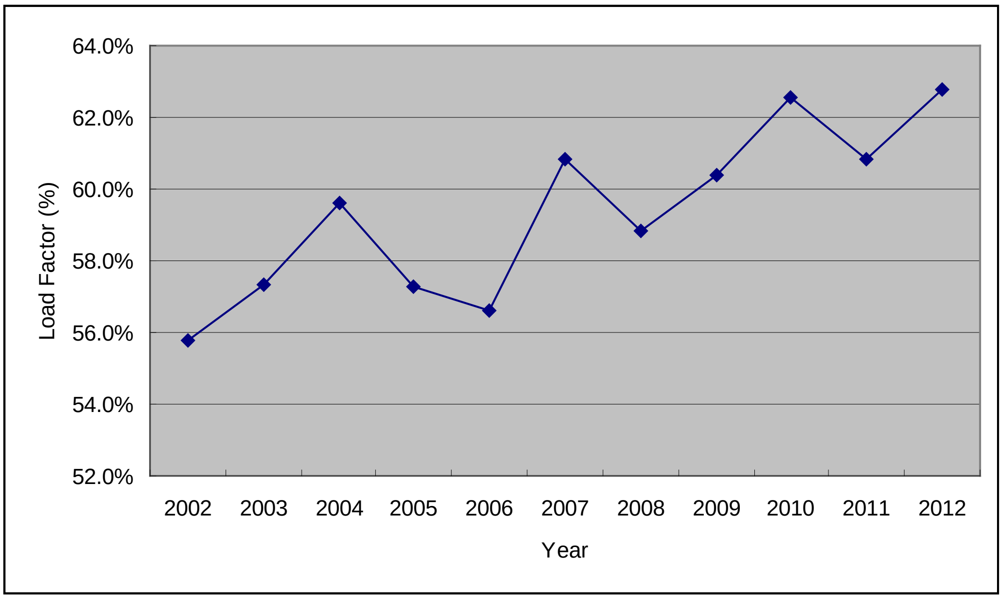

Figure 2.1.1-5 Sri Lanka: Load Factor (2002-2012)

2.1.2 Government Power Sector Policy

Serving electricity in Sri Lanka has been recognized as basic infrastructure service for peoples' quality life and economic development, and successive governments have placed electricity service as one of the priority sectors. Energy sector (including power sector) development policy papers were developed several time in the past, but most comprehensive and detail one was "National Energy Policy and Strategies of Sri Lanka" prepared by Ministry of Power and Energy, and approved by the Cabinet of Ministers in May 2006. The document spells out the implementing strategies, specific targets and milestones. Institutional responsibilities to implement each policy elements and associated strategies to reach the specified targets are also stated in the document. The document was also approved by the Parliament, which intended to ensure ownership by all political parties, and published in the Gazette in June 2008.

Although the Policy and Strategies Document categorically states that "the electricity sub-sector will be reformed by unbundling of the CEB in accordance with the Electricity Reform (Amendment) Act, and Ceylon Electricity Board (Amendment) Act", the government decided to leave CEB vertically integrated and delinked regulatory reform from the restructuring of CEB.

Some important specific targets of the Document are as follows;

- Electrification of Households: 80% through grid extension; and 6% by off-grid connection by 2010 (These targets have been achieved already.)
- Targeted Subsidies: Targeting only to all the Samurdhi beneficiaries
- Fuel Diversity and Security: Lowering oil-fuel generation to 8% by 2015, and increase of coal to 54%, and non-conventional renewable energy to 10% by 2015

- Electricity Pricing: Average electricity price to each category of consumers will be gradually made cost reflective. A conductive environment will be created to fully utilize the demand side management (DSM) opportunities arising from this change.

In order materialize the policy and strategies, the Government enacted the Sri Lanka Electricity Act No. 20 of 2009 which empowers the Public Utilities Commission of Sri Lanka (PUCSL) as the regulator of the electricity industry. Accordingly the PUCSL shall perform the roles of an economic, technical, and safety regulator for the electricity industry in Sri Lanka, ensuing transparency, fairness, and flexibility for the industry participants whilst safeguarding consumer rights to achieve policy objectives. Accordingly, PUCSL is to assure that a coordinated, efficient and economical system of electricity supply is provided for and maintained throughout Sri Lanka, at all times.

Under Section 5 of the Sri Lanka Electricity Act, the Minister of Power and Energy shall have the power to formulate “General Policy Guidelines on the Electricity Industry for the Public Utilities Commission of Sri Lanka” and these guidelines are to be forwarded to the Cabinet of Ministers for approval. The Guidelines must take into consideration, among other matters, the requirements for electricity to attain national targets including different geographical areas, and different socio-economic groups; fuel diversity; pricing policy; and the measures being taken the Government. The first Guidelines was issued by the Ministry in June 2009. PUCSL has to play its roles and functions, being consistent with the Guidelines.

While the Electricity Act does not require CEB for unbundling, the Government designed to make CEB be divided into functional business units (functional separation and financial segregation from each other business unit) to encourage CEB’s efficiency improvements by regulating each of its functional business units.

2.1.3 Organizations for Electricity Supply

The inter-organizational relations were drastically changed by enactment of Sri Lanka Electricity Act in 2009. The Ministry of Power and Energy in pre-enactment period played both policy making roles and regulatory functions. The Ministry’s role is now restricted to formulate policy guidelines of electricity sector, and supervising CEB performance. The Public Utilities Commissions of Sri Lanka now plays roles as regulator, issuing licenses for generation, transmission and distribution, and approving and regulating tariffs and other charges.

The organizational relationships among stakeholders in electricity sector are shown in Figure 2.1.3-1.

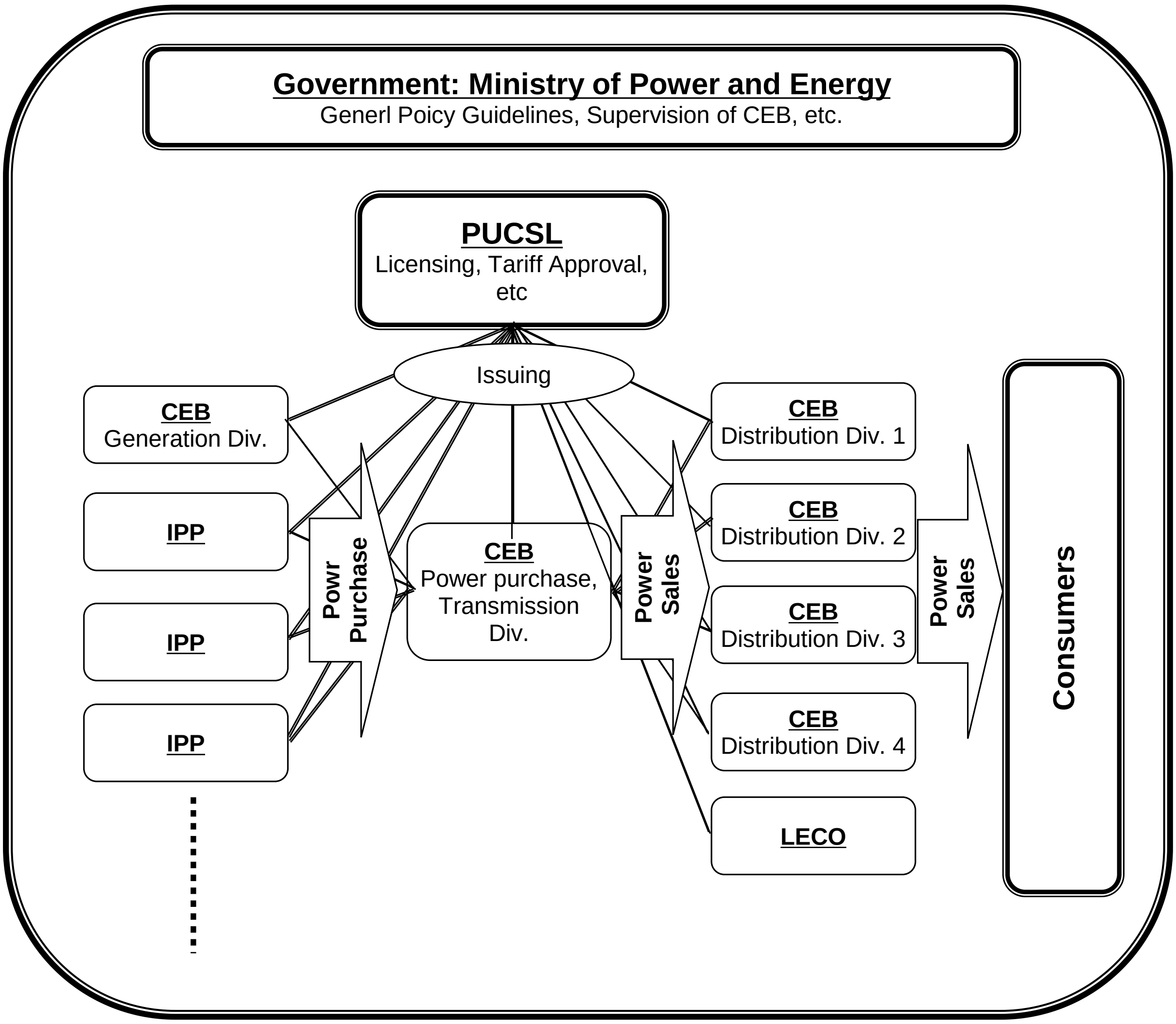

Figure 2.1.3-1 Institutional Framework of Electricity Industry in Sri Lanka

PUCSL has issues six licenses to CEB; one generation, one transmission, and four distributions. Another distribution license to Lanka Electricity Company (LECO) and 11 generation licenses to IPPs. Small scale IPPs are also given generation licenses. In total, PUCSL has issued about 120 licenses to date.

2.1.4 Foreign Assistance to Power Sector

Most of development projects in generation, transmission and distribution have been implemented with foreign assistance in Sri Lanka. In electricity generation, recently completed notable projects are Norochcholai Coal Power Project financed by China (300MW × 3), and Upper Kotmale Hydro Power Project by JICA ODA Loan (150MW). Other bilateral export credit institutions have provided financing in power generation (Austria and France for Rehabilitation of Old Laxapana, and JBIC for Ukuwela Rehabilitation). Ongoing electricity generation projects are Broadlands Hydro 35MW by China, Uma Oya Hydro 120MW (with irrigation) by Iran, Moragolla Hydro 27MW by ADB, and National Thermal Power Corporation of India and CEB signed a joint venture agreement for a

500MW coal-fired power plant in Trincomalee. ADB and JICA have been continuously assisting in transmission and distribution expansion as the major development partners. China, Iran, Sweden and some other countries are assisting projects in rural electrification projects.

2.2 Issuing Generation License by PUCSL

Peak power generation plan needs to be approved by PUCSL before commencing the project. The PUCSL reviews at two stages for new generation plans; one is at approving long term generation expansion plan; and another stage is at approving and licensing individual power plant. In both cases, CEB's transmission licensee has to take initiatives.

(1) Sri Lanka Electricity Act of 2009

In the past before enactment of the Sri Lanka Electricity Act 2009, long term generation expansion plans had been annually developed and issued by CEB as the guidelines for new generation power plant development. Main objectives of such exercises were to determine each new plant with specific generation technology, generation capacity size, and commissioning year. The SYstem SIMulation package (SYSIM), developed during the Master Plan Study in 1989 and updated in 2006 and Wien Automatic System Planning (WASP) package –WASP IV developed by International Atomic Energy Agency (IAEA) tools are extensively used in conducting the system expansion planning studies to determine optimal Long Term Generation Expansion Plan.

LTGEP: In the original Sri Lanka Electricity Act of 2009, it did not mention about long term generation expansion plan, but specifies that in Section 24 (1) A transmission licensee shall (b) procure and sell electricity in bulk to distribution licensees so as to ensure a s secure, reliable and economical supply of electricity to consumers; and (c) ensure that there is sufficient capacity from generation plant to meet reasonable forecast demand for electricity. In order to satisfy the above conditions, it must formulate long term generation expansion plan which fulfills the future electricity demand with minimum economic costs.

New Generation Plant: In Section 43 of the Act stipulates that a transmission licensee shall call for tenders to provide new generation plant, in accordance with procurement guidelines relating procurement as prescribed by regulation and by notice published in the Gazette. It also state that "A transmission licensee shall with the consent of PUCSL, select a person to provide at least cost, the new generation plant from amongst the persons who have submitted technically acceptable tenders." It is, however, the procurement guidelines to be noticed by the Gazette have not so far issued by the PUCSL. General Policy Guidelines issued by the Ministry of Power and Energy also instruct PUCSL to confirm independently the economic viability of development plans prepared by licensees and the adequacy of such plans to meet the national power demand to an acceptable level of reliability. Methodologies and procedure to confirm economic viability so far not announced by PUCSL yet.

(2) Sri Lanka Electricity (Amendment) Act of 2013

Sri Lanka Electricity (Amendment) Act was enacted by the Parliament in August 2013. The Act (Amendment) defined “Least Cost Long Term Generation Expansion Plan (LCLTGEP) as a plan prepared by the transmission licensee and amended and approved by PUCSL on the basis of the submissions made by the licensees and published by PUCSL, indicating the future electricity generating capacity requirements determined on the basis of least economic cost and meeting the technical and reliability requirements of the electricity network of Sri Lanka which is duly approved by PUCSL and published in the Gazette from time to time.” This definition has made requirements of LCLTGEP clear. PUCSL issued the Least Cost Generation Expansion Planning Code to CEB and it is a part of the Grid Code issued in May 2012.

The Least-Cost Generation Expansion Planning Code is not very much different from the method used by CEB in the past. The differences are (i) planning period extended to 20 years, (ii) LCLTGEP to be updated at least once in two years, (iii) as generating system security, typical LOLP is given as 0.8%, (iv) value of unserved energy be decrease to US$ 0.5/kWh, etc.

The Sri Lanka Electricity (Amendment) Act also stipulates procedure for approving new generation plant (or expansion of generation capacity of existing plant). Main items are as follows;

- A transmission licensee shall submit proposals to proceed with the procuring of any new generation plant or for the expansion of the generation capacity of an existing plant, to the Commission (PUCSL) for its written approval
- Upon obtaining the approval of the Commission, the transmission licensee shall call for tenders by notice published in the Gazette
- Upon the closed of the tender, transmission licensee shall through a properly constituted tender board, recommend to the Commission for its approval, the person who is best capable of (a) developing the new generation plant or the expansion of the generation capacity of an existing generation plant, as the case may be, as specified in the notice published in the Gazette in compliance with the technical and economic parameters of the transmission licensee, (b) selling electrical energy or electricity generating capacity at least cost, and (c) meeting the requirements of the Lease Cost Long Term Generation Expansion Plan of the transmission licensee duly approve by the Commission.
- The Commission shall be required on receipt of any recommendations of the transmission licensee to grant its approval at its earliest convenience.

The (Amendment) Act, however, allow an exception for waiving tender if “an offer received from a foreign sovereign Government to the Government of Sri Lanka, for which the approval of the Cabinet of Ministers have been obtained”. In this case, transmission licensee submits proposal to proceed with the new project with project feasibility study results of technical and economic parameters, including cost estimates. Once approval is granted by PUCSL, transmission licensee (CEB) proceeds with the project implementation. At this stage, cost is an estimate, and real cost to CEB is only known after implementation of the project. PUCSL review economic appropriate of the project, once the project is completed, and generation license is issued only if PUCSL confirms economic viability of this generation project.

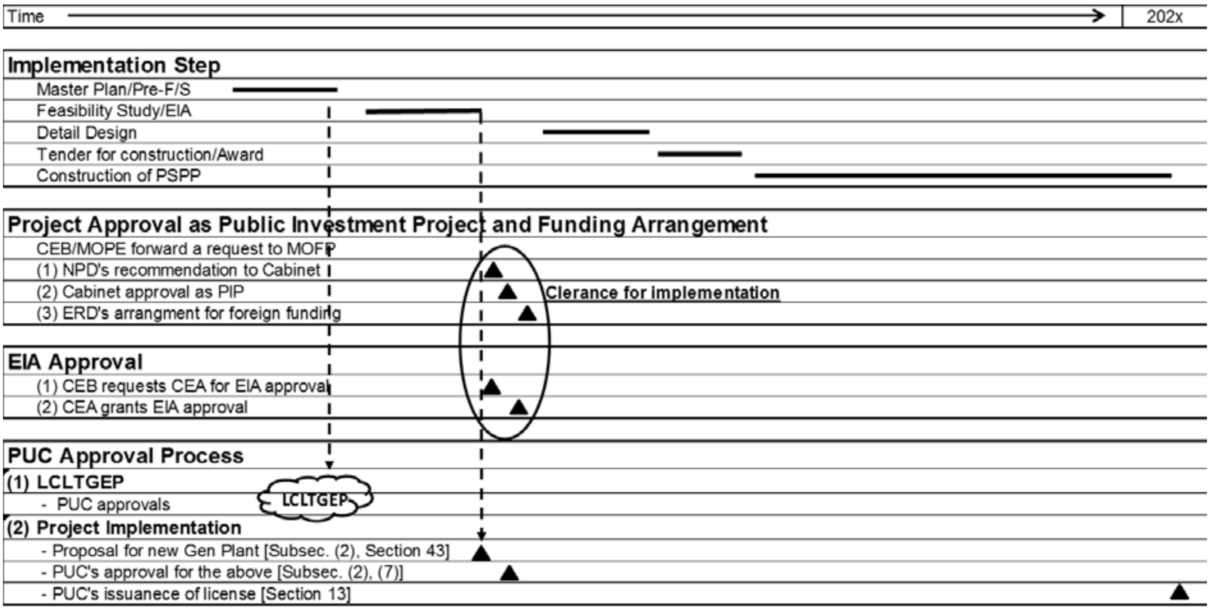

Figure 2.2-1 Project Approval and Implementation Process for Foreign Sovereign Offer

2.3 Electricity Tariffs and CEB's Financial Performance

Since electricity tariffs in Sri Lanka are to be determined by cost-reflective pricing including a reasonable return on equity[1], the licensees are not expected to face financial difficulties as far as they perform their business in efficient manner. There is, however, an extremely large financial loss in transmission licensee (it means CEB) because actual pricing has been always lower than actual costs. Revisions of tariff have been always facing with political and social difficulties. In 2011 and 2012 was an exceptionally difficult years for CEB, as were extreme draught conditions together with high oil price.

2.3.1 Electricity Tariffs

(1) Revisions in the past

Determining electricity tariffs are ruled by (i) Electricity Act Section 30 Tariffs, and (ii) General Policy Guidelines on the Electricity Industry issued by the Ministry of Power and Energy, (iii) Tariff Methodology, Dec. 2011, PUCSL. Principal rule to determining tariff is "supplying

[1] Sec. 3.5, National Energy Policy ad Strategies of Sri Lanka, 2008 GOSL Gazette Notification

electricity to all categories of consumers at reasonable prices while ensuring financial viability of the sector. Average electricity price be gradually made cost reflective. Lifeline tariff to domestic consumers will be limited to Samurdi Beneficiaries. Licensees will be compensated adequately for all reasonable cost, if they are compelled to sell electricity to any category of consumers at subsidized prices, on directives by the GOSL."

Under the new electricity tariff setting system, the first 5-year electricity tariff for the period of 2011-2015 was prepared in 2010[2]. It plans gradually moving to cost reflective within 5 years with an expectation of lowering tariff by commissioning of Sri Lanka's first coal power plant.[3]

The first electricity tariff determined by PUCSL became effective on January 1st, 2011. Historical changes of electricity tariff in major consumer categories including pre-PUCSL period is summarized in Table 2.3.1-1.

2 Consultation Paper on Setting Tariffs for the Period of 2011-2015, PUCSL, 2010
3 At the end of this master plan study period, the Government announced reduction of domestic tariff by about 25% effective from September 2014, and other categories reduction by 15-25% effective from November 2014.

Table 2.3.1-1 Revisions of Electricity Tariffs 2008 - 2013

Effective from 2008/11/1		Effeftive fm 2011/1/1		Effective fm 2012/2/		Effective fm 2013/4/20	
Customer Catgry	Rs./kWh	Cus. Cat.	Rs./kWh	Cus. Cat.	Rs./kWh	Cus. Cat.	Rs./kWh
Domestic							
<=30	**3.00**	*<=30*	**3.00**	*<=30*	**3.75**	*<=30*	**3.75**
31 - 60	**4.70**	*31 - 60*	**4.70**	*31 - 60*	**6.35**	*31 - 60*	**6.35**
61 - 90	**7.50**	*61 - 90*	**7.50**	*61 - 90*	**10.50**	*61 - 90*	**13.20**
91 - 180	**20.80**	*91 - 120*	**21.00**	*91 - 120*	**29.40**	*91 - 120*	**37.10**
		121 -180	**24.00**	*121 -180*	**33.60**	*121 -180*	**42.70**
181 - 600	**32.50**	*181=<*	**36.00**	*181=<*	**50.40**	*181=<*	**58.80**
601=<	**39.00**						
General							
GP1	**19.50**	*GP1*	**19.50**	*GP1*	**24.38**	*GP-1 <211*	**24.38**
						GP-1 >210	**26.88**
GP2	**17.94**	*GP2*	**19.40**	*GP2*	**24.25**	*GP-2 peak*	**31.25**
						day	**25.63**
						off-p	**18.13**
GP3	**17.68**	*GP3*	**19.10**	*GP3*	**23.88**	*GP-3 peak*	**30.00**
						day	**24.38**
						off-p	**16.88**
Industrial							
I-1	**13.65**	*I-1*	**10.50**	*I-1*	**12.08**	*I-1*	**14.38**
I-2	**12.09**						
I-3	**11.83**						
I-2 (TD) peak	**31.98**						
off-p	**10.92**						
I-3 (TD) peak	**29.90**						
off-p	**10.40**						
I-2 (TD3) peak	**29.90**	*I-2 peak*	**13.60**	*I-2 peak*	**15.64**	*I-2 peak*	**24.15**
day	**9.49**	*day*	**10.45**	*day*	**12.02**	*day*	**13.00**
off-p	**6.89**	*off-p*	**7.35**	*off-p*	**8.45**	*off-p*	**8.05**
I-3 (TD3) peak	**27.90**	*I-3 peak*	**13.40**	*I-3 peak*	**15.41**	*I-3 peak*	**27.60**
day	**8.97**	*day*	**10.25**	*day*	**11.79**	*day*	**12.08**
off-p	**6.50**	*off-p*	**7.15**	*off-p*	**8.22**	*off-p*	**6.90**

Note: Above figures are uint charges (Rs./kWh) only. Fixed and demand charges not includ
Fuel adjustment charges are included in above figures.

(Source: CEB, PUCSL)

Table 2.3.1-2 Comparison of Category-wise Average Charge 2012/2013

Year	Category	Domstic	Religious	Industrial	Hotel	General Purpose	Govt+ Str light	LECO	Total
2012	Sales (GWh)	3,522	55	3,285	160	2,042	109	1,302	10,475
	Revenue (Rs. Mil)	42,887	377	46,079	2,676	52,309	0	18,628	162,956
	Revenue/unit (Rs./kWh	**12.2**	**6.9**	**14.0**	**16.7**	**25.6**		**14.3**	**15.6**
2013 (estimate)	Sales (GWh)	3,488	58	3,344	168	2,059	197	1,308	10,622
	Revenue (Rs. Mil)	52,373	405	53,529	3,297	56,783	1,724	22,376	190,487
	Revenue/unit (Rs./kWh	**15.0**	**7.0**	**16.0**	**19.6**	**27.6**	**8.8**	**17.1**	**17.9**
2013/12	Increase rate (%)	**23.3%**	**1.9%**	**14.1%**	**17.3%**	**7.7%**		**19.6%**	**15.3%**

Source: CEB Statistical Digest 2013

Some of noteworthy characters are summarized as below;

- The primarily important matter of fist PUCSL approved tariff is to show a Road Map for the next five years. Thus increase was not so significant. Time of use (TOU) for Industries category (I-2, I-3), which used to be optional, became mandatory. Fuel adjustment charge (FAC) became zero, by incorporating such then factor into tariff itself.
- In February 2012, the tariff was changed. But tariff itself is not changed, only adjusted by applying fuel adjustment charge (FAC), for domestic 25-40%, general purpose 25%, industry and hotel 15%.
- The revision of tariff in April 2013 was a relatively big change, compared with past changes. While revision of already high general purpose tariff kept in small scale, domestic category, and industry and hotel were increased larger. The average change for domestic category was 23.3% (Effects of 9 months from April to December. For 12 months, change is more than 30%). As no increase for consumers less than 60kWh/month, steep increase was placed in large domestic consumers. As was the case for industries (I-2, I-3), time of use (TOU) tariff became mandatory for general purpose categories G-2 and G-3.
- Level of tariff of energy charges is lowest for domestic less than 90kWh/month due to lifeline tariff, next lowest industry and hotel, then general purpose, and the highest is domestic more than 90kWh/month. While the lowest of Rs. 3.75/kWh, the highest is Rs. 58.8/kWh with FAC. Highest tariff is as large as 15.7 times of the lowest tariff.

(2) Issues in Electricity Tariffs

- <u>Tariff Approving Authority</u>: PUCSL approved and announced new electricity tariffs in April 2013. That revision included about 25% increase of lifeline tariff, which caused a number of objections by socio-political groups. On May Day, the President indicated that no increase below 60kWh/month tariff, and moderate increase for 60-120kWh consumptions. Finally, PUCSL announced changes in the way the President indicated. The intervention hampered independence of PUCSL, and CEB's financial performance.
- <u>Periodic Tariff Adjustment</u>: Adjustment of tariff is supposed to be made every six months. It is, however, not practiced. Less frequent revisions of tariff tends to make changes relatively large, which may raise more oppositions. Periodic and automatic adjustment is preferable.
- Wider categories are now using mandatory application of time of use (TOU) tariff. It motivates consumers to shift from evening peak higher tariff to lower day and off-peak periods. Consumers, however, do not simply react to tariff changes. Therefore, it needs assessment of TOU effects. In parallel to introduction of TOU tariff, it is also important to create awareness and to provide technical support to consumers for their effective actions. Consumers response to TOU brings benefit to CEB, too.

2.3.2 CEB's Financial Performance

CEB recorded largest loss in 2012. While sales of electricity Rs. 164.0 billion (up 24% from 2011), the cost of sales was Rs. 222.2 billion (up 46% from 2011). Loss before tax was Rs. 61.2 billion (up 212% from 2011). The size of CEB's loss is nearly 1% of Sri Lanka's GDP. This loss does not include subsidized portion of fuel from Ceylon Petroleum Corporation (CPC). Ministry of Finance and Planning, in its annual report, indicated that subsidies in fuel to CEB be estimated as Rs. 54.0 billion in 2012. The net loss to the economy caused by electricity sector becomes Rs. 115.2 billion, which accounts for 1.5% of Sri Lanka's GDP. Though this huge financial loss, the cash-flow of CEB has been maintained by short-term borrowing from government's commercial banks and moratorium of repayment to the government.

Major causes of increase of supply cost in 2012 were decrease of hydro generation and increase of fuel thermal generation, and high fuel oil price, and depreciation of SL rupees against US dollars. As a result, the balance sheet of CEB has deteriorated badly, accumulating borrowing (short and long terms) Rs. 325.6 billion (up 60% from 2011).

Table 2.3.2-1 CEB's Financial `Performance 2007 - 2013

		2007	2008	2009	2010	2011	2012	2013
Profit and Loss								
Sales of Electricity	Rs. Mln	87,575	111,287	110,518	121,226	132,460	163,513	194,147
Cost of Sales	Rs. Mln	-108,355	-145,713	-118,186	-116,168	-152,427	-222,419	-166,926
Gross Profit/(Loss)	**Rs. Mln**	**-20,780**	**-34,426**	**-7,668**	**5,058**	**-19,967**	**-58,906**	**27,221**
Admin. Expenses	Rs. Mln	-1,534	-1,487	-2,870	-1,851	-2,013	-2,997	-2,598
Operationg Profit/(Los	**Rs. Mln**	**-22,314**	**-35,913**	**-10,538**	**3,207**	**-21,980**	**-61,903**	**24,623**
Other Income	Rs. Mln	9,205	3,581	4,273	4,230	4,543	6,355	6,460
Finance Cost	Rs. Mln	-1,703	-1,537	-3,073	-2,605	-1,828	-5,898	-12,490
Profit/(Loss) Bef Tax	**Rs. Mln**	**-14,812**	**-33,869**	**-9,338**	**4,832**	**-19,265**	**-61,446**	**18,593**

Source: CEB Annual Report 2011, 2012, and CEB Financial Statements 2013 (unaudited)

Table 2.3.2-2 shows the government financial support to CEB, published in MOFP annual report. Though on-lending to government institutions is common to all and thus not an issue, but (i) moratorium of repayment of government loan and (ii) issuance of government bond to cover payment to CPC are irregular contingency measures. Total of these two contingency measures from 2007 to 2012 is more than Rs. 100 billion.

Table 2.3.2-2 Government Support to CEB 2007 - 2012

	2007	2008	2009	2010	2011	2012
On-lending (External loans)	23,945	16,807	32,857	23,586	31,357	29,401
Rural Electrification Grant				1,200	1,595	710
Debt moratorium - loss to gov revenu	11,315	12,893	14,273	14,896	17,047	21,920
Cost of Rs. 50 billion bond issue						5,750
Total support	**35,260**	**29,700**	**47,130**	**39,682**	**49,999**	**57,781**

Source: Annual Report 2012, Ministry of Finance and Planning

Repayment for government loans is agreed to restart after 2014 when Puttalam Coal Power Plant Units 2 and 3 commencing operations. Annual repayment amount is estimated to be Rs. 25 billion, including principal and interests.

For steady financial recovery, CEB needs to (i) increase and periodic revision of electricity tariff by cost-reflective principle, (ii) as-planned commencement of operations of Puttalam Coal Power Units 2 and 3, and continuous operations of all units. Others may be external factors, but (iii) average rain fall for hydro generations, (iv) low and stable fuel oil prices, and (v) stable exchange rate, etc.

Chapter 3

Electric Power Demand Forecast

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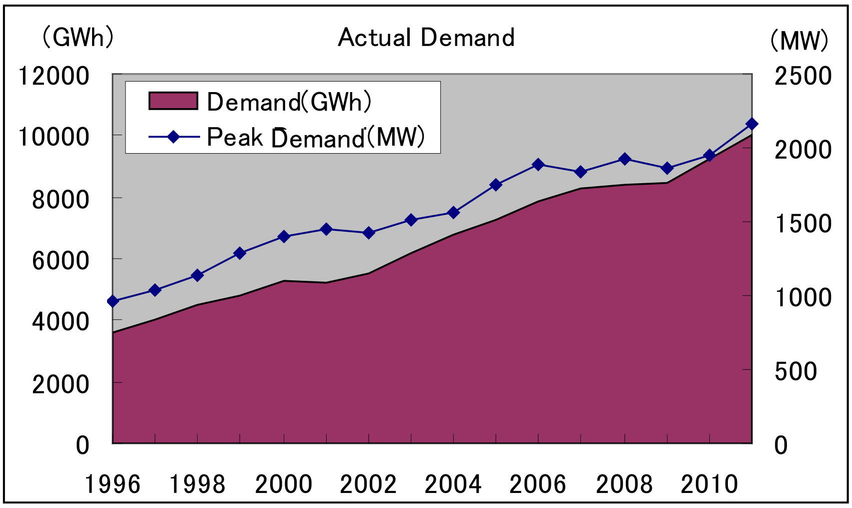
Chapter 3 Electric Power Demand Forecast

3.1 Current Situation

3.1.1 Actual Record of Electric Power Demand

According to the 2013 edition long-term plan of the CEB (LTGEP2013-32), power generation of 2012 in Sri Lanka was 11,801 GWh (generating end, except private power generation), and electricity sales were 10,389 GWh. Average annual growth rate of power generation and electricity sales over the past 10 years are 4.6% and 5.5% respectively.

Though maximum power of the country remained lower than the previous year's level in 2009 and 2007, it grew solidly and reached 2,163 MW in 2011 and its annual growth rate was 3.6% on average over the past 10 years. A factor behind the decrease in maximum power in 2007 was the significant increase of electricity price for industry in September 2006. Regarding the factors behind the drop in 2009, the global financial crisis triggered by the Lehman Brothers bankruptcy of the previous year, the global economic downturn that followed it, and the revision of electricity rates in November 2008, are assumed.

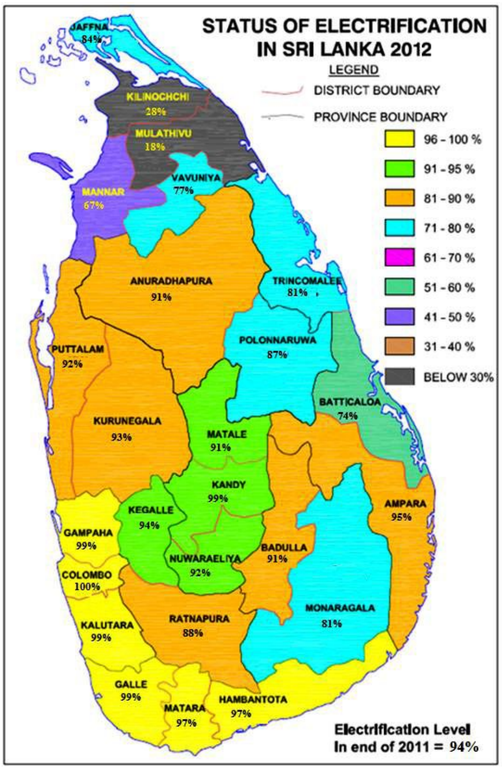


(Source: JICA Study Team based on CEB data)

Figure 3.1.1-1 Electric Power Sales and Peak Power Demand Records

3.1.2 Electrification Rate

At the end of December 2012, household electrification of 93% had been achieved. Current status of the regional electrification rate of Sri Lanka is shown in Figure 3.1.2-1. Electrification rate has already reached more than 97% in the western and southern regions. On the other hand, electrification is delayed in the northern and eastern regions. Interconnection of the northern power system and Sri Lanka system is planned for 2012.

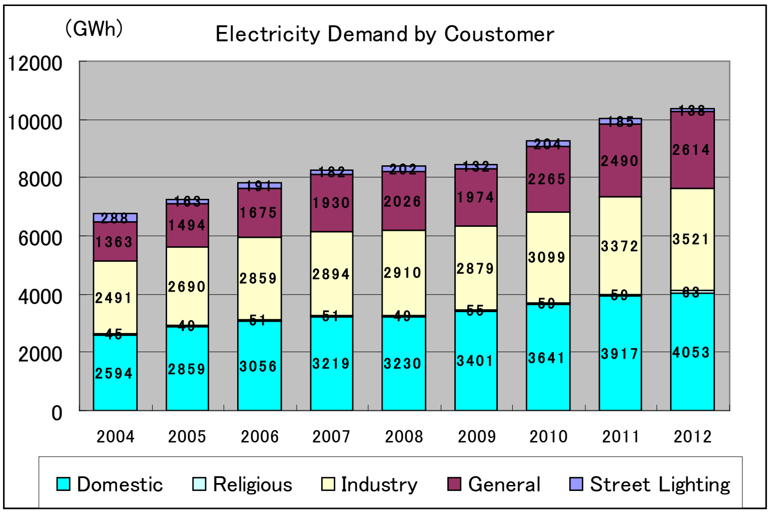


(Source: Long Term Generation Expansion Plan 2013-32,CEB)

Figure 3.1.2-1 Electrification in Sri Lanka 2012

3.1.3 Electricity Consumption by Customer

In 2012, electricity demand/consumption comprised 39% domestic, 34% industrial, 25% commercial (general), and 2% of religion/street lights. In 2004, it was 40% domestic, 37% industrial, 20% commercial, and 3% religion/street lights. Therefore, the share of commercial use has increased, while the amount of demand in the domestic sector, which is the primary sector, has grown.

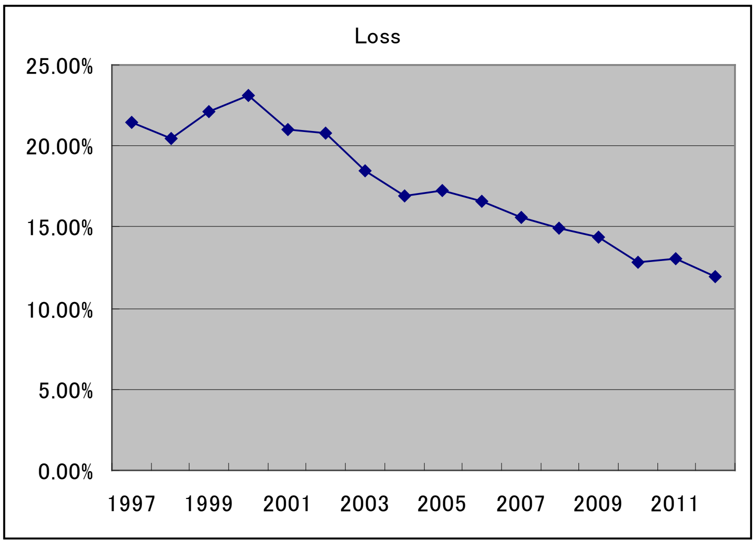


(Source: JICA Study Team based on CEB data)

Figure 3.1.3-1 Electricity Demand by Customer

3.1.4 Transmission and Distribution Loss

Transmission and distribution loss of the power system improved to 11% in the second half of 2012 after exceeding 20% in 1997. One of the reasons for the loss improvement seems to be the change of the electricity tariff system, which has introduced meter pricing instead of a flat-rate. Electric power meters were installed following the revision. Meanwhile, measures have been taken for reducing technical losses such as introducing a low-loss cable for some parts of the transmission line from the coal thermal power plant in Trincomalee that is under construction.



(Source: JICA Study Team based on CEB data)

Figure 3.1.4-1 Actual Record of Transmission/Distribution Loss

3.1.5 Load Factor of the Power System

Load factor increased to 57% in 2011 from 51.6% in 1996. In 2012, the load factor was 62.8% but this value does not reflect the actual situation since planned outages were carried out in this year.

According to the analysis of the CEB, the increase in the load factor is considered to be the result of reducing peak demand by micro-hydropower. In addition, the policy of introducing fluorescent lights instead of filament bulb lights has been taken since peak demand appears at night.

As a peak cut measure by DSM, the introduction of time-of-day tariffs to increase the tariff rate in the peak time zone has been studied.

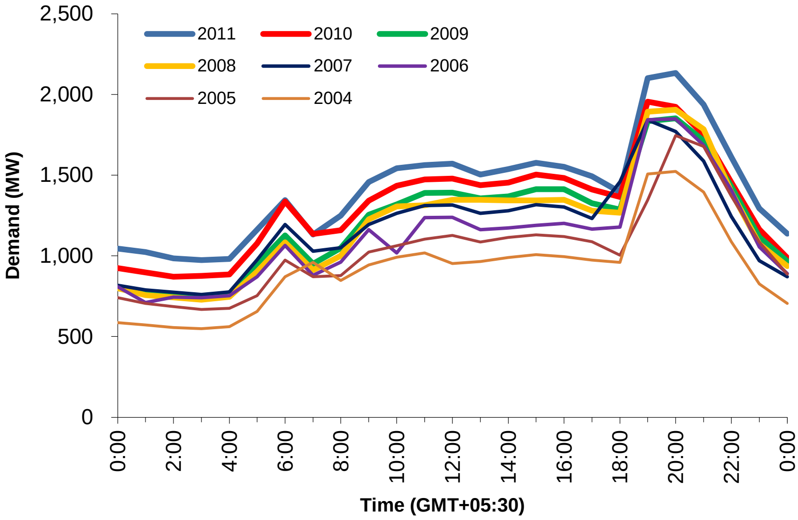
3.1.6 Daily Load Profile

(1) Load profile on the annual peak day

The peak demand in 2011 reached 2,163 MW and occurred at 19 o'clock on May 20th. According to the daily load profile of CEB data, there is a small peak at 6 o'clock in the morning. The demand once decreased at 7 o'clock and then day time demand, which is forming gentle peak, appears. In the evening, a peak occurs between 19:00 to 22:00, which is the maximum demand of the day.

The CEB System Control Center explains that the peak in the early morning is the power demand for lights for preparing lunchboxes for school children and this peak does not appear during school holidays.

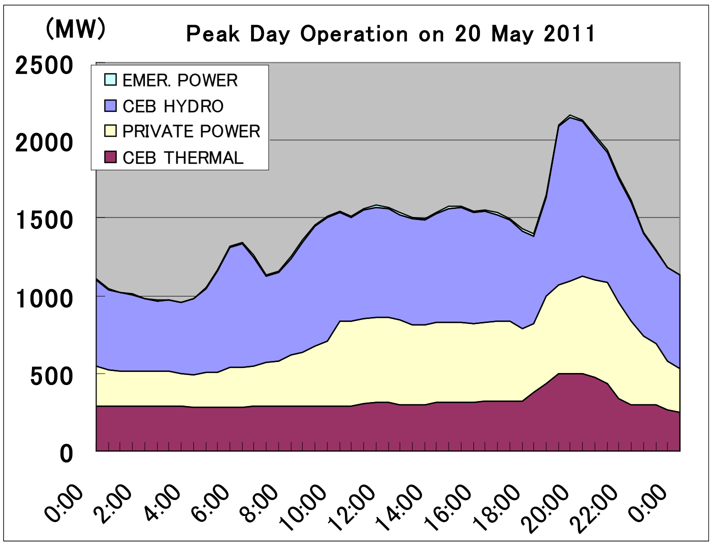
The shape of the daily load profile is not a big change over time, and peak demand is increasing year by year. Duration time of the evening peak is 3-4 hours. Demand scale, which appears as a peak, is about 600MW.



(Source: JICA Study Team based on CEB data)

Figure 3.1.6-1 Actual Record of Load Profile on the Annual Peak Day

Peak demand of 2,163 MW was recorded at 19:00 on the 20th May. Maximum power of Colombo district on the same day was 181MW, which is only about 8% of the peak demand of the whole country, even though the share of electricity sales in Colombo district is about 12%. It seems, therefore, the load factor of the rural areas is low.



(Source: JICA Study Team based on CEB data)

Figure 3.1.6-2 Daily Load Profile on the Annual Peak Day in 2011

(2) Change of daily load profile

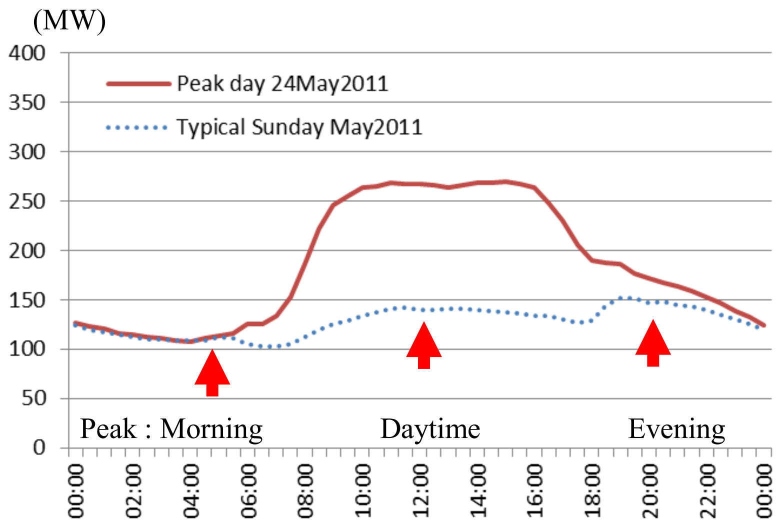
Since Sri Lanka aims at a tourism nation, it is expected that the day time demand stretches in the future when service sector is developed and becomes more active in addition to the industry development.

Daytime demand on weekdays in Colombo district has already increased and daily peak demand appears in daytime. Meanwhile on holidays, there are three peaks, i.e. the morning, daytime and evening peaks, on the daily load profile as same as that of whole country. (Refer to Figure 3.1.6-3). There is no difference of the demand in night time between weekdays and holidays, but day time demand on weekdays are higher than on holidays. Therefore, it is assumed that power demand in weekdays for industry and service sector have been increasing.

Change of load profile is important for the demand forecasting. It is necessary to reflect the change to the load factor. Especially there is an influence to the peak demand forecasting when the peak demand in daytime will be bigger than the peak in evening. Therefore it is necessary to take into account of the trend of future demand profile and the change of the national development policy/plan.

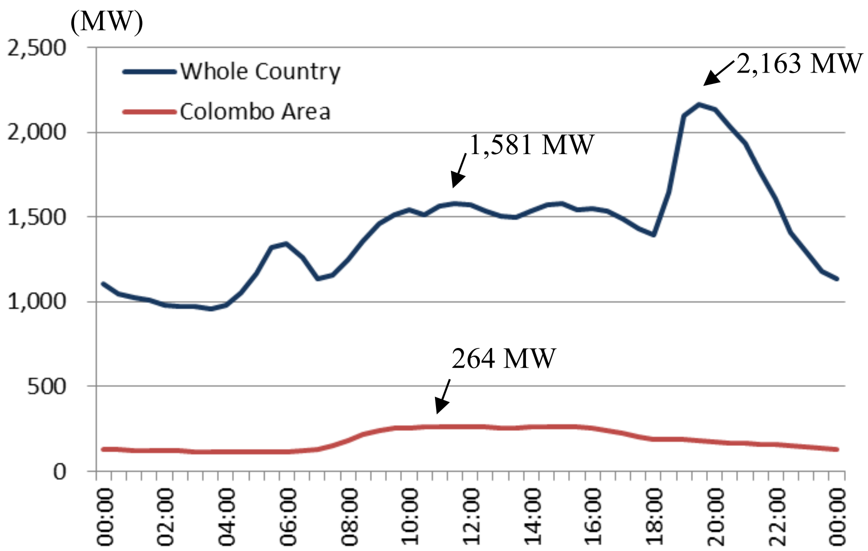
However, in the current situation, daytime demand in the Colombo district is still small enough compared to the demand of the whole country, and it has not yet led to significant change in the daily load profile. According to the actual record of load profile on the annual peak day shown in Figure 3.1.6-1, peak demand in daytime and evening has been increasing by the rate of 5% and 4% respectively in average. Increase rate of daytime is slightly larger than that of evening peak but the difference is only about 1%. Since the difference between the daytime/evening peaks is about 600MW that is 30% of the daily peak demand, it seems to require a considerable number of years until daytime peak will be increased to the same level of evening peak demand.

Therefore peak demand needs to forecast based on the trend of the evening peak. It is required to make a development plan for the peak supply to meet the increase of the peak demand forecasted, and also required to reliably develop.



(Source: JICA Study Team based on CEB data)

Figure 3.1.6-3 Daily Load Profile of Colombo District in 2011



(Source: JICA Study Team based on CEB data)

Figure 3.1.6-4 Daily Load Profile of the Whole Country and Colombo District (Annual Peak day in 2011)

3.2 Electric Power Demand and Economic Conditions

The population of Sri Lanka is about 20 million, and GDP per capita is approaching 3,000 USD. The annual average growth rate of GDP is increasing by 3.5-8%.

GDP share by each sector in 2012 is 23% trade, 17% industry, 14% transportation and communication, 11% agriculture/forestry/fisheries, 9% bank securities/real estate, 8% construction, 7% government -related, 3% mining, 3% services, 2% power/ gas/ water supply, and 3% others.

GDP share of the industry and mining sector, which has large electric power consumption, is 20% in total. Moreover electrification has not progressed in the transport sector. Therefore, a feature is that share of sectors which depend on electric power is low.

Table 3.2-1 Demographic and Economic Indicators of Sri Lanka

	Unit	2006	2007	2008	2009	2010	2011	2012
Population	Million	19.89	20.01	20.22	20.45	20.65	20.87	20.32
Population growth rate	%	1.1	1.1	1.0	1.1	1.0	1.0	n.a.
GDP real growth rate	%	7.7	6.8	6.0	3.5	8.0	8.2	6.4
GDP/Capita	USD	1,421	1,634	2,014	2,057	2,400	2,836	2,923
Exchange rate	LKR/USD	103.96	110.62	108.33	114.94	113.06	110.57	127.60
GDPconstant 2002 price	Mill. LKR	2,090,564	2,232,656	2,365,501	2,449,214	2,645,542	2,863,854	3,047,277

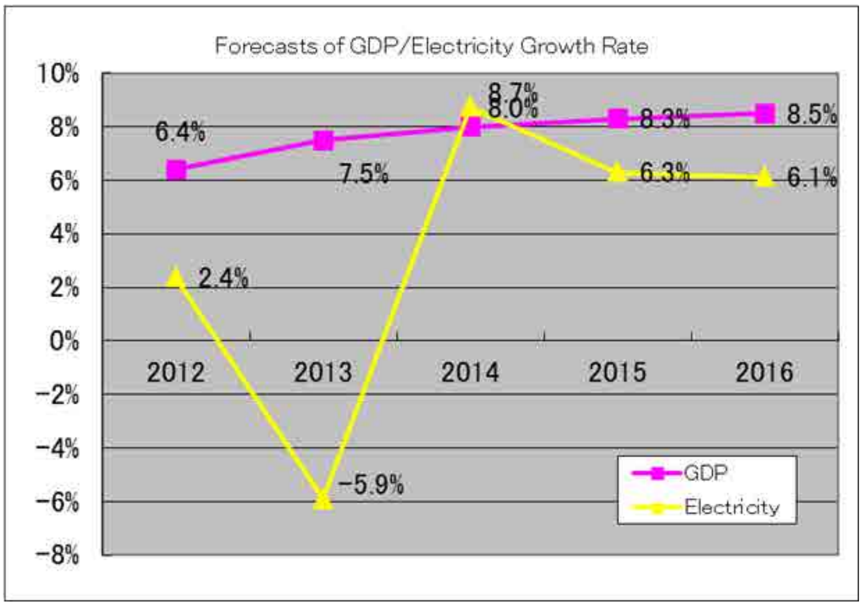
(Source: Long Term Generation Expansion Plan 2013-32,CEB)

3.2.1 Relationship of GDP and Electricity Demand

The Central Bank of Sri Lanka has announced the GDP growth rate forecast for the four years in 2012 as shown in the following figure. Growth rate of electricity demand in this figure is the rate forecasted in LTGEP except the rate in 2012 and 2013 which are the actual records.

Actual records of the electricity growth rate are about 2%, which are lower than that of GDP. Forecasted growth rates for 2012 and 2013 are 6.3% and 7.3% respectively, which are almost the same rates of actual records. Therefore, the trend is the same in case of forecasted growth rate.

In 2014 growth rate of GDP and electricity demand is comparable, but growth rate of electricity demand is in the low status compared to the GDP growth rate.

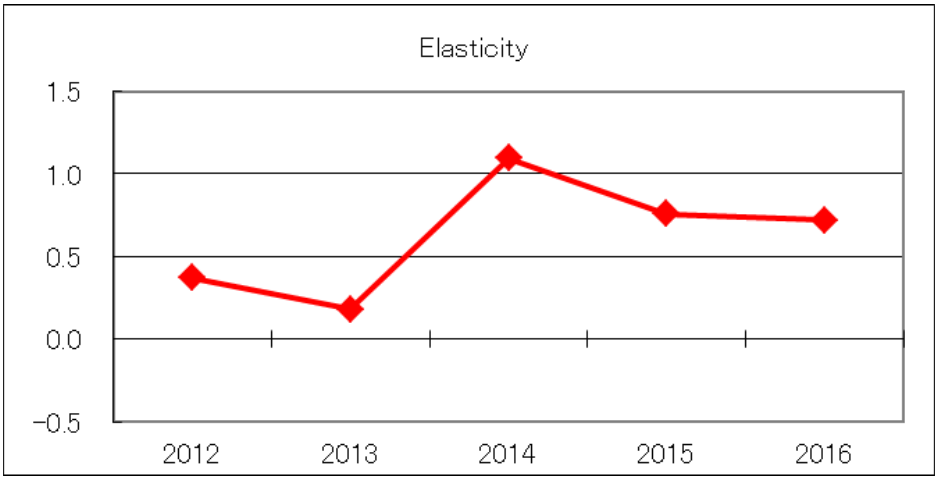


(Source: JICA Study Team based on CEB data)

Figure 3.2.1-1 Forecasted Growth of GDP and Electricity Demand

GDP elasticity, which is obtained by dividing the electricity demand growth rate by the GDP growth rate, is as shown in the following figure. GDP elasticity is less than 1 since electric power consumption of the sectors, which account for a large proportion of GDP, is not so large.

However, it is believed that GDP elasticity will increase to the range of 1-1.2 when GDP share of Industry/Service sector is increased and/or electrification of transportation is progressed in the future.



(Source: JICA Study Team based on CEB data)

Figure 3.2.1-2 GDP Elasticity

3.3 Demand Forecast

3.3.1 Electric Power Demand Forecast

Since the economy, energy, and electric power policies of the Sri Lanka government have big influence on the future demand of electric power in Sri Lanka, it is valuable to confirm the forecasted demand of CEB and necessity of peaking supply, from the following viewpoints.

(i) Impact on electric power demand and load pattern changes by industrial structural change based on economic policy

(ii) Verification econometric model and variables of electric power demand forecast

(iii) Demand-Side Management (DSM) policy, energy conservation policy

The CEB Planning Department is in charge of power demand forecast in Sri Lanka. The demand forecast is revised once every several years. CEB makes up the power demand forecast along with the power facility development plan, and then the Public Utility Committee approves them.

Power demand in the future is forecasted utilizing econometric models. Based on this forecast, peak demand is forecasted considering effect of demand side management and improvement of the load factor based on policy, which is about 1.5% per year.

As stated in section 3.1.6, although peak demand appears in daytime in the capital area but peak demand of the whole country occurs in the evening. Daytime peak demand has remained at about 75% of the evening peak. Also, there is no significant difference in the annual growth rate for daytime/evening peak, and the load profile has not changed yet. Therefore it seems to be appropriate for demand forecasting based in the current load profile.

Econometric models that are currently used are a model the effect of past records and GDP is large. However, it is considered appropriate as the assumed method of current situation since the contribution rate is high.

3.3.2 Power Demand Forecast Method

Electricity sales are forecasted using econometrical analysis. The model for the analysis is carefully composed based on the national policy of each category.

Power generation at sending end is projected based on the electricity sales forecast, considering the transmission/distribution losses, renewable energy forecasting, and the effect of energy conservation measures /DSM prediction.

Actual demand consists of four categories, which are Domestic, Industrial, Commercial and others including street lighting and religious use. And the power demand of each category is forecasted using multiple regression analysis.

Up to 2011, demand for industry and commercial category was forecasted together. But it has changed to independent forecasting taking into consideration the government’s commercial promotion policy.

Power generation of renewable energy is assumed by Renewable Energy Authority, and CEB uses this for its forecast.

(1) Econometrical analysis for electricity sales forecast

Electricity sales are assumed by summation of the forecasted sales of categories which is performed by utilizing econometrical analysis. Variables used in the analysis modeling of multiple regression analysis are shown in the table below. Electricity sales of each category are forecasted using variables of previous demand, domestic consumer accounts and GDP.

As previously mentioned, growth rate of electricity sales is smaller than growth rate of GDP. Meanwhile correlation of them is strong. Therefore, it is believed that selecting these variables is reasonable.

Table 3.3.2-1 Variables used for Econometrical Modeling

Category	Variables
Domestic	Previous year Demand, GDP per Capita, Domestic Consumer Accounts
Industrial	Previous year Demand, GDP
Commercial	Previous year Demand, GDP
Others	Year

(Source: Long Term Generation Expansion Plan 2013-32,CEB)

(2) Econometrical modeling for each category

Multiple regression models for each category are as follows.

1) Domestic sector

Multiple regression model of domestic sales is as follows.

$$Ddom(t) = -51.01 + 0.0037GDPPC(t) + 0.00016CAdom(t) + 0.74Ddom(t-1)$$

Where,

Ddom (t) : Demand for electricity in domestic consumer category (GWh)

GDPPC (t) : GDP per capita in year t

CAdom (t) : Number of domestic consumer accounts

Ddom(t-1) : Previous year’s electricity demand in domestic consumer category (GWh)

Each variable in the year (t) is calculated by the past trend. Coefficient of determination of this model is 0.997, which is quite high.

2) Industrial sector

Multiple regression model of industrial sales is as follows.

$$Di(t) = -16.58 + 0.00036GDP(t) + 0.75Di(t-1)$$

Where,

Di (t) : Demand for electricity in industrial consumer category (GWh)

GDP (t) : GDP in year t

Di(t-1) : Previous year's electricity demand in industrial consumer category (GWh)

As well as the domestic sector, each variable in the year (t) is calculated by the past trend. Coefficient of determination of this model is 0.969, which is very high.

3) Commercial sector

Multiple regression model of commercial sales is as follows.

$$Dc\ (t) = -228.07 + 0.0006GDP\ (t) + 0.48Dc(t-1)$$

Where,

Dc (t) : Demand for electricity in commercial consumer category (GWh)

GDP (t) : GDP in year t

Dc(t-1) : Previous year's electricity demand in commercial consumer category (GWh)

Also, each variables in the year (t) is calculated by the past trend. Coefficient of determination of this model is 0.988, which is very good.

4) Other sectors

Multiple regression model of other sales is as follows.

$$Ln\ (Dos\ (t)) = -108.4 + 0.057t$$

Where,

t : Year

Coefficient of determination of this model is 0.980, which is high

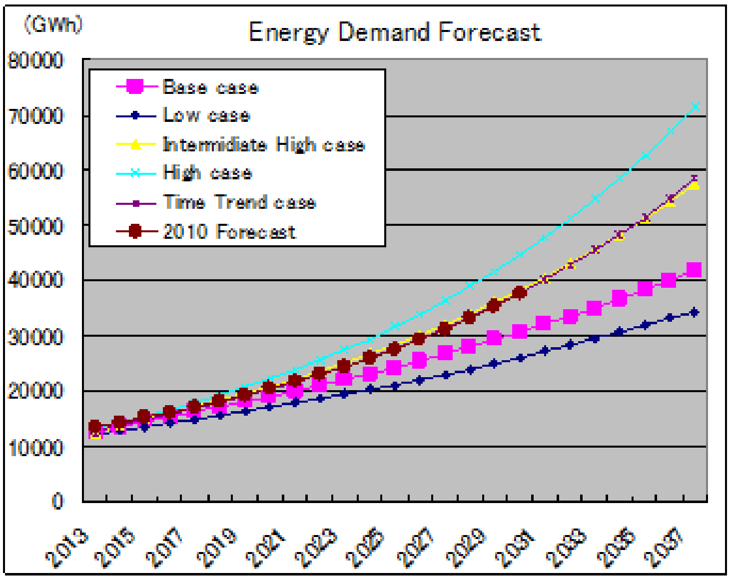
3.3.3 Electric Power Demand Forecast

(1) Power generation

CEB set the case based on the demand forecast using econometrical analysis mentioned in section 3.3.2 as the base case. In addition, sensitivity study was conducted, therefore, there are four other cases of forecast, which are;

- Low case: considering effects of the energy saving and the DSM, assumed by the Sustainable Energy Authority
- Middle-high case: considering population growth and GDP growth, assumed by the Central Bank of Sri Lanka
- High case: considering high population growth scenario and economic growth
- Time trend case: based on past trend of demand

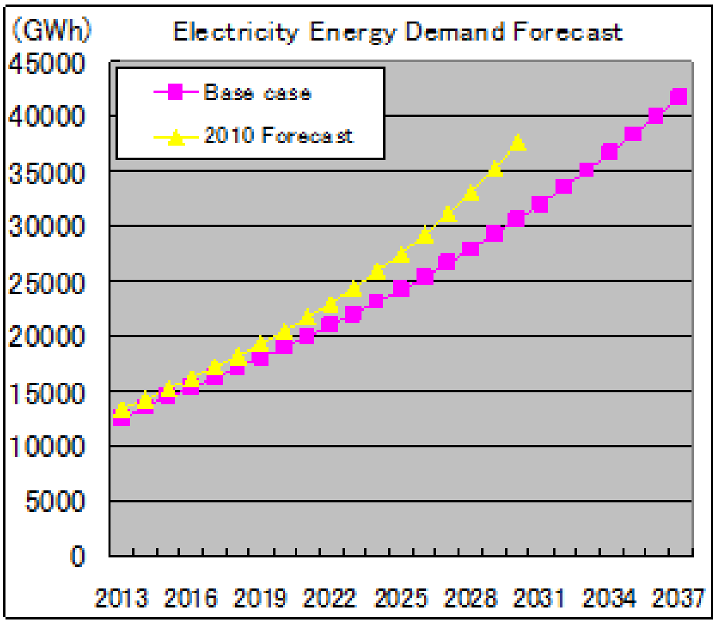
Comparing the projected values in these cases in 10 years' time, compared to the base case, the low case is delayed two years, the middle-high case is two years ahead, and the high cases is five years ahead.



(Source: JICA Study Team based on CEB data)

Figure 3.3.3-1 Electric Power Demand Forecast (GWh)

Power demand estimation of base case in Long Term Generation Expansion Plan 2013-32 is two years delay compared to the previous estimation of base case in 2010.



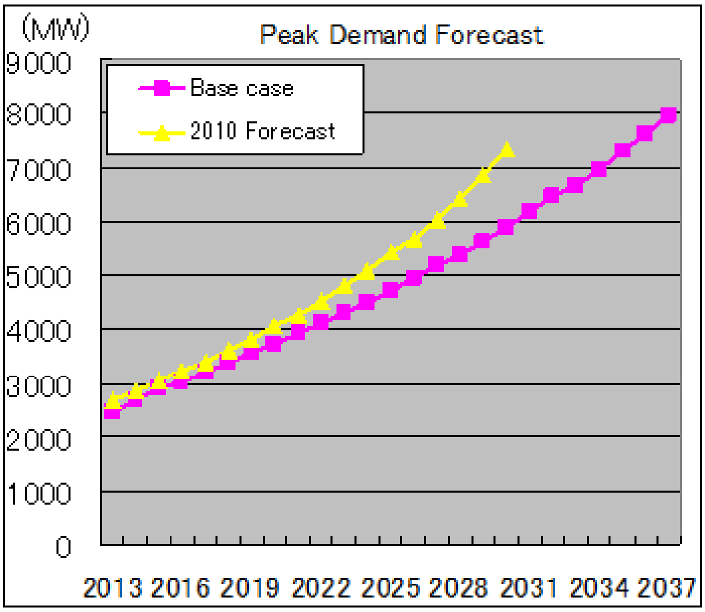
(Source: JICA Study Team based on CEB data)

Figure 3.3.3-2 Electric Power Demand Forecast in 2010 and 2013 (Base Case, GWh)

(2) Peak demand forecast

Peak demand is forecasted, considering estimated load factor and transmission/distribution losses, based on the assumed power generation. Load factor is assumed in the single regression analysis from past records. Load factor was 57% in 2011, and it is assumed to increase to 58-60%.

Forecasted peak demand is shown as follows.



(Source: JICA Study Team based on CEB data)

Figure 3.3.3-3 Peak Demand Forecast in 2010 and 2013

(3) Daily load profile

Regarding daily load profile, that of the daily peak power demand recorded in the past is used for planning. Since load factor is assumed to increase in the future, the peak demand will be estimated smaller.

Meanwhile share of the commercial sector is increasing according to the power demand records of the customer category. Therefore, it is recommended to conduct analysis of daily load profile of commercial sector, and to forecast daily load profile by weighted averaging of load profile for each sector in accordance with the demand share of the sector.

3.3.4 Issues of Demand Forecast and Recommended Measures

There is a possibility that the actual demand will not go with the past trend if infrastructure is developed in the future. It may be necessary to strengthen information collection including reinforcement of the structure since grasping the actual situation of demand correctly is essential for forecasting.

For this purpose, the following recommendations are given.

(1) Survey of private power generation and self-consumption

Currently, with respect to private power generation and self-consumption of large customers, a system to collect information from customers is not in place. Therefore, it is difficult to determine the full extent of the power demand. It is necessary to grasp actual situation for considering utilization of private power generation to mitigate supply shortages.

For this purpose, establishment of a system, including tallying and legislation for reporting private power generation / self-consumption, is needed.

(2) Impact assessment of the daily load profile due to a change in the use of power

It is necessary to examine the changes in electricity usage due to the influence of the national development plan and changes in the industrial structure. Specifically, it is necessary to analyze the characteristics of daily load profile for each sector and to create an end user model, to forecast the future profile of daily demand by weighted averaging of load profile of each sector in accordance with the demand share of the sector.

For this purpose, accumulation of the hourly power usage data for the customer side is necessary. Introduction of measures to collect actual data widely, such as installation of meters which can record every hour, and construction of AMI (Advanced Meter Infrastructure) utilizing smart meters, will be the basis of the study in the future.

Chapter 4

Power Development Plan

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Chapter 4 Power Development Plan

4.1 Long Term Generation Expansion Plan of CEB

The Ceylon Electricity Board (CEB) is under a statutory duty to develop and maintain an efficient, coordinated and economical system of Electricity Supply for the whole of Sri Lanka. Therefore, CEB is required to generate or acquire sufficient amount of electricity to satisfy the demand. In order to fulfill the requirement, CEB annually plans its development activities in the document as Long Term Generation Expansion Plan covering the growing electric power demand.

In accordance with the power demand estimate mentioned in the Chapter 3, the LTGEP 2013 to 2032 was elaborated and approved in April 2014, and its base plan was made (refer to the Table 4.1-1). This generation expansion plan selects base case[1] out of 22 scenarios by mainly comprehensive economic index, and then determines the order of project development.

Table 4.1-1 Generation Expansion Plan

YEAR	RENEWABLE ADDITIONS	THERMAL ADDITIONS	THERMAL RETIREMENTS	LOLP %
2013			4x5 MW ACE Power Matara 4x5 MW ACE Power Horana 4x5.63 MW Lakdanavi	1.821
2014		*4x5 MW Northern Power* *3x8 MW Chunnakum Extension* *1x300 MW Puttalam Coal (Stage II)*		1.357
2015		*1x300 MW Puttalam Coal (Stage II)* 3x75 MW Gas Turbine	6x16.6 MW Helandanavi Puttalam 14x7.11 MW ACE Power Embilipitiya 4x15 MW Colombo Power	1.228
2016	*35 MW Broadlands* *120 MW Uma Oya*			1.017
2017		1x105 MW Gas Turbine		1.483
2018	27 MW Moragolla	2x250 MW Trincomalee Coal	4x5 MW Northern Power 8x6.13 MW Asia Power	0.399
2019		2x300 MW Coal Plant	5x17 MW Kelanitissa Gas Turbines 4x18 MW Sapugaskanda Diesel	0.080
2020				0.247
2021		1x300 MW Coal Plant		0.162
2022	49 MW Gin Ganga	1x300 MW Coal Plant		0.085
2023		2x300 MW Coal Plant	163 MW AES Kelanitissa CCY 115 MW Gas Turbine 4x9 MW Sapugaskanda Diesel Ext.	0.045
2024				0.169
2025		1x300 MW Coal Plant	4x9 MW Sapugaskanda Diesel Ext.	0.162
2026				0.518
2027		1x300 MW Coal Plant		0.466
2028		1x300 MW Coal Plant		0.370
2029				1.078
2030		1x300 MW Coal Plant		1.094
2031		1x300 MW Coal Plant		1.140
2032		1x300 MW Coal Plant		1.233

Note: Committed plants are shown in *Italics*.
Source: LTGEP 2013-2032 Revised Base Case Plan

[1] The generation expansion plan with least cost present value.

The Table 4.1-2 and Figure 4.1-1 show the demand estimate made by CEB and the power demand supply balance calculated from the generation expansion plan. When the generation expansion plan realize on schedule, the total generation facility of CEB can make sure of 15% to 20% margin to the power demand in coming 10 years from 2013. However, it is necessary to note the projects scheduled to be commissioned after 2017 have not committed yet.

Meantime, hydropower dedicated for peak demand is not listed in the generation expansion plan except Upper Kotmale Hydropower Project commissioned in 2012.

Table 4.1-2 Power Development Plan

Year	Existing (MW)	On Going (MW)	Plan (MW)	Retirement (MW)	Total (MW)	Peak Load (MW)	Margin Capacity (MW)	Margin (%)
2013	2,874				2,874	2,451	423	15
2014	2,874	319	4		3,197	2,692	505	16
2015	2,874	594	234	-260	3,442	2,894	548	16
2016	2,874	749	238	-260	3,601	3,016	585	16
2017	2,874	749	347	-260	3,710	3,193	517	14
2018	2,874	749	832	-329	4,126	3,383	743	18
2019	2,874	749	1,386	-486	4,523	3,556	967	21
2020	2,874	749	1,390	-486	4,527	3,731	796	18
2021	2,874	749	1,669	-486	4,806	3,920	886	18
2022	2,874	749	1,997	-486	5,134	4,125	1,009	20
2023	2,874	749	2,551	-637	5,537	4,287	1,250	23
2024	2,874	749	2,555	-800	5,378	4,499	879	16
2025	2,874	749	2,834	-836	5,621	4,717	904	16
2026	2,874	749	2,838	-836	5,625	4,948	677	12
2027	2,874	749	3,117	-836	5,904	5,187	717	12
2028	2,874	749	3,396	-836	6,183	5,369	814	13
2029	2,874	749	3,400	-836	6,187	5,625	562	9
2030	2,874	749	3,679	-836	6,466	5,893	573	9
2031	2,874	749	3,958	-836	6,745	6,171	574	9
2032	2,874	749	4,237	-836	7,024	6,461	563	8

Source: LTGEP 2013-2032 excluding mini hydro and NCRE

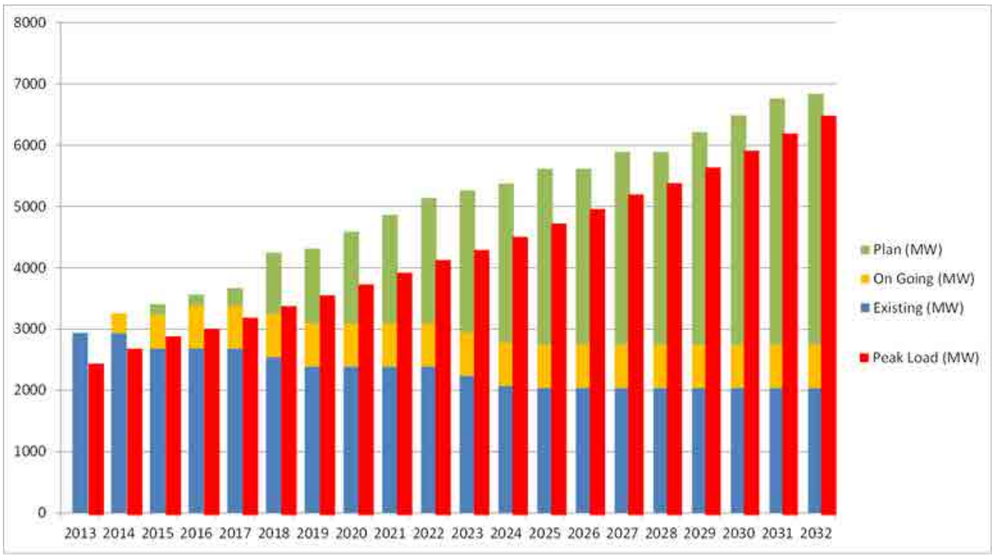

Figure 4.1-1 Generation Capacity and Peak Load

4.2 Necessity of Power Generation for Peak Power Demand

The composition of Power Generation in 2012 is shown in the Figure 4.2-1 according to the LTGEP 2013 to 2032.

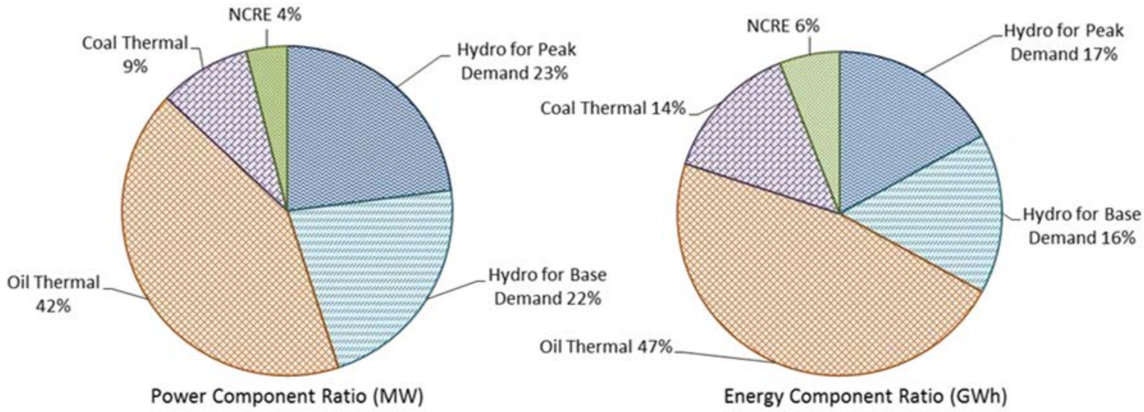

Figure 4.2-1 Composition of Power Generation in 2012

As mentioned in the Chapter 4.1 "Long Term Generation Expansion Plan of CEB", CEB has established generation expansion plan for the year 2013 to 2032 in LTGEP to supply adequately electricity for the growing power demand in future in accordance with the Sri Lankan economic growth. The generation expansion plan up to the year 2016 contains projects already committed to develop or under construction, but there are still following problems remaining:

a. There is no new construction of hydropower plant dedicated to supply for peak power demand after 2013.

b. It is not economical and difficult to construct new thermal power plant for peak power demand because of global inflationary prices of fossil fuel[2].

c. Thermal power plants taking on the supply for peak power demand is aging enough to retire.

For taking countermeasures in the generation expansion planning aspect, new construction of hydropower plant with large scale reservoir, shifting existing hydropower plant from middle or base road operation to peak load operation, and construction of pumped storage power plant can be considered as securement of power source for increment of peak power demand. These developments surely contribute to utilization of domestic renewable energy.

However, almost all potential hydropower in Sri Lanka has already developed or been under construction and promising hydropower site is quite limited, especially large scale hydropower site has already developed. In addition, for the existing hydropower expansion projects have real problems such as its economic efficiency and lowering of reservoir water level (means outage of existing power plant) during construction and so on. Only Victoria Power Plant and Samanalawewa Power Plant have

2 e.g. according to U.S. Energy Information Administration Data, the spot price of U.S. Gulf Coast Ultra-Low Sulfur No.2 Diesel as of January 2014 is 204% compared with five years back price.

the potential of expansion of their output as power generation for peak power demand. Among them, Victoria Expansion Project can be constructed in the near future, because the intake for expansion units has already constructed, therefore other facilities can be constructed without lowering of the Victoria reservoir.

The maximum-ever electric power demand was recorded at 19:30 on May 20, 2011. The daily load curve on the day is shown in Figure 4.2-2. The figure shows that the peak demand duration is 4 to 5 hours from 17:30 and the peak load is 735 MW. This peak load is supplied with CEB thermal power plant approximately 180 MW, IPP thermal power plant 130 MW[3] and CEB hydropower plant 425 MW[4].

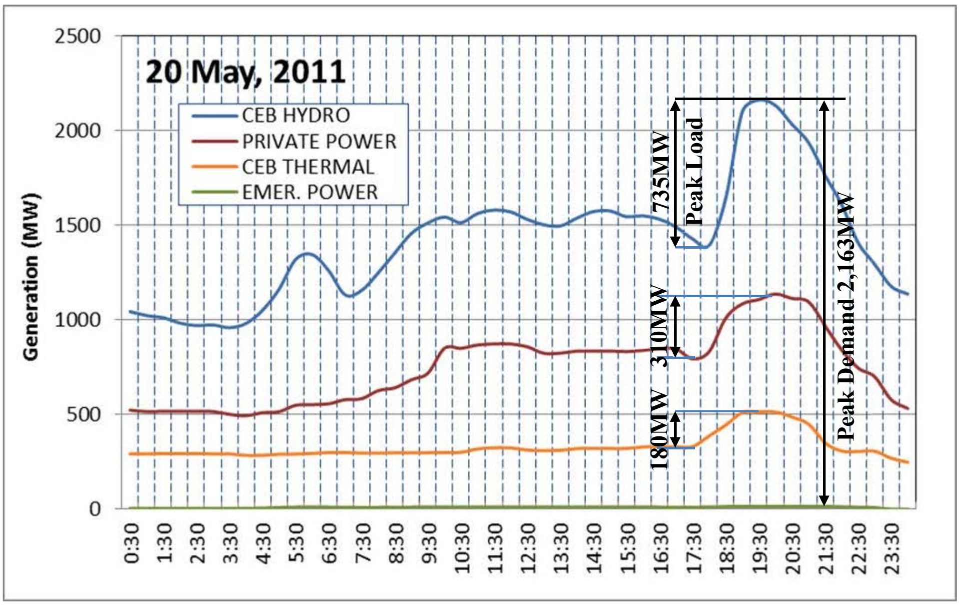

Figure 4.2-2 Generation Capacity and Peak Load

The daily load curve in Figure 4.2-2 is that of rather wet season. Figure 4.2-3 shows a daily load curve on November 16, 2011 as rather dry season for reference. There were no enough water for generation in the reservoir of hydropower plants in this day, and thermal power plants were almost in full operation even in off peak time, and the water of hydropower plants were backlogged for duration of peak power demand. As a result of this operation, the peak load of 514 MW was supplied with CEB hydropower plants 476 MW, CEB thermal power plants approximately 13 MW and IPP thermal plants 22 MW.

[3] 130MW=310MW-180MW
[4] 425MW=735MW-310MW

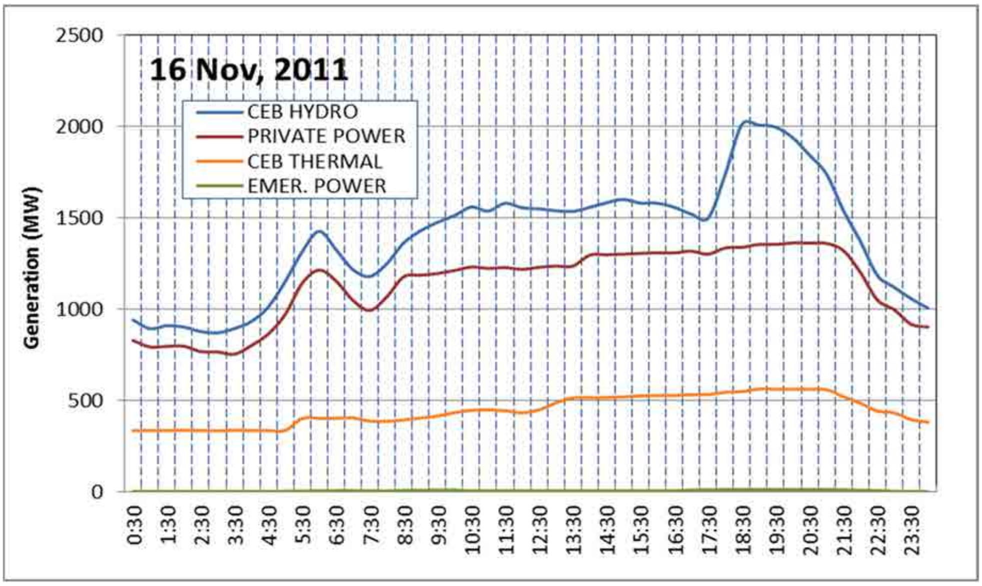

Figure 4.2-3 Generation Capacity and Peak Load

As mentioned above, CEB thermal power plants and IPP thermal power plants that have been used for peak power demand are now in retirement period. In addition, it is expected that the peak demand is increasing yearly. Therefore, measures of lining up of power source for peak demand are urgently needed n the future.

4.3 Necessary Development Scale of Power Source for Peak Power Demand

Table 4.3-1 shows generation records of power generation at just before off-peak time and peak time on maximum power demand day of each month in 2011. From this Table, the maximum peak load is 734 MW (34% of peak demand), the minimum peak demand is 514 MW (25% of the same) and average is 573 MW (28% of the same).

Table 4.3-1 Generation Record of Power Generation on Monthly Peak Demand Day in 2011

	Off-Peak Time (17:30) Load & Supply (A) MW					Peak Time (18:30-19:30) Load & Supply (B) MW					Balance (B-A) MW				
	Total	Hydro	CEB T.	IPP T.	Emer. P	Total	Hydro	CEB T.	IPP T.	Emer. P	Total	Hydro	CEB T.	IPP T.	Emer. P
Jan. 25	1,352.5	746.2	112.5	484.7	9.1	1,873.3	1,090.6	125.3	644.0	13.4	520.8	344.4	12.8	159.3	4.3
Feb. 23	1,358.1	639.3	337.0	371.1	10.7	1,961.1	907.7	391.7	646.9	14.8	603.0	268.4	54.7	275.8	4.1
Mar. 30	1,493.9	597.6	383.0	503.2	10.1	2,020.3	877.8	555.0	572.8	14.7	526.4	280.2	172.0	69.6	4.6
Apr. 05	1,465.4	737.2	284.5	433.6	10.1	1,994.3	1,157.2	385.8	438.2	13.1	528.9	420.0	101.3	4.6	3.0
May 20	1,428.6	634.2	320.5	463.9	10.0	2,163.1	1,055.0	499.5	594.0	14.6	734.5	420.8	179.0	130.1	4.6
Jun. 28	1,448.5	406.7	391.5	643.2	7.1	2,013.4	815.9	398.3	784.9	14.3	564.9	409.2	6.8	141.7	7.2
Jul. 21	1,388.5	264.0	469.0	648.6	6.9	1,985.5	619.8	566.5	785.4	13.8	597.0	355.8	97.5	136.8	6.9
Aug. 29	1,406.8	288.3	603.0	500.9	14.6	1,999.6	756.0	691.7	537.3	14.6	592.8	467.7	88.7	36.4	0.0
Sep. 28	1,446.8	257.0	350.0	828.4	11.4	2,033.4	783.1	397.5	838.0	14.8	586.6	526.1	47.5	9.6	3.4
Oct. 06	1,453.8	257.6	388.5	799.6	8.1	2,040.2	818.2	396.8	811.2	14.0	586.4	560.6	8.3	11.6	5.9
Nov. 16	1,500.3	197.9	522.0	768.2	12.2	2,013.8	673.8	535.2	789.9	14.9	513.5	475.9	13.2	21.7	2.7
Dec. 06	1,513.1	286.9	616.5	599.0	10.7	2,032.1	779.3	629.4	609.8	13.6	519.0	492.4	12.9	10.8	2.9
Minimum	1,352.5	197.9	112.5	371.1	6.9	1,873.3	619.8	125.3	438.2	13.1	513.5	268.4	6.8	4.6	0.0
Maxmum	1,513.1	746.2	616.5	828.4	14.6	2163.1	1157.2	691.7	838	14.9	734.5	560.6	179	275.8	7.2
Average	1,438.0	442.7	398.2	587.0	10.1	2,010.8	861.2	464.4	671.0	14.2	572.8	418.5	66.2	84.0	4.1

As target year 2025, the daily load curve is assumed under the following conditions:

- As record in 2011, peak load is 25 to 34 % of peak demand.
- From the LTGEP 2013 to 2032, the maximum electric energy and the maximum peak demand are 24,284 GWh and 4,717 MW, respectively.
- As mentioned in the Chapter 3.1.6 (2) power demand in daytime will increase with the development of industry and service sector, it will take time to mature these industries.
- Peak load is 1,320 MW as 28 % of peak power demand, assuming the daily load curve is keeping similar shape as 2011.
- Minimum power demand is 2,000 MW as 44 % of peak power demand.
- Middle peak load is 1,400 MW.

Assumed daily load curve model in 2025 is shown the Figure 4.3-1.

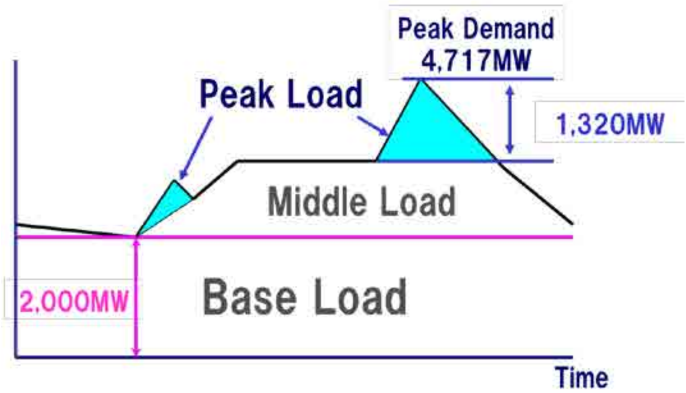

Figure 4.3-1 Daily Load Curve Model in 2025

Since there is no power plant for peak power demand in the LTGEP 2013 to 2032 as already mentioned, the necessary capacity for peak power demand to be developed in future is estimated as follows:

- Only hydropower will supply power for peak load in order to achieve high efficiency of thermal power plants
- Available capacity of hydropower plants for peak load in 2025 is 570 MW (420 MW + 150 MW: UKHP)
- Victoria Expansion (228 MW) will be commissioned before the year 2025.
- Necessary power sources to be newly developed by the year 2025 is about 520 MW (1,320 MW – 570 MW – 228 MW: Victoria Expansion)

It is assessed, from the above, that necessary capacity for peak power demand in 2025 to be developed is 750 MW and the capacity of new project other than Victoria Expansion is about 600 MW (> 520 MW) in consideration of future increment of power demand.

4.4 Constitution of Power Generation in 2025

The composition ratio in 2025 is shown in the Figure 4.4-1 according to the LTGEP 2013 to 2032.

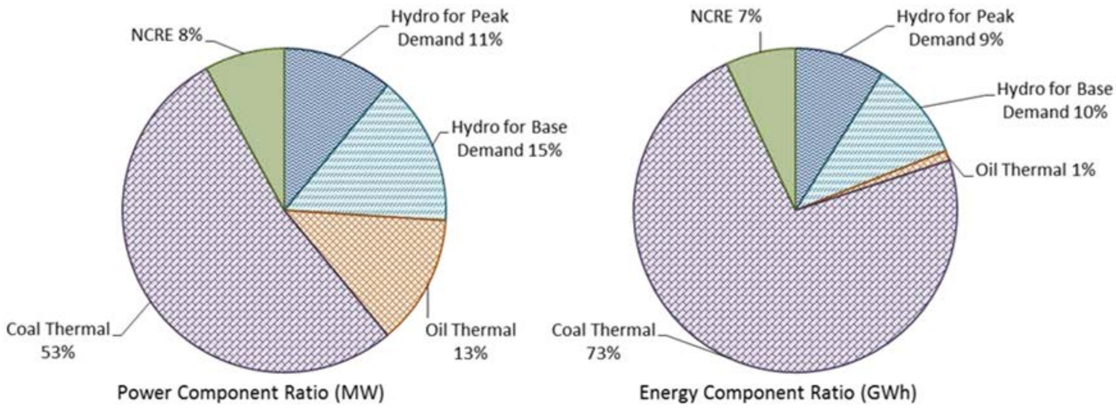

Figure 4.4-1 Composition of Power Generation in 2025

As shown in the figure, the energy constitution ratio of coal fired thermal power plants is around 73 % and large. This is because development of coal fired thermal plants has priority in order to reduce the electricity tariff in Sri Lanka. However, the constitution ratio of coal fired thermal plants is too high from a standpoint of best mix of power source. In this sense, substantial development of power generation for peak power demand is necessary for efficient operation of coal-fired thermal plant of low load following capability.

In 2025, the base load will be supplied by coal-fired thermal plant under currently developing. Their surplus capacity will be for the middle peak load or power source for pumping of pumped storage power plant that will be developed for peak power load or standby power source. Middle peak load will be supplied by existing CEB thermal, IPP thermal, a part of coal-fired thermal plants, and LNG combined cycle power plant though its development schedule is uncertain.

4.5 Commissioning Timing of Power Source for Peak Power Demand

At the present day, the peak load is managed by hydropower plants with reservoir solely used by power generation and petroleum thermal power plants. As shown in the Figure 4.2-1, available power output for peak load is around 65% (about 1,900MW) of total capacity in 2013. It will be reduced 24% (about 1,400MW) in 2025 as shown in the Figure 4.4-1. This phenomenon comes from that there is no development plan of large scale hydropower project with reservoir and retirements of petroleum thermal power plants are increasing. Consequently, the development of substantial amount of power generation for peak demand is required by the year 2025 when the retirement of thermal power plans reaches a peak.

Chapter 5

Long Term Transmission Development Plan and Power System Operation

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Chapter 5 Long Term Transmission Development Plan and Power System Operation

5.1 Status of Power System Operation

5.1.1 Criteria of Power System Operation

Criteria of the power system presently adopted by CEB are as described in this chapter.

(1) Voltage Criteria

The criteria for voltage variation (%) for 220 kV system and 132 kV system are shown in Table 5.1.1-1.

Table 5.1.1-1 Voltage Criteria

Bus Bar Voltage	Allowable Voltage variation[%]	
	Normal Operation Condition	Single Contingency Condition
220kV	±10%	±10%
132kV	±10%	±10%

(Source: LTTDP 2013-2022)

(2) Thermal Criteria

The system should not exceed the capacity for transmission line and transformer of grid substations.

(3) Stability Criteria

The system stability shall be kept even if following accidents/disturbances occurs;

- Three-phase fault at any one overhead line terminal, cleared by the primary protection with successful and unsuccessful auto re-closing
- Loss of a generation unit
- Load rejection by loss of a transformer

The stability analysis as carried out in the Chapter 10 is carried out under two switching sequences given in Table 5.1.1-2.

Table 5.1.1-2 Stability Study Case

Switching Sequence	Steps
I. Successful Re-closing	1. t=0 fault occurs 2. t=120ms fault cleared and circuit tripped 3. t=620ms circuit re-closed with fault
II. Unsuccessful Re-closing	1. t=0 fault occurs 2. t=120ms fault cleared and circuit tripped 3. t=620ms circuit re-closed with fault 4. t=740ms circuit tripped

(Source: LTTDP 2013-2022)

(4) Short Circuit Criteria

The short circuit criteria limit the maximum three-phase fault currents at the bus-bars of any grid substations as shown in Table 5.1.1-3.

Table 5.1.1-3 Allowable Maximum 3 ϕ Short Circuit Levels

Bus-bar voltage	System	Maximum three-phase fault level (kA)
132kV and above	Over head	40.0
	Underground cable	40.0
33kV	Over head	13.1
	Underground cable	16.0
11kV	Underground cable	20.0

(Source: LTTDP 2013-2022)

(5) System Frequency Criteria

The system frequency shall be within 50Hz±1% under normal operations. If the system frequency drops due to faults, the load shedding shall be taken place to keep the system in stable until the system frequency can be recovered within 50Hz±1%. Load shedding scheme for frequency drops are shown in Table 5.1.1-4.

Table 5.1.1-4 Load Shedding Scheme for Frequency Drops

Stage	Target Frequency (Hz)	Break Time	Load Shedding
I	48.75Hz	100ms	5.00%
II	48.50Hz	500ms	5.00%
III	48.25Hz	500ms	10.00%
	49Hz AND df/dt<-0.85Hz/s	100ms	3.00%
IV	48.00Hz	500ms	10.00%
	49Hz AND df/dt<-0.85Hz/s	100ms	3.00%
V	47.50Hz	instantaneous	10.00%
	49Hz AND df/dt<-0.85Hz/s	100ms	4.00%
VI	49Hz AND df/dt<-0.85Hz/s	100ms	10.00%

(Source: CEB System Control Center (As of June 2013))

(6) Spinning Reserve

Spinning Reserve for CEB should be kept more than 5%.

5.1.2 Status of Power System Operation

(1) Outline

Colombo City which is the largest city in Sri Lanka is the demand center of this country. Demand of Colombo metropolitan area occupied around a half; 1,009MW, of the total demand in Sri Lanka; 2,143MW in 2012.

The main power sources of this country are generally composed of thermal power plants located around Colombo metropolitan area (gas turbines, combined cycle and oil plants output around 1,300MW), hydro power plants in central high land area (output: 1,300MW), and thermal power plants North West area (coal, diesel, output: 400MW).

In the rainy season, the rate of power generation by hydro power plants is likely to be high; accordingly, the large part of generated power by hydro power plants in central high land is to be supplied to Colombo metropolitan area through 220kV T/L between Kotmale P/S plant and Biyagama G/S. As such, it is supposed that those lines are exposed heavier electricity flows during peak time.

(2) Possible Concerns for Power System Operation

Possible concerns with power system operation are shown below. Countermeasures should be taken in the future.

- Voltage drops and over load of lines in and around Colombo metropolitan area under the normal state, especially in one line outage. Voltage drop is heavily dependent on the generation scenario.
- Voltage drops at New Anuradhapura GS 220kV bus-bars, Trincomalee GS and Valanchenai 132kV bus-bars in Eastern area under one line outage
- There may exist cases that Randeniga - Rantambe transmission line is overloaded under hydro maximum generating state in central highland area. Especially this occurs when the generation of Laxapana and Samanalawewa plants is low. Outage of that line would cause voltage collapse. As one of the countermeasures against such critical voltage drop, Hydro powers in Laxapana complex should be operated with their maximum generation level.

Concerns above-mentioned are illustrated in Figure 5.1.2-1

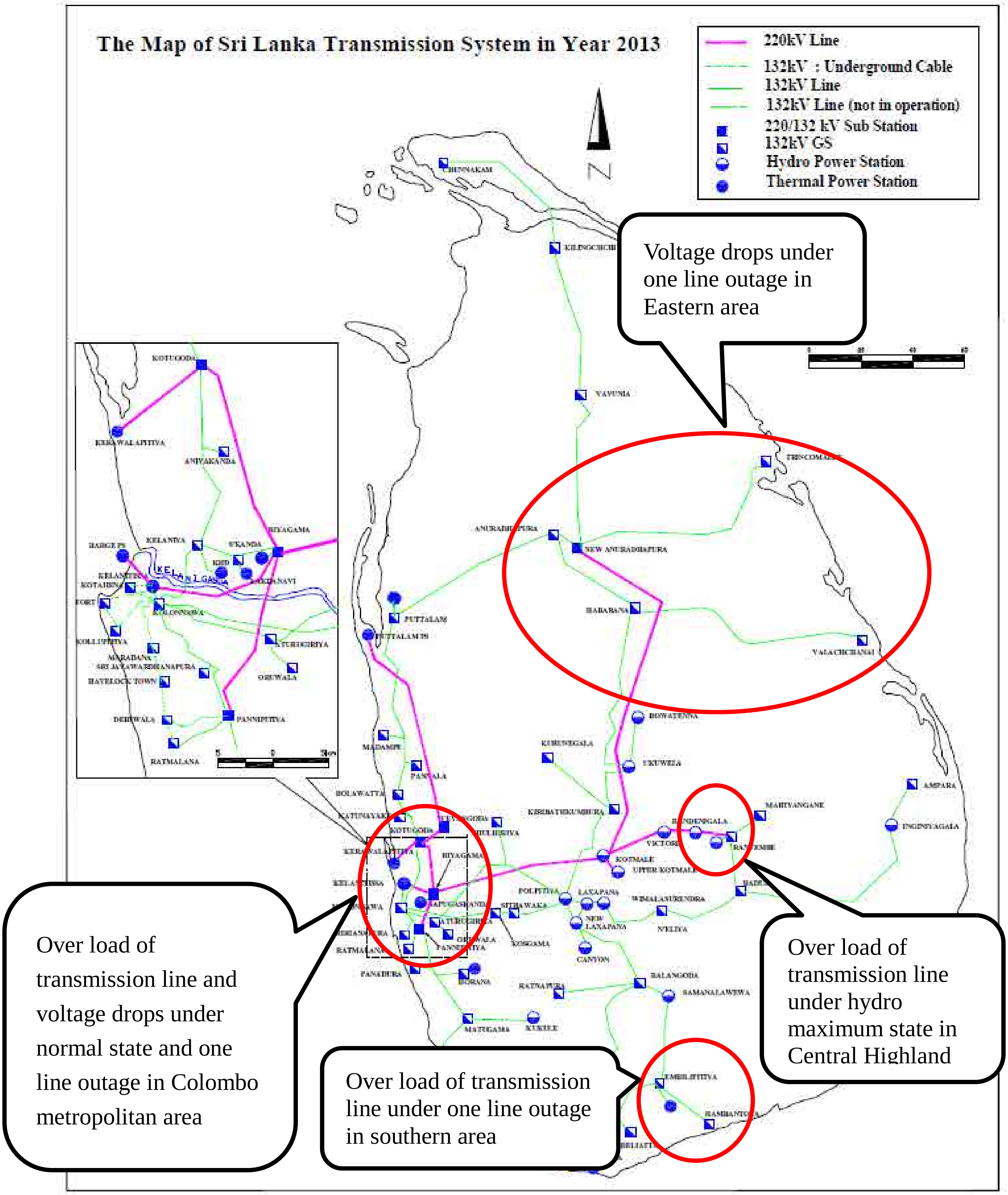


Figure 5.1.2-1　The Current Problem of Power System in Sri Lanka

(3) System Frequency Operation

Presently, the system frequency is controlled automatically with free governor mode operations of units. However, the system frequency which is insufficient to control with free governor mode operations has to be controlled manually by one generator of hydro power plants, such as Victoria

P/S, Kotmale P/S, Samanalawera P/S, and New Laxapana P/S following to orders from the system control center.

The list of power plants can be operated with a free governor mode is shown below.

Table 5.1.2-1 Power Station Operating with Free Governor Modes

Plant Name	Classification	Capacity(MW)
Victoria	Hydro	210
Kotmale	Hydro	201
Upper Kotmale	Hydro	150
Samanalawera	Hydro	120
AES	C.C.	163
WCP	C.C.	270

(Source: CEB System Control Center)

However, in case that several coal fired thermal plants are developed in the future as planed in LTGEP, the present facilities in the network will not be able to sustain frequency stability in years, and additional facilities to manage/absorb surplus energy in the off-peak will be required to be installed.

Adjustable speed pumped storage units can take the frequency control ability and the surplus power absorption ability in off-peak time, which is capable to control the network frequency in a pumping mode as well as in a generating mode and also has a wider adjustable range for generating output and pumping input than the conventional units.

In this regard, it is recommended that functions of the central dispatch center should be enhanced so as to make appropriate orders to various plants in a moment to keep the network in stable. In the network, some plants, which have frequency control ability, are operated not only to supply power but to keep network frequency in stable. In order to use adjustable speed pumped units effectively, the central dispatch center has a capability to grasp current operation status of each unit in the network; especially affordable ability for frequency controlling such as reservoir water level of hydro power plants. Necessary correction to keep the frequency in stable and allocation of roles of each unit are calculated based on such current status of each unit, and appropriate orders are sent to each unit from the central dispatch center.

5.2 Status of Long Term Transmission Development Plan

5.2.1 Outline of Long Term Transmission Development Plan

Considered that countermeasures against possible concerns of the present power system as mentioned in the sub-chapter 5.1, establishment of the optimal power system based on the Long Term Generation Development Plan is needed. In Long Term Transmission Development Plan (2013-2022), the development plan is studied in detail up to 2022 and the preliminary development plan is studied up to 2032.

The list of transmission lines and substations proposed up to 2022 are shown in Table 5.2.1-1.

Table 5.2.1-1 Transmission and Substation Expansion Proposals up to 2022

Sub Station	Transmission Line & Under Ground Cable
400kV New Habarana	400kV Sampoor – New Habarana (95km)
220kV Kappalthurei	400kV Ambalangoda – Padukka (75km)
220kV New Polpitiya	220kV New Habarana – Veyangoda (148km)
220kV Vavunia	220kV Kotmale – New Polpitiya (23km)
220kV Padukka	220kV Veyangoda – Kirindiwera (18km)
220kV New Chailaw	220kV New Polpitiya – Padukka (41km)
220kV Kilindiwera	220kV Kerawalpitiya – Port (14.9km)
220kV Port	220kV New Anuradhapura – Puttalam (100km)
132kV Chemmany	220kV Kirindiwera– Padukka (20km)
132kV Mannar	220kV Vavunia – New Anuradhapura (55km)
132kV Eluwankulama	220kV Pannipitiya – Padukka (18km)
132kV Maho	132kV Mannar – Vavunia (75km)
132kV Polonnaruwa	132kV Puttalam – Maho (42km)
132kV Naula	132kV New Chilaw – Madampe (7km)
132kV Madampe	132kV Ampara – Akkaraipattu (25km)
132kV Vavunativu	132kV Umaoya – Badulla (25km)
132kV Akkaraipattu	132kV Ampara – Vavunativ (50km)
132kV Nawalapitiya	132kV Ampara – Mahiyange (97km)
132kV Monaragala	132kV Monaragala – Badulla (32.5km)
132kV Wellawaya	132kV Monaragala – Inginitagala (47.5km)
132kV Wewalwatta	132kV Suriyawewa – Embipitiya (22km)
132kV Suriyawewa	132kV Suriyawewa – Hambantota (31km)
132kV Tissamaharama	132kV Galle – Ambalangoda (36km)
132kV Port City	132kV Pettah – Kotahena (2km)
132kV Slave Island	132kV Kelanitissa – Kotahena (2km)
132kV Wellawatta	132kV Kolonnawa – Pettah (4km)
132kV Colombo K	132kV Port – Slave Islamd (3.2km)
132kV Battaramulla	132kV Port – Fort (1.2km)
132kV Oruwala	132kV Fort – Hunupittiya (2.4km)
132kV Pettah	132kV Wellawatta – Kollupittiya (6.5km)
132kV Hunupitiya	132kV Wellawatta – Pannipitiya (14.1km)
	132kV Hambantota – Tiswsamaharama (22km)
	132kV Athurugiriya – Oruwala (3.4km)
	132kV Padukka – Athurugiriya (13km)
	132kV New habarana – Naula (37km)
	132kV Naula – Ukuwela (45km)
	132kV Colombo K – Dehiwala (6km)
	132kV Colombo K – Havelock Town (7km)

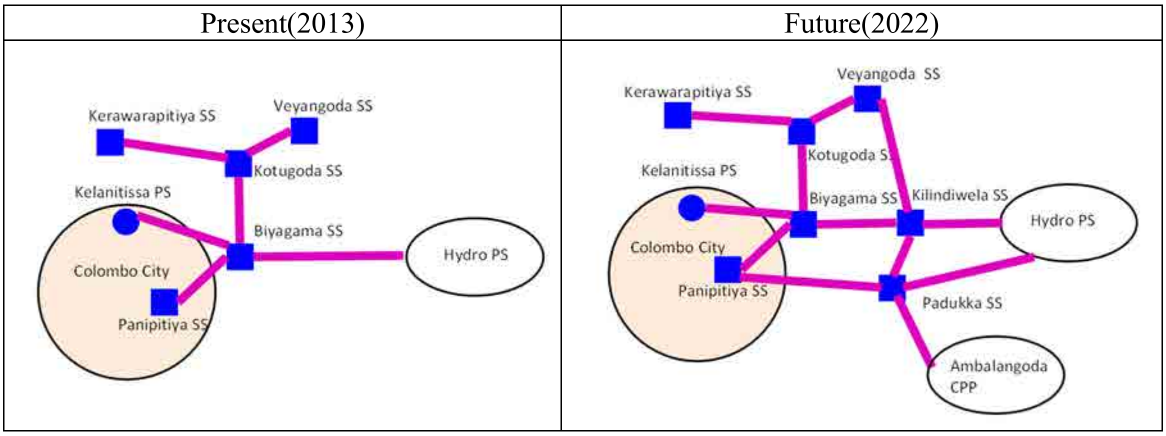
(Source: LTTDP)

5.2.2 Power Supply Measures for Metropolitan Area

As mention in the sub-chapter 5.1.2, possible concerns are supposed as voltage drops and over load of transmission line in the metropolitan area. Also, Biyama GS is only 220kV substation which receives power to from main plants area. Then, power is distributed to the main grid substations in the metropolitan area. Under this situation, even if a fault occurs at Biyagama GS, such as a bus fault, power supply to the metropolitan area has to be limited significantly. In order to avoid such serious situation, expansion of transmission lines and substations as mentioned below are planned in LTTDP by 2022 , which seems to be effective. Figure 5.2.2-1 shows the expansion plan of the transmission lines and the substations around the metropolitan area.

- Construction of 2nd rout from the metropolitan area to hydro power plants of the central highland
- Construction of 400 kV (Padukka) substation, 220kV (Kilindiwela) substations as trunk substations

The differences of the power system in the metropolitan area between 2013 and 2022 are shown in Figure 5.2.2-1.



(Source: LTTDP)

Figure 5.2.2-1 Power System for Metropolitan Area

5.2.3 Long Term Transmission Development Plan to LTGEP

According to Long Term Generation Expansion Plan (LTGEP 2013-2032), the main plants installed in the future are the coal fired power plants. New installation of 2,300MW is proposed up to 2022, which includes following 3 plants.

- Puttalam: 900MW (Installation of 600MW) North Western Area
- Sampoor: 800MW Eastern Area
- Ambalangoda: 900MW Southern Area

Power generated by above power plants will be supply to the metropolitan area. Therefore, the power system expansion should be planned considering the generation expansion plan.

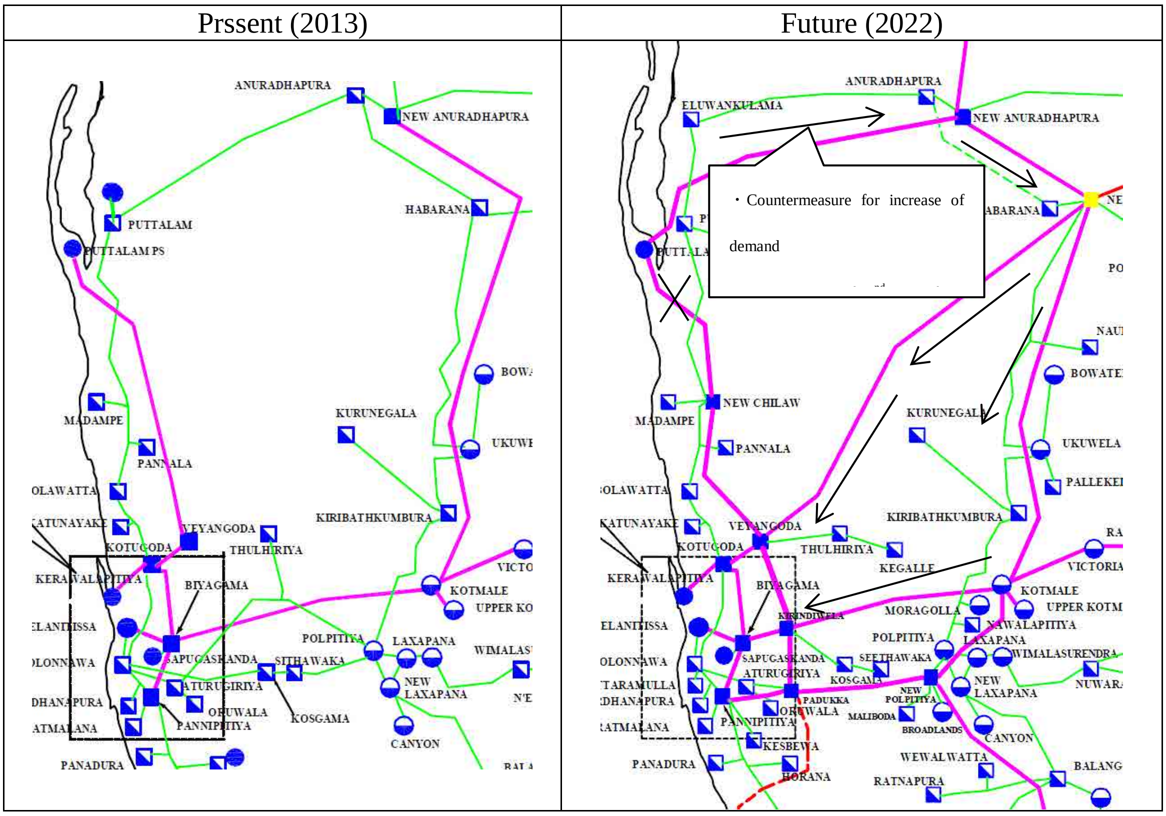
(1) Puttalam: 900MW North Western area

There is a route from Puttalam to the metropolitan area (Puttalam - Veyangoda 220kV transmission line) at present. However, according to Long Term Transmission Development Plan 2013-2022, the second route from Puttalam – New Anuradhapura will be constructed.

Even if one rout failure occurs, power can be supplied to the metropolitan area by remaining transmission line, and it is thought to be useful to avoid a supply failure.

Also, it can be useful for increased demand in Northern Area.

The difference of the power system in 2013 and in 2022 are shown Figure 5.2.3-1.



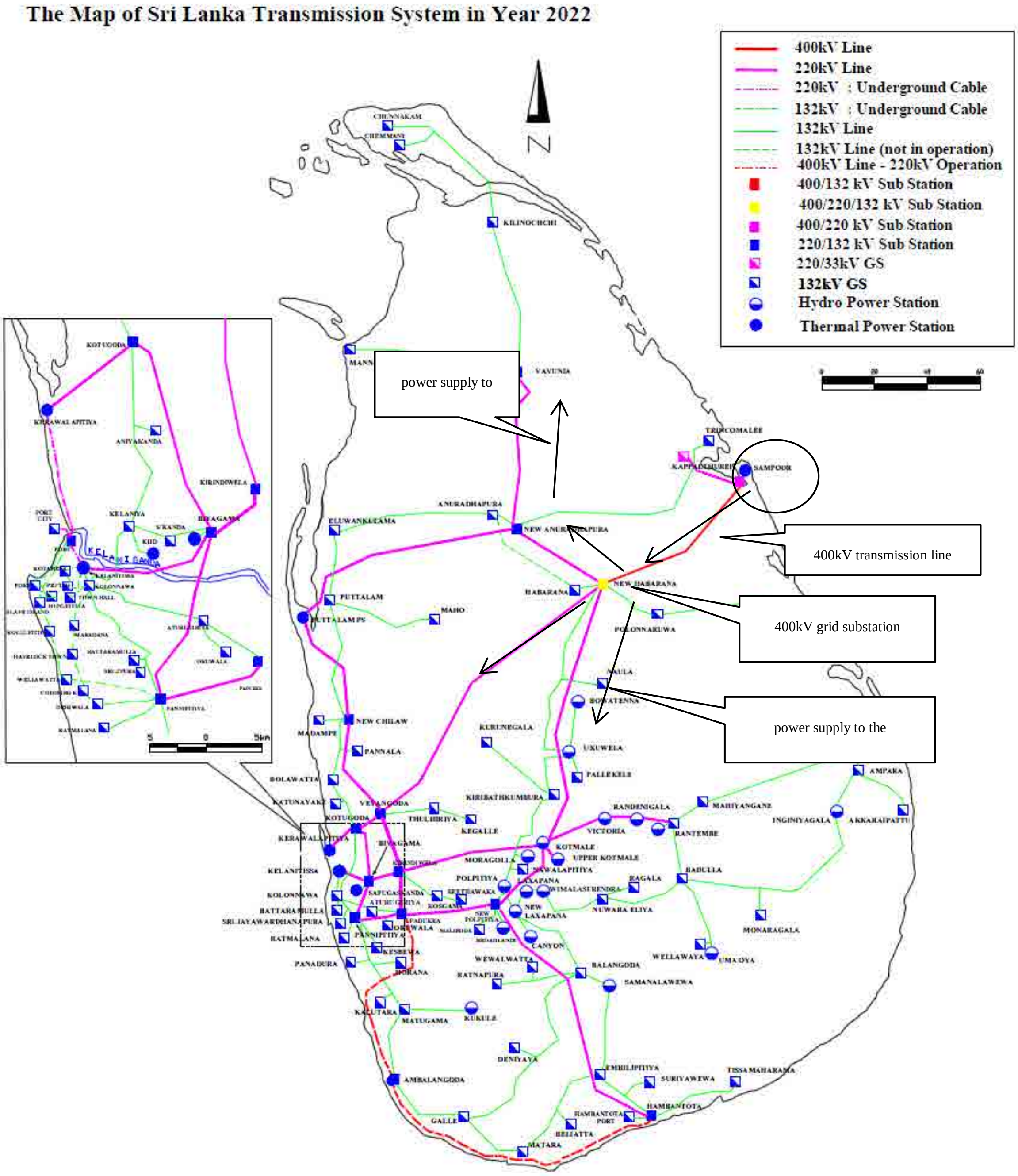
(Source: LTTDP)

Figure 5.2.3-1 Difference of Power System due to Installation of Puttalam between 2013 and 2022

(2) Sampoor: 800MW Eastern Area

Construction of Sampoor coal power plant (capacity: 800MW) is proposed in the eastern area at present up to 2022. Corresponding to this plan, construction of 400kV substation; New Habarana, and 400kV transmission line from Sampoor to Habarana are proposed. It is thought that 400kV transmission line from Sampoor to New Habarana is useful to avoid over load even under one line outage.

Electric power generated at Sampoor will mainly be supplied to the metropolitan area and the northern area via the said transmission line and substation.



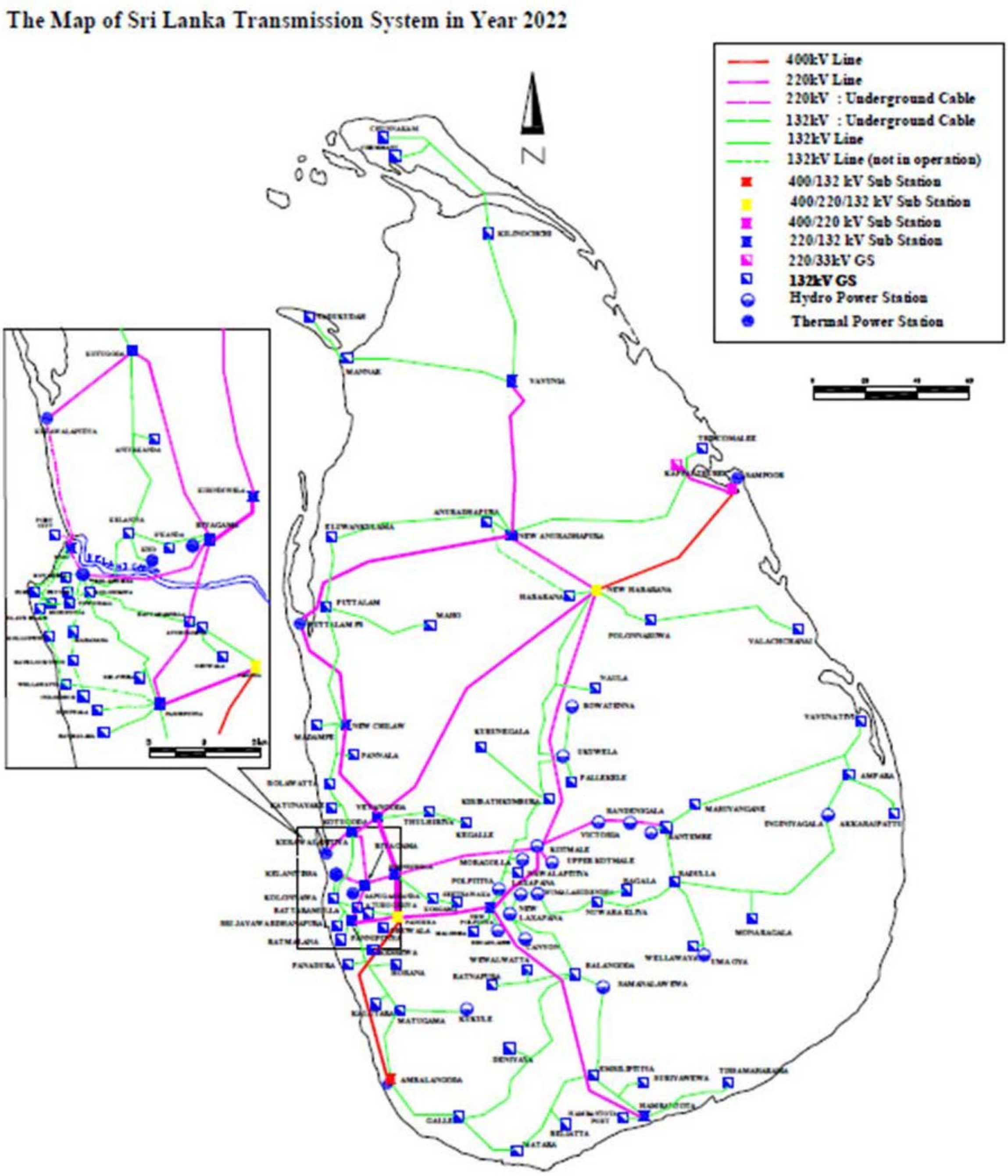
(Source: LTTDP)

Figure 5.2.3-2 Transmission and Substation Expansion due to Installation of Sampoor

(3) Ambalangoda: 900MW Southern Area

Construction of Ambalangoda coal power plant (capacity: 900MW) is proposed in the southern area at present up to 2022. Corresponding to this plan, construction of 400kV transmission line, from Ambalangoda to Padukka is proposed.

Also, according to LTGEP, in 2032, Hambantota coal power plant is planned to be constructed at approximately 150km east of Ambalangoda. Since the power flow at this line to the metropolitan area will be heavy, it is operated at 400kV.



(Source: LTTDP 2013-2022)

Figure 5.2.3-3 Transmission and Substation Expansion due to Installation of Ambalangoda

5.2.4 India - Sri Lanka Interconnection

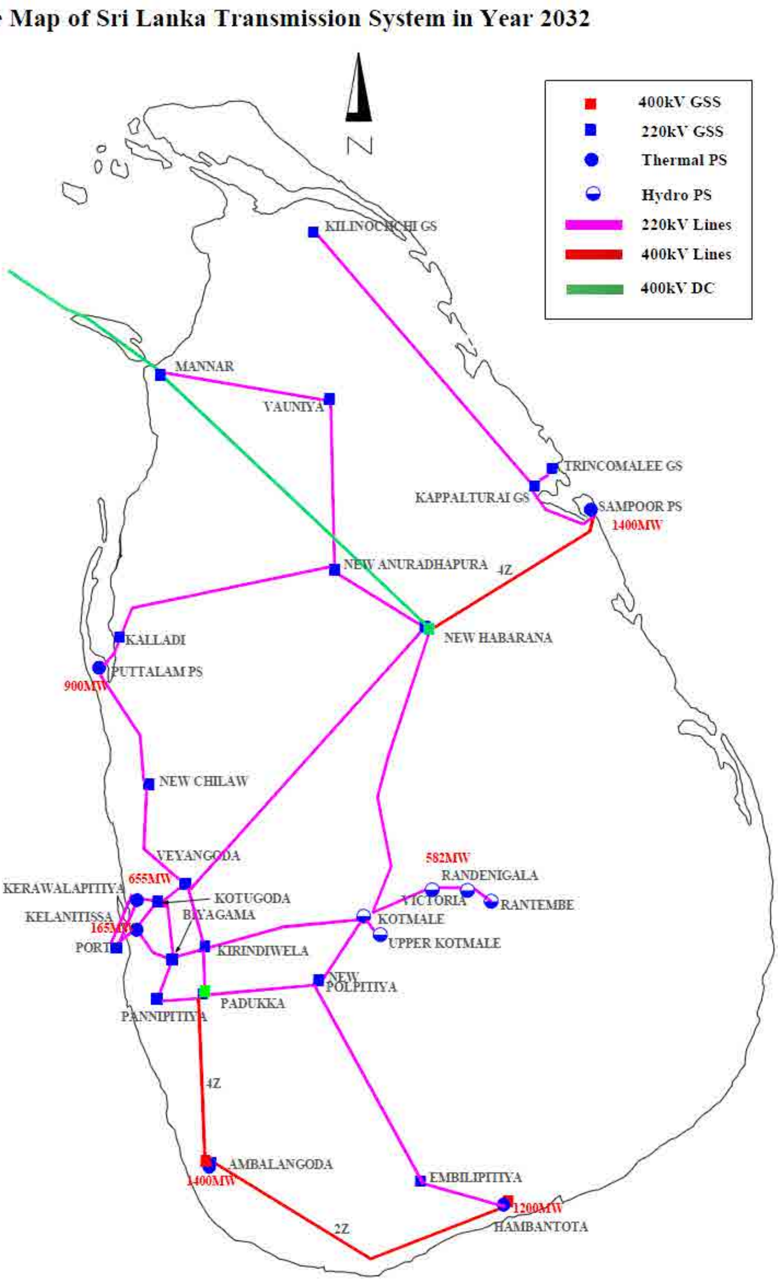
India - Sri Lanka interconnection with High-voltage direct current (HVDC) transmission line has been studied on preliminary basis. According to LTGEP 2013-2032, 500MW transmission connection is considered as 1st stage and it is to be expanded up to 1,000MW later stage.

According to LTGEP, total installed capacity of coal fired thermal power plants is to be 4,900MW in

2032. Even if the coal power plants are operated with their minimum output, surplus power cannot be avoided in the off-peak time. Also, since coal power plants take a role of the base power supply, the efficiency of generation would be low in case of partial load operation.

As one of countermeasures for surplus power at off-peak time, India - Sri Lanka interconnection is aiming to keep balance between the demand and the supply to connect the larger Indian power system.

Also, it seems to be reasonable to study on HVDC system for India – Sri Lanka interconnection line because the cost of HVDC system is generally competitive compared to that of AC system if the length of submarine cable is from 30 to 50km.



(Source: LTTDP)

Figure 5.2.4-1 India - Sri Lanka Interconnection

Chapter 6

Environmental and Social Considerations

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Chapter 6 Environmental and Social Considerations

6.1 General Information on Environmental and Social Conditions in Sri Lanka

6.1.1 Physical Features[1]

Sri Lanka is an island located at the south east of the Indian sub-continent, between 5° 54' and 9° 52' North and 79° 39' and 81° 53' East. Its land area is 65,610 km^2.

The island consists of a south central mountainous region with an elevation of 2,500 m above sea level, surrounded by broad lowland plains at an elevation of 0 - 75 m. From the mountainous region nine major rivers and 94 other rivers drain across the lowlands into the Indian Ocean.

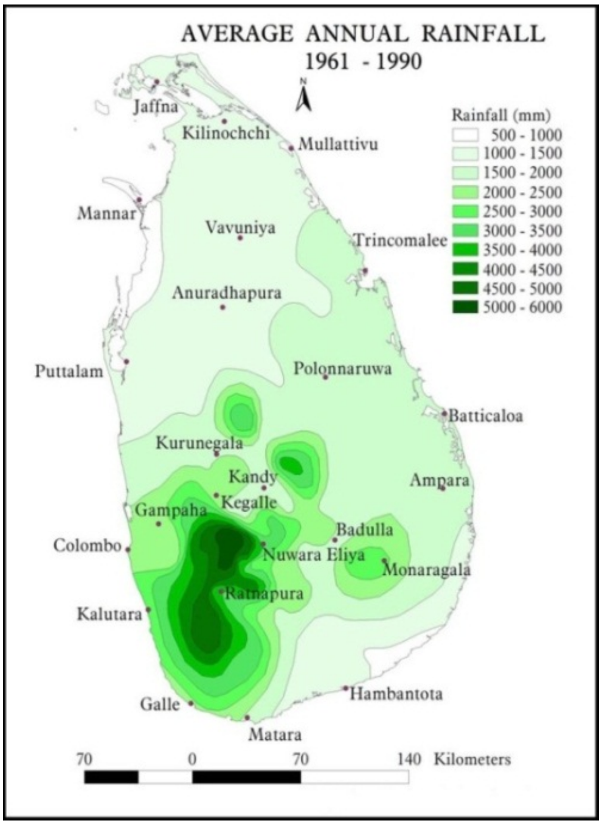
Sri Lanka is in the equatorial and tropical zone, and it is influenced by the monsoons. North-east monsoon brings rain in the northern and eastern regions in December and January while the western, southern and central regions of the island get rain from May to July due to the south west monsoon.

The country is generally divided into three climatic regions the wet zone, dry zone and intermediate zone. Its south-west area is in moist climate (wet zone), the area from north-east to south-east is in dry climate (dry zone), and the middle area (hills and mountains) is in the intermediate climate (intermediate zone).

The rainfall shows seasonal fluctuations and is dependent on the southwest and northeast monsoons and on convectional and cyclonic effects. The mean temperature in the lowland areas is 27°C in the wet region and 30°C in the dry zone. It decreases with increase in altitude, and in the montane region the mean monthly temperature varies from 13°C to 16°C, with the night temperature occasionally dropping to around zero.

Figure 6.1.1-1 shows average annual rainfall in the country.

[1] The information of this section are from Biodiversity Conservation in Sri Lanka – A Framework for Action (Ministry of Forestry and Environment, 1999), Climate Change Secretariat, Ministry of Environment, Sri Lanka web site: http://www.climatechange.lk/ccs_index.html, and Central Bank of Sri Lanka Annual Report 2013.



(Source: Climate Change Secretariat, Ministry of Environment, Sri Lanka)

Figure 6.1.1-1 Average Annual in Sri Lanka

6.1.2 Ecosystems in Sri Lanka

(1) General

The Ministry of Forestry and Environment[2] identifies, in Sri Lanka, four major groups of ecosystems, which are further divided into various ecosystems (Table 6.1.2-1). Figure 6.1.2-1 shows the vegetation map of Sri Lanka.

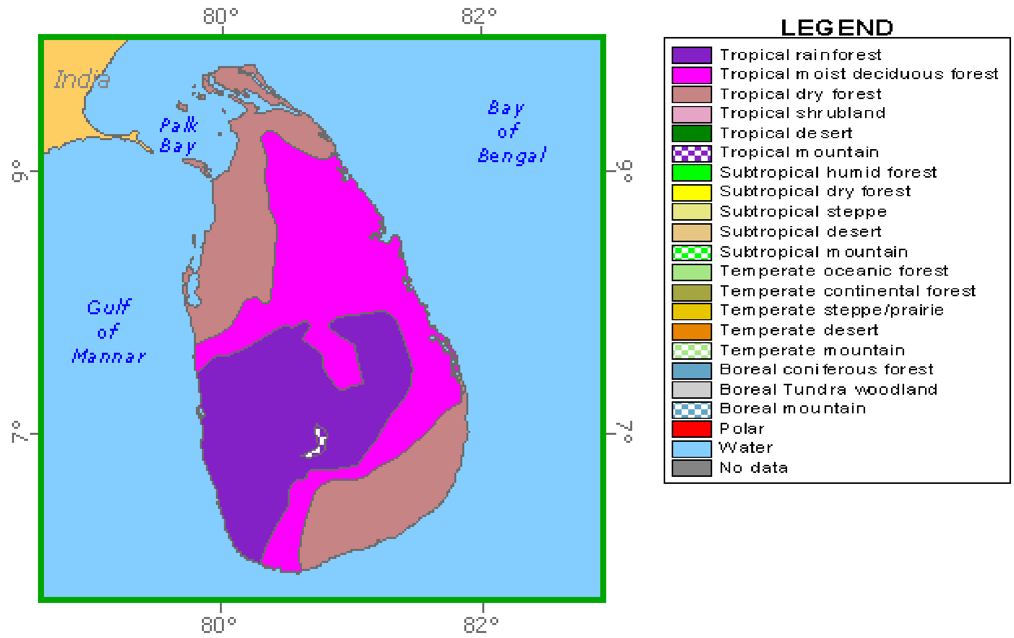
Table 6.1.2-1 Ecosystem Diversity in Sri Lanka

Group	Ecosystems
Forest and related ecosystems	• Tropical wet evergreen forest (lowland rain forest) • Tropical moist evergreen forest • Tropical dry mixed evergreen forest • Tropical thorn forest • Savannah • Riverine forest • Tropical sub montane forest • Tropical montane forest • Dry montane grasslands dry patanas
Inland wetland ecosystems	• Flood plains • Swamps • Streams and rivers • Reservoirs and ponds

[2] Biodiversity Conservation in Sri Lanka – A Framework for Action (Ministry of Forestry and Environment,1999).

Group	Ecosystems
	• Wet Villu grasslands • Wet montane grasslands wet patanas
Coastal and marine ecosystems	• Mangroves • Salt marshes • Sand dunes and beaches • Mudflats • Seagrass beds • Lagoons and estuaries • Coral reefs • Coastal seas
Agricultural ecosystems	• Paddy lands • Horticultural farms • Small crop holdings or other field crops (pulses, sesame etc.) • Crop plantations • Home gardens • Chena lands (slash and burn cultivation)

(Source: Biodiversity Conservation in Sri Lanka – A Framework for Action (Ministry of Forestry and Environment, 1999).)



(Source: FAO Country Profiles: Sri Lanka)

Figure 6.1.2-1 Vegetation Map of Sri Lanka

Forest and related ecosystems[3]: Among those ecosystems, wet zone rainforests (lowland, sub-montane and montane) are exceptionally rich in biodiversity. The most important areas for the wet zone rainforests are the Peak Wilderness Sanctuary, the Kanneliya-Dediyagala-Nakiyadeniya Reserve, the Sinharaja Forest, the Knuckles Range of Forests, and the Horton Plains National Park.

[3] Information on "Forest and related ecosystems", "Inland wetland ecosystems" and "Coastal and marine ecosystems" and part of "Agricultural lands" are from Biodiversity Conservation in Sri Lanka – A Framework for Action (Ministry of Forestry and Environment,1999).

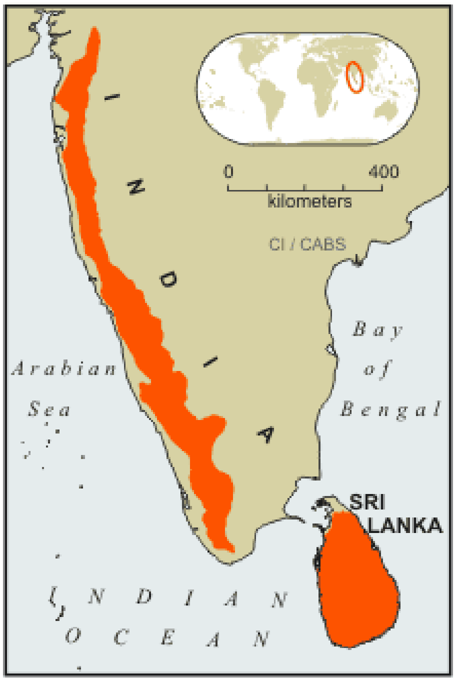
Inland wetland ecosystems: Rivers and streams especially in and from the wet zone forests hold indigenous freshwater fish. Artificial reservoirs – tanks – in the lowland plains are home of fish species. Wet patanas in the montane area are unique in the wetland flora. The coastal wetlands are important especially for birds including migratory species.

Coastal and marine ecosystems: Among them, coral reefs are rich in biodiversity and provide key habitats for flora and fauna.

Agricultural lands: Agricultural lands such as rubber, tea plantations and paddy fields can be habitats for number of species. For example, tea plantations harbor a community of birds[4]. Sri Lanka also is known as holding high crop biodiversity.

(2) Biodiversity Hotspot

Conservation International, international nature conservation NGO, identifies areas with high biodiversity and needs of urgent conservation actions as "Biodiversity Hot Spots". Sri Lanka belongs to one of the Hot Spots, "Western Ghats & Sri Lanka", which means that it is necessary to pay high attentions to the nature conservation and to take appropriate actions to conserve all ecosystems and species including common species in the country. One of the threats to the hot spot is the fragmentation of its forest. In Sri Lanka, only 1.5 % of the original forest remains[5].



(Source: Conservation International)

Figure 6.1.2-2 Western Ghats & Sri Lanka Hot Spot

[4] Birds of Sri Lanka (Deepal Warakagoda, Carol Inskipp, Tim Inskipp and Richard Grimmett, 2012).
[5] Conservation International web site.
http://www.conservation.org/where/priority_areas/hotspots/asia-pacific/Western-Ghats-and-Sri-Lanka/Pages/default.aspx

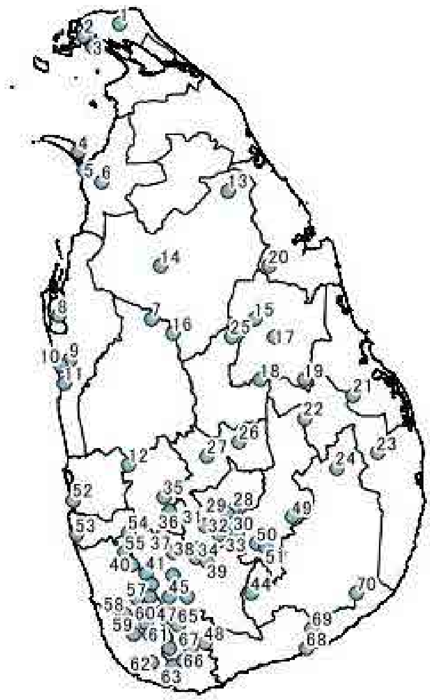
(3) Important Bird Areas[6]

BirdLife International, international bird conservation NGO, has identified "Important Bird Areas (IBAs)" in the world (including Sri Lanka) since the areas usually have one (or more) of the following features:

- Significant numbers of one or more globally threatened species;
- One of a set of sites that together hold a suite of restricted-range species or biome-restricted species ; and,
- Exceptionally large numbers of migratory or congregating species.

IBAs are considered to be key sites for conservation – small enough to be conserved in their entirety and often already part of a protected area network in the concerned country.

Sri Lanka has 70 IBAs (Figure 6.1.2-3) and the list of them is attached as Appendix 6.1.



(Source: Important Bird Areas in Asia: key sites for conservation (BirdLife International, 2004)).
The map is prepared by the Study Team.

Figure 6.1.2-3 Important Bird Areas in Sri Lanka

6.1.3 Current Status of Species

(1) Endangered species

Sri Lanka is part of one of the Biodiversity Hotspots as described in the previous lines. Its high biodiversity can be derived from a wide variety of climatic, topographic and soil conditions that has resulted in a diverse array of aquatic and terrestrial habitats and also from its zoogeographic

[6] BirdLife International web site. http://www.birdlife.org/action/science/sites/

features – history of the continental drift and the eventual separation from the Indian continent[7].

Many of its fauna and flora are now facing risk of extinction because of increase of human population, and decrease and fragmentation of its forests. In 2007, the International Union for Conservation of Nature (IUCN) with the Government of Sri Lanka published “The 2007 Red List of Threatened Fauna and Flora of Sri Lanka”. In 2012, the Ministry of Environment updated the data and revised it as “The National Red List 2012 of Sri Lanka – Conservation Status of the Fauna and Flora”.

Table 6.1.3-1 ~ Table 6.1.3-5 summarize the contents of the Red List 2012.

The Red List 2012 identifies that habitat degradation and loss such as deforestation is one of the major threats to the all taxonomic groups and that the wet zone (lowland to montane area) of the south- western corner of the country is one of the most important areas for all the taxonomic groups. It also states that most of the information currently available for the fauna and flora of the country is on higher plants or vertebrates which make up only about 3 % all species described to date. It indicates that there is a big gap between the current information and the real status of the fauna and flora.

Table 6.1.3-1 Red List of Faunal Species of Sri Lanka

Taxonomic group	Critically Endangered	Critically Endangered possibly extinct	Endangered	Vulnerable	Total number of threatened species	Total number of species
Spiders	41 (14)	-	21 (10)	-	62 (24)	501 (257)
Freshwater crabs	34 (34)	-	12 (11)	-	46 (45)	51 (50)
Dragonflies	26 (22)	-	18 (14)	17 (4)	61 (40)	118 (47)
Ants	25 (5)	-	18 (3)	16	59 (8)	194 (33)
Bees	48	-	38	20	106	130
Butterflies	21 (5)	-	38 (10)	40 (7)	99 (22)	245 (26)
Land snails (excluding 21 not evaluated)	80 (70)	-	76 (72)	23 (20)	179 (162)	253 (205)
Freshwater fish	19 (16)	2 (2)	19 (17)	5 (4)	45 (39)	91 (50)
Amphibians	34 (34)	1 (1)	28 (27)	10 (9)	73 (71)	111 (95)
Reptiles (including marine species)	38 (36)	1 (1)	50 (39)	18 (11)	107 (87)	211 (124)
Birds	18	-	18 (7)	31 (11)	67 (18)	240 (27)
Terrestrial mammals	13 (6)	-	25 (8)	15 (4)	53 (18)	95 (21)

Numbers with brackets indicate endemic species.

Critically Endangered possibly extinct is defined as “species with no distribution records in last 60 years”. Total number of threatened species means the total number of Critically Endangered, Endangered and Vulnerable species.

(Source: The National Red List 2012 of Sri Lanka – Conservation Status of the Fauna and Flora (Ministry of Environment, Sri Lanka, 2012))

[7] The National Red List 2012 of Sri Lanka - Conservation Status of the Fauna and Flora (Ministry of Environment, Sri Lanka, 2012).

Table 6.1.3-2 Red List of Floral Species of Sri Lanka

Taxonomic group	Critically Endangered	Critically Endangered possibly extinct	Endangered	Vulnerable	Total number of threatened species	Total number of species
Pteridophytes	42 (10)	21 (5)	88 (11)	70 (12)	200 (33)	336 (49)
Angiosperms	218 (1029	177 (72)	552 (272)	615 (220)	1,385 (594)	3,154 (894)
Gymnosperms	1	-	-	1	2	-

Numbers with brackets indicate endemic species.

Critically Endangered possibly extinct is defined as “species with no distribution records in last 60 years”. Total number of threatened species means the total number of Critically Endangered, Endangered and Vulnerable species.

(Source: The National Red List 2012 of Sri Lanka ‐ Conservation Status of the Fauna and Flora (Ministry of Environment, Sri Lanka, 2012))

Table 6.1.3-3 Summary of the Status of Each Taxonomic Group

Taxonomic group	Distribution in Sri Lanka	Threats	Conservation
Dragonflies	➢ Majority of the common Oriental species are found in tanks (reservoirs) in the dry zone. ➢ One species is restricted to the coastal areas. ➢ Several other common species are widespread in the wet lowlands and mid-hills, in marshes, streams and seeps. ➢ A few species are restricted to the higher elevations. ➢ The endemics tend to localized to specialized habitats within wet zone rainforest.	➢ Deforestation ➢ Water pollution ➢ Changes in water sources	➢ Enforce existing conservation measures in protected areas ➢ Establish new protected areas in the wet zone and montane areas ➢ Legislate additional protection for streams, rivulets and forest corridors in the wet zone ➢ Restore already degraded areas in key locations ➢ Limit agricultural expansion in forest areas ➢ Enforce existing legislation regarding corridors and reservations ➢ Conduct comprehensive faunisitic work
Ants	➢ *No detailed information due to lack of data.*	➢ Lack of ground vegetation and leaf litter in cultivated lands ➢ Setting fire to land before cultivating or to promote grass growth in pasture lands	➢ Conduct awareness programme on the ecological and economic (where applicable) importance of the species ➢ Identify and protect habitats that do not come within protected area network.
Butterflies	➢ Many species are generalists and occur in a range of climatic zones. ➢ Few species have a very local and restricted distribution.	➢ The most significant threat is the disappearance and degradation of forest, grassland and coastal habitats due to human activity.	➢ Conduct comprehensive research on the group especially on the endangered and critically endangered species.
Spiders	➢ Endemic Sri Lankan spiders are confined mostly to the intact natural forest remaining in the south-west and central highlands.	➢ Forest disappearance and degradation ➢ Utilization of pesticide	➢ Identify the key habitats necessary for spider conservation and draw up a plan to protect them especially in natural ecosystems of the wet zone. ➢ Regulate pesticide.
Freshwater crabs	➢ Nearly half the freshwater crabs (23 species) are point endemics. ➢ 80 % of the crabs (41 spp.) are restricted to the wet zone.	➢ Invasive alien species ➢ Influx of fertilizer and pesticide, local climate change ➢ Loss of forest cover due to encroachment and illegal timber extraction	➢ Conduct a national survey to identify key habitats for conservation attention. ➢ Monitor at least critically endangered species. ➢ Maintain water quality of their habitats. ➢ Introduce legal and institutional reforms necessary to engage local communities in the in situ conservation of point-endemic species. ➢ Promote awareness programmes to conserve the

Taxonomic group	Distribution in Sri Lanka	Threats	Conservation
			group.
Land snails	➢ Five endemic genera and their species show discontinued distribution and are restricted to few specific habitats in the wet and southwestern portion of the island. ➢ Lowland rainforest zone and the montane rainforest zone have distinctive snail faunas.	➢ Habitat loss (fragmentation and clearance of forest floor) ➢ Frequent fire in the grasslands, scrublands and forests ➢ Utilization of agrochemicals	➢ Conserve effectively the remaining rainforest fragments in the lowland rainforests of wet zone and the montane forests. ➢ Conduct research on the group. ➢ Develop plans for population restoration of endemic and relict species that are facing extinction due to habitat loss ➢ Establish strict regulation to control the entry of exotic land snails to the country. ➢ Carefully control the spread of predatory gastropods. ➢ Promote awareness programmes to conserve the group.
Freshwater fishes	➢ South Western and Mahaweli zones support the highest diversity in freshwater fish. ➢ Number of species are only known from a single location (point endemics). ➢ Some species are only known from a single river basin. ➢ Most of the threatened or endemic species are found in streams outside the protected area network.	➢ Habitat loss ➢ Invasive alien plant species ➢ Water quality ➢ Agrochemicals ➢ Invasive alien fish species ➢ Aquarium trade ➢ Destructive fishing techniques	➢ Protect habitats of threatened or endemic species that occur outside the protected area network, especially their catchment areas. ➢ Carefully establish and implement ex situ breeding programmes.
Amphibians	➢ The vast majority of the amphibians are restricted to the south western wet zone quarter of the island.	➢ Habitat loss ➢ Utilization of pesticide ➢ Erosion from sloping lands ➢ Acid rain (?)	➢ Conduct comprehensive research on the group including its habitats.
Reptiles	➢ The majority of the endemic and threatened reptiles are restricted to the lowland and montane forests.	➢ Loss of habitat and fragmentation due to deforestation ➢ Forest fire ➢ Agrochemicals ➢ Road kills ➢ Non-selective killing of snakes ➢ Predation by farm and domestic animals	➢ Conduct comprehensive research on the group including its habitats.
Birds	➢ Low country wet zone, Mid country wet zone and Hill country wet zone contain most of the	➢ Habitat loss ➢ Degradation of wetlands due to	➢ Conduct comprehensive research on the group including its habitats.

Taxonomic group	Distribution in Sri Lanka	Threats	Conservation
	endemic and threatened species. ➢ Nearly one third of all the resident birds are forest birds including all the endemic species. ➢ Out of the endemic birds, more than 60 % are restricted to the forests in the wet zone.	development and spread of invasive species ➢ Illegal pet trade	➢ Preserve the existing habitats. ➢ Establish a captive breeding programme for the threatened endemic birds. ➢ Monitor the critical bird species, important bird habitats and large breeding colonies.
Mammals	➢ Most of the endemic and threatened mammals are restricted to wet zone and especially montane zone.	➢ Habitat loss and degradation ➢ Influx of pest species and domestic predators ➢ Hunting and conflict	➢ *No specific measures are stated.*
Pteriodophyte	➢ About 81 % of pteriodophytespecies in the National Herbarium have been collected from the wet zone. ➢ Majority of endemic pteriodophyte have been collected in the Central Province.	➢ Habitat loss ➢ Alien invasive species ➢ Soil erosion ➢ Environmental pollution ➢ Over exploitation of ornamental pteriodophyte	➢ Conserve natural forests in the wet zone areas. ➢ Monitor populations of at least threatened species. ➢ Strengthen ferneries of the network of the National Botanic Gardens.
Seed plants	➢ Dry-zone (Dry forest, Savanna, grassland) flora, lowland wet zone flora, montane forests, fresh water aquatic flora and mangroves are stated separately. ➢ The highest number of threatened species are found in the wet zone districts such as Kandy, Ratnapura, Nuwara Eliya, Badulla, Galle and Kalutara.	➢ Habitat destruction ➢ Forest fire ➢ Direct exploitation (grazing, trade) ➢ Invasive species ➢ Pollution	➢ Conserve natural forests and grassland in all zones. ➢ Conduct comprehensive research on the group including its habitats.

Prepared by the JICA Study Team

(Source: The National Red List 2012 of Sri Lanka - Conservation Status of the Fauna and Flora (Ministry of Environment, Sri Lanka, 2012))

Table 6.1.3-4 Geographic Distribution of Threatened Vertebrates in Sri Lanka

District	Freshwater fish			Amphibians			Reptiles			Birds			Mammals			Total
	CR	EN	VU	CR	EN	VU	CR	EN	VU	CR	EN	VU	CR	EN	VU	
Ampara	1 (1)	1 (0)	1 (1)	1 (1)				4 (2)	7 (3)	1 (0)	2 (0)	11 (1)		3 (1)		32 (11)
Anuradhapura	1 (1)	3 (2)	4 (3)			3 (2)	2 (2)	5 (3)	8 (3)		1 (0)	6 (0)		12 (1)	12 (1)	57 (18)
Badulla	1 (1)	2 (1)	1 (1)	1 (1)	4 (4)	5 (5)	5 (4)	14 (12)	5 (3)	1 (0)	6 (1)	18 (10)	4 (3)	11 (4)	10 (2)	88 (52)
Batticaloa		1 (0)							1 (0)			2 (0)		1 (1)		5 (1)
Colombo	3 (2)	14 (12)	3 (2)		7 (6)	6 (6)		2 (1)	3 (0)		2 (0)	11 (3)		3 (1)	4 (1)	58 (34)
Galle	4 (3)	18 (17)	3 (2)	3 (3)	20 (19)	8 (8)	4 (4)	11 (10)	13 (8)		10 (5)	16 (10)	1 (0)	8 (2)	10 (3)	129 (94)
Gampaha	2 (1)	10 (9)	2 (1)			1 (1)		3 (2)	3 (1)		3 (1)	5 (2)		3 (1)	6 (2)	35 (21)
Hambantota	1 (1)		2 (2)					6 (3)	11 (6)	2 (0)	7 (0)	20 (6)		10 (2)	7 (1)	66 (21)
Jaffna						1 (0)	1 (0)		3 (0)		1 (0)	3 (0)				9 (0)
Kalutara	7 (5)	16 (14)	3 (2)		9 (8)	5 (5)		9 (9)	8 (5)		8 (4)	17 (10)	1 (0)	5 (2)	9 (3)	97 (62)
Kandy	5 (5)	2 (1)	3 (3)	13 (13)	12 (12)	8 (8)	9 (7)	25 (23)	13 (10)	1 (0)	15 (6)	19 (11)	1 (1)	12 (4)	6 (2)	144 (108)
Kegalle	4 (2)	15 (13)	2 (2)	1 (1)	10 (9)	5 (5)	1 (1)	9 (9)	9 (7)		11 (7)	17 (11)		2 (2)	8 (3)	94 (72)
Kilinochchi																0 (0)
Kurunegala		2 (1)			1 (1)	2 (1)		2 (2)	2 (2)		1 (0)	3 (1)	1 (0)	6 (2)	6 (0)	26 (10)
Mannar	1 (1)	1 (0)				1 (0)		2 (0)	4 (0)	1 (0)	1 (0)	6 (0)		1 (0)		18 (1)
Matale	4 (4)		2 (2)	5 (5)	5 (5)	8 (7)	7 (6)	8 (8)	8 (6)	2 (0)	10 (2)	23 (7)	2 (0)	9 (2)	5 (1)	96 (55)
Matara	4 (3)	10 (10)	3 (2)	2 (2)	13 (12)	6 (6)	2 (2)	12 (11)	10 (7)		6 (4)	15 (11)		5 (2)	8 (3)	96 (75)
Monaragala	1 (1)	2 (1)	1 (1)	1 (1)	1 (1)	4 (4)	3 (1)	6 (5)	11 (8)	4 (0)	6 (0)	14 (4)		10 (3)	5 (1)	69 (31)
Mullaitivu	1 (1)	1 (0)				1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	2 (0)	11 (1)		2 (1)		22 (3)
Nuwara Eliya	1 (1)	1 (1)	1 (1)	12 (12)	17 (16)	7 (7)	7 (6)	18 (15)	10 (7)		1 (0)	6 (0)	4 (3)	14 (6)	8 (3)	107 (78)
Polonnaruwa	3 (3)	3 (2)	3 (3)			4 (3)	1 (1)	3 (2)	6 (5)	1 (0)	6 (1)	18 (10)		5 (1)	6 (1)	59 (32)
Puttalam	1 (1)	2 (1)	2 (1)			2 (1)	1 (1)	3 (0)	6 (2)			2 (0)		5 (0)	3 (0)	27 (7)
Ratnapura	6 (5)	15 (13)	2 (2)	19 (19)	27 (26)	8 (8)	13 (12)	23 (21)	12 (9)		2 (0)	11 (3)	1 (1)	15 (5)	12 (3)	166 (127)
Trincomalee	1 (1)	1 (0)				2 (1)			2 (0)		10 (5)	16 (10)		5 (1)	1 (0)	36 (18)
Vavuniya	1 (1)	1 (0)							1 (0)		3 (1)	5 (2)				11 (3)

Numbers with brackets indicate endemic species.

CR: Critically Endangered; EN: Endangered; and, VU: Vulnerable

(Source: The National Red List 2012 of Sri Lanka – Conservation Status of the Fauna and Flora (Ministry of Environment, Sri Lanka, 2012))

Table 6.1.3-5 Geographic Distribution of Threatened Seed Plants in Sri Lanka

District	Threatened speceis	Total species
Ampara	94 (17)	477 (39)
Anuradhapura	236 (47)	956 (100)
Badulla	421 (145)	1129 (246)
Batticaloa	85 (12)	474 (24)
Colombo	174 (53)	652 (111)
Galle	411 (252)	1050 (385)
Gampaha	81 (24)	418 (48)
Hambantota	178 (24)	885 (65)
Jaffna	97 (7)	546 (21)
Kalutara	361 (213)	902 (338)
Kandy	868 (388)	1952 (567)
Kegalle	281 (167)	699 (275)
Kilinochchi	11 (2)	43 (3)
Kurunegala	215 (55)	825 (128)
Mannar	77 (5)	365 (13)
Matale	344 (111)	1125 (212)
Matara	261 (165)	667 (276)
Monaragala	217 (48)	766 (108)
Mullaitivu	22 (3)	86 (7)
Nuwara Eliya	596 (260)	1261 (400)
Polonnaruwa	127 (21)	645 (52)
Puttalam	117 (13)	694 (47)
Ratnapura	739 (397)	1539 (570)
Trincomalee	101 (8)	594 (29)
Vavuniya	41 (5)	218 (9)

Numbers with brackets indicate endemic species.

(Source: The National Red List 2012 of Sri Lanka – Conservation Status of the Fauna and Flora (Ministry of Environment, Sri Lanka, 2012))

(2) Globally threatened species

IUCN prepares “The IUCN Red List of Threatened Species” as “the most comprehensive, objective global approach for evaluating the conservation status of plant and animal species[8]”. Regarding Sri Lanka, IUCN recognized the status of threatened species as in Table 6.1.3-6.

[8] http://www.iucnredlist.org/about/red-list-overview#introduction

Table 6.1.3-6 Numbers of Globally Threatened Species in Sri Lanka

Taxonomic group	Mammals	Birds	Reptiles	Amphibians	Fishes	Molluscs	Other invertebrates	Plants	Total
Number	30	15	11	56	43	0	130	286	571

(Source: Threatened species in each country (totals by taxonomic group) in IUCN Red List version 2013.1.)

It must be noted that The IUCN Red List of Threatened Species is different from The National Red List 2012 of Sri Lanka: the former lists globally threatened species while the latter does nationally threatened ones. Some examples are shown in Table 6.1.3-7. Whenever species are assessed, their conservation statuses need to be carefully examined and appropriate considerations must be given to them.

Table 6.1.3-7 Differences in the IUCN Red List and the National Red List

Species		Status in the IUCN Red List*1	Status in the National Red List*2
Scientific name	English name		
Francolinus pictus	Painted Francolin	LC	CR
Ficedula subrubra	Kashmir Flycatcher	VU	Not listed
Rhinolophus beddomei	Beddome's Horseshoe Bat or Great Horseshoe Bat	LC	VU
Macaca sinica	Toque Monkey	EN	LC

(Source: *1: The IUCN Red List of Threatened Species, *2: The National Red List 2012 of Sri Lanka

CR: Critically Endangered, EN: Endangered, VU: Vulnerable, LC: Least Concern)

(3) Invasive alien species

Invasive alien species (IAS) are described by IUCN as “animals, plants or other organisms introduced by man into places out of their natural range of distribution, where they become established and disperse, generating a negative impact on the local ecosystem and species.”, and can negatively impact human health and the economy (i.e. tourism, agriculture)[9].

12 faunal and 17 floral species are identified as the most troublesome IAS in Sri Lanka (Table 6.1.3-8) [10].

Table 6.1.3-8 Most Troublesome Invasive Alien Species in Sri Lanka

	Fauna	Flora
1	Knife fish *Chitala ornate*	Water hyacinth *Eichhornia crassipes*
2	Mozambique tilapia *Oreochromis mossambicus*	Salvinia *Salvinia molesta*
3	Walking catfish *Clarias batrachus*	Pond weed *Najas marina*
4	Rainbow trout *Oncorhynchus mykiss*	Pond apple *Annona glabra*
5	Ship rat *Rattus rattus*	‘Diyapara’ *Dillenia suffruticosa*
6	Domestic / feral cat *Felis catus*	Giant sensitive plant *Mimosa pigra*
7	Domestic / feral dog *Canis familiaris*	Prickly lantana *Lantana camara*
8	Feral buffalo *Bubalus bubalis*	Gorse *Ulex europaeus*
9	Apple snail *Pomacea diffusa*	Mesquite *Prosopis juliflora*

[9] http://www.issg.org/index.html

[10] The National Atlas of Sri Lanka – second edition (Survey Department, Sri Lanka, 2007).

	Fauna	Flora
10	Giant African snail *Lissachatina fulica*	Prickly pear cactus *Opuntia dillenni*
11	Slug *Deroceras reticulatum*	Koster's curse *Clidemis hirta*
12	Red eared slider turtle *Trachemys scripta*	Ipil ipil *Leucaena leucocephala*
13		Congress weed *Parthenium hysterophorus*
14		Wedelia *Wedelia trilobata*
15		Mile-a-minute *Mikania micrantha*
16		Cogon grass *Imperata cylindrica*
17		Guinea grass *Panicum maximum*

(Source: The National Atlas of Sri Lanka ‐ second edition (Survey Department, Sri Lanka, 2007)).

The ornamental fish trade and the horticultural trade (ornamental plants and vegetable crops) are considered to be the major contributory sources of IAS in Sri Lanka[11].

6.1.4 Conservation Status of Biodiversity in Sri Lanka

(1) Protected Areas and conservation of forests

Department of Wildlife Conservation, Sri Lanka, manages the total area of 938,771.91 ha as protected areas such as national parks[12], and Forest Department manages the total area of 1,180,227ha such as National Heritage and Wilderness Area[13] to conserve important ecosystems (Table 6.1.4-1 ~ Table 6.1.4-3).

Regarding the conservation of the remaining forests, logging ban in natural forests was imposed in 1990, and a change to this policy is not to be anticipated in the near future[14].

Table 6.1.4-1 Protected Areas managed by Department of Wildlife Conservation and Forest Department

Name		Number	Area (ha)
Department of Wildlife Conservation	Strict Natural Reserve	3	31,574.40
	National Park	22	535,181.50
	Nature Reserve	5	64,585.01
	Sanctuary	64	307,431.00
	Jungle Corridor	-	-
	Refuge	-	-
	Marine Reserve	-	-
	Intermediate Zone	-	-
	Total		**938,771.91**
Forest Department	National Heritage and Wilderness Area	1	11,187
	Conservation Forest	55	76,822
	Reserved Forest	360	575,228
	Village Forest	-	-
	Other State Forest	-	516,990
	Total		**1,180,227**

(Source: Department of Wildlife Conservation: Information from Mr. Channa Suraweera, Assistant Director - Natural Resource management, Department of Wildlife Conservation received on 15July 2013.
Forest Department: Progress Report 2011 and Action Plan 2012 (Ministry of Environment))

[11] The National Atlas of Sri Lanka – second edition (Survey Department, Sri Lanka, 2007).
[12] Information from Mr. Channa Suraweera, Assistant Director - Natural Resource management, Department of Wildlife Conservation received on 15July 2013.
[13] Progress Report 2011 and Action Plan 2012 (Ministry of Environment).
[14] Sri Lanka Forestry Outlook Study (FAO, 2009).

Table 6.1.4-2 Protected Areas managed by Department of Wildlife Conservation - their Categories and Restrictions

Category	Restrictions
Strict Natural Reserve	Off limits. Research activities are allowed with permission by the Director General DWC.
National Park	In principle, off limits. For the purposes of education, research and sightseeing, entry and observation may be allowed with the permission of the DWC. Traditional human activities are allowed.
Nature Reserve	Only traditional human activities are allowed. Research activities are allowed under the supervision of DWC.
Sanctuary and Managed Elephant Reserve	Only traditional human activities (agriculture and residence etc.) are allowed in privately owned lands; they are prohibited in state-owned lands. There is no need to obtain permission for entering sanctuaries.
Jungle Corridor	Animal trails (e.g. elephants). Only traditional human activities are allowed. Research activities are allowed under the supervision of DWC.

(Source: Department of Wildlife Conservation: Information from Mr. Channa Suraweera, Assistant Director - Natural Resource management, Department of Wildlife Conservation received on 08 November 2013).

Table 6.1.4-3 Protected Areas managed by Forest Department - their Categories and Restrictions

Category	Law provision	Description and restrictions
National Heritage and Wilderness Area	National Heritage Wilderness Areas Act	These are the unique ecosystems of the country under the maximum legal protection. Sinharaja forest is the only area declared as a national heritage wilderness area at present.
Conservation Forest	Forest Ordinance (Section 3)	These are the most important ecosystems under the maximum legal protection. No activity other than research and visitations is allowed within these forests.
Reserved Forest	Forest Ordinance (Section 3)	These are the important forest areas for conservation of soil, water and biodiversity. Activities confined to non-extractive uses are allowed within these forests.
Village Forest	Forest Ordinance (Section 12)	These are the forest areas to provide forest products and services for the local communities.
Other State Forest	Forest Ordinance (Section 20)	Forests areas do not fall under the previous categories. After surveying and demarcation of forest boundaries these forests will eventually be declared in to one of the above categories.

(Source: Forest Department web site-
http://www.forestdept.gov.lk/web/index.php?option=com_content&view=article&id=124)

(2) Environmental Protection Areas[15]

Central Environment Authority (CEA) has declared areas with unique environmental features as Environmental Protection Areas under the provisions in the National Environmental Act. CEA is responsible for physical planning and development within an Environmental Protection Areas.

The following nine (9) areas declared up to date:

- Muthurajawela buffer zone
- Bolgoda Lake
- Maragala Kanda, Moneragala

[15] PROGRESS REPORT 2011 and ACTION PLAN 2012 Ministry of Environment

- Wathurana Swamp Forest
- Bulathsinhala
- Hanthana
- Knuckles
- Thalangama Tank
- Lake Gregory, Nuwara Eliya

The following four (4) areas to be declared as EPAs:

- Benthara Ganga
- Dedigamuwa Kanda
- Koggala Lagoon
- Gin Oya

(3) Ramsar Wetlands[16]

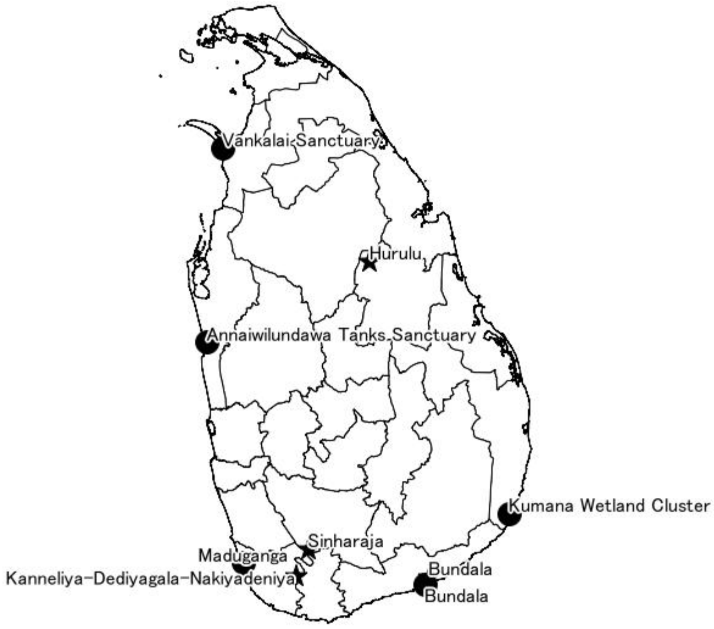
The Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention, 1971) states that "Each Contracting Party shall designate suitable wetlands within its territory for inclusion in a List of Wetlands of International Importance", and the listed wetlands are recognized as being of significant value not only for the country, or the countries, in which they are located, but for humanity as a whole.

There are 5 (five) Ramsar Wetlands in Sri Lanka (Table 6.1.4-4 and Figure 6.1.4-1).

Table 6.1.4-4 Ramsar Wetlands in Sri Lanka

No.	Name	Province or district	Area (ha)	Coordinates
1	Annaiwilundawa Tanks Sanctuary	Northwestern Province	1,397	07°42'N 079°49'E
2	Bundala	Southern Province	6,210	06º10'N 081º12'E
3	Kumana Wetland Cluster	Ampara District	19,011	06°37'N 081°44'E
4	Maduganga	Southern Province	915	06°18'N 080°03'E
5	Vankalai Sanctuary	North West, Mannar District	4,839	08°56'N 079°55'E

[16] From the website of Ramsar Convention (http://www.ramsar.org/cda/en/ramsar-documents-list/main/ramsar/1-31-218_4000_0__)



(Source: Ramsar Convention web site and UNESCO web site. The map is prepared by the Study Team)

Figure 6.1.4-1 Ramsar Sites (●)and Biosphere Reserves (★) in Sri Lanka

(4) World Natural Heritages[17]

The Government of Sri Lanka is a member of "Convention Concerning the Protection of the World Cultural and Natural Heritage (World Heritage Convention)", and has registered two (2) natural heritages - Sinharaja Forest Reserve and Central Highlands.

(5) Biosphere Reserves[18]

United Nations Educational, Scientific and Cultural Organization (UNESCO) and Sri Lankan Government establish Biosphere Reserves under UNESCO's Man and the Biosphere (MAB) Programme to promote sustainable development based on local community efforts and sound science. There are four (4) biosphere reserves in Sri Lanka (Table 6.1.4-5 and Figure 6.1.4-1).

Table 6.1.4-5 Biosphere Reserves in Sri Lanka

No.	Name	Province or district	Area (ha)	Coordinates
1	Hurulu	Anuradhapura	25,500	08°05' to 08°20'N; 80°47' to 80°55'E
2	Sinharaja	Rathnapura	11,187	06º21' to 06º26'N; 80º21' to 80º34'E
3	Kanneliya-Dediyagala-Nakiyadeniya	Galle and Matara	20,139	6°13'40.26"N; 80°23'6.08"E[19] (Central point)
4	Bundala	Southern Province	24,838	06°12'50"N; 81°13'30"E (Central point)

17 From the website of UNESCO World Heritage Centre (http://whc.unesco.org/en/list/#note28)
18 From the website of UNESCO Biosphere Reserves (http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/biosphere-reserves/)
19 National Atlas of Sri Lanka (Sri Lanka Survey Department, 2006)

(5) Species protection

Species in Sri Lanka are protected under Fauna and Flora Protection Ordinance. The Fauna and Flora Protection (amendment) Act, 2009, specifies these protected species and not protected ones under the following schedules. These provisions mainly prohibit collection such as hunting and other activities on individual of each species.

Schedule I:	List of Mammals and Reptiles that are not protected;
Schedule II:	Mammals and Reptiles that are strictly protected;
Schedule III:	List of Birds that are not protected;
Schedule IV:	Birds that are strictly protected;
Schedule V:	List of Amphibians that are not protected;
Schedule VI:	List of Fish that are protected;
Schedule VII:	List of Invertebrates that are protected; and,
Schedule VIII:	List of Plants that are protected.

(6) Threats to the biodiversity

The government of Sri Lanka has identified following factors as the threats to its biodiversity[20]:

- Habitat loss and fragmentation;
- Habitat degradation;
- Overexploitation of biological resources;
- Loss of traditional crop and livestock varieties and breeds;
- Pollution;
- Human – wildlife conflicts;
- Spread of invasive alien species; and,
- Increasing human population density

Whenever a development project is planned, the above-mentioned threats are well considered and the project proponent needs to pay special attentions not to cause these threats due to the development project.

[20] Fourth Country Report from Sri Lanka to the United Nations Convention on Biological Diversity (2009)

6.1.5 Social Environment

(1) Population

While 13 censuses were conducted in Sri Lanka from 1871 to 1989, relatively recent censuses did not include population data for the Northern and Eastern Provinces because of civil conflict. In 2011 after the end of the conflict, the 14^{th} census was conducted for the first time in 22 years.

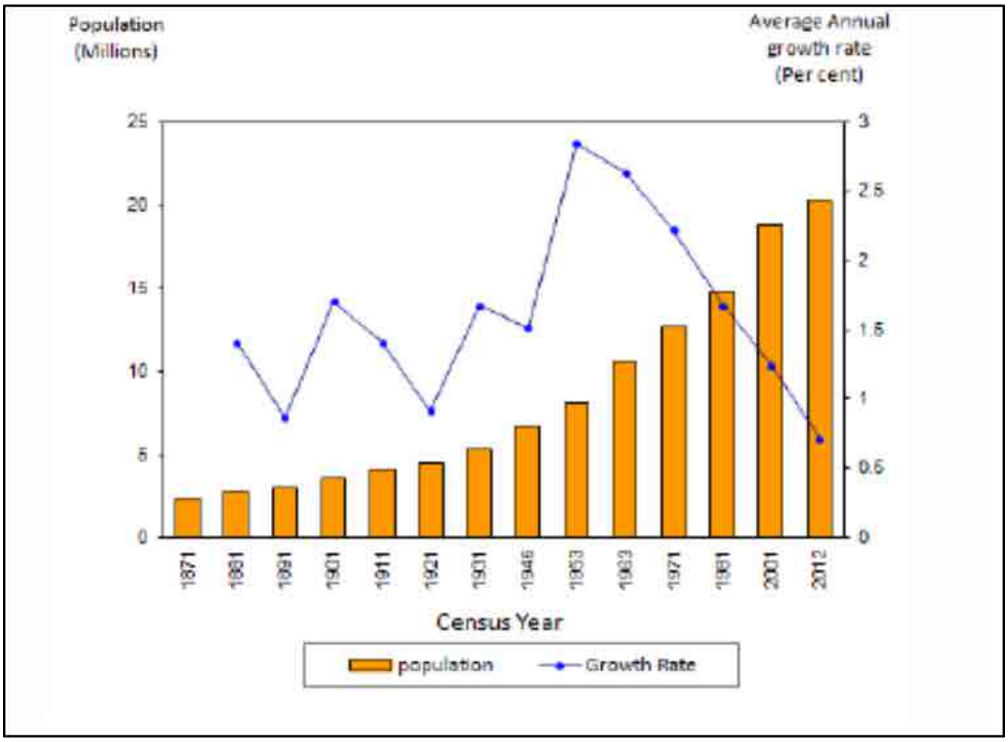
According to the Census of Population and Housing 2011: Preliminary Report-1 published by the Department of Census and Statistics, the national population stands at approximately 20 million (Table 6.1.5-1) as of 2011, an increase of 1.4 million or 7.9% compared to 2001. As shown in Figure 6.1.5-1, the rate of annual population growth reached a peak of 2.8% in 1953 and then dropped to 1.2% in 2001 and 0.7% in 2011.

Some 28.8% of the total population live in the Western Province while only 5.2% live in the Northern Province. Colombo and Gampaha are the only two districts where the population exceeds the two million level. Meanwhile, the population density has shown an increasing trend from 230 persons/km^2 in 1981 to 300 persons/km^2 in 2001 and 323 persons/km^2 in 2011.

Table 6.1.5-1 Population Distribution by Province and District, 2011

Province and District	Population enumerated		Total population enumerated	
	Usual residents	Homeless	Number	Percentage
Sri Lanka	20,274,179	3,418	20,277,597	100.0
Western Province	5,835,852	1442	5,837,294	28.8
Colombo	2,322,942	884	2,323,826	11.5
Gampaha	2,298,190	398	2,298,588	11.3
Kalutara	1,214,720	160	1,214,880	6.0
Central Province	2,556,350	424	2,556,774	12.6
Kandy	1,367,900	316	1,368,216	6.7
Matale	482,294	54	482,348	2.4
NuwaraEliya	706,156	54	706,210	3.5
Southern Province	2,465,333	293	2,465,626	12.2
Galle	1,058,902	144	1,059,046	5.2
Matara	810,629	74	810,703	4.0
Hambantota	595,802	75	595,877	2.9
Northern Province	1,059,888	135	1,060,023	5.2
Jaffna	582,995	76	583,071	2.9
Mannar	99,063	0	99,063	0.5
Vavuniya	172,730	59	172,789	0.9
Mullaitivu	92,228	0	92,228	0.5
Kilinochchi	112,872	0	112,872	0.6
Eastern Province	1,547,306	71	1,547,377	7.6
Batticaloa	525,166	20	525,186	2.6
Ampara	645,803	22	645,825	3.2
Trincomalee	376,337	29	376,366	1.9
North Western Province	2,371,881	304	2,372,185	11.7
Kurunegala	1,611,230	177	1,611,407	7.9
Puttalam	760,651	127	760,778	3.8
North Central Province	1,259,200	221	1,259,421	6.2
Anuradhapura	855,373	189	855,562	4.2
Polonnaruwa	403,827	32	403,859	2.0
Uva Province	1,259,218	201	1,259,419	6.2
Badulla	811,138	87	811,225	4.0
Monaragala	448,080	114	448,194	2.2
Sabaragamuwa Province	1,919,151	327	1,919,478	9.5
Ratnapura	1,082,051	248	1,082,299	5.3
Kegalle	837,100	79	837,179	4.1

(Source: Population & Housing Data 2012, Department of Census and Statistics Sri Lanka)



(Source: Census of Population and Housing 2011, Department of census and Statistics)

Figure 6.1.5-1 Population Enumerated at the Census and Average Annual Growth Rate, 1871-2012

(2) Ethnic Groups and Religions

According to 2012 data published by the Department of Census and Statistics, the principal ethnic groups in Sri Lanka are Sinhalese (74.9%), Sri Lankan Tamils (11.1%), Indian Tamils (4.1%) and Sri Lankan Moors (9.3%) (Table 6.1.5-2). Other minority groups include Burghers and Malays with a few percent each. The identity of many of these ethnic groups is based on religion and language. Sinhalese are the majority in the Southern, Western, Central and North Central Provinces. In particular, they account for more than 95% of the population of wet lowland agricultural areas. Sri Lankan Tamils and Indian Tamils mainly live on the Jaffna Peninsula and in the central highland, Colombo and northern wet lowland. Sri Lankan Moors mainly live in the eastern wet lowland.

As shown in, Distribution of Population by Religion, Buddhists account for 70.1%, Muslims for 9.7%, Hindus for 12.6%, Catholics for 6.2% and other Christians for 1.4%

Table 6.1.5-2 Population by Ethnic Group, Sex and Sector

Table A8: Population by ethnic group, sex and sector

Sector and sex	All ethnic groups	Ethnic groups								
		Sinhala	Sri Lanka Tamil	Indian Tamil	Sri Lanka Moor	Burgher	Malay	Sri Lanka Chetty	Bharatha	Other
Sri Lanka										
Both Sexes										
Total	**20,359,439**	**15,250,081**	**2,269,266**	**839,504**	**1,892,638**	**38,293**	**44,130**	**5,595**	**1,717**	**18,215**
Male	9,856,634	7,393,041	1,089,030	401,076	920,228	18,157	21,001	2,662	1,025	10,414
Female	10,502,805	7,857,040	1,180,236	438,428	972,410	20,136	23,129	2,933	692	7,801
Urban										
Total	3,704,470	2,325,065	619,246	46,622	662,642	19,416	20,811	1,167	998	8,503
Male	1,800,327	1,129,837	296,589	22,354	326,808	9,156	9,948	560	481	4,594
Female	1,904,143	1,195,228	322,657	24,268	335,834	10,260	10,863	607	517	3,909
Rural										
Total	15,753,322	12,823,212	1,534,359	116,045	1,223,799	18,321	23,126	4,385	711	9,364
Male	7,623,176	6,213,235	736,174	55,354	590,472	8,735	10,955	2,081	543	5,627
Female	8,130,146	6,609,977	798,185	60,691	633,327	9,586	12,171	2,304	168	3,737
Estate										
Total	901,647	101,804	115,661	676,837	6,197	556	193	43	8	348
Male	433,131	49,969	56,267	323,368	2,948	266	98	21	1	193
Female	468,516	51,835	59,394	353,469	3,249	290	95	22	7	155

(Source: Census of Population and Housing 2012, Department of Census and Statistics Sri Lanka)

Table 6.1.5-3 Population by Religion Sex and Sector

Table A6: Population by religion, sex and sector

Sector and sex	All religions	Religion					
		Buddhist	Hindu	Islam	Roman Catholic	Other Cristian	Other
Sri Lanka							
Both Sexes							
Total	**20,359,439**	**14,272,056**	**2,561,299**	**1,967,523**	**1,261,194**	**290,967**	**6,400**
Male	9,856,634	6,935,594	1,232,315	955,704	593,884	135,064	4,073
Female	10,502,805	7,336,462	1,328,984	1,011,819	667,310	155,903	2,327
Urban							
Total	3,704,470	2,007,401	480,480	697,200	410,206	106,361	2,822
Male	1,800,327	981,960	232,119	343,403	192,044	49,186	1,615
Female	1,904,143	1,025,441	248,361	353,797	218,162	57,175	1,207
Rural							
Total	15,753,322	12,163,955	1,366,785	1,261,106	801,356	156,688	3,432
Male	7,623,176	5,904,124	657,510	607,894	378,375	72,890	2,383
Female	8,130,146	6,259,831	709,275	653,212	422,981	83,798	1,049
Estate							
Total	901,647	100,700	714,034	9,217	49,632	27,918	146
Male	433,131	49,510	342,686	4,407	23,465	12,988	75
Female	468,516	51,190	371,348	4,810	26,167	14,930	71

(Source: Census of Population and Housing 2012, Department of Census and Statistics Sri Lanka)

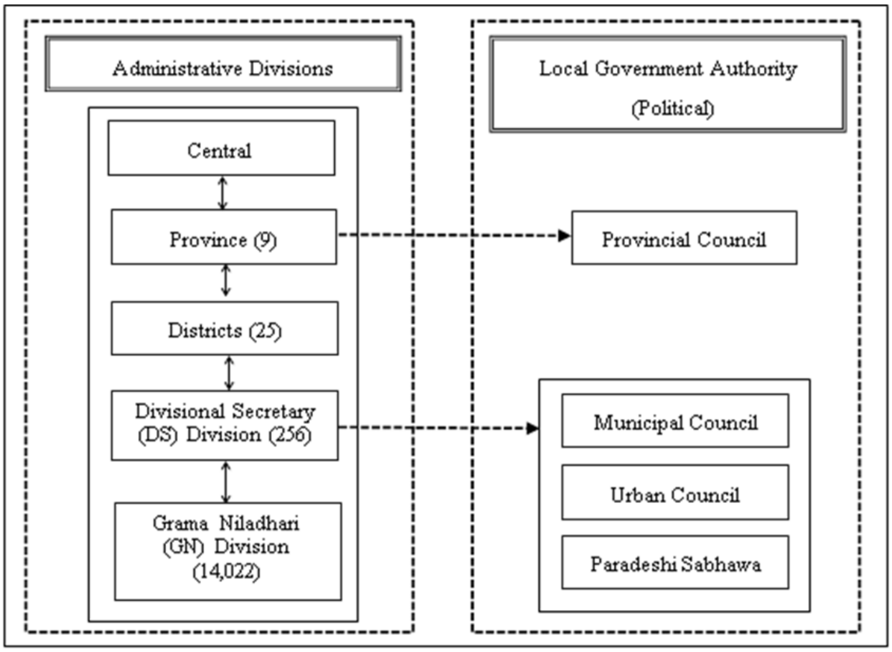
(3) Politics and Administration

Sri Lanka is a republic which combines a presidential system and parliamentary cabinet system. The legislative branch consists of a unicameral parliament with 225 seats. Members service six year terms of office. 196 out of 225 are elected with a system of proportional representation in respect of 22 electoral districts, while 29 out of 225 to be declared elected on the basis of the total number of votes polled by the respective political parties or independent groups at the national level. Therefore the parliament has a proportional system at the district level and a proportional system at the national level based on the same poll[21].

Local administration is handled by administrative divisions and local authorities headed by elected governors, etc. as shown in Figure 6.1.5-2. Local administrative services were first introduced in the late 19th century, primarily for the collection of taxes. Local administrative services consist of several levels: province, district, and divisional secretariat and Grama Niladara (GW) division from top to bottom. GN divisions are the lowest administrative units[22]. According to the Department of Census and Statistics, there are 9 provinces, 25 districts, 256 divisional secretariats and 14,022 GN divisions. The head of each administrative unit is appointed by the central government.

Meanwhile, local authorities were first introduced under the British colonial rule, allowing the autonomy of local residents. Each authority dealt with various needs of local residents, including roads, agriculture and irrigation, to improve the socioeconomic conditions of its locality.

Over a long period of time, local authorities have been differentiated to form the present structure consisting of provincial councils, municipal councils, urban councils and Pradeshiya Sabha to be responsible for local administration in their own areas. Figure 6.1.5-3 shows the administrative boundaries.

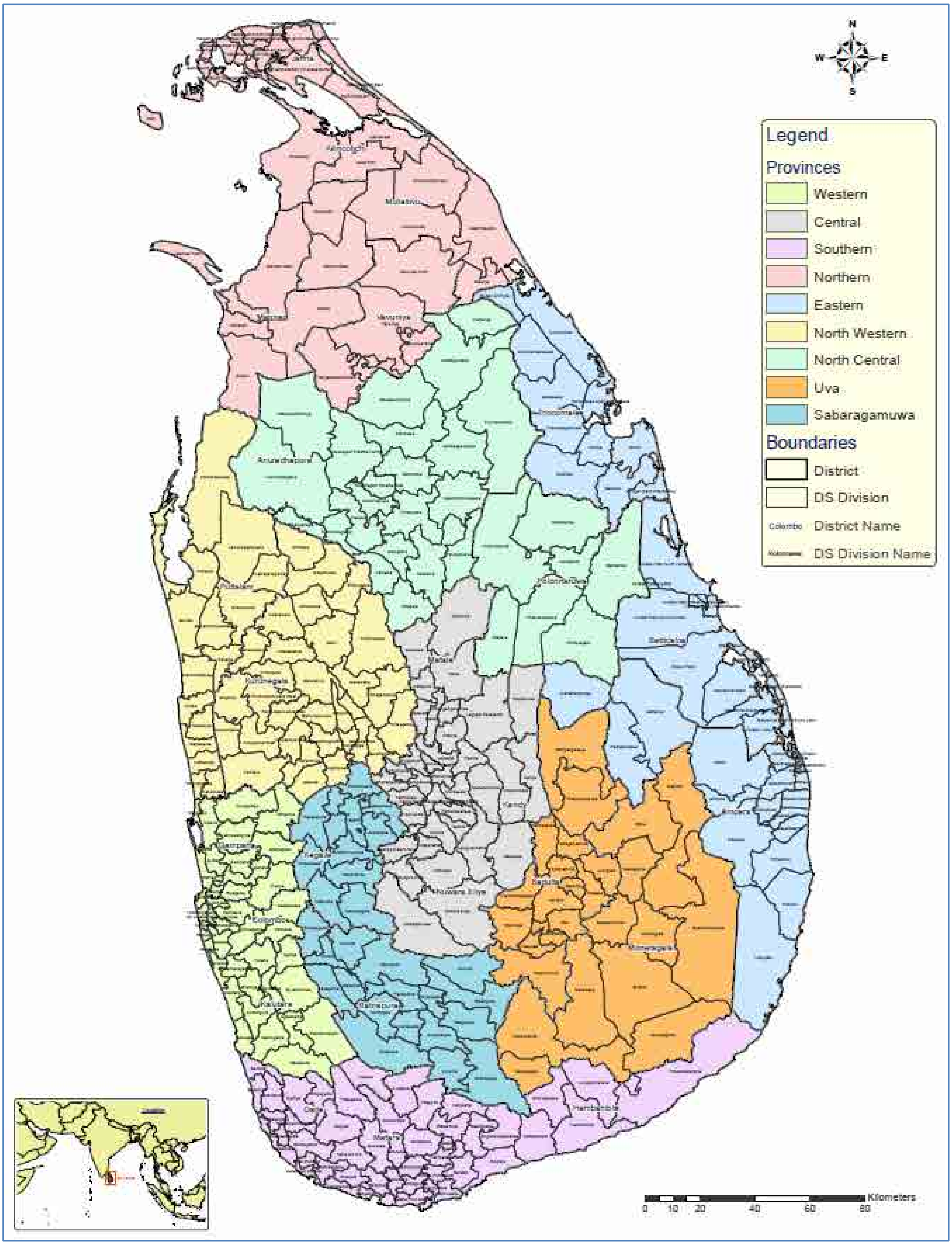


(Source: made by the JICA Study Team)

Figure 6.1.5-2 Administrative Services and Local Authorities

21 From the website of Parliament of Sri Lanka:
http://www.parliament.lk/en/members-of-parliament/the-system-of-elections-in-sri-lanka/the-electoral-system

22 Source: National Atlas of Sri Lanka, Chapter 10.2 Local Government



(Source: Department of Census and Statistics Sri Lanka)

Figure 6.1.5-3 Administrative Boundaries

(4) Outline of Industries

The Sri Lanka economy has traditionally relied on agriculture centering on the production of rice and three major plantation crops (tea, rubber and coconuts). The economic growth of the country has expanded the shares of the manufacturing sector and wholesale and retailing sector. Garments have been the largest export item in recent years.

In 2010, the real GDP growth rate was as high as 8%, recording the highest figure in 30 years. The service sector in particular made an impressive contribution as the revitalized domestic demand and increased number of foreign visitors due to the improved security situation since the end of the civil war pushed up the turnover of hotels and restaurants. There has been a growing demand for construction materials for the reconstruction and development of infrastructure in the Northern and Eastern Provinces[23].

Following trend describe each sector such as, Agriculture, Inland water fishery, and Forestry, Services business, and industry's present situation which would be predicted of social impact by the proposed hydropower development[24].

1) Agriculture

Agricultural sector in Sri Lanka accounts for 11% of GDP which is supported by small scale farmers of plantation and traditional paddy field. 80% of total populations in Sri Lanka or 45% of workforce are engaged in agriculture, and many of them belong to poor. Due to two third of the land in Sri Lanka is dry zone or semi-dry zone, many irrigation systems had been implemented over many years. But agricultural production and its profit are small because of insufficient of maintenance system and deterioration. Some farmers changed agricultural products from paddy to Banana with high profit recently; there are still many issues on facilitation of production technology, market and mobilization.

Such crops as tea and natural rubber are still major export products of Sri Lanka today. Small farmers accounted for 71.4% of the tea production and their production increased by 2.7% on the previous year. In contrast, the overall production volume of tea by large plantations on medium high and high land fell by 7.4% on the previous year to 93,200 tons. While the production volume of traditional tea declined, the production volume of tea with added value, such as specially treated tea, organic tea and instant tea, increased.

2) Inland water fishery

There are 50 major inland reservoirs in Sri Lanka that contribute significantly to inland production. Sri Lanka has around 80 indigenous fish species in its freshwater ecosystem. Among the important indigenous species, Cyprinids, such as puntius sarana (Mas Pethiya) and Labeo dussumieri (Hirikanaya), contribute to fresh water inland fish production. The exotic cichlid species Oreochromis mossambicus were introduced into Sri Lanka freshwaters since in 1952.

[23] The website of Ministry of Foreign Affairs of Japan, the situation of Sri Lanka
[24] Central Bank of Sri Lanka Annual report 2012, National Atlas of Sri Lanka 2007, JETRO Annual report 2012

During the 1979-89 periods, the government of Sri Lanka took steps to develop capture fisheries in reservoirs under a subsidy scheme. As a result, fishing endeavors in reservoirs have considerably increased. The peak fish production with 39,000 ton annually was in 1980s due to the ability of exotic cichlid species (tilapias) to colonize the lacustrine habitats of reservoirs of Sri Lanka. Annual inland fish production declined markedly after 1990, when the state discontinued patronage of the fisheries for a four year period. However, inland fisheries have made an almost fully recovery since the state renewed support to these fisheries after the mid -1990s, providing 15,600 employment opportunities.

3) Forestry

Although Sri Lanka was a small island country, 150 or more sorts of endemic species trees were distributed over the rain zone on geographical features. However large scale forest plantations commenced in 1916 due to the rehabilitation of degraded non-forest lands through a reforestation scheme aimed at providing the necessary timber and other forest products to the country. Initially, exotic tree species such as Eucalyptus, Teak and Mahogany were used for the reforestation programme. Later on, Pine, mainly Carbbean Pine (Pinus caribaea), was introduced as a good species for reforestation of degraded patanas in the mid-country intermediate zone and mid-country dry zone as well as in some parts of the wet zone. Natural forest area is decreasing due to reforestation and expansion of the agricultural output by the increase of population. Although artificial reforestation is advanced, the amounts of planting are small, and most timber production is consumed as fuel.

4) Service business

Development of the tourist industry is remarkable after the conclusion of a civil war in 2009. One of major reason that many tourists from Europe and the Middle East visit in Sri Lanka where there are 8 UNESCO World Heritage sites including Buddhist temple and beach resorts. The number of foreign tourists were 850,000, and the tourism revenue was 800 million US$ in 2011. The government of Sri Lanka targets the number of foreign visitor will increase in 2,500,000 and its income will increase in 2,700 million US$ by 2016. So as the government promotes making a policy for further investment by tax incentives and the reduction of the power rate for tourist facilities such as hotel.

5) Industry

One of major export item in Sri Lanka is textiles and clothing with around 4,200 million US$ exports increase of 24.9 % over last year 2011. The reason of high demand of textiles and clothing in Sri Lanka is the high quality of products and raising wage cost in other countries. Exports of rubber products, petroleum products, jewelry and diamond are also expanded by duty concession for import levy.

(5) Work Force

The census report 2011 mentioned earlier lists the population of 10 years old or older at 17.9 million (males: 8.4 million; females: 9.4 million), of which some 8.5 million are classified as working age population. As the actual number of employed people stands at 8.19 million, the unemployment rate is approximately 4.2%, indicating an almost halving of the unemployed in the last 10 years (see Table 6.1.5-4).

In the period from 1993 to 2011, the employed population by sector has shown a gradual increase in the manufacturing and service sectors. In contrast, the agricultural population has been gradually declining since 1997 (Figure 6.1.5-4).

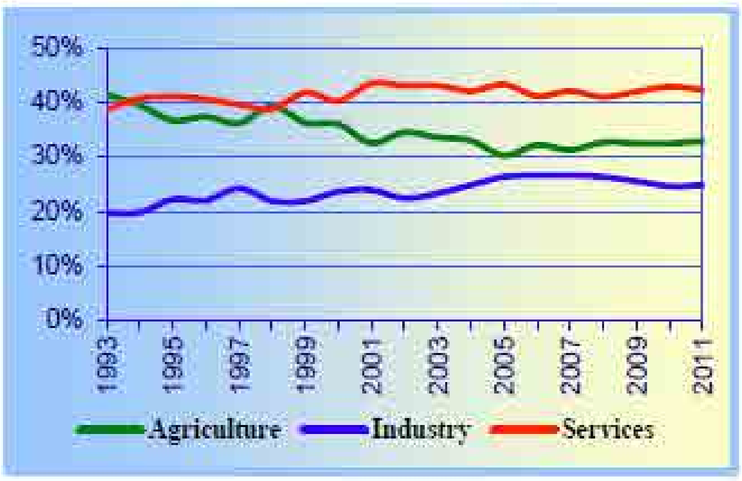
The minimum wage for workers by sector (Table 6.1.5-5) was 1,176.5 Rp per month in 2001 and 3,427.2 Rp in 2011 for agricultural workers. In the manufacturing sector, the minimum monthly wage was 919.6 Rp in 2001 and 2,402.1 Rp in 2011. In the service sector, the corresponding figure was 657.6 Rp in 2001 and 1,851.8 Rp in 2011. In each sector, the minimum monthly wage more than doubled in 10 years.

Table 6.1.5-4 Unemployment Rate

Year	Total	Gender	
		Male	Female
1993	13.8	9.7	21.7
1994	13.1	9.7	20.1
1995	12.3	9.0	18.7
1996	11.3	8.2	17.7
1997	10.5	7.7	16.1
1998	9.2	6.5	14.0
1999	8.9	6.7	13.0
2000	7.6	5.8	11.0
2001	7.9	6.2	11.5
2002	8.8	6.6	12.9
2003	8.1	6.0	12.3
2004	8.1	6.0	12.1
2005	7.2	5.3	10.7
2006	6.5	4.7	9.7
2007	6.0	4.3	9.0
2008	5.2	3.6	8.0
2009	5.7	4.3	8.2
2010	4.9	3.5	7.5
2011	4.0	2.7	6.3

* Excluding Northern & Eastern provinces

(Source: Labour Force Survey Annual report 2011, Department of Census and statistics)



(Source: Census of Population and Housing 2011)

Figure 6.1.5-4 Employed Population by Major Industry Group 1992-2011

Table 6.1.5-5 Minimum Wage Rate Index Numbers, 1978 December - 100 (For Workers in Wages Boards Trades)

	Worker in Agriculture(a)		Workers in Industry and Commerce(b)		Workers in Services(c)		Wokers in Wages Board Trades(d)	
Period**	Minimum Wage Rate Index	Real Wage Rate Index	minimum Wage Rate Index	Real Wage Rate Index	Minimum Wage Rate Index	Real Wage Rate Index	Minimum Wage Rate Index	Real Wage Rate Index
1993	803.7	136.6	528.7	89.8	365.8	62.2	685.7	116.6
1994	821.4	128.8	555.8	87.2	431.4	67.6	712.5	111.7
1995	830.9	121.1	651.6	94.8	456.7	66.5	740.3	107.8
1996	907.9	113.9	682.8	85.9	559.7	61.3	801.7	100.7
1997	971.8	114.4	710.8	81.4	487.2	55.9	849.1	97.3
1998	1,097.7	115.0	807.7	84.6	506.4	53.0	953.3	99.9
1999	1,115.9	111.7	829.2	83.0	559.7	56.0	977.6	97.8
2000	1,142.7	107.7	857.2	80.8	559.7	52.8	1,004.4	94.0
2001	1,176.5	97.1	919.6	75.9	657.6	54.3	1,049.3	86.6
2002	1,269.6	95.6	986.5	74.4	678.0	51.1	1,126.5	84.9
2003	1,382.3	98.0	1,009.4	71.6	678.0	48.1	1,205.2	85.4
2004	1,397.7	92.2	1,044.1	68.9	750.9	49.5	1,233.0	81.3
2005	1,527.4	90.2	1,078.4	63.7	779.7	46.0	1,329.7	78.5
2006	1,567.1	81.3	1,090.7	56.6	779.7	40.5	1,358.2	70.5
2007	1,821.4	81.3	1,522.4	67.9	1,057.1	47.1	1,648.8	73.6
2008	2,286.6	83.5	1,877.5	68.5	1,370.8	49.9	2,070.4	75.5
2009	2,349.4	83.0	2,054.0	72.5	1,545.8	54.6	2,171.4	76.7
2010	3,327.6	110.7	2,199.0	73.1	1,673.3	55.6	2,865.3	95.3
2011	3,427.2	106.8	2,402.1	74.9	1,851.8	57.7	2,996.1	93.3

Sources:Statistics Division,Dept,.of Labour and Central Bank of Sri Lanka

* The index numbers are calculated on fixed weights based on the numbers employed as at 31st December 1978. The wage rates used in the calculation of index numbers are minimum wages for different trades fixed by the Wages Boards.

** Annual figures shown are average of monthly figures

(a)The index refers to wage rates of tes growing and manufactutring,rubber growing and manufacturing,coconut,cocoa,cardamoms and pepper growing trades only.

(b)Incledes baking,brick and tile manufacturing coconut manufacturing,printing,tyre and tube manufacturing,coir mattersses & bristle fibre export,hosiery manufacturing,engineering,garment manu facturing,match manufacturing,biscuit and confectonery tea export and rubber export traders only

(c)This includes cinema,motor transport and nursing home trades only.

(d)Combined index for workers in agriculture,in industry and in services.

(Source: Sri Lanka Labour Gazette Volume 63 No. 4 Ministry of Labour and Labour Relations)

(6) Education

The literacy rate in Sri Lanka is 92.5%[25]. Sri Lanka's education system consists of five years of primary education, six years of secondary education, two years of collegiate education and tertiary education. Only person who pass a uniform examination can enroll collegiate education. The primary school enrolment rate is 99%, secondary education is 70%, and college is 2.5%[26].

(7) Poverty

Many criteria for poverty are used in Sri Lanka. Data based on the Household Income and Expenditure Survey (HIES)[27] conducted by the Department of Census and Statistics or data based on the Consumer Finances and Socio Economic Survey (CFS) conducted by the Central Bank of Sri Lanka was used to determine the poverty line until 2004 when the Office Poverty Line (OPL)[28] was introduced. Poverty-related data is classified as national, sectoral, provincial and district poverty data. Sectoral poverty data consists of urban, rural and estate poverty data. Urban areas are those areas governed by either municipal councils or urban councils. Estates are plantation areas of 20 acres or more with 10 or more live-in workers. Rural areas are those areas which do not belong to either urban areas or estates.

According to the latest survey (HIES) conducted in FY 2009/10, the national poverty rate of Sri Lanka is 8.9%. By sector, urban areas have the lowest poverty rate of 5.3%, followed by rural areas with 9.4% and estates with 11.4%.

By province, Eastern Province has the highest poverty rate of 20.3%, followed by Uva province (13.7%) and Northern Province (12.8%).

By district, Batticaloa in the Eastern Province has a high poverty rate of 20.3%, while Jaffina in the Northern Province and Moneragala in Uva Province have a poverty rate of 20.3% and 14.5% respectively.

Among the 10 candidate sites which are located in Kandy, Nuwara-eliya, Badulla, Ratnapura and Kegalle Districts for pumped storage hydroelectric power generation, the Badulla District has a relatively high poverty rate of 13.3% as shown in Table 6.1.5-6.

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[25] United Nations Educational, Scientific and Cultural Organization (UNESCO) as of 2010

[26] The website of Ministry of Education in Sri Lanka

[27] This is based on measuring criteria used by the World Bank. The food basket providing a standard daily calorific intake of 2,500 Kcal and protein intake of 53 grams for adult males in the age bracket of 20 – 39 is converted to a currency value to calculate the food poverty line. With the addition of basic non-food expenditure, the reference poverty line is determined. (Refer to: http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTPOVERTY/EXTPA/0,,contentMDK:22405907~menuPK:6626650~pagePK:148956~piPK:216618~theSitePK:430367,00.html)

[28] A minimum calorific intake of 2,030 Kcal was adopted in 2002 and the official poverty line is determined as the amount of expenditure to provide 2,030 Kcal (Department of Census and Statistics2004), Refer to http://www.statistics.gov.lk/poverty/OfficialPovertyLineBuletin.pdf

Table 6.1.5-6 Poverty Ratio by District

District	HIES survey period				
	1990/91	1995/96	2002	2006/07	2009/10
Colombo	16.2	12.0	6.4	5.4	3.6
Gampaha	14.7	14.1	10.7	8.7	3.9
Kalutara	32.3	29.5	20.0	13.0	6.0
Kandy	35.9	36.7	24.9	17.0	10.3
Matale	28.7	41.9	29.6	18.9	11.5
Nuwara-eliya	20.1	32.1	22.6	33.8	7.6
Galle	29.7	31.6	25.8	13.7	10.3
Matara	29.2	35.0	27.5	14.7	11.2
Ham bantota	32.4	31.0	32.2	12.7	6.9
Jaffna					16.1
Vavuniya					2.3
Batticalos				10.7	20.3
Ampara				10.9	11.8
Trincomalee					11.7
Kurunegala	27.2	26.2	25.4	15.4	11.7
Puttlam	22.3	31.1	31.3	13.1	10.5
Anuradhapura	24.4	27.0	20.4	14.9	5.7
Polonnaruwa	24.9	20.1	23.7	12.7	5.8
Badulla	31.0	41.0	37.3	23.7	13.3
Moneragala	33.7	56.2	37.2	33.2	14.5
Ratnapura	30.8	46.4	34.4	26.6	10.5
Kegalle	31.2	36.3	32.5	21.1	10.8

(Source: Poverty Indicators May 2011, Department of Census and Statistics Sri Lanka)

(8) Indigenous People

According to the 2011 update report of International Group for Indigenous Affairs (IWGIA)[29], Vedda (huntsmen) are historically recognized as indigenous people who served a defined role, recognised by royal decree, and who owed allegiance to the King with European colonisation. They used to live in south-eastern and eastern coastal belt, the northern tracts and the central part of the island. Vedda people as a distinct ethnic group and gave population figures of between 1,229 and 4.510 people during British colonial record, but census surveys of the last three decades have not distinguished them as a separate ethnic group. A systematic census to estimate the population of Vedda has yet to be conducted. Integration with neighbouring forest-dependent communities, the population census counts the Vedda people are incorporated in the major ethnic group of Sinhalese, Muslims and Tamil people. There is no national legislation that would recognize the status and protect the right of the Vedda.

(9) World Cultural Heritages[30]

The Government of Sri Lanka is a member of “Convention Concerning the Protection of the World Cultural and Natural Heritage (World Heritage Convention)”, and has registered six (6) cultural heritages as follows.

[29] http://www.iwgia.org/iwgia/who-we-are-/organisational-structure

[30] The website of UNESCO World Heritage Centre, http://whc.unesco.org/en/statesparties/LK/

- Sacred City of Anuradhapura
- Ancient City of Polonnaruwa
- Ancient City of Sigiriya
- Sacred City of Kandy
- Old Town of Galle and its Fortifications
- Golden Temple of Dambulla

6.2 Profile of Environmental and Social Consideration in Sri Lanka

6.2.1 List of Governmental Organizations related to Environmental and Social Considerations in Sri Lanka

Table 6.2.1-1 shows a list of governmental organizations related to environmental and social considerations in Sri Lanka.

Table 6.2.1-1 List of Governmental Organizations related to Environment in Sri Lanka

Organizations		Assigned role
Ministry	Environment and Renewable Energy	Provide leadership to manage the environment and natural resources in order to ensure national commitment for sustainable development for the benefit of the present and future generation.
	Economic Development	The Ministry of Economic Development in Sri Lanka has a varied purview including regional and rural development, poverty alleviation and empowerment of the poor, promoting investments to Sri Lanka, travel and tourism industry development and nature and wildlife conservation.
	Industries and Commerce	Responsible for promoting industrial development in the country within the wide policy framework of Mahinda Chintana spelt out by the government.
	Economic Reform, Science and Technology	Responsible for the formulation of policies, programmes and projects with regard to Technology and Research and for the direction of the implementation of such policies, programmes and projects.
	Finance & Planning	Responsible of the Preparation of a Long Term /Medium Term Development Plans and the Investment Programme Development of a macro-economic framework,strategies. Review of economic development policies, strategies, programmes and project appraisal
	Health, Nutrition & Welfare	To contribute to social and economic development of Sri Lanka by achieving the highest attainable health status through promotive, preventive, curative and rehabilitative services of high quality made available and accessible to people of Sri Lanka.

Organizations		Assigned role
	Local Government & Provincial Councils	To ensure efficient and effective Provincial and Local Administrative system responsive to the aspirations of the people and facilitate the achievement of Sustainable and equitable human development in Sri Lanka by advocating and strengthening the systems of Decentralized Governance
	Fisheries & Aquatic Resources Development	It is the principal National Institute charged with the responsibility of carrying out and coordinating research, development and management activities on the subject of Aquatic Resources in Sri Lanka.
	Land & Land Development	In case where a land is required for a public purpose of any Ministry, Department, Corporation, Statutory Board, Provincial Council or a Local Government Institution, the Head of the particular Department forwards an acquisition proposal to the Secretary, Ministry of Land and Land Development through the Secretary to the Ministry of which the particular institution fallen under the purview. After confirming accuracy of the proposal, the acquisition procedure is commenced on the approval of the Minister of Land and Land Development. The lands are acquired under the provisions of the Land Acquisition Act and regulations imposed thereto and compensation and interests are paid to the land owners in respect of the lands acquired.
	Culture and the Arts	To assist in building Sri Lanka as a proud nation with a unique Sri Lankan identity by facilitating the emergency of a culture that would develop all communities of the country while in the process protecting and preserving Sri Lankan national heritage.
	Disaster Management	To facilitate harmony and the prosperity and dignity of human life through effective prevention and mitigation of natural and man-made disasters in Sri Lanka
	Cultural Affairs & National Heritage	Formulation and implementation of policies and programme for Preservation, Promotion, and Propogation of Culture
Department	Forest	Conserve and develop the Forest Resources in Sri Lanka to ensure the prosperity of the nation
	Wildlife Conservation	Responsible for maintaining national parks, nature reserves and wildlife in wilderness areas in Sir Lanka. Forest reserves and wilderness areas are maintained by the Department of Forest Conservation
	Census and Statistics	To collect, compile and disseminate relevant, reliable and up-to-date statistical information required to plant a better future for our country and the people for Sri Lanka, to monitor the progress of development and other Socio-economic activities and to measure the impact of various government policies of the economy of our country and the living standards of the people.

Organizations		Assigned role
Authority	Central Environmental Authority	CEA was established in 1981, under the provision of the National Environmental Act No.47 of 1980. The Ministry of Environment has the overall responsibility in the affairs of the CEA with the objective of integrating environmental considerations into the development process of the country. CEA was given wider regulatory powers under the National Environment Amendment Acts No. 56 of 1988 and No. 53 of 2000. Protect, manage and enhance the environment, regulate, maintain and control the quality of the environment, and prevent, abate and control pollution.

(Source: collect information from the website of each government agency and made by JICA study team)

6.2.2 Legal System Relating to Environmental and Social Consideration

(1) Environmental Policies

The basic document stipulating the environmental policies in Sri Lanka is the National Environmental Action Plan 1992 - 1996 formulated by the Ministry of Environment and Parliamentary Affairs. The contents of this strategy were a) general statement on the Sri Lankan environment, b) management of the ecosystem for sustainable development, c) human activities, including those related to the environment, d) constraints for environmental protection and sustainable development, e) strategy and f) implementation of the strategy.

In subsequent years, the CEA classified the subject matters in the fields of water, marine resources, land resources (biological), land resources (non-biological), forests, biological diversity and wildlife, urban and industrial pollution, energy, living environment for people, education and cultural resources based on the basic strategy and stated the present conditions and problems of individual fields in the National Environmental Action Plan.

The National Environmental Action Plan of Sri Lanka has been reviewed every five years. The latest version covers the period from 2009 to 2013 and the annual report has been published[31].

Below are summaries of the parts dealing with land, water resources and energy in the current Action Plan as these matters are specially connected to hydroelectric power generation.

1) Land

For over two millennia, Sri Lanka’s society has been agrarian based. During the time of Sri Lanka’s ancient, farmed hydraulic civilization, the rulers, while promoting agricultural development, recognized the importance of proper use of the land. In the undulating landscape of the dry zone, different areas were appropriately set apart for cultivation, for settlements, and for retention in forest cover. The changes that have taken place subsequently, mainly the birth of the crop plantation sector, the growth of the industrial sector, and the rapid rise in population with

[31] The website of Ministry of Environment and Natural Resources, National Action Plan for Haritha Lanka Programme

the consequential emergence of a wide range of social issues have led to a situation where the country's vital land resource began to be heavily overexploited, leading to land degradation. Given such historical background, the Action Plan examines and presents improvement methods for such environmental issues as a) reduce land degradation in agricultural areas, b) rehabilitate deteriorated lands, c) develop and implement programmes for the use of non-cultivated agricultural lands, d) optimize soil conservation through mandatory & other measures, (e) promote precision farming, traditional verities of crops and crops to fit agro-ecological condition, f) conserve, restoring and improve important representative landscapes, g) carry out assessment on forest cover of Sri Lanka, including different categories of forests h) promote the integrated management of upper watersheds, i) mitigate and adaptation to drought

2) Water Resources

Sri Lanka can be considered as a country that is well endowed with water resources since it receives, on an average, over 2000 mm of rainfall annually. Its spatial and temporal distribution, however, is such that a large part of the country (65%), referred to as the dry zone, experiences water shortages and droughts during several months in the year. Before colonisation, the people of Sri Lanka lived in a dry zone and had developed an irrigation system to manage water from the highland. This ancient irrigation system collapsed in the 12th century due to various reasons and a new irrigation system was established much later in the 18th century. The biggest problems today are the shortage of usable water, deterioration of the water quality and emergence of health problems due to the poor water quality. Another critical issue in relation to water, even in parts of the country where the resource is adequate in quantity, is the rapid deterioration of water quality owing to pollution from industrial, agricultural and domestic wastes. In the face of these problems, the Action Plan examines a) establish a systematic water allocation system and improve efficiency and equity in water distribution for various purposes, b) organize a rehabilitation scheme for small tanks and revitalize the tank cascade system developed, c) transform the irrigation system to meet new challenges, d) keep drinking water sources free from contamination through proper zoning and control measures, e) Strengthen implementation of integrated water resource management systems, f) reduce fertilizer leaching and eutrophication

3) Energy[32]

The sources of primary energy supply in Sri Lanka are biomass (46%), oil (42%) and hydropower (12%). Of the potential hydro-energy of some 2,000 MW, 1,551 MW has already been developed, leaving hardly any economic hydropower potential.

The energy consumption in the last 10 years has increased at an average annual rate of some 2%. The Action Plan to deal with the growing power demand in the coming years calls for (a) diversification of the sources of electric energy, (b) reduction of oil-fired thermal power plants,

[32] National Energy Policy & Strategies of Sri Lanka 2008

(c) promotion of coal-fired thermal power plants and wide use of renewable energies and (d) promoting energy efficiency and conservation.

(2) Poverty reduction policy[33]

The Government of Sri Lanka made the Millennium Development Goals by 2015 in 2000, and the Poverty reduction strategy Paper in 2002. Based on these documents, poverty reduction policy was stated in Mahinda Chintana as follows.

- Eradication of hunger and hard-core poverty
- Universalization of secondary education for all
- Reducing malnutrition rate of children from a third to 12-15 percent
- Increasing life expectancy from 76 to 80 years.
- Increasing access to clean water in urban areas from 65 to 90 percent

(3) Empower agriculture and rural development

80% of the people live in rural areas and 70 percent of the people work in agriculture. Accounting for 11% of GDP and one third of export revenues, a vibrant agriculture sector can be a driving force for economic growth over the coming decade. The followings are the strategies in this sector.

- Intensifying agricultural production to increase output by 6% per annum
- Diversifying agricultural production to raise livelihood activities
- Creating opportunities for off-farm employment
- Rural infrastructure expansions

(4) Laws Relating to Environmental and Social Considerations

The Constitution of Sri Lanka of 1978 stipulates that “It is the duty of every person in Sri Lanka to protect nature and conserve its riches” (Article 28 (d) and (f)), and “The State shall protect, preserve and improvement the environment for the benefit of the community (Article 27-(14)). Based on this Constitution, the National Environmental Act No. 47 of 1980 (NEA) was enacted in 1980 to stipulate the basic framework for environmental protection and management in Sri Lanka. In 1981, the Central Environmental Authority (CEA) was established as the implementing agency for official environmental protection and management measures. This National Environmental Act was subsequently revised in 1998 and 2000.

The environmental laws related to hydropower development in Sri Lanka are showed in Table 6.2.2-1.

[33] Extract from the Development Policy Framework (Mahinda Chintana) which targets from 2006 until 2016. It was revised in 2010.

Table 6.2.2-1 Environmental Laws related to Hydropower Development

Law		Description
Natural Environment		
Forest Ordinance	No.16 of 1907 No.11 of 1912 No.24 of 1918 No.23 of 1931 No.16 of 1935 No.30 of 1945 No.8 of 1947	Consolidates the laws relating to forests and to the felling and transportation of timber. Empowers the Minister to declare any area of state land as a Reserved Forest Conservation Forest or Village Forest.
Forest Act	No.34 of 1951 No.49 of 1954 No.13 of 1966 No.56 of 1979 No.13 of 1982 No.84 of 1988 No.23 of 1995	Supplemental rules for forests
Felling of Trees Ordinance	No.9 of 1951	Provides for the prohibition, regulation and control of the felling of specified tree species, including cultivated tree species such as Jack, Bread Fruit and female Palmyra trees. .
Fauna and Flora Protection Ordinance	No.2 of 1937 No.31 of 1942 No.12 of 1944 No.12 of 1945	Provides for the conservation of plants and animals that have been declared as protected species. Empowers the Minister to declare any area of state land as a National Reserve or Sanctuary.
Fauna and Flora Protection Ordinance Act	No.38 of 1949 No.44 of 1964 No.1 of 1970 No.49 of 1993 No.12 of 2005	Supplemental rules for fauna and flora
Mines and Minerals Act	No.4 of 1973 No.33 of 1992	Regulates mining, exploitation, processing, trading and export of minerals.
National Water Supply and Drainage Board Law	No.2 of 1974	Responsible for the provision of safe drinking water and facilitating the provision of sanitation to the people in Sri Lanka.
National Aquatic Resources Research and Development Agency Act	No.54 of 1981 No. 2 of 1996	Makes provision to protect and conserve fisheries and aquatic biodiversity in marine and freshwater areas and for the declaration of fisheries reserves. Imposes licensing and registration requirements for fishing. Defines the terms ‘Sri Lankan Waters’.
National Heritage Wilderness Act	No.3 of 1988	Provides for the declaration, protection and preservation of any area of state land with unique ecosystems, genetic resources or outstanding natural features such as National Heritage Wilderness Areas.
Flood Protection Ordinance	No. 4 of 1924 No. 22 of 1955	Flood protection
Land Reclamation and Development Corporation	No. 15 of 1968 No. 52 of 1982	Flood protection area declared

Law		Description
Act		
Botanic Gardens Ordinance	No. 32 of 1973	The plant protection ordinance
Social Environment		
Sri Lanka Electricity Act	No.20 of 2009	
Mahaweli Authority of Sri Lanka Act	No.23 of 1979	Established the Mahaweli Authority of Sri Lanka and provides for the conservation and maintenance of the physical environment of Mahaweli Areas, including watershed management, soil erosion and the protection of reservation areas.
Soil Conservation Act	No.25 of 1951 No.29 of 1953 No.30 of 1996	Provides for the conservation of soil resources, mitigation of soil erosion and protection of lands against flood and drought.
Irrigation Ordinance	No.32 of 1946 No.1 of 1951 No.48 of 1968 No.37 of 1973	Deals with environmental aspects of water, irrigation and land use in irrigated agricultural activities.
Antiquities Ordinance	No.9 of 1940 No.24 of 1998	Provide for the better preservation of the Antiquities of Sri Lanka
Antiquities Act	No.2 of 1955 No.22 of 1955 No.24 of 1998	Supplemental rules for Antiquities Ordinance
Land Acquisition Act	No.9 of 1950 No.13 of 1986	To make provision for the acquisition of lands and servitudes for public purpose
Crown Lands Ordinance	No.8 of 1947	To make provision for the grant and disposition of crown lands
National Involuntary Resettlement Policy	2001	Outline legislative and regulatory framework that guide land acquisition and valuation process
State Lands (Recovery of Possession) Act	No.7 of 1979	To make provision for the recovery of possession of state lands from persons in unauthorized possession or occupation
Tourist Development Act	No.14 of 1968 No.38 of 2005	Policy relating the tourism industry

(Source: From the website of each government and made by JICA study team)

(5) Environment-related International Conventions and Treaties

Table 6.2.2-2 shows the list of International Conventions and Treaties.

Table 6.2.2-2 International Conventions and Treaties

No.	Environment related International Conventions and Treaties	
1	International Plant Protection Convention	Rome 1951
2	Plant Protection Agreement for the South East Asia and Pacific Region	Rome 1956
3	Convention on Wetlands of International Importance especially as Waterfowl Habitat	Ramsar 1971
4	Convention Concerning the Protection of the World Cultural and Natural Heritage	Paris 1972
5	Convention on International Trade in Endangered Species of Wild Fauna and Flora	Washington 1973
6	Convention on Conservation of Migratory Species	Bonn 1979
7	Convention on Biological Diversity	Rio De Janeiro 1994
8	International Convention to Combat Desertification	Paris 1994
9	Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks	New York 1995
10	United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa	Paris 1994
11	Cartagena protocol on Biosafety to the Convention on Biological Diversity	Cartagena 2003

(Source: Hand book on multilateral environment agreements 2008, Ministry of Environment & Natural Resources)

(6) Permits and licenses for hydropower development in Sri Lanka

It is necessary to obtain the following permits and licenses for hydropower development in Sri Lanka. Table 6.2.2-3 is the list of permits and licenses.

Table 6.2.2-3 Necessary Permits and Licenses for Hydropower Development

No.	Name of government agency	Requirement
1	Divisional Secretariat	Approval of social acceptability
2	Local government authorities' (Urban council, Municipal Council, and Pradeshiya Sabhas) approval for construction	Approval for construction activities (ex. Transport, unloading, excavation, building, dumping and so on.)
3	Mahaweli Authority	In case of a project location is along Mahaweli River and its reservation.
4	Road Development Authority	In case of existing roads are to be affected by a proposed project, and/or new road is necessary for a project
5	Department of Archaeology	To study on archaeological artifacts and structures of historical interest whether lying or hidden beneath

No.	Name of government agency	Requirement
		the surface of the ground or in any water/lake
6	Geological Survey and Mines Bureau	Quarry permit, quarry extraction, transport and unloading
7	Department of Agriculture	Soil erosion, and soil conservation plan In case of a proposed project site is within a radius of 1 km from the boundary of botanic gardens
8	National Water Supply & Drainage Board, Department of Irrigation, Mahaweli Authority, and the concerned government agencies	There is no written rule for water right in Sri Lanka. But if a proposed project will affect water distribution for water supply for drinking, irrigation and so on, the concerned agencies have to be consulted.
9	Project Approving Agency appointed by CEA	EIA/IEE
10	Land and Land Development Authority	Resettlement Action Plan Land acquisition

(Source: made by JICA study team after hearing with CEB, and CEA)

(7) Strategic Environmental Assessment[34] (SEA)

Sri Lanka is an island Republic situated off the southern tip of the Indian sub-continent. It has a long and continuous recorded history dating back approximately 2500 years, and claims to have one of the oldest nature reserves in the world. Environmental Impact Assessment (EA) in this country has a much shorter history. It can be traced back to the early eighties when there was a dramatic change in economic policies and EA legislation was enacted. Although there were some EAs predating this legislation they were voluntarily prepared for large infrastructure projects such as the Mahaweli Scheme. The final three amendments to the initial legislation making EAs mandatory came into force in 1993. Since then a number of EAs and Initial Environmental Examinations (IEEs) have been prepared for a wide variety of projects with varying degrees of success. Despite this the natural environment is still suffering rapid deterioration in quality and proper implementation of good EA practice is still needed. To address the accumulative effect, strategic environmental assessment (SEA) is currently being introduced. SEA is a system of incorporating environmental considerations into policies, plans, programmes and strategies before or simultaneously with the formulation of them. In May 2006, the Government of Sri Lanka endorsed that all policies and plans, programmes should be subjected to SEA in future. To promote the introduction of SEA, CEA formulated ‘A Simple Guide to Strategic Environmental Assessment (SEA)’ in 2009 to help all administrative entities understand the contents and implementation method. Under the SEA, all such environmentally sensitive areas as forests, wildlife areas, elephant corridors and other unique ecosystems have been identified for conservation purposes.

[34] A simple guide to strategic environmental assessment, Central Environmental Authority

(8) Environmental Impact Assessment[35] (EIA)

1) EIA in the National Environment Act

The National Environmental (Amendment) Act (NEA) No. 56 of 1988 introduced EIA, as a part of the strategy to achieve sustainable development for the entire country and the Central Environmental Authority was assigned regulatory functions.

Part IV C of the amendment act mandated that all “prescribed” development projects are required to be subjected to Environmental Impact Assessment. (Gazette No. 772/22 of 24 June 1993, 859/14 of 23 February 1995, 1104/22 of 5 November 1999 and 1106/1 of 29 November 1999.)

Concerning the power generation and transmission, above mentioned gazette stipulates at Part I as below (Table 6.2.2-4).

Table 6.2.2-4 Power Generation and Transmission Projects

1	Construction of hydroelectric power stations exceeding 50 MW
2	Construction of thermal power plants having generation capacity exceeding 25 MW at a single location or capacity addition exceeding 25 MW to existing plants
3	Construction of nuclear power plants
4	All renewable energy based electricity generating stations exceeding 50 MW
5	Installation of overhead transmission lines of length exceeding 10 km and voltage above 50 kv
6	Involuntary resettlement exceeding 100 families other than resettlement effected under emergency situations

(Source：Guidance for implementing the environmental impact assessment process No.1 (CEA))

Only large scale development projects that are likely to have significant impacts on environment are listed as prescribed projects. In addition “prescribed projects” if located in “environmental sensitive areas (Table 6.2.2-5)” are required to undergo EIA irrespective of their magnitude.

Table 6.2.2-5 Sensitive Areas by Projects

1	Projects and undertaking if located wholly or partly outside the coastal zone as defined by coast conservation act. No. 57 of 1981
2	All river basin development and irrigation projects excluding minor irrigation works (as defined by Irrigation Ordinance chapter 453)
3	Reclamation of land, wetland area exceeding 4 hectares
4	Extraction of timber covering land area exceeding 5 hectare
5	Conversion of forests covering an area exceeding 1 hectare into no-forest uses
6	Clearing of land areas exceeding 50 hectares
7	Within 100 meters from the boundaries of, or within, any area declared as a Sanctuary under the Fauna and Flora Protection Ordinance (Chapter 469)

[35] Guidance for implementing the environmental impact assessment process No.1 and No.2, CEA

8	Within 100 meters from the high flood level contour of, or within, a public lake as defined in the Crown Lands Ordinance (Chapter 454) including those declared under section 71 of the said ordinance
9	60 meter from the bank of a public stream as defined in the Crown Lands Ordinance (Chapter 454) and having width of more than 25 meters at any point of its courses
10	100 meters from the boundaries of or within any area declared under the National Heritage Wilderness, Act No 3 of 1988
11	100 meters from the boundaries of or within any area declared 1981 under the Forest Ordinance (Chapter 451)
12	Any erodible area declared under the Soil Conservation Act (Chapter 450)
13	Any flood area declared under the Flood Protection Ordinance (Chapter 449)
14	Any flood protection area declared under the Sri Lanka Land Reclamation and Development Corporation Act 15 of 1968 as amended by Act No. 52 of 1982
15	Any reservation beyond the full supply level of a reservoir
16	Any archaeological reserve, ancient or protected monument as defined or declared under the Antiquities Ordinance (Chapter 188)
17	Any area declared under the Botanic Gardens Ordinance (Chapter 446)
18	Within a distance of 1 mile of the boundary of a National Reserve declared under the Fauna and Flora Protection Ordinance

(Source：Guidance for implementing the environmental impact assessment process No.1 (CEA))

2) Project Approving Agency (PAA)

The NEA stipulates that approval for all prescribed projects must be granted by a Project Approving Agency (PAA). At present, 23 Government Agencies have been designated as PAAs (Table 6.2.2-6). A single Project Approving Agency is established as responsible for administrating the EIA process for a project. When there is more than once PAA is involved the appropriate PAA is decided by the CEA. It is important to note that a state agency which is a project proponent cannot function as a PAA for that project.

Table 6.2.2-6 Designated PAAs

Ministry	National Planning
	Irrigation
	Energy
	Agriculture
	Lands
	Forests
	Industries
	Housing
	Construction
	Transport
	Highway
	Fisheries
	Aquatic Resources
	Plantation Industries

Department	Coast Conservation
	Wildlife Conservation
	Forest
Authority	The Urban Development Authority
	The Central Environmental Authority
	The Mahaweli Authority of Sri Lanka
Others	The Geological Survey and Mines Bureau
	The Ceylon Tourist Board
	The Board of Investment of Sri Lanka

(Source: Guidance for implementing the environmental impact assessment process No.1 (CEA))

3) Steps in EIA Process

The National Environmental Act has identified two levels in the EIA process. If the environmental impacts of the project are not very significant then the project proponent may be asked to do an Initial Environmental Examination (IEE), which is a relatively short and simple study. However, if the potential impacts appear to be more significant, the project proponent may be asked to do an EIA which is a more detail and comprehensive study of environmental impacts. EIA reports must be kept open for public comments for 30 working days. IEE reports have been exempted from this requirement. However, an IEE report shall be deemed to be a public document for the purposes of sections 74 and 76 of the Evidence Ordinance (Chapter 21) and shall be open for inspection by the public.

In EIA report, a project proponent has to address land acquisition and involuntary resettlement. But approval of them has to be obtained from Ministry of Land & Land Development Authority, not PAA. The information about land acquisition and involuntary resettlement during EIA study is general estimation. Once the implementation of project is decided, detail study is conducted for them. Therefore, approval of EIA and land acquisition & involuntary resettlement are acquired from different government agencies. And their timing of approval is not same time. Description of land acquisition & involuntary resettlement is in section 6.2.2 (9).

Table 6.2.2-7 shows whose responsibility of each step, and the following a) to f) is the EIA steps.

Table 6.2.2-7 EIA Process and its Executive Agency

EIA Steps	Executive Agency
Preliminary Information	Project Proponent (PP)
Scoping (including Screening)	Project Approving Agency (PAA)
Make up EIA TOR	
EIA Study	PP
Publication of EIA Report	PAA
Approval of EIA	

(Source: JICA study team made after hearing from CEA)

a) Preliminary Information

A project proponent is required to provide the CEA with preliminary information on the proposed project, in order for the EIA process to be initiated.

The best time for a project proponent to submit the preliminary information on the proposed project is as soon as the project concept is finalized and the location of the project is decided. The Basic Information Questionnaire form prepared

According to hearing from CEA official last March 2014, A PI is just only information to decide which assessment of IEE or EIA to be taken for the proposed project. PAA does not prepare a TOR for environmental impact assessment on the basis of the PI.

b) Environmental Scoping[36]

When a prescribed project is referred to CEA, the CEA will decide a suitable Project Approving Agency (PAA). The PAA will organize a scoping meeting that a project proponent will present the project outline. Then the scoping meeting members visit the project site, and carry out scoping and Terms of Reference (ToR) for the EIA/IEE will be issued to the project proponent..

c) EIA/IEE Report Preparation

It is the responsibility of the project proponent to prepare the EIA/IEE report and to submit it to the PAA for evaluation. Preparation of EIA reports may require the services of a team of consultants as many specialized areas have to be covered. A list of consulting firms who prepare EIA reports is available at the CEA. In addition to this, project proponents may use the services of suitably qualified consultants who may reliable and adequately qualified experts in the relevant field, in order to ensure that EIA reports will be of the required standard.

d) Public Participation and Evaluation of the Report

On receipt of an EIA report, it will be subjected to an adequacy check in order to ensure that the TOR issued by the PAA has been met. It will then be open for public inspection / comments for a period of 30 working days

If there are any public comments on the IEA report, they will be sent to the project proponent for response.

Subsequent to the public commenting period the PAA will appoint a Technical Evaluation Committee (TEC) to evaluate the EIA report and make its recommendations.

IEE reports are not required to be opened for public comments and are thus subjected to technical evaluation only.

[36] Based on the EIA guideline in Sri Lanka, official and unofficial stake holder meetings are held though; direct affected individuals or groups are not always included during scoping. Only up to Divisional Secretariat level attend scoping meeting. Thus there is a gap on scoping between the EIA guideline by CEA and the JICA guideline on Environmental and Social Consideration

e) Decision Making

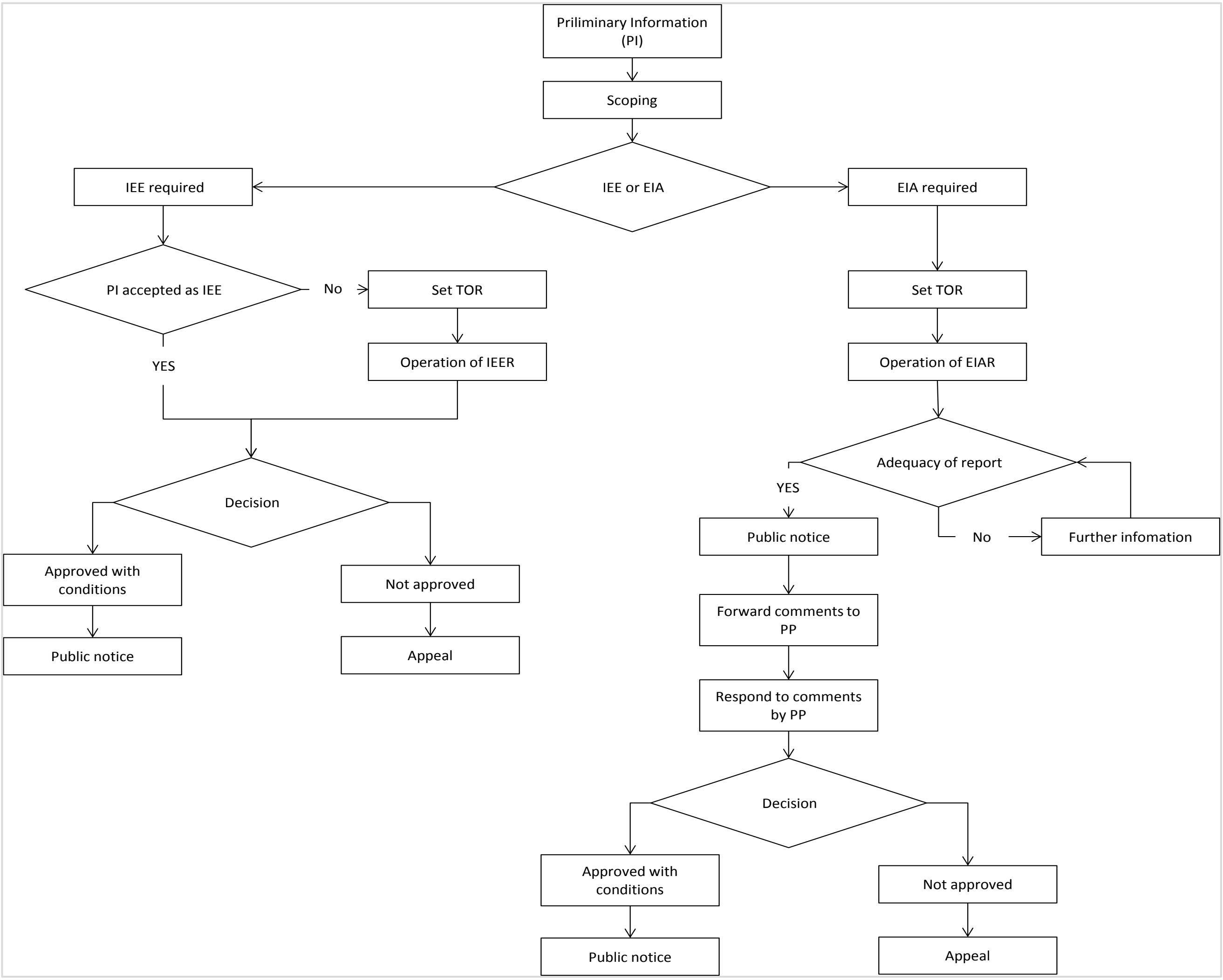
Based on the recommendation of the TEC, the PAA makes its decision on whether to grant approval for a project. If the PAA is not the CEA, it should obtain the concurrence of the CEA prior to granting approval.

If the project proponent does not agree with the decision he has a right to appeal to the Secretary to the Ministry of Environment. The decision of the Secretary to the Ministry of Environment is final

f) Compliance Monitoring

EIA/IEE approval is generally given with conditions which the project proponent is expected to meet. The CEA or the PAA will monitor the implementation of conditions / mitigation measures. If the project proponent violates the conditions, the approval may be revoked.

Figure 6.2.2-1 shows the flow of EIA/IEE.



(Source: Guidance for Implementing the Environmental Impact Assessment Process No.1)

Figure 6.2.2-1 Flow of EIA (on the Right Flow) and IEE

4) The timing of EIA/IEE step

And the Table 6.2.2-8 shows the timing of each step in EIA and IEE process, but actual duration for approval take longer than expected.

Table 6.2.2-8 Timing of Each Step in EIA/IEE Process

Step	Timing		Law background
	EIA	IEE	
Acknowledgement of the preliminary information	6 days	6 days	Regulations Article 6-i/No.772/22,18th June, 1993
Producing of the TOR	30 days	14 days	Regulation Article 6-iii/No. 772/22 18th June, 1993
Public commenting	30 days	-	Regulations Article 11-(i)/772/22, 18th June, 1993
Sending comments to the project proponents (PP)	6 days		Regulations Article 12/722/22,18th June, 1993
Approval (After receiving the comments of the PP)	30 days	21 days	Regulations Article 13/772/22, 18th June, 1993, Regulation Article 8/1159/22,21st Nov. 2000

(Source: Guidance for Implementing the Environmental Impact Assessment Process No.1)

(9) Land acquisition and involuntary resettlement

1) Land acquisition and involuntary resettlement

In Sri Lanka, the Land Acquisition Act of 1950, as amended from time to time, only provides for compensation for land, structures and crops. It did not direct project executing agencies to address key resettlement planning and implementation issues such as a) exploring alternative project options to avoid or minimize impacts on people, b) compensating the non-titled persons who will be affected by a project, c) consulting affected persons and resettlement hosts on resettlement options, d) rehabilitating affected persons.

The Government of Sri Lanka has adopted the National Involuntary Resettlement Policy in 2001, and issued the guide[37] for public officials on good practice in 2013. The policy is designed to ensure that i) project affected persons are adequately compensated, relocated and rehabilitated, ii) delays in project implementation and cost overruns are reduced, and iii) better community relations are restored.

The policy states “Development projects require acquisition of private land and other property in the absence of suitable alternative state land. This sometimes results in physical and economic displacement of persons and bringing adverse impacts on affected communities. Development projects with compulsory land acquisition or restrictions on access to public land have shown that such actions could trigger impoverishment risks among the project affected persons. In this

[37] Land Acquisition and Implementation of the National Involuntary Resettlement Policy

context, it is necessary to identify categories of affected persons and their impoverishment risks arising from land acquisition and to carefully plan mitigatory measures to minimize such risks and impacts. If compulsory land acquisition cannot be avoided, adequate measures must be implemented to minimize such adverse impacts and risks by paying sufficient and fair compensation for all losses, and providing alternative land, particularly, to those who depended on land for their livelihood. They also need to be helped in restoring sourced and livelihood at least, to the level that prevailed prior to the loss of land and physical relocation.”

In case where a land is required for a public purpose of any Ministry, Department, Corporation, Statutory Board, Provincial Council or a Local Government Institution, the Head of the particular Department forwards an acquisition proposal to the Secretary, Ministry of Land and Land Development through the Secretary to the Ministry of which the particular institution fallen under the purview. Process for land acquisition and resettlement, which is based on the Land Acquisition Act, No. 9 of 1950 (LAA) was built upon the Land Acquisition Ordinance of 1876. After confirming accuracy of the proposal, the acquisition procedure is commenced on the approval of the Minister of Land and Land Development. The lands are acquired under the provisions of the Land Acquisition Act and regulations imposed thereto and compensation and interests are paid to the land owners in respect of the lands acquired[38].

2) Relevant laws related to land acquisition and resettlement

Table 6.2.2-9 shows the relevant laws related to land acquisition and resettlement

Table 6.2.2-9 The related Laws for Land Acquisition and Resettlement

Land Development Ordinance	No.19 of 1935
Land Grants (Special Provisions) Act	No.43 of 1979
State Land Ordinance	No.8 of 1947
State Land (Recovery of possession) Act	No.7 of 1979
Land Acquisition Act	No. 9 of 1950 No.39 of 1954 No.22 of 1955
Land Acquisition regulations	2008
Land Settlement Ordinance	No.20 of 1931
Title registration Act	No21 of 1998
Crown Lands Ordinance	No.8 of 1947
National Involuntary resettlement Policy	2001

(Source：Land and Land Development Authority HP)

3) Relevant agencies concerning land acquisition

- Department of Surveys
- Offices of the Government Agents

[38] The website of Ministry of Land & Land Development

- Divisional Secretariats
- All District Courts and Fiscal Offices
- Department of Government Press
- Department of Valuation
- Registration office of the Ministry of Land and Land Development

4) Procedure for land acquisition

Table 6.2.2-10 shows the normal procedure for land acquisition

Table 6.2.2-10 Acquisition Process

Procedures		Agency in Charge
Step 1	Investigation of the land, preparation of acquisition proposal and obtaining approval (Section 2 of Land Acquisition Act(LAA))	Project executing / implementing agency
	Issuance of order	Ministry of Land and Land Development
Step 2	Publication of Section 2 Notice and preparation of advance tracing (Section 2 of LAA)	Divisional Secretary
	Advance tracing	Survey Department
Step 3	Intention of acquisition and calling for objections (Section 4 of LAA)	Ministry of Land and Land Development
	Publish the notice inviting objections	Divisional Secretary
Step 4	Decision to acquire land and preparation of preliminary plan (Section 5 & 6 of LAA)	Ministry of Land and Land Development
	Publish a gazette notice that Hon. Minister of Land and Land Development decided that the land is to be acquired	Divisional Secretary/Government Printer
	Final plan	Survey Department
Step 5	Publication of Section 7 Notice, submission of claims for ownership and compensation and the conduct of inquiry (Section 7 & 9 of LAA)	Divisional Secretary
Step 6	Determination of ownership status and request for valuation (Section 10.1.A of LAA)	Divisional Secretary
	Valuation	Valuation Department
Step 7	Award of compensation, payment of compensation and appeal process (Section 17,22 and 23 of LAA)	Divisional Secretary
	Payment of Compensation (Allocate financial provisions from the Ministry of Lands or the relevant institution and make payments to the land owner)	Divisional Secretary
Step 8	Taking over the possession of the land (Section 38(a) proviso of LAA)	Ministry of Land and Land Development
Step 9	Revocation of vesting orders and divesting of lands (Section 39, 50(1) and 39 A of LAA)	Ministry of Land and Land Development
Step 10	Vesting of land (Section 44 of LAA)	Divisional Secretary
Step 11	Registration of land acquired by the State	Divisional Secretary / Project executing /implementing agency

(Source：Land and Land Development Authority HP)

5) Types of resettlement plans

The National Involuntary Resettlement Policy (NIRP) of 2001 requires that a Resettlement Action Plans (RAP) is prepared for the projects where 20 or more families are affected regardless of the source of funding of the project. The NIRP showed the example of Asian Development Bank (ADB) funded projects, if 200 or more people experience involuntary resettlement, the project will be considered as a category “A” project, which means the project has significant involuntary resettlement impacts. The National Environmental Act (NEA) of 1980 and its regulations of 1993 and 1995 requires approval of the Central Environmental Authority (CEA) for prescribed project; i.e. those resulting in involuntary resettlement of more than 100 families because of state acquisition of private land. The approval granted by CEA for such prescribed projects is based on an Environmental Impact Assessment Report or an Initial Environmental Examination Report. These reports although are prepared following the CEA Guidelines, contain details of resettlement and recommendations for mitigating adverse impact.

The Land Acquisition Act of 1950 (LAA) said that an application for land acquisition for a specified public purpose can be submitted to the Ministry of Land and Land Development (MLLD) by any government agency or local government institution. If the Optimal Power Generation for Peak Demand project will push through, the Ministry of Power and Energy (MOPE) and/or Ceylon Electricity Board (CEB) will be the one to submit the RAP.

A Resettlement Plan (RP) is a time-bounded action plan with a dedicated budget. A full RP is required when involuntary resettlement effects are significant in terms of the large number of persons/families/household affected and displaces. On the other hand, a short RP could be prepared for a project with minor social impacts. A draft RP is prepared at the project feasibility study stage which is subsequently updated after the completion of engineering designs, survey of inventory of losses and public consultations.

Formulation of an RP and its implementation is the responsibility of the project executing agency and project management unit (PMU) of a development project.

6) Grievance redress

The Land Acquisition Act (LAA) provides a limited grievance redress mechanism whereby certain grievances of the affected persons relating to compensation can be referred to the Board of review established under the LAA. This is a limited redress mechanism that only addresses issues pertaining to compensation. The National Involuntary Resettlement Policy (NIRP) recommends the establishment of an internal monitoring system by project executing agencies to monitor the implementation of resettlement Action Plans and handling of grievances. Grievances redress mechanism formally instituted by the project authorities with the support of the Divisional Secretaries of the project area.

7) Compensation and Transaction cost

a) Definition of Compensation

Under laws, compensation is defined as “the amount of money required to make the owner no better or worse off than if no land had been acquired from him”.

Payment of compensation can take place on three types or contexts

i. Compensation for land acquired
ii. Compensation for injurious affection and severance, and
iii. Compensation for disturbance and other losses

Accordingly, a compensation equation can be built as follows.

Compensation = Market value of land acquired + Severance and injurious affection to land detained + Disturbance and other losses

b) Payment of compensation

The NIRP recommends that compensation for loss of land, structures, other assets and income should be based on full replacement cost and should be paid promptly together with transaction costs. This policy principle aligns with international resettlement practices.

The LAA provides for the payment of compensation on the basis of “market value” which is defined as the “amount which the land might be expected to have realized if sold by a willing seller in the open market as a separate entity”.

The Land Acquisition regulations of 2008 redefines the valuation approach to determine “market value” stating that “in case of land where part of land is acquired and when its value as a separate entity deems to realize a value proportionately lower than the market value of the main land the compensation should be proportionate to the value of the main land.

c) Compensation for Non-titled displaced persons

The NIRP recommends that affected persons who do not have documented title to land should receive fair and just treatment.

(10) Environmental Standards[39]

The central Environment Authority (CEA) would be established by the National Environmental Act enacted in 1980, the comprehensive regulation in connection with ambient air, water pollution, waste, soil pollution, noise, and a bad smell will be defined in the Act revision in 1988, and an effluent standard, a standard of noise pollution control were introduced.

It was decided upon the framework about execution of environmental regulation with it, and the acquisition duty of the environmental protection license (EPL) to an environmental pollution company was defined.

[39] Source: Environmental Norms 2011, Board of Investment of Sri Lanka

As for the regulatory standard about water pollution and soil pollution was enacted in 1990, and the control of excessive noise was enacted in 1996.

1) Ambient air quality

The National Environmental Act (NEA) of 1980 as amended in 1988 prohibits any discharge of pollutants into the environment. Sections 23J and K prohibit emission of pollutants into the atmosphere. The CEA in December 1994, gazetted national ambient air quality standards for Sri Lanka as amended in 2008. These regulations do not, however, address vehicular air pollution. Though the NEA gives the CEA the mandate to regulate and control air pollution, enforcement has been rather slow due to the lack of specific emission standards and reliable data. While the Motor Traffic Act considers visible emissions an offence, it is not rigorously enforced. The impending amendments to the Motor Traffic Act will give greater authority to the Department of Motor Traffic and the Police Department to control vehicular emissions. The need for expertise and equipment is acutely felt. Table 6.2.2-11 shows Sri Lanka National Ambient Air Quality Standards.

Table 6.2.2-11 Ambient Air Quality Standards

Pollutant	*Average Time	Maximum Permissible Level		+Method of measurement
		μg/m³	ppm	
1.Particulate Matter -Aerodynamic diamenter is less than 10 μm in size (PM_{10})	Annual	50	-	Hi-volume sampling and Gravimetric or Beta Attenuation
	24hrs.	100	-	
2.Particulate Matter -Aerodynamic diameter is less than 2.5 μm in size (PM2.5)	Annual	25	-	Hi-volume sampling and Gravimetric or Beta Attenuation
	24hrs.	50	-	
3.Nitrogen Dioxide(NO_2)	24hrs.	100	0.05	Colorimetric using Saltzman ,method or equivalent gas phase chemiluminescence
	8hrs.	150	0.08	
	1hr.	250	0.13	
4.Suplphur Dioxide(SO_2)	24hrs.	80	0.03	Pararosanilene method or equivalent pulse fluorescent
	8hrs.	120	0.05	
	1hr.	200	0.08	
5.Ozone(O_3)	1hr.	200	0.10	Chemiluminescence method or equivalent ultraviolet photometric
6.Carbon Monoxide(CO)	8hrs.	10,000	9.00	Non-Dispersive Infrared Spectroscopy
	1hr.	30,000	26.00	
	Any time	58,000	50.00	

*Minimum number of observations required to determine the average over the specified period-
03 hour average-03 consecutive hourly average.
08 hour average-08 hourly average.
24 hour average-18 hourly average.
yearly average-09 monthly averages with at least 02 monthly average each quarter.

(Source: Environmental Norm, Board of Investment of Sri Lanka 2011)

2) Water pollution

a) Provisional water quality standards for major rivers and lakes

It is difficult to comprehend the trend of water quality in public water bodies because of a lack of monitoring data. However CEA set the provisional water quality standard which has not been officials for surface water on major rivers and lakes (Table 6.2.2-12).

Table 6.2.2-12 Provisional Water Quality Standards for Surface Water on Major Rivers and Lakes

	Class 1 Drinking (Boiling only, no scientific processing)	Class 2 Bathing	Class 3 Fish and aquatic life	Class 4 Drinking (Filtering and chlorination)
Biochemical Oxygen Demand (BOD) (mg/l)	3	4	4	5
Chemical Oxygen Demand (COD) (mg/l)	15	20	15	30
Dissolved Oxygen (DO) (mg/l)	6	5	3	4
Most Probable Number (MPN/100ml)	5,000	1,000	20,000	5,000
NO3-N(mg/l)	5	5	5	5
PO4-P(mg/l)	0.7	0.7	0.4	0.7

(Source: Water Environment Partnership in Asia (WEPA) 2012)

a) Effluent standard

i) Tolerance limits for the discharge of industrial waste water in to inland surface water

ii) Tolerance limits for industrial waste water discharged on land for irrigation purpose

Table 6.2.2-13 Tolerance Limits for Discharge of Industrial Waste Water into Inland Surface Water

№	Parameter	Unit type of limit	Tolerance Limit Value
1	Total suspended solids	mg/l, max.	50
2	Particle size of the total suspended solids	μ m, less than	850
3	pH at ambient temperature	-	6.0-8.5
4	Biochemical Oxygen Demand (BOD^5 in five days at 20^0C or BOD^3 in three days at 27^0C)	mg/l, max.	30
5	Temperature of discharge	^0C, max.	Shall not exceed 40^0C in any section of the stream within 15m down
6	Oils and greases	mg/l, max.	10
7	Phenolic compounds (as phenolic OH)	mg/l, max.	1
8	Chemical Oxygen Demand(COD)	mg/l, max.	250
9	Colour	Wave length range 436nm(Yellow ranger) 525(Red range) 620(Blue range)	Maximum spectral absorption coefficient $7m^{-1}$ $5m^{-1}$ $3m^{-1}$
10	Dissolved phosphates(as P)	mg/l, max.	5
11	Total Kjedahl nitrogen(as N)	mg/l, max.	150
12	Ammonical nitrogen(as N)	mg/l, max.	50
13	Cyanide(as CN)	mg/l, max.	0.2
14	Total residual chlorine	mg/l, max.	1.0
15	Fluorides(as F)	mg/l, max.	2.0
16	Nickel(as Ni)	mg/l, max.	3.0
17	Selenium(as Zn)	mg/l, max.	0.05
18	Zinc(as Zn)	mg/l, max.	2.0
19	Pesticides	mg/l, max.	0.005
20	Detergents/surfactants	mg/l, max.	5
21	Faecal Coliform	MPN/100 ml, max.	40
22	Radio Active Material: (a)Alpha emitters (b)Beta emitters	micro curie/ml, max micro curie/ml, max	10^{-8} 10^{-7}

Note 1 : All efforts should be made to remove unpleasant odour as far as possible.
Note 2 : These values are based on dilution of effluents by at least 8 volumes of clean receiving water. If the dilution is below 8 times, the tolerance limits are multiplied by the 1/8 of the actual
Note 3 : The above mentioned general standards shall cease to apply with regards to a particular industry when industry specific standards are notified for that industry.
Note 4 : Pesticides as per World Health Organization (WHO) and Food and Agriculture Organization (FAO) requirements.

(Source： Environmental Norms, Board of Investment of Sri Lanka 2011)

Table 6.2.2-14 Tolerance Limits for Industrial Waste discharged on Land for Irrigation Purpose

№	Parameter	Unit Type of limit	Tolerance Limit Value
1	Total dissolved solids	mg/l, max	2100
2	pH at ambient temperature	-	5.5-9.0
3	Biochemical Oxygen Demand (BOD_5 in five days at 20⁰C or BOD_3 in three days 27⁰C)	mg/l, max	250
4	Oils and greases	mg/l, max	10
5	Chemical Oxygen Demand (COD)	mg/l, max	400
6	Chlorides(as $C1^-$)	mg/l, max	600
7	Sulphates (as SO_4^{2-})	mg/l, max	1000
8	Boron (as B)	mg/l, max	2.0
9	Arsenic (as As)	mg/l, max	0.2
10	Cadmium(as Cd)	mg/l, max	2.0
11	Chromiun,total(as Cr)	mg/l, max	1.0
12	Lead(as Pb)	mg/l, max	1.0
13	Mercury(as Hg)	mg/l, max	0.01
14	Sodium Adsorption Ration(SAR)	-	10-15
15	Residual Sodium Carbonate(RSC)	mol/l, max	2.5
16	Electrical conductivity	μs/cm, max	2250
17	Faecal Coliform	MPN/100ml, max	40
18	Copper(as Cu)	mg/l, max	1.0
19	Cyanide(as CN^-)	mg/l, max	0.2
20	Radio Active Material: (c)Alpha emitters (d)Beta emitters	micro curie/ml, max micro curie/ml, max	10^{-9} 10^{-8}

(Source：Environmental Norms, Board of Investment of Sri Lanka 2011)

3) Waste disposal

In Sri Lanka, solid waste is basically managed by Local Authorities such as Urban Council, Municipal Council and Pradeshiya Sabha and CEA is responsible for the supervision of hazardous waste management. Solid waste is categorized into three groups mainly according to the generation sites: Municipal solid waste, health-care waste and hazardous waste. As for municipal solid waste, CEA asks Local Authorities for site clearance of municipal solid waste facilities, including landfills. A facility that receives over 100 tons/day has to perform an Environmental Impact Assessment (EIA) and receives approval. A facility that receives over 10 tons/day has to obtain an Environmental Protection License (EPL).

The government of Sri Lanka developed regulations for the Management of Hazardous Waste in 1996, as an amendment to the National Environmental Regulations No. 1 of 1990, and guidelines for the implementation of hazardous waste management was published in 1999.

National Environmental (Protection & Quality) Regulation was enacted. Part II of the regulation deals with Scheduled Waste. A scheduled Waste Management License should be obtained from the CEA for the management (generation, collection, transportation, storage, recovery, recycling or disposal of waste or establishment of any site or facility for disposal) of waste specified in the

Schedule VIII of the Regulation.

The other related laws are as follows.

- Municipal Council Ordinance, No.47 of 1947
- Urban Development Authority Act, No. 41 of 1978
- Code of Criminal Procedure, No.15 of 1979: Public nuisances
- Public Nuisance Ordinance, No. 15 of 1982
- National Environmental Act, No.47 of 1980: Environmental Protection License system and infrastructure relevant to solid waste management (sanitary landfills, incinerators)
- Urban Councils Ordinance and the Pradeshiya Sabha Act No. 15, 1987: Establishment of local government ownership of collected waste, and local government' retainment of authority to formulate regulations for waste disposal

4) Soil pollution

Although there is no standard for soil quality in Sri Lanka, one specific law pertaining to it exists: the Soil Conservation Act No. 25 of 1951 (amended in 1953 and 1981). The act aims at the conservation of soil resources for the prevention or mitigation of soil erosion and at the protection of land against damages by flood and drought rather than discharges from industries and agriculture.

5) Noise pollution

Noise pollution has traditionally been controlled by the laws pertaining to nuisance, e.g., the 1865 Police Ordinance. After the establishment of the National Environmental Act (NEA), the ordinance covers noise pollution additionally, defining noise pollution as the presence of sound at a level which causes irritation, fatigue, hearing loss or interferes with the perception of other sounds and with creative activity through distraction'. The CEA may require a local authority to comply with its recommendations for the regulation of noise pollution. The CEA has the mandate to ensure public compliance on noise pollution and deal with nuisances arising 3 - 39 from industries and other miscellaneous sources (UNEP 2009).

Table 6.2.2-15 Permissible Noise Levels in Accordance with Noise Control Regulations

Area	L Acq T, dB(A)	
	Day Time	Night Time
Low Noise (Pradeshiya Sabha area)	55	45
Medium Noise (Municipal Council/Urban Council area)	63*	50
High Noise (EPZZ of BOI & Industrial Estates approved under part IVC of the NEA)	70	60
Silent Zone (100 m from the boundary of a courthouse, hospital,public library,school,zoo,sacred areas and areas set apart for recreation or environmental purposes)	50	45

*Provided that the noise level should not exceed 60 dB (A)inside existing houses,during day time.

(Source: Environmental Norms, Board of Investment of Sri Lanka 2011)

6.2.3 Differences between the JICA Guidelines and the Sri Lankan legislations

Regarding an EIA process and involuntary resettlement issues in the Social and Environmental Considerations, there are some differences between the JICA Guidelines (2010) and the Sri Lankan legislation. Table 6.2.3-1 and Table 6.2.3-2 summarize the differences.

Table 6.2.3-1 Differences regarding an EIA process in the JICA Guidelines and the Sri Lankan legislation

Item	JICA Guidelines	Sri Lankan legislation
Public consultation in an EIA process	SEA stage: The project proponent is obliged to collect comments and/or concerns from the stakeholders in the affected areas and to reflect the comments and concerns to the plan.	SEA stage: No specific opportunities for general stakeholders are provided.
	EIA stage: At the stages of Scoping (draft) and EIA Report (draft), the project proponent is obliged to hold stakeholders meetings (especially for affected people) in the affected area to explain the contents of the scoping (draft) and EIA report (draft). Appropriate comments and concerns should be reflected in the plan.	EIA stage: Stakeholders are provided an opportunity to comment on the plan at its scoping stage. In this case, the stakeholders are usually related governmental organizations (not local/general stakeholders). The stakeholders can submit queries and comments on the EIA report.
Environmental checklist	Environmental checklist is provided by the guidelines for each sector. An EIA report should contain the items in the checklist.	No specific checklist is provided. The PAA shall prepare terms of reference for an EIA (or IEE) study.

(Source: JICA Study Team)

Table 6.2.3-2 Differences regarding involuntary resettlement issues in the JICA Guidelines and the Sri Lankan legislation

Item	JICA Guidelines	Sri Lankan legislation
Resettlement Action Plan (RAP)	The project proponent is obliged to prepare a RAP. If number of resettled household is small (e.g. one household), the RAP can be simplified one. The RAP is prepared as part of the EIA Report.	In case that the number of resettled households is 20 or more, the NIRP requires a RAP.
Compensation for land resettlement	Full replacement cost must be applied as much as possible.	The LAA provides for the payment of compensation on the basis of "market value" which is defined as the "amount which the land might be expected to have realized if sold by a willing seller in the open market as a separate entity". The Land Acquisition regulations of 2008 redefines the valuation approach to determine "market value" stating that "in case of land where part of land is acquired and when its value as a separate entity deems to realize a value proportionately lower than the market value of the main land the compensation should be proportionate to the value of the main land". The NIRP recommends that compensation for loss of land, structures, other assets and income should be based on full replacement cost and should be paid promptly together with transaction costs.
Compensation for non-registered residents	All residents before the cut-off-date are eligible.	The LAA does not have any provisions on this issue. The NIRP recommends that affected persons who do not have documented title to land should receive fair and just treatment.
Grievance redress mechanism	The project proponent is obliged to have a grievance redness mechanism.	The LAA provides a limited grievance redress mechanism whereby certain grievances of the affected persons relating to compensation can be referred to the Board of Review established under the LAA. The NIRP recommends the establishment of an internal monitoring system by project executing agencies to monitor the implementation of RAPs and handling of grievances. Grievances redress mechanism formally instituted by the project authorities with the support of the Divisional Secretaries of the project area.

(Source: JICA Study Team)

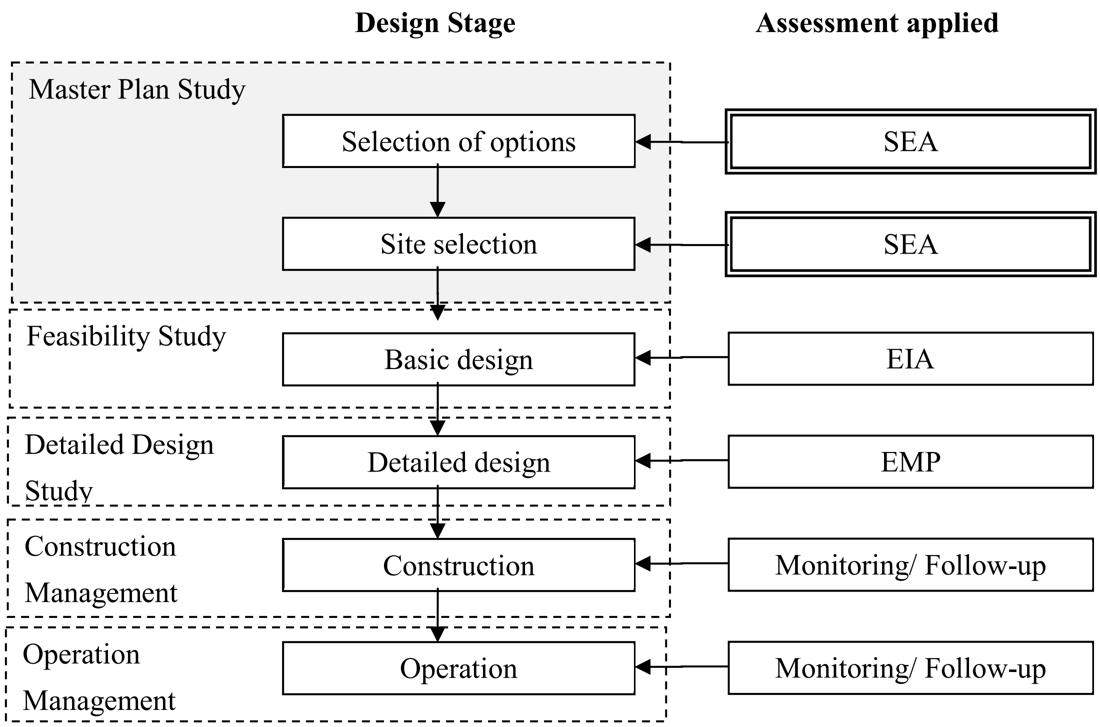
6.3 Strategic Environmental Assessment

6.3.1 Strategic Environmental Assessment and the Study

Environmental assessment is a vital part of all development projects to avoid, minimize and mitigate induced negative impacts on natural and social environment.

In the Study, Strategic Environmental Assessment (SEA) is conducted. Figure 6.3.1-1 shows a flow of the environmental assessments in a development study. The Study is “Master Plan Study” in the figure, and SEA is one of the most suitable environmental assessments at a master plan study. This is because a) project details are not decided; and, b) alternative options can be discussed with wider stakeholders.

In the Study, SEA is conducted in the following two stages - the stage of selecting a power generation option for peak demand, and the site selection stage - to set up a logical framework of appropriateness of power generation development scenario and site selection.



(EIA: Environmental Impact Assessment, EMP: Environmental Management Plan)

Figure 6.3.1-1 Design Stages and Assessment applied

Power generation options and candidate sites are examined in technical, economic and environmental & social aspects at each stage. Information on the SEA is disclosed, and stakeholders meetings are held to discuss the main contents of the SEA throughout the SEA process in the Study.

The JICA Study Team follows the guidelines provided by CEA, Sri Lanka, and experiences from other master plan studies carried out by JICA in other countries.

6.3.2 SEA at Selecting Power Generation Options

At the selection of power generation options for peak demand, two screenings are conducted. At the 1st screening step, all alternative power generation options are examined by critical conditions for the power generation for peak demand in Sri Lanka. At the 2nd step, the remaining alternatives are compared by technical, economic and environmental & social criteria. Figure 6.3.2-1 describes the two-step process.

The details of this exercise are described in Chapter 8.

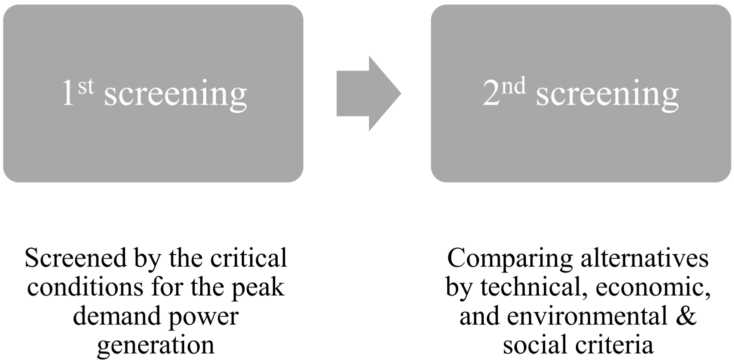


Figure 6.3.2-1 Two-step Screening Process among Alternative Power Generation Options

6.3.3 SEA at Selecting Candidate Sites

At the stage of selecting a suitable site for pumped storage power plant development, two screenings are conducted.

At the 1st screening step, 11 candidate sites are examined at technical, economic and environmental & social criteria, and three (3) promising sites are selected. For comparing 11 candidate sites from environmental and social aspects, it is necessary to collect information on the sites (upper and lower dams / ponds at each site). It is therefore an Environmental Study (the 1st Environmental Study) is conducted to collect information on natural and social environments of the sites.

At the 2nd step, the three (3) selected sites are examined in more details at technical, economic and environmental & social criteria. The 2nd Environmental Study is conducted to collect more detailed information on natural and social environments of the three sites to compare them at environmental and social criteria. The most suitable site for the pumped storage power plant development is selected based on the examination. Figure 6.3.3-1 describes this two-step process.

The details of this exercise are described in Chapter 9 (1st screening) and Chapter 10 (2nd screening).

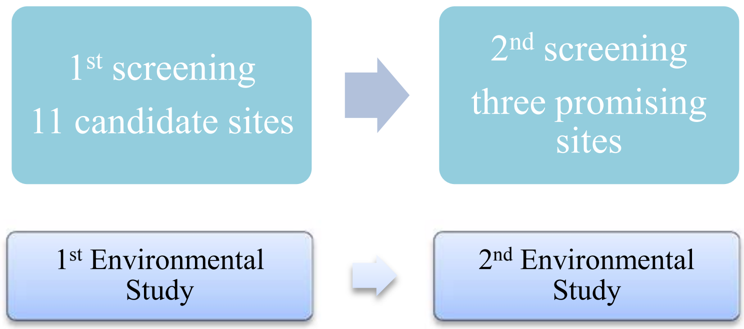


Figure 6.3.3-1 Two-Step Screening Process among Candidate Sites for Pumped Storage Power Plant Development

6.3.4 Stakeholders Meetings

One of the most important steps of SEA is information discloser and reflecting comments from stakeholders into a plan as much as possible.

In the Study, three (3) Stakeholders Meetings (SHMs) are held according to Figure 6.3.4-1 and the proposed agenda of each SHM is shown in Table 6.3.4-1.

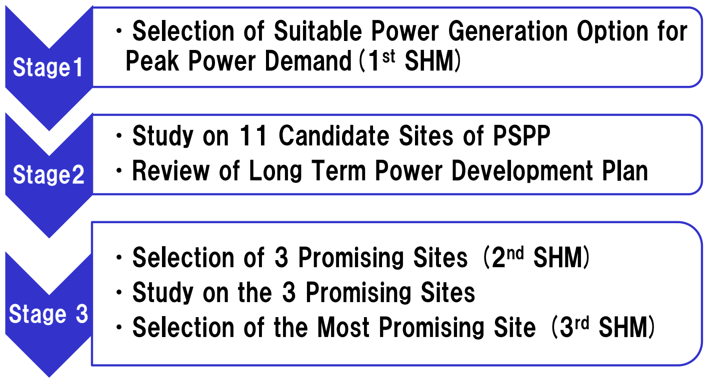


Figure 6.3.4-1 Study Stages and the Flow of SHMs

Table 6.3.4-1 SHMs and Proposed Agenda

SHM	Agenda
1st SHM	• Comparative study of power generation options • 1st site selection study (11 candidate sites) and scoping
2nd SHM	• Result of the 1st site selection study (from 11 candidate sites to 3 promising sites) • 2nd site selection study (3 promising sites) and scoping
3rd SHM	• Result of the 2nd site selection study (from 3 promising sites to one most suitable site)

At each SHM, questions from the participants are answered by CEB and the JICA Study Team. Comments from the participants are collected, and they are reflected into the plan as much as possible.

The details of each SHM are described in Chapter 7.

Chapter 7

Stakeholders Meetings

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7.1 Introduction

The Study applies SEA for selecting power generation options and a suitable site for pumped storage power plant development. Holding Stakeholder Meetings (SHMs) is one of the most important steps of SEA to disclose information and reflect comments from stakeholders into a development plan. The Study, therefore, conducts three (3) Stakeholders Meetings (SHMs) indicated as in Figure 7.1-1.

Regarding SEA and SHMs refer to “6.3 Strategic Environmental Assessment”.

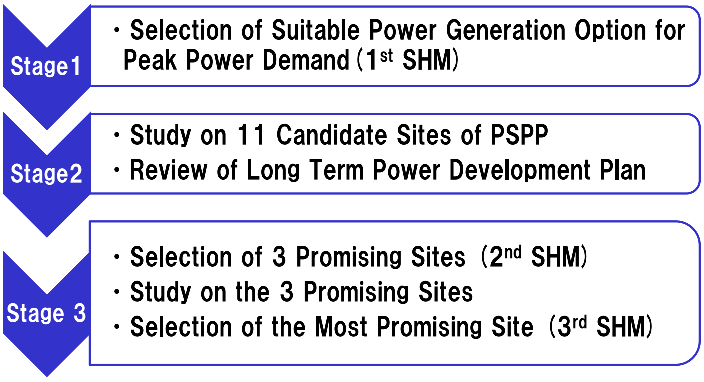

Figure 7.1-1 Study Stages and the Flow of SHMs

7.2 1st Stakeholders Meeting

7.2.1 Objectives and Stakeholders

(1) Objectives

There are two main objectives of the 1st SHM as follows:

- To discuss power generation options for peak demand in Sri Lanka, and to agree on validity of pumped storage power plant (PSPP) development based on the above discussion; and,
- To explain and discuss SEA on selecting suitable sites from candidate sites of PSPP.

(2) Stakeholders

The JICA Guidelines[1] defines “stakeholders” as follows:

> “Local stakeholders” means affected individuals or groups (including illegal dwellers) and local NGOs. “Stakeholders” are individuals or groups who have views about cooperation projects, including local stakeholders.

In case of the 1st SHM, the first half of the meeting is allocated to discuss power generation options in Sri Lanka, and all citizens in the country are theoretically considered as the stakeholders. However, since it is not realistic to invite them to the meeting, experts and social

[1] GUIDELINES FOR ENVIRONMENTAL AND SOCIAL CONSIDERATIONS (JICA, 2010)

Non-governmental Organizations (NGOs) are invited to the meeting. These experts and social NGOs are expected to express their questions and comments on behalf of the citizens.

The latter half of the meeting is allocated to discuss on the selection of suitable sites from candidate sites of PSPP. Since the JICA Guidelines recommend inviting local stakeholders to a SHM from a master plan study stage, CEB and the JICA Study Team have an intensive meeting on this matter. As a result, it is concluded that Divisional Secretaries of each concerned site are invited to the meeting because of the following reasons - it is necessary to give a deep consideration on disclosed information and contents of the meeting; and, it may cause unnecessary confusions or conflicts among the local stakeholders at the stage of selecting several candidate sites. However, since it may be difficult for them to come to Colombo, it is decided that CEB and the JICA Study Team visit them before the 1st SHM to collect their general views and comments on the PSPP development in their divisions.

Regarding natural environmental aspects of the plan, experts and NGOs on natural environment are invited to the SHM.

Table 7.2.1-1 Invited Experts and NGO

Social environment	Natural environment
- Centre for Environmental Justice（Friends of the Earth Sri Lanka）	- IUCN
- Green Movement of Sri Lanka	- Dr. Sarah W. Kotagama
- Consortium of Humanitarian Agencies	- Field Ornithology Group of Sri Lanka (FOGSL)
- International Centre for Ethnic Studies	- Environmental Foundation Limited
- Lanka Mahila Samiti	- EMACE Foundation
- Sarvodaya	- National Solid Waste Management Support Centre
- Sewalanka Foundation	- Sri Lanka Environmental Journalists Forum
	- Sri Lanka Wildlife Conservation Society
	- Wildlife & Nature Protection Society

The following relevant governmental organizations are invited to the meeting.

Table 7.2.1-2 Invited Governmental Organizations

Government Agency
- Ministry of Power and Energy
- Central Environmental Authority
- Department of External Affairs (Ministry of Finance and Planning)
- Department of Irrigation
- Mahaweli Authority (Ministry of Irrigation and Water Resources Management)
- Department of Wildlife
- Department of Forest
- Sustainable Energy Authority

7.2.2 Reconnaissance Site Visits

CEB and the JICA Study Team conducted reconnaissance site visits and interviews with the Divisional Secretaries as in Table 7.2.2-1.

Table 7.2.2-1 Names of the Divisional Secretaries visited

Date in 2013	Candidate site	Name of DS division	District	Remarks
11 June	Loggal	Meegahakiula	Badulla	
12 June	Halgran	Walapane	Nuwara Eliya	
13 June	Maha	Ganga Ihala Korale Aranayaka	Kandy Kegalle	Upper pond Lower pond
18 June	Kiriketi	Imbulpe	Ratnapula	
19 June	Maussakelle	Ambagamuwa	Nuwara Eliya	

The results are summarized as in Table 7.2.2-2.

Table 7.2.2-2 Current Situations of Each Candidate Sites

Candidate site	Situation and comments from some secretaries
Loggal[2]	・ There is an existing irrigation facility at the lower pond. ・ Mini hydro power plant is under construction and there is another plan. ・ There are no protected areas. ・ There are tea plantations. ・ COMMENT: Paddy field should be avoided from inundation.
Halgran	・ The area is prone to landslide. ・ There are paddy fields and tea plantation. ・ There are settlements. ・ During the dry season, water shortage for paddy fields is a concern among the local people. There is an existing irrigation facility at one of the lower ponds. ・ COMMENT: Local people are afraid of landslide.
Maha	・ At the upper pond, tea plantation is the main land use, and there are line houses for tea plantation workers. ・ There are many rock crops in both ponds. ・ There are two existing mini-hydro facilities at the lower pond. ・ There are paddy fields and houses at downstream of the lower dam site. ・ At the right bank of the lower dam site, there is a patch of good natural forest.
Kiriketi	・ Tea plantation is the main land use of the site. ・ Water shortage during the dry season is a concern of the local people. ・ Along the river there is small patch of good natural forest. ・ There are important fish species recorded from the river.
Maussakelle	・ There are big waterfalls. ・ Tea plantation is the main land use of the lower pond areas. ・ There is a protected area close to the upper and lower ponds.

Based on the reconnaissance site visits, a scoping table (draft: Table 7.2.2-3) was prepared and presented at the 1st SHM.

[2] After the visit, the site of Loggal was changed due to technical reasons.

Table 7.2.2-3 Scoping (draft) for 11 Candidate Sites

Natural environment	Impacts on fauna and flora	Inundated forest area
		Impacts on protected areas
		Impacts on endangered species (especially fish and other aquatic species)
Social environment	Impacts on local communities	Number of those who to be resettled
		Area of land to be acquired
		Impacts on water utilization (e.g. drinking water, irrigation)
		Impacts on utilization of forest and grassland
		Impacts on public facilities (e.g. school)
	Impacts on industries	Agriculture
		Forestry
		Tourism
	Impacts on cultural heritages	Religious, cultural and/or archeological facilities
		Impacts on landscape

7.2.3 Contents of the 1st SHM

The 1st SHM was held on 27 June 2013 at Hilton Hotel in Colombo, and the contents of the meeting are summarized in Table 7.2.3-1. The total number of participants was 66 excluding JICA Study Team members (8 National Government agencies, and 4 NGOs). Regarding the selection of power generation options for peak demand, the participants had no objections for the process of selecting power generation option, and the evaluation methodology, and they agreed that the best option for peak demand was PSPP. The methodology for optimization process of planning of PSPP, and the draft scoping for the environmental assessment for 10 candidate sites of PSPP were accepted by the participants. The Department of Forest and IUCN had comments for the survey as in Table 7.2.3-2, and the Study Team agreed to reflect their advices to the next survey plan.

Table 7.2.3-1 Summary of the 1st SHM

Date	27 June 2013 (Thursday)
Time	09:00 – 13:00
Venue	Moonstone & Amethyst Room, Hilton Hotel, Colombo
Participants	77 persons including 11 persons from the JICA Study team 12 persons from 8 concerned government agencies except CEB 5 persons from 4 NGOs (13 NGOs are invited)
Main points of the meeting	1. Power generation for peak power demand ・ To explain the current status of electricity demand and supply in Sri Lanka; ・ To list up the possible power generation options for dealing peak power demand ・ To compare the options from technical, economic and environmental aspects; and, ・ To confirm pumped storage power plant development as one of the most feasible and necessary option for the Study. 2. Optimization process of planning of pumped storage power plant ・ To explain the study process and 10 candidate sites for planning of pumped storage power plant. 3. Scoping of strategic environmental assessment (SEA) for development of pumped storage power plant ・ To explain the process of the SEA for the selection of candidate sites; and, ・ To explain the scoping (draft: Table 7.2.2-3); and, ・ To invite comments / suggestions from the stakeholders. 4. Questions and answers

The presentation material and the list of the participants are attached as Appendix 7.4 and 7.1.

Questions and answers are summarized as in Table 7.2.3-2.

Table 7.2.3-2 Questions and Answers at the 1st SHM

Questioner	Question	Answer/Reflection in the Study
Mr. Harsha Wickramasinghe (Deputy Director General-Sustainable Energy Authority)	Mini-hydro power plants are not allowed to construct in forest reserves like Yala National Park. Yala National Park is shown in the map. But others are not shown. So natural reserves should be properly identified and confirm no sites in other reserves.	There is a need to check the actual site locations in district area wise and actual coordinates. We are on the process of studying on the maps and no sites are selected in natural reserve areas.
Mr. T.M.S.K.Tillekeratne (Deputy General Manager Other Hydro-CEB)	Why don't you consider the capacity expansion of Victoria and Samanalawewa power stations?	We have considered the expansion of the existing hydro power stations. First option is the expansion of the existing hydro power stations, and the construction of PSPP is another option. The Victoria expansion has already been studied. But irrigation diversion at upstream of the power station has not been finalized yet. The final decision is needed to be made so that the project can proceed to the next step. Samanalawewa has an environmental issue.
Mr. Upali Daranagama (Additional Secretary-Ministry of Power and Energy)	Have you studied in detail the other options for peak power generation (technical, economic, environmental, and social) and selected the PSPP?	We have considered and already addressed other options in this presentation.
Dr. Kamal Laksiri (PD-Broadlands CEB)	According to the slide no. 59, the cost of PSPP is 1,000USD/kW. Is this correct for our country?	Based the experiences in other Asian counties as India, Thailand, the construction cost in this range is introduced in the Study.
Mr. Mohan Heenatigala (Forest Department)	There are reserved and protected area maps which belong to the forest department. Since any construction project is not allowed in forest reservation areas, it is recommended to consult the Forest Department before the finalization of the sites.	We already have a protected area map in Sri Lanka. In the next step of the Study, we will conduct an environmental study by a local consultant. They will consult with the Forest Department. We try to avoid the forest reservation areas and the protected areas.
Mr. Harsha Wickramasinghe (Deputy Director General-Sustainable Energy Authority)	Have you considered DSM, Smart meters and thermal power plant extensions (which are considered as retire) as options for peak power generation? What is the reason that capacities of the upper pond and of the lower pond are so different in Loggal?	DSM is to reduce the peak demand. But here our target is to construct power plant for supply peak demand. Therefore DSM is out of our scope. Since the fuel cost is high, thermal extensions should be studied in the economic point of view. The pond sizes show the gross reservoir capacity (water + sedimentation level). The catchment area of the lower pond is much larger than that of the upper pond; therefore the lower pond has the

Questioner	Question	Answer/Reflection in the Study
		higher capacity.
Mr. Shamen P. Vidanage (IUCN, NGO)	You should consider aquatic environment and fauna in PSPP site area as well as the power transmission line in the surrounding areas.	We consider the aquatic species, flora and fauna in the expected site areas. We are going to conduct an environmental study and consider these facts. We undertake study on aquatic environment. Environmental consideration for transmission line, we will also do for the 3 most promising sites.
Mr. Alahakoon (System Control Center)	According to your presentation, the PSPP capacity is 500MW. During the switching to the pumping, the system frequency will drop. If pumping mode trips suddenly, frequency will be increased. Have you considered these facts?	Unit capacity of PSPP is under the study considering the impact on power system as pointed out. We will address the issue in the Study.

At the SHM, e-mail addresses of CEB and the JICA Study Team were presented to send comments and questions if any. The deadline of the comments and questions was set up on 5 July 2013 (Friday), and there were no comments and questions from both NGOs/experts and other governmental organizations.

Figure 7.2.3-1 Opening Speech by Ms. Jayasekera, Deputy General Manager (upper left), CEB, and Q&A Session (upper right and bottom)

7.3 2nd Stakeholders Meeting

7.3.1 Objectives and Stakeholders

(1) Objectives

There are two main objectives of the 2nd SHM as follows:

- To explain and discuss the primary screening results (from 11 candidate sites to 3 promising sites) under the SEA by the JICA Study Team; and,
- To explain and discuss the methodology of the secondary screening exercise (from 3 promising sites to the most promising site).

(2) Stakeholders

The stakeholders of the 2nd SHM are basically the same as the 1st SHM. The related Tea Estate, World Vision (NGO), Divisional Secretariat Offices and Public Utility Commission of Sri Lanka are additionally invited to the 2nd SHM.

Table 7.3.1-1 Invited Experts and NGO

Social environment	Natural environment
- Centre for Environmental Justice (Friends of the Earth Sri Lanka)	- IUCN
	- Dr. Sarah W. Kotagama
- Green Movement of Sri Lanka	- Field Ornithology Group of Sri Lanka (FOGSL)
- Consortium of Humanitarian Agencies	- Environmental Foundation Limited
- International Centre for Ethnic Studies	- EMACE Foundation
- Lanka Mahila Samiti	- National Solid Waste Management Support Centre
- Sarvodaya	- Sri Lanka Environmental Journalists Forum
- Sewalanka Foundation	- Sri Lanka Wildlife Conservation Society
- Maturata Plantations	- Wildlife & Nature Protection Society
- World Vision Lanka	

Table 7.3.1-2 Invited Governmental Organizations

Government Agency
- Ministry of Power and Energy
- Department of Irrigation
- Ministry of Irrigation and Water Resources Management
- Mahaweli Authority (Ministry of Irrigation and Water Resources Management)
- Department of Wildlife
- Department of Forest
- Sustainable Energy Authority
- Public Utility Commission of Sri Lanka
- Divisional Secretariats (Aranayake, and Walapane)

7.3.2 Reconnaissance Site Visits

CEB and the JICA Study Team conducted reconnaissance site visits and interviews with the Divisional Secretaries before the 2nd SHM as in Table 7.3.2-1.

Table 7.3.2-1 Names of the Divisional Secretaries visited

Date in 2013	Name of site	Name of GN Division	Divisional Secretariat	District
11th Nov.	Loggal Upper	Pitamaruwa	Meegahakiula	Badulla
	Loggal Lower	Kalugahakandura		
12th Nov.	Halgran 3 Upper	Morabedda Mantreehena	Walapane	Nuwara Eliya
	Halgran 3 Lower	Dambagolla Puranakumbura Denamure Hagama		
13th Nov.	Maha 2 Upper	Podape Narangala	Aranayake	Kegalle
		Pathithalawa	Ganga Ihala Korale	Kandy
	Maha 2 Lower	Arama Deiyanwela	Aranayake	Kegalle
		Uduwella Watakedenya	Ganga Ihala Korale	Kandy

The results are summarized as in Table 7.3.2-2.

Table 7.3.2-2 Current Situations of Each Candidate Sites

Candidate site	Interviewee	Situation and comments from some secretaries
Loggal	2 GN officers Monks of the Buddhist temples	< Common issues on both proposed reservoirs of upper and lower> ・ Temples are located at each upper and lower proposed reservoir which the local people do not accept to be inundated. ・ Both temples are only the ones in these villages. ・ Before starting any study, consultations with the local people to disseminate information about PSPP are necessary. ・ The local people basically do not like to relocate the temples because the only one temple in the upper and lower proposed reservoir. < Issues on the proposed upper reservoir > ・ The local people use the river water for drinking which proposed upper reservoir is located. ・ 70 out of 300 households in Pitamaruwa village make use of Samurdhi (a government aid for poverty).
Halgran 3	6 GN officers 1 DS officer	< Common issues on both proposed reservoirs of upper and lower > ・ Most of workers of tea plantation are Tamil. ・ 10% of the local people (Sinhalese) in Walapane help tea plantation. ・ The DS officers strongly requested that consultation meetings should be hold at the site to invite the local communities together with related government agencies such as Land Use, Environment, Agriculture and Irrigation agencies. ・ Even though CEB/JICA shows the map of the proposed project site, they have no image how much area is affected. So they said they would like to see the location of proposed project site. ・ The local communities are afraid of land slide, though they have never experience of it. There were a road project and a mini-hydropower project in the past, but nobody has experience of land slide. ・ Water distribution is the farmer's issue especially in the dry season from July to September.
Maha	7 GN officers 3 DS officers	< Issues on the proposed upper reservoir > ・ Regarding the tea plantation which will be inundated by the project in Aranayake Divisional Secretariat side, most of farmers are Sinhara. And they are individual small-scale workers.

Candidate site	Interviewee	Situation and comments from some secretaries
		・ The tea plantation in Ihala Ganga Divisional Secretariat side is managed by several tea estates. ・ Most of the tea plantation workers in Ganga Ihala Korale Divisional Secretariat side are Tamil, but there are also Shinhala workers and the number of their households is around 150. ・ There are 5-6 line houses. The total number of the family members is about 50-60. < Issues on the proposed lower reservoir > ・ About 8 households will be inundated by the proposed project on the left bank. ・ The local communities are afraid of land slide because some stones sometimes fall from the mountain. ・ Regarding the rubber plantation in the proposed lower dam/reservoir which will be inundated, are managed by individual farmers as a small-scale plantation. Each farmer has around 1 to 2 acres of the rubber plantation. ・ There are 4 pipes for drinking water come from the Maha Oya. Two of them were installed by the government in 1993, and after that the other two were done by a private sector. ・ There is a water fall which is nationally famous is seen from the proposed dam axis and the straight distance is about 2 km. About 5-600 foreign tourists visit the site annually. The number of domestic tourist is more than that. There is a view point on the left bank. ・ The GN officers requested to see the proposed project site, so that they can make any opinions or concerns related the project.


Figure 7.3.2-1 Interview with 2 GN Officers in Loggal Site


Figure 7.3.2-2 13 Persons from 5 GN Offices and Walapane Divisional Secretariat Officers in Halgran Site

Figure 7.3.2-3 Interview with 3 GN Officers in Maha Site

Based on the reconnaissance site visits, a scoping table (draft: Table 7.3.2-3) was prepared and presented at the 2nd SHM.

Table 7.3.2-3 Scoping (draft) for 3 Promising Sites

Natural environment	Impacts on fauna and flora	Inundated forest area (including natural, secondary, plantation forests, and home garden)
		Impacts on faunal endangered species (including aquatic species)
		Impacts on floral endangered species (including aquatic species)
		Impacts on ecosystems
Social environment	Impacts on local communities	Number of those who to be resettled
		Area of land to be acquired
		Number of those who to be affected by losing livelihood
		Impacts on public facilities (e.g. school, road)
		Impacts on the poor people and minority
		Impacts on water utilization (e.g. drinking water, bathing, washing, irrigation, mini-hydropower plant) of rivers and wells
	Impacts on industries	Agriculture (including tree & rubber plantation)
		Tourism (e.g. water fall)
	Impacts on culture and landscape	Religious, and/or cultural facilities, burial ground
		Impacts on landscape

7.3.3 Contents of the 2nd SHM

The 2nd SHM was held on 21 November 2013 at Galadari Hotel in Colombo, and the contents of the meeting are summarized in Table 7.3.3-1.

The total number of participants was 66 excluding JICA Study Team members (9 National Government Agencies including 2 Local Government Administrations, 4 NGOs, and 1 Tea Estate.) The participants agreed the primary screening results from 11 candidate sites to 3 promising sites for the PSPP development after the confirmation of the opinions by the Department of Forest, NGO (social environment) and IUCN. There was no participant against the process of the selection and evaluation.

Before the 2nd SHM, one of the JICA Study Team members visited the sites. Divisional Secretary Divisions expressed their ideas (they could not attend the 2nd SHM). They expected to hold SHMs at their sites to explain the project to the local communities. The member of the JICA Study Team explained to them that a SHM would be held at the selected site when the detailed study was implemented as a next step.

Table 7.3.3-1 Summary of the 2nd SHM

Date	21st November 2013 (Thursday)
Time	09:00 – 13:00
Venue	Meeting Room-Bougainvillea, Galadari Hotel, Colombo
Participants	77 persons including 11 persons from the JICA Study team 13 persons from 9 concerned government agencies except CEB 4 persons from 4 NGOs (13 NGOs are invited) 1 person from 1 tea estate (2 tea estates are invited)
Main points of the meeting	1. Introduction ・ Briefing of the Project ・ Present progress of the Project ・ Points of the 2nd Stakeholders Meeting 2. Primary screening results from 11 candidate sites to 3 promising sites ・ First screening ・ Evaluation from the geological aspects ・ Evaluation from the ease of construction works ・ Manufacturing limitation of pump turbine ・ Construction cost ・ Evaluation from the natural and social environmental aspects ・ Ranking of the candidate sites by even evaluation ・ Ranking of candidates sites by environment weighted evaluation ・ Selection of the 3 promising sites ・ Briefing of the 3 sites 3. Methodology of the secondary screening from 3 promising sites to the most promising site ・ Technical and economic aspects ・ Environmental aspects from the results of detailed sites survey ・ Assessment from economic aspects ・ Overall discussion and conclusion

The presentation material and the list of the participants are attached as Appendix 7.5 and 7.2.

Questions and answers are summarized as in Table 7.3.3-2.

Table 7.3.3-2 Questions and Answers at the 2nd SHM

	Questioner		Question	Answer/Reflection in the Study
1	Mr. Hemantha Withanage	Centre for Environmental Justice	1. Have you consider the impact on the downstream of river? Especially, agricultural impact on downstream of river. 2. Have you consider the utilizationof the existing reservoir instead of constructing a new reservoir for PSPP? 3. Information disclosure is important as a safeguard policy of international development assistance. It is better to disclose information for local stakeholders as soon as possible, though Mr. Usui (JICA Study Team) said that such information at this stage make local people confused and/or too much expectation that a project comes to realize. 4. Have you considered the net climate impact (such as emission of CO_2) from this project since it use coal-fired thermal power for pumping?	1. Impacts on the downstream area of the river have been studied. If there are irrigation canals, it is necessary to check the water volume for maintaining the sufficient flow. During the construction and the first impounding periods, necessary mitigation measures will be taken to keep the necessary water volume to the downstream. During the operation period, the water flow will be maintained as it is. It is because the stored water will be circulated between the upper and lower reservoirs. There will, therefore, be no occurrence of scarcity water the downstream of the river because of the PSPP. 2. The JICA Study Team has examined the possibility of utilization of the Randenigala and Victoria reservoirs as a lower reservoir of PSPP, but there is no good site for an upper reservoir near there. There are two reasons: (1) the surroundings of the reservoirs are within a protected area (a sanctuary); (2) it is necessary to stop the operation of existing power plants for a long period in order not to reduce the water level during the construction period of PSPP. 3. There are many ways of information disclosure, such as holding stake holder meetings at site, and/or hearing opinions from local authorities. The JICA Study Team has consulted with the University of Peradeniya, the sub-contractor to conduct environmental studies, how to obtain opinions from the local people without giving them misunderstanding. It is understood that stakeholder meetings at the site will be held during a feasibility study stage but not during this Study (a master plan study stage). 4. Generation power for pumping water at PSPP will come from the national grid, which does not mean that it comes directly from a coal-fired thermal power plant. But, it is assumed that the coal-fired power plant would be the major power generation source of the PSPP in 2025. There is no clear view of GHG efficiency by PSPP, but it is considered that the efficiency of PSPP is around 40% of a coal-fired thermal power plant.

2	Dr. Sugathapala	Sustainable Energy Authority	1. Site evaluation methodology consists only 3 ratings (A, B & C). Also some sites have very near marks. Therefore it is better to do an analysis to remove the barriers. 2. This PSPP contributes to improve NCRE (Non-Conventional Renewable Energy) component in the power generation. The government target is also to improve the NCRE grid connectivity. Therefore PSPP will benefit by thinking of this way, other than use of least cost coal during off peak.	1. The Study is at a master plan stage, and the JICA Study Team uses the standard unit costs (i.e. the figures from the JICA manual). It is therefore that the data for the evaluation is not very accurate but sufficient for comparing the candidate sites. The evaluation exercise has been conducted for 3 months to compare 11 candidate sites, which forces the JICA Study Team to use these standard unit costs. For the evaluation of the 3 selected sites, the JICA Study Team would like to consider the comment. 2. The JICA Study Team would like to consider the comment.
3	Prof. Lakdas Fernando	President / Wildlife & Nature Protection Society	If there are important fauna and flora in the 3 selected sites, what will happen? Are you going to find/change another site?	The JICA Study Team has already conducted surveys on endangered species at 11 candidate sites. At the 3 selected sites, more detailed survey on them will be conducted.
4	Mr. Kanchan	PUCSL	Regarding the economic evaluation, it should not only evaluate cost per kW of each proposed power plant, but include the cost of transmission line.	The Study includes the cost of transmission line utilizing standard unit costs. The routes of transmission lines for the 3 selected sites will be examined considering their connection points, and then the economic evaluation will be conducted reflecting such costs.
5	Mr. Mohan	Forest Department	1. I am confused about the slide no. 31 which mentioned the protected areas. Did you consider the reserved and protected forests? 2. In this stage you have eliminated 8 sites and selected final 3 sites. These may within the reserved/protected forests. 3. In 2012 we have published the Red List & Rich Biodiversity Areas list. Did you check it? In your ranking, you have given lower marks to Halgran & Maha which are rich of fauna & flora. Also Halgran has a planted forest. It is recommended to contact the Forest Department.	The JICA Study Team has checked such protected areas and endangered species at 11 candidate sites by Environmental Study by the University of Peradeniya. The Department of Forest will be visited by CEB and the JICA Study Team to reconfirm them during the present study period. Regarding the "Rich Biodiversity Areas", since information has not been collected, it will be studied and will be reflected in the evaluation if necessary.
6	Mr. Hemantha Withanage	Centre for Environmental Justice	1. EIA will not do much for environment cost benefit analysis. You should think about pumping up by solar power (or that kind of renewable resources) instead of coal power. This Project will come in next 10 or 12 years later. That time this may be possible.	PSPP can absorb unstable renewable energy generation power, which will benefit to promote renewable energy development, and will contribute resolving the global environmental issue. However, solar power cannot be used as a source of pumping water at PSPP. It is, therefore, difficult to evaluate environmental cost and benefit in a quantitative manner.

7	Prof. Lakdas Fernando	President / Wildlife & Nature Protection Society	Sri Lanka has rich of nature. Have you checked the freshwater fish and endemic species in the proposed sites? You mentioned that you have used economic, environment & construction sectors for site evaluation. Final 3 sites, you have given equal weights for environment sector. But you should give higher marks for higher biodiversity areas such as Halgran & Maha.	Aquatic and endemic species have been studied. The Study evaluates all candidate sites in the environmental weighted case (refer to slide 56). The more detailed evaluation will be conducted for selecting one site from the 3 most promising sites.
8	Mr. Mohan	Forest Department	If you find out a site in protected area, what is your next step? Because in protected area, any construction are not allowed. Contact forest department at your earliest.	Although the JICA Study Team has checked not only protected areas but also forest reserves through the Environmental Study by the University of Peradeniya, the Forest Department will be visited to reconfirm them during the course of the Study.

At the SHM, e-mail addresses of CEB and the JICA Study Team were presented to send comments and questions if any. The deadline of the comments and questions was set up on 29 November 2013 (Friday), and there were no comments and questions from both NGOs/experts and other governmental organizations.

Figure 7.3.3-1 Message from JICA Headquarter, Mr. Ogasawara (upper left), Presentation by JICA Study Team Leader (upper right), Mr. Hagihara, and Q & A Session (bottom)

7.4 3rd Stakeholders Meeting

7.4.1 Objectives and Stakeholders

(1) Objectives

There are two main objective of the 3rd SHM as follows:

- To explain and discuss the process of the selection of the most promising candidate site from 3 promising sites; and,
- To explain the outlines of the most promising site and to confirm the site among the stakeholders.

(2) Stakeholders

The stakeholders of the 3rd SHM are basically the same as the 1st and the 2nd SHM. National Water Supply & Drainage Board (Head and Regional offices), chairmans of related Pradeeshiya Sabha, and mini hydropower developers are additionally invited to the 3rd SHM.

7.4.2 Contents of the 3rd SHM

The 3rd SHM was held on 27 May 2014 at Galadari Hotel in Colombo, and the contents of the meeting are summarized in Table 7.4.2-1. The total number of participants was 77 excluding the JICA Study Team members (10 National Government Agencies including 2 Local Governments Administrations, 1 Local Government Authority, 7 NGOs, 1 Tea Estate, and 1 hydropower company). There was no objection to the methodology and the process of evaluation to select the most promising site from the 3 candidates' sites. Comments from the participants were on the features of each site, and the JICA Study Team explained the conditions of each site in details. The participants agreed that the Maha 3 site was the most promising site for the PSPP development.

Table 7.4.2-1 Summary of the 3rd SHM

Date	27st May 2014 (Tuesday)
Time	09:30 – 13:00
Venue	Meeting Room-Grand Ballroom C, Galadari Hotel, Colombo
Participants	86 persons including 9 persons from the JICA Study Team 10 persons from 7 concerned government agencies except CEB 7 persons from 7 NGOs (13 NGOs were invited) 1 person from a tea estate (2 tea estates were invited) 1 person from 1 Pradeeshiya Sabha (2 Pradeeshiya Sabhas were invited) 1 person from 1 mini hydropower developer (2 developers were invited)
Main points of the meeting	Session I : Briefing of the Study Session II: Evaluation of the promising sites II-1 Technical/Economic evaluation of options II-2 Environmental evaluation of options Session III: Overall rating and ranking for the most promising site Session IV: Overall discussion and conclusion

The presentation material and the list of the participants are attached as Appendix 7.6, 7.7 and 7.3.

Questions and answers are summarized as in Table 7.4.2-2.

Table 7.4.2-2 Questions and Answers at the 3rd SHM

	Questioner		Question	Answer/Reflection in the Study
1	Mr. Hemantha Withanage	Centre for Environmental Justice	The Scores given to the environmental aspects for the recommended Maha 3 are less than 50%, which implies significant environmental restoration cost. Does construction cost shown in the table include the environmental mitigation cost or not?	The construction cost includes certain (uniform) percentages of the civil works' cost at this moment. It will be re-estimated with certain accuracy at the feasibility study stage
2			What are the specific environmental issues at each candidate sites? Eg: No. of endemic species in those areas, How much paddy fields are gone without water.	Mr. Usui explained the major environmental impacts by using slide 28
3			The future power generation depends very much on coal and/or LNG, which give negative impacts to the Global warming. What is the share of the Non-conventional Renewable Energy (NCRE) in 2025?	The plan in 2025 has already accommodated 830MW of NCRE
4	Mr. Upali Daranagama	Ministry of Power and Energy	What is the position of the Victoria Capacity Extension project in this study?	This study identifies the said project as the best option for peak power demand since its feasibility study has already been conducted. However, this study is the master plan for pumped storage power plant development. The Study Team, today, suggests the most promising site for the PSPP.
5	Mr. Sameera Ganegoda	LTL Holdings	When the existing mini hydro plant in the Maha Lower site will be affected? At construction period, or after commencement of operation?	It depends where the plant is located. Details will be explained and discussed with all stakeholders at the feasibility study stage.
6	Mr. Hemantha Withanage	Centre for Environmental Justice	The power generation cost by coal may increase in the future. Does the study take this factor into account?	Such factors will be taken into account in the final report by a sensitivity analysis in the economic analysis.

At the SHM, e-mail addresses of CEB and the JICA Study Team were presented to send comments and questions if any. The deadline of the comments and questions was set up on 30 May 2014 (Friday), and there were no comments and questions from both NGOs/experts and other governmental organizations.

Figure 7.4.2-1 Opening Message from CEB, Ms. Kamani (upper left), Message from the JICA Headquarter, Ms. Watanabe (upper right), Presentation by JICA Study Team Leader (lower left), Mr. Hemantha, Center for Environmental Justice during Q & A Session (lower right)

Chapter 8

Selection of Power Generation Options for Peak Power Demand

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Chapter 8 Selection of Power Generation Options for Peak Power Demand

8.1 Introduction

The Revised Base Case of long term generation expansion plans is plotted out in the current LTGEP 2013-2032 in order to reduce the electricity tariff in Sri Lanka and to improve financial situation of CEB through simulations in consideration of least cost of whole power system of each expansion scenario. In consequence, it lays major emphasis on the development of coal thermal power plants that is cheap in fuel cost and generation cost. However, since the power generation of coal thermal power plant has no advantage in point of load following capability, it is necessary to develop other power supply plants for peak demand with enough load following capability, relatively small environmental impact, and in addition, with economical efficiency and contribution to whole power stability of Sri Lanka.

Objectivity and reliability are emphasized in process of the selection of power generation options for peak power demand. For this reason, power generation options described in the LTGEP 2013-2032 are adopted as potential options for development, and their aptitude for the peak power demand is examined as the first screening in this chapter. Then, the second screening is carried out from viewpoints of power generation characteristics, environmental and social consideration, and economic effectiveness. In addition, the necessity of combination development of power generation options with further efficient measures to peak power demand is reviewed.

8.2 Selection of Options (First Screening)

8.2.1 Power Generation Options

(1) Hydropower Plant (New Construction)

Most of comparatively large scale hydro resources in Sri Lanka have been developed, and only following projects are under construction or study according to the LTGEP 2013-2032.

Table 8.2.1-1 Options of Hydropower (New)

	Output	Remarks
Broadlands	35 MW	Committed, Run-of-River Type
Uma Oya	120 MW	Committed, Multipurpose
Moragolla	27 MW	Run-of-River Type
Gin Ganga	49 MW	Run-of-River Type
Total	231 MW	

In case of Run-of-River type hydropower, the electric energy from power station totally subjects to the river flow rate and it cannot be used for power generation for peak power demand because its reservoir capacity is too small. In case of hydropower attached to multipurpose dam project, the priority of usage of stored water in the reservoir for power station is lower than that for irrigation project, and its contribution to peak power demand cannot always be expected.

Existing hydropower can supply approximately 570 MW for peak power demand (refer to Chapter 4) during wet season, but in dry season expected supply for peak power demand may decreased unless power supply during off peak time is limited. To sum it up, new hydropower plants cannot be expected as supply for future peak power demand, because they are run-of river type or attached to multipurpose dam project as mentioned in the Table 8.2.1-1.

Characteristics of hydropower for peak power demand are as follows; Power control range 25 to 100%, Power variation 50%/min, Start-up time 1 to 2 min.

(2) Hydropower Plant (Capacity Extension, Upgrading)

According to the LTGEP 2013-2032, the following projects are reviewed. They can be categorized into three, that is, capacity expansion project that aim at peaking duty by new installation of power generation unit, upgrading projects by refresh works of generation equipment and enhancement projects in kWh by increasing utilizable water for power generation.

Table 8.2.1-2 Options of Hydropower (Extension)

	Output	Remarks
Samanalawewa	120 MW	for peaking duty, economically unfeasible
Wimalasurendra	-	upgrading
New Laxapana	-	upgrading
Old Laxapana	-	upgrading
Victoria	228 MW	for peaking duty, waiting for determination of irrigation intake location
Kotmale	-	30m dam raising, approx. 20% energy to be increased
Upper Kotmale	-	Additional diversion scheme, approx. 30% energy to be increased
Total	348 MW	

Among them, only Samanalawewa and Victoria capacity extension projects can be options for peak power demand. However, the status of the study on Samanalawewa capacity extension project is too primitive without feasibility study and environmental impact assessment to develop shortly, even though the facilities such as a bifurcation and a space for additional units have been provided during construction stage of existing power station. In addition, the existing power station is in trouble with the leakage of the storage water in the reservoir through the dam abutment.

On the contrary, feasibility and environmental impact assessment have already provided for Victoria capacity extension project by JICA and the project is ready to move on to the next step. As a sticking point, as an intake location of the irrigation project for the northern part of Sri Lanka has not determined yet whether downstream of the Victoria reservoir or upstream, the expected value of the extension project has not been fixed and the procedure for the development has been suspended. Once the location of the intake determined in a short time, the Victoria capacity extension project is expected for the peak power demand in 2020. However, since the increasing capacity by the extension project is 228 MW and rather small compared with the expected peak power demand in 2025 (1,000-1,600 MW), combination development with further option for peak power demand is necessary.

In addition, such capacity extension project is not listed in the Revised Base Case Scenario of the LTGEP 2013-2032.

(3) Pumped Storage Power Plant (PSPP)

During the off-peak time, electric energy generated mainly by base load and middle peak power plants is stored in Upper Pond of pumped storage power plant as Potential Energy. During the peak time, power is generated using stored potential energy in Upper Pond for peak power demand. The PSPP technology is a well-established technology with 86 GW of installed capacity in the world. Since stored water can be utilized repeatedly for pumping and generation, operation of pumped storage power plant can be operated without any restriction by river floe due to even heavy drought. It has side benefits as follows as well:

- Contribution to improvement in efficiency of base load or middle peak load power plants
- Contribution to maintenance of stability by absorbing grid turbulence during generation mode
- Contribution to the same stability during pumping mode by adoption of variable speed PSPP

CEB has selected 10 sites at the central mountainous area in the island and preliminary study has carried out. However, no PSPP project is planned in the Revised Base Case of the LTGEP 2013-2032.

Characteristics of PSPP for peak power demand are as follows; Power control range 25 to 100%, Power variation 50%/min, Start-up time 1 to 2 min.

(4) Coal Fired Thermal Plant

According to the LTGEP 2013-2032, the following coal fired thermal power plants are planned to develop before 2025 in order to achieve the policy element “provision of electricity at the lowest possible cost” in the “National Energy Policy & Strategies of Sri Lanka” published by MOPE in 2008.

Table 8.2.1-3 Options of Coal Thermal Power

	Output	Remarks
Puttalam	300MW × 3units	2nd and 3rd units are under construction
Trincomalee	250MW × 2units	Not committed, expected to be completed in 2018 & 2019
New Site	300MW × 6units	Expected to be completed up to 2025
Total	3,200 MW	

The New Site without site name in the above table, the project under the study “Prefeasibility Study for High Efficiency Coal Fired Thermal Plant” appears promising as post Trincomalee. Sri Lanka side expects the new site also in the vicinity of Trincomalee.

Coal fired thermal plant has the advantage of being low cost of power generation compared with other fossil fired thermal plant because its fuel cost is cheaper than that of other fossil fuel. On the contrary, coal fired thermal plant has low load following capability because coal is a solid fuel and is disqualified as power generation for peak power demand. Meanwhile, coal thermal power plants in Thailand and Philippine are under operation with pumped storage power plants to improve their load following capabilities. Characteristics of Coal Fired Thermal for peak power demand are as follows; Power control range 30 to 100%, Power variation 1%/min, Start-up time 10 to 20 hours.

(5) LNG Combined Cycle Power Plant

LNG combined cycle power plant is studied in the LTGEP 2013-2032 as case study with condition that certain restriction would be put on the development of coal fired thermal plant in future and is not planed in the base case of the generation expansion plan. It is now under study for energy diversification enhancement by introducing LNG operated power generation option in Sri Lanka using JICA Engineering Service scheme. This study consists of an LNG import facility (via tanker ships), domestic storage, regasification unit and a power plant and aims at stable and low cost power generation for rapid growth of power demand and economic development and social stability in Sri Lanka.

LNG combined cycle power plant has high load following capability (Power control range 20 to 100%, Power variation 10%/min, Start-up time around 1 hour) compared with other fossil thermal power plant and is used for power generation for peak power demand in countries and areas where are not blessed with hydro resources. However, the operation specialized for peak power demand results in high generation cost because the load factor of the LNG combined cycle power plant is held down by such operation. In this sense, for the country like Sri Lanka with abundant hydro potential, LNG combine cycle power plant should be an option for middle or base load demand and it should contribute as an option for peak demand only in a dry spell in term of economic efficiency.

In addition, there is no commercially developed gas field in Sri Lank and no background of storage, transportation and regasification for industry and domestic areas. Therefore, the completion date of LNG import facility is unclear by thought of its economic efficiency.

(6) Gas Turbine Power Plant

Existing gas turbine power plant of CEB is only Kelanitissa 215 MW (old: 20 MW × 5 units, new: 115 MW × 1 unit). New projects in the expansion plan in the LTGEP 2013-2032 are 225 MW (75 MW x 3 units) in 2015, 105 MW (1 unit) in 2017.

The characteristics of gas turbine power plant are short start-up time and good load following capability (Power control range 20 to 100%, Power variation 10%/min, Start-up time around 10 to 20 minutes) during operation and short construction period. On the other hand, it has demerits such as low heat rate and short life period. In addition, its fuel cost is comparatively high as same as other petroleum fuel thermal power plants. Therefore, gas turbine power plant is used for peak power demand and standby generator if an emergency arises.

(7) Diesel Power Plant

Existing diesel power plants of CEB are Sapugaskande 160 MW (A: 20 MW × 4 units, B: 10 MW x 8 units) at outskirts of Colombo and Chunnakam 8 MW (1 unit) at northern island. No new diesel power plant other than remote power sources in northern island since 1999.

Since diesel power plant is small scale and its fuel cost is comparatively high in general, it is not taken up as an option for the LTGEP 2013-2032 and only planned as power source for restoration of northern district. Start-up time of Diesel for peak power demand is within several minutes and load following characteristics is good.

(8) Power Plant using Renewable Energy

The development of renewable energy (mini hydro, wind, solar and biomass) belongs to Sustainable Energy Authority (SEA, Ministry of Environment). The National Energy Policy and Strategies of Sri Lanka states that Sri Lanka will endeavor to reach a target of at least 10% by 2015 and “Mahinda Chinthana” future vision states the target of 20% by 2020 from the total energy supplied to the grid from non-conventional renewable resources by a process of facilitation including access to green funding such as CDM. In accordance with this vision, CEB has started a study using ADB fund and will set up by November 2014 a development plan of renewable energy up to 2030. Cap amount of development of renewable energy through stability analysis of the grid and its development potential are under study.

- Mini Hydro: Hydropower less than 10MW in output is categorized as mini hydro and shall be developed by private company. The generated electricity shall be sold to CEB under Feed-in-Tariffs (FIT) system. Total 217MW mini hydro has been developed up to 2012 and Standard Power Purchase Agreement (SPPA) has been signed among developers and CEB for 153 MW.
- Wind Power: Mannar Island located north-west of Sri Lanka has 400 to 500 MW potential of wind power and 100 MW among them is under study as a wind farm in the said study. As of

2012, 74 MW wind power has been developed and SPPA has been signed for 31MW.

- Solar Power: Solar power is regarded as power option for remote area. As of 2012, 1.4 MW solar powers have been developed.
- Biomass Power: Biomass power generation using particular plant as fuel has been planned and 0.5 MW power generation is undergoing and 62 MW SPPA has been signed as of 2012. Co-generation using industrial and agricultural waste as fuel has been also developed and 11 MW power generations are undergoing and 4MW SPPA has been signed.

However, as renewable power options generally respond to natural phenomena and its output has large fluctuation, it possesses low reliability, and, therefore, are not suitable for power generation for peak power demand. In case of the biomass power, because there is uncertainty in stable fuel securement, it cannot be expected as power generation for peak power demand.

8.2.2 Other Options other than Power Generation

(1) IPP

IPP thermal power was introduced in Sri Lanka where the power supply capacity has been in severe shortage of electricity in past years. Nine sites of IPP thermal power are now under operation and their total capacity is 804.5 MW and account for about 49 % of total thermal power plants' output. Its breakdown is 7 small diesel power plants less than 100 MW, total 371.5 MW, and 2 combined cycle power plants using diesel or naphtha as fuel possessed by AES Kelanitissa and West Coast, total 433 MW. These IPP thermal power plants undertake an important role at the moment as base load, middle load and peak load power generation under constant shortage of supply capability of CEB.

On the contrary, the heat rate of small scale IPP thermal power plants is low and the procurement cost of petroleum fuel is unstable, and they weigh on the financial standings of CEB. The unit costs of IPP thermal, CEB thermal and hydropower plant are shown in the Table 8.2.2-1.

Table 8.2.2-1 Generation Cost (2012)

	Annual Generation (GWh)	Total Cost to CEB (M.LKR)	Average Unit Cost (LKR/kWh)
All Hydro	2,466	10,269	4.16
All CEB Thermal	3,442	57,464	16.69
All IPP Thermal	4,906	110,609	22.55
All Plants	11,543	188,174	16.30

Consequently, CEB is carrying out its vision of fuel diversification from oil to coal and LNG and development of high efficiency large scale thermal power plant and turning up of CEB financial standings. Concurrently, CEB is going to phase out the procurement of electricity from IPP.

As mentioned above, IPP thermal power plant cannot be considered as power source for peak power demand in future but only for a limited time by the introduction of new peak power generation.

(2) Demand Side Management (DSM)

DSM is not a power generation, but allows for reduction of peak power demand and shifting of its timing and is regarded as measures for peak power demand. Specifically, reduction of electric power consumption by introduction of energy-saving products and peak time shift by introducing hourly tariff of electricity by linking with smart grid technology are effective.

- Introduction of Energy-saving Products: Night time peak demand of electricity is caused by mainly domestic lighting demand. As for lighting, compact fluorescent lamp (CFL) and light emitting diode (LED) are commonly used. According to the data of the Japanese producer’s association of light fixture, a 60W incandescent lamp has same luminance level of a 12W CFL and a 7.5W LED. Replacement of incandescent lamp to CFL has a profound effect on cut down of power consumption. However, CFL has been already in widespread use even in rural area, the effect on peak power cut in the replacement of CFL with LED is limited.
- Hourly Electricity Tariff: Hourly electricity tariff system in Sri Lanka is applied for general and industrial consumers but not for domestic consumers. If it is applied for domestic consumers, peak shift or peak cut can be expected. However, as shown in the Figure 3.1.6-4, night peak in large city area like Colombo is not predominant and the night peak is caused by mainly lighting demand of citizen. Because the lighting demand cannot be shifted, the introduction of hourly tariff causes degradation of convenience and strong objection from citizen. In addition, its effect is small and the feasibility of hourly electricity tariff for domestic consumers is quite low.

(3) Interconnection with Indian Grid

Power Grid Corporation of India Limited (PGCIL) carried out preliminary study of the linkage between Indian grid and Sri Lankan grid in 2006. In 2010, MOU for study was concluded between Sri Lanka and India and now feasibility study is undergoing base on the MOU. This project will firstly connect both grid with 400 kV with 500 MW capacity transmission line and then expand double circuit with 1,000 MW capacity. According to Country Operation Business Plan of ADB (December 2012), ADB plans Technical Assistance Loan for the detailed design of the project from 2015. However, because there are critical environmental issues in overhead transmission line at straight portion in both Sri Lanka and India, the development schedule is uncertain.

When the power interchange realizes after completion of the interconnecting transmission line, it will definitely contribute to the stability of Sri Lankan grid and expected to receive electricity for peak power demand from India. However, Karnataka State and Tamil Nadu State in the south of

India has same daily load curve pattern with Sri Lanka and night time lighting demand. They also suffer from shortage of peak power generation and rolling blackouts are executed during peak power demand on a daily basis. Even optimistic case that Sri Lanka can purchase electricity for peak demand duration, its tariff might be quite high. Therefore, the linkage with Indian grid cannot contribute to peak power demand in Sri Lanka.

8.2.3 Result of First Screening

Capability and suitability of 11 power generation options for peak power demand are mentioned in the Chapter 8.2.1 and 8.2.2. As a result of the first screening, the following options are selected for the reason mentioned in the chapters.

- Hydropower Plant (Capacity Extension)
- Pumped Storage Power Plant
- LNG Combined Cycle Power Plant
- Gas Turbine Power Plant

8.3 Optimal Options (Second Screening)

The suitable and feasible power generation options, viz. Hydropower Plant (Capacity Expansion), Pumped Storage Power Plant, LNG Combined Cycle Power Plant, and Gas Turbine Power Plant, for peak power demand selected in the Chapter 8.2.3 are compared each other from the aspects of load following capability and generating characteristics. In this chapter, the most suitable option for peak power demand after 2025 is selected by conducting comparison studies on load following capability and generation, environmental and social considerations, and economic efficiency.

8.3.1 Load Following Capability and Generation Characteristics

The expected daily load curve in 2025 is shown in the Figure 4.3-1. Power demand starts increasing rapidly at around 4:00 AM. After 6:00 AM with the coming of dawn, the power demand for lighting goes down once. And then, the power demand starts increasing again and keeps in a certain level up to the evening due to industrial activities. In addition, the lighting demand after 18:00 rapidly makes it markedly high level up to 21:00. It is necessary to divide power supply capability into three; peak, middle and base, and to develop power plants suitable for each in order to supply electricity in an economic and stable manner.

The Table 8.3.1-1 shows variety of power options corresponding to each category with its qualifications.

Table 8.3.1-1 Characteristics of Power Options and their Qualifications

Demand	Demand Characteristics	Operation Characteristics	Power Option
Peak Demand	- Considerably large fluctuation in demand - Short duration of demand	- Good load following capability - Short Start-up Time - Capability of frequent start and stop	- **Pumped Storage (reservoir type)** - **Hydro Power** - **Gas Turbine** - **LNG Combined Cycle** - Oil Fired Thermal
Middle Demand	- Large fluctuation in demand - Around a half day duration of demand	- Capability of DSS operation	- **LNG Combined Cycle** - Oil Fired Thermal - Coal Fired Thermal - Hydropower (run-of-river type)
Base Demand	- Small fluctuation in demand - Whole day duration of demand	- Capability of continuous operation	- Coal Fired Thermal - Hydropower (run-of-river type) - Nuclear Power

(Source: Made by JICA Study Team)

The Comparison table is shown in the Table 8.3.1-2. In this table, the following rating is applied for four options; 3 = very good, 2 = good and 1 = fair. This table also includes the evaluation of potential capacity, easiness of procurement of fuel during operation stage. The option having high total score has high suitability and feasibility as power generation for peak power demand.

Table 8.3.1-2 Comparison of Generation Characteristics

	Hydropower (Extension)	PSPP	LNG CC	Gas Turbine
Power Control Range	3	3	2	2
Start-up Time	3	3	1	2
Load Following Capability	3	3	2	2
Potential Capacity	1	3	3	3
Procurement of Fuel	3	2	1	2
Total Score	13	14	9	11
Total Ranking	2	1	4	3

The grounds for evaluation for each item are shown below:

- Power Control Range: with or without limitation of minimum operation output
- Start-up Time: time length of warm-up for start-up
- Load following Capability: quick-response capability to order of power control operation
- Potential Capacity: potential capacity for future development
- Procurement of Fuel: easiness of fuel procurement, no record in LNG procurement

8.3.2 Environmental and Social Considerations

The power generation options after the 1st screening are compared in the following 10 environmental and social aspects: air pollution; water pollution; greenhouse gas emissions; impacts on ecosystems; impacts caused by resettlement; impacts on water right / water resources; impacts on agriculture; impacts on fishery; impacts on tourism; and impacts on human health.

Rating is conducted by the JICA Study Team in four (4) ranks: 4 = no negative impacts; 3 = small negative impacts; 2 = medium negative impacts; and 1 = large negative impacts are expected..

1) Air pollution

Although new hydro PP is excluded from the option, it is shown as a baseline scenario to rate Hydro power extension and Pumped storage PP. The impacts from air pollution by New hydro PP are estimated based on life cycle assessment conducted by International Energy Agency (IEA) in 2000. The assessment includes the periods of manufacturing, construction, operation, and closing.

The rating of Hydro power extension is “1” because some impacts from air pollution are expected in its life cycle.

Pumped storage PP uses electricity for pumping from other energy sources (i.e. coal fired thermal PP in Sri Lanka), of which pollutants needs to be counted.

Regarding LNG Combined Cycle PP (LNG CC), the impacts from air pollution are estimated based on the life cycle assessment of IEA as New hydro PP.

Gas turbine thermal PP produces more air pollutants than LNG CC PP, however the Gas turbine thermal PP is not considered to give “large negative impacts” like a coal fired PP. The same datum of LNG CC PP, therefore, is applied for its evaluation, and “2” is given as its rating.

The results are shown in Table 8.3.2-1.

Table 8.3.2-1 Air Pollution by Each Power Generation Option

Power Generation Option	SO_2 (t SO_2/TWh)	NOx (t NOx/TWh)	Particulate Matter (t/TWh)	Rating
New hydro PP* *(A baseline scenario)*	5 to 60	3 to 42	5	3
Hydro capacity extension	Less than New hydro PP	Less than New hydro PP	Less than New hydro PP	3
Pumped storage PP	More than New hydro PP	More than New hydro PP	More than New hydro PP	2
LNG Combined Cycle PP (LNG CC) PP*	4 to 15,000+	13+ to 1,500	1 to 10+	2
Gas turbine thermal PP*	N/A	N/A	N/A	2

*: Hydropower and the Environment: Present Context and Guidelines for Future Action. Vol. II: Main Report (International Energy Agency, 2000)

2) Water pollution

The impact on water by effluents is evaluated by types of impacts, probability of occurrence, and severity of impacts with mitigation measures. This is because the quantitative figures by each power source are not available.

The impacts are considered to be in the areas which may directly be affected.

The results are shown in Table 8.3.2-2.

Table 8.3.2-2 Water Pollution by Each Power Generation Option

Power Generation Option	Impacts	Probability of occurrence	Severity of impacts with mitigation	Rating
Hydro capacity extension	• Alternation of the water temperature • Prolongation of turbid water discharging	Low	Low	3
Pumped storage PP	• Alternation of the water temperature • Prolongation of turbid water discharging	Low	Low	3
LNG CC PP*	• Change of the water temperature due to heated effluent • Boiler blowdown • Boiler cleaning wastes	Low	Low	3
Gas turbine thermal PP	• Change of the water temperature due to heated effluent • Boiler blowdown • Boiler cleaning wastes	Low	Low	3

All data are prepared by the JICA Study Team, and the rating is conducted by the JICA Study Team.

3) Greenhouse gas emissions

Greenhouse gas (GHG) emissions are estimated based on the life cycle assessment by IEA. GHG includes CO_2, CH_4, N_2O, CF_4 and C_2F_6 for New hydro PP and LNG CC PP. Although New hydro PP is excluded from the option, it is shown as a baseline scenario to rate Hydro power extension and Pumped storage PP.

Since Pumped storage PP uses electricity for pumping from other energy sources (i.e. coal fired thermal PP in Sri Lanka), of which GHGs need to be counted.

The data shows in the Table 8.3.2-3 are the emissions of CO_2 equivalent of these gases.

Table 8.3.2-3 Greenhouse Gas Emissions of Power Generation Option

Power Generation Option	Greenhouse Gas Emissions (kt eq. CO_2/TWh)	Rating
New hydro PP* *(A baseline scenario)*	2 to 48	3
Hydro capacity extension	Less than New hydro PP	3
Pumped storage PP	Depending on GHG emission of Pumping Power*[1]	1
LNG CC PP*[2]	389 to 511	2
Gas turbine thermal PP*	Similar to LNG CC PP.	2

*[1]: Trial assessment because there is no common perspective in GHG emission of PSPP (Refer to Appendix)

*[2]: Hydropower and the Environment: Present Context and Guidelines for Future Action. Vol. II: Main Report (International Energy Agency, 2000)

4) Impacts on ecosystems

New hydro PP is excluded from the option, it is shown as a baseline scenario to rate Hydro power extension and Pumped storage PP. Its impacts on the ecosystem are evaluated by types of impacts, impacts on local and regional ecosystems, impacts on biomass, and impacts on genetic diversity at the world level. This is based on the assessment by IEA (2000).

Pumped storage PP has fewer and less impacts on ecosystems than New hydro PP. This is because a) its reservoirs sizes are smaller; b) rivers where dams are constructed are smaller; and c) the duration which affects water flow to the downstream are shorter than New hydro PP. However, Pumped storage PP uses electricity for pumping from other energy sources (i.e. coal fired thermal PP in Sri Lanka), of which effects on climate changes and acid precipitation are counted.

Thermal PPs (LNG CC and Gas turbine) may affect coastal habitats such as egg laying site of marine turtles and mangroves. Their heated effluent may affect species composition in their surrounding marine habitats.

The results are shown in Table 8.3.2-4.

Table 8.3.2-4 Impacts on Ecosystems by Each Power Generation Option

Power Generation Option	Impacts	Local and regional ecosystems	Biomass	Genetic diversity at the world level	Rating
New hydro PP* *(A baseline scenario)*	• Barriers to migratory fish • Loss of terrestrial habitats • Change in water quality • Modification of water flow	x x x x			1
Hydro capacity extension	Nil	Nil	Nil	Nil	4
Pumped storage PP	• Barriers to migratory fish • Loss of terrestrial habitats • Change in water quality • Modification of water flow • Climate change • Acid precipitation	x x x x x x	x	x	2

Power Generation Option	Impacts	Local and regional ecosystems	Biomass	Genetic diversity at the world level	Rating
LNG CC PP	• Climate change • Acid precipitation • Loss of coastal habitats • Change of the water temperature due to heated effluent	x x x x	x	x	1
Gas turbine thermal PP	• Climate change • Acid precipitation • Loss of coastal habitats • Change of the water temperature due to heated effluent	x x x x	x	x	1

*: Hydropower and the Environment: Present Context and Guidelines for Future Action. Vol. II: Main Report (International Energy Agency, 2000)

5) Impacts caused by resettlement

Impacts caused by resettlement are evaluated by land requirements and severity of impacts with mitigation measures.

New hydro PP is excluded from the option, it is shown as a baseline scenario. The data on its land requirements are from the assessment by IEA (2000).

It is considered that impacts totally depend on site location. Although LNG CC and Gas turbine thermal PPs generally require less land than Hew hydro PP, they may give medium negative impacts if it is planned in an urban area. They are therefore given rating "2".

The results are shown in Table 8.3.2-5.

Table 8.3.2-5 Impacts Caused by Resettlement by Each Power Generation Option

Power Generation Option	Land Requirements (km^2/TWh/y)	Severity of impacts with mitigation	Rating
New hydro PP* *(A baseline scenario)*	2 to 152*	High to Medium	1
Hydro capacity extension	Nil	Nil	4
Pumped storage PP	Less than New hydro PP	High to Low	2
LNG CC PP	Small	Medium to Low	2
Gas turbine thermal PP	Small	Medium to Low	2

*: Hydropower and the Environment: Present Context and Guidelines for Future Action. Vol. II: Main Report (International Energy Agency, 2000)

6) Impacts on water right / water resources

Impacts on water right / water resources are evaluated by types of impacts, probability of occurrence, and severity of impacts with mitigation measures.

In case of Pumped storage PP, only during the first water storage stage, the flow pattern of the river water is changed.

Thermal PPs (LNG CC and Gas turbine) discharge heated effluent and may affect water utilization pattern around the plants.

The results are shown in Table 8.3.2-6.

Table 8.3.2-6 Impacts on Water Right /Water Resources by Each Power Generation Option

Power Generation Option	Impacts	Probability of occurrence	Severity of impacts with mitigation	Rating
Hydro capacity extension	Nil	Nil	Nil	4
Pumped storage PP	• Change in the flow pattern	Low	Low	3
LNG CC PP	• Change of the water temperature due to heated effluent	Low	Low	3
Gas turbine thermal PP	• Change of the water temperature due to heated effluent	Low	Low	3

7) Impacts on agriculture

Impacts on agriculture are evaluated by types of impacts, the types of impacts, probability of occurrence, and severity of impacts with mitigation measures.

In case of Pumped storage PP, the rating is “1”. This is because a) only during the first water storage stage, the flow pattern of the river water is changed; and b) its reservoir sizes are small and the effect is limited.

The results are shown in Table 8.3.2-7.

Table 8.3.2-7 Impacts on Agriculture by Each Power Generation Option

Power Generation Option	Impacts	Probability of occurrence	Severity of impacts with mitigation	Rating
Hydro capacity extension	Nil	Nil	Nil	4
Pumped storage PP	• Loss of land • Degradation of water quality • Change in the flow pattern	Low	Low	3
LNG CC PP	• Loss of land • Degradation of air quality	Low	Low	3
Gas turbine thermal PP	• Loss of land • Degradation of air quality	Low	Low	3

8) Impacts on fishery

Impacts on fishery are evaluated by types of impacts, probability of occurrence, and severity of impacts with mitigation measures.

Since reservoirs of Pumped storage PP are located in small rivers, there are usually no commercial fisheries in these rivers. The duration affecting water flow to the downstream is short.

Thermal PPs (LNG CC and Gas turbine) may affect coastal habitats such as mangroves and substrates. Their heated effluent may affect species composition in their surrounding marine habitats.

The results are shown in Table 8.3.2-8.

Table 8.3.2-8 Impacts on Fishery by Each Power Generation Option

Power Generation Option	Impacts	Probability of occurrence	Severity of impacts with mitigation	Rating
Hydro capacity extension	Nil	Nil	Nil	4
Pumped storage PP	• Change in the flow pattern	Low	Low	3
LNG CC PP	• Change in water quality • Loss of coastal habitats • Change of the water temperature due to heated effluent • Degradation on substrate	Medium	Low	2
Gas turbine thermal PP	• Change in water quality • Loss of coastal habitats • Change of the water temperature due to heated effluent • Degradation on substrate	Medium	Low	2

9) Impacts on tourism

Impacts on tourism are evaluated by types of impacts, probability of occurrence, and severity of impacts with mitigation measures.

Pumped Storage PP is constructed in relatively small river, and the impact is considered to be limited. Although it initially gives impacts on sport / leisure and landscape, the created new landscape sometimes can be used as a new tourist attraction.

Thermal PPs (LNG CC and Gas turbine) require relative small area, and their impacts are considered to be limited. However, depending on their locations, it may affect coastal landscape and newly created landscape cannot be used as a new tourism attraction.

The results are shown in Table 8.3.2-9.

Table 8.3.2-9 Impacts on Tourism by Each Power Generation Option

Power Generation Option	Impacts	Probability of occurrence	Severity of impacts with mitigation	Rating
Hydro capacity extension	Nil	Nil	Nil	4
Pumped storage PP	• Impacts on sport / leisure • Impacts on landscape	Low	Low	3
LNG CC PP	• Impacts on sport / leisure • Impacts on landscape	Low	Low	3
Gas turbine thermal PP	• Impacts on sport / leisure • Impacts on landscape	Low	Low	3

10) Impacts on human health

Impacts on human health are evaluated by types of impacts, probability of occurrence, and severity of impacts with mitigation measures.

The results are shown in Table 8.3.2-10.

Table 8.3.2-10 Impacts on Human Health by Each Power Generation Option

Power Generation Option	Impacts	Probability of occurrence	Severity of impacts with mitigation	Rating
Hydro capacity extension	• Risks from water-borne diseases, particularly when there is irrigation (local and/or regional)	Low	Low	3
Pumped storage PP	• Acid precipitation by power supply sources (local) • Climate change by power supply sources (global)	High to Low	Low	2
LNG CC PP	• Fire (local) • Explosion (local) • Acid precipitation (local) • Photochemical smog (local) • Climate change (global)	High to Low	Medium	2
Gas turbine thermal PP	• Fire (local) • Explosion (local) • Acid precipitation (local) • Photochemical smog (local) • Climate change (global)	High to Low	Medium	2

11) Result

The result of the assessment is summarized in Table 8.3.2-11.

Hydro capacity extension has the smallest negative impacts, and has the lowest score. The rest of the options are not very different in the aspects of environmental and social considerations.

Table 8.3.2-11 Environmental and Social Considerations on Power Generation Options

POWER GENERATION OPTION	Air pollution	Water pollution	Greenhouse gas emissions	Impacts on ecosystems	Impacts caused by resettlement	Impacts on water right/ water resources	Impacts on agriculture	Impacts on fishery	Impacts on tourism	Impacts on human health	TOTAL
Hydro capacity extension	3	3	3	4	4	4	4	4	4	3	36
Pumped storage PP	2	3	1	2	2	3	3	3	3	2	24
LNG CC PP	2	3	2	1	2	3	3	2	3	2	23
Gas turbine thermal PP	2	3	2	1	2	3	3	2	3	2	23

8.3.3 Economic Aspect of Options

The most suitable peak power generation in term of economic efficiency is selected in this chapter by comparison study among power generation options to be developed and connected to Sri Lankan electric power system in future after calculation of their annual cost related to construction unit cost and fuel cost, and generation cost. Using this method, which power generation option has an economic aptitude for peak power generation (plant factor less than 30%), middle one (the same 30% to 59%) and base one (60% and above) can be figured out.

Economic characteristics of power generation options respond to their site conditions such as topographical and geological condition, distance to backbone transmission line and so on, in addition to their inherent economic efficiency. In case of pumped storage power plant, its economic characteristics also vary depending on pumping power source. In this chapter, firstly, the comparison of generation options is made in general terms, and then the same of peak power generation options is made.

The generation unit cost ($/kWh) is roughly expressed as sum of unit capital cost mainly consists of interest and depreciation of project construction cost, and unit energy cost mainly consists of fuel cost.

Where: *Capital Cost* ($/kWh) = $\frac{Construction\ Unit\ Cost\ (\$/kW) \times CapitalRecovery\ Factor}{Plant\ Factor \times 8{,}760\ (hr)}$

$$Energy\ Cost\ (\$/kWh) = \frac{Fuel\ Unit\ Cost\ (\$/kcal) \times 860\ (kWh/kcal)}{Thermal\ Efficiency}$$

The power generation options are categorized into three, namely:

- Low capital cost but high energy cost like gas turbine and pumped storage power plant
- Middle range option like LNG combined cycle
- High capital cost but low energy cost like coal thermal plant and run-of river hydropower plant

The Figure 8.3.3-1 shows basic concept of annual generation cost in relation to the variation of plant factor. For the power generation option for the peak power demand of which plant factor must be low less than 30%, a low capital cost option should be selected. In this sense, gas turbine and pumped storage power plants are suitable for power generation for peak power demand provided that their unit construction unit cost is low. In case pumped storage power plant, its output scale can be made larger considering the development scale and the construction unit cost can be lower, accordingly. Regarding hydropower expansion option, it is also suitable for power generation for peak power demand because its construction unit cost is lower compared with the same scale new hydropower plant.

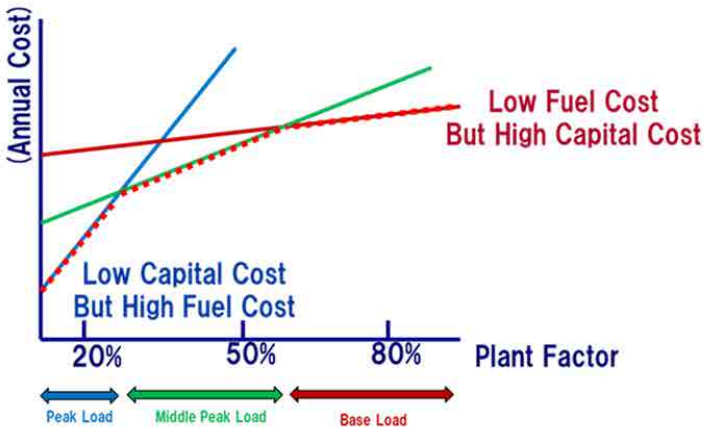

Figure 8.3.3-1 Annual Cost of Generation

The Table 8.3.3-1 shows capital cost, economic life time and so on of each power generation option that is planned to develop in future in the LTGEP 2013-2032. In the table, the capital cost of pumped storage power plant is 1,200 USD/kW that is from estimated construction cost in this JICA study, and indices of hydropower expansion come from JICA study "Feasibility Study for Expansion of Victoria Hydropower Station (May, 2009)". Other indices come from LTGEP 2013-2032. Indices of combined cycle power plant using auto diesel and coal thermal power plant are also indicated for reference.

Table 8.3.3-1 Indices of Generation Options

	PSPP (PSPP)	Gas Turbine (ADGT)	Combined Cycle (ADCC)	LNG CC (LNGCC)	Coal Steam (CST)	Hydro Ex. (HPPEx)
Unit Capacity (MW)	600	105	300	250	300	228
Minimum Capacity (%)	N.A.	30	33	33	75	N.A.
Fuel	El. from CST	Auto Diesel	Auto Diesel	LNG	Coal	N.A.
Capital Cost ($/kW)	1,200	515	935	1,300	1,964	1,022
ELT (years)	50	20	30	30	30	50

(Source: as mentioned above)

Annual cost and specific cost is calculated using indices of each option in the Table 8.3.3-1. The calculation results are shown in the Figure 8.3.3-2 and Figure 8.3.3-3. In case of necessity of daily load control to the rate less than the minimum capacity in the table, DSS (daily start and stop) operation may be required, but the annual cost and specific cost in the figure do not include start-up loss due to DSS operation. Coal thermal power plant also needs DSS operation in the event the plant factor becomes less than 50%. Since stop of its operation poses an obstacle in its resumption in the next day, the coal thermal power plant is treated it is unable to partially operate less than 50%. Pumped storage power plant has 6 hours water storage capacity in both ponds, its plant factor never exceed 25%.

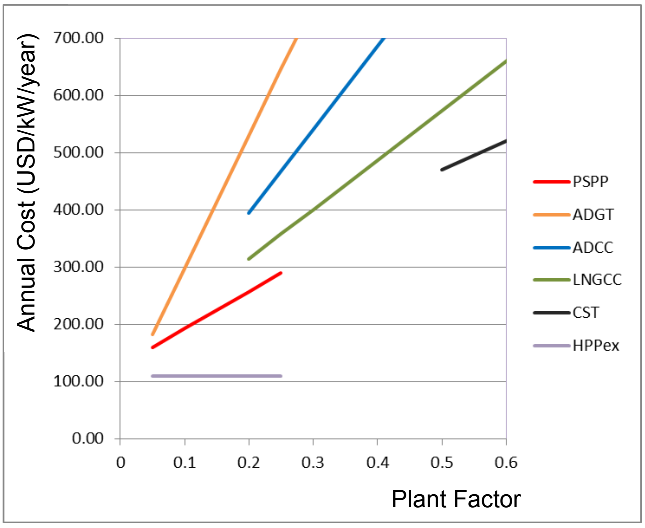

Figure 8.3.3-2 Annual Cost of Generation of Options

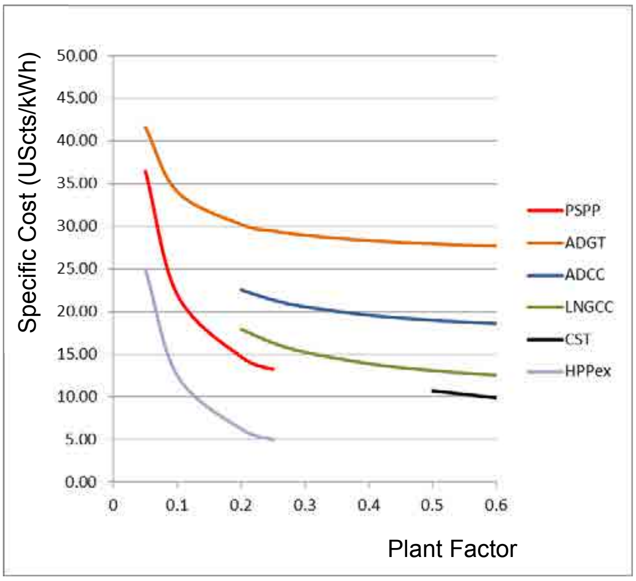

Figure 8.3.3-3 Specific Cost of Generation of Options

As is clear from the Figure 8.3.3-2 and Figure 8.3.3-3, the ranking of four peak power options from economic aspects is shown in the Table 8.3.3-2.

Table 8.3.3-2 Ranking of Options from Economic Aspect

	Hydropower (Extension)	PSPP	LNG CC	Gas Turbine
Ranking from Economic Aspect	1	2	3	4

8.3.4 Selection of Optimal Option for Peak Power Demand

The evaluation and ranking from load following capability and generation characteristics, environmental and social considerations, and economic aspects are mentioned in the Chapters 8.3.1, 8.3.2 and 8.3.3. The Table 8.3.4-1 shows concise summary of the ranking.

Table 8.3.4-1 Ranking Summary of Options

	Hydropower (Extension)	PSPP	LNG CC	Gas Turbine
Generation Characteristics	2	1	4	3
Environment & Social Considerations	1	2	3	3
Economic Aspect	1	2	3	4

It is very obvious from the Table 8.3.4-1 that hydropower capacity extension and pumped storage power plant should be selected as optimal power options from technical, environmental and economi aspects.

Regarding the hydropower extention, however, the Victoria Expansion is only a potential project in future as mentioned in the Chapter 8.1.2 (2). Since the feasibility study report and environmental impact assessment report for the Victoria Expansion Project have already prepared by JICA, the project is ready for its development and will come to completion in a short period once the Sri Lanka Government commits. Meantime, this JICA study aims at master plan of power generation for peak power demand after the year 2025, however, the capacity of the Victoria Expansion Project by itself is not enough for the peak demand in 2025.

On the other hand, pumped storage power plant has high development potential in Sri Lanka, but no systematical study in detail has been carried out. In addition, since the pumped storage power plant is suitable for increasing peak power demand after the year 2025, the Stage 2 and Stage 3 of this study highlights solely pumped storage power plant and its optimization study (master plan study) is carried out.

As a result of the second screening, it is recommended that the Victoria Expansion Project should be constructed for the peak power demand in the year 2020 and pumped Storage power plant should be constructed for peak power demand after the year 2025.

8.4 Proportion of Pumped Storage Power Plant

As mentioned in the Chapter 4.3, necessary capacity for peak power demand in 2025 to be developed is 750 MW and the capacity of new project other than Victoria Expansion is about 600 MW in consideration of future increment of power demand. In case that a pumped storage power plant with 600 MW is developed by the year 2025 in the Sri Lankan power system, its validity check is carried out by comparing with the generation capacity of other power companies. For this purpose, Japanese power companies with same generation capacity level of Sri Lankan system are selected, namely

Hokkaido Electric Power Co., Inc. and Shikoku Power Electric Power Co., Inc. that locate in isolated islands with limited link with Japanese Main Island. Table 8.4-1 shows the component of the power generation.

Table 8.4-1 Comparison of Power Generation Capacity

	Sri Lanka (2025)	Hokkaido	Shikoku
Hydropower	1,517 MW	1,239 MW	527 MW
Pumped Storage	(600 MW)	600 MW*	615 MW
Thermal	4,189 MW	4,214 MW	3,797 MW
Nuclear	0 MW	2,070 MW	2,022 MW
Renewable	855 MW	26 MW	2 MW
Total	5,706 MW**	7,549 MW	6,963 MW

*: under construction, **: capacity of Pumped Storage and Renewable is not included.

From the Table 8.4-1, the development of pumped storage power plant with 600 MW in capacity is considered reasonable in consideration of future increment of power demand in Sri Lanka.

8.5 Combination Development

8.5.1 Pumped Storage Power Plant and Renewable Energy Power Plant

As mentioned in the Chapter 8.2.1 (3), pumped storage power plant has side benefits that it can absorb fluctuation of frequency and contributes to the stability of the grid. If the variable speed PSPP is applied, same stability can be attained during pumping mode.

Contrary, if significant amount of wind and solar power plant are developed and linked to the grid, the following troubles may come up:

- Fluctuation of voltage
- Difficulty of maintaining frequency
- Generation of surplus electricity

For the breakthrough of these problems, backup power generation such as pumped storage and LNG combined cycle power plant with high load following capability or battery system are effective. As for the battery system, since it is still under research and development and has high cost, it adoption is very limited. In case of LNG combined cycle, if the renewable energy has priority to generate, the plant factor of the LNG combined cycle power plant becomes low and its economic efficiency becomes low. According to National Energy Policy and Mahinda Chinthana 10 Years Development Framework, it is the target that 10 % of total power generation in Sri Lanka will be supplied by the renewable energy power plant in 2015. In addition the Sri Lankan Government established Sustainable Energy Authority (SEA) in October 2007, and expects stable and reliable electric power supply with low electricity tariff through renewable energy. For approaching steadily toward the target, the construction of the pumped storage power plant is requisite.

8.5.2 Pumped Storage Power Plant and LNG Combined Cycle Power Plant

Though the timing of introduction of LNG combined cycle power plant is unknown, the combination development of pumped storage and LNG combined cycle power plant is expected for future power generation for peak power load and middle load in Sri Lanka.

Until the development of the LNG combined cycle power plant, hydropower and IPP thermal power plant will supply for middle power load. However the small scale IPP power plant has low heat rate and its fuel procurement is unstable and high cost, and weighs on the CEB financial standings. In this sense, CEB has a plan to phase out the power supply from IPP thermal power plant in order to maintain the minimization of power cost in the LTGEP 2013-2032.

Consequently, for the future best mix of power source in Sri Lanka, demarcation of power source is necessary, namely pumped storage power plan is for peak power load and LNG combined cycle is for mainly middle power load sometimes peak power load and base load as a complementary supply to deficit, if any.

8.5.3 Pumped Storage Power Plant and LNG Gas Turbine

This is just a case study of peak power generation after the point that the LNG supply system and LNG combined cycle would be available in Sri Lanka. Though LNG combined cycle power plant is not for peak power demand, but LNG gas turbine power plant can be an option for peak power demand after LNG supply system would be available. In this chapter, comparison study between pumped storage power plant and LNG gas turbine solely for the peak power demand is executed.

Pumped storage power plant comes under influence of fuel cost of pumping-up source generation. Study cases are selected from the coal limited cases in the scenarios of LTGEP 2013-2032 and shown in the Table 8.5.3-1, because only coal limited cases contain LNG combine cycle power plants, and LNG gas turbine power plants can be available.

Table 8.5.3-1 Study Cases

	Case-1	Case-2
Limitation of Coal Thermal	60％ from total generation	No coal plants permitted after Trincomalee
Time point of 2025		
Total Capacity of Coal Plants	2,600 MW	2,000 MW
Total Capacity of LNGCC	750 MW	1,250 MW
Pump-up Source for PSPP	Mix of coal plants 600 MW and LNG CC 750 MW	LNG CC 1,250 MW

Among 23 scenarios of power generation expansion in future, Revised Base Case is selected for LTGEP 20013-2032 because it is a reasonable case and the least cost case in the total development cost up to the year 2032. However, it includes no LNG combined cycle power plants at all. In other words, the total development cost gets larger according as the number of LNG combined cycle power plants increases. Especially, the scenario of the Case-2 is an extreme example and an impractical scenario.

The comparison of annual cost and specific cost to a plant factor as variable between pumped storage power plant and LNG gas turbine is conducted by the same method mentioned in the Chapter 8.3.3. Where, the unit capacity of LNG gas turbine is assumed at 35 MW, in order to keep good response to load change as a peak power generation. The unit construction cost of LNG gas turbine is referred to FOB price in 2012 GTW Handbook.

The annual cost and specific cost of the Case-1 are shown in the Figure 8.5.3-1 and Figure 8.5.3-2. The same data of gas turbine using auto diesel also indicated in the figure for reference.

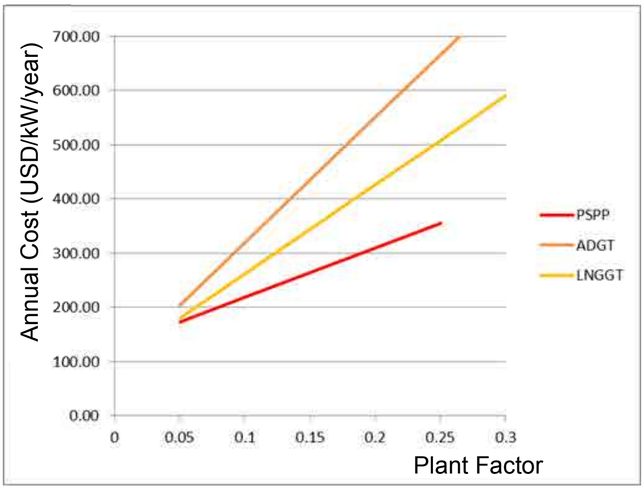

Figure 8.5.3-1 Annual Cost of Generation of Options (Case-1)

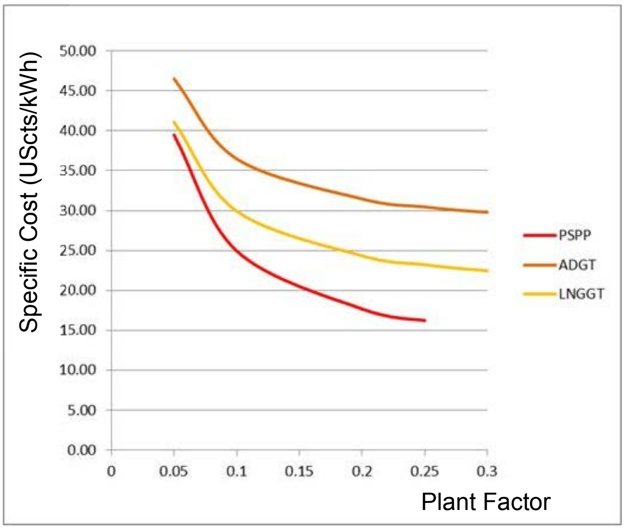

Figure 8.5.3-2 Specific Cost of Generation of Options (Case-1)

These figures show that LNG gas turbine is economically better than auto diesel gas turbine but has no advantage over pumped storage power plant.

The same comparison is made for the Case-2 and the results are shown in the Figure 8.5.3-3 and Figure 8.5.3-4. The difference in the figures between the Case-1 and Case-2 is only the data of pumped storage power plant that depends entirely on pumping-up power source due to the development scenario of coal thermal and LNG CC. In other word, the pumping-up power source is only from high price LNG combined cycle in the Case-2.

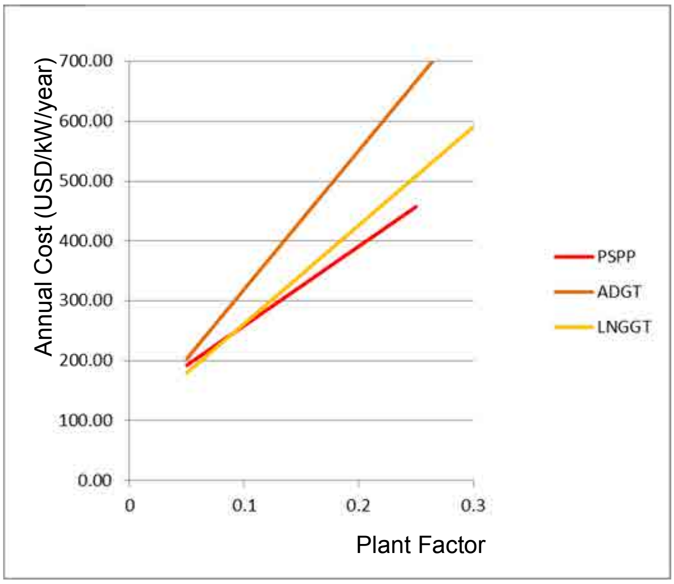

Figure 8.5.3-3 Annual Cost of Generation of Options (Case-2)

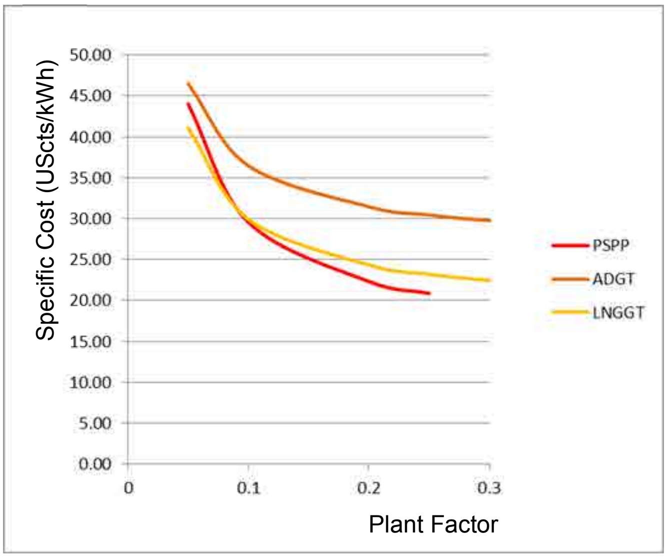

Figure 8.5.3-4 Annual Cost of Generation of Options (Case-2)

From the Figure 8.5.3-3 and Figure 8.5.3-4, pumped storage power plant has better economic efficiency than LNG gas turbine above the boundary plant factor 0.09, and not economical below it, but no remarkable difference. Consequently, the annual cost can be calculated in the case of standard operation hours per annum at 1,000 hours (plant factor: 11.4%) as the Table 8.5.3-2.

Table 8.5.3-2 Case Study of Annual Cost along with Pumping Source

		Revised Base Case	Case-1	Case-2
Pumping Power Source	Coal Thermal	100%	62%	0%
	LNG CC	0%	38%	100%
Annual Operation Time (hour)		1,000		
Plant Factor		11.4% (1,000 hours operation per year)		
Annual Cost (USD/kW/year)	PSPP (A)	201.40	231.21	277.37
	LNG GT (B)	285.04		
	(B) – (A)	83.64	53.83	7.67

As aforesaid, the development of the LNG combined cycle power plant leads annual cost rise of the total power development cost in future and electricity tariff rise, though it has significant outcome in security of stable supply of energy and global environmental issue. However, the more development of LNG combined cycle power plant, the lesser economic efficiency of pumped storage. In this sense, the development of LNG combined cycle should be subjected to the policy decision of the government. Even in the extreme case LNG combined cycle power plant supply pumping power 100%, it is demonstrated that the pumped storage power plant has an economical advantage over LNG gas turbine in case it operates during its standard operation hours.

On the other hand, LNG gas turbine has an advantage of shorter construction period. Therefore, LNG gas turbine can be an emergency electric power source for peak power demand in future, but its future development in the country is uncertain at the moment, since the availability of LNG supply system is under consideration.

Chapter 9

Selection of Promising Candidate Sites

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Chapter 9 Selection of Promising Candidate Sites

9.1 Outlines of 11 Candidate Sites

9.1.1 Over View of Project Planning

Table 9.1.1-1 shows the general outline of 11 candidate sites planned in this study. 10 pumped storage power projects were planned in the project formation study by JICA carried out in 2012 (hereafter the initial JICA study). In this study, those 10 projects are reviewed more definitely, and one possible site is added newly. As shown in Table 9.1.1-1, all candidate sites have the installed plant capacity of 600 MW. Thus, the base cases composed of three sets of a unit capacity 200 MW, and the alternative cases composed of four sets of a unit capacity 150 MW are planned respectively. The alternative cases having four sets of a unit capacity can be applicable to only 6 candidate sites out of 11 sites due to restrictions from heads and discharges of candidate sites. Detailed explanation on this issue is described in the later.

In this study, the three of promising sites are selected from these 11 candidate sites in the first selection, subsequently, the one of most promising sites are selected from 33 promising candidate sites. This chapter describes the first selection. In this chapter, the primary study on every 11 candidate sites from natural and social environmental aspects, topographic and geological aspects, technical aspects, and economical aspects are carried out. Every candidate site is evaluated from those aspects and the three of promising candidate sites are selected.

Table 9.1.1-1 Summary of Candidate Sites

Candidate Site	unit	Kiriketi I	Kiriketi II	Maussa-kelle A	Maussa-kelle B	Halgran 1	Halgran 2	Halgran 3	Halgran 4	Maha 1	Maha 2	Logal
Installed Capacity	MW	600	600	600	600	600	600	600	600	600	600	600
Peak Generating Time	hours	3.8	2.52	6.42	6.28	6.19	6.11	6.05	6.1	6.03	6.09	6.16
Rated Head	m	664.67	731.81	450.30	463.60	576.01	679.25	657.08	465.18	464.23	434.78	561.76
Rated Discharge	m^3	108.37	98.43	159.96	155.37	125.05	106.04	109.62	154.84	155.16	165.67	128.22
Base Cases												
Unit Capacity	MW	200	200	200	200	200	200	200	200	200	200	200
Number of Units	unit	3	3	3	3	3	3	3	3	3	3	3
Alternative Cases												
Unit Capacity	MW			150	150				150	150	150	150
Number of Units	unit			4	4				4	4	4	4

(Source: Study Team)

9.1.2 Environmental Studies

(1) General

Environmental Studies are conducted to obtain necessary information to select promising sites for PSPP (2 steps). Refer to “6.3.3 SEA at Selecting Candidate Sites”.

The following two (2) Environmental Studies are carried out:

- Environmental Study (1): to collect information and to conduct a rapid impact assessment on 11 candidate sites for PSPP development; and,
- Environmental Study (2): to collect more detailed information and rapid environmental

assessment on three (3) promising sites selected from the 11 candidate sites

All works are conducted by a Sri Lankan consultant based on the Terms of Reference (TOR) prepared by the JICA Study Team. The Sri Lankan consultant is the University of Peradeniya.

(2) Preliminary assessment on the natural environment

1) Protected areas

All candidate sites for pumped storage hydropower plants are plotted on the district wise Sensitive Maps provided by CEA, and the JICA Study examines whether the candidate sites are in or close to the designated protected areas such as forest reserves (including proposed ones) and national parks.

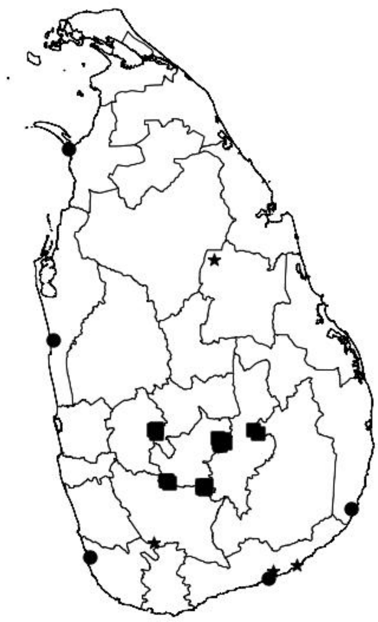
As a result, some parts of Kiriketi and Maussakelle sites are within sanctuaries. A local consultant confirms the result in the Environmental Study (1).

2) Other areas of conservation interest

The JICA Study Team examines that whether the candidate sites are in or close to the World Cultural and Natural Heritage Sites, Ramsar wetlands, Biosphere reserves and Important Bird Areas (IBAs).

The World Cultural Heritage sites are not close to the all sites. However, the World Natural Heritage site (Central Highlands) is closed to some of the candidate sites.

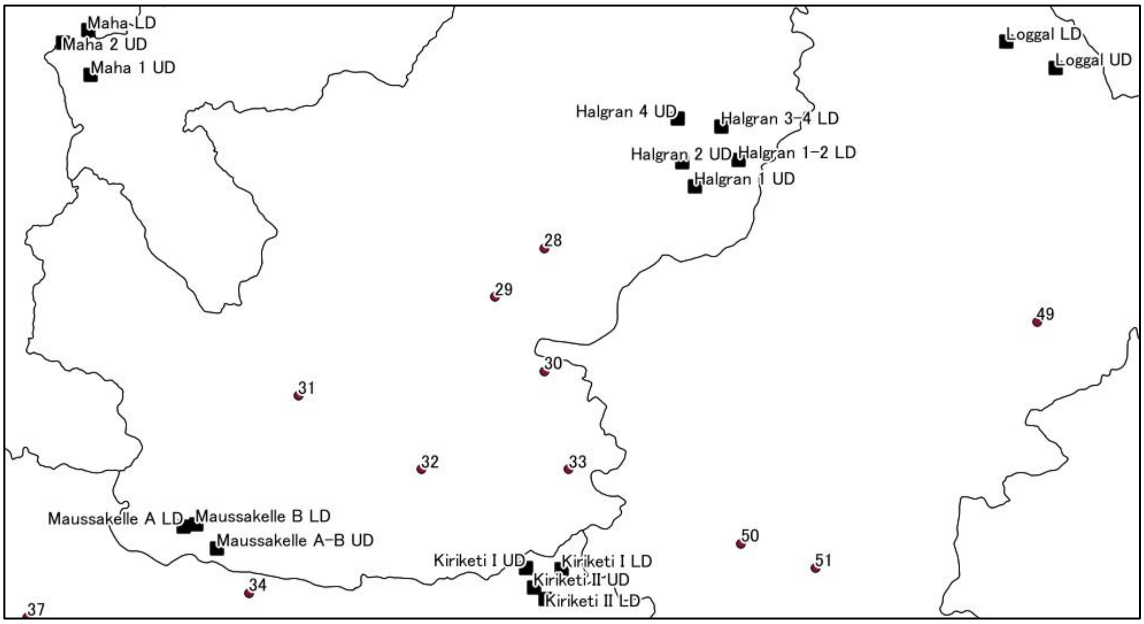
Regarding the Ramsar Wetlands and Biosphere reserves, Figure 9.1.2-1 shows the locations of them and candidate sites. The candidate sites do not affect the wetlands and reserves.



(Source: Ramsar Convention web site and UNESCO web site. The map is prepared by the Study Team)

Figure 9.1.2-1 Ramsar Wetlands (●), Biosphere Reserves (★) and the Candidate Sites (■)

Figure 9.1.2-2 shows the locations of the IBAs and candidate sites. The candidate sites do not affect the IBAs.



(Source: Important Bird Areas in Asia: key sites for conservation (BirdLife International, 2004).
The map is prepared by the Study Team.)

Figure 9.1.2-2 IBAs (numbers) and the Candidate Sites (■)

The local consultant also confirms the results in the Environmental Study (1).

(3) Environmental Study (1)

The Study on Environmental and Social Conditions of 11 sites for Pumped Storage Power Plant (Environmental Study (1)) aims to collect information on environmental and social conditions of the 11 candidate sites for PSPP and to compare 11 sites in view of expected impacts on the natural and social environments as the 1st step of the site selection.

The following information is collected at each candidate site (upper and lower dams / ponds at each site):

- Physical environment
  Meteorological condition; hydrological condition (e.g. rivers, streams and ground water); conditions on pollution of air, water and soil (if any); and, information on landslide prone area.
- Biological environment
  Existing and planned protected areas; fauna and flora; important habitats; and, World Cultural and Natural Heritage Sites, Ramsar wetlands, Biosphere reserves and Important Bird Areas.
- Social environment
  District; Division; GN Division; extent of resettlement; extent of land acquisition; land use

pattern of the area; forest cover; non-timber forest products (NTFPs); river utilization especially in downstream areas; water utilization pattern (surface and ground water); religious, cultural and archeological heritages; tourism site; mining concession; existence of ingenious people; and, existence of poverty people.

The local consultant conducts a rapid impact assessment at each site based on the scoping table prepared and agreed at the 1st SHM (Table 9.1.2-1).

Table 9.1.2-1 Scoping for 11 Candidate Sites

Natural environment	Impacts on fauna and flora	Inundated forest area
		Impacts on protected areas
		Impacts on endangered species (especially fish and other aquatic species)
		Risk of landslide*
Social environment	Impacts on local communities	Number of those who to be resettled
		Area of land to be acquired
		Impacts on water utilization (e.g. drinking water, irrigation)
		Impacts on utilization of forest and grassland
		Impacts on public facilities (e.g. school)
	Impacts on industries	Agriculture
		Forestry
		Tourism
	Impacts on cultural heritages	Religious, cultural and/or archeological facilities
		Impacts on landscape

Note: "Risk of landslide" is added to the scoping table after the 1st SHM based on the discussion between CEB and the JICA Study Team.

9.2 Geomorphology and Geology

9.2.1 Geomorphology

Sri Lanka is an island country, ranging between 5° 50′ N-9° 55′ N and 79° 30′ E-81° 55′ E, to the southeast of India, that appears like a "water drop shape". The central (to the south) part of the island comprises highlands with elevation of Mt. Pidurutalagala 2,524m as the highest peak, and the proportion of the central highland is as high as 20% of the whole island.

The noting feature of the country is that it is made of three distinguished platforms as "peneplains" (4 peneplains if continental shelfs included). Those peneplains are the highest peneplain above EL. 1,500m in southern part of the island, the middle peneplain with elevation from EL. 500m to 1,500m, and the lowest peneplain below EL. 500m. The climate of Sri Lanka also varies over the area into 3 climatic zones of Wet Zone, Dry Zone and the Intermediate Zone and the average annual rainfall in the southwest of the country is over 4,000 mm. It is seen frequent occurrence of landslides or collapses of surface weathered materials in the Wet Zone due to significant progress of weathering and alteration of various mother rocks.

Sri Lanka river basins are with catchment areas in the highlands that flow and erode passages towards surrounding coast areas radially and form waterfalls and torrents at escarping cliffs and steep surfaces, suddenly at plains turn into nearly flat streams around 1:5,000 gradient. Such currents often with meandering form flood plains.

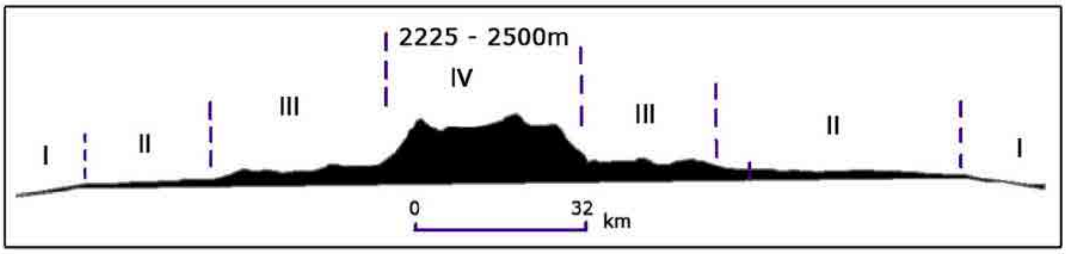


Figure 9.2.1-1 Digrammatic Section of Sri Lanka from West to East. Showing 4 Peneplains

(I:1st submerged, II:2nd flat terrain to undulating terrain, rolling and hilly terrains, III:3rd dissected rolling and hilly, steeply dissected rolling and hilly terrains, IV: 4th mountainous and rugged central highland) (J. Katupotha, 2013)

9.2.2 Geology

Rocks forming Sri Lanka island is very old in age that studies have proven high grade metamorphism in some 2-1.1 billion years of Pre Cambrian, and occurrence of post metamorphism movement with granitic intrusions in 500 Million years. It was a craton, a part of the super continent Gondwanaland, and was connected with the craton of the Indian sub continent, until it departed in 70 Million years. The present shape and forms of peneplains were formed in erosional outcomes it experienced through upthrusts and/or glacial regression/expansion during the island craton's movement towards north till now.

Sri Lanka is geologically is made up of a crust of mostly Pre Cambrian age upto 90% of the island, with the remaining 10% of north and northwestern part of Miocene granite, south and eastern coast part of the Quaternary sedimentary rocks. It is a stable island geologically.

The island rocks of Pre Cambrian age are divided and distributed into 4 lithologic and lithotectonic province namely, Highland complex (HC), Wanni complex (WC), Vijayan complex (VC) and Kadugannawa complex (KC). Broadly HC is considered most ancient rock form experiencing higher grade metamorphisms, WC is rather newer compared to HC, and VC was regionally thrusted down into HC in 500Million years initiating significant undulation structures within itself. Such divisions do not imply much technical meanings that not significant difference occurred in physical properties of each rocks (only except HC has various gems resources concentrations in itself).

The geologic structure is shown in Figure 9.2.2-1 as well as geological map of the island in Figure 9.2.2-2. The typical characteristic of each complex is shown in Table 9.2.2-1.

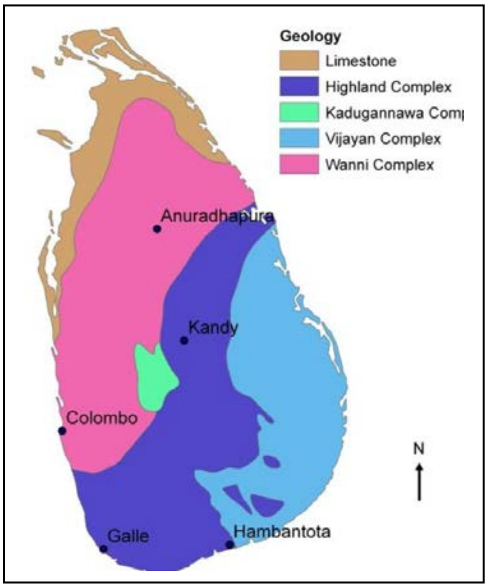


Figure 9.2.2-1 Lithological Structure of Sri Lanka

Table 9.2.2-1 Typical Rock Types of Sri Lankan Geological Complexes

Highland-Complex	Granulite faces Metamorphic rocks (Charnokite, Marble, Quartzite, and varied Gneisses)
Wanni-Complex	Metamorphic rocks (Hornblende Gneiss, Granitic rocks)
Vijayan-Complex	Amphibolite faces metamorphic rocks
Kadugannawa Complex	Granulitic facies metamorphic rocks (Biotite Hornblende Amphibolite Gneiss,Quartzite)

Figure 9.2.2-2 Geology of Sri Lanka (National Atlas of Sri Lanka, 2009)

These rock of each complex all have shown significant broad folding, yet all geotechnically hard enough when fresh and unweathered in gneiss, quartzite etc. thus there are practically not much sense in categorizing field rocks into any of the 4 complexes. It is known in Sri Lanka some typical bedrocks suffer in depth weathering. It is like some rocks of granitic origin may easy to accelerate weathering. In this respect it may be noted some reports recently indicate HC gneisses mostly have granitic facies in their origin.

Another example of bedrock facies in their geotechnical terms is, some rocks as quartzite, gneiss, schists tend to increase their permeability and weathering with their natures of lamina, joints and schistosity development. Slope collapses of such rocks when these joints are in dipping slope structures were reported in many cases in the past.

Limestone is another example as it contains growth of karst, druse, cavity formation caused by calcite erosion and deposition. In Sri Lanka SAMANALAWEWA dam site had and has been facing water leakage problems caused by kalstic water leakage.

As noted before Pre Cambrian bedrocks of Sri Lanka have significant foldings. Many are fine once they were consolidated, and some yet may still be being crashed or being differentially eroded. Such featrures caused by foldings need to be carefully investigated in hydropower project.

Almost all of candidate sites in this pumped storage projects are in the main HC (Maha-1,2 in KC). These are formed by metamorphic rocks as gneisses, quartzites or marble. These are all lined up in N-S direction in broad sense associated with some foldings. The basic elements of geologic and geotechtonic components are thus carried by, not limited to, the investigations on rock facies, rocks like of coarse minerals as granitic rocks, or folding induced fractures or weathering conditions.

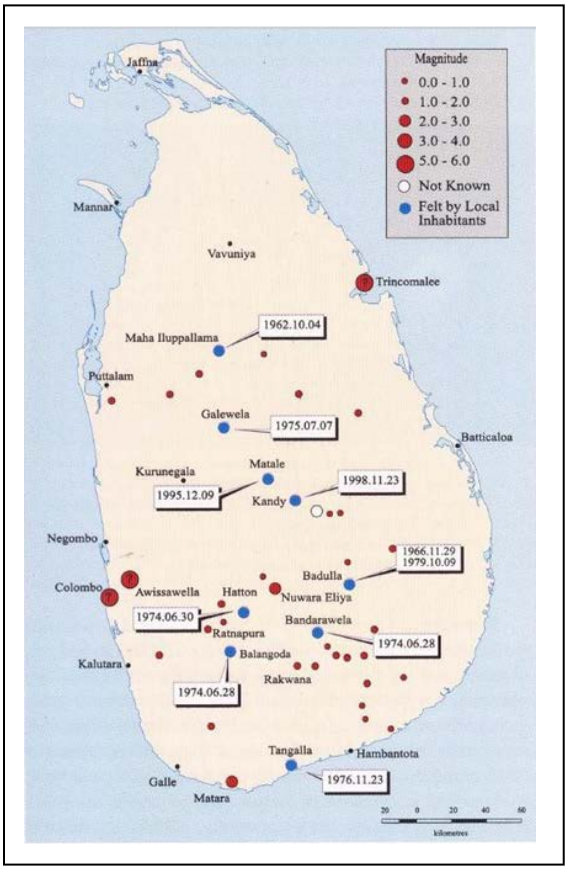
9.2.3 Seismicity

Earthquakes are the element for consideration for infrastructure hazards like reservoir rim slope or dam site. Yet Sri Lanka situates its island far from the plate boundaries that it is one of the poor seismic zone as is a stable crustal plateau. Only a quite few seismic motions are recorded in history for intra-plate earthquakes.

It is not accurate historical record as is no such were ready for a long time, but there are almost no significant seismic recorded motions. Seismicity in Sri Lanka is shown in Figure 9.2.3-1.

Nearly oldest motion was one at 1615 April 14 of M>6.5. Since then were major ones as at 1615 January of M 6.3, at 1823 February 9 and March 9 (both of which is unconfirmed). All these are intra-plate earthquakes however with no detailed information.

There practically have been no problems in terms of hydro power projects for seismicity. On the contrary in India for example, there is a NCSDP (National Committee on Seismic Design Parameters) which authorizes the project and for its approval seismic study should be accompanied. In Sri Lanka no such regulatory procedures are explicitly-defined in terms of seismicity.



(National Atlas of Sri Lanka, 2009)

Figure 9.2.3-1 Seismicity Map of Sri Lanka

Table 9.2.3-1 Historical Earthquakes reported to have Occurred in Sri Lanka

Year	Month	Date	Longitude (East)	Latitude (North)	Magnitude	Remarks
1615	04	14	?	?	Probably over 6	Death = about 2000, over 200 houses were damaged (Peiris, 1920).
1823	02	09	80° 0′	7° 0′	5.7(?)	Epicentre close to Mahara, northeast of Colombo. (Felt in many areas, including Kandy)
1823	03	09	80° 0′	7° 0′	5.0(?)	Epicentre close to Mahara, northeast of Colombo (Felt in south India)
1843	06	19	79° 9′	6° 9′	3.0(?)	Near Kalapaluwawa, east of Colombo
1848	03	--	79° 9′	6° 9′	--	Near Kalapaluwawa, east of Colombo
1857	08	16	80° 0′	7° 0′	3.7(?)	Epicentre close to Mahara northeast of Colombo
1866	12	19	80° 0′	7° 0′	3.7(?)	Epicentre close to Mahara northeast of Colombo
1871	09	--	79° 9′	6° 9′	--	Near Kalapaluwawa, east of Colombo
1871	12	--	81° 0′	7° 4′	--	Near Mahiyangana
1882	01	--	81° 2′	8° 6′	6.3(?)	Occurred near Trincomalee fell all over Sri Lanka. (Felt in Madras, India)
1891	04	07	81° 0′	7° 4′	--	Near Mahiyangana
1891	04	18	81° 0′	7° 4′	--	Near Mahiyangana
1900	09	09	79° 9′	6° 9′	--	Near Kalapaluwawa, east of Colombo

(National Atlas of Sri Lanka, 2009)

It is considered no plate boundary type earthquakes in Sri Lanka. But it is not absolute aseismic region that preparation of seismic monitoring can contribute the in depth understanding of Sri Lanka seismic background together with the re-evaluation of the past historic seismicity, and it is expected to do so.

For reference, The Global Seismic Hazard Assessment Program (GSHAP) compiled for whole nations by UN show the seismicity of Sri Lanka is as small as 0.1 m/s^2. The studies in near dam sites show 0.05g in Samanalawewa and Kukule, 0.1g in other sites like Upper Kotmale.

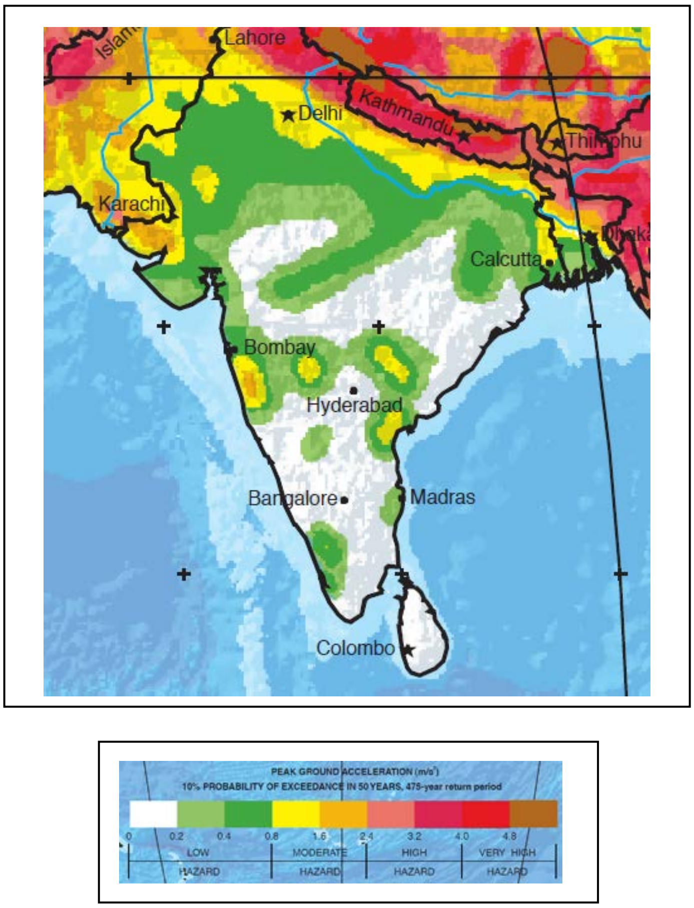


Figure 9.2.3-2 Seismic Acceleration Map around Sri Lanka **(GSHAP, 1999)**

9.2.4 Each Candidate Site Geology

In evaluating first grade ranking study of each pumped storage candidate site, it has been encouraged to collect available data and information. The particular collected data and information are listed below for each particular site. General data and information are also collected including geological mineralogical articles by various researchers for referring the in-depth weathering of particular rock facies etc. Reports of existing hydropower projects were also visited for geotechnical views.

- Geological maps (1:100,000)

  The scale of 1:100,000 map is the only available map in Sri Lanka for geology except local particular projects. There are none in and around 11 candidate sites so inevitably such scale were taken for consideration. Geological Survey and Mines Bureau partially prepares 1:50,000 geology maps and such data was expected, but interviews revealed those are just raw data maps of 1:100,000 maps without any further detailed information in them. Therefore given up.

- Existing boring data

  NO such data is in and around 11 candidate sites.

- Aerophotographs (1:20,000)

  Most of them are rather old before 1999 but cover most of the island and thus are trustworthy.

Lineaments collected from the photos are referred on the geological maps of 1:100,000 so such photos were revisited during site studies.

- Landslide hazard zone maps (1:50,000 ~ 10,000)
  There are about 20,000km^2 of landslide hazardous areas mainly on highland mountain regions. JICA and/or some agencies have been assisting the preparation of Landslide hazard zone maps. Nearly 1:50,000 maps were completed then 1:10,000 scale maps successively under are being studied. Specific geologic names on each of 11 candidate sites are not noted, but landslide ranking criteria contains geological condition of the area so can be expected of some values in hydropower investigation purposes too.

During the work, we performed basic preliminary investigations based on the above available data and information first. Then with the brief understanding of the site geology we visited each site, leading to the final investigation outcome of the area with actual observations at sight.

The first stage preliminary investigation at desk top study was noted in Table 9.2.4-1. The final investigation outcome was detailed in 9.5.

Table 9.2.4-1 Outline of Geological Features of 11 Candidate Sites (4-1)

No	Site	1;100,000 Gelogical map	Strucutre	Landslide Hazard Map (1:50,000 or 1:10,000)	Aerophotographs	Mines permits
1	Kiriketti 1	North wing of syncline axis thus NW dipping (dipping upstream). NE-SW faults developped area. Upper reservoir: Hard Charnokite with no faults. Lower reservoir: Charnokite with partial quartzite on right. NE-SW fractured fault along Kiriketti river crossing dam axis. Water route passes 2 NNE-SSW faults.	many faults, crosssing dam axis	1:50,000 hazard map : Upper damsite 2, upper reservoir 2, Lower damsite 1, lower reservoir 3	Upper reservoir: Impossible to use photo (covererd by clouds), Lower reservoir: Possible colluvium deposit on left rim from scarp cliff. No landslide or talus on right steep rim. River flow anticipated to be formed by fault erosion	none
2	Kiriketti 2	North wing of syncline thus NW dipping (dipping upstream). NE-SW faults developped area. Upper reservoir: Hard Charnokite with no faults. NE-SW trending fault right NE of the ridge (water leakage). Lower reservoir: Charnokite with gneiss on left. NE-SW fractured fault along Kiriketti river crossing dam axis. Water route passes NNE-SSW 1 fault.	many faults, crosssing dam axis	1:50,000 hazard map : Upper damsite 3, upper reservoir 3, Lower damsite 3, lower reservoir 3	Upper reservoir: Very steep mountain ridge valley with fault eroding on the ridge. Thin weathering but water sealing problem esp. for right abutment. Lower reservoir: Steep slope on right but without landslides. Many colluviums on left bank .Clear NE-SW fault scarp cliff on the left rim with many colluviums on the bottom. NE-SW fault along river flow with lateral displacement and river flow anticipated to be formed by fault erosion.	one Exploration License is close
3	Maussakelle 1	Upper reservoir: North wing of syncline thus SW dipping (dipping downstream). Placed on the summit- ridge of Charnokite mountain and hard. Partially granitic but anticipated minor issue. No faults. Lower reservoir: North wing of synbcline thus SW dipping. comprises Biotite gneiss. EW fault is right downstream of the dam axis with a waterfall. Water route passes in gneiss without fault.	fault crossing reservoir	1:50,000 hazard map : Upper damsite 1, upper reservoir 1, Lower damsite 2, lower reservoir 2	Upper reservoir: Flat plateou on the mountain that is hard and weatherering anticipated shallow from its shape. The mountain is a residual hill of Charnokite. Lower reservoir: No landslide on both banks (right bank with slow slope but none, left bank with small possible collapses. a collapse in the upper end of the reservoir on left but higher than HWL. EW fault passes around this steep slope on the left bank but no unstable features on the left bank other than this place)	none
4	Maussakelle 2	Upper reservoir: same as above. Lower reservoir: North wing of syncline thus S dipping (dipping upstream). biotite gneiss. EW fault right downstream of the dam axis with a waterfall. Water route passes no fault in gneiss.	fault crossing reservoir	1:50,000 hazard map : Upper damsite 1, upper reservoir 1, Lower damsite 2, lower reservoir 2	Upper reservoir: same as above. Lower reservoir: Slow slope without minor undulation. No landslides in the reservoir (not clear due to the clouds). EW fault crosses the right abutment ridge. The upstream of the reservoir on the right has a landslide colluvium.	none

Table 9.2.4-1 Outline of Geological Features of 11 Candidate Sites (4-2)

	Site	1;100,000 Gelogical map	Strucutre	Landslide Hazard Map (1:50,000 or 1:10,000)	Aerophotographs	Mines permits
5	Halgran 1	Upper reservoir: North wing of syncline thus SW dipping (dipping upstream). quartzite on the right, Charnokite on the left. Rocks are fine. Shape indicates the right quartzite harder as it suffers no erosion remaining itself as residual hill. the left bank is low in elevation with many tea plants. Potentially thick in weathering. NE-SW fault near by the left of the reservoir does not touch the HWL line. Lower reservoir: South wing of syncline axis thus NE dipping (dipping upstream), Charnokite but limestone possiblly extends to right dam abutment. the reservoir is supported by Charnokite beneath limestone. No faults. Water route passes close to NE-SW fault. It also passes NW-SE fractured fault that may be made by the anticlinal folding between 2 synclines. It has certain displacement. The water route may encounter inferior limestone as the Charnokite embeds limestone near the fault. (this limestone may be encountered in any of Halgran 1-4 water routes)	fault crossing reservoir	1:100,000 hazard map : Upper damsite 3, upper reservoir 3 (right2 left3), Lower damsite 4, lower reservoir 4 (right3 left4) as a whole no good	Upper reservoir: No landslides around dam and reservoir. The right rim middle slope and left rim slow slope. NE-SW fault (on the geology map) is not clearly visible. Lower reservoir: Left rim-left abutment steep in slope with possible landslides. 300m wide landslide on right rim but higher than HWL thus little affects. The possibility of landslide occurence on the left rim may be not so high as the shape of the mountain is firm and little weathered.	none
6	Halgran 2	Upper reservoir: North wing of syncline thus SW dipping (dipping upstream). Charnokite -quartzite, quartzite schist. a fault apart but pararell to river on the left rim. (limestone appears but apart from reservoir). Lower reservoir : same as above. The water route passes NW-SE fractured fault that may be made by the anticlinal folding between 2 synclines. It has certain displacement. The water route may encounter inferior limestone as the Charnokite embeds limestone near the fault. (this limestone may be encountered in any of Halgran 1-4 water routes)	fault 2	1:100,000 hazard map : Upper damsite 3, upper reservoir 3 (right3 left2), Lower damsite 4, lower reservoir 4 (right3 left4) as a whole no good	Upper reservoir: Slow slope in right rim but no landslides around reservor. Quartzite is hard residual hill and has no unstable slopes. Charnokite on right rim may possibly has a deep weathering. NE-SW fault is not clearly visible. Lower reservoir : same as above.	none
7	Halgran 3	Upper reservoir: North wing of syncline thus SW dipping (dipping upstream). quartzite - quartzite schist. (limestone appears but apart from reservoir on the left). Lower reservoir : South wing of syncline thus NE dipping (dipping downstream). Limestone covers reservoir thorough left bank of dam to downstream. (limestone overlain by Charnokite thus no waterleakage in reservoir likely. but the rock extends through downstream of the damsite). NE-SW fault in reservoir. Water route passes NW-SE fractured fault that may be made by the anticlinal folding between 2 synclines. It has certain displacement. The water route may encounter inferior limestone as the Charnokite embeds limestone near the fault. (this limestone may be encountered in any of Halgran 1-4 water routes)	fault 2	1:100,000 hazard map : Upper damsite 2, upper reservoir 2 , Lower damsite 2, lower reservoir 2	Upper reservoir: No landslides around dam and reservoir. Lower reservoir: No landslides on dam and reservoir. But Dam left abutment is thin (200m aprat from dam abutment is Limestone. the rock forms sunk basin shape thus indicating lower water level). May need to extend water sealing treatment towards left upheight. few issues on right abutment as it is gneiss.	none

Table 9.2.4-1 Outline of Geological Features of 11 Candidate Sites (4-3)

cc	Site	1;100,000 Gelogical map	Strucutre	Landslide Hazard Map (1:50,000 or 1:10,000)	Aerophotographs	Mines permits
8	Halgran 4	Upper reservoir: South wing of anticline axis thus dipping SW (dipping towards left bank). Charnokite and partially on higher place on right bank is quartzite. NW-SE fractured fault on right bank 200m apart from reservoir but firm residual hill of quartzite lies inbetween reservoir and fault. a NE-SW fault crosses reservoir. the upper reservoir is close to ancline thus potentially easier to develop fractures. Lower reservoir; same as above. Water route paase NW-SE fractured fault that may be made by the anticlinal folding between 2 synclines. It has certain displacement. The water route may encounter inferior limestone as the Charnokite embeds limestone near the fault. (this limestone may be encountered in any of Halgran 1-4 water routes)	fault 2	1:100,000 hazard map : Upper damsite 3, upper reservoir 2 , Lower damsite 2, lower reservoir 2	Upper reservoir; No landslides on right banks of dam and reservoir. A clear landslide on the upper end of the reservoir on the left on higher elevation. Another potential landslide on near HWL.(needs to be verified). Both NE-SW fault and NW-SE fault are not clearly visible.	none
9	Maha 1	Upper reservoir: South wing of syncline axis thus dipping NE. Gneisses. NE-SW fault along river on left bank. Rock layer dipping downstream. Lower reservoir: Gneiss (gneiss on right, Charnokite on left), and a limestone band lies along riverbed with certain thickness embedded by gneisses. NW-SE fractured fault erodes the river in the same direction. the fault displacement is not clear on the map. Water route passes 1 NW-SE fractured fault and 1 fault. the limestone band may have suffered successive erosion caused by the fractured fault and river flow.	fault crossing dam axis in Lower reservoir	1:50,000 hazard map : Upper damsite 4, upper reservoir 3 , Lower damsite 4 (right 4 left 3), lower reservoir 4	Upper reservoir: Some minor scale collapses on the right bank. None on the left. Lower reservoir: Thin ridge on the right bank, possibly landslide form (needs to be verified). A clear landslide is shown on the left bank. Lineament along the river flow is anticipated as a lateral fault with surrounding ridge shapes. Fracture scale unknown. Small scale if consolidated but possibly differentially eroded)	none
10	Maha 2	Upper reservoir: South wing of anticline axis thus dipping NE. Gneisses without fault. A NS fractured fault on upstream ot resservoir but above HWL. rock layer dipping downstream. Water route paases 1 NW-SE fractured fault. The limestone band may have suffered successive erosion caused by the fractured fault and river flow. Lower reservoir: same as above.	fault crossing dam axis in Lower reservoir	1:50,000 hazard map : Upper damsite 3, upper reservoir 3 , Lower damsite 4 (right 4 left 3), lower reservoir 4	Upper reservoir: some ridge on right is partially thin. steep valley beneath dam axis. No landslides or collapses near damsite but 1km upstream of the reservoir on left bank is the landslide trace on the right bank (it may be issue when HWL can possibly raises). There are none landslides on Landslide Hazard Map thus the trace can be just deep weathered slow slope.	none

Table 9.2.4-1 Outline of Geological Features of 11 Candidate Sites (4-4)

	Site	1;100,000 Gelogical map	Strucutre	Landslide Hazard Map (1:50,000 or 1:10,000)	Aerophotographs	Mines permits
11	Loggar	Upper reservoir: A long anticline axis thus dipping NW. Charnokite. No faults. Lower reservoir: North wing of suncline axis to anticline axis thus dipping NW (nearly flat but dipping towards left bank). Quartzite and Charnokite, no limestone. No faults. Water route paases in gneisses, with partially limestone but without faults. Limestone may have been fractured but has 2-300m in thickness from the map.	fault crossing dam axis in Lower reservoir	1:50,000 hazard map : Upper damsite 2, upper reservoir 2, Lower damsite 3, lower reservoir 3	Upper reservoir: Slow in slope, no landslides. Lower reservoir: A Steep cliff on left bank but no landslide traces. Right bank medium-slow slope. Riverbed is a broad alluvium deposit.	none

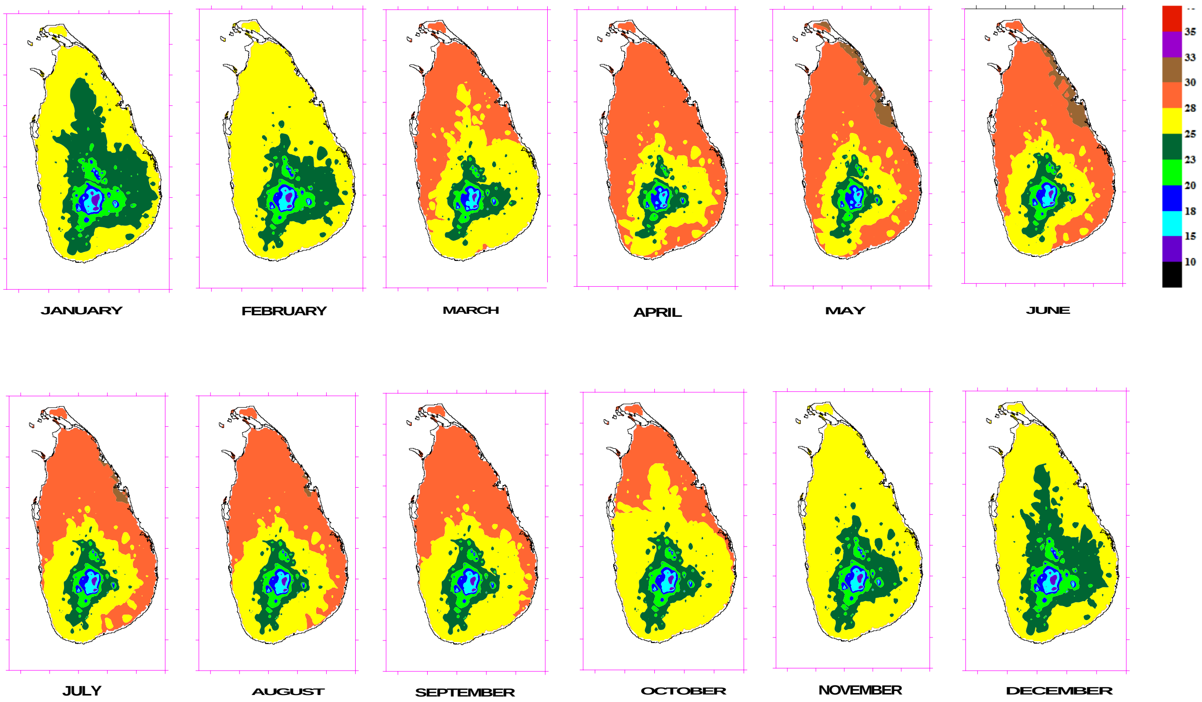
(Landslide map 凡例)

1: landslides not likely	2: landslides modest level
3: landslides expected	4: landslides most likely
5. subsidence & rockfall	6: landslides occurred in the past

9.3 Meteorology • Hydrology

9.3.1 Climate Condition

The island of the Sri Lanka belongs to the tropical monsoon climate zone. The average annual temperature at Colombo is 27 degree Celsius. At the highland the temperature is lower than lowland relatively. The average annual temperature at Nuwara Eliya is 15 degree Celsius where height is about 1,800m. Figure 9.3.1-1 shows the averaged mean monthly temperature map in Sri Lanka Island.

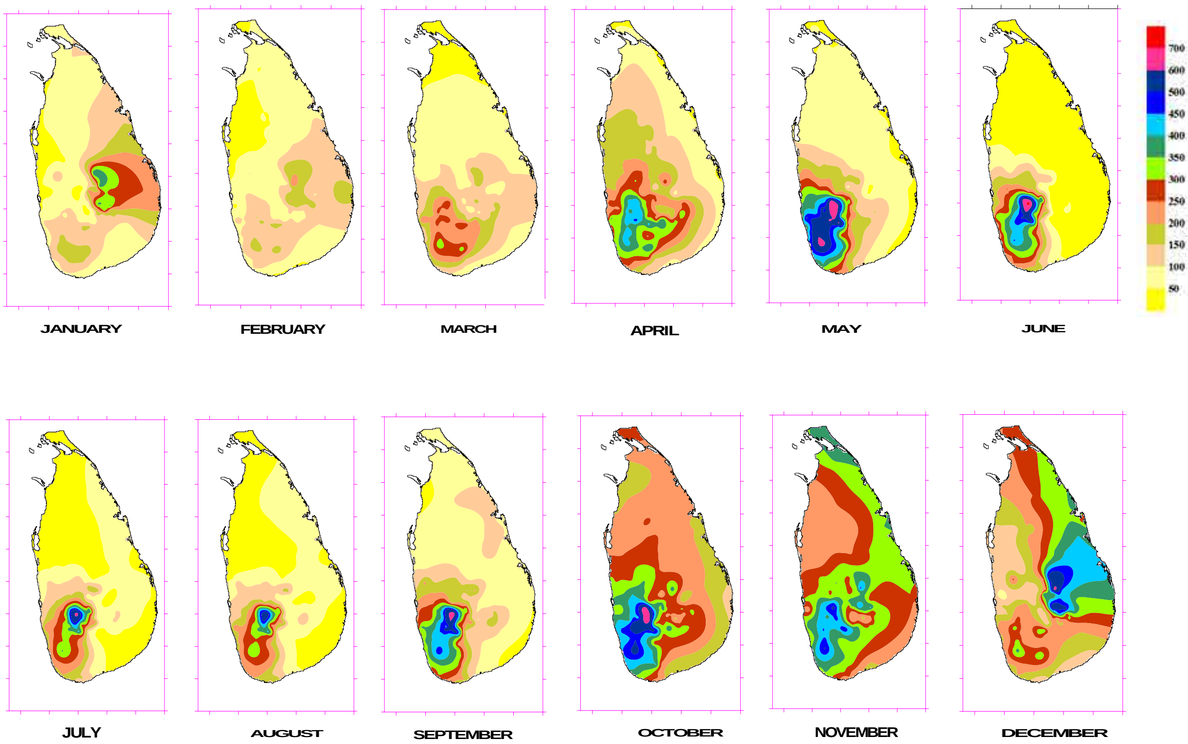


(Source：Department of Meteorology)

Figure 9.3.1-1 Averaged Mean Monthly Temperature 1961-1990 (°C)

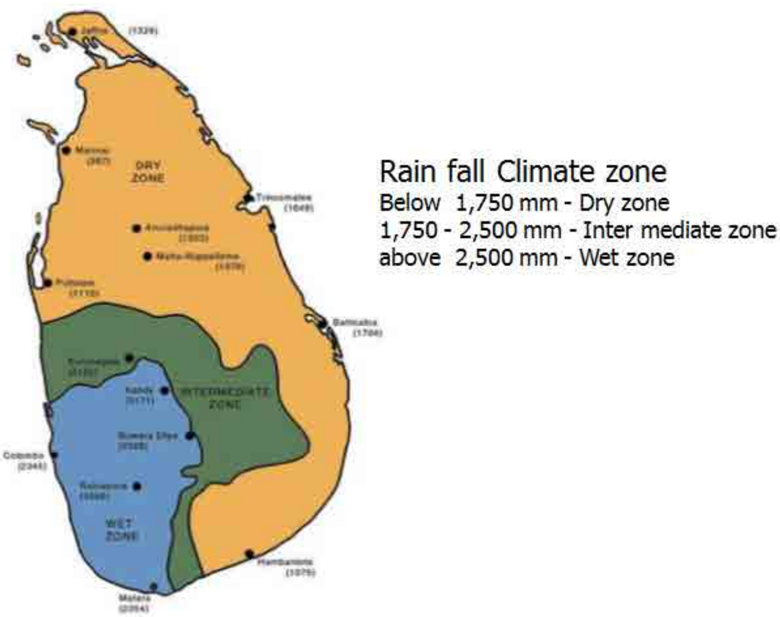
The rainfall of the island is influenced by two monsoons. Four seasons in the country consist of southwest monsoon, northeast monsoon, and two inter monsoon periods which are called Intermonsoons. The rainfall pattern is strongly influenced by the direction of these monsoons. In the first season from the middle of May to October the southwest monsoon brings much watery cloud which comes to the highland of the central island and pours much rainfall in the southwest part of Sri Lanka. On the other hand at the opposite side - the east and the northeast of the highland it rarely rains. In the second season from October to November it rarely brow due to nothing of the monsoons. In this season squalls often come and it sometimes rains caused by tropical low pressures in the southwest, the northeast and the east side of the island. In the third season from December to March the northeast monsoon brings much watery cloud from Bengal bay pours much rainfall in the northeast of the highland in Sri Lanka. In the fourth season from March to May it rarely rains. Figure 9.3.1-2 shows the averaged mean monthly rainfall map.

The land of Sri Lanka is further subdivided to three zones, i.e. the wet zone, intermediate zone, and dry zone. Wet zone is the area where annual rainfall has more than 2,500 mm. Dry zone is defined where the annual rainfall has less than 1,750mm. Intermediate zone is transition zone between the wet and the dry zones. Figure 9.3.1-3 shows rainfall zone map in Sri Lanka.



(Source：Department of Meteorology)

Figure 9.3.1-2 Average Monthly Rainfalls 1961-1990 (mm)



(Source：Department of Meteorology)

Figure 9.3.1-3 Rain Fall Climate Zone in Sri Lanka

9.3.2 Meteorological Stations and Hydrological Stations

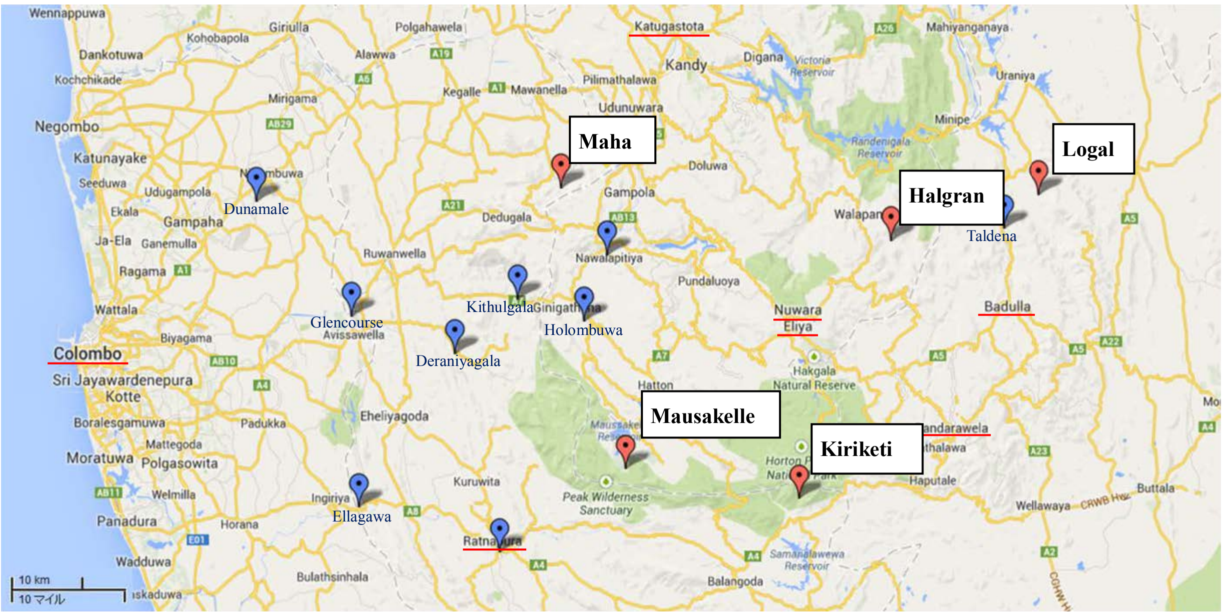
Table 9.3.2-1 shows the list of meteorological stations and hydrological gauging stations near the candidate sites. Figure 9.3.2-1 shows the map of meteorological stations and gauging stations.

Five met stations - Ratnapura, Katugastota, Badulla, Bandarawela, and Nuwara Eliya of the Principal Met. Stations owned by Meteorological department near the candidate sites are selected for this study. Required data items of each station are as follows;

- Temperature (Latest 30years Average mean monthly data)
- Rainfall (Latest 30years Average monthly data)
- Evaporation (Latest 30years Average monthly data)
- Wind Speed (Latest 30years Average monthly data)

The each data item of Colombo met station is required as the reference data

Nine gauging stations - Glencourse, Kithulgala, Holombuwa, Deraniyagala, Rathnapura, Ellagawa, Taldena, Dunamale and Nawalapitiya owned by Irrigation department near the candidate sites are selected for this study. Required data item from irrigation department is the peak flood discharge for flood analysis.



(Source：Study Team)

Figure 9.3.2-1 Location of Candidate Sites and Hydrological Gauging Station

Table 9.3.2-1 List of Meteorological and Hydrological Stations

Category	Name	Location		Data
		Latitude	Longitude	
Meteorological St.	Ratnapura	6.68	80.40	rainfall, evaporation, temperature, wind speed
	Katugastota	7.33	80.63	rainfall, evaporation, temperature,
	Badulla	6.98	81.05	rainfall, evaporation, temperature,
	Bandarawela	6.81	80.96	rainfall, evaporation, temperature, wind speed
	Nuwara Eliya	6.96	80.76	rainfall, evaporation, temperature, wind speed
	Colombo	6.90	79.86	rainfall, evaporation, temperature, wind speed
Gauging Station	Deraniyagala	6.924	80.338	Annual peak discharge
	Dunamale	7.116	80.081	Annual peak discharge
	Ellagawa	6.732	80.210	Annual peak discharge
	Glencourse	6.978	80.203	Annual peak discharge
	Holombuwa	6.937	80.462	Annual peak discharge
	Kithulgala	6.989	80.418	Annual peak discharge
	Nawalapitiya	7.048	80.534	Annual peak discharge
	Rathnapura	6.679	80.395	Annual peak discharge
	Taldena	7.091	81.048	Annual peak discharge

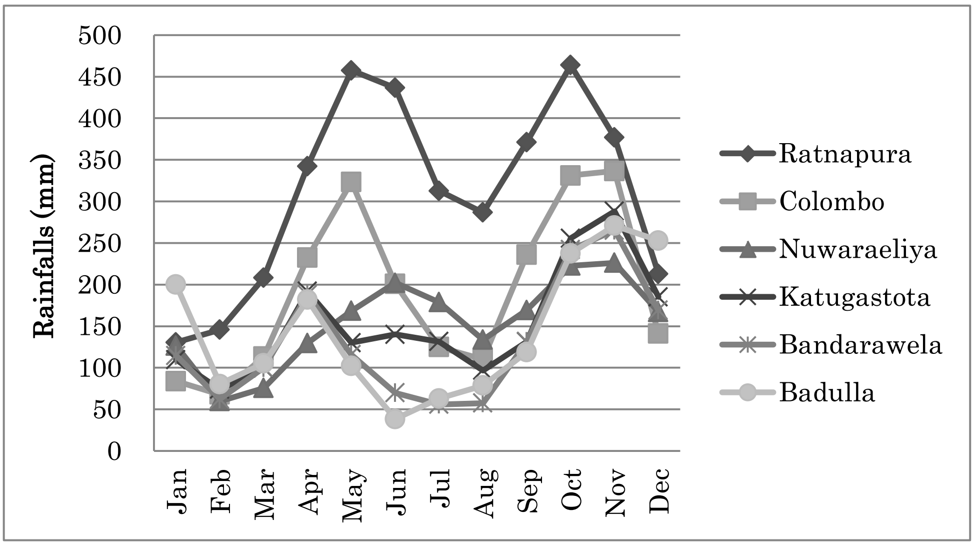
(Source：Study Team)

9.3.3 Meteorology

In this clause the basic climate condition is shown to collect the data from Principal Meteorological Station of meteorological department in Sri Lanka.

(1) Rain fall

Figure 9.3.3-1 shows the monthly average rain falls observed at the six principal meteorological stations from 1981 to 2010. The stations have much rain in May and October. At Rathnapura station the amount of average rain fall is more than 450mm. On the other hand the dry season it rarely rain, the amount of average rain falls of each station are about 100mm in January and February.

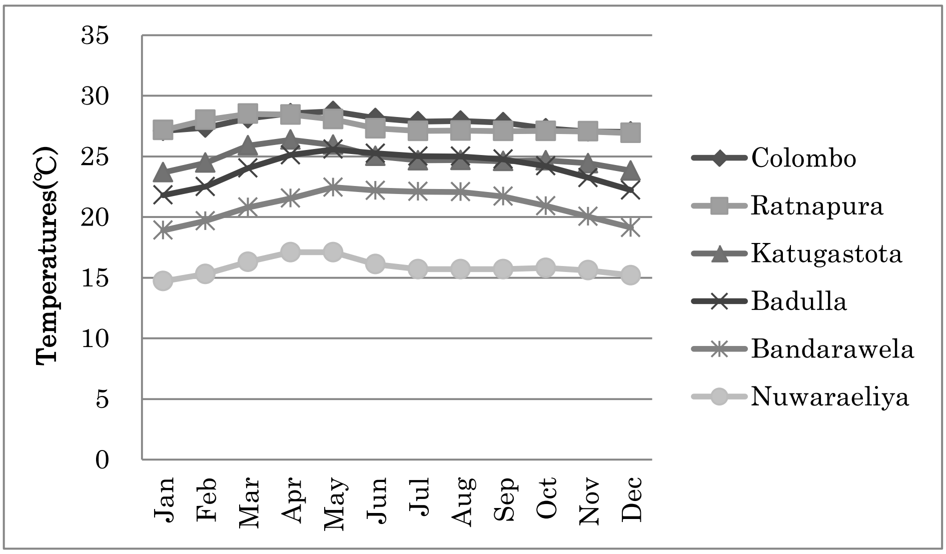


(Source：Department of Meteorology)

Figure 9.3.3-1 Average Monthly Rainfalls (1981-2010)

(2) Temperature

Figure 9.3.3-2 shows the monthly average temperatures observed at the six principal meteorological stations from 1981 to 2010. The change of monthly temperatures is not differenct. At the lowland stations- Rathnapura and Colombo the average annual temperatures are more than 25 degree Celsius. On the other hand at Nuwara Eliya station which is the highest altitude the average annual temperature is about 15 degree Celsius.

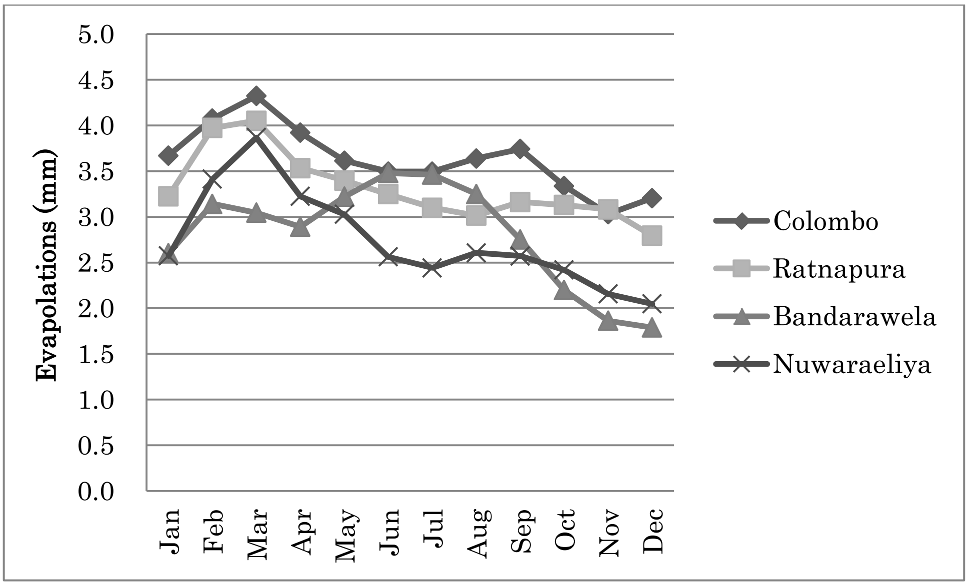


(Source：Department of Meteorology & World Meteorological Organization)

Figure 9.3.3-2 Average Monthly Temperatures (1981-2010)

(3) Evaporation

Figure 9.3.3-3 shows the average monthly evaporation data observed at the four principal meteorological stations from 1981 to 2010.

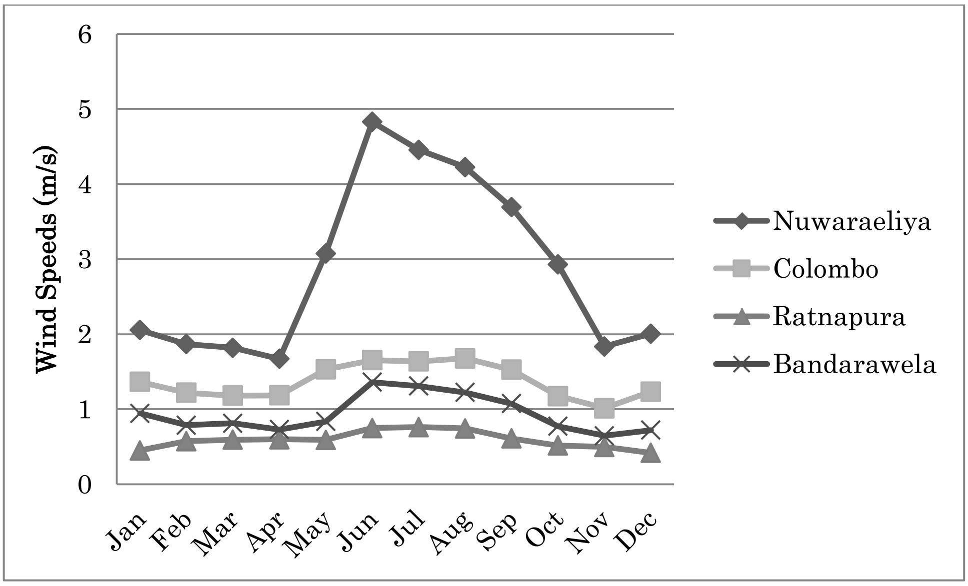


(Source：Department of Meteorology)

Figure 9.3.3-3 Average Monthly Evaporations (1981-2010)

(4) Wind Speed

Figure 9.3.3-4 shows the average monthly wind speed data observed at the four principal meteorological stations from 1981 to 2010.



(Source：Department of Meteorology)

Figure 9.3.3-4 Average Monthly Wind Speed (1981-2010)

9.3.4 Flood Analysis

The 11 candidate sites are scattered along the huge area of the center region in Sri Lanka and located at a number of rivers. In this study three hydrological gauging stations near the site are applied to flood analysis from nine stations covered up the sites. The reference hydrological gauging stations for each site's analysis are as follows;

- Kiriketi1 and Kiriketi2 : Holombuwa Gauging station
- Maussakelle1 and Maussakelle2 : Holombuwa Gauging station
- Halgran1, Halgran2, Halgran3 and Halgran4 : Taldena Gauging station
- Maha1, Maha2 and Maha3 : Kithulgala Gauging station
- Loggal : Taldena Gauging station

(1) Method of Flood Analysis

Probable Flood analysis method is applied to this study. A suitable probable distribution model is chosen by the procedure as shown in Figure 9.3.4-1, which is extracted from Japanese relevant Guideline. According to this procedure, goodness of fit and stability of the distribution model is evaluated by indexes such as SLSC[1] value and Jackknife estimated error, and most suitable distribution model is selected. SLSC value is an index which expresses a deviation of distribution by plotting position formula to the probable distribution model.

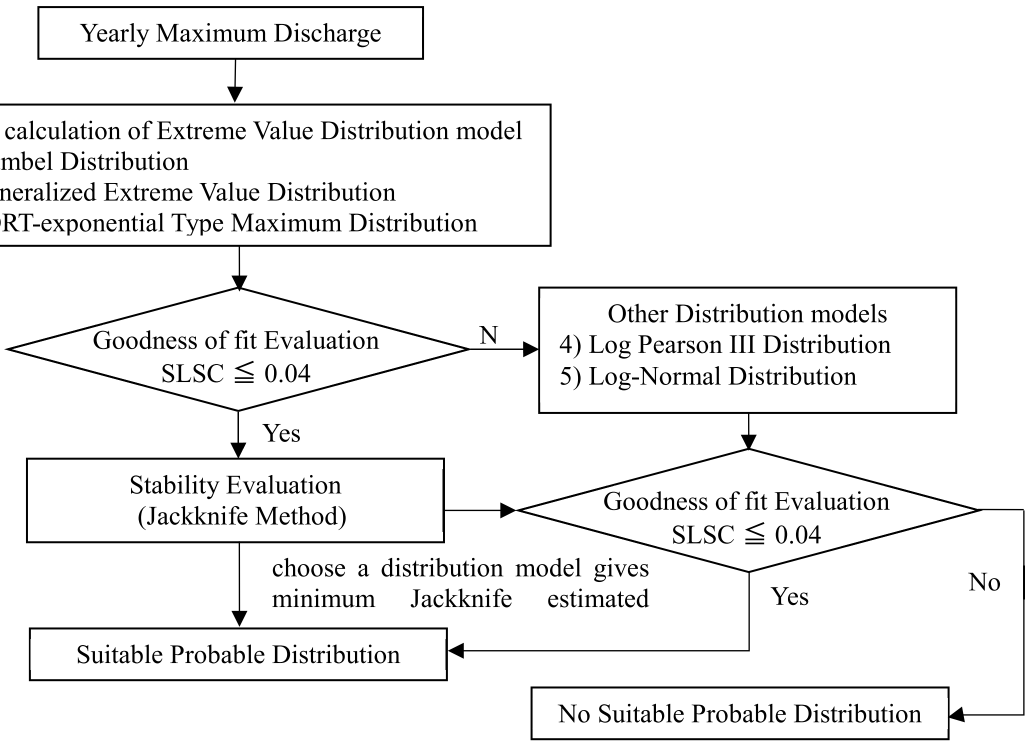


Figure 9.3.4-1 Probable Flood Analysis

[1] Standard Least-squares Criterion, the index shows goodness of fit of applied distribution model

(2) Yearly Maximum Peak Inflow of each Hydrological station

1) Yearly Maximum Peak Inflow at Holombuwa Gauging Station

The yearly maximum peak inflow data at Holombuwa gauging station from 1985 to 2011 are summarized in Table 9.3.4-1. Total 27 data are available for flood analysis. As shown in Table 9.3.4-1, the yearly maximum peak inflow for 27 years occurred on 3rd June, 1989, which was recorded as 644 m^3/s for 155 km^2 catchment area.

Table 9.3.4-1 Yearly Maximum Inflow of Holombuwa Gauging Station

(Unit: m^3/s)

Rank	Date	Qmax	Rank	Date	Qmax
1	03-06-89	644.11	15	09-05-95	228.00
2	20-07-97	525.00	16	24-07-98	204.70
3	26-10-88	484.18	17	02-11-91	193.00
4	13-10-93	475.00	18	08-10-96	192.94
5	27-05-11	456.40	19	21-04-02	190.44
6	04-10-86	431.76	20	23-10-12	189.23
7	19-07-08	329.24	21	30-07-01	179.03
8	08-10-94	316.73	22	03-11-04	175.66
9	12-11-07	297.67	23	02-06-87	174.12
10	03-06-92	280.00	24	17-08-09	173.13
11	02-11-05	279.35	25	22-10-06	172.29
12	18-11-90	248.15	26	24-09-00	137.82
13	20-04-99	246.89	27	17-05-03	102.82
14	30-04-10	241.54	-	-	-

2) Yearly Maximum Peak Inflow at Taldena Gauging Station

The yearly maximum peak inflow data at Taldena gauging station from 1996 to 2012 are summarized in Table 9.3.4-2. Total1 17 data are available for flood analysis. As shown in Table 9.3.4-2, the yearly maximum peak inflow for 17 years occurred on 13th March, 2007, which was recorded as 730 m^3/s for 700 km^2 catchment area.

Table 9.3.4-2 Yearly Maximum Inflow of Taldena Gauging Station

(Unit: m^3/s)

Rank	Date	Qmax	Rank	Date	Qmax
1	13-03-08	730.22	10	16-12-05	73.33
2	02-02-11	585.17	11	29-01-01	56.81
3	29-02-00	309.23	12	14-01-06	49.96
4	25-11-12	309.23	13	05-02-96	42.18
5	12-12-10	295.96	14	03-03-99	32.08
6	09-03-98	258.38	15	19-12-03	32.08
7	20-12-07	258.38	16	07-12-02	26.31
8	29-11-09	198.85	17	11-01-04	21.26
9	28-11-97	78.72	-	-	-

3) Yearly Maximum Peak Inflow at Kithulgala Gauging Station

The yearly maximum peak inflow data at Kithulgala gauging station from 1985 to 2012 are summarized in Table 9.3.4-3. Total128 data are available for flood analysis. As shown in Table 9.3.4-3, the yearly maximum peak inflow for 28 years occurred on 30th May, 1989, which was recorded as 2,157 m^3/s for 383 km^2 catchment area.

Table 9.3.4-3 Yearly Maximum Inflow of Kithulgala Gauging Station

(Unit: m^3/s)

Rank	Date	Qmax	Rank	Date	Qmax
1	30-05-89	2157.00	15	29-09-98	406.00
2	15-07-85	925.00	16	20-05-09	403.00
3	03-06-92	886.00	17	02-10-10	403.00
4	28-06-93	853.00	18	06-11-06	379.00
5	04-08-88	808.00	19	12-06-02	365.00
6	08-10-96	727.00	20	16-09-97	337.00
7	19-05-99	726.00	21	04-05-00	288.00
8	17-05-90	704.00	22	02-05-11	288.00
9	17-06-95	704.00	23	09-07-12	269.00
10	28-04-08	704.00	24	01-10-87	268.00
11	08-10-94	577.00	25	02-11-91	247.00
12	06-05-03	503.00	26	15-06-07	244.00
13	12-11-86	497.00	27	27-07-01	228.00
14	05-10-05	439.00	28	27-05-04	178.00

(3) Probable Flood

Based on the procedure shown in Figure 9.3.4-1, probable floods for several return periods are calculated. Calculation is done by three probability distribution models as shown firstly. In case that the criteria of “Goodness of fit evaluation” is not satisfied by three probability distribution models, other probability distribution models are applied in trial until the criteria is satisfied.

1) Kiriketi1, Kiriketi2, Maussakelle1, Maussakelle2 sites: Refer to Holombuwa Gauging station

The probable floods at the sites for several return periods are calculated by applying yearly maximum peak inflow data at Holombuwa Gauging station. The calculation is done by three probability distribution models: 1) Exponential Distribution model, 2) Generalized Extreme Value (Gev) Distribution model, and 3) Pearson 3 (LogP3) Distribution model. SLSC values for each distribution model are also shown in Table 9.3.4-4. Each SCLC value is acceptable from the view point of fit goodness. As the next step, the stability of model is evaluated by Jackknife estimated errors. Table 9.3.4-4 also shows calculated Jackknife estimated errors and smallest Jackknife estimated error is obtained in 1) Exp. Distribution model. Therefore, 1) Exp. model is chosen as the most suitable probability distribution model. Probable flood calculated by Exp. Distribution model is applicable to the projects.

In flood discharge calculation in the upper reservoir area and the lower reservoir area at every site, due to small catchment area of those compared to the catchment area of used gauging station, it is concerned that calculated flood discharge would be less estimation if it is calculated by proportion of catchment areas; therefore, the flood discharge is to be corrected by Creager formula as shown below;

$$Q_G = C \cdot A_G^{\,(A_G^{-0.05}-1)}$$

$$Q_R = C \cdot A_R^{\,(A_R^{-0.05}-1)}$$

$$\therefore Q_R = \frac{A_R^{\,(A_R^{-0.05}-1)}}{A_G^{\,(A_G^{-0.05}-1)}} \cdot Q_G$$

where,

Q_G : flood discharge at a gausing station (m^3/s)

Q_R : flood discharge at the upper reservoir or the lower reservoir (m^3/s)

C : regial coefficient

A_G : catchment area of a gauging station (km^2)

A_R : catchment area of the upper reservoir or thelower reservoir (km^2)

Estimated probable flood at the sites as shown Table 9.3.4-5.

Table 9.3.4-4 Probable Flood and Jackknife Estimated Errors in Holombuwa

Return period (yrs.)	Probable Flood			Jackknife Estimated Errors		
	Exp	Gev	LogP3	Exp	Gev	LogP3
2	235	243	245	20	26	25
3	295	294	299	28	36	33
5	370	359	365	40	46	42
10	472	452	458	57	57	56
20	574	555	559	75	70	73
30	633	622	622	85	79	86
50	708	714	706	98	96	107
80	777	807	790	110	120	132
100	810	855	832	116	134	147
150	870	946	911	126	166	176
200	912	1016	971	133	195	201
400	1014	1202	1125	151	284	274
500	1047	1268	1178	157	319	301
1,000	1148	1491	1355	175	456	403
2,000	1250	1749	1551	193	638	532
4,000	1352	2046	1770	210	877	692
SLSC	0.037	0.039	0.039	--	--	--

Table 9.3.4-5 Probable Flood at the Sites

Site	Maussakelle1		Maussakelle2		Kiriketi1		Kiriketi2	
Upper / Lower Dam	UD	LD	UD	LD	UD	LD	UD	LD
CA (km^2)	2	20	2	10	1	5	1	14
Return Period (yrs.)								
2	9	62	9	36	5	21	5	47
3	11	77	11	46	6	26	6	59
5	14	97	14	57	7	32	7	74
10	18	124	18	73	9	41	9	95
20	22	150	22	89	11	50	11	115
30	25	166	25	98	13	55	13	127
50	27	185	27	109	14	62	14	142
80	30	203	30	120	15	68	15	156
100	31	212	31	125	16	71	16	162
150	34	228	34	134	17	76	17	175
200	35	239	35	141	18	80	18	183
400	39	265	39	157	20	89	20	203
500	41	274	41	162	21	92	21	210
1000	45	301	45	177	23	101	23	230
2000	48	327	48	193	25	110	25	251
4000	52	354	52	209	27	119	27	271

2) Halgran1, Halgran2, Halgran3, Halgran4, Loggal : Refer to Taldena Gauging station

The probable floods at the sites for several return periods are calculated by applying yearly maximum peak inflow data at Taldena Gauging station. The calculation is done by three probability distribution models: 1) Exponential Distribution model, 2) LN3Q Distribution model, and 3)LN4PM Distribution model. SLSC values for each distribution model are also shown in Table 9.3.4-6. Each SLSC values are not acceptable from the view point of fit goodness. As the next step, stability of model is evaluated by Jackknife estimated errors for your reference. Table 9.3.4-6 also shows calculated Jackknife estimated error.

In flood discharge calculation in the upper reservoir area and the lower reservoir area at every site, due to small catchment area of those compared to the catchment area of used gauging station, it is concerned that calculated flood discharge would be less estimation if it is calculated by proportion of catchment areas; therefore, the flood discharge is to be corrected by Creager formula as shown below;

$$Q_G = C \cdot A_G^{(A_G^{-0.05}-1)}$$

$$Q_R = C \cdot A_R^{(A_R^{-0.05}-1)}$$

$$\therefore Q_R = \frac{A_R^{(A_R^{-0.05}-1)}}{A_G^{(A_G^{-0.05}-1)}} \cdot Q_G$$

where,

Q_G : flood discharge at a gausing station (m^3/s)

Q_R : flood discharge at the upper reservoir or the lower reservoir (m^3/s)

C : regial coefficient

A_G : catchment area of a gauging station (km^2)

A_R : catchment area of the upper reservoir or thelower reservoir (km^2)

Estimated probable flood at the sites as shown Table 9.3.4-7.

Table 9.3.4-6 Probable Flood in Taldena

Return period (yrs.)	Probable Flood		
	Exp	LN3Q	LN4PM
2	131	96	108
3	219	165	182
5	330	286	296
10	481	526	480
20	632	878	685
30	720	1150	807
50	831	1574	956
80	934	2059	1086
100	982	2326	1144
150	1071	2879	1243
200	1133	3330	1308
400	1284	4645	1445
500	1333	5146	1484
1,000	1483	6986	1589
2,000	1634	9327	1672
4,000	1785	12274	1739
SLSC	0.042	0.049	0.049

Table 9.3.4-7 Probable Flood at the Sites

Site	Halgran 1		Halgran 2		Halgran 3		Halgran 4		Logal	
Upper / Lower Dam	UD	LD	UD	LD	UD	LD	UD	LD	UD	LD
CA (km^2)	32	70	20	70	2	16	2	16	5	5
Return Period										
2	35	58	25	58	4	21	4	21	8	8
3	58	98	41	98	6	35	6	35	14	14
5	87	147	62	147	9	53	9	53	21	21
10	127	214	91	214	13	77	13	77	30	30
20	167	282	120	282	18	101	18	101	40	40
30	191	321	136	321	20	116	20	116	46	46
50	220	370	157	370	23	133	23	133	53	53
80	247	416	177	416	26	150	26	150	59	59
100	260	438	186	438	28	158	28	158	62	62
150	283	477	203	477	30	172	30	172	68	68
200	300	505	214	505	32	182	32	182	72	72
400	340	572	243	572	36	206	36	206	81	81
500	353	594	252	594	37	214	37	214	84	84
1000	393	661	281	661	42	238	42	238	94	94
2000	433	728	309	728	46	262	46	262	104	104
4000	472	796	338	796	50	286	50	286	113	113

3) Maha1, Maha2, Maha3: Refer to Kithulgala Gauging station

The probable floods at the sites for several return periods are calculated by applying yearly maximum peak inflow data at Kithulgala Gauging station. Calculation is done by three probability distribution models: 1) Generalized Extreme Value (Gev) Distribution model, 2) Pearson 3 (LogP3) Distribution model, and 3) LN3Q Distribution model. SLSC values for each distribution model are also shown in Table 9.3.4-8. The SLSC values of LogP3 and LN3Q models are acceptable from the view point of fit goodness. As the next step, stability of model is evaluated by Jackknife estimated errors. Table 9.3.4-8 also shows calculated Jackknife estimated errors and smallest Jackknife estimated error is obtained to 1) LN3Q Distribution model. Therefore, 1) LN3Q model is chosen as the most suitable probability distribution model. Probable flood calculated by LN3Q model is applicable to the project.

In flood discharge calculation in the upper reservoir area and the lower reservoir area at every site, due to small catchment area of those compared to the catchment area of used gauging station, it is concerned that calculated flood discharge would be less estimation if it is calculated by proportion of catchment areas; therefore, the flood discharge is to be corrected by Creager formula as shown below;

$$Q_G = C \cdot A_G^{(A_G^{-0.05}-1)}$$

$$Q_R = C \cdot A_R^{(A_R^{-0.05}-1)}$$

$$\therefore Q_R = \frac{A_R^{(A_R^{-0.05}-1)}}{A_G^{(A_G^{-0.05}-1)}} \cdot Q_G$$

where,

Q_G : flood discharge at a gausing station (m^3/s)

Q_R : flood discharge at the upper reservoir or the lower reservoir (m^3/s)

C : regial coefficient

A_G : catchment area of a gauging station (km^2)

A_R : catchment area of the upper reservoir or thelower reservoir (km^2)

Estimated probable flood at the sites as shown Table 9.3.4-9.

Table 9.3.4-8 Probable Flood and Jackknife Estimated Errors in Kithulgala

Return period (yrs.)	Probable Flood			Jackknife Estimated Errors		
	Gev	LogP3	LN3Q	Gev	LogP3	LN3Q
2	452	442	437	58	53	50
3	575	566	566	73	69	64
5	733	732	740	101	101	104
10	969	988	1007	176	185	210
20	1242	1291	1313	306	325	373
30	1424	1494	1514	411	438	496
50	1679	1783	1790	578	616	681
80	1944	2086	2069	769	822	885
100	2081	2243	2211	875	936	993
150	2351	2553	2484	1094	1172	1210
200	2560	2793	2690	1272	1364	1382
400	3130	3453	3231	1793	1929	1857
500	3336	3692	3420	1991	2146	2030
1,000	4055	4528	4054	2723	2945	2638
2,000	4912	5528	4765	3661	3976	3360
4,000	5935	6722	5559	4859	5296	4211
SLSC	0.045	0.039	0.037	--	--	--

Table 9.3.4-9 Probable Flood at the Sites

Site	Maha 1		Maha 2		Maha 3	
Upper / Lower Dam	UD	LD	UD	LD	UD	LD
CA (km^2)	10	35	5	35	5	35
Return Period						
2	41	103	23	103	23	103
3	53	134	30	134	30	134
5	69	175	39	175	39	175
10	95	238	54	238	54	238
20	123	311	70	311	70	311
30	142	358	81	358	81	358
50	168	423	95	423	95	423
80	194	489	110	489	110	489
100	208	523	118	523	118	523
150	233	588	132	588	132	588
200	253	636	143	636	143	636
400	303	764	172	764	172	764
500	321	809	182	809	182	809
1000	381	959	216	959	216	959
2000	447	1127	254	1127	254	1127
4000	522	1315	296	1315	296	1315

(4) Issue and recommendation

For esxample, for Maha 3 site, the flood data of Kithulgala gausing staitions is applyied to estimate the peak flood finally. Figure 9.3.4-2 shows the specific flood discharge of Kithulgala, as well as Nawalapitiya and Holombuwa gausing stations which are also located near Maha 3 sitea are shown. In this figure, the curves shows calculated return periods by the selected distribution models and the dots shows the return period converted from the records by Canan plotting method. In this study, the flood discharge of Maha 3 site is estimated by using the log-normal distribution curve of Kithulgala. Because it gives the largest value for the return period 1,00 years in estimations by the three models. However, this estimated peak flood for the design seems to have still some uncertainty due to limited number of available data. Therefore, it is recommeded that the probable flood should be reviewd in detail more in the next study stage for the most promising site. In order to enhance reliability of the estimated probable flood, increasing number of available data is one of effective way. Threfore, colloting reliable data around selected candidate site would be required as well as installing new gauging station at the selected candidate site.

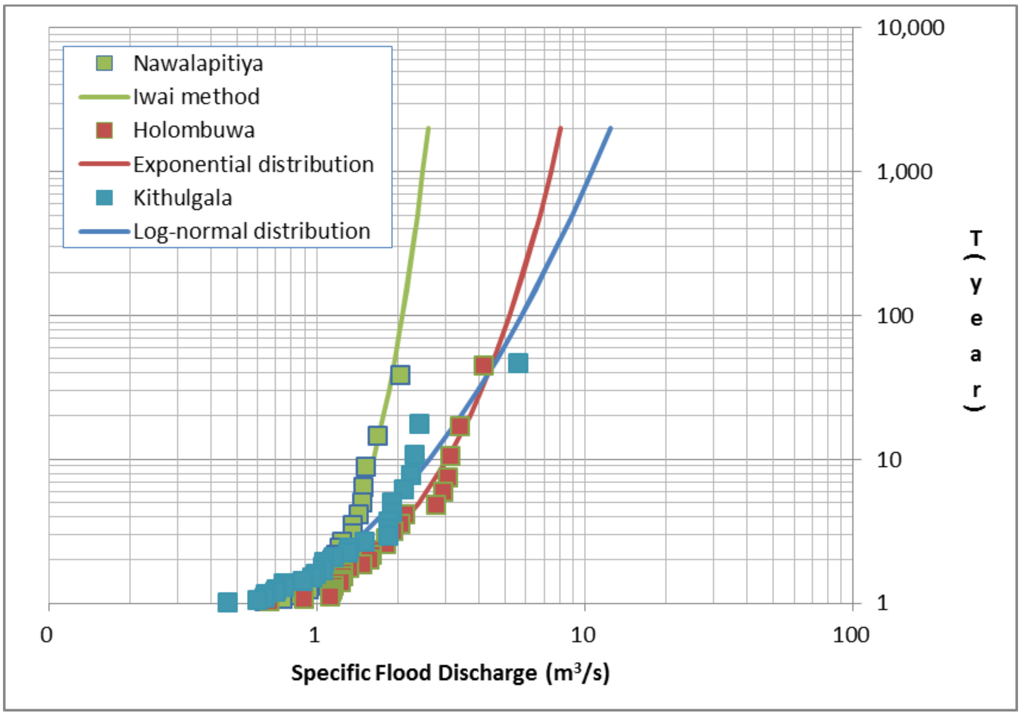


Figure 9.3.4-2 Specific Flood Discharge Curve

For reference to hydrological analysis the rain gauging stations near the each site are as follows;

Kiriketi1, Kiriketi2 : Belihl Oya (N6.75, E80.78)

Maussakelle1, Maussakelle2 : Gauravilla Estate (N6.78, E80.60)

Halgran1, Halgran2, Halgran3, Halgran4 : Liddes Dale (N7.02, E80.85)

Maha1, Maha2, Maha3 : Aranayake Mini Hydro (N7.13, E80.47)

Logal : Galoola Estate (N7.07, E81.15)

Figure 9.3.4-5 shows the location of Halgran3, Maha3 and Logal sites, and the rain gauging stations near those sites.

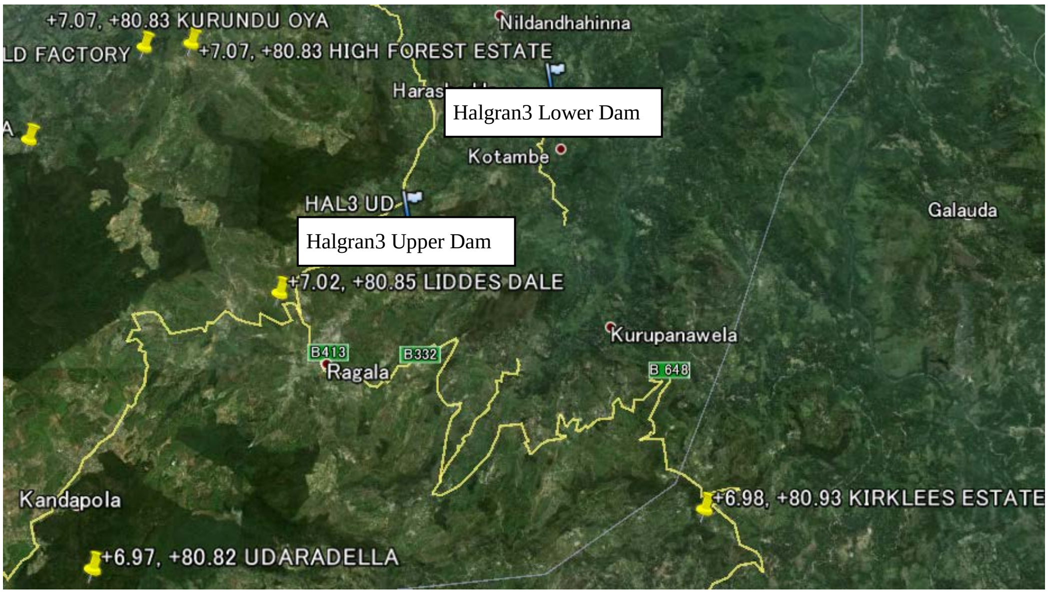


Figure 9.3.4-3 Rain Gauging Stations near Halgran Sites

Figure 9.3.4-4 Rain Gauging Stations near Maha Sites

Figure 9.3.4-5 Rain Gauging Stations near Logal Sites

9.3.5 Sedimentation

Suspended sediment concentration data at the hydrological gauging station managed by irrigation dept. is few in Sri Lanka. Because the equipment to collect the data are rarely installed at the stations. And some equipment is not working after breaking down. Therefore in this study some past design value of the other projects and the values of some papers for the sedimentation in Sri Lanka are reviewed and applied for this project. The specific sedimentation yield is calculated by these values.

(1) Actual values for sedimentation design

Following table shows the past actual values for designing sedimentations for each project in Sri Lanka. The values of Upper Kotmale Project and Kukule project which are the latest hydro power projects in Sri Lanka are 180 m^3/km^2/year and 320 m^3/km^2/year. And the actual value measured for sediment yields are in the range from 238 to 320m^3/km^2/year.

Table 9.3.5-1 Specific Sediment Yield for Design

Location	River Basin	Catchment Area (km^2)	Sediment Yield m^3/km^2/year	Note
Peradeniya	Mahaweli	1167	320	Measured
Kotomale	Kotomale	565	194	Design
Upper Kotmale	Kotomale	311	180	Design
Matiyadola	Kelani	606	238	Measured
Kukule	Karu	312	250	F/S Design
Moragolla	Mahaweli	243	265	F/S Design
Samanalawewa	Walawe	337	238 - 243	Measured
Broadlands	Kelani	139	350	F/S Design

(2) Empirical Formula to estimate sedimentation

Master Plan for the Electricity supply of Sri Lanka (February 1988) proposes the formula to estimate the sedimentation in Sri Lanka based on the actual data observed at Peradeniya station. The formula is as follows;

$$S = \left(\frac{Pm^2}{P} \right)^b \cdot (H50 \cdot G)^c \ {}^1\!/\!_a \leq 500 m^3 / km^2 / Year$$

Then,

S : Specific sedimentation yields (m^3/km^2/year)
Pm : Average monthly rain fall at the most much month (mm)
P : Average rain fall (mm)
H50 : Average elevation of the catchment area (m)
G : Slope Index
a = 317, b= 2.65, c= 0.46

As shown in Table 9.3.5-2, the sediment yield value 500m3/km2/year is calculated by this formula.

Table 9.3.5-2 Specific Sedimentation by Empirical Formula

Item	Mark	Estimation
Mean rainfall in wettest month (mm)	Pm	460
Mean annual rainfall (mm)	P	3,750
Mean elevation of catchment area (m)	H50	500
Slope index	G	0.035
Sediment yield (m^3/km^2)	S	500

(3) Estimation of the specific sedimentation yield for this study

Table 9.3.5-3 shows the summary of this study for the specific sedimentation yield. The values are in the range from about 200 to 500 m^3/km^2/year. Generally the specific sedimentation yield for designing is estimated by using past records in same country. On the other hand the empirical formula is used for confirming the digit for the estimation. In this study the designing value for the specific sedimentation yield is selected based on the past records method. The value 350 m^3/km^2/year for Broadland project is the largest of all. Then the 350 m^3/km^2/year for designing the specific sedimentation yield for this study is selected finally.

Table 9.3.5-3 Summary of Specific Sedimentation

	Values (m^3/km^2/year)	Remarks
Late cases in S.L.	180 ,250	Upper Kotmale & Kukule
Empirical formula	500	Maximum : 500m^3/km^2/year
Selected	350	Design for Broadlands

(4) Issue and recommendation

There are few hydrological gauging stations to observe the suspended sediment concentration data in Sri Lanka. In this study the specific sedimentation value is estimated by using the past actual record for design. Therefore, at the next F/S stage, it is better to observe the suspended sediment concentration data at the site for the specific sedimentation in detail.

9.4 Pumped Storage Power Project Planning

9.4.1 Outline of Pumped Storage Power Project Planning

In this study, pumped storage power project planning is conducted according to the flow chart shown in Figure 9.4.1-1. Definite procedure is described as follows.

(1) Locations of dam axes for 10 candidate sites, as well as waterway layouts are reviewed on topographical maps scale 1 to 50,000 and/or 1 to 10,000. In addition, suitable sites for pumped storage power projects are searched on available topographic maps scale 1 to 50,000 and 1 to 10,000.

(2) Catchment areas of reservoirs are measured using CAD software on maps scale 1 to 50,000 and 1 to 10,000 scanned.

(3) Reservoir capacities curves are prepared to measure areas surrounded by dam axes and contour lines in 10 m interval.

(4) Sedimentation capacity of every reservoir is calculated for 100 years and specific sediment inflow rate of 350 m3/km/year. Sediment level is set from the reservoir capacity curve prepared in (3) assuming horizontal deposition.

(5) The intake sill level is set 1 m above from sedimentation level. And then, Low Water Level (LWL) is set to assure the depth more than 2 times of headrace tunnel diameter from the intake sill level. In the planning of 11 candidate sites, 12 m of the depth from the intake sill is taken to every site as simplified way and for ensuring margin for the project planning.

(6) High water level (HWL) is set above LWL so as to assure necessary water volume as an effective volume. In principle, maximum drawdown depth (HWL - LWL) should be set within 30 m for slope stability around a planned reservoir.

(7) Gross head and Effective head obtained between Upper reservoir and Lower Reservoir is set as follows;

Gross Head (H_g)= H_{rated}(UD) - H_{rated}(LD)
Effective Head (H_e)= Hg - H_{loss}

Where,

Hrated = HWL(UD) - 1/3*{HWL(UD)-LWL(UD)}
Hloss = Hg*5%

(8) Maximum discharge for the power generation; Qg, is set as follows;

Qg = Ve / (6 hours*3,600s)

(9) Maximum output is set taking 0.85 of a combined efficiency for a pump-turbine and a generator as follows;

$$P = 9.8 \times Qg \times He \times 0.85 \quad (kW)$$

(10) Until 600 MW (600,000 kW) of a output and equivalent peaking time are obtained, from above procedure (6) to (9) are repeated.

Site selection (1/50,000 map, 1/10,000 map)

↓

Dam axis (U/D, L/D) selection (1/50,000 map, 10/10,000 map)

↓

Measuring catchment area (1/50,000 map)

↓

Measuring and calculating reservoir capacity (1/10,000 map)

↓

Sedimentation capacity in the reservoir for 100 years
$350m^3/km^2$/year, horizontal deposition

↓

Setting up LWL
(Sedimentation level + 1m + 2* waterway tunnel diameter)

↓

Setting up HWL
(Draw Down ≤ 30 m in principle)

↓

Calculating effective reservoir capacity V_e

↓

Calculating generating discharge Qg = Ve / (6 hrs*3,600 s)

↓

Calculating gross head: Hg and HWL
Hg = [HWL(UD) - {(1/3*{HWL(UD)-LWL(UD)}] -
[HWL(LD) – {(1/3*{HWL(LD)-LWL(LD)}]

↓

Calculating effective head
$H_e = H_g - H_{loss}$ (H_{loss}= Hg * 5%)

↓

Calculating Installed capacity
$P = 9.8 * 0.85 * Q_g * H_e$

↓

P ≥ 600 MW ? no

↓ yes

END

Figure 9.4.1-1 Pumped Storage Power Project Planning Flowchart

In candidate sites planed by the initial JICA Study, several topographically advantageous sites are included, which have more than 700 m of the gross heads and upper reservoirs and lower reservoirs of which can be connected with relatively short waterways. However, on the other hand, such candidate sites have to be reviewed from following two issues; one is an applicable unit capacity restricted by the stability of the power grid in 2025, which is a target year of installation of the first pumped storage power project, and the other is subsequently caused manufacturing limitation of pump-turbines to be installed.

As a result, 600 MW of a maximum installed capacity and 6 hours of an equivalent peaking time are set as the basic condition for the projects planning, which fits into three sets of 200 MW/unit and/or four sets of 150 MW/unit. In this regard, the project planning was conducted under condition of the maximum installed capacity 500 MW which fits into two set of 250MW/unit in the initial JICA Study.

The study on the unit capacity and the manufacturing limitation of pump-turbines, which is subsequently derived, is shown as follows.

9.4.2 Study on Applicable Unit Capacity

(1) Impact on Power System

As shown in follows, the study on the impact on the power system is conducted from two view points; one is a frequency drop by a generator trip and the other is a frequency up by a pump trip.

1) Frequency Drop by a Generator Trip

When the power system frequency drop occurs by a generator trip, and then a gap from normal frequency level becomes more than designated value, the partial load shedding is to be carried out based on Load Shedding Scheme as shown in Tabele5.1-4. Load shedding rates are depended upon caused frequency gaps. In this study, the unit capacity is determined so that the power system frequency remains more than 48.75 Hz, which is the threshold value for the first step of the power shedding schedule, even if a generator trip occurs.

2) Frequency up by a Pump Trip

When the power system frequency up occurs by a pump trip, trips of other generators may be induced as chained impact. In this regard, according to the given information from CEB, if the power system frequency up more than 51.5 Hz is observed and such state continues more than 3 minutes, the alarm is given in 3 existing thermal power plants. In this study, the unit capacity also determined so that the power system frequency is remains less than 51.5 Hz, even if a pump trip occurs.

(2) Conditions of Study

1) The System Frequency Constant

Data of actual frequency diviation (fault data) caused by trips of generators is obtained from CEB's System Control Center. Accordingly, data is analyzed by the least-square method and then system frequency constant for whole day is identified as 4.92% MW/Hz. In this analysis, uncertain data were excluded.

On the other hand, the system frequency constant is defined by the following equation.

$$\mathrm{K}(\%MW/Hz) = \frac{dp/p}{df}$$

dp: outage capacity (MW), p: demand at outage (MW), df: frequency deviation (Hz)

By the above formula, if a unit capacity of a pumped storage power plant is dp, frequency deviation to be calculated when it drop off

2) Load Demand Forecast

In this study, the target year for the first pumped storage power project installation is 2025. Therefore, the applicable unit capacity is studied for demand on and after 2025. According to Long Term Generation Expansion Plan 2012-2032 (LTGEP 2012-2032), the peak demand in 2025 has been forecasted as 4,717MW, and annual demand energy has been forecasted as 21,737GWh.

A pumped storage power project will generate in the night peak duration. Therefore, the applicable unit capacity is calculated under the condition that a generator trip occurs at the minimum demand in the night peak duration. The minimum demand in the night peak duration is approximately equivalent to annual average demand according to the past experience, so that it is calculated as 2,480 MW in 2025.

On the other hand, a pumped storage power project will pump up in off-peak duration. Therefore, the applicable unit capacity is calculated under the condition that a pump trip occurs at the minimum demand in one day. According to the past hourly demand records, daily minimum demand approximately equals to 44 % of the maximum demand, so that the minimum demand for this study is assumed as 2,075 MW in 2025.

(3) Applicable Unit Capacity Study by Generator Trip

In case of a generator trip, using the system frequency constant; K, 4.92%MW/Hz, the load demand; p, 2,487MW, and allowable frequency deviation for the stage 1 of the load shedding scheme; df, 1.25Hz (=50 Hz - 48.75Hz), applicable unit capacity is calculated as follows.

$$\Delta\mathrm{P} = 4.92/100 \times 1.25 \times 2{,}480 = 152.2\mathrm{MW}$$

In addition, Table 9.4.2-1 shows the growth of demand and corresponding applicable unit capacities. The calculation results show that 150 MW/unit clears 1.25 Hz for stage I of the power shedding scheme in and after 2025, and 200 MW/unit in 2031. In this regard, according to the calculation results, in case that a generator of 200 MW/unit trip occur from 2025 to 2031, frequency deviation exceeds stage II (-1.5 Hz) from 2025 to 2026, exceeds stage I (-1.25 Hz) from 2027 to 2030.

Table 9.4.2-1 Yearly Transition of Allowable Unit Capacity

	Year									
	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Energy(GWh)	21,737	22,813	23,932	25,101	26,318	27,581	28,899	30,258	31,670	33,131
Demand(MW)	4,717	4,948	5,187	5,369	5,625	5,893	6,171	6,461	6,671	6,978
Acceptable Outage Capacity (MW)	**152.2**	160.2	168.0	176.2	184.8	193.6	**202.9**	212.4	222.3	232.6

(Source：the Study Team)

(4) Applicable Unit Capacity Study by Pump Trip

In case of a pump trip, using the system frequency constant; K, 4.92%MW/Hz, the load demand; p, 2,075 MW, and allowable frequency deviation determined from alarm given level in three thermal power stations; df, 1.50 Hz (=51.5 Hz - 50Hz), applicable unit capacity is calculated as follows.

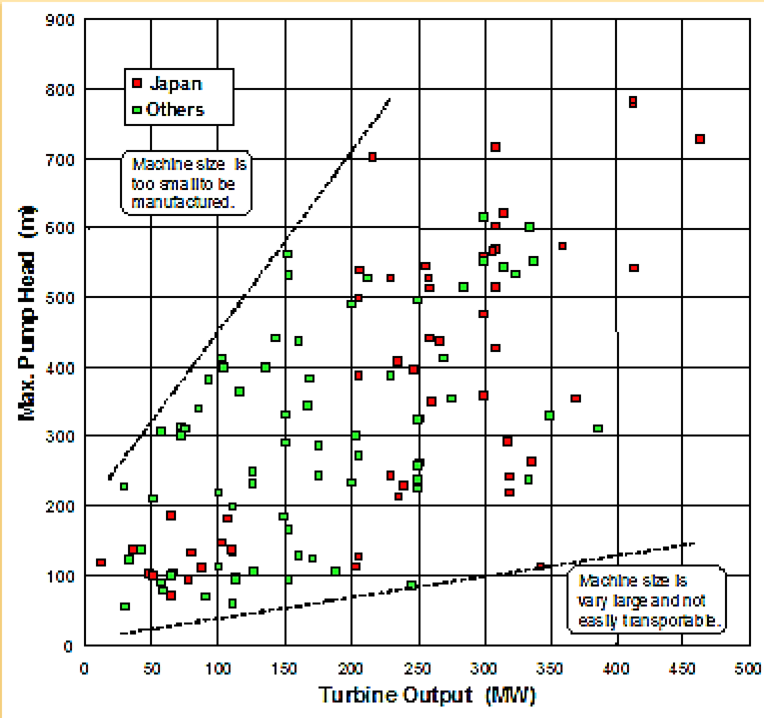
$$\Delta P = 4.92/100 \times 1.50 \times 2{,}075 = 153.1\text{MW}$$

Therefore, 150 MW/unit is the applicable unit capacity in order to avoid the frequency deviation of alarm given level in thermal power stations. In this regard, frequency deviation would be mitigated to introduce “Governor-free” in thermal power stations and “Adjustable speed type” in pumped storage power stations, etc. As well as the study on a generator trip, allowable unit capacity would become larger along demand growth.

9.4.3 Manufacturing Limitation of Pump-turbine

As Shown in Table 9.1-1, several candidate sites have their rated heads more than 600 m. Figure 9.4.3-1 shows plots of past manufacturing achievements on the chart of which vertical axis is maximum pump head and horizontal axis is turbine output. Red color plots shows achievement of Japanese manufactures and green color plots those of other countries. In this chart, two broken lines are also shown. Upper broken line means the manufacturing limitation for small size side due to high-head and small discharge, lower broken line shows that for large size side due to low head and large discharge. It is understood that approximately 700 m of the maximum pump head would be limit for 200 MW/unit manufacturing as well as approximately 570 m of that would be for 150 MW/unit manufacturing based on the past achievement.

Since this figure shows the past manufacturing achievement only; therefore, in this study, dimensions of pump-turbine are roughly designed. Based on designed dimension of pump-turbine in every candidate site, its manufacturing limitation is individually examined.

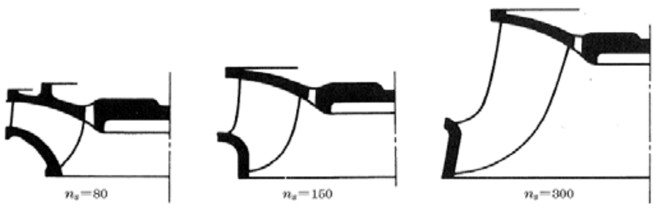


(Source; Study Team)

Figure 9.4.3-1 The Past Achievement of Manufacturing of Pump-turbine

(1) Manufacturing Limitation of Runner

Inlet height of a runner, as shown in Figure 9.4.3-2, shall be made lower in case of a higher design head, on the other hand, it shall be made higher in case of a lower design head.

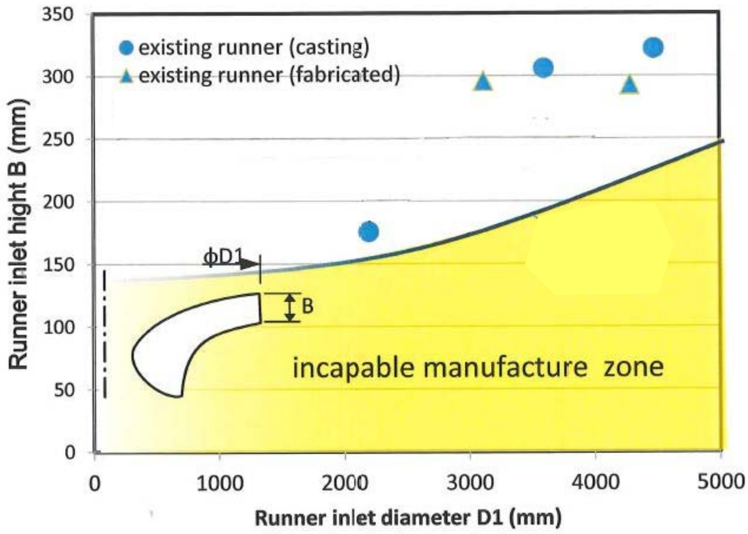


←High Head and High Rotation Number Low Head and Low Rotation Number→

(Source: Hydro Turbine)

Figure 9.4.3-2 Shape of Francis Type Runner

Manufacturing methods of runners are typically categorized as following two methods; one is to being made from a mold by machine cutting, and the other is to being made by welding parts as runner-vanes, etc. In both methods, finishing works and detailed dimension checking by the hands of a professional is the one of essential processes. In case of a runner having an extremely low inlet height and a relatively large diameter, such works by humans' hands would be difficult. Figure 9.4.3-3 shows the incapable manufacture zone of runners in relation to inlet heights and diameters. In this study, manufacturing limitation for pump-turbine in every site is judged by the shown zone.



(Source; Hitachi-Mitsubishi Documents)

Figure 9.4.3-3 Manufacturing Limitation for High Head Type Pump-turbine

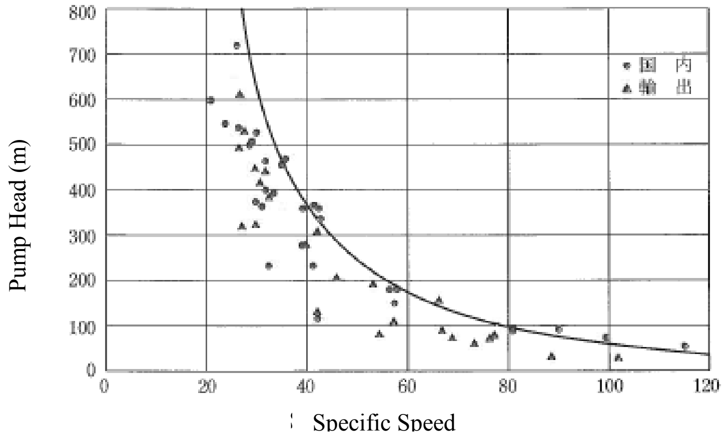
(2) Limitation of Specific Speed (ns)

A shape of a runner becomes a "low inlet height and large diameter" type along with a high head and high rotating. In addition, a specific speed; Ns (m-m3/s) also becomes lower. Since to take a low specific speed may conduce to an extremely lower effective rate, more than 25 of specific speeds are taken in the design in practice. Therefore, the specific speed of every candidate sites is to be checked whether its specific speed is higher than 25 or not. In this regard, the specific speed is calculated by following formula introduced in JEC 4001.

$$Ns = 12500 / (H+100) + 10 \text{ (m-m3/s)}$$

H: Gross Head

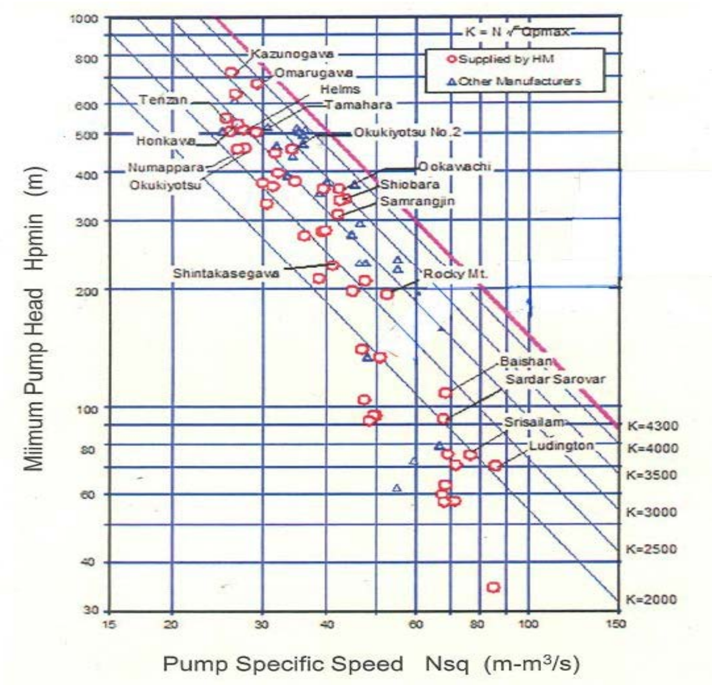
The distribution of specific speeds of existing plants is shown in Figure 9.4.3-4. (by Japanese Electrical Committee)



(Source; JEC4001-2006)

Figure 9.4.3-4 Past Record of Specific Speeds of Pump-turbine N_s

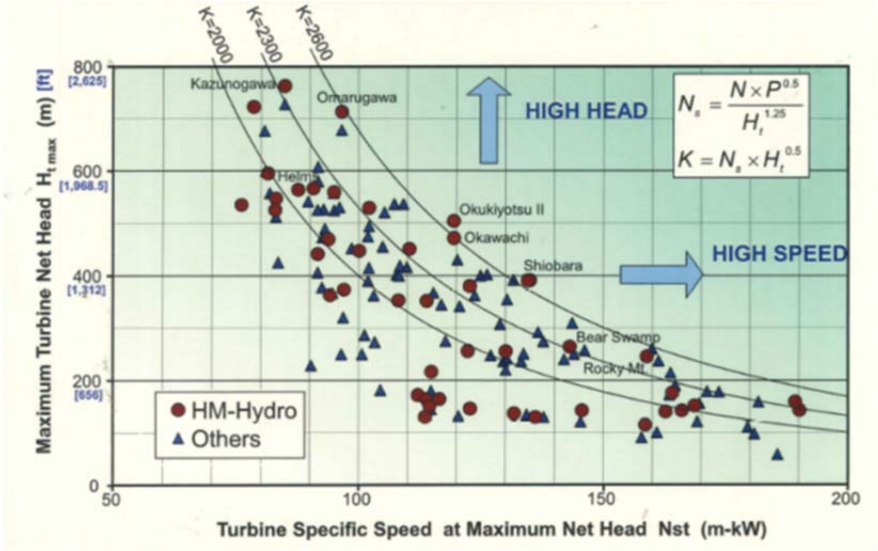
Furthermore, if constant values ($K = N*Qp^{0.5}$) are calculated from the relation between rotation numbers (N) and Pumped discharges (Qp) in past records, it is understood that they are distributed in the zone less than 4,300; therefore, the constant of every candidate site's pump-turbine is checked whether it is less than 4,300 or not in this study.



(Source: Hitachi-Mitsubishi Documents)

Figure 9.4.3-5 Relation of Pump Specific Speeds and Head (K<4,300)

As for output specific speeds, they are designed so as to be more than 80 to 85 (m-kW) in generation mode; therefore, it is checked that whether the output specific speed of every candidate sites are more than 80 or not.



(Source: Hitachi-Mitsubishi Documents)

Figure 9.4.3-6 Generation Specific Speeds Curve

Based on the above-mentioned criteria, the manufacturing limitation of the pump-turbine is examined by the design head, the designed dimension, the design rotation number, and design specific speed in every candidate site. Examined results are as shown in Table 9.4.3-1 and Table 9.4.3-2, respectively.

Table 9.4.3-1 Examined Results of Manufacturing Limitation of Pump-turbine (200MW*3units)

Candidate site	unit	Kirikete 1	Kirikete 2	Maussa -kelle A	Maussa -kelle B	Halgran 1	Halgran 2	Halgran 3	Halgran 4	Maha 1	Maha 2	Logal
Maximum Gross Pumping Head	m	741	811	500	514	637	750	734	532	514	490	626
Effective Head	m	664	731	450	463	576	677	657	465	464	434	561
Discharge	m3/s	108	98	159	155	125	106	109	154	154	165	128
Installed Capacity (total)	MW	594	594	606	609	609	594	591	612	606	612	606
Turbine unit Out-put	kW	202,000	202,000	206,000	207,000	207,000	202,000	201,000	208,000	206,000	208,000	206,000
Rotation Speed	min-1	600	600	500	500	600	600	600	500	500	500	600
Manufactuaring Limiation (200 MW*3units)												
(1) Dimension of Runner												
Inlet Dia (D1)	mm	3570	3720	3,610	3640	3350	3600	3560	3620	3640	3530	3310
Inlet Height (B1)	mm	199	174	323	312	247	193	203	310	308	339	254
Evaluation		(OK)	NG	OK	OK	OK	NG	(OK)	OK	OK	OK	OK
(2) Specific Speed												
Pump Specific Speed >25	m-m3/s	27.5	24.4	37.3	36.0	32.9	26.9	27.9	35.8	35.8	39.0	34.0
Kq <4300		3,600	3,429	3,640	3,594	3,873	3,567	3,617	3,582	3,582	3,708	3,919
Power Specific Speed	m-kW	80.0	70.9	109.5	105.9	96.7	78.1	80.9	105.6	105.4	115.1	99.7
Evaluation		OK	NG	OK	OK	OK	NG	OK	OK	OK	OK	OK

(Source: the Study Team)

Table 9.4.3-2 Examined Results of Manufacturing Limitation of Pump-turbine (150MW*4units)

Candidate site	unit	Kirikete 1	Kirikete 2	Maussa -kelle A	Maussa -kelle B	Halgran 1	Halgran 2	Halgran 3	Halgran 4	Maha 1	Maha 2	Logal
Maximum Gross Pumping Head	m	741	811	500	514	637	750	734	532	514	490	626
Effective Head	m	664	731	450	463	576	677	657	465	464	434	561
Discharge	m3/s	108	98	159	155	125	106	109	154	154	165	128
Installed Capacity (total)	MW	600	600	600	600	600	600	600	600	600	600	600
Turbine unit Out-put	kW	150,000	150,000	150,000	150,000	150,000	150,000	150,000	150,000	150,000	150,000	150,000
Rotation Speed	min-1	600	600	600	600	600	600	600	500	600	500	600
Manufactuaring Limiation (150 MW*4units)												
(1) Dimension of Runner												
Inlet Dia (D1)	mm	3610	3760	3,050	3080	3380	3640	3580	3680	3080	3570	3370
Inlet Height (B1)	mm	155	133	273	262	192	151	157	246	262	270	200
Evaluation		NG	NG	OK	OK	NG	NG	NG	OK	OK	OK	OK
(2) Specific Speed												
Pump Specific Speed >25	m-m3/s	24.9	23.7	30.8	30.4	27.0	24.7	25.0	29.8	30.4	31.2	27.2
Kq <4300		3,118	2,970	3,783	3,735	3,354	3,089	3,132	3,102	3,723	3,211	3,394
Power Specific Speed	m-kW	68.9	61.1	112.1	108.2	82.4	67.3	69.9	89.7	107.9	97.8	85.1
Evaluation		NG	NG	OK	OK	OK	NG	OK	OK	OK	OK	OK

(Source: the Study Team)

Every candidate site planned by the initial JICA Study was 500 MW of plant capacity composed of two sets of 250 MW/unit. However, although allowable unit capacity may be variable based on demand scale and/or daily load pattern in the future, studied results from the system stability aspect reveal that 150 MW/unit is applicable in 2025 and 200 MW/unit is applicable in 2031. Accordingly, it is decided that this study takes 200 MW/unit as the base case as well as 150 MW/unit as the alternative case and every candidate site by the initial JICA study is to be reviewed and revised, if necessary.

Through reviewing on those candidate sites, it is revealed that confliction with the manufacturing limitation cannot be avoided in Kiriketi 2 and Halgran 2 in case of two sets of 200 MW/unit. Furthermore, Kiriketi 1 and Halgran 3 also fall into manufacturing limitation issue in case of four sets of 150 MW/unit. In this regard, relations between the inlet diameter and the runner diameter in Kiriketi 2 and Halgran 3 are plotted on the zone near the boundary to the incapable manufacturing zone as shown in Figure 9.4.3-3, careful consideration would be required in the study in the later stages of the study.

9.4.4 Method of Construction Cost Calculation

The construction cost of every candidate sites are estimated according to “Chapter 6 in Volume 1, JICA Hydropower Development Manual; 2011, JICA”. Unit prices in the civil works is basically decided to assume the price level from actual unit prices of similar projects in Sri Lanka (Umaoya Hydropower Project, and Upper Kotmale Hydropower Project) , which has been provided by CEB. Regarding the construction cost of the electrical equipment is estimated in every main equipment basis, which prices are extracted from those of similar projects.

Table 9.4.4-1 shows the applied unit prices for the civil works. In addition, unit prices from Upper

Kotmale Hydropower Project contains JPY portions and LKR portions and in 2006. To convert those on USD basis and in 2013, exchange rate 1 JPY=0.01010US$ and 1 LKR=0.00755US$ is used and the ratio of GNP in 2006 and in 2013; Japan 0.92, Sri Lanka 1.88, are considered for the prices escalation.

Table 9.4.4-1 Unit Price of Civil Works for Cost Estimation

Item		Unit	Price	Remarks
Excavation				
	Common	US$/$m^3$	15	for Open excavation
	Rock	US$/$m^3$	25	for Open excavation
	Tunnel	US$/$m^3$	80	for Horizontal Tunnel
	Penstock	US$/$m^3$	220	for Inclined Tunnel, Surge Shaft
	Underground	US$/$m^3$	115	for Powerhouse Cavern
Embankment				For fill type dams
	Rock	US$/$m^3$	18	
	Core	US$/$m^3$	23	
Concrete				
	Mass	US$/$m^3$	150	for RCC Dam
	Open	US$/$m^3$	220	for Structure (Intake, Outlet, etc)
	Lining	US$/$m^3$	220	for Tunnel
	Lining	US$/$m^3$	275	for Surge tank
	Filling Concrete	US$/$m^3$	100	for Aournd Steel Liner
	Powerhouse	US$/$m^3$	220	for Sub-structure in Powerhouse
Reinforcing Bar		US$/ton	1,550	
Hydro-Mechanical				
	Gate	US$/ton	3,825	
	Penstock	US$/ton	5,500	
	Trashrack	US$/ton	2,200	

(Source; Study Team)

Regarding the construction cost of dams, both of the types such as RCC type and Rock-fill Type are calculated and then, the more economical economic one is incorporated in the total construction cost. In this connection, unit prices of Rock-fill type dam are extracted from actual prices of past similar projects in India as the neighboring country, because there are not available ones in Sri Lankan past projects. However, other unit prices for civil works in Sri Lanka shows rather higher than those in India, therefore, applied Indian unit prices for Rock-fill type dams are increased by the ratio of other unit prices in Sri Lanka and in India.

9.5 Evaluation of Candidate Sites

9.5.1 Kiriketti 1

(1) General Outline

Upper reservoir of this site is located in the top of the hill in right bank of Kiriketi River and Lower reservoir is located in the main course of Kiriketi River. The rated head obtained from the difference in height between Upper reservoir and Lower reservoir is 664.7 m and the rated discharge for generating is 108.37 m^3/s, and the rated output is 600 MW. Due to the topographical condition, Upper reservoir capacity is limited, so that the equivalent peaking time is limited to around 3.8 hours only.

Review of the project scheme (250 MW/unit * 2 unit) by the initial JICA Study was carried out to reduce the head, because it was concerned about the manufacturing limitation of the unit capacity 200 MW due to around 700 m of its gross head; however, there are not any sites having suitable topological conditions for reservoirs except the locations decided by the initial JICA Study.

Ratio of the horizontal waterway length (L) and the gross head (H) is 3.6 (=L/H).

(2) Geomorphology and geology

The site geology belongs to Highland Complex and mainly comprises gneisses. The site locates itself on the north wing of the syncline fold axis thus dipping NW in general.

The upper reservoir site consists of Charnokite. It is anticipated generally hard and low permeable. The slope around the reservoir is of a shallow gradient, it appears to have relatively thin alluvial deposits and to have shallow weathering layers. There are no landslide materials around both rims right handside and left handside. There concludes no particular water leakage nor instabilization issues arise.

The upper dam axis is planned at a mountain’s ridge, with thin anticipated surface weathering depth.

Water route passes in the gneisses zone, but passes 2 faults within its short route length. Inferior geology may be encountered in the zones along these faults.

The underground powerhouse is planned near such faults as due support is likely required.

The lower reservoir comprises Charnokite, partially quartzite. The NE-SW trending Kiriketti river coincides with the NE-SW fault eroding itself along the river. The river path was formed by the successive erosion along NE-SW fault (in fracture zone most likely) that river presents very steep valley feature. The lower reservoir bed rock is considered to hold sufficient water sealing capability though some quartzite may contains developed joints inside. The right hand reservoir rim is a steep valley slope with thin surface weathering, and with the stable structure of reverse dipping judging from the NE60N trend outcrops observed on the river bed. The left hand side reservoir rim form rather slow slope of 30 degree. colluvial deposits of certain thickness can be seen from the aerophotographs. This rim forms dipping slope structure along bedding layers.

The lower dam is located at Charnokite, quartzite. Though quartzite potentially may contains joints but in general both rocks are hard. It is noted that NE-SW trending fault crosses across the dam axis. The colluvium and alluvium are thin at river bed. The surface weathering depth may be thin at right hand river bank slope and potentially thicker at left hand river bank.

(3) Natural and social environments

1) Upper dam/reservoir

a) Natural environment

Table 9.5.1-1 shows the conditions of the natural environment of the Kiriketi 1 upper dam/reservoir. These descriptions of each candidate site are based on the results of the Environmental Study (1).

Table 9.5.1-1 Conditions of the Natural Environment of the Kiriketi 1 Upper Dam/Reservoir

Name of site / Characteristics	Kiriketi 1 Upper dam/reservoir
Meteorological condition	The area is on the border of the Wet and Intermediate Zones. There are two rainfall peaks in a year: from March to May; and from October to December. The average annual rainfall is about 2,200 – 2,400 mm.
Hydrological condition	No data available.
Land slide	According to the Landslide Map of the National Building Research Organization (NBRO), landslides are not likely to occur around the site.
Water quality	No data available.
Protected area including other important areas (e.g. World Heritage Site)	The site is within the Peak Wilderness Sanctuary, and close to the Horton Plains National Park. It is within an IBA (Peak Wilderness Sanctuary).
Fauna and flora	Number of faunal endangered species CR: 6, EN: 16, VU: 6 Number of floral endangered species CR: 1, EN: 13, VU: 20
Habitats	The site is covered with natural montane cloud forests. Their biodiversity and species richness are high. The close downstream of the dam site is also covered with natural montane cloud forests, and their biodiversity and species richness are high.

Note[2]: CR: Critically Endangered、EN: Endangered、VU: Vulnerable

[2] Refer to “The National Red List 2012 of Sri Lanka - Conservation Status of the Fauna and Flora”.

b) Social environment

Table 9.5.1-2 shows the conditions of the social environment of the Kiriketi 1 upper dam/reservoir.

Table 9.5.1-2 Conditions of the Social Environment of the Kiriketi 1 Upper Dam/Reservoir

Name of site / Characteristics	Kiriketi 1 Upper dam/reservoir
Location	Kumburutheniwela (GN), Imbulpe Division, Rathnapura District
Demographic status of the GND	Population: 1,059, No. of household(HH): 320, Average number(No.) of family : 3.31 Major local industry: Agriculture, Average monthly income: Most of the people receive Rs.1,500-2,500
Accessibility to the proposed site	The site is accessible only from the Horton Plains. There are no access roads from the end of the Worlds End trail. There are not even proven foot paths to the site.
Extent of resettlement	None
Extent of land acquisition	Natural forest: 11.7ha
Land use pattern of the area	Natural forest
River utilization especially in downstream areas	The Kiriketi Oya is not used by people at this location as it is far away from human settlements. However, further downstream when it emerges out of the Peak Wilderness Sanctuary, it is used by people for domestic purposes. No fishery.
Religious, cultural and archeological heritages	None
Tourism site	The site is located within the Peak Wilderness Sanctuary, near Horton Plains National Park. The both have been declared as a World Heritage Site "Central Highlands of Sri Lanka"
Existence of indigenous people	None
Existence of poverty people	None

2) Lower dam/reservoir

a) Natural environment

Table 9.5.1-3 shows the conditions of the natural environment of the Kiriketi 1 lower dam/reservoir.

Table 9.5.1-3 Conditions of the Natural Environment of the Kiriketi 1 Lower Dam/Reservoir

Name of site / Characteristics	Kiriketi 1 Lower dam/reservoir
Meteorological condition	The area is on the border of the Wet and Intermediate Zones. There are two rainfall peaks in a year: from March to May; and from October to December. The average annual rainfall is about 2,200 – 2,400 mm.
Hydrological condition	No data available.
Land slide	According to the Landslide Map of NBRO, landslides are not likely to occur around the site.
Water quality	No data available.
Protected area including other important areas (e.g. World Heritage Site)	The site is within the Peak Wilderness Sanctuary, and close to the Horton Plains National Park. It is within an IBA (Peak Wilderness Sanctuary).
Fauna and flora	Number of faunal endangered species CR: 5, EN: 10, VU: 6 Number of floral endangered species CR: 0, EN: 0, VU: 1
Habitats	The site is mainly covered with tea plantation. There are also Panata grassland, rocky areas and degraded riverine vegetation. The biodiversity and species richness are low. The close downstream of the dam site is also dominated by tea plantation, and the biodiversity and species richness are low.

Note: CR: Critically Endangered、EN: Endangered、VU: Vulnerable

b) Social environment

Table 9.5.1-4 shows the conditions of the social environment of the Kiriketi 1 lower dam/reservoir.

Table 9.5.1-4 Conditions of the Social Environment of the Kiriketi 1 Lower Dam/Reservoir

Name of site / Characteristics	Kiriketi 1 Lower dam/reservoir
Location	Yakdehiwela (GN), Imbulpe Division, Rathnapura District
Demographic status of the GND	Population: 1,141, No. of HH: 342, Average No. of family: 3.34, Major local industry: Agriculture Average monthly income: No data Average monthly income of Nonpareil Estate: Rs.5,000-7,500
Accessibility to the proposed site	The site is accessible through the Nanperil Estate, however the access road is very narrow and extremely steep. Widening about 8 km of this narrow access road will be extremely difficult. The last 500 meters has to be negotiated along a foot path through both forest and grassland.
Extent of resettlement	13 households including line houses of the workers of the Nonpereli Estate will be affected by the project.
Extent of land acquisition	Tea plantation: 8.4ha
Land use pattern of the area	Tea plantation
River utilization especially	The stream is used extensively by the people living in the line rooms for

Name of site / Characteristics	Kiriketi 1 Lower dam/reservoir
in downstream areas	bathing and washing and for drinking they depend on a piped water system provided by the Estate. No fishery.
Religious, cultural and archeological heritages	None
Tourism site	The site is located within the Peak Wilderness Sanctuary. The area is not a tourist attraction and thus no tourists visit the site. The access to the holiday bungalow maintained by the Nonpareil Estate is about 2 km away.
Existence of indigenous people	None
Existence of poverty people	None

3) Evaluation of the natural and social environments of the Kiriketi 1

a) Evaluation of the upper dam/reservoir

The environmental study was conducted on both natural and social conditions of 11 sites for pumped storage power plant for two months, and the descriptions of each site are not in very details. The assessment, therefore, is conducted in the following major scoping items, 1) Impacts on fauna and flora, 2) Impact on local communities, 3) Impacts on industries, and 4) Impacts on cultural heritage. In each major scoping item, an evaluation is conducted using the rating A, B and C as described as follows.

A: Project is not likely to have significant adverse impacts on natural environment and society and/or limited to a small scale.

B: Project is likely to have negative impact on natural environment and society, but less adverse than C

C: Project is likely to have significant adverse impacts on natural environment and society.

Natural environment:

The result of the evaluation of the natural environment of the Kiriketi 1 upper dam/reservoir is shown in Table 9.5.1-5.

Table 9.5.1-5 Evaluation of The Natural Environment of the Kiriketi 1 Upper Dam/Reservoir

Scoping items	Evaluation
Impacts on fauna and flora	Rating [C] The project would give significant impacts on the natural environment. This is because (1) the site is within a protected area (Peak Wilderness Sanctuary); (2) there are many faunal and floral endangered species; and (3) the biodiversity and species richness are high.

Social environment:

The results of the evaluation of the social environment of the Kiriketi 1 upper dam/reservoir are shown in Table 9.5.1-6.

Table 9.5.1-6 Evaluation of the Social Environment of the Kiriketi 1 Upper Dam/Reservoir

Scoping items	Evaluation
Impacts on local communities	Rating [A] The site is located within the Peak Wilderness Sanctuary, there is no settlement. The downstream of Kiriketi Oya is used by local people for domestic purposes, but the impact on water utilization is limited to a small scale. Therefore the evaluation rating is [A]
Impacts on industries	Rating [A] There is no local industry since the site is within a protected area of the Peak Wilderness Sanctuary. Though 11.7 ha of natural forest will be inundated by the project, there is no forest plantation and Non Timber Forest Product (NTFP). Therefore the evaluation rating is [A].
Impacts on cultural and landscape	Rating [C] The Fauna and Flora Protection Act No. 22 of 2009 explicitly prohibits any development activity within sanctuaries. Therefore the evaluation rating is [C].

b) Evaluation of the lower dam/reservoir

Natural environment:

The result of the evaluation of the natural environment of the Kiriketi 1 lower dam/reservoir is shown in Table 9.5.1-7.

Table 9.5.1-7 Evaluation of the Natural Environment of the Kiriketi 1 Lower Dam/Reservoir

Scoping items	Evaluation
Impacts on fauna and flora	Rating [C] The biodiversity and species richness are low. However, since 15 faunal endangered species (CR: 5, EN: 10) are recorded and the site is within a protected area (Peak Wilderness Sanctuary), the project would give significant impacts on the natural environment.

Social environment:

The results of the evaluation of the social environment of the Kiriketi 1 lower dam/reservoir are shown in Table 9.5.1-8.

Table 9.5.1-8 Evaluation of the Social Environment of the Kiriketi 1 Lower Dam/Reservoir

Scoping items	Evaluation
Impacts on local communities	Rating [B] The site is spread with tea plantation, and 13 households will have to be relocated due to the project. Therefore the evaluation rating is [B].
Impacts on industries	Rating [B] 8.4 ha of tea plantation will be affected by the project. Therefore the evaluation rating is [B].
Impacts on cultural and landscape	Rating [C] The Fauna and Flora Protection Act No. 22 of 2009 explicitly prohibits any development activity within sanctuaries. Therefore the evaluation rating is [C].

c) Overall evaluation

Table 9.5.1-9 shows the overall evaluation of the Kiriketi 1 as a cluster with the evaluations of the upper and lower dam/reservoirs.

In case that rating of upper dam/reservoirs is different from the one of the other such as "Impacts on local communities" in Table 9.5.1-1, the rating of the worse is treated as the overall evaluation rating from the precautionary point of view.

Table 9.5.1-9 Overall Evaluation of the Kiriketi 1 Cluster

Scoping items	Evaluation		
	Upper dam/reservoir	Lower dam/reservoir	Overall
Impacts on fauna and flora	C	C	C
Impacts on local communities	A	B	B
Impacts on industries	A	B	B
Impacts on cultural and landscape	C	C	C

A: Project is not likely to have significant adverse impacts on natural environment and society and/or limited to a small scale.

B: Project is likely to have negative impact on natural environment and society, but less adverse than C

C: Project is likely to have significant adverse impacts on natural environment and society.

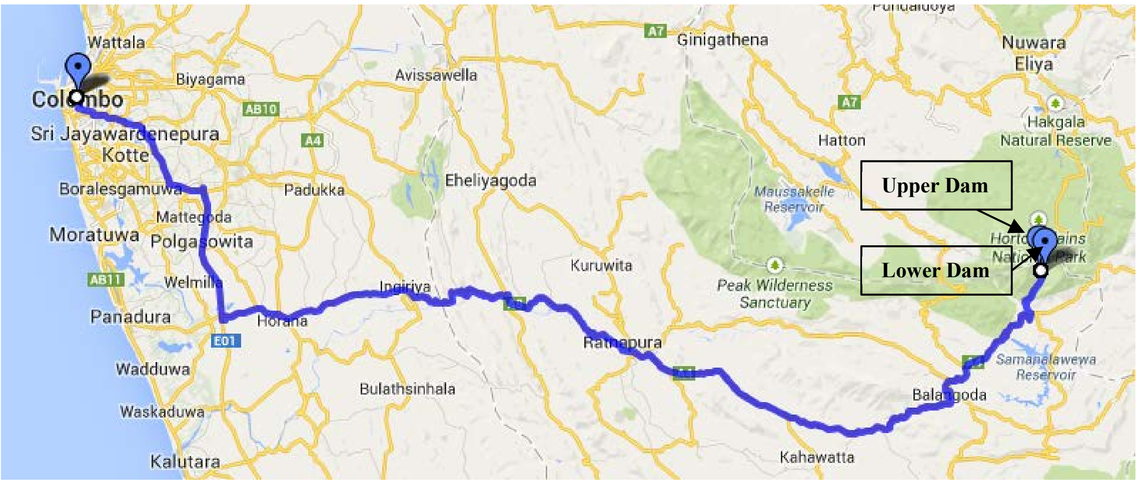
(4) Technical Evaluation

As for accessibility to Upper reservoir, the distance on the roads from Colombo to Upper reservoir is around 170 km. The back water of Upper reservoir is accessible by vehicles taking following routes; after driving on 8 km of by-road along Kiriketi River from the main road A4, furthermore, it takes around 1 hour on narrow and winding road in the tea plantation. Dam axis cannot be approached by vehicles. It is necessary to improve long distance of the by-load and the path in the tea plantation in order to transport materials and equipment for the construction.

As for accessibility to Lower reservoir, the distance on the roads from Colombo to Lower reservoir is around 160 km. The dam axis of Lower reservoir is accessible by vehicles taking following routes; after driving on 8 km of by-Road and the path along Kiriketi River from the main road A4. However, topography around the dam axis is a very steep valley, and there is around 50 m of difference in height from the by-road surface to the river bed.

Furthermore, as for temporary yards and access roads for the construction works, it would be so difficult due to very steep topographic condition in and around Upper reservoir area, and Lower reservoir area, as well as the area on the waterway route judging from the topographic map scale 1 to 10,000.

The manufacturing limitation of 200 MW/unit is cleared; however, it is plotted near the boundary to incapable zone, so that careful examination is required for the later study. 150 MW/unit cannot be applicable to this scheme.



(Source; Study Team)

Figure 9.5.1-1 Access Route for Kiriketi 1 Site

(5) Construction Cost

Table 9.5.1-10 shows the construction cost for Kiriketi 1 scheme, which is calculated according to method and condition shown in the sub-clause 9.4.4. The scheme by four sets of 150 MW/unit is not applicable.

Table 9.5.1-10 Construction Cost for Kiriketi 1 Scheme

Item/Project		Kiriketi 1 200MW*3unit *10^3USD	Kiriketi 1 150MW*4units *10^3USD	Remarks
1.	Preparation and Land Acquisition	5,458		
	(1) Access Roads			
	(2) Compensation & Resettlement			
	(3) Camp & Facilities	5,458		3. Civil Works * 2%
2.	Environmental Mitigation Cost	8,187		3. Civil Works * 3%
3.	Civil Works	272,889		
4.	Hydromechanical Works	71,328		
5.	Electro-Mechanical Equipment	186,500		
6.	Transmission Line			
	Direct Cost	544,361		
7.	Administration and Engineering Service	81,654		Direct Cost * 15%
8.	Contingency	54,436		Direct Cost * 10%
9.	Interest during Construction			
	Total Cost	680,451		
	Power Output	600,000		
	USD per kW	1,134		

(Source; Study Team)

Main features of the civil structures are shown as follows.

- Upper Dam		
Type	Rock Fill	
Height *Crest Length	35m * 1,280m	
Volume	2,300 * 10^3m^3	
- Lower Dam		
Type	Rock Fill	
Height * Crest Length	93m * 250m	
Volume (*10^3m^3)	2,300 * 10^3m^3	
- Headrace Tunnel Dia *Length*line	200MW/unit	4.8m * 1,070m * 1 line
	150MW/unit	N.A
- Penstock Tunnel Dia *Length*line	200MW/unit	3.8m * 1,260m * 1 line
	150MW/unit	N.A
- Tailrace Tunnel Dia *Length*line	200MW/unit	5.3m * 500m * 1 line
	150MW/unit	N.A

9.5.2 Kiriketi 2

(1) General Outline

Upper reservoir of this site is located in the top of the hill in right bank of Kiriketi River and Lower reservoir is located in the main course of Kiriketi River. The rated head obtained from the difference in height between Upper reservoir and Lower reservoir is 731.81 m and the rated discharge for generating is 98.43m^3/s, and the rated output is 600 MW. Due to the topographical condition, Upper reservoir capacity is limited, so that the equivalent peaking time is limited to around 2.5 hours only.

Review of the project scheme (250 MW/unit * 2 unit) by the initial JICA Study was carried out to reduce the head, because it was obviously concerned about the manufacturing limitation of the unit capacity 200 MW due to around 770 m of its gross head; however, there are not any sites having suitable topological conditions for reservoirs except the locations decided by the initial JICA Study.

Ratio of the horizontal waterway length (L) and the gross head (H) is 1.7 (=L/H).

(2) Geomorphology and geology

The site geology belongs to Highland Complex and comprises mainly gneisses. It situates itself at the north wing of the syncline folding axis thus with NW dipping in general. The geological conditions and water sealing capability are anticipated unfavorable for the hydropower site.

The upper reservoir is located at the summit to ridge of a hard mountain formed of gneisses with NE opening valley near summit planned for reservoir. Gneiss's hard summit has practically no surface weathered sediments atop, thus so as for the upper damsite and the upper reservoir. However, there estimated a NE-SW trending fault along NE opening valley at the planned damsite (NE opening valley itself can be said formed by NE-SW fault's erosion). In observation at site there are many NE/20NW trending layers and joints at summit and mountain slopes, thus NE/20NW trend is considered major decisive structure trend around the site. There are well enough reasons to anticipate water leakage issues when a dam is constructed at NE opening and steeping valley eroded and formed by NE-SW trending fault coupled with the same trending joints at mountain slope. To be added is that the right abutment of the dam is thin and nearly at EL 1,750m with the planned HWL of 1,725m needing some treatment if it is chosen.

The water route passes 1 fault along within its short length. Inferior geology may be encountered.

The underground powerhouse is planned near such fault as due support is likely required.

The lower reservoir comprises gneisses and hard. But the same as Kiriketi 1 NE-SW trending fault erodes itself along NE-SW trending Kiriketi River. This fault's successive erosion forms the river in NE-SW direction. The fault plain is high in angle with lateral movement that may be beneficial for the water sealing capability of the reservoir. The NE/60-70NW trend of the layers along the river is the decisive direction of the whole area, and such trend forms "dipping plane" on the left bank and "reverse dipping plane" on the right abutment. Geographically, and also from aerophotographs there are many collapses on the left bank side but are stable slope on the right bank. But the bedding plane on the left bank, which is marked as fault plane on the existing geological map, remains stable.

The lower dam is at gneiss rocks. It has outcrops at both abutments, shows hard and impermeable features. It is also noted as Kiriketi 1 that a NE-SW trending fault crosses across the dam axis. Cares must be paid for preserving dipping planes on the left bank during excavation works.

Another additional note is that an existing exploration permit was allotted to Dukes Investments (pvt) Ltd, of EL1 2011 777, at 500-600 m apart in south side. It may be likely no activities take place there and no overlaps in areas are recognized though close. But if this site is to be chosen it may require some coordination works with mining developers (Kiriketi 2 is the only site that falls close proximity to any mining or exploration lease).

(3) Natural and social environments

1) Upper dam/reservoir

a) Natural environment

Table 9.5.2-1 shows the conditions of the natural environment of the Kiriketi 2 upper dam/reservoir.

Table 9.5.2-1 Conditions of the Natural Environment of the Kiriketi 2 Upper Dam/Reservoir

Characteristics \ Name of site	Kiriketi 2 Upper dam/reservoir
Meteorological condition	The area is on the border of the Wet and Intermediate Zones. There are two rainfall peaks in a year: from March to May; and from October to December. The average annual rainfall is about 2,200 – 2,400 mm.
Hydrological condition	No data available.
Land slide	According to the Landslide Map of NBRO, landslides are not likely to occur in the most of the area around the site and part of the right bank of the site is designated as "moderate".
Water quality	No data available.
Protected area including other important areas (e.g. World Heritage Site)	The site is within the Peak Wilderness Sanctuary, and close to the Horton Plains National Park. It is within an IBA (Peak Wilderness Sanctuary).
Fauna and flora	Number of faunal endangered species CR: 6, EN: 13, VU: 8 Number of floral endangered species CR: 0, EN: 0, VU: 1
Habitats	There are extensive Patana grasslands dominated by *Cymbopogon*, rocky areas. The biodiversity and species richness are low. The close downstream of the dam site is also dominated by grasslands, and the biodiversity and species richness are low.

Note: CR: Critically Endangered、EN: Endangered、VU: Vulnerable

b) Social environment

Table 9.5.2-2 shows the conditions of the social environment of the Kiriketi 2 upper dam/reservoir.

Table 9.5.2-2 Conditions of the Social Environment of the Kiriketi 2 Upper Dam/Reservoir

Name of site / Characteristics	Kiriketi 2 Upper dam/reservoir
Location	Belihuloya (GN), Imbulpe Division, Rathnapura District
Demographic status of the GND	Population: 703, No. of households: 211, Average No. of family: 3.3, Major local industry: Agriculture, Average monthly income: Most of the HHs receives more than Rs. 15,000 (37%), and next biggest range is Rs. 1,500 – 2,500 (27%).
Accessibility to the proposed site	The site is accessible through the Nonperil Estate road. From this road access road has to be constructed to the dam site.
Extent of resettlement	The site is accessible through the Nonperil Estate however the access road is very narrow and extremely steep. Widening about 8 km of the narrow access road will be extremely difficult. The last 500 meters has to be negotiated along a foot path through both forest and grassland.
Extent of land acquisition	Grassland: 27.1 ha, Rocks: 7.1 ha, small strip of forest land: less than 1 ha, Total: 35.2 ha
Land use pattern of the area	Grassland, Rocks and a small strip of forest land
River utilization especially in downstream areas	The proposed dam will be constructed at the uppermost reaches of a stream, a tributary of Kiriketi Oya. The stream is not perennial. However, further downstream when it emerges out of the Peak Wilderness Sanctuary and joins the main Kiriketi Oya, it is used by people for domestic purposes. No fishery.
Religious, cultural and archeological heritages	None
Tourism site	The site is located within the Peak Wilderness Sanctuary, near the Horton Plains National Park. The both have been declared as a World Heritage Site “Central Highlands of Sri Lanka”.
Existence of indigenous people	None
Existence of poverty people	None

2) Lower dam/reservoir

a) Natural environment

Table 9.5.2-3 shows the conditions of the natural environment of the Kiriketi 2 lower dam/reservoir.

Table 9.5.2-3 Conditions of the Natural Environment of the Kiriketi 2 Lower Dam/Reservoir

Name of site / Characteristics	Kiriketi 2 Lower dam/reservoir
Meteorological condition	The area is on the border of the Wet and Intermediate Zones. There are two rainfall peaks in a year: from March to May; and from October to December. The average annual rainfall is about 2,200 – 2,400 mm.

Name of site / Characteristics	Kiriketi 2 Lower dam/reservoir
Hydrological condition	No data available.
Land slide	According to the Landslide Map of NBRO, landslides may occur at a moderate level around the site.
Water quality	No data available.
Protected area including other important areas (e.g. World Heritage Site)	The site is within the Peak Wilderness Sanctuary, and close to the Horton Plains National Park. It is within an IBA (Peak Wilderness Sanctuary).
Fauna and flora	Number of faunal endangered species CR: 6, EN: 15, VU: 9 Number of floral endangered species CR: 0, EN:1, VU:4
Habitats	There are riverine forests and patches of semi-evergreen forests. The semi-evergreen forests are important as a “refuge area” of the forest species in the Intermediate Zone. The biodiversity and species richness are high. The close downstream of the dam site is also covered with riverine forests and semi-evergreen forests, and the biodiversity and species richness are high.

Note: CR: Critically Endangered、EN: Endangered、VU: Vulnerable

b) Social environment

Table 9.5.2-4 shows the conditions of the social environment of the Kiriketi 2 lower dam/reservoir.

Table 9.5.2-4 Conditions of the Social Environment of the Kiriketi 2 Lower Dam/Reservoir

Name of site / Characteristics	Kiriketi 2 Lower dam/reservoir
Location	Muttetuwagama (GN), Yakdehiwala (GN), Imbulpe Division, Rathnapura District
Demographic status of the GND	Muttetuwagama(GN) Population: 1,586, No. of HHs: 447, Average No. of family: 3.55, Major local industry: Private sector, Agriculture, Self employment, Labor Average monthly income: Most of the HHs receives Rs.5, 000-10,000. Yakdehiwala (GN) Population: 1,141, No. of HHs: 342, Average No. of family: 3.34 Major local industry: No data Average monthly income: No data
Accessibility to the proposed site	The site is accessible through the Nonperil Estate road. From this road a new access road has to be constructed to the dam site.
Extent of resettlement	None
Extent of land acquisition	Shrubs: 54 ha, forest: 34.1, Total: 88.1ha
Land use pattern of the area	Shrubs, Forest
River utilization especially in downstream areas	The stream at the site is not used by people for any purpose but further downstream (3 km downstream from the proposed dam site) when the stream enters the populated area, it is heavily used for bathing and washing. No fishery.

Characteristics \ Name of site	Kiriketi 2 Lower dam/reservoir
Religious, cultural and archeological heritages	None
Tourism site	The site is located within the Peak Wilderness Sanctuary
Existence of indigenous people	None
Existence of poverty people	None

3) Evaluation of the natural and social environments of the Kiriketi 2

a) Evaluation of the upper dam/reservoir

Natural environment:

The result of the evaluation of the natural environment of the Kiriketi 2 upper dam/reservoir is shown in Table 9.5.2-5.

Table 9.5.2-5 Evaluation of the Natural Environment of the Kiriketi 2 Upper Dam/Reservoir

Scoping items	Evaluation
Impacts on fauna and flora	Rating [C] The biodiversity and species richness are low. However, since 19 faunal endangered species (CR: 6, EN:13) are recorded and the site is within a protected area (Peak Wilderness Sanctuary), the project would give significant impacts on the natural environment.

Social environment:

The results of the evaluation of the social environment of the Kiriketi 2 upper dam/reservoir are shown in Table 9.5.2-6.

Table 9.5.2-6 Evaluation of the Social Environment of the Kiriketi 2 Upper Dam/Reservoir

Scoping items	Evaluation
Impacts on local communities	Rating [A] The proposed site is covered by shrubs, and there is no human settlement. The river water is used by people which 3 km downstream from the proposed dam site), but the impacts is limited to a small scale. Therefore the evaluation rate is [A].
Impacts on industries	Rating「A」 The proposed site is covered by shrubs, and there is no local industry. Therefore the evaluation rate is [A].
Impacts on cultural and landscape	Rating [C] The Fauna and Flora Protection Act No. 22 of 2009 explicitly prohibits any development activity within sanctuaries. Therefore the evaluation rating is [C].

b) Evaluation of the lower dam/reservoir

Natural environment:

The result of the evolution of the natural environment of the Kiriketi 2 lower dam/reservoir is shown in Table 9.5.2-7.

Table 9.5.2-7 Evaluation of the Natural Environment of the Kiriketi 2 Lower Dam/Reservoir

Scoping items	Evaluation
Impacts on fauna and flora	Rating [C] The project would give significant impacts on the natural environment because (1) the site is within a protected area (Peak Wilderness Sanctuary); (2) 21 faunal endangered species (CR: 6, EN: 15) and one floral endangered species (EN) are recorded; and (3) the biodiversity and species richness are high.

Social environment:

The results of the evaluation of the social environment of the Kiriketi 2 lower dam/reservoir are shown in Table 9.5.2-8.

Table 9.5.2-8 Evaluation of the Social Environment of the Kiriketi 2 Lower Dam/Reservoir

Scoping items	Evaluation
Impacts on local communities	Rating [A] There is no human settlement due to very steep valley. Nobody use stream at the proposed dam site. The further downstream of the stream 3 km from the dam site is used by people for domestic purposed, but the impact by the project is limited to a small scale. Therefore the evaluation rating is [A].
Impacts on industries	Rating [A] Since the site is steep valley, there is no local industry such as tea plantation. Therefore the evaluation rating is [A].
Impacts on cultural and landscape	Rating [C] The Fauna and Flora Protection Act No. 22 of 2009 explicitly prohibits any development activity within sanctuaries. Therefore the evaluation rating is [C].

c) Overall evaluation

Table 9.5.2-9 shows the overall evaluation of the Kiriketi 2 as a cluster with the evaluations of the upper and lower dam/reservoirs.

Table 9.5.2-9 Overall Evaluation of the Kiriketi 2 Cluster

Scoping items	Evaluation		
	Upper dam/reservoir	Lower dam/reservoir	Overall
Impacts on fauna and flora	C	C	C
Impacts on local communities	A	A	A
Impacts on industries	A	A	A
Impacts on cultural and landscape	C	C	C

A: Project is not likely to have significant adverse impacts on natural environment and society and/or limited to a small scale.

B: Project is likely to have negative impact on natural environment and society, but less adverse than C

C: Project is likely to have significant adverse impacts on natural environment and society.

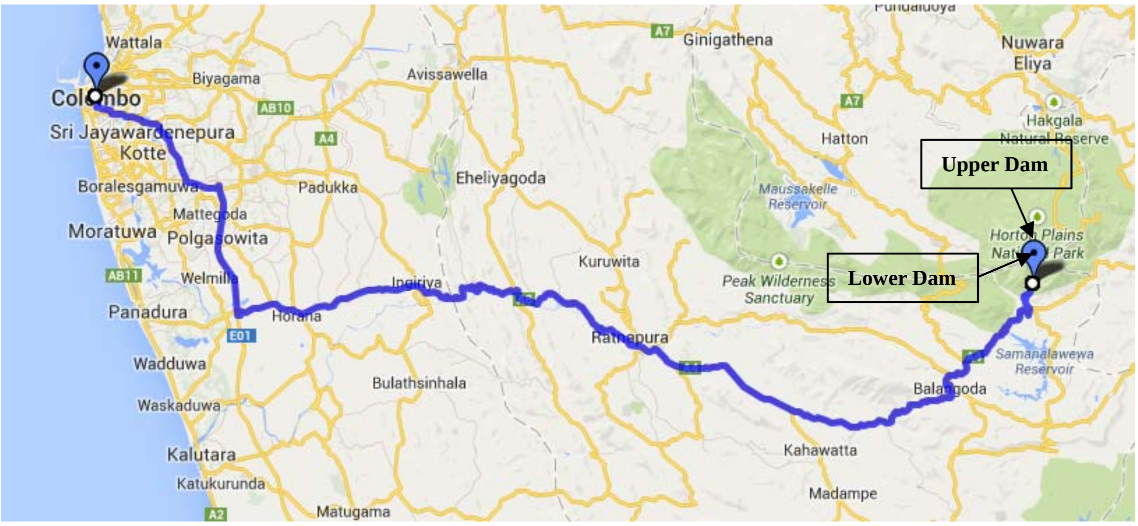
(4) Technical Evaluation

As for accessibility to Upper reservoir, the distance on the roads from Colombo to Upper reservoir is around 160 km. Upper reservoir is not accessible but point where Upper reservoir area is able to be seen by vehicles taking following routes; after driving on 8 km of by-road along Kiriketi River from the main road A4, furthermore, it takes around 40 minutes on narrow and winding road in the tea plantation. Dam axis cannot be approached by vehicles. It is also necessary to improve long distance of the by-load and the path in the tea plantation in order to transport materials and equipment for the construction as well as in Kiriketi 1.

As for accessibility to Lower reservoir, the distance on the roads from Colombo to Lower reservoir is around 160 km. The dam axis of Lower reservoir, which is located at around 2 km downstream from Kiriketi 1 ‘s Lower dam, is accessible by vehicles taking following routes; after driving on 8 km of by-road along Kiriketi River from the main road A4. However, topography around the dam axis is a very steep valley, and there is around 70 m of difference in height from the by-road surface to the river bed.

Upper reservoir site is planned in a depression located on steep mountain slope, and there are many facilities such as the tea factory, the office buildings, houses for the tea plantation labors, etc. in the just down area of Upper dam axis. Large scale protection measures shall be installed for those before construction works. Long saddle dam is required because of lower right bank than planned dam crest elevation; however, the slope behind the right bank is too steep to design and to execute construction works. Thus, there are many problems for the construction works.

As for the manufacturing limitation, both 200 MW/unit and 150 MW/unit are not applicable.



(Source: Study Team)

Figure 9.5.2-1 Access Rout to Kiriketi 2 Site

(5) Construction Cost

Table 9.5.2-10 shows the construction cost for Kiriketi 2 scheme, which is calculated according to method and condition shown in the sub-clause 9.4.4. Since the scheme by both three sets of 200 MW/unit and four sets of 150 MW/unit is not applicable, following construction cost is reference purpose only.

Table 9.5.2-10 Construction Cost of Kiriketi 2 Scheme

Item/Project		Kiriketi 2		Remarks
		200MW*3unit *10^{3}USD	150MW*4units *10^{3}USD	
1.	Preparation and Land Acquisition	4,724		
	(1) Access Roads			
	(2) Compensation & Resettlement			
	(3) Camp & Facilities	4,724		3. Civil Works * 2%
2.	Environmental Mitigation Cost	7,085		3. Civil Works * 3%
3.	Civil Works	236,180		
4.	Hydromechanical Works	75,244		
5.	Electro-Mechanical Equipment	184,800		
6.	Transmission Line			
	Direct Cost	508,033		
7.	Administration and Engineering Service	76,205		Direct Cost * 15%
8.	Contingency	50,803		Direct Cost * 10%
9.	Interest during Construction			
	Total Cost	635,041		
	Power Output	600,000		
	USD per kW	1,058		

(Source: Study Team)

Main features of the civil structures are shown as follows.

- Upper Dam		
Type	Rock Fill	
Height *Crest Length	81m * 300m	
Volume	2,600 * 10^3m^3	
- Lower Dam		
Type	Rock Fill	
Height * Crest Length	72m * 240m	
Volume (*10^3m3)	1,900 * 10^3m^3	
- Headrace Tunnel Dia *Length*line	200MW/unit	4.6m * 100m * 1 line (NA)
	150MW/unit	N.A
- Penstock Tunnel Dia *Length*line	200MW/unit	3.6m * 1,349m * 1 line (NA)
	150MW/unit	N.A
- Tailrace Tunnel Dia *Length*line	200MW/unit	5.1m * 180m * 1 line (NA)
	150MW/unit	N.A

9.5.3 Maussakelle 1

(1) General Outline

In this scheme, Upper reservoir is located on the top of the hill located in the east-south area of Maussakelle reservoir’s back water zone, and Lower reservoir is located in left bank of Mausakelle reservoir’s back water zone. The rated head obtained from the difference in height between Upper reservoir and Lower reservoir is 450.30 m and the rated discharge for generating is 159.96 m^3/s, and the rated output is 600 MW. The equivalent peaking time is assured as 6.0 hours.

Review of the scheme by the initial JICA Study is carried out in order to revise to 200 MW/unit basis scheme and 150 MW/unit basis scheme, either. Since it is obvious that 200 MW/unit is applicable as around 470 m of the gross head, re-location of dam axis is not intended..

Ratio of the horizontal waterway length (L) and the gross head (H) is 6.5 (=L/H).

(2) Geomorphology and geology

The site geology belongs to Highland Complex and mainly comprises gneisses.

The upper reservoir consists of Charnokite. It locates itself on the north wing of syncline folding axis thus trending SW dipping in general. Where the upper reservoir falls on Charnokite, the water route to the lower reservoir fall on biotite gneisses. Both rock facies are hard and gneiss broad sense, but comparably Charnokite forms high mountain body (500 m in height) with sharp scarping cliff on front. This is, assumingly, Charnokite is highly more resistant against erosion than surrounding rocks (biotite gneiss) that still remains capable enough to form of “residual hill” body. The permeability of the rocks are considered as sufficiently low. The whole reservoir bed rocks, though not visited or investigated this time, is slow in slope, and anticipated to be thinly weathered on surface nor have any unstable slopes.

The upper dam axis is planned at gneiss and it is hard. Thinly weathered. There does not anticipate any particular geological problems.

Water route and underground powerhouse is planned at gneiss zone that anticipated hard.

The lower reservoir site comprises biotite gneisses. It may be deeply weathered in where biotites are rich but generally water sealing capability is considered maintained and arises no significant issues. The right rim is generously slow slope, but considered not to cause unstablization issues. The left bank forms a steep valley slope with many outcrops on the hill slope indicating shallow in weathering.

There are no unstable slopes observed. One sharp scarp cliff by EW fault appears at 1 km upstream on the left bank with 150m high but it may be a distance for HWL elevation line. There are river sediments of middle gravels but thin. No landslides are seen from the aerophotographs.

The lower dam is located at gneiss and the rocks are hard. The bedding planes are dipping upstream (NW/20S) and it is a favorable direction from stabilization of dam foundation. There are no geological issues in the lower dam site.

(3) Natural and social environments

1) Upper dam/reservoir

a) Natural environment

Table 9.5.3-1 shows the conditions of the natural environment of the Maussakelle 1 upper dam/reservoir.

Table 9.5.3-1 Conditions of the Natural Environment of the Maussakelle 1 Upper Dam/Reservoir

Characteristics \ Name of site	Maussakelle 1 Upper dam/reservoir
Meteorological condition	The area is in the Wet Zone. From March to November, the area receives lots of rainfall and in November there is a sharp peak of the rainfall. The average annual rainfall is about 2,900mm.
Hydrological condition	No data available.
Land slide	According to the Landslide Map of NBRO, landslides may occur at low to moderate levels around the site.
Water quality	No data available.
Protected area including other important areas (e.g. World Heritage Site)	The site is within the Peak Wilderness Sanctuary. It is within an IBA (Peak Wilderness Sanctuary).
Fauna and flora	Number of faunal endangered species No data due to difficult access to the site. Number or floral endangered species No data due to difficult access to the site.
Habitats	There are montane forests, mountain grasslands and marshy areas. The biodiversity and species richness are high. In the area of the close downstream of the dam site, there are tea plantation and montane forests. The biodiversity and species richness are high.

Note: CR: Critically Endangered、EN: Endangered、VU: Vulnerable

b) Social environment

Table 9.5.3-2 shows the conditions of the social environment of the Maussakelle 1 upper dam/reservoir.

Table 9.5.3-2 Conditions of the Social Environment of the Maussakelle 1 Upper Dam/Reservoir

Name of site / Characteristics	Maussakelle 1 Upper dam/reservoir
Location	Moca, Ambagamuwa Division, Nuwara Eliya District
Demographic status of the GND	Population: 5,221, No. of HHs: 1,320, Average No. of family: 3.96 Major local industry: Tea plantation, Agriculture Average monthly income: No data.
Accessibility to the proposed site	The site is accessible by the motorable road from Maskeliya to the Garmore Estate. From the edge of the state there is no motorable road to the site.
Extent of resettlement	The entire site is located inside the Peak Wilderness Sanctuary, thus there is no human settlement.
Extent of land acquisition	Natural forest, Grasslands, Total: 37.34ha
Land use pattern of the area	Natural forest, Grasslands
River utilization especially in downstream areas	The stream heavily used by the estate laborers for washing and bathing. No fishery.
Religious, cultural and archeological heritages	None
Tourism site	The site is located within the Peak Wilderness Sanctuary and in the Central Highlands of Sri Lanka which is declared as World Heritage site.
Existence of indigenous people	None
Existence of poverty people	None

2) Lower dam/reservoir

a) Natural environment

Table 9.5.3-3 shows the conditions of the natural environment of the Maussakelle 1 lower dam/reservoir.

Table 9.5.3-3 Conditions of the Natural Environment of the Maussakelle 1 Lower Dam/Reservoir

Name of site / Characteristics	Maussakelle 1 Lower dam/reservoir
Meteorological condition	The area is in the Wet Zone. From March to November, the area receives lots of rainfall and in November there is a sharp peak of the rainfall. The average annual rainfall is about 2,900mm.
Hydrological condition	No data available.
Land slide	According to the Landslide Map of NBRO, landslides may occur at low to moderate levels around the site.
Water quality	No data available.
Protected area including other important areas (e.g. World Heritage Site)	The right bank of the proposed reservoir is in the Peak Wilderness Sanctuary. The right bank of the proposed reservoir is within an IBA (Peak Wilderness Sanctuary).
Fauna and flora	Number of faunal endangered species CR: 15, EN: 23, VU: 16

Name of site / Characteristics	Maussakelle 1 Lower dam/reservoir
	Number of floral endangered species CR: 2, EN: 26, VU: 28
Habitats	The left bank is covered with tea plantation. The right bank is covered with secondary montane forests and riverine forests. The biodiversity and species richness are high. The area of the close downstream of the dam site has similar habitats as the upper stream, and the biodiversity and species richness are high.

Note: CR: Critically Endangered、EN: Endangered、VU: Vulnerable

b) Social environment

Table 9.5.3-4 shows the conditions of the social environment of the Maussakelle 1 lower dam/reservoir.

Table 9.5.3-4 Conditions of the Social Environment of the Maussakelle 1 Lower Dam/Reservoir

Name of site / Characteristics	Maussakelle 1 Lower dam/reservoir
Location	Murray (GN), Ambagamuwa Division, Nuwara Eliya District
Demographic status of the GND	Population: 4,198, No of HHs: 1,093, Average No. of family: 3.84 Major local industry: Tea plantation, Private sector, Agriculture Average monthly income: No data
Accessibility to the proposed site	The site is accessible by the motorable road along Maussakele Murray Estate Road. The last 2 km of the estate road is very poor and need extensive rehabilitation.
Extent of resettlement	None
Extent of land acquisition	Tea plantation: 11.8ha, Natural forest: 17.3ha, River water body: 4.5ha, Total : 33.6ha
Land use pattern of the area	Tea plantation, Natural forest, River water body
River utilization especially in downstream areas	The local people uses as washing and bathing. No fishery.
Religious, cultural and archeological heritages	None
Tourism site	The site is located within the Peak Wilderness Sanctuary and in the Central Highlands of Sri Lanka which is declared as World Heritage site.
Existence of indigenous people	None
Existence of poverty people	None

3) Evaluation of the natural and social environments of the Maussakelle 1

a) Evaluation of the upper dam/reservoir

Natural environment:

The result of the evolution of the natural environment of the Maussakelle 1 upper dam/reservoir is shown in Table 9.5.3-5.

Table 9.5.3-5 Evaluation of the Natural Environment of the Maussakelle 1 Upper Dam/Reservoir

Scoping items	Evaluation
Impacts on fauna and flora	Rating [C] The project would give significant impacts on the natural environment because (1) the site is within a protected area (Peak Wilderness Sanctuary); (2) the biodiversity and species richness are high. Regarding endangered species, although no data is available due to its inaccessibility, it is highly expected that many endangered species occur in the site.

Social environment:

The results of the evaluation of the social environment of the Maussakelle 1 upper dam/reservoir are shown in Table 9.5.3-6.

Table 9.5.3-6 Evaluation of the Social Environment of the Maussakelle 1 Upper Dam/Reservoir

Scoping items	Evaluation
Impacts on local communities	Rating[A] There is no human settlement due to the Peak Wilderness Sanctuary. The tea estate workers uses river water for bathing and washing, but the impact on them is limited to a small scale. Therefore the evaluation rating is [A].
Impacts on industries	Rating[A] There is no local industry due to the Peak Wilderness Sanctuary. 37.34ha of natural forest and grasslands will be inundated, but there is no use of NTFP. Therefore the evaluation rating is [A].
Impacts on cultural and landscape	Rating [C] The Fauna and Flora Protection Act No. 22 of 2009 explicitly prohibits any development activity within sanctuaries. Therefore the evaluation rating is [C].

b) Evaluation of the lower dam/reservoir

Natural environment:

The result of the evolution of the natural environment of the Maussakelle 1 lower dam/reservoir is shown in Table 9.5.3-7.

Table 9.5.3-7 Evaluation of the Natural Environment of the Maussakelle 1 Lower Dam/Reservoir

Scoping items	Evaluation
Impacts on fauna and flora	Rating [C] The project would give significant impacts on the natural environment because (1) part of the site is within a protected area (Peak Wilderness Sanctuary); (2) many faunal and floral endangered species occur (fauna: CR: 15, EN: 23; flora: CR: 2, EN: 26); and, (3) the biodiversity and species richness are high.

Social environment:

The results of the evaluation of the social environment of the Maussakelle 1 lower dam/reservoir are shown in Table 9.5.3-8.

Table 9.5.3-8 Evaluation of the Social Environment of the Maussakelle 1 Lower Dam/Reservoir

Scoping items	Evaluation
Impacts on local communities	Rating[A] There is no settlement within the inundation area. The nearest settlement, the line rooms are located about 1 km away on the left bank, but no need resettlement. The workers of tea plantation uses river water for bathing and washing, but the impact by the project is limited to a small scale. Therefore the evaluation rating is [A].
Impacts on industries	Rating[B] 11.8ha of tea plantation will be inundated. Therefore the evaluation rating is [B].
Impacts on cultural and landscape	Rating [C] The Fauna and Flora Protection Act No. 22 of 2009 explicitly prohibits any development activity within sanctuaries. Therefore the evaluation rating is [C].

c) Overall evaluation

Table 9.5.3-9 shows the overall evaluation of the Maussakelle 1 as a cluster with the evaluations of the upper and lower dam/reservoirs.

Table 9.5.3-9 Overall Evaluation of the Maussakelle 1 Cluster

Scoping items	Evaluation		
	Upper dam/reservoir	Lower dam/reservoir	Overall
Impacts on fauna and flora	C	C	C
Impacts on local communities	A	A	A
Impacts on industries	A	B	B
Impacts on cultural and landscape	C	C	C

A: Project is not likely to have significant adverse impacts on natural environment and society and/or limited to a small scale.

B: Project is likely to have negative impact on natural environment and society, but less adverse than C

C: Project is likely to have significant adverse impacts on natural environment and society.

(4) Technical Evaluation

As for accessibility to Upper reservoir, the distance on the roads from Colombo to Upper reservoir is around 150 km. Upper reservoir is not accessible by vehicles because it is located on the top of the very steep hill. Route for Upper dam area is as follows; it goes through the main road A1, A7, and B328, and then, after driving on 9 km of by-road, it arrives at the mountain foot of the hill on which Upper reservoir is located.

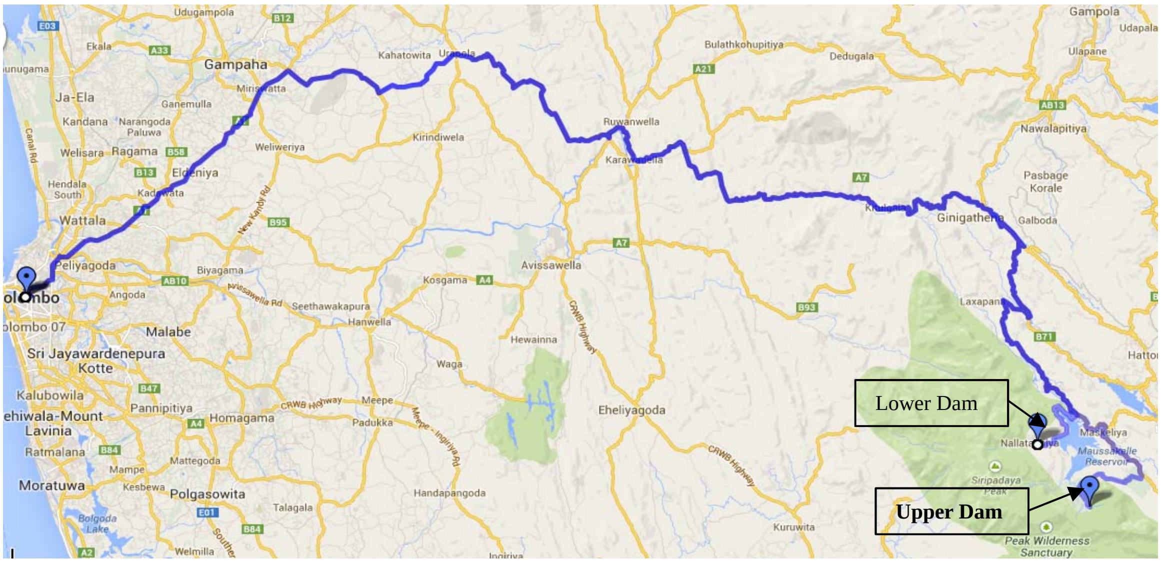
As for accessibility to Lower reservoir, the distance on the roads from Colombo to Lower reservoir is around 145 km. The route to the Lower reservoir area is same as that to Upper reservoir area. It can be approached by vehicles to around Lower dam axis. The configuration is rather gentle and there is small difference in height from the by-road surface to the river bed. The access to the river bed is not so difficult.

Upper reservoir site is planned in a depression located on the steep mountain slope, and there are many facilities such as the tea factory, the office buildings, houses for the tea plantation labors, etc. in the just down area of Upper dam axis. Large scale protection measures shall be installed for those before construction works. Long saddle dam is required because of lower right bank than planned dam crest elevation; however, the slope behind the right bank is too steep to design and to execute construction works. Thus, there are many problems for the construction works.

As for the manufacturing limitation, both 200 MW/unit and 150 MW/unit are not applicable.

Judging from topographic maps scale 1 to 10,000, there are some problems for civil works executions of Upper reservoir judging from topographic map scale 1 to10,000. As mentioned in the above, Upper reservoir is planned on the top of the hill, of which height is around 300 m from the mountain foot; accordingly access roads construction would be very tough. In addition, the top of the hill is indicated as a depression covered by a marsh area, so that drainage of water and removing mud materials are required before the dam construction, which would also take much cost and long period.

As for the manufacturing limitation, both of 200 MW/unit and 150 MW per unit are applicable.



(Source: Study Team)

Figure 9.5.3-1 Access route to Maussakelle A Site

(5) Construction Cost

Table 9.5.3-10 shows the construction cost of Maussakelle A scheme, which is calculated according to the method and conditions mentioned in sub-clause 9.4.4 This site is applicable to 200 MW/unit and 150 MW/unit.

Table 9.5.3-10 Construction Cost of Maussakelle A Scheme

	Item/Project	Maussakelle A 200MW*3unit *10³USD	Maussakelle A 150MW*4units *10³USD	Remarks
1.	Preparation and Land Acquisition	5,094	5,237	
	(1) Access Roads			
	(2) Compensation & Resettlement			
	(3) Camp & Facilities	5,094	5,237	3. Civil Works * 2%
2.	Environmental Mitigation Cost	7,641	7,855	3. Civil Works * 3%
3.	Civil Works	254,695	261,839	
4.	Hydromechanical Works	54,393	53,357	
5.	Electro-Mechanical Equipment	196,300	202,000	
6.	Transmission Line			
	Direct Cost	518,122	530,288	
7.	Administration and Engineering Service	77,718	79,543	Direct Cost * 15%
8.	Contingency	51,812	53,029	Direct Cost * 10%
9.	Interest during Construction		0	
	Total Cost	647,653	662,860	
	Power Output	600,000	600,000	
	USD per kW	1,079	1,105	

(Source: Study Team)

Main features of the civil structures are shown as follows;

- Upper Dam		
Type	RCC	
Height *Crest Length	39m * 1,200m	
Volume	400 * 10^3m^3	
- Lower Dam		
Type	Rock Fill	
Height * Crest Length	55m * 170m	
Volume (*10^3m3)	1,900 * 10^3m^3	
- Headrace Tunnel Dia	200MW/unit	5.9m * 300m * 1 line
*Length*line	150MW/unit	4.2m * 300m * 2 line
- Penstock Tunnel Dia	200MW/unit	4.6m * 939m * 1 line
*Length*line	150MW/unit	3.2m * 939m * 2 line
- Tailrace Tunnel Dia	200MW/unit	6.4m * 2,050m * 1 line
*Length*line	150MW/unit	4.6m * 2,050m * 2 line

9.5.4 Maussakelle 2

(1) General Outline

In this scheme, Upper reservoir is located on the top of the hill located in the east-south area of Maussakelle reservoir's back water zone, and Lower reservoir is located in the right bank of Mausakelle reservoir's back water zone. The rated head obtained from the difference in height between Upper reservoir and Lower reservoir is 463.60 m and the rated discharge for generating is 155.37m^3/s, and the rated output is 600 MW. The equivalent peaking time is assured as 6.0 hours. Upper reservoir is a common with that of Maussakelle A.

Review of the scheme by the initial JICA Study is carried out in order to revise to 200 MW/unit basis scheme and 150 MW/unit basis scheme. Since it is obvious that 200 MW/unit is applicable as around 470 m of the gross head, re-location of dam axis is not intended.

Ratio of the horizontal waterway length (L) and the gross head (H) is 6.5 (=L/H).

(2) Geomorphology and geology

The upper reservoir is the same as Maussakelle 1 as in 9.5.3.

The lower reservoir site comprises biotite gneisses, and colluvials flows from upstream forms a broad flatland in the reservoir. The thickness of the colluvials are unknown but seemingly 5 m at most. The basement gneiss is considered to hold sufficient water sealing capability though it may partially in depth weathering when it contains rich biotite, and anticipates no significant issues. The riverbed has not shown clear outcrops but is thin in thickness.

The lower dam is located at gneiss and the rocks are hard. The bedding planes are dipping upstream (EW/30S) and are a favorable from stabilization of dam foundation. There are thin in weathering on left abutment but is thin in width with weathering on the right abutment. The height of the abutment is hardly above HWL thus is not firm enough for dam site without forming a saddle dam there. Above those, the exact downstream of the right abutment bank lies a long length EW fault's scarping cliff, possibly encountering fracture zone. This feature may well indicate many geological issues to face.

(3) Natural and social environments

1) Upper dam/reservoir

They are the same as the upper dam/reservoir in "9.5.3 Maussakelle 1".

2) Lower dam/reservoir

a) Natural environment

Table 9.5.4-1 shows the conditions of the natural environment of the Maussakelle 2 lower dam/reservoir.

Table 9.5.4-1 Conditions of The Natural Environment of the Maussakelle 2 Lower Dam/Reservoir

Name of site / Characteristics	Maussakelle 2 Lower dam/reservoir
Meteorological condition	The area is in the Wet Zone. From March to November, the area receives lots of rainfall and in November there is a sharp peak of the rainfall. The average annual rainfall is about 2,900mm.
Hydrological condition	No data available.
Land slide	According to the Landslide Map of NBRO, landslides may occur at a moderate level around the site.
Water quality	No data available.
Protected area including other important areas (e.g. World Heritage Site)	The site is close to the Peak Wilderness Sanctuary. The site is close to IBA (Peak Wilderness Sanctuary).
Fauna and flora	Number of faunal endangered species CR: 11, EN: 16, VU: 7 Number of floral endangered species CR: 0, EN: 0, VU: 0
Habitats	The site is an agricultural land dominated by tea plantation and there are many residents of tea workers. The biodiversity and species richness are low. The area of the close downstream of the dam site has similar habitats as the upper stream, and the biodiversity and species richness are low.

Note: CR: Critically Endangered、EN: Endangered、VU: Vulnerable

b) Social environment

Table 9.5.4-2 shows the conditions of the social environment of the Maussakelle 2 lower dam/reservoir.

Table 9.5.4-2 Conditions of the Social Environment of the Maussakelle 2 Lower Dam/Reservoir

Name of site / Characteristics	Maussakelle 2 Lower dam/reservoir
Location	Moca (GN), Ambaganuwa Division, Nuwara Lliya District
Demographic status of the GND	Population: 5,221, No. of HHs: 1,320, Average No. of family: 3.96 Major local industry: Tea plantation, Agriculture Average monthly income: No data Average monthly income of middle level supervisors and staff officers of Gartmore Estate: Rs. 5,000-16,000 The general welfare of these employees is taken care of by the Estate.
Accessibility to the proposed site	The site is accessible by the motorable road from Maskeliya to the Garmore Estate.
Extent of resettlement	64 structures including line hoses, a pre-school, a few buildings of the tea factory, store rooms, sheds, officers' quarters, and child care center.
Extent of land acquisition	Tea plantation: 21.6ha, River water body: 2.9ha, Total: 24.5ha
Land use pattern of the area	Tea plantation, River water body
River utilization especially in downstream areas	The workers of tea estate use river water for bathing and washing. No fishery.
Religious, cultural and archeological heritages	Although there are no archaeological places, the proposed reservoir will inundate at least 2 Hindu shrines.
Tourism site	The site is not a tourist attraction but the waterfall is one of sights highlighted by Sri Lanka Tourist Board and there is a vista point on the Murray Estate road precisely targeting the waterfall.
Existence of indigenous people	None
Existence of poverty people	None

3) Evaluation of the natural and social environments of the Maussakelle 2

a) Evaluation of the upper dam/reservoir

They are the same as the upper dam/reservoir in "9.5.3 Maussakelle 1".

b) Evaluation of the lower dam/reservoir

Natural environment:

The result of the evaluation of the natural environment of the Maussakelle 2 lower dam/reservoir is shown in Table 9.5.4-3.

Table 9.5.4-3 Evaluation of the Natural Environment of the Maussakelle 2 Lower Dam/Reservoir

Scoping items	Evaluation
Impacts on fauna and flora	Rating [B] The site has already been altered to an agricultural land and residential area by tea plantation activities, and their biodiversity and species richness are low. However, since there are records of endangered species (fauna: CR: 11, EN: 16), the project may give impacts on the natural environment.

Social environment:

The results of the evaluation of the social environment of the Maussakelle 2 lower dam/reservoir are shown in Table 9.5.4-4.

Table 9.5.4-4 Evaluation of the Social Environment of the Maussakelle 2 Lower Dam/Reservoir

Scoping items	Evaluation
Impacts on local communities	Rating [C] 64 structures will be inundated including the Gartmore Estate of tea plantation, the building of tea factories, line houses, a pre-school, store rooms, sheds, officers' quarters, child care center, and 2 Hindu shrines will be adverse impacted. The workers of tea plantation use river water for bathing and washing. Therefore the evaluation rating is [C].
Impacts on industries	Rating [B] 21.6ha of tea plantation of the Gartmore Estate will be inundated. Therefore the evaluation rating is [B].
Impacts on cultural and landscape	Rating [C] There is a picturesque waterfall below the proposed lower dam/reservoir which flow into the Maussakelle lake. This will spoil the beauty of landscape. And the Hindu shrines will be inundated. Therefore the evaluation rate is [C].

c) Overall evaluation

Table 9.5.4-5 shows the overall evaluation of the Maussakelle 2 as a cluster with the evaluations of the upper and lower dam/reservoirs.

Table 9.5.4-5 Overall Evaluation of the Maussakelle 2 Cluster

Scoping items	Evaluation		
	Upper dam/reservoir	Lower dam/reservoir	Overall
Impacts on fauna and flora	C	B	C
Impacts on local communities	A	C	C
Impacts on industries	A	B	B
Impacts on cultural and landscape	A	C	C

A: Project is not likely to have significant adverse impacts on natural environment and society and/or limited to a small scale.

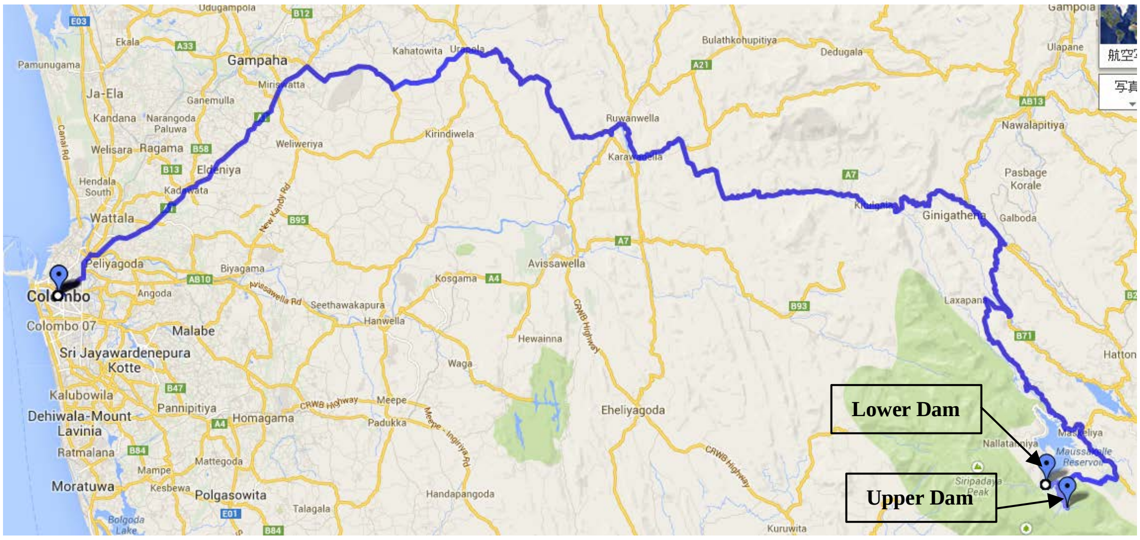
B: Project is likely to have negative impact on natural environment and society, but less adverse than C

C: Project is likely to have significant adverse impacts on natural environment and society.

(4) Technical Evaluation

Access and route to Upper reservoir is same as Maussakelle A's ones. As for Lower reservoir, the distance on the roads from Colombo to Lower reservoir is around 160 km. The route is composed of the main road A1, A7, B328, B273, and 8 km of the by-road. It can be approached by vehicles to the close area from Lower dam. Gentle topography is dominant around Lower dam area, so that there are not any serious problems for land reclamation of the temporary yards as well as the access to the river bed.

Both unit capacities of 200 MW and 150 MW are applicable



(Source: Study Team)

Figure 9.5.4-1 Access Rout to Mausakelle B

(5) Construction Cost

Table 9.5.4-6 shows the construction cost of Maussakelle A scheme, which is calculated according to the method and conditions mentioned in sub-clause 9.4.4. This site is applicable to 200 MW/unit and 150 MW/unit.

Table 9.5.4-6 Construction Cost of Maussakelle B Scheme

Item/Project		Maussakelle B 200MW*3unit *10^3USD	Maussakelle B 150MW*4units *10^3USD	Remarks
1.	Preparation and Land Acquisition	6,799	6,924	
	(1) Access Roads			
	(2) Compensation & Resettlement			
	(3) Camp & Facilities	6,799	6,924	3. Civil Works * 2%
2.	Environmental Mitigation Cost	10,198	10,386	3. Civil Works * 3%
3.	Civil Works	339,942	346,199	
4.	Hydromechanical Works	54,567	55,768	
5.	Electro-Mechanical Equipment	195,700	201,300	
6.	Transmission Line			
	Direct Cost	607,206	620,577	
7.	Administration and Engineering Service	91,081	93,087	Direct Cost * 15%
8.	Contingency	60,721	62,058	Direct Cost * 10%
9.	Interest during Construction		0	
	Total Cost	759,008	775,721	
	Power Output	600,000	600,000	
	USD per kW	1,265	1,293	

(Source: Study Team)

Main features of the civil structures are shown as follows;

- Upper Dam
  - Type: RCC
  - Height *Crest Length: 400m * 1,200m
  - Volume: 400 * 10^3m^3
- Lower Dam
  - Type: Rock Fill
  - Height * Crest Length: 52m * 1,070m
  - Volume (*10^3m3): 3,700 * 10^3m^3
- Headrace Tunnel Dia *Length*line: 200MW/unit 5.8m * 300m * 1 line; 150MW/unit 4.1m * 300m * 2 line
- Penstock Tunnel Dia *Length*line: 200MW/unit 4.5m * 961m * 1 line; 150MW/unit 3.2m * 961m * 2 line
- Tailrace Tunnel Dia *Length*line: 200MW/unit 6.3m * 1,280m * 1 line; 150MW/unit 4.5m * 1,280m * 2 line

9.5.5 Halgran 1

(1) General Outline

Both of Upper reservoir and Lower reservoir are located in the main course of Halgran River. The rated head obtained from the difference in height between Upper reservoir and Lower reservoir is 576.01 m and the rated discharge for generating is 125.05 m^3/s, and the rated output is 600 MW. 6 hours of the equivalent peaking hours is ensured.

Review of the scheme by the initial JICA Study is carried out in order to revise to 200 MW/unit basis scheme and 150 MW/unit basis scheme. Since it is confirmed that 200 MW/unit is applicable for 615 m of the gross head, re-location of dam axis is not intended.

Ratio of the horizontal waterway length (L) and the gross head (H) is 6.8 (=L/H).

(2) Geomorphology and geology

The site geology belongs to Highland Complex and mainly comprises gneisses.

The upper reservoir consists of Charnokite and quartzite. It locates itself on the north wing of the syncline folding axis thus dipping SW in general.

The upper reservoir has quartzite on its right bank, and Charnokite on its left bank. Both rocks are hard. The right bank's quartzite may contain developed joints partially but has no problem for water sealing capability as it does not suffer erosions from its geomorphic shape. The right bank quartzite rock especially shows hard in strength from its shape. Left bank of gneisses shows rather slow slope with some colluviums beneath but yet the weathering layers are not thick (max. 10m) as it has shown outcrops on slope. Some colluvium deposits are at HWL level. The NE-SW trending fault is estimated on the left reservoir bank, but such features are not clearly visible from aerophotographs. There are no significant unstable slopes around the reservoir rims.

The upper dam axis is located at where the right abutment is the steep slope of the quartzite mountain as high as 1,450m on which there are many outcrops and scarce surface colluvium on the slope. The depth of weathering is generally shallow, and no geological issues anticipated. The left abutment is at Charnokite and is also hard, the surface weathering depth may be thin. No unstable slope as landslide features are seen from aerophotographs at dam axises. There are no geological issues in the upper damsite.

The water route passes through gneisses and partially limestone. It also crosses 2 faults. Among all, a NE-SW trending fault runs parallel in close to the headrace tunnel on the left rim, thus some geological issues may come along with parts of headrace. But there are no features as faults are clearly visible from aerophotographs, or no significant geomorphological abnormality is found at the site visit. The water route also runs across NW-SE trending fault fracture zone. This zone can be made in association with an anticlinal axis folding movement induced by 2 synclinal axes folding motions, and with features that this fault has a certain fault displacement and that gneiss contains limestone band near the fault, the water route may encounter crushed inferior limestone nearby the fault.

The underground powerhouse is planned at gneisses and is hard, but certain cares should be paid to avoid faulting zone and limestone bands.

The lower reservoir situates itself on the south wing of the syncline axis thus dipping NE in general. it comprises Charnokite gneisses and generally hard but the right abutment may partially encounter some limestones.

The reservoir comprises Charnokite, very hard, has almost few sand gravel deposits on riverbed. The gneisses are very massive (low angle joints are clear but joint spacing is 1-2m in NS/10E). It is considered low permeable, thin in weathering with fine mineral gneiss. The slope around the left abutment and left rim is steep and shows hard and little weathered in site visit's observation. The right rim is slower in slope, with possible colluviums around HWL level but probably thin. No unstable slopes can be seen from the aerophotographs. The NE-SW trending fault are shown in the geological map at the upstream end of the reservoir but not clear in the aerophotographs nor unstable slopes are visible.

The lower dam is located at Charnokite, and is anticipated hard and low permeable. The limestone distributes right downstream of the dam axis but the geological map does not anticipate it extends farther upstream of the damsite. The limestone itself may be fine unless it is well crystallized and contains no cavities, but confirmation of limestone distribution is required. There are no problems arisen if the distribution shown in the existing geological map is correct.

(3) Natural and social environments

1) Upper dam/reservoir

a) Natural environment

Table 9.5.5-1 shows the conditions of the natural environment of the Halgran 1 upper dam/reservoir.

Table 9.5.5-1 Conditions of the Natural Environment of the Halgran 1 Upper Dam/Reservoir

Name of site / Characteristics	Halgran 1 Upper dam/reservoir
Meteorological condition	The area is in the Intermediate Zone. From November to January, the area receives lots of rainfall, and in April there is a small peak of the rainfall. The average annual rainfall is about 1,300 – 1,600 mm.
Hydrological condition	No data available.
Land slide	According to the Landslide Map of NBRO, landslides may occur at low to moderate levels around the site.
Water quality	No data available.
Protected area including other important areas (e.g. World Heritage Site)	The site is located at about 5 km from the closest protected area (Kandapola Forest Reserve).
Fauna and flora	Number of faunal endangered species CR: 1, EN: 3, VU: 4 Number of floral endangered species CR: 0, EN: 0, VU: 6
Habitats	The site is agricultural lands dominated by tea plantation. There are eucalyptus plantations, crop fields and home gardens. On the steep slope of the valley, there is some riverine natural vegetation. The biodiversity and species richness are low. The area of the close downstream of the dam site has similar habitats as the upper stream (crop fields and some riverine forests, and the biodiversity and species richness are low.

Note: CR: Critically Endangered、EN: Endangered、VU: Vulnerable

b) Social environment

Table 9.5.5-2 shows the conditions of the social environment of the Halgran 1 upper dam/reservoir.

Table 9.5.5-2 Conditions of the Social Environment of the Halgran 1 Upper Dam/Reservoir

Name of site / Characteristics	Halgran 1 Upper dam/reservoir
Location	Pandithaya Kumbura (GN), Senarathwela (GN),Walapane Division, Nuwara Eliya District
Demographic status of the GND	Pandithaya Kumbura (GN) Population: 880, No. of HHs: 232, Average No. of family: 3.79 Majore industry: Agriculture Average monthly income: No data Senarathwela(GN) Population: 2,946, No. of HHs: 659, Average No. of family: 4.47 Majore industry: Labor Average monthly income: No data
Accessibility to the proposed site	The site is accessible by the estate road which needs to be widened and improved as the potential access road.
Extent of resettlement	15 households
Extent of land acquisition	Home gardens: 2.3ha, Tea plantation: 7.8ha, Other Cultivation: 16.3ha Total: 26.4ha
Land use pattern of the area	Home gardens, Tea plantation, Other Cultivation
River utilization especially in downstream areas	None
Religious, cultural and archeological heritages	None
Tourism site	None
Existence of indigenous people	None
Existence of poverty people	Pandithaya Kumbura (GN) : 54.3% of households (HHs) receive government aid package known as “Samurdhi” given to people who are considered “poor”. Senarathwela(GN) : 15.93% of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”.

2) Lower dam/reservoir

a) Natural environment

Table 9.5.5-3 shows the conditions of the natural environment of the Halgran 1&2 lower dam/reservoir.

Table 9.5.5-3 Conditions of the Natural Environment of the Halgran 1&2 Lower Dam/Reservoir

Name of site / Characteristics	Halgran 1&2 Lower dam/reservoir
Meteorological condition	The area is in the Intermediate Zone. From November to January, the area receives lots of rainfall, and in April there is a small peak of the rainfall. The average annual rainfall is about 1,300 – 1,600 mm.
Hydrological condition	No data available.
Land slide	According to the Landslide Map of NBRO, landslides may occur at low to moderate levels around the site.
Water quality	No data available.
Protected area including other important areas (e.g. World Heritage Site)	The site is located at about 6.5 km from the closest protected area (Victoria, Randenigala, Rantembe Sanctuary).
Fauna and flora	Number of faunal endangered species CR: 1, EN: 0, VU: 3 Number of floral endangered species CR: 0, EN: 1, VU: 9
Habitats	The site is manly dominated by terraced paddy fields and home gardens. There are some riverine forests and patches of secondary forests. The biodiversity and species richness are low. The close downstream of the dam has similar habitats, and the biodiversity and species richness are low.

Note: CR: Critically Endangered、EN: Endangered、VU: Vulnerable

b) Social environment

Table 9.5.5-4 shows the conditions of the social environment of the Halgran 1&2 lower dam/reservoir.

Table 9.5.5-4 Conditions of the Social Environment of the Halgran 1&2 Lower Dam/Reservoir

Name of site / Characteristics	Halgran 1&2 Lower dam/reservoir
Location	Madulla South (GN), Meepanawa(GN), Rupaha-East (GN), Maliyadda (GN), Walapane District, Nuwara Eliya
Demographic status of the GND	Madulla_South Population: 816, No. of HHs: 236, Average No. of family:3.46, Major local industry: Agriculture Average monthly income: No data Meepanawa Population: 612, No. of HHs: 179, Average No. of family: 3.42 Major local industry: Agriculture Average monthly income: No data Rupaha-East Population: 258, No. of HHs: 78, Average No. of family: 3.31, Majore local industry: Agriculture Average monthly income: No data Maliyadda

Name of site / Characteristics	Halgran 1&2 Lower dam/reservoir
	Population: 747, No. of HHs: 205, Average No. of family: 3.64 Major local industry: Agriculture Average monthly income: No data
Accessibility to the proposed site	The site is accessible by the motorable road from Walapane through Nildandahinna towards Ragala and through a village road in Madulla. There is no motorable road for the last 1.5 km to the dam site and this has to be newly constructed through the home gardens and the paddy fields.
Extent of resettlement	9 households
Extent of land acquisition	Paddy: 12.5ha, Home garden: 7.6ha, Other Cultivation: 5.9ha Total: 26.0ha
Land use pattern of the area	Paddy, Home garden, Other Cultivation
River utilization especially in downstream areas	The river is used by the people and farmers within the inundation area for bathing purposes. And there is 1 irrigation canal on the right bank. No fishery.
Religious, cultural and archeological heritages	A small burial ground is on the left bank.
Tourism site	None
Existence of indigenous people	None
Existence of poverty people	Madulla South: 55.51％ of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”. Meepanawa: 53.63% of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”. Bupaha_East: 62.82% of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”. Maliyadda: 40% of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”.

3) Evaluation of the natural and social environments of the Halgran 1

a) Evaluation of the upper dam/reservoir

Natural environment:

The result of the evaluation of the natural environment of the Halgran 1 upper dam/reservoir is shown in Table 9.5.5-5.

Table 9.5.5-5 Evaluation of the Natural Environment of the Halgran 1 Upper Dam/Reservoir

Scoping items	Evaluation
Impacts on fauna and flora	Rating [B] The site has already been altered to agricultural lands, and their biodiversity and species richness are low. However, since there are records of endangered species (fauna: CR: 1, EN: 3), the project may give impacts on the natural environment.

Social environment:

The results of the evaluation of the social environment of the Halgran 1 upper dam/reservoir are shown in Table 9.5.5-6.

Table 9.5.5-6 Evaluation of the Social Environment of the Halgran 1 Upper Dam/Reservoir

Scoping items	Evaluation
Impacts on local communities	Rating [B] 15 households will be inundated. There is no people using the river water. Therefore, the evaluation rating is [B].
Impacts on industries	Rating [B] The total inundated area is 26.4ha (Home garden: 2.3ha, Tea plantation: 7.8ha, Other cultivation: 16.3ha. There is no tourism activity at or in the vicinity of the site. Therefore the evaluation rating is [B].
Impacts on cultural and landscape	Rating [A] There is no religiously or culturally significant place including burial grounds at or in the vicinity of the site. There is no issue on landscape. Therefore the evaluation rating [A].

b) Evaluation of the lower dam/reservoir

Natural environment:

The result of the evaluation of the natural environment of the Halgran 1&2 lower dam/reservoir is shown in Table 9.5.5-7.

Table 9.5.5-7 Evaluation of the Natural Environment of the Halgran 1&2 Lower Dam/Reservoir

Scoping items	Evaluation
Impacts on fauna and flora	Rating [B] The site has already been altered to agricultural lands such as terraced paddy fields, and their biodiversity and species richness are low. However, since there are records of endangered species (fauna: CR: 1, flora: EN: 1), the project may give impacts on the natural environment.

Social environment:

The results of the evaluation of the social environment of the Halgran 1&2 lower dam/reservoir are shown in Table 9.5.5-8.

Table 9.5.5-8 Evaluation of the Social Environment of the Halgran 1&2 Lower Dam/Reservoir

Scoping items	Evaluation
Impacts on local communities	Rating [B] 9 households will be inundated. Halgran Oya is used for bathing by local people. There is a small irrigation canal, but the impact on it is limited to a small scale. Therefore the evaluation rating is [B].
Impacts on industries	Rating [B] The total inundated area is 26.0ha (Paddy: 12.5ha, Home garden: 7.6ha, Other cultivation: 5.9ha). There is no tourism activity at or in the vicinity of the site. Therefore the evaluation rating is [B].
Impacts on cultural and landscape	Rating [A] There is no religiously or culturally significant place, though there is a small burial ground. There is no issue on landscape. Therefore the evaluation rating is [A].

c) Overall evaluation

Table 9.5.5-9 shows the overall evaluation of the Halgran 1 as a cluster with the evaluations of the upper and lower dam/reservoirs.

Table 9.5.5-9 Overall Evaluation of the Halgran 1 Cluster

Scoping items	Evaluation		
	Upper dam/reservoir	Lower dam/reservoir	Overall
Impacts on fauna and flora	B	B	B
Impacts on local communities	B	B	B
Impacts on industries	B	B	B
Impacts on cultural and landscape	A	A	A

A: Project is not likely to have significant adverse impacts on natural environment and society and/or limited to a small scale.

B: Project is likely to have negative impact on natural environment and society, but less adverse than C

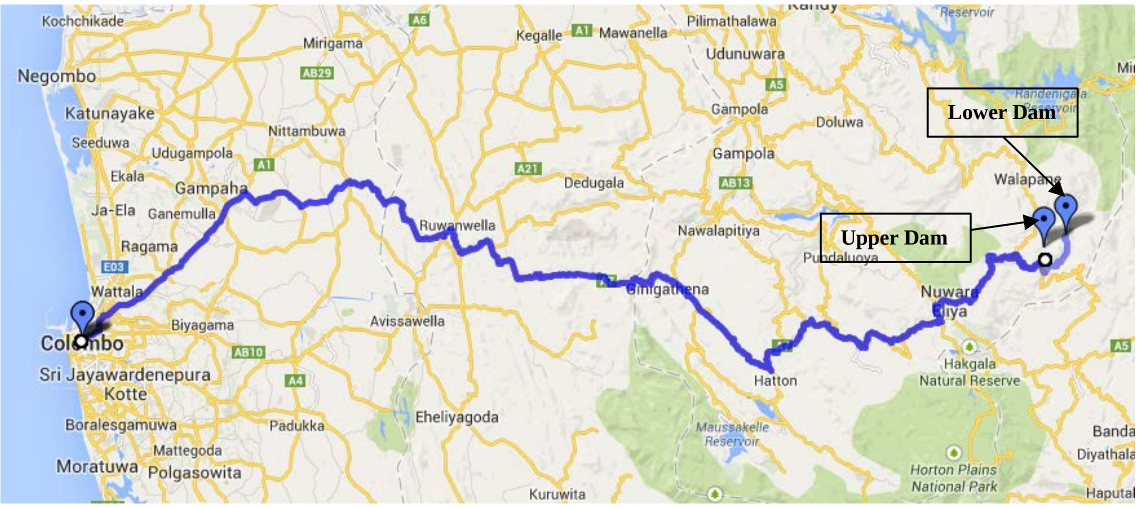
C: Project is likely to have significant adverse impacts on natural environment and society.

(4) Technical Evaluation

The distance on the roads to Upper reservoir is around 190 km from Colombo. The route is composed of the main road A1, A7, B332, B413, and B332. So far, there is not an accessible road to the dam axis; therefore, to approach by vehicle is not possible. The distance from the closest point on the existing main road to the dam axis is around 2 km, the difference in height between the main road surface and the dam crest is around 200 m and to the river bed is around 300 m. A new access road is required to connect the dam crest, the river bed, and existing road. Considering these road conditions and topographical conditions as a steep valley is dominant, the evaluation from the accessibility is rather low.

As for Lower reservoir, the distance on the roads from Colombo to Lower reservoir is around 200 km. The route is composed of the main road A1, A7, B332, B413, and 332, and 9 km of the by-road. It seems to be approached by vehicles to Lower dam axis; however, the evaluation of accessibility is also rather low due to the topographic condition of a steep valley around the dam axis and more than 100 m of the difference in height between the road surface and the river bed.

Both unit capacities of 200 MW and 150 MW are applicable



(Source: Study Team)

Figure 9.5.5-1 Access Route to Halgran 1 Site

(5) Construction Cost

Table 9.5.5-10 shows the construction cost of Halgran 1 scheme, which is calculated according to the method and conditions mentioned in sub-clause 9.4.4. This site is applicable to 200 MW/unit only.

Table 9.5.5-10 Construction Cost of Halgran 1 Scheme

Item/Project		Halgran 1		Remarks
		200MW*3unit	150MW*4units	
		$*10^3$USD	$*10^3$USD	
1.	Preparation and Land Acquisition	7,415		
	(1) Access Roads			
	(2) Compensation & Resettlement			
	(3) Camp & Facilities	7,415		3. Civil Works * 2%
2.	Environmental Mitigation Cost	11,123		3. Civil Works * 3%
3.	Civil Works	370,761		
4.	Hydromechanical Works	61,952		
5.	Electro-Mechanical Equipment	189,700		
6.	Transmission Line			
	Direct Cost	640,951		
7.	Administration and Engineering Service	96,143		Direct Cost * 15%
8.	Contingency	64,095		Direct Cost * 10%
9.	Interest during Construction			
	Total Cost	801,189		
	Power Output	600,000		
	USD per kW	1,335		

(Source: Study Team)

Main features of the civil structures are shown as follows;

- Upper Dam
  - Type: Rock Fill
  - Height *Crest Length: 80m * 250m
  - Volume: 2,700 * 10^3m^3
- Lower Dam
  - Type: RCC
  - Height * Crest Length: 81m * 420m
  - Volume: 600 * 10^3m^3

- Headrace Tunnel Dia *Length*line	200MW/unit	5.2m * 950m * 1 line
	150MW/unit	N.A
- Penstock Tunnel Dia *Length*line	200MW/unit	4.0m * 1,116m * 1 line
	150MW/unit	N.A
- Tailrace Tunnel Dia *Length*line	200MW/unit	5.7m * 2,300m * 1 line
	150MW/unit	N.A

9.5.6 Halgran 2

(1) General Outline

This scheme is the pumped storage power project having 600 MW of the rated output, which utilizes 679.25 m of the rated head created by the difference in height between Upper reservoir and Lower reservoir, and 106.04 m3/s of the rated discharge for power generation. 6.0 hours of the equivalent peaking time is ensured. Upper reservoir is located in one of the tributary of Halgran River, which flows west side from the main river course. Lower reservoir is a common with that of Halgran 1.

Review on the plan (250 MW/unit * two units) by the initial JICA Study is carried out in order to make it appropriate to the restriction of the unit capacity; 200 MW/unit basis and 150 MW/unit basis. It is obvious that 745 m of the gross head by the initial JICA Study is beyond the applicable head range for 200 MW/unit. Therefore, the location of upper dam axis is shifted to around 500 m in downstream direction from the original location. Thus, the revised plan is studied under the condition that 745 m of the original head is reduced to 679.25 m.

Ratio of the horizontal waterway length (L) and the gross head (H) is 5.8 (=L/H).

(2) Geomorphology and geology

The geology of the site belongs to Highland Complex and mainly comprises gneisses and quartzite.

The upper reservoir consists of Charnokite and quartzite, and locates itself on the north wing of the syncline fold axis thus dipping SW in general. The most of the upper reservoir comprises quartzite and quartzite schist and the partially Charnokite on the left rim, and the site as a whole is anticipated hard. The quartzite schist may contain developed joints partially, but has no problem for water sealing capability as it does not suffer erosions from its geomorphic shape, and keeps high steep mountain shape. The NE-SW trending fault is estimated on the left reservoir bank in the existing geological map but such features are not clearly visible from aerophotographs, and the fault is apart from the reservoir by 500m. The left rim forms slow slope and weathered on the surface, but there are no significant unstable slopes around the rim from the aerophotographs or from the site visit.

The upper dam axis is located on Charnokite on the left abutment, and quartzite on the right abutment. Both are hard. The depth of weathering is anticipated shallow. The left Charnokite is stable and so is the quartzite with no colluvium deposit with thin surface weatherings.

The water route passes through gneisses, quartzite, and partially limestone. It also crosses 2 faults. Among all, one NW-SE trending fault fracture zone can be made in association with an anticlinal axis folding movement induced by 2 synclinal axis folding motions and with features that this fault has a certain fault displacement and that gneiss contains limestone band near the fault, the water route may encounter a crushed inferior limestone nearby the fault.

The underground powerhouse is planned at gneisses and is hard, but certain cares should be paid to avoid faulting zone and limestone bands.

The lower reservoir is the same as Halgran 1 as in 9.5.5.

(3) Natural and social environments

1) Upper dam/reservoir

a) Natural environment

Table 9.5.6-1 shows the conditions of the natural environment of the Halgran 2 upper dam/reservoir.

Table 9.5.6-1 Conditions of the Natural Environment of the Halgran 2 Upper Dam/Reservoir

Characteristics \ Name of site	Halgran 2 Upper dam/reservoir
Meteorological condition	The area is in the Intermediate Zone. From November to January, the area receives lots of rainfall, and in April there is a small peak of the rainfall. The average annual rainfall is about 1,300 – 1,600 mm.
Hydrological condition	No data available.
Land slide	According to the Landslide Map of NBRO, landslides may occur at low to moderate levels around the site.
Water quality	No data available.
Protected area including other important areas (e.g. World Heritage Site)	The site is located at about 4 km from the closest protected area (Kandapola Forest Reserve).
Fauna and flora	Number of faunal endangered species CR: 3, EN: 5, VU: 8 Number of floral endangered species CR: 0, EN: 4, VU: 3
Habitats	Although the site is dominated by tea plantations, crop fields and eucalyptus plantations, there are rich natural riverine forests along the stream. The biodiversity and species richness are high. The area of the close downstream of the dam has poor riverine vegetation, and the biodiversity and species richness are moderate.

Note: CR: Critically Endangered、EN: Endangered、VU: Vulnerable

b) Social environment

Table 9.5.6-2 shows the conditions of the social environment of the Halgran 2 upper dam/reservoir.

Table 9.5.6-2 Conditions of the Social Environment of the Halgran 2 Upper Dam/Reservoir

Characteristics \ Name of site	Halgran 2 Upper dam/reservoir
Location	Harasbedda North (GN), Morabedda (GN), Walapane Division, Nuwara Eliya District
Demographic status of the GND	Harasbeda_North Population: 1,325, No. of HHs: 392, Average No. of family: 3.38, Major local industry: Agriculture Average monthly income: No data Morabedda Population: 588, No. of HHs: 168, Average No. of family: 3.5 Major local industry: Agriculture Average monthly income: No data
Accessibility to the proposed site	The site is accessible by the estate road which needs to be widened and improved as the potential access road.
Extent of resettlement	There is no resettlement within the inundation area.
Extent of land acquisition	Paddy: 0.004ha, Tea plantation: 14.8ha, Other Cultivation: 2.4ha, Forest: 10.1ha Total: 27.3ha
Land use pattern of the area	Paddy, Tea plantation, Other Cultivation, Forest
River utilization especially in downstream areas	The river is not used by the people either within the inundation area or in the immediate downstream. There is one place on a small tributary on the left bank that is used by people for bathing. No fishery.
Religious, cultural and archeological heritages	None
Tourism site	None
Existence of indigenous people	None
Existence of poverty people	Harasbedda North(GN) : 27.3% of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”. Morabedda(GN) : 61.3% of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”.

2) Lower dam/reservoir

They are the same as the lower dam/reservoir in “9.5.5 Halgran 1”.

3) Evaluation of the natural and social environments of the Halgran 2

a) Evaluation of the upper dam/reservoir

Natural environment:

The result of the evaluation of the natural environment of the Halgran 2 upper dam/reservoir is shown in Table 9.5.6-3.

Table 9.5.6-3 Evaluation of the Natural Environment of the Halgran 2 Upper Dam/Reservoir

Scoping items	Evaluation
Impacts on fauna and flora	Rating [B] Although the site has already been altered to agricultural lands dominated by tea plantations, there are rich natural riverine forests along the stream. The biodiversity and species richness are high. Regarding the endangered species, endangered species (fauna: CR: 3, EN: 5. flora: EN: 4) are recorded. The project may give impacts on the natural environment.

Social environment:

The results of the evaluation of the social environment of the Halgran 2 upper dam/reservoir are shown in Table 9.5.6-4.

Table 9.5.6-4 Evaluation of the Social Environment of the Halgran 2 Upper Dam/Reservoir

Scoping items	Evaluation
Impacts on local communities	Rating [A] There is no resettlement. Nobody use the river water of Halgra Oya. Therefore the evaluation rate is [A].
Impacts on industries	Rating [B] The total inundated area is 27.3 ha (Tea plantation: 14.8 ha, Other cultivation: 2.4 ha, Forest: 10.1 ha, Paddy: 0.004 ha). The impact on Tea planation and Eucalyptus plantation will be relatively large that the livelihood of local people may have an impact. Therefore the evaluation rate is [B].
Impacts on cultural and landscape	Rating [A] There is no religiously or culturally significant place, though there is a small burial ground which impact is limited to small scale. There is no issue on landscape. Therefore the evaluation rating is [A].

b) Evaluation of the lower dam/reservoir

They are the same as the lower dam/reservoir in “9.5.5 Halgran 1”.

c) Overall evaluation

Table 9.5.6-5 shows the overall evaluation of the Halgran 2 as a cluster with the evaluations of the upper and lower dam/reservoirs.

Table 9.5.6-5 Overall Evaluation of the Halgran 2 Cluster

Scoping items	Evaluation		
	Upper dam/reservoir	Lower dam/reservoir	Overall
Impacts on fauna and flora	B	B	B
Impacts on local communities	A	B	B
Impacts on industries	B	B	B
Impacts on cultural and landscape	A	A	A

A: Project is not likely to have significant adverse impacts on natural environment and society and/or limited to a small scale.

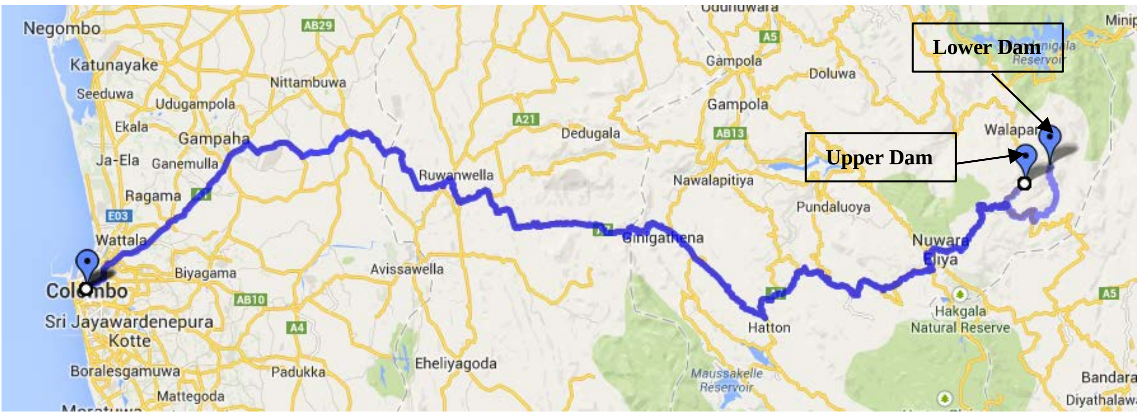
B: Project is likely to have negative impact on natural environment and society, but less adverse than C

C: Project is likely to have significant adverse impacts on natural environment and society.

(4) Technical Evaluation

The distance from Colombo to Upper reservoir is around 190 km through the main roads; A1, A7, B332, B413 and from 2 km to 3 km of the by-road in the tea estate. Access by vehicles to Upper dam axis is possible. There is from 20 m to 30 m of difference in height between the existing road surface to the dam crest and from 130 to 140 m of it between the existing road surface and the river bed. However, there seems to exist one path from the existing road surface to the river bed according to the topographical map scale 1 to 10,000, it may be utilizable for the construction works, even though modification is required.

As for Lower reservoir, it is a common with that of Halgran 1 scheme.



(Source; Study Team)

Figure 9.5.6-1 Access Route to Halgran 2 Site

Regarding an easy of temporary yards reclamation and new work roads construction, it is thought that development of such temporary facilities would be difficult due to rather steep topography in around Upper and Lower reservoir area.

As for the manufacturing limitation of the pump-turbine, in spite of shifting the dam axis to around 500 m downstream direction to reduce the head, it is resulted that both 200MW/unit and 150 MW/unit are not applicable. Other than the axis shifted, there may not exist any suitable location as dam axes.

(5) Construction Cost

Table 9.5.6-6 shows the construction cost of Halgran 2 scheme, which is calculated according to the method and conditions mentioned in sub-clause 9.4.4. This site is not applicable to both 200 MW/unit and 150 MW/unit, so that shown construction cost is a reference purpose only.

Table 9.5.6-6 Construction Cost of Halgran 2 Scheme

Item/Project		Halgran 2		Remarks
		200MW*3unit	150MW*4units	
		*10^3USD	*10^3USD	
1.	Preparation and Land Acquisition	10,767		
	(1) Access Roads			
	(2) Compensation & Resettlement			
	(3) Camp & Facilities	10,767		3. Civil Works * 2%
2.	Environmental Mitigation Cost	16,150		3. Civil Works * 3%
3.	Civil Works	538,333		
4.	Hydromechanical Works	69,445		
5.	Electro-Mechanical Equipment	186,200		
6.	Transmission Line			
	Direct Cost	820,894		
7.	Administration and Engineering Service	123,134		Direct Cost * 15%
8.	Contingency	82,089		Direct Cost * 10%
9.	Interest during Construction			
	Total Cost	1,026,118		
	Power Output	600,000		
	USD per kW	1,710		

(Source: Study Team)

Main features of the civil structures are shown as follows;

- Upper Dam		
Type	Rock Fill	
Height *Crest Length	116m * 500m	
Volume	7,900 * 10^3m^3	
- Lower Dam		
Type	RCC	
Height * Crest Length	79m * 430m	
Volume	600 * 10^3m^3	
- Headrace Tunnel Dia	200MW/unit	4.8m * 960m * 1 line (N.A)
*Length*line	150MW/unit	N.A
- Penstock Tunnel Dia	200MW/unit	3.7m * 1,256m * 1 line (N.A)
*Length*line	150MW/unit	N.A
- Tailrace Tunnel Dia	200MW/unit	5.2m * 2,240m * 1 line (N.A)
*Length*line	150MW/unit	N.A

9.5.7 Halgran 3

(1) General Outline

This scheme is the pumped storage power project having 600 MW of the rated output, which utilizes 657.08 m of the rated head created by the difference in height between Upper reservoir and Lower reservoir, and 109.62 m^3/s of the rated discharge for power generation. 6.0 hours of the equivalent peaking time is ensured. Upper reservoir is located in one of the tributary of Halgran River, which flows west side from the main river course. Lower reservoir is located in the downstream of the Upper reservoir.

Review on the plan (250 MW/unit * two units) by the initial JICA Study is carried out in order to make it appropriate to the restriction of the unit capacity; 200 MW/unit basis and 150 MW/unit basis. According to the original plan by the initial JICA Study, it has 689 m of the gross head; therefore, it is estimated that the project is to be plotted in the boundary zone of the manufacturing limitation. However, there are any suitable sites for Upper and/or Lower dams other than the original ones, so that the review is carried out under the condition of the original Upper reservoir and the original Lower reservoir.

Ratio of the horizontal waterway length (L) and the gross head (H) is 6.5 (=L/H).

(2) Geomorphology and geology

The site geology belongs to Highland Complex and mainly comprises gneisses and quartzite.

The upper reservoir consists of quartzite and quartzite schist, and locates itself on the north wing of the syncline fold axis thus dipping SW in general. The quartzite and quartzite schist are anticipated hard. The quartzite schist may contain developed joints partially, but has no problem for water sealing capability as it does not suffer erosions from its geomorphic shape, keeping high steep mountain shape. The right bank rock forms a steep mountain. There are outcrops on the slopes thus surface weathering is shallow. The NE-SW trending fault is estimated in the existing geological map but such features are not clearly visible from aerophotographs. The fault is apart from the reservoir by 500m. There are no landslides around the reservoir from the aerophotographs.

The left ridge of the reservoir at 300m upstream from the dam axis, is relatively thin. There lies some distance to the top ridge from HWL (the ridge height is EL 1,417m and the HWL is 1,406m, bearing the horizontal distance between the ridge and HWL location as 60m), however, the weathering depth of the left rim of the reservoir is uncertain, one lineament lies along the river on the other side of the ridge with certain geologic boundary, and the quartzite forming the reservoir has a various joints inside though rock itself is hard in nature. Further verification through survey must be conducted for the potential impact on the water sealing capability.

The upper dam axis is located on quartzite and the rock is hard. No dips/strikes were able to be measured but may be favorable for dam foundation if the rock is SW dipping as shown on the geological map. The left abutment is placed near to the boundary of the rock facies between quartzite and gneiss, forms rather slower in slope with some colluvium and surface weatherings but the weathering depth is anticipated shallow as it shows rock outcrops near the surface. There are no landslide shapes near damsite from the aerophotographs. There are no critical geological issues in the upper dam site.

The water route passes through gneisses, quartzite, and partially limestone. It also crosses 2 faults. Among all, one NW-SE trending fault fracture zone can be made in association with an anticlinal axis folding movement induced by 2 synclinal axis folding motions and with features that this fault has a certain fault displacement and that gneiss contains limestone band near the fault, the water route may encounter a crushed inferior limestone nearby the fault.

The underground powerhouse is planned at gneisses and are hard, but certain cares should be paid to avoid faulting zone and limestone bands.

The lower reservoir locates itself on the south wing of the syncline folding axis thus dipping NE in general. It comprises Charnokite and limestone. The limestone is distributed on the left bank from the reservoir in upstream through down to the downstream of the dam site. The beneath of the limestone lies Charnokite in the reservoir site so there are little concerns for the holding water sealing capability of the reservoir. But the rock extends itself to the downstream in 2-400m apart from the left dam abutment, so the site investigation is required for the area including the permeability and ground water level along the left abutment. The preliminary site outlook does not show particular geomorphological features of dissolved limestone as karst or drape. But the site is covered by the surface soils without outcrops having certain limit on the surface geological mapping, thus it requires some drilling surveys to investigate limestone of its characteristics especially permeability aspect. There are no landslides around the dam and the reservoir. The NW-SW trending fault is estimated on the existing geological map at the upstream end of the reservoir but no unstable slopes are observed.

The lower dam axis is located at gneisses on both abutments and both are hard. The left abutment forms slow slope and surface layers covers without showing outcrops. The left abutment rim is rather thin in width with certain weathering thickness (limestone is expected in 2-400m apart from the dam abutment and the zone is relatively sunken lower in shape. The water level may be lower). The right abutment is hard and few issues anticipated.

(3) Natural and social environments

1) Upper dam/reservoir

a) Natural environment

Table 9.5.7-1 shows the conditions of the natural environment of the Halgran 3 upper dam/reservoir.

Table 9.5.7-1 Conditions of the Natural Environment of the Halgran 3 Upper Dam/Reservoir

Characteristics / Name of site	Halgran 3 Upper dam/reservoir
Meteorological condition	The area is in the Intermediate Zone. From November to January, the area receives lots of rainfall, and in April there is a small peak of the rainfall. The average annual rainfall is about 2,200 – 2,400 mm.
Hydrological condition	No data available.
Land slide	According to the Landslide Map of NBRO, landslides may occur at low to moderate levels around the site.
Water quality	No data available.
Protected area including other important areas (e.g. World Heritage Site)	The site is located at about 4 km from the closest protected area (Kandapola Forest Reserve).
Fauna and flora	Number of faunal endangered species CR: 0, EN: 5, VU: 9 Number of floral endangered species CR: 0, EN: 2, VU: 1
Habitats	Although the site is agricultural lands dominated by tea plantations, there are rich natural riverine forests along the stream. The biodiversity and species richness are high. The area of the close downstream of the dam has rich natural riverine forests, and the biodiversity and species richness are high.

Note: CR: Critically Endangered、EN: Endangered、VU: Vulnerable

b) Social environment

Table 9.5.7-2 shows the conditions of the social environment of the Halgran 3 upper dam/reservoir.

Table 9.5.7-2 Conditions of the Social Environment of the Halgran 3 Upper Dam/Reservoir

Characteristics / Name of site	Halgran 3 Upper dam/reservoir
Location	Morabedda (GN), Mantreehena (GN), Walapane Division, Nuwara Liya District
Demographic status of the GND	Morabedda Population: 588, No. of HHs: 168, Average No. of family:3.5 Major local industry: Agriculture Average monthly income: No data Mantreehena Population: 1,620, No. of HHs: 389, Average No. of family: 4.16 Major local industry: Agriculture Average monthly income: No data
Accessibility to the proposed site	The site is accessible by the estate road which needs to be widened and improved as the potential access road.
Extent of resettlement	None
Extent of land acquisition	Tea plantation: 14.3ha, Forest: 13.2ha, Total: 27.5ha
Land use pattern of the area	Tea plantation, Forest
River utilization especially in	None

Name of site / Characteristics	Halgran 3 Upper dam/reservoir
downstream areas	
Religious, cultural and archeological heritages	None
Tourism site	None
Existence of indigenous people	None
Existence of poverty people	Morabedda(GN) : 61.31% of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”. Mantreehena(GN) : 22.1％ of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”.

2) Lower dam/reservoir

a) Natural environment

Table 9.5.7-3 shows the conditions of the natural environment of the Halgran 3&4 lower dam/reservoir.

Table 9.5.7-3 Conditions of the Natural Environment of the Halgran 3&4 Lower Dam/Reservoir

Name of site / Characteristics	Halgran 3&4 Lower dam/reservoir
Meteorological condition	The area is in the Intermediate Zone. From November to January, the area receives lots of rainfall, and in April there is a small peak of the rainfall. The average annual rainfall is about 2,200 – 2,400 mm.
Hydrological condition	No data available.
Land slide	According to the Landslide Map of NBRO, landslides may occur at low to moderate levels around the site.
Water quality	No data available.
Protected area including other important areas (e.g. World Heritage Site)	The site is located at about 5 km from the closest protected area (Victoria, Randenigala, Rantembe Sanctuary).
Fauna and flora	Number of faunal endangered species CR: 1, EN: 0, VU: 1 Number of floral endangered species CR: 0, EN: 1, VU: 3
Habitats	The site is developed as agricultural lands: terraced paddy field, crop fields and home gardens. The riverine vegetation is poor. The biodiversity and species richness are low. The close downstream of the dam has similar habitats, and the biodiversity and species richness are low.

Note: CR: Critically Endangered、EN: Endangered、VU: Vulnerable

b) Social environment

Table 9.5.7-4 shows the conditions of the social environment of the Halgran 3&4 lower dam/reservoir.

Table 9.5.7-4 Conditions of the Social Environment of the Halgran 3&4 Lower Dam/Reservoir

Name of site / Characteristics	Halgran 3&4 Lower dam/reservoir
Location	Dambagolla (GN), Puranakumbura (GN), Hegama(GN), Denamure (GN), Walapane Division, Nuwara Eliya District
Demographic status of the GND	Damubagolla Population: 510, No. of HHs: 148, Average No. of family: 3.45 Major local industry: Private sector, Abriculture Average monthly income: No data Puranakumbura Population: 541, No. of HHs: 153, Average No. of family: 3.54, Major local industry: Agriculture Average monthly income: No data Hegama Population: 379, No. of HHs: 123, Average No. of family: 3.08 Major local industry: Agriculture, Private sector Average monthly income: No data Denamure Population: 375, No. of HHs: 119, Average No. of family: 3.15 Major local industry: Agriculture Average monthly income: No data
Accessibility to the proposed site	The site is accessible by the motorable road from Walapane through Nildandahinna towards Ragala and through a village road in Dambagolla. There is no motorable road for the last 1 km to the dam site and this has to be newly constructed through the home gardens and the paddy fields.
Extent of resettlement	3 households
Extent of land acquisition	Paddy: 21.8ha, Home garden: 6.9ha, Tea plantation: 0.18ha, Other Cultivation: 0.6ha Total: 29.48ha
Land use pattern of the area	Paddy, Home garden, Tea plantation, Other cultivation
River utilization especially in downstream areas	The river is used by the people and farmers within the inundation area for bathing purposes. Also there are 2 small irrigation canals providing water to the downstream paddy fields. No fishery.
Religious, cultural and archeological heritages	A small burial ground is on the left bank.
Tourism site	None
Existence of indigenous people	None
Existence of poverty people	Dambagolla: 37.16% of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”. Purankumbura: 43.09% of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”. Hegama: 40.34% of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”. Denamure: 50.33％ of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”.

3) Evaluation of the natural and social environments of the Halgran 3

a) Evaluation of the upper dam/reservoir

Natural environment:

The result of the evaluation of the natural environment of the Halgran 3 upper dam/reservoir is shown in Table 9.5.7-5.

Table 9.5.7-5 Evaluation of the Natural Environment of the Halgran 3 Upper Dam/Reservoir

Scoping items	Evaluation
Impacts on fauna and flora	Rating [B] Although the site has already been altered to agricultural lands dominated by tea plantations, there are rich natural riverine forests along the stream. The biodiversity and species richness are high. Regarding the endangered species, endangered species (fauna: EN: 5, flora: EN: 2) are recorded. The project may give impacts on the natural environment.

Social environment:

The results of the evaluation of the social environment of the Halgran 3 upper dam/reservoir are shown in Table 9.5.7-6.

Table 9.5.7-6 Evaluation of the Social Environment of the Halgran 3 Upper Dam/Reservoir

Scoping items	Evaluation
Impacts on local communities	Rating [A] There is no resettlement. Nobody use the river water. Therefore the evaluation rating is [A].
Impacts on industries	Rating [B] The total inundated area is 27.5ha (Tea plantation: 14.3ha, Forest: 13.2ha). The impact on Tea planation and forest will be relatively large that the livelihood of local people may have an impact. Therefore the evaluation rate is [B].
Impacts on cultural and landscape	Rating [A] There is no religiously or culturally significant place. There is no issue on landscape. Therefore the evaluation rating is [A].

b) Evaluation of the lower dam/reservoir

Natural environment:

The result of the evaluation of the natural environment of the Halgran 3&4 lower dam/reservoir is shown in Table 9.5.7-7.

Table 9.5.7-7 Evaluation of the Natural Environment of the Halgran 3&4 Lower Dam/Reservoir

Scoping items	Evaluation
Impacts on fauna and flora	Rating [B] The site has already been altered to agricultural lands such as terraced paddy fields, and the riverine vegetation is poor. The biodiversity and species richness are low. However, since there are records of endangered species (fauna: CR: 1, flora: EN: 1), the project may give impacts on the natural environment.

Social environment:

The results of the evaluation of the social environment of the Halgran 3&4 lower dam/reservoir are shown in Table 9.5.7-8.

Table 9.5.7-8 Evaluation of the Social Environment of the Halgran 3&4 Lower Dam/Reservoir

Scoping items	Evaluation
Impacts on local communities	Rating [B] There is no resettlement. The river is used by local people for bating. There are 2 irrigation canals. Therefore the evaluation rating is [B].
Impacts on industries	Rating [B] The total inundated area is 29.48ha (Paddy: 21.8ha, Home garden: 6.9ha, Tea plantation: 0.18ha, Other cultivation: 0.6ha). It may impact on livelihood of local people. Therefore the evaluation rating is [B].
Impacts on cultural and landscape	Rating [A] There is no religiously or culturally significant place, though there is a small burial ground which impact is limited to small scale. There is no issue on landscape. Therefore the evaluation rating is [A].

c) Overall evaluation

Table 9.5.7-9 shows the overall evaluation of the Halgran 3 as a cluster with the evaluations of the upper and lower dam/reservoirs.

Table 9.5.7-9 Overall Evaluation of the Halgran 3 Cluster

Scoping items	Evaluation		
	Upper dam/reservoir	Lower dam/reservoir	Overall
Impacts on fauna and flora	B	B	B
Impacts on local communities	A	B	B
Impacts on industries	B	B	B
Impacts on cultural and landscape	A	A	A

A: Project is not likely to have significant adverse impacts on natural environment and society and/or limited to a small scale.

B: Project is likely to have negative impact on natural environment and society, but less adverse than C

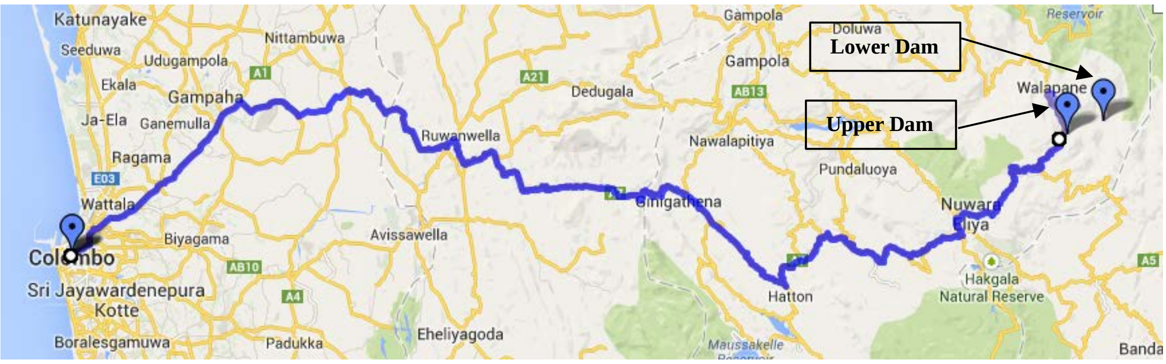
C: Project is likely to have significant adverse impacts on natural environment and society.

(4) Technical Evaluation

The distance from Colombo to Upper reservoir is around 190 km through the main roads; A1, A7, B332, B413 and from 2 km to 3 km of the by-road in the tea estate. (Upper reservoir is located in upstream of the upper reservoir of Halgran 2) Access by vehicles to Upper dam axis is possible. There seems to exist one path from the existing road surface to the river bed according to the topographical map scale 1 to 10,000, it may be utilizable for the construction works, even though some modification is required.

As for Lower reservoir, the distance from Colombo to Lower reservoir is around 205 km through the main roads; A1, A7, B332, B413 and the by-road. Vehicles can approach up to the 5 km point on the by-road to the main dam axis direction; however, it is not possible to proceed beyond that point by vehicles. According to the topographical map scale 1 to 10,000, the horizontal distance from the said closest point to the dam axis is roughly 700 m and the difference in height is around 100 m to the dam crest, and 200 m to the river bed level. Because of the gentle topography in around the dam area, new access road to the river bed would be constructed without serious difficulties.

As for the manufacturing limitation of the pump-turbine, 200 MW/unit can be applicable; however, it is plotted near the boundary zone to incapable manufacturing zone. Therefore, careful study on this issue is required in the later stage.



(Source: Study Team)

Figure 9.5.7-1 Access Route to Halgran 3 Site

(5) Construction Cost

Table 9.5.7-10 shows the construction cost of Halgran 3 scheme, which is calculated according to the method and conditions mentioned in sub-clause 9.4.4. This site is not applicable to 150 MW/unit.

Table 9.5.7-10 Construction Cost of Halgran 3 Scheme

Item/Project		Halgran 3		Remarks
		200MW*3unit	150MW*4units	
		$*10^3$USD	$*10^3$USD	
1.	Preparation and Land Acquisition	4,644		
	(1) Access Roads			
	(2) Compensation & Resettlement			
	(3) Camp & Facilities	4,644		3. Civil Works * 2%
2.	Environmental Mitigation Cost	6,967		3. Civil Works * 3%
3.	Civil Works	232,223		
4.	Hydromechanical Works	69,407		
5.	Electro-Mechanical Equipment	186,800		
6.	Transmission Line			
	Direct Cost	500,041		
7.	Administration and Engineering Service	75,006		Direct Cost * 15%
8.	Contingency	50,004		Direct Cost * 10%
9.	Interest during Construction			
	Total Cost	625,051		
	Power Output	600,000		
	USD per kW	1,042		

(Source: Study Team)

Main features of the civil structures are shown as follows;

- Upper Dam
  - Type: Rock Fill
  - Height *Crest Length: 57m * 200m
  - Volume: $900 * 10^3 m^3$
- Lower Dam
  - Type: Rock Fill
  - Height * Crest Length: 65m * 220m
  - Volume: $1,500 * 10^3 m^3$

- Headrace Tunnel Dia *Length*line	200MW/unit	4.9m * 1,350m * 1 line
	150MW/unit	N.A
- Penstock Tunnel Dia *Length*line	200MW/unit	3.8m * 1,236m * 1 line
	150MW/unit	N.A
- Tailrace Tunnel Dia *Length*line	200MW/unit	5.3m * 2,200m * 1 line
	150MW/unit	N.A

9.5.8 Halgran 4

(1) General Outline

This scheme is the pumped storage power project having 600 MW of the rated output, which utilizes 465.18 m of the rated head created by the difference in height between Upper reservoir and Lower reservoir, and 154.84 m3/s of the rated discharge for power generation. 6.0 hours of the equivalent peaking time is ensured. Upper reservoir is located in the course of Yakkatawa River. Lower reservoir is a common with Halgran 3 scheme.

Review on the plan (250 MW/unit * two units) by the initial JICA Study is carried out in order to make it appropriate to the restriction of the unit capacity; 200 MW/unit basis and 150 MW/unit basis. It is obvious that 868 m of the gross head by the initial JICA Study is beyond the applicable head range for 200 MW/unit. Therefore, the location of upper dam axis is shifted to closer location to Lower reservoir from the original one. Thus, the revised plan is studied under the condition that 868 m of the original head is reduced to 465.18 m.

Ratio of the horizontal waterway length (L) and the gross head (H) is 6.4 (=L/H).

(2) Geomorphology and geology

The site geology belongs to Highland Complex and mainly comprises gneisses and quartzites.

The upper reservoir area consists of Charnokite, locates itself right south wing of the anticlinal folding axis thus dipping SW in general.

The upper reservoir site comprises Charnokite and some quartzite on the right bank on the higher in elevation. The upper reservoir site is close to the anticline axis thus some fracture development is anticipated, but the outlook is hard and considered to hold water sealing capability. The right rim forms a steep quartzite mountain as high as 300m from the riverbed with rock outcrops on the slope showing thin surface weathering and stable slope condition. On the other hand the left rim forms slow slope with probably flood plain sediment from upstream with colluvium. Thus some concerns on stability issues arise. The collapse from landslide was obvious from the aerophotographs on the higher mountain slope on the left bank with some possible feature of landslide on HWL level. The NE-SW trending fault is estimated on the reservoir in the existing geological map but such features are not clearly visible from the aerophotographs.

The upper dam axis is located on gneisses on the left abutment and on quartzite on the right abutment. Both are hard with shallow weatherings. The NW-SE trending fracture zone is estimated 200m apart from the right rim of the reservoir along with the anticline folding axis. But it does not cross the reservoir itself, and the exact right rim is occupied by the hard quartzite mountain hill. There are no landslide features around the reservoir from the aerophotographs, nor NW-SE fault is clearly visible from the aerophotographs. There are no geological issues in the upper damsite.

The water route passes through gneisses, quartzites, and partially limestone. It also crosses 2 faults. Among all, Among all, one NW-SE trending fault fracture zone can be made in association with an anticlinal axis folding movement induced by 2 synclinal axis folding motions and with features that this fault has a certain fault displacement and that gneiss contains limestone band near the fault, the water route may encounter a crushed inferior limestone nearby the fault.

The underground powerhouse is planned at gneisses and is hard, but certain cares should be paid to avoid faulting zone and limestone bands.

The lower reservoir is the same as Halgran 3 as in 9.5.7.

(3) Natural and social environments

1) Upper dam/reservoir

a) Natural environment

Table 9.5.8-1 shows the conditions of the natural environment of the Halgran 4 upper dam/reservoir.

Table 9.5.8-1 Conditions of the Natural Environment of the Halgran 4 Upper Dam/Reservoir

Name of site / Characteristics	Halgran 4 Upper dam/reservoir
Meteorological condition	The area is in the Intermediate Zone. From November to January, the area receives lots of rainfall, and in April there is a small peak of the rainfall. The average annual rainfall is about 2,200 – 2,400 mm.
Hydrological condition	No data available.
Land slide	According to the Landslide Map of NBRO, landslides may occur at low to moderate levels around the site.
Water quality	No data available.
Protected area including other important areas (e.g. World Heritage Site)	The site is located at about 5.5 km from the closest protected area (Kandapola Forest Reserve).
Fauna and flora	Number of faunal endangered species CR: 0, EN: 2, VU: 2 Number of floral endangered species CR: 0, EN: 0, VU: 1
Habitats	The site is agricultural lands dominated by tea plantations, and there are some areas of crop fields and eucalyptus plantations. The riverine vegetation is poor. The biodiversity and species richness are low. The area of the close downstream of the dam is dominated by tea plantation and scrub lands. The biodiversity and species richness are low.

Note: CR: Critically Endangered、EN: Endangered、VU: Vulnerable

b) Social environment

Table 9.5.8-2 shows the conditions of the social environment of the Halgran 4 upper dam/reservoir.

Table 9.5.8-2 Conditions of the Social Environment of the Halgran 4 Upper Dam/Reservoir

Name of site / Characteristics	Halgran 4 Upper dam/reservoir
Location	Maha Uva (GN), Werellapatana (GN), Walapane Division, Nuwara Eliya District
Demographic status of the GND	Maha Uva Population: 3,115, No. of HHs: 752, Average No. of family: 4.14 Major local industry: Temporary worker, Private Sector, Agriculture Average monthly income: No data Werellapathana Population: 1,027, No. of HHs: 285, Average No. of family: 3.6 Major local industry: Agriculture Average monthly income: No data
Accessibility to the proposed site	Accessible by the main road (B 413) and through the estate road which needs to be widened and improved as the potential access road. About 0.25 km of B413 (located at 21 km post) which is currently undergoing rehabilitation will be inundated by the proposed reservoir and thus an alternative detour of at least 0.5 km has to be constructed.
Extent of resettlement	11 households, a pre-school, a muster shed, a domestic water distribution tank.
Extent of land acquisition	Paddy: 0.005ha, Home garden:0.005ha, Tea plantation: 15.8ha, Other cultivation: 7.4ha, Forest: 0.2ha Total: 23.41ha
Land use pattern of the area	Paddy, Home garden, Tea plantation, Other cultivation, Forest
River utilization especially in downstream areas	None
Religious, cultural and archeological heritages	None
Tourism site	None
Existence of indigenous people	None
Existence of poverty people	Maha Uva: 8% of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”. Werellapatana: 65.96% of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”.

2) Lower dam/reservoir

They are the same as the lower dam/reservoir in “9.5.7 Halgran 3”.

3) Evaluation of the natural and social environments of the Halgran 4

a) Evaluation of the upper dam/reservoir

Natural environment:

The result of the evaluation of the natural environment of the Halgran 4 upper dam/reservoir is shown in Table 9.5.8-3.

Table 9.5.8-3 Evaluation of the Natural Environment of the Halgran 4 Upper Dam/Reservoir

Scoping items	Evaluation
Impacts on fauna and flora	Rating [B] The site has already been altered to agricultural lands such as tea plantations, crop fields and eucalyptus plantations. The riverine vegetation is poor. The biodiversity and species richness are low. Regarding endangered species, two faunal EN species are recorded. The project may give impacts on the natural environment.

Social environment:

The results of the evaluation of the social environment of the Halgran 4 upper dam/reservoir are shown in Table Table 9.5.8-4.

Table 9.5.8-4 Evaluation of the Social Environment of the Halgran 4 Upper Dam/Reservoir

Scoping items	Evaluation
Impacts on local communities	Rating [B] 11 households, a pre-school, muster shed, a domestic water distribution tank will be inundate. Nobody use the river water. Therefore the evaluation rating is [B].
Impacts on industries	Rating [B] The total inundated area is 23.41ha (Paddy: 0.005ha, Home garden: 0.005ha, Tea plantation: 15.8ha, Other cultivation: 7.4ha, Forest: 0.2ha). It may impact on livelihood of local people. Therefore the evaluation rating is [B].
Impacts on cultural and landscape	Rating [A] There is no religiously or culturally significant place. There is no issue on landscape. Therefore the evaluation rating is [A].

b) Evaluation of the natural and social environments of the Halgran 4

They are the same as the lower dam/reservoir in “9.5.7 Halgran 3”.

c) Overall evaluation

Table 9.5.8-5 shows the overall evaluation of the Halgran 4 as a cluster with the evaluations of the upper and lower dam/reservoirs.

Table 9.5.8-5 Overall Evaluation of the Halgran 4 Cluster

Scoping items	Evaluation		
	Upper dam/reservoir	Lower dam/reservoir	Overall
Impacts on fauna and flora	B	B	B
Impacts on local communities	B	B	B
Impacts on industries	B	B	B
Impacts on cultural and landscape	A	A	A

A: Project is not likely to have significant adverse impacts on natural environment and society and/or limited to a small scale.

B: Project is likely to have negative impact on natural environment and society, but less adverse than C

C: Project is likely to have significant adverse impacts on natural environment and society.

(4) Technical Evaluation

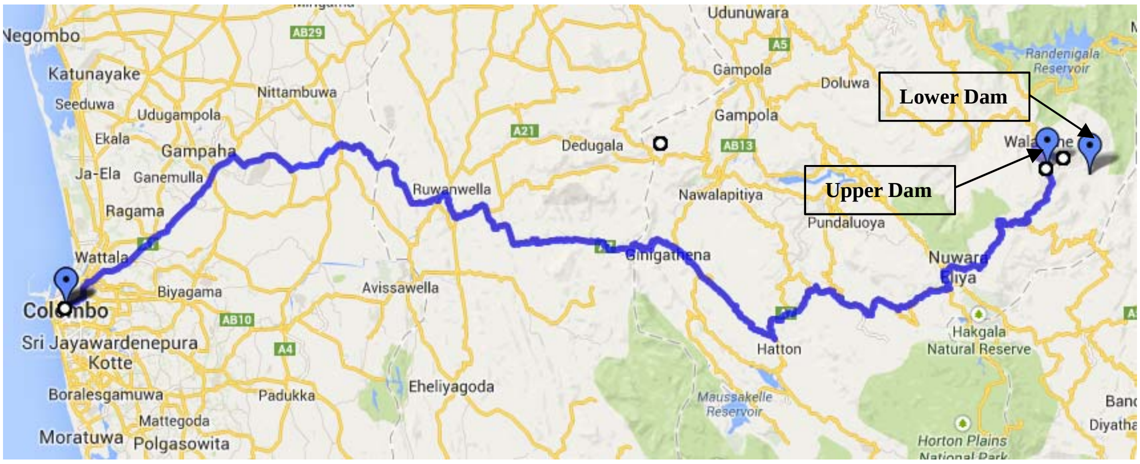
The distance from Colombo to Upper reservoir is around 190 km through the main roads; A1, A7, B332, and B413. The dam axis exists on the main road B413, so that access by vehicles to Upper dam axis is possible. However, due to the steep topography, there are not available path to the river bed and it would be difficult to construct the access road to the river bed.

Lower reservoir is a common with Halgran 3 scheme.

As for the temporary yards for construction works and access roads construction, both works would be considerably difficult due to reasons as follows; topography in around Upper reservoir area is so steep, since the main land B311 is submerged in Upper reservoir, its new alternative road is required. In this regard, the alternative one is needed to be raised around 100 m at around the dam axis, so that the length of the new road construction would be considerably long.

As for the manufacturing limitation, both 200MW/unit and 150 MW/unit are applicable.

In addition, the drawdown depth of Upper reservoir is 58 m in this site. Generally, a maximum drawdown depth of a pumped storage power project is set within 30 m, considered possible affection to slope stability around a reservoir in case of a deep drawdown depth. In this regard, the drawdown depth of Upper reservoir significantly exceed 30 m, large scale protection measures would be required.



(Source: Study Team)

Figure 9.5.8-1 Access Route for Halgran 4 Sit

(5) Construction Cost

Table 9.5.8-6 shows the construction cost of Halgran 4 scheme, which is calculated according to the method and conditions mentioned in sub-clause 9.4.4. This site is applicable to both of 200 MW/unit and to 150 MW/unit.

Table 9.5.8-6 Construction Cost of Halgran 4 Scheme

Item/Project		Halgran 4		Remarks
		200MW*3unit	150MW*4units	
		*10^{3}USD	*10^{3}USD	
1.	Preparation and Land Acquisition	8,214	8,386	
	(1) Access Roads			
	(2) Compensation & Resettlement			
	(3) Camp & Facilities	8,214	8,386	3. Civil Works * 2%
2.	Environmental Mitigation Cost	12,321	12,579	3. Civil Works * 3%
3.	Civil Works	410,691	419,313	
4.	Hydromechanical Works	53,284	54,459	
5.	Electro-Mechanical Equipment	194,400	201,300	
6.	Transmission Line			
	Direct Cost	678,910	696,037	
7.	Administration and Engineering Service	101,836	104,406	Direct Cost * 15%
8.	Contingency	67,891	69,604	Direct Cost * 10%
9.	Interest during Construction		0	
	Total Cost	848,637	870,047	
	Power Output	600,000	600,000	
	USD per kW	1,414	1,450	

(Source: Study Team)

Main features of the civil structures are shown as follows;

- Upper Dam

Type	Rock Fill	
Height *Crest Length	89m * 550m	
Volume	4,900 * 10^3m^3	

- Lower Dam

Type	Rock Fill	
Height * Crest Length	71m * 290m	
Volume	2,100 * 10^3m^3	

- Headrace Tunnel Dia	200MW/unit	5.8m * 1,000m * 1 line
*Length*line	150MW/unit	4.1m * 1,000m * 2 line
- Penstock Tunnel Dia	200MW/unit	4.5m * 927m * 1 line
*Length*line	150MW/unit	3.2m * 927m * 2 line
- Tailrace Tunnel Dia	200MW/unit	6.3m * 1,430m * 1 line
*Length*line	150MW/unit	4.5m * 1,430m * 1 line

9.5.9 Maha 1

(1) General Outline

This scheme is the pumped storage power project having 600 MW of the rated output, which utilizes 464.23 m of the rated head created by the difference in height between Upper reservoir and Lower reservoir, and 155.16 m3/s of the rated discharge for power generation. 6.0 hours of the equivalent peaking time is ensured. Upper reservoir is located in one of the left bank tributary of Maha River. Lower reservoir is located in Maha River main stream.

Review on the plan (250 MW/unit * two units) by the initial JICA Study is carried out in order to make it appropriate to the restriction of the unit capacity; 200 MW/unit basis and 150 MW/unit basis. It is obvious that 496 m of the gross head by the initial JICA Study is within the applicable head range for 200 MW/unit. However, the location of upper dam axis is shifted to closer location to Lower reservoir from the original one, because the dam axis site having more suitable topographic conditions than the original ones.

Ratio of the horizontal waterway length (L) and the gross head (H) is 6.4 (=L/H).

(2) Geomorphology and geology

The site geology belongs to Kadugannawa Complex (or HC in close to KC/HC boundary) and mainly comprises gneisses.

The upper reservoir consists of gneisses, and locates itself on the north wing of the anticline folding axis thus dipping NE in general. The upper reservoir site gneiss is hard and is anticipated to have no problem for water sealing capability. There are small collapses on the right rim from the aerophotographs but none on the left rim.

The upper dam axis is locate on gneisses, forming a steep slope on both abutment keeping it hard and stable. The weathering depth is anticipated shallow. There are some colluviums on the bottom of the abutment but does not represent landslide features, there are no geological issues in the upper damsite.

The water route passes gneisses and is anticipated hard. It also passes 1 fault but is not anticipated to have much issues except the crossing zone.

The underground powerhouse is planned at gneisses and is anticipated hard.

The lower reservoir locates itself on the north wing of the anticline folding axis thus dipping NE in general. The lower reservoir site comprises mainly gneisses (gneiss on the right rim, Charnokite on the left rim) and is hard. However, the limestone band (it is likely banded between gneisses with around 200m in thickness) is seen on the riverbed. Along side the NW-SE river, NW-SE trending fault is estimated. This Maha river is considered have been formed by the successive erosion of the NW-SE fault, and the limestone band also may have been suffered continuous erosion caused by the fault and the river. The fault displacement on the fault is not clear on the existing geological map but may be lateral fault from the geomorphological features of the surrounding ridges.

The right rim forms a relatively steep mountain slope, and the left rim forms rather slower slope with thicker weatherings. The left rim is anticipated to be “dipping plane” with thicker colluviums. It also shows a clear landslide at higher place in the mountain slope. The extent of the landslide must be surveyed for the impact on the site. The left rim thus is possibly easier to cause surface collapses.

The lower dam is at mainly gneisses (gneisses on the right abutment, Charnokite on the left abutment), both are hard. The bottom of the right abutment stays some colluvium (roughly below EL 330m and maybe limited in volume) and the left abutment has relatively thicker surface weatherings. The riverbed shows large outcrops of hard gneisses without any sand- gravels. Gneiss is massive (spacing 1-2m) with a few joints dipping to right bank (NNE/10-20N). The firm fresh gneiss can be revealed only a few meter excavation, and it is expected to hold a sufficient water sealing capability of the basement rock. The issue is the limestone band on the riverbed which may be not so thick but is not known for the characteristics yet. Some drilling surveys are required to investigate it of its characteristics and its permeability aspect (and maybe suitable sealing treatment). There are no critical geological issues in the upper dam site.

(3) Natural and social environments

1) Upper dam/reservoir

a) Natural environment

Table 9.5.9-1 shows the conditions of the natural environment of the Maha 1 upper dam/reservoir.

Table 9.5.9-1 Conditions of the Natural Environment of the Maha 1 Upper Dam/Reservoir

Name of site / Characteristics	Maha 1 Upper dam/reservoir
Meteorological condition	The area is in the Wet Zone. From March to November, the area receives lots of rainfall. In May and June and in November there are peaks of the rainfall. The average annual rainfall is about 1,600 – 2,300 mm.
Hydrological condition	No data available.
Land slide	According to the Landslide Map of NBRO, landslides may occur at modest levels around the reservoir, and it is likely to occur near the dam.
Water quality	No data available.
Protected area including other important areas (e.g. World Heritage Site)	The site is located at about 20 km from the closest protected area (Hantana Environmental Protection Area).
Fauna and flora	Number of faunal endangered species CR: 0, EN: 0, VU: 2 Number of floral endangered species CR: 0, EN: 0, VU: 2

Characteristics \ Name of site	Maha 1 Upper dam/reservoir
Habitats	The site is agricultural lands dominated by tea plantations, and there is poor riverine vegetation along the stream. The biodiversity and species richness are low. The area of the close downstream of the dam is tea plantations, and the riverine vegetation is disturbed by the human activities. The biodiversity and species richness are low.

Note: CR: Critically Endangered、EN: Endangered、VU: Vulnerable

b) Social environment

Table 9.5.9-2 shows the conditions of the social environment of the Maha 1 upper dam/reservoir.

Table 9.5.9-2 Conditions of the Social Environment of the Maha 1 Upper Dam/Reservoir

Characteristics \ Name of site	Maha 1 Upper dam/reservoir
Location	Alugolla (GN), Pathithalawa (GN), Keligruop (GN), Ganga Ihala Korale Division, Kandy District
Demographic status of the GND	Alugolla Population: 1,994, No. of HHs: 491, Average No. of family: 4.06 Major local industry: Agriculture Average monthly income: No data Patithalawa Population: 1,998, No. of HHs: 538, Average No. of family: 3.71 Major local industry: Temporary worker, Private sector Average monthly income : No data Keligruop Populaton: 682, No. of HHs: 164, Average No. of family: 4.16 Major local industry: Agriculture, Private sector Average monthly income: No data
Accessibility to the proposed site	The site is accessible by the main road from Gampola to Dolobage and through the rural roads to the Kelly Group. Existing estate roads need to be improved for the access roads.
Extent of resettlement	76 households including shops and line rooms, About 2 km of the estate roads.
Extent of land acquisition	Paddy: 2.6ha, Home garden: 1.1ha, Tea plantation: 50.0ha, Other cultivation: 5.3ha、 Total: 59.0ha
Land use pattern of the area	Paddy, Home garden, Shurubs, Tea plantation, Other cultivation
River utilization especially in downstream areas	None
Religious, cultural and archeological heritages	None
Tourism site	None
Existence of indigenous people	None
Existence of poverty people	Alugolla: 32.6% of HHs receive government aid package known as

Name of site / Characteristics	Maha 1 Upper dam/reservoir
	"Samurdhi" given to people who are considered "poor". Pathithalawa: 41.6% of HHs receive government aid package known as "Samurdhi" given to people who are considered "poor". Keligruop: 48.7% of HHs receive government aid package known as "Samurdhi" given to people who are considered "poor".

2) Lower dam/reservoir

a) Natural environment

Table 9.5.9-3 shows the conditions of the natural environment of the Maha 1&2 lower dam/reservoir.

Table 9.5.9-3 Conditions of the Natural Environment of the Maha 1&2 Lower Dam/Reservoir

Name of site / Characteristics	Maha 1&2 Lower dam/reservoir
Meteorological condition	The area is in the Wet Zone. From March to November, the area receives lots of rainfall. In May and June and in November there are peaks of the rainfall. The average annual rainfall is about 1,600 – 2,300 mm.
Hydrological condition	No data available.
Land slide	According to the Landslide Map of NBRO, a landslide is likely to occur around the reservoir, and it is not likely to occur near the dam.
Water quality	No data available.
Protected area including other important areas (e.g. World Heritage Site)	The site is located at about 18 km from the closest protected area (Hantana Environmental Protection Area).
Fauna and flora	Number of faunal endangered species CR: 3, EN: 5, VU: 12 Number of floral endangered species CR: 1, EN: 1, VU: 10
Habitats	In the site, there are home gardens, rubber plantations and secondary forests. The riverine vegetation is disturbed by the human activities. Although the habitats are altered by the human activities, since various habitats are distributed in a mosaic pattern, the biodiversity and species richness are medium. The area of the close downstream of the dam has poor forest and riverine vegetation, and the biodiversity and species richness are low.

Note: CR: Critically Endangered、EN: Endangered、VU: Vulnerable

b) Social environment

Table 9.5.9-4 shows the conditions of the social environment of the Maha 1&2 lower dam/reservoir.

Table 9.5.9-4 Conditions of the Social Environment of the Maha 1&2 Lower Dam/Reservoir

Name of site / Characteristics	Maha 1&2 Lower dam/reservoir
Location	Arama(GN), Deiyanwela(GN), Watakedeniya(GN), Uduwella (GN), Aranayake Division, Kegalle District
Demographic status of the GND	Arama Population: 911, No. of HHs: 239, Average No. of family: 3.81 Major local industry: No data Average monthly income: No data Deiyanwela Population: 987, No. of HHs: 272, Average No. of family: 3.63 Major local industry: No data Average monthly income: No data Watakedeniya Population: 1,845, No. of HHs: 536, Average No. of family: 3.44 Major local industry: Agriculture Average monthly income: No data Uduwella Population: 1,372, No. of HHs: 360, Average No. of family: 3.81 Major local industry: Private sector, Temporary worker Average monthly income: No data
Accessibility to the proposed site	The site is accessible by the main road from Mawanella via Aranayake to Arama. The last 1.5 km of the existing estate road which leads to Asupiniella Mini-hydropower plant needs to be improved for the access roads.
Extent of resettlement	8 households including a line room where 16 families are residing, 2 Mini-hydropower plants (1.5MW＆4MW)
Extent of land acquisition	Paddy: 0.02ha, Home garden: 6.4ha, Rubber plantation: 20.7ha, Total: 27.1ha
Land use pattern of the area	Paddy, Home garden, Rubber plantation
River utilization especially in downstream areas	Local people use river water for bathing, and 4 pipes of drinking water which the source is from Maha Oya. 2 Mini-hydropower plants and a small irrigation canal will be affected by the proposed project. No fishery.
Religious, cultural and archeological heritages	None
Tourism site	There is no tourism activity at the site, but nationally famous water fall (Asupini Ella) can be clearly seen from the site (the straight line distance is about 2 km from the dam axis).
Existence of indigenous people	None
Existence of poverty people	Arama: 39.74% of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”. Deiyanwela: 40.44% of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”. Watakedeniya: 43.47% of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”. Uduwella: 49.44% of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”.

3) Evaluation of the natural and social environments of the Maha 1

a) Evaluation of the upper dam/reservoir

Natural environment:

The result of the evaluation of the natural environment of the Maha 1 upper dam/reservoir is shown in Table 9.5.9-5.

Table 9.5.9-5 Evaluation of the Natural Environment of the Maha 1 Upper Dam/Reservoir

Scoping items	Evaluation
Impacts on fauna and flora	Rating [A] The site has already been altered to tea plantations, and the remaining riverine vegetation is poor. The biodiversity and species richness are low. No Critically Endangered and/or Endangered species are recorded. The project may give not significant or limited impacts on the natural environment.

Social environment:

The results of the evaluation of the social environment of the Maha 1 upper dam/reservoir are shown in Table 9.5.9-6.

Table 9.5.9-6 Evaluation of the Social Environment of the Maha 1 Upper Dam/Reservoir

Scoping items	Evaluation
Impacts on local communities	Rating [C] 76 households, about 2 km of existing estate road and some dug wells will be inundated. This is adverse impact on the local people. Therefore the evaluation rating is [C].
Impacts on industries	Rating [B] The total inundated area is 59.0ha (Tea plantation: 50.0ha, Other cultivation: 5.3ha, Paddy: 2.6ha, Home garden: 1.1ha). It may quite big impact on livelihood of local people. Therefore the evaluation rating is [B].
Impacts on cultural and landscape	Rating [A] There is no religiously or culturally significant place. There is no issue on landscape. Therefore the evaluation rating is [A].

b) Evaluation of the lower dam/reservoir

Natural environment:

The result of the evaluation of the natural environment of the Maha 1&2 lower dam/reservoir is shown in Table 9.5.9-7.

Table 9.5.9-7 Evaluation of the Natural Environment of the Maha 1&2 Lower Dam/Reservoir

Scoping items	Evaluation
Impacts on fauna and flora	Rating [B] The site has already been disturbed by the human activities, but various habitats are distributed in a mosaic pattern, the biodiversity and species richness are medium. Regarding endangered species, endangered species (fauna: CR: 3, EN: 5, flora: CR: 1, EN: 2) are recorded. The project may give impacts on the natural environment.

Social environment:

The results of the evaluation of the social environment of the Maha 1&2 lower dam/reservoir are shown in Table 9.5.9-8.

Table 9.5.9-8 Evaluation of the Social Environment of the Maha 1&2 Lower Dam/Reservoir

Scoping items	Evaluation
Impacts on local communities	Rating [B] 8 households, 2 existing Mini-hydropower plants, and 4 pipes of drinking water which the source is from Maha Oya will be inundated. Therefore the evaluation rate is [B].
Impacts on industries	Rating [B] Total inundated area is 27.1ha (Rubber plantation: 20.7ha, Home garden: 6.4ha, Paddy: 0.02ha). It may impact on livelihood of local people. Therefore the evaluation rating is [B].
Impacts on cultural and landscape	Rating [A] There is a nationally famous water fall can be seen from the proposed dam axis the straight distance is about 2 km. It will affirmative impact that the existing road will be improved by the project. Seeing the water fall by tourist will be increased that will contribute the local revitalization. There is no religiously or culturally significant place. Therefore the evaluation rating is [A].

c) Overall evaluation

Table 9.5.9-9 shows the overall evaluation of the Maha 1 as a cluster with the evaluations of the upper and lower dam/reservoirs.

Table 9.5.9-9 Overall Evaluation of the Maha 1 Cluster

Scoping items	Evaluation		
	Upper dam/reservoir	Lower dam/reservoir	Overall
Impacts on fauna and flora	A	B	B
Impacts on local communities	C	B	C
Impacts on industries	B	B	B
Impacts on cultural landscape	A	A	A

A: Project is not likely to have significant adverse impacts on natural environment and society and/or limited to a small scale.

B: Project is likely to have negative impact on natural environment and society, but less adverse than C

C: Project is likely to have significant adverse impacts on natural environment and society.

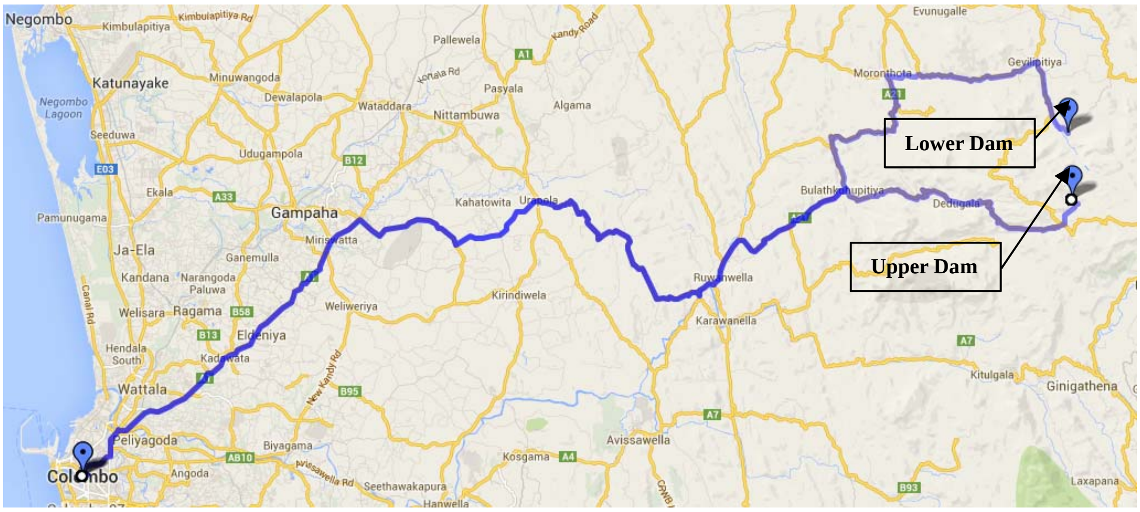
(4) Technical Evaluation

The distance from Colombo to Upper reservoir is around 103 km through the main roads; A1, A21, and 4 km of the by-road. Access by vehicles to the dam axis area is possible. Although, there are not any existing accesses to the river bed so far, the construction of new accesses would not be so difficult, due to the gentle topography in around dam axis area and the difference in height is limited from 20 to 30 m, judging from the topographic map scale 1 to 10,000.

The distance from Colombo to Upper reservoir is around 110 km through the main roads; A1, A21, B136, B278 and 2 km of the by-road. Access by vehicles to the dam axis area is possible. The difference in height from the river bed to the existing road is in the range of less than 10 m and the gentle topography is dominant; therefore, new access road construction and reclamation of temporary yards for the construction activity would be rather easy.

Furthermore, the plateau having almost horizontal top which covers the upstream section of the waterway makes possible to locate the surge tank of the headrace tunnel in the downstream side. Consequently, the powerhouse cavern can be also located in rather downstream side, which contributes to shorten the length of the access tunnel to powerhouse cavern. Since all of construction activities in a powerhouse cavern, in general, cannot be started until access to a cavern is assured, relatively shorter access tunnel length in this scheme would be advantageous point in terms of the construction schedule. On the other hand, waterway alignment should be determined carefully paying attention to possible negative pressure in the headrace tunnel caused by the long headrace tunnel.

As for the manufacturing limitation, both 200MW/unit and 150 MW/unit are applicable.



(Source: Study Team)

Figure 9.5.9-1 Access Rout to Maha 1 Site

(5) Construction Cost

Table 9.5.9-10 shows the construction cost of Maha 1scheme,which is calculated according to the method and conditions mentioned in sub-clause 9.4.4. This site is applicable to both of 200 MW/unit and 150 MW/unit.

Table 9.5.9-10 Construction Cost of Maha 1 Site

Item/Project		Maha 1		Remarks
		200MW*3unit	150MW*4units	
		$*10^3$USD	$*10^3$USD	
1.	Preparation and Land Acquisition	5,251	5,393	
	(1) Access Roads			
	(2) Compensation & Resettlement			
	(3) Camp & Facilities	5,251	5,393	3. Civil Works * 2%
2.	Environmental Mitigation Cost	7,877	8,089	3. Civil Works * 3%
3.	Civil Works	262,568	269,637	
4.	Hydromechanical Works	53,622	54,801	
5.	Electro-Mechanical Equipment	195,700	201,300	
6.	Transmission Line			
	Direct Cost	525,018	539,219	
7.	Administration and Engineering Service	78,753	80,883	Direct Cost * 15%
8.	Contingency	52,502	53,922	Direct Cost * 10%
9.	Interest during Construction		0	
	Total Cost	656,273	674,024	
	Power Output	600,000	600,000	
	USD per kW	1,094	1,123	

(Source: Study Team)

Main features of the civil structures are shown as follows;

- Upper Dam		
Type	Rock Fill	
Height *Crest Length	52m * 210m	
Volume	900 * 10^3m^3	
- Lower Dam		
Type	Rock Fill	
Height * Crest Length	75m * 360m	
Volume	2,800 * 10^3m^3	
- Headrace Tunnel Dia	200MW/unit	5.8m * 2,030m * 1 line
*Length*line	150MW/unit	4.1 m * 2,030m * 2 line
- Penstock Tunnel Dia	200MW/unit	4.5m * 940m * 1 line
*Length*line	150MW/unit	3.2 m * 940m * 2 line
- Tailrace Tunnel Dia	200MW/unit	6.3m * 390m * 1 line
*Length*line	150MW/unit	4.5 m * 390m * 2 line

9.5.10 Maha 2

(1) General Outline

This scheme is the pumped storage power project having 600 MW of the rated output, which utilizes 434.78 m of the rated head created by the difference in height between Upper reservoir and Lower reservoir, and 165.67 m3/s of the rated discharge for power generation. 6.0 hours of the equivalent peaking time is ensured. Upper reservoir is located on the plateau of the left bank of Maha River. Lower reservoir is a common one with that of Maha 1 scheme.

The site for Upper reservoir is newly found by the Study Team.

Ratio of the horizontal waterway length (L) and the gross head (H) is 4.8 (=L/H).

(2) Geomorphology and geology

The site geology belongs to Kadugannawa Complex (or HC in close to KC/HC boundary) and comprises mainly gneisses. The upper reservoir consists of gneiss. It locates itself on the north wing of the anticline folding axis thus dipping NE in general. The axis of the anticline forms the deformation zone but it remains west of the reservoir, thus does not touch the rim of the reservoir. The reservoir site gneiss is hard and is anticipated to have no problem for water sealing capability. There are no large landslides or colluviums around the reservoir.

The upper dam axis is located at gneisses with both abutments' steep slopes thus hard and stable.The surface outcrops are seen on the slopes that the depth of the weathering is shallow. The development of layers cannot be confirmed (some outcrop are seen 60W50E of beddings with joint interval 10cm, on the right rim, but may be not representing the whole trend). Some colluviums are seen on the bottom but not thick. The right downstream of the dam axis is a steep downward valley that a preferable dam location shall be at rather upstream side.

The water route and the underground powerhouse site are in gneiss and hard.

The lower reservoir is the same as Maha 1 as in 9.5.9.

(3) Natural and social environments

1) Upper dam/reservoir

a) Natural environment

Table 9.5.10-1 shows the conditions of the natural environment of the Maha 2 upper dam/reservoir.

Table 9.5.10-1 Conditions of the Natural Environment of the Maha 2 Upper Dam/Reservoir

Name of site / Characteristics	Maha 2 Upper dam/reservoir
Meteorological condition	The area is in the Wet Zone. From March to November, the area receives lots of rainfall. In May and June and in November there are peaks of the rainfall. The average annual rainfall is about 1,600 – 2,300 mm.
Hydrological condition	No data available.
Land slide	According to the Landslide Map of NBRO, landslides are not likely to occur around the site.
Water quality	No data available.
Protected area including other important areas (e.g. World Heritage Site)	The site is located at about 21 km from the closest protected area (Hantana Environmental Protection Area).
Fauna and flora	Number of faunal endangered species CR: 0, EN: 1, VU: 2 Number of floral endangered species CR: 0, EN: 0, VU: 0
Habitats	The site is agricultural lands dominated by tea plantations, and there are home gardens and outcrops. The biodiversity and species richness are low. The area of the close downstream of the dam is tea plantations, terraced paddy fields and poor riverine vegetation. The biodiversity and species richness are low.

Note: CR: Critically Endangered、EN: Endangered、VU: Vulnerable

b) Social environment

Table 9.5.10-2 shows the conditions of the social environment of the Maha 2 upper dam/reservoir.

Table 9.5.10-2 Conditions of the Social Environment of the Maha 2 Upper Dam/Reservoir

Characteristics \ Name of site	Maha 2 Upper dam/reservoir
Location	Patithalawa (GN), Podape (GN), Narangala (GN), Ganga Ihala Korale Division, Kandy District
Demographic status of the GND	Patithalawa Population: 1,998, No. of HHs: 538, Average No. of family: 3.71 Major local industry: Temporary worker, Private sector Average monthly income: No data Podape Population: 971, No. of HHs: 273, Average No. of family: 3.56 Major local industry: No data Average monthly income: No data Narangala Population: 833, No. of HHs: 152, Average No. of family: 5.48 Major local industry: No data Average monthly income: No data
Accessibility to the proposed site	The site is accessible by the main road from Gampola to Dolosbage and from Dolosbage to the Berawila village and through estate roads. Existing estate roads need to be improved for the access roads.
Extent of resettlement	16 households including a line house where 16 families are residing, and about1 km of the estate roads.
Extent of land acquisition	Tea plantation: 21.8ha, Home garden: 1.8ha, Total: 23.6ha
Land use pattern of the area	Tea plantation, Home garden
River utilization especially in downstream areas	None
Religious, cultural and archeological heritages	None
Tourism site	None
Existence of indigenous people	None
Existence of poverty people	Pathithalawa: 41.6% of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”. Podape: 46.5% of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”. Narangala: 60.5% of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”.

2) Lower dam/reservoir

They are the same as the lower dam/reservoir in “9.5.9 Maha 1”.

3) Evaluation of the natural and social environments of the Maha 2

a) Evaluation of the upper dam/reservoir

Natural environment:

The result of the evolution of the natural environment of the Maha 2 upper dam/reservoir is shown in Table 9.5.10-3.

Table 9.5.10-3 Evaluation of the Natural Environment of the Maha 2 Upper Dam/Reservoir

Scoping items	Evaluation
Impacts on fauna and flora	Rating [B] The site has already been altered mainly to tea plantations, and the biodiversity and species richness are low. One faunal Endangered (EN) species is recorded. The project may give impacts on the natural environment.

Social environment:

The results of the evaluation of the social environment of the Maha 2 upper dam/reservoir are shown in Table 9.5.10-4.

Table 9.5.10-4 Evaluation of the Social Environment of the Maha 2 Upper Dam/Reservoir

Scoping items	Evaluation
Impacts on local communities	Rating [B] 16 households including line house, and about 1 km of the tea estate road will be inundated. Therefore the evaluation rating is [B].
Impacts on industries	Rating [B] Total inundated area is 23.6ha (Tea plantation: 21.8ha, Home garden: 1.8ha). It may impact on the livelihood of local people. Therefore the evaluation rating is [B].
Impacts on cultural and landscape	Rating [A] There is no religiously or culturally significant place. There is no issue on landscape. Therefore the evaluation rating is [A].

b) Evaluation of the lower dam/reservoir

They are the same as the lower dam/reservoir in “9.5.9 Maha 1”.

c) Overall evaluation

Table 9.5.10-5 shows the overall evaluation of the Maha 2 as a cluster with the evaluations of the upper and lower dam/reservoirs.

Table 9.5.10-5 Overall Evaluation of the Maha 2 Cluster

Scoping items	Evaluation		
	Upper dam/reservoir	Lower dam/reservoir	Overall
Impacts on fauna and flora	B	B	B
Impacts on local communities	B	B	B
Impacts on industries	B	B	B
Impacts on cultural and landscape	A	A	A

A: Project is not likely to have significant adverse impacts on natural environment and society and/or limited to a small scale.

B: Project is likely to have negative impact on natural environment and society, but less adverse than C

C: Project is likely to have significant adverse impacts on natural environment and society.

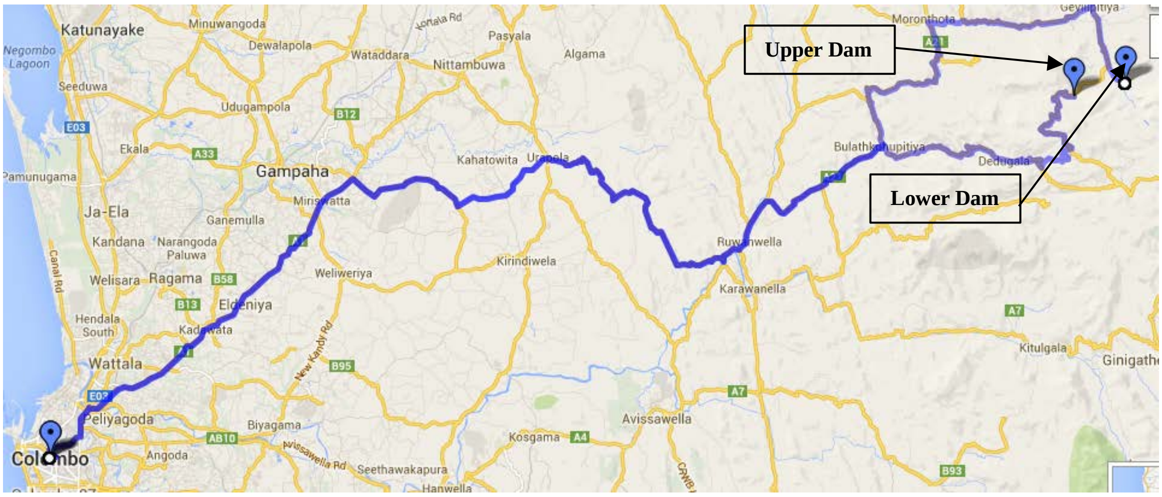
(4) Technical Evaluation

The distance from Colombo to Upper reservoir is around 107 km through the main roads; A1, A21, B67, B588 and 9 km of the by-road. Vehicles can access to near Upper reservoir. Upper reservoir is planned in the one topographic depression of which slope is almost covered by the tea plantation. Some of foot-paths are available to the dam axis. Construction works for new accesses to the dam foundation would not be done with so much difficulty.

Lower reservoir is a common one with Maha 1 scheme.

As for temporary yards for construction works, even though topography around the dam axis is rather steep, there exists relatively dominant gentle topography in upstream area, and the works area is compact because of limited Upper reservoir area (inundated area). Also, it should be considered that the broad area is available in Lower reservoir area. Due to the above-mentioned reasons, any serious difficulties do not exist.

As for the manufacturing limitation, 200 MW/unit and 150 MW/unit are both applicable to this site.



(Source: Study Team)

Figure 9.5.10-1 Access Route to Maha 2 Site

(5) Construction Cost.

Table 9.5.10-6 shows the construction cost of Maha 1scheme, which is calculated according to the method and conditions mentioned in sub-clause 9.4.4. This site is applicable to both of 200 MW/unit and 150 MW/unit.

Table 9.5.10-6 Construction Cost of Maha 2 Scheme

Item/Project		Maha 2		Remarks
		200MW*3unit	150MW*4units	
		*10^3USD	*10^3USD	
1.	Preparation and Land Acquisition	6,394	6,539	
	(1) Access Roads			
	(2) Compensation & Resettlement			
	(3) Camp & Facilities	6,394	6,539	3. Civil Works * 2%
2.	Environmental Mitigation Cost	9,591	9,808	3. Civil Works * 3%
3.	Civil Works	319,712	326,945	
4.	Hydromechanical Works	50,606	52,588	
5.	Electro-Mechanical Equipment	197,300	204,400	
6.	Transmission Line			
	Direct Cost	583,604	600,280	
7.	Administration and Engineering Service	87,541	90,042	Direct Cost * 15%
8.	Contingency	58,360	60,028	Direct Cost * 10%
9.	Interest during Construction		0	
	Total Cost	729,505	750,350	
	Power Output	600,000	600,000	
	USD per kW	1,216	1,251	

(Source: Study Team)

Main features of the civil structures are shown as follows;

- Upper Dam		
Type	RCC	
Height *Crest Length	79m * 310m	
Volume	380 * 10^3m^3	
- Lower Dam		
Type	Rock Fill	
Height * Crest Length	76m * 360m	
Volume	2,800 * 10^3m^3	
- Headrace Tunnel Dia	200MW/unit	6.0m * 510m * 1 line
*Length*line	150MW/unit	4.2 m * 510m * 2 line
- Penstock Tunnel Dia	200MW/unit	4.6m * 898m * 1 line
*Length*line	150MW/unit	3.3 m * 898m * 2 line
- Tailrace Tunnel Dia	200MW/unit	6.5m * 1,000m * 1 line
*Length*line	150MW/unit	4.6 m * 1,000m * 2 line

9.5.11 Loggal

(1) General Outline

This scheme is the pumped storage power project having 600 MW of the rated output, which utilizes 561.76 m of the rated head created by the difference in height between Upper reservoir and Lower reservoir, and 128.22 m3/s of the rated discharge for power generation. 6.0 hours of the equivalent peaking time is ensured. Upper reservoir is located in the course of Kegale River, which is one of the tributary of Loggal River. Lower reservoir is located in Katugaha Kandura River, which is also one of the tributary of Loggal River.

Review on the plan (250 MW/unit * two units) by the initial JICA Study is carried out in order to make it appropriate to the restriction of the unit capacity; 200 MW/unit basis and 150 MW/unit basis. It is obvious that 781 m of the gross head by the initial JICA Study is out of the applicable head range for 200 MW/unit. Therefore, Lower reservoir is shifted from the original location ,which is located in the main course of Loggal River to the tributary flowing in the west side parallel to the main course.

Ratio of the horizontal waterway length (L) and the gross head (H) is 6.5 (=L/H).

(2) Geomorphology and geology

The site geology belongs to Highland Complex and comprises mainly gneiss. The upper reservoir consists of gneisses and locates itself on the anticline folding axis thus dipping NW in general. The axis of the anticline forms the deformation zone but it remains west of the reservoir, thus does not touch the rim of the reservoir.

The upper reservoir site is Charnokite gneisses and hard. Some develops joints but is anticipated to have a few issues for water sealing capability. There are some colluviums on the right rim slope but stable. There are no unstable slopes around the reservoir from the aerophotographs.

The upper dam axis is located at gneisses and the rock is hard. Fine layers (dipping toward upstream in high angle) develop but such joints are anticipated sealed except surface weathering zone (NW/80N, spacing 10-20cm). There are sands and gravels on the riverbed but they are thin. There are no landslides around the damsite from the aerophotographs. There are no geologic issues in the upper damsite.

The water route passes in the gneisses dipping in high angle. It also passes through some limestone but the estimated length would be 2-300m. there are no faults in the water route.

The underground powerhouse is planned at gneisses and the rocks are hard.

The lower reservoir locates itself on the north wing to the center of the syncline folding axis, thus dipping NW with almost flat to gently dipping to the left rim. It comprises quartzite and Charnokite. The lower reservoir site comprises a sharp dipping quartz mountain on the left abutment and is stable. There are no landslides from the aerophotographs. Quartzite may contains developed joints inside but the weathering remains only on the surface thus the rock itself is hard. The right abutment comprises gneisses with medium to slow slope but is stable. The colluvium is relatively thick. The riverbed is broadly covered by the alluvium deposits with some thickness (200m wide and estimated depth is 10m). it is anticipated to hold water sealing capability.

The lower dam is located at quartzite on the left, and gneisses on the right. The quartzite, dipping in low angle towards upstream thinly weathered on surface (a few m) is anticipated to hold sufficient strength when fresh and has no problem as a damsite. The gneiss is massive (2-3m in size) and is also hard. The dam length is wide as 500m but there are no geological issues in the lower damsite.

(3) Natural and social environments

1) Upper dam/reservoir

a) Natural environment

Table 9.5.11-1 shows the conditions of the natural environment of the Loggal upper dam/reservoir.

Table 9.5.11-1 Conditions of the Natural Environment of the Loggal Upper Dam/Reservoir

Name of site / Characteristics	Loggal Upper dam/reservoir
Meteorological condition	The site is in the Intermediate Zone, and receives rainfall from October to February. No data on average annual rainfall is available since there is not a meteorological station near the site.
Hydrological condition	No data available.
Land slide	According to the Landslide Map of NBRO, landslides are likely to occur at a moderate level around the site.
Water quality	No data available.
Protected area including other important areas (e.g. World Heritage Site)	The site is located at about 16.5 km from the closest protected area (Victoria, Randenigala, Rantembe Sanctuary).
Fauna and flora	Number of faunal endangered species CR: 1, EN: 2, VU: 3 Number of floral endangered species CR: 0, EN: 1, VU: 5
Habitats	In the site, there are tea plantations, home gardens, acacia and eucalyptus plantations, grasslands, paddy fields and savanna in a mosaic pattern. The biodiversity and species richness are high. The area of the close downstream of the dam has tea plantations, savanna and narrow riverine forests, and the biodiversity and species richness are medium.

Note: CR: Critically Endangered、EN: Endangered、VU: Vulnerable

b) Social environment

Table 9.5.11-2 shows the conditions of the social environment of the Loggal upper dam/reservoir.

Table 9.5.11-2 Conditions of the Social Environment of the Loggal Upper Dam/Reservoir

Characteristics \ Name of site	Loggal Upper dam/reservoir
Location	Pitamaruwa (GN),
Demographic status of the GND	Population: 869, No. of HHs: 249, Average No. of family: 3.49 Major local industry: No data Average monthly income: No data
Accessibility to the proposed site	The site is accessible by the main road B 36 and through a rural road from Meegahakiula through Kalugahakandura to Pitimadura.
Extent of resettlement	18 households, 1 Buddhist temple, the access road to the temple 10 dug wells will be inundated
Extent of land acquisition	Paddy: 13.7ha, Home garden: 19.3ha, Forest: 3.4ha Total: 36.4ha
Land use pattern of the area	Paddy, Home garden, Forest
River utilization especially in downstream areas	The local people uses the river water for drinking, bathing and washing. No fishery. A mini-hydropower plant (4MW) which contracts with the Ceylon Electricity Board expires in 2023 is located about 0.5 km downstream from the dam axis. It will be affected during construction of the proposed project.
Religious, cultural and archeological heritages	There is no burial ground at or in the vicinity of the site, some people have used their own home garden to bury the dead relatives. The Buddhist temple which is a culturally the most important and the only temple in the vicinity of the area will be inundated.
Tourism site	None
Existence of indigenous people	None
Existence of poverty people	Pitamadura: 7.3% of HHs receive government aid package known as "Samurdhi" given to people who are considered "poor".

2) Lower dam/reservoir

a) Natural environment

Table 9.5.11-3 shows the conditions of the natural environment of the Loggal lower dam/reservoir.

Table 9.5.11-3 Conditions of the Natural Environment of the Loggal Lower Dam/Reservoir

Characteristics \ Name of site	Loggal Lower dam/reservoir
Meteorological condition	The site is in the Intermediate Zone, and receives rainfall from October to February. No data on average annual rainfall is available since there is not a meteorological station near the site.
Hydrological condition	No data available.
Land slide	According to the Landslide Map of NBRO, landslides are likely to occur at low and moderate levels around the site.
Water quality	No data available.
Protected area including other important areas (e.g. World	The site is located at about 12.5 km from the closest protected area (Victoria, Randenigala, Rantembe Sanctuary).

Name of site / Characteristics	Loggal Lower dam/reservoir
Heritage Site)	
Fauna and flora	Number of faunal endangered species CR: 0, EN: 2, VU: 3 Number of floral endangered species CR: 0, EN: 0, VU: 2
Habitats	In the site, there are paddy fields, crop fields, home gardens, secondary forests, and degraded riverine forests. The biodiversity and species richness are medium. The area close downstream of the dam has the similar habitats, and the biodiversity and species richness are medium.

Note: CR: Critically Endangered、EN: Endangered、VU: Vulnerable

b) Social environment

Table 9.5.11-4 shows the conditions of the social environment of the Loggal lower dam/reservoir.

Table 9.5.11-4 Conditions of the Social Environment of the Loggal Lower Dam/Reservoir

Name of site / Characteristics	Loggal Lower dam/reservoir
Location	Kalugahakandura (GN), Meegahakiula Division, Badulla District
Demographic status of the GND	Population: 651, No. of HHs: 192, Average No. of family: 3.39 Major local industry: No data Average monthly income: No data
Accessibility to the proposed site	The site is accessible by the main road B 36 and through a rural road from Meegahakiula to Kalugahakandura. An access road has to be constructed from the road to the dam crest site through home garden.
Extent of resettlement	14 households, A Buddhist temple with historic and cultural value is located on the right bank, a primary school and a post office is located on the left bank will be inundated. About 1 km long stretch of the Kalugahakandura road will be inundated.
Extent of land acquisition	Paddy: 9.4ha, Home garden: 8.3ha, Total: 17.7ha
Land use pattern of the area	Paddy, Home garden, Shrub
River utilization especially in downstream areas	The river is not used by the people either within the inundation area or in the immediate downstream for drinking or fishing but the villagers, especially farmers use it for washing and bathing. No fishery.
Religious, cultural and archeological heritages	A Buddhist temple will be inundated.
Tourism site	None
Existence of indigenous people	None
Existence of poverty people	Kalugahakandura : 13.8% of HHs receive government aid package known as “Samurdhi” given to people who are considered “poor”.

3) Evaluation of the natural and social environments of the Loggal

a) Evaluation of the upper dam/reservoir

Natural environment:

The result of the evaluation of the natural environment of the Loggal upper dam/reservoir is shown in Table 9.5.11-5.

Table 9.5.11-5 Evaluation of the Natural Environment of the Loggal Upper Dam/Reservoir

Scoping items	Evaluation
Impacts on fauna and flora	Rating [B] The site has various habitats in a mosaic pattern, and the biodiversity and species richness are high. Regarding endangered species, endangered species (fauna: CR: 1, EN: 2, flora: EN: 1) are recorded. The project may give impacts on the natural environment.

Social environment:

The results of the evaluation of the social environment of the Loggal upper dam/reservoir are shown in Table 9.5.11-6.

Table 9.5.11-6 Evaluation of the Social Environment of the Loggal Upper Dam/Reservoir

Scoping items	Evaluation
Impacts on local communities	Rating [B] 18 households will be inundated. The river water is used by local people for bathing and washing. Therefore the evaluation rating is [B].
Impacts on industries	Rating [B] Total inundated area is 36.4ha (Paddy: 13.7ha, Home garden: 19.3ha, Forest: 3.4ha). It may impact on the livelihood of local people. A mini-hydropower plant (4MW) is located about 0.5 km downstream from the dam axis may also impact during construction by the project. Therefore the evaluation rating is [B].
Impacts on cultural and landscape	Rating [B] Pitamaruwa Buddhist temple which is a culturally the most important center in Pitimadura and other villages in the area will be affected by the project, though it is not declared as heritage. Therefore the evaluation rate is [B].

b) Evaluation of the lower dam/reservoir

Natural environment:

The result of the evaluation of the natural environment of the Loggal lower dam/reservoir is shown in Table 9.5.11-7.

Table 9.5.11-7 Evaluation of the Natural Environment of the Loggal Lower Dam/Reservoir

Scoping items	Evaluation
Impacts on fauna and flora	Rating [B] The site has various habitats in a mosaic pattern, and the biodiversity and species richness are medium. Regarding endangered species, endangered species (fauna: EN: 2) are recorded. The project may give impacts on the natural environment.

Social environment:

The results of the evaluation of the social environment of the Loggal lower dam/reservoir are shown in Table 9.5.11-8.

Table 9.5.11-8 Evaluation of the Social Environment of the Loggal Lower Dam/Reservoir

Scoping items	Evaluation
Impacts on local communities	Rating [B] 14 households, a primary school, a post office, and about 1 km existing village road will be inundated by the project. The river is not used by the people either within the inundation area or in the immediate downstream for drinking or fishing but the villagers, especially farmers use it for washing and bathing. Therefore the evaluation rating is [B].
Impacts on industries	Rating [B] Total inundated area is 17.7ha (Paddy: 9.4ha, Home garden: 8.3ha). It may impact on the livelihood of local people. Therefore the evaluation rate is [B].
Impacts on cultural and landscape	Rating [B] A Buddhist temple which is located on the right bank will be inundated, though it is not declared as heritage. Therefore the evaluation rating is [B].

c) Overall evaluation

Table 9.5.11-9 shows the overall evaluation of the Loggal as a cluster with the evaluations of the upper and lower dam/reservoirs.

Table 9.5.11-9 Overall Evaluation of the Loggal Cluster

Scoping items	Evaluation		
	Upper dam/reservoir	Lower dam/reservoir	Overall
Impacts on fauna and flora	B	B	B
Impacts on local communities	B	B	B
Impacts on industries	B	B	B
Impacts on cultural and landscape	B	B	B

A: Project is not likely to have significant adverse impacts on natural environment and society and/or limited to a small scale.

B: Project is likely to have negative impact on natural environment and society, but less adverse than C

C: Project is likely to have significant adverse impacts on natural environment and society.

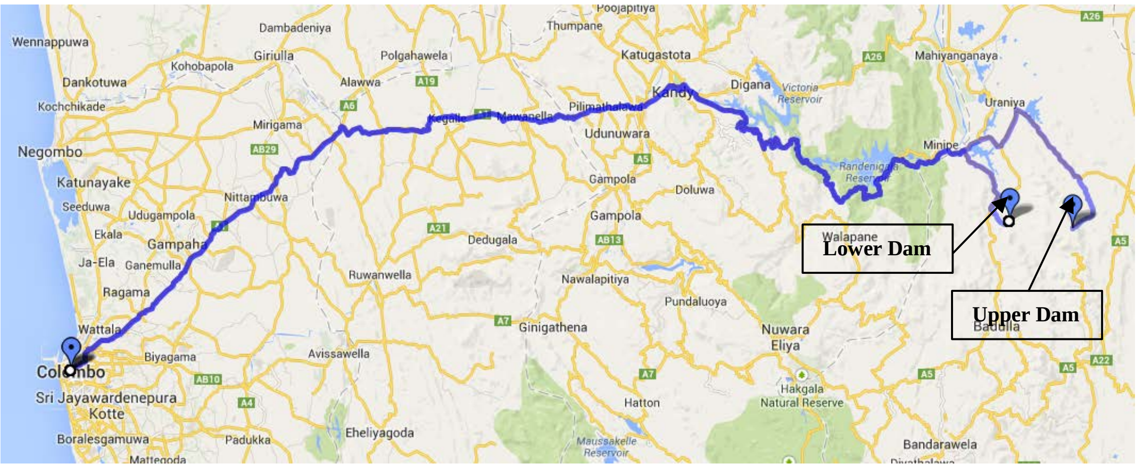
(4) Technical Evaluation

The distance from Colombo to Upper reservoir is around 230 km through the main roads; A1, A26, B413, B492, B36, and 10 km of the by-road. Vehicles can access to near Upper reservoir although steep, narrow, and the most of the by road is steep, narrow and unpaved. Due to rather gentle topography in the dam axis area, which is covered by rice fields almost totally, access to the river bed is possible by walk.

As for access to Lower reservoir, the distance from Colombo to Lower reservoir is around 203 km through the main roads; A1, A26, B413, B492, B36, B57 and 9 km of the by-road (B46). Vehicles can access to near Upper reservoir. A footpath exists to the dam axis, so that access to the river bed is possible.

As for temporary yard acquisition for construction works, rather gentle topography is dominant in both areas of Upper dam axis and Lowe dam axis, so that there do not exist any serious difficulties for land reclamation for them and new access and work road construction.

As for the manufacturing limitation, both 200 MW/unit and 150 MW/unit are applicable to this site; however, applicability of 150 MW/unit is plotted in near boarder line to incapable zone, careful examination would be required in later stage.



(Source: Study Team)

Figure 9.5.11-1 Access Route to Loggal Site

(5) Construction Cost

Table 9.5.11-10 shows the construction cost of Loggal scheme, which is calculated according to the method and conditions mentioned in sub-clause 9.4.4. This site is applicable to both of 200 MW/unit and 150 MW/unit.

Table 9.5.11-10 Construction Cost of Loggal Scheme

Item/Project		Loggal		Remarks
		200MW*3unit	150MW*4units	
		$*10^3$USD	$*10^3$USD	
1.	Preparation and Land Acquisition	6,916	7,054	
	(1) Access Roads			
	(2) Compensation & Resettlement			
	(3) Camp & Facilities	6,916	7,054	3. Civil Works * 2%
2.	Environmental Mitigation Cost	10,373	10,581	3. Civil Works * 3%
3.	Civil Works	345,782	352,692	
4.	Hydromechanical Works	62,287	62,978	
5.	Electro-Mechanical Equipment	188,900	196,700	
6.	Transmission Line			
	Direct Cost	614,258	630,005	
7.	Administration and Engineering Service	92,139	94,501	Direct Cost * 15%
8.	Contingency	61,426	63,000	Direct Cost * 10%
9.	Interest during Construction		0	
	Total Cost	767,823	787,506	
	Power Output	600,000	600,000	
	USD per kW	1,280	1,313	

(Source: Study Team)

Main features of the civil structures are shown as follows;

- Upper Dam		
Type	RCC	
Height *Crest Length	42m * 220m	
Volume	110 * 10^3m^3	
- Lower Dam		
Type	Rock Fill	
Height * Crest Length	76m * 540m	
Volume	5,200 * 10^3m^3	
- Headrace Tunnel Dia	200MW/unit	5.3m * 1,750m * 1 line
*Length*line	150MW/unit	3.7 m * 1,750m * 2 line
- Penstock Tunnel Dia	200MW/unit	4.1m * 1,106m * 1 line
*Length*line	150MW/unit	2.9 m * 1,106m * 2 line
- Tailrace Tunnel Dia	200MW/unit	5.8m * 1,230m * 1 line
*Length*line	150MW/unit	4.1 m * 1,230m * 2 line

9.6 Selection of Promising Sites

9.6.1 General Features of Candidate Sites

Table 9.6.1-1 shows the general features of 11 candidate sites.

Table 9.6.1-1 General Features of 11 Candidate Sites (200MW * 3 units)

Candidate Site		unit	Kiriketi I	Kiriketi II	Maussa-kelle A	Maussa-kelle B	Halgran 1	Halgran 2	Halgran 3	Halgran 4	Maha 1	Maha 2	Logal
Installed Capacity		MW	600	600	600	600	600	600	600	600	600	600	600
Unit Capacity		MW	200	200	200	200	200	200	200	200	200	200	200
Number of Units		unit	3	3	3	3	3	3	3	3	3	3	3
Peak Generating Time		hours	3.8	2.52	6.42	6.28	6.19	6.11	6.05	6.1	6.03	6.09	6.16
Rated Head		m	664.67	731.81	450.30	463.60	576.01	679.25	657.08	465.18	464.23	434.78	561.76
Rated Discharge		m^3	108.37	98.43	159.96	155.37	125.05	106.04	109.62	154.84	155.16	165.67	128.22
Upper Pond	Latitude		6°46'00"	6°45'13"	6°46'49"	6°46'49"	7°01'30"	7°02'30"	7°02'14"	7°04'14"	7°06'01"	7°07'20"	7°06'20"
	Longitude		80°46'15"	80°46'34"	80°33'42"	80°33'42"	80°53'06"	80°52'35"	80°52'31"	80°52'24"	80°28'35"	80°27'26"	81°07'46"
	Catchment Area	km^2	1	1	2	2	32	20	2	2	10	5	5
	Reservoir Area	km^2	0.14	0.04	0.37	0.37	0.17	0.12	0.16	0.15	0.39	0.15	0.43
	Crest Elevation	E.L.-m	1960	1731	1829	1829	1270	1381	1412	1224	792	769	1002
	High Water Level	E.L.-m	1,954	1,725	1,823	1,823	1,264	1,375	1,406	1,218	786	763	996
	Low Water Level	E.L.-m	1,934	1,687	1,813	1,813	1,243	1,343	1,384	1,166	774	729	985
	Drawdown	m	20	38	10	10	21	32	22	52	12	34	11
	Sediment Level	E.L.-m	1,921	1,673	1,800	1,799	1,230	1,330	1,371	1,153	760	715	369
	Gross Capacity	MCM	1.96	1.12	3.82	3.82	4.80	3.48	3.21	3.68	6.08	4.35	4.59
	Available Capacity	MCM	1.62	0.99	3.69	3.69	2.79	2.33	2.39	3.42	3.71	3.67	3.16
	Dam Height	m	35	81	39	39	80	116	57	89	52	79	42
	Crest Length	m	1280	300	1200	1200	250	500	200	550	210	310	220
Lower Pond	Latitude		6°45'58"	6°44'44"	6°47'42"	6°47'48"	7°02'34"	7°02'34"	7°03'57"	7°03'57"	7°07'50"	7°07'50"	7°7'23"
	Longitude		80°47'43"	80°47'03"	80°32'21"	80°32'50"	80°54'53"	80°54'53"	80°54'11"	80°54'11"	80°28'27"	80°28'27"	81°05'46'
	Catchment Area	km^2	5	14	20	10	70	70	16	16	35	35	5
	Reservoir Area	km^2	0.08	0.09	0.34	0.25	0.30	0.28	0.15	0.18	0.24	0.24	0.15
	Crest Elevation	E.L.-m	1263	952	1355	1342	661	659	720	726	305	306	416
	High Water Level	E.L.-m	1,257	946	1,349	1,336	655	653	714	720	299	300	410
	Low Water Level	E.L.-m	1,229	934	1,339	1,323	642	642	693	693	282	282	383
	Drawdown	m	28	12	10	13	13	11	21	27	17	18	27
	Sediment Level	E.L.-m	1,216	920	1,326	1,309	628	628	680	680	269	269	369
	Gross Capacity	MCM	1.91	2.04	5.31	4.25	7.82	7.22	3.95	4.83	6.13	6.40	3.66
	Available Capacity	MCM	1.48	0.89	3.71	3.51	2.94	2.33	2.52	3.40	3.37	3.63	2.84
	Dam Height	m	93	72	55	52	81	79	65	71	75	76	76
	Crest Length	m	250	240	170	1070	420	430	220	290	360	360	540
Headrace Tunnel													
	Inner Diameter	m	4.8	4.6	5.9	5.8	5.2	4.8	4.9	5.8	5.8	6.0	5.3
	Length	m	1,070	100	300	300	950	960	1,350	1,000	2,030	510	1,750
	Nos. of lines	-line	1	1	1	1	1	1	1	1	1	1	1
Penstock Tunnel													
	Inner Diameter	m	3.8	3.6	4.6	4.5	4.0	3.7	3.8	4.5	4.5	4.6	4.1
	Length	m	1,260	1,349	939	961	1,116	1,256	1,236	927	940	898	1,106
	Nos. of lines	-line	1	1	1	1	1	1	1	1	1	1	1
Tailrace Tunnel													
	Inner Diameter	m	5.3	5.1	6.4	6.3	5.7	5.2	5.3	6.3	6.3	6.5	5.8
	Length	m	500	180	2,050	1,280	2,300	2,240	2,200	1,430	390	1,000	1,230
	Nos. of lines	-line	1	1	1	1	1	1	1	1	1	1	1
Access Tunnel to PH													
	Length	m	350	550	1,300	1,050	1,650	1,850	1,500	1,850	850	1,000	1,600

(Source: Study Team)

9.6.2 First Screening

As described in the sub-clause 9.5, some candidate sites have difficulties for their developments. In those sites, the upper and/or the lower reservoirs are located within the sanctuaries, in which any actions for developments are prohibited by the concerned laws. In other sites, the manufacturing limitation of the pump-turbines, which is derived from limitation of applicable unit capacity for ensuring stability of the national grid, cannot be cleared. Therefore, candidates site falling into such those two issues are eliminated from the candidate sites list for promising candidate sites selection conducted in the later.

Table 9.6.2-1 shows the result of the first screening. Rating “C” for “Impacts on Fauna and Flora” means that those of Upper reservoir and/or Lower reservoir are located in the environmental protected areas (sanctuaries) and that for “Manufacturing Limitation” is given if 200 MW/unit cannot be applicable. In this regard, if the 200 MW/unit is applicable, those sites can be developed at least by 200 MW/unit basis. (If 150 MW/unit is applicable, it is judged that 200 MW/unit is also applicable automatically because the manufacturing limitation becomes more severe when it goes smaller unit capacity.) This is the reason why evaluation of 200 MW/unit is employed for the first screening.

As a result, 6 candidate sites out of 11 candidate sites remains in the list for later promising sites selection; Halgran 1, Halgran 3, Halgran 4, Maha 1, Maha 2, and Loggal.

Table 9.6.2-1 Result of First Screening

	Kiriketi 1	Kiriketi 2	Maussa-kelle A	Maussa-kelle B	Halgran 1	Halgran 2	Halgran 3	Halgran 4	Maha 1	Maha 2	Loggal
Impacts on Fauna and Flora (Sanctuary)	C	C	C	C							
Manufacturing Limitation		C				C					
1st screening	NG	NG	NG	NG		NG					

(Source: Study Team)

9.6.3 Evaluation from Natural and Social Environmental Aspects

The environmental survey for natural environmental aspects, as well as from social environmental aspects, is conducted for every candidate site as described in the sub-chapter 9.5. Results of the survey and the evaluation are as summarized in Table 9.6.3-1.

Table 9.6.3-1 Summary of the Natural and Social Environments of the Six Candidate Sites

Evaluation points/Name of site	Halgran 1	Halgran 3	Halgran 4	Maha 1	Maha 2	Loggal
1. Impacts on fauna and flora	[Upper dam/reservoir]: B · Biodiversity and species richness = low (farmland mainly tea plantation; already altered by human activities) · National endangered species: Fauna: CR - 1, EN- 3 [Lower dam/reservoir]: B · Biodiversity and species richness = low (farmland - terraced rice fields and others; already altered by human activities) · Fauna: CR - 1, Flora: CR - 1	[Upper dam/reservoir]: B · Biodiversity and species richness = high (farmland mainly tea plantation; already altered by human activities; good riverine vegetation) · Fauna: EN - 5 · Flora: EN-2 [Lower dam/reservoir]: B · Biodiversity and species richness = low (farmland; already altered by human activities) · Fauna: CR - 1, Flora: EN - 1	[Upper dam/reservoir]: A · Biodiversity and species richness = low (tea plantation, crop fields and eucalyptus plantation) · Fauna: EN - 2 [Lower dam/reservoir]: B The same as the lower dam/reservoir of the Halgran 3.	[Upper dam/reservoir]: A · Biodiversity and species richness = low (farmland mainly tea plantation) [Lower dam/reservoir]: B · Biodiversity and species richness = medium · Fauna: CR - 3, EN - 5, Flora: CR – 1, EN - 1	[Upper dam/reservoir]: B · Biodiversity and species richness = low (farmland mainly tea plantation) · Fauna: EN - 1 [Lower dam/reservoir]: B The same as the lower dam/reservoir of the Maha 1 .	[Upper dam/reservoir]: B · Biodiversity and species richness = high · Fauna: CR - 1, EN - 2, Flora: EN - 1 [Lower dam/reservoir]: B · Biodiversity and species richness = medium · Fauna: EN - 2
	Rating: B	Rating: B	Rating: B	Rating: B	Rating: B	Rating: B
2. Impacts on local communities	[Upper dam/reservoir]: B · Inundated No. of houses: 15 · No use of river water by local community · No fishery [Lower dam/reservoir]: A · Inundated No. of houses: 9 · Local people use river water for bathing · 1 existing irrigation canal on the right bank · No fishery	[Upper dam/reservoir]: A · No resettlement · No use of river water by local community · No fishery [Lower dam/reservoir]: B · Inundated No. of houses: 3 · Local people use river water for bathing · 2 existing irrigation canals (One of the canals will be inundated). · No fishery	[Upper dam/reservoir]: B · Inundated No. of houses: 11 · A pre-school, tank of drinking water, 0.25 km of B413 inundated · No use of river water by local community · No fishery [Lower dam/reservoir]: B The same conditions as the lower dam/reservoir of Halgran 3	[Upper dam/reservoir]: C · Inundated No. of houses: 76 · 2km of estate road and some wells inundated · No fishery [Lower dam/reservoir]: B · Inundated No. of houses: 8 · 2 existing mini-hydro will be inundated · 4 water pipes for drinking inundated · No fishery	[Upper dam/reservoir]: B · Inundated No. of houses: 8 · 1 km of estate road inundated · No fishery [Lower dam/reservoir]: B The same conditions as the lower dam/reservoir of Maha 1	[Upper dam/reservoir]: B · Inundated No. of houses: 18 · Local people use river water for washing and bathing · 1 existing mini-hydro will be affected during construction. · No fishery [Lower dam/reservoir]: B · Inundated No. of houses: 14 · A primary school, a post office, and 1 km of village road inundated · No fishery
	Rating: B	Rating : B	Rating : B	Rating : C	Rating : B	Rating : B
3. Impacts on industries	[Upper dam/reservoir]: B · Extent in ha within the inundation area+ 50 m buffer zone Home garden:2.3ha Tea plantation: 7.8ha Other cultivation: 16.3ha Total: 26.4ha [Lower dam/reservoir]: B · Extent in ha within the inundation area+50 m buffer zone Paddy: 12.5ha Home garden: 7.6ha Other cultivation: 5.9ha Total: 26.0ha	[Upper dam/reservoir]: B · Extent in ha within the inundation area+ 50 m buffer zone Tea plantation: 14.3ha Forest: 13.2ha Total: 27.5ha [Lower dam/reservoir]: B · Extent in ha within the inundation area+ 50m buffer zone Paddy: 21.8ha Home garden: 6.9ha Tea plantation: 0.18ha Other cultivation: 0.6ha Total: 29.5ha	[Upper dam/reservoir]: B · Extent in ha within the inundation area+ 50 m buffer zone Tea plantation: 15.8ha Other cultivation: 7.4ha Forest: 0.2ha Total: 23.4ha [Lower dam/reservoir]: B The same condition as the lower dam/reservoir of Halgran 3	[Upper dam/reservoir]: B · Extent in ha within the inundation area+ 50m buffer zone Tea plantation : 50ha Other cultivation: 5.3ha Paddy: 2.6ha Home garden: 1.1ha Total: 59.0ha [Lower dam/reservoir]: B · Extent in ha within the inundation area+ 50 m buffer zone Rubber plantation: 20.7ha Home garden: 6.4ha Total: 27.1ha	[Upper dam/reservoir]: B · Extent in ha within the inundation area+ 50m buffer zone Tea plantation: 21.8ha Home garden: 1.8ha Total: 23.6ha [Lower dam/reservoir]: B The same condition as the lower dam/reservoir of Maha 1	[Upper dam/reservoir]: B · Extent in ha within the inundation area+ 50m buffer zone Paddy: 13.7ha Home garden: 19.3ha Forest: 3.4ha Total: 36.4ha [Lower dam/reservoir]: B · Extent in ha within the inundation area+ 50m buffer zone Paddy: 9.4ha Home garden: 8.3ha Total: 17.7ha
	Rating : B	Rating : B	Rating : B	Rating : B	Rating : B	Rating : B

Evaluation points/Name of site	Halgran 1	Halgran 3	Halgran 4	Maha 1	Maha 2	Loggal
4. Impacts on culture and landscape	[Upper dam/reservoir]: A ・No cultural heritage ・No impact on landscape [Lower dam/reservoir]: A ・No cultural heritage ・No impact on landscape ・There is a small burial ground.	[Upper dam/reservoir]: A ・No cultural heritage ・No impact on landscape [Lower dam/reservoir]: A ・No cultural heritage ・No impact on landscape ・There is a small burial ground.	[Upper dam/reservoir]: A ・No cultural heritage ・No impact on landscape [Lower dam/reservoir]: A The same condition as the lower dam/reservoir of Halgran 3	[Upper dam/reservoir]: A ・No cultural heritage ・No impact on landscape [Lower dam/reservoir]: A ・Nationally famous water fall can be seen from the site (2 km straight line distance from the dam axis). ・No cultural heritage ・No impact on landscape	[Upper dam/reservoir]: A ・No cultural heritage ・No impact on landscape [Lower dam/reservoir]: A The same condition as the lower dam/reservoir of Maha 1	[Upper dam/reservoir]: B ・A Buddhist temple which has a long history of over a century and it is the only temple in the vicinity of the area. But it is not designated as cultural heritage ・No impact on landscape [Lower dam/reservoir]: B A Buddhist temple with historic and cultural value is located on the right bank will be inundated.
	Rating：A	Rating：A	Rating：A	Rating：A	Rating：A	Rating：B

A：Project is not likely to have significant adverse impacts on natural environment and society and/or limited to a small scale,
B：Project is likely to have negative impact on natural environment and society, but less adverse than C ,
C：Project is likely to have significant adverse impacts on natural environment and society

9.6.4 Evaluation from Geological Aspects

Based on the description in the sub-chapter 9.5, geological conditions of every candidate site is evaluated in terms of the strength of foundation rocks, the impermeability, the faults, the river bed deposits thickness, and the stability around the reservoirs. The result of evaluation is as shown in Table 9.6.4-1. Meanings of rating A, B, and C are respectively as follows;

A: likely to be no serious problems, or very limited to, if any,

B: likely to have some problems but not serious

C: obviously serious problems exist, or serious problems with high possibility

Table 9.6.4-1 Evaluation from Geological Aspects

	Halgran 1	Halgran 3	Halgran 4	Maha 1	Maha 2	Logal
Strength	B	B	A	B	B	A
Impermiability	A	B	B	B	B	A
Faults	B	B	B	B	B	A
Riverbed Deposite	A	A	A	A	A	B
Slope	B	A	B	B	B	A
Overall Evaluation	B	B	B	B	B	B

Notes; the ratings are given based on the study by site reconnaissance, evaluation from existing relevant materials, etc. (not by any geological investigations)

(Source: Study Team)

9.6.5 Evaluation from Easy of Construction Works

Based on the description in the sub-chapter 9.5, the easy of construction works of every candidate sites is evaluated in terms of the access to Upper reservoirs and Lower reservoirs, reclamation of temporary yards for construction works including new access road constructions, and others. The result of evaluation is as shown in Table 9.6.5-1. Meanings of rating A, B, and C are respectively as follows;

A: likely to be no serious problems, or very limited to, if any,

B: likely to have some problems but not serious, and

C: obviously serious problems exist, or serious problems with high possibility.

Table 9.6.5-1 Evaluation from Easy of Construction Works

	Halgran 1	Halgran 3	Halgran 4	Maha 1	Maha 2	Logal
Access to Upper Dam	C	B	C	A	A	A
Access to Lower Dam	B	B	B	A	A	B
Temporary Yards	C	A	C	A	A	A
Others			C	A		
Overall Evaluation	C	B	C	A	A	B

(Source: Study Team)

The rating C is given to Halgran 4 as well as the rating A is given to Maha 1 in “Others” row in Table 9.6.4-1 from following reasons;

In Halgran 4, the drawdown depth of Upper reservoir exceed to 50 m, which may cause the instability of surrounding slope of the reservoir because the large extent in height on the slope is to be exposed wet and dry conditions repeated by daily pumping and generating operation. Consequently, a large scale of countermeasures would be required to ensure the slope stability.

In Maha 1, the length of the access tunnel to the powerhouse is less than 1,000 m, which is advantageous points to shorten the whole of the construction period because all of construction activities in the powerhouse cannot be started until the access tunnel from the outside is completed in case of underground type.

9.6.6 Manufacturing Limitation of Pump-turbine

The candidate sites by the initial JICA Study included those of which the gross head exceed 700 m on the basis of 250 MW/unit. In this study, unit capacity is limited to less than 200 MW/unit from the stability of the national power system; consequently, the manufacturing limitation of pump-turbines is examined in every site, because a smaller unit capacity with a high head has generally more severe manufacturing limitation. Therefore, the candidate sites concerned about the manufacturing limitation are reviewed in order to make those appropriate for 200 MW/unit basis at least. However, in several candidate sites, the issue of the manufacturing limitation remains still due to topographical conditions. Evaluation from the manufacturing limitation is definitely described in the sub-chapter 9.5. Table 9.6.6-1 shows result of the evaluation from manufacturing limitation aspects. Meanings of rating A, B, and C are respectively as follows;

A: both 200 MW/unit and 150MW/unit are applicable

B: 200MW/unit is applicable; however, 150MW/unit is not applicable

C 200MW/unit is not applicable (already eliminated in the first screening)

Table 9.6.6-1 Result of Evaluation from Manufacturing Limitation Aspects

	Halgran 1	Halgran 3	Halgran 4	Maha 1	Maha 2	Logal
Evaluation	B	B	A	A	A	A

(Source: Study Team)

9.6.7 Construction Cost

As described in the sub-chapter 9.5, the construction cost of every site is estimated. Table 9.6.7-1 shows unit price per kW and its evaluation. Meanings of the rating A, B, and C for the evaluation are as follows;

A: less than 1,200 USD/kW

B: from 1,200 to 1,400 USD/kW

C: more than 1,400USD/kW

Table 9.6.7-1 Unit Price of Construction Cost

	unit	Halgran 1	Halgran 3	Halgran 4	Maha 1	Maha 2	Loggal
Construction Cost	USD/kW	1,335	1,042	1,414	1,094	1,216	1,280
Evaluation		B	A	C	A	B	B

(Source: Study Team)

9.6.8 Selection of Promising Sites

The ranking study on 6 candidate sites is conducted with the evaluation results as the above mentioned, and three of the promising site are selected in this sub-chapter. The method of the sites ranking is as described below;

1) 1. Score is allocated to every large criterion for the evaluation; such as “1. Technical Evaluation”, “2. Economical Evaluation”, “3. Environmental Evaluation”. In the Even Case, 50 points are given to “1. Technical Evaluation, 2. Economical Evaluation”, and the other 50 points are given to “3. Environmental Evaluation”. In the environment weighed case, 30 points are given to “1. Technical Evaluation, 2. Economical Evaluation” and 70 points are given to “3. Environmental Evaluation”.

2) “1. Technical Evaluation” is divided into three of small criteria; therefore, the score is allocated to every small criterion so that the total score of the three can be equal to allocated score to “1. Technical Evaluation” as a large criterion. As for the manufacturing limitation, two rating remain still in six candidate sites after the first screening; one is applicable for both 150 MW/unit and 200 MW/unit as rated A, and the other is applicable for 200 MW/unit only as rated in B. There are not significant differences in unit price of the construction cost between the scheme by three sets of 200 MW/unit and by four sets of 150 MW/unit; therefore, a scheme by 150 MW/unit has a potential for the project forming in the later stages. The criteria of “the manufacturing limitation” is weighed in “1. Technical Evaluation” considered following two aspects; a) a plant having four sets of 150 MW/unit would be more convenient in its operation than a plant having three sets of 200 MW/unit and b) 150 MW/unit has less impact on the power system than 200 MW/unit.

3) “3. Environmental Evaluation is divided into four of small criteria; the score is allocated to every small criterion so that the total score of the four can be equal to allocated score to “3. Environment Evaluation”. As for the small criteria of “Impact on local communities”, it is weighed considered that it includes the evaluation of the number of possible resettlements.

4) Rating A, B, and C, are given 1.0, 0.6, and 0.3 respectively.

5) Each candidate site is ranked by the sum of small criterion’s score. The score of each criterion is calculated with multiplying the points and the rating A, B, and C.

In addition, as another consideration for three promising candidate sites selection, one project is selected from same region. This is taken in order to avoid concentrating plural promising sites in one region. Furthermore, a common reservoir in plural candidate sites is also considered. That is to say, if one project has been developed, others could not be developed anymore, because a common reservoir is already utilized by the developed project in advance. For example, Halgran 3 has a common lower reservoir with Halgran 4, as well as Maha 1 has a common lower reservoir with Maha 2.

As a result, in Halgran region, Halgran 3 is the highest in both cases; the even case and the environment weighed case.

In Maha region, ranking of Maha 1 is higher than that of Maha 2 in the even case; however, Maha 2 predominates in the environment weighed case. This is due to Maha 1’s evaluation by “Impact on social environmental”, which has low rating because of the number of possible inundated houses; total 76, in Upper reservoir. On the other hand, Maha 2’s ranking is ranked 3 to Maha 1’s ranking 1, and it does not have such serious environmental problems; therefore, Maha 2 is selected from Maha region.

Loggal is a sole candidate site in Loggal region; however, it is not automatically selected but following considerations are taken into. Loggal has higher ranking than Halgran 1’s one in the even case; however, it is reversed in the environment weighed case. (Halgran 4 cannot be developed if Halgran 3 is selected because its Lower dam is a common reservoir with Halgran 3, so that Halgran 4 is automatically dropped off when Halgran 3 is selected.) Halgran 1’s Upper reservoir is located near Halgran 3’s one, environmental impact on the region would be rather significant. The score difference between Halgran 1 and Loggal is so limited even in the environmental weighed case. Therefore, it is better to follow the consideration as the above-mentioned; to avoid more than two projects are selected from the same region.

As a result, Halgran 3, Maha 2, and Loggal are selected as three of the promising site.

Table 9.6.8-1 Result of Ranking Study on Candidate Sites (Even Case)

Criteria		Score	Halgran 1			Halgran 3			Halgran 4			Maha 1			Maha 2			Loggal		
		allocation	Eva	Rate	Score	Eva	Rate	Score	Eva	Rate	Score	Eva	Rate	Score	Eva	Rate	Score	Eva	Rate	Score
1. Technical Evaluation		25			12.75			15.00			16.75			22.00			22.00			19.00
1.1	Geological aspects	7.5	B	0.60	4.50	B	0.60	4.50	B	0.60	4.50	B	0.60	4.50	B	0.60	4.50	B	0.60	4.50
1.2	Ease of construction works	7.5	C	0.30	2.25	B	0.60	4.50	C	0.30	2.25	A	1.00	7.50	A	1.00	7.50	B	0.60	4.50
1.3	Manufacturing Limitation	10	B	0.60	6.00	B	0.60	6.00	A	1.00	10.00	A	1.00	10.00	A	1.00	10.00	A	1.00	10.00
2. Economical Ealuation		25	B	0.60	15.00	A	1.00	25.00	C	0.30	7.50	A	1.00	25.00	B	0.60	15.00	B	0.60	15.00
3. Environmental Evaluation		50			33.60			33.60			33.60			27.60			33.60			30.00
3.1	Impact on Fauna and Flora	12	B	0.60	7.20	B	0.60	7.20	B	0.60	7.20	B	0.60	7.20	B	0.60	7.20	B	0.60	7.20
3.2	Impact on local communities	20	B	0.60	12.00	B	0.60	12.00	B	0.60	12.00	C	0.30	6.00	B	0.60	12.00	B	0.60	12.00
3.3	Impact on industries	9	B	0.60	5.40	B	0.60	5.40	B	0.60	5.40	B	0.60	5.40	B	0.60	5.40	B	0.60	5.40
3.4	impact on culture and landscape	9	A	1.00	9.00	A	1.00	9.00	A	1.00	9.00	A	1.00	9.00	A	1.00	9.00	B	0.60	5.40
	Total	100			61.35			73.60			57.85			74.60			70.60			64.00
	Rank				5			2			6			1			3			4

Table 9.6.8-2 Result of Ranking Study on Candidate Sites (Environment Weighed Case)

Criteria	Score allocation	Halgran 1			Halgran 3			Halgran 4			Maha 1			Maha 2			Loggal		
		Eva	Rate	Score	Eva	Rate	Score	Eva	Rate	Score	Eva	Rate	Score	Eva	Rate	Score	Eva	Rate	Score
1. Technical Evaluation	15			7.65			9.00			10.05			13.20			13.20			11.40
1.1 Geological aspects	4.5	B	0.60	2.70	B	0.60	2.70	B	0.60	2.70	B	0.60	2.70	B	0.60	2.70	B	0.60	2.70
1.2 Ease of construction works	4.5	C	0.30	1.35	B	0.60	2.70	C	0.30	1.35	A	1.00	4.50	A	1.00	4.50	B	0.60	2.70
1.3 Manufacturing Limitation	6	B	0.60	3.60	B	0.60	3.60	A	1.00	6.00	A	1.00	6.00	A	1.00	6.00	A	1.00	6.00
2. Economical Ealuation	15	B	0.60	9.00	A	1.00	15.00	C	0.30	4.50	A	1.00	15.00	B	0.60	9.00	B	0.60	9.00
3. Environmental Evaluation	70			46.80			46.80			46.80			37.80			46.80			42.00
3.1 Impact on Fauna and Flora	16	B	0.60	9.60	B	0.60	9.60	B	0.60	9.60	B	0.60	9.60	B	0.60	9.60	B	0.60	9.60
3.2 Impact on local communities	30	B	0.60	18.00	B	0.60	18.00	B	0.60	18.00	C	0.30	9.00	B	0.60	18.00	B	0.60	18.00
3.3 Impact on industries	12	B	0.60	7.20	B	0.60	7.20	B	0.60	7.20	B	0.60	7.20	B	0.60	7.20	B	0.60	7.20
3.4 impact on culture and landscape	12	A	1.00	12.00	A	1.00	12.00	A	1.00	12.00	A	1.00	12.00	A	1.00	12.00	B	0.60	7.20
Total	100			63.45			70.80			61.35			66.00			69.00			62.40
Rank				4			1			6			3			2			5