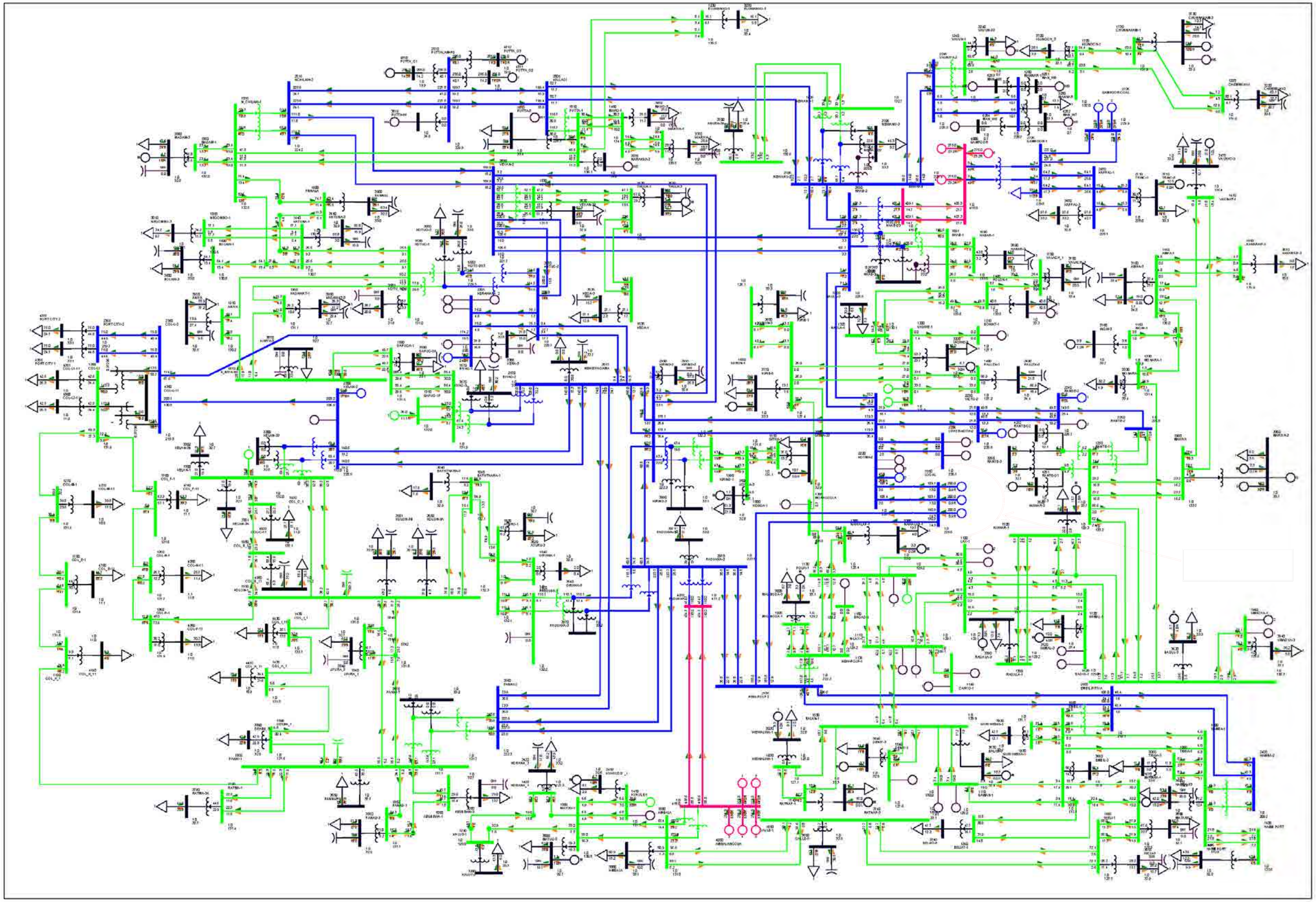
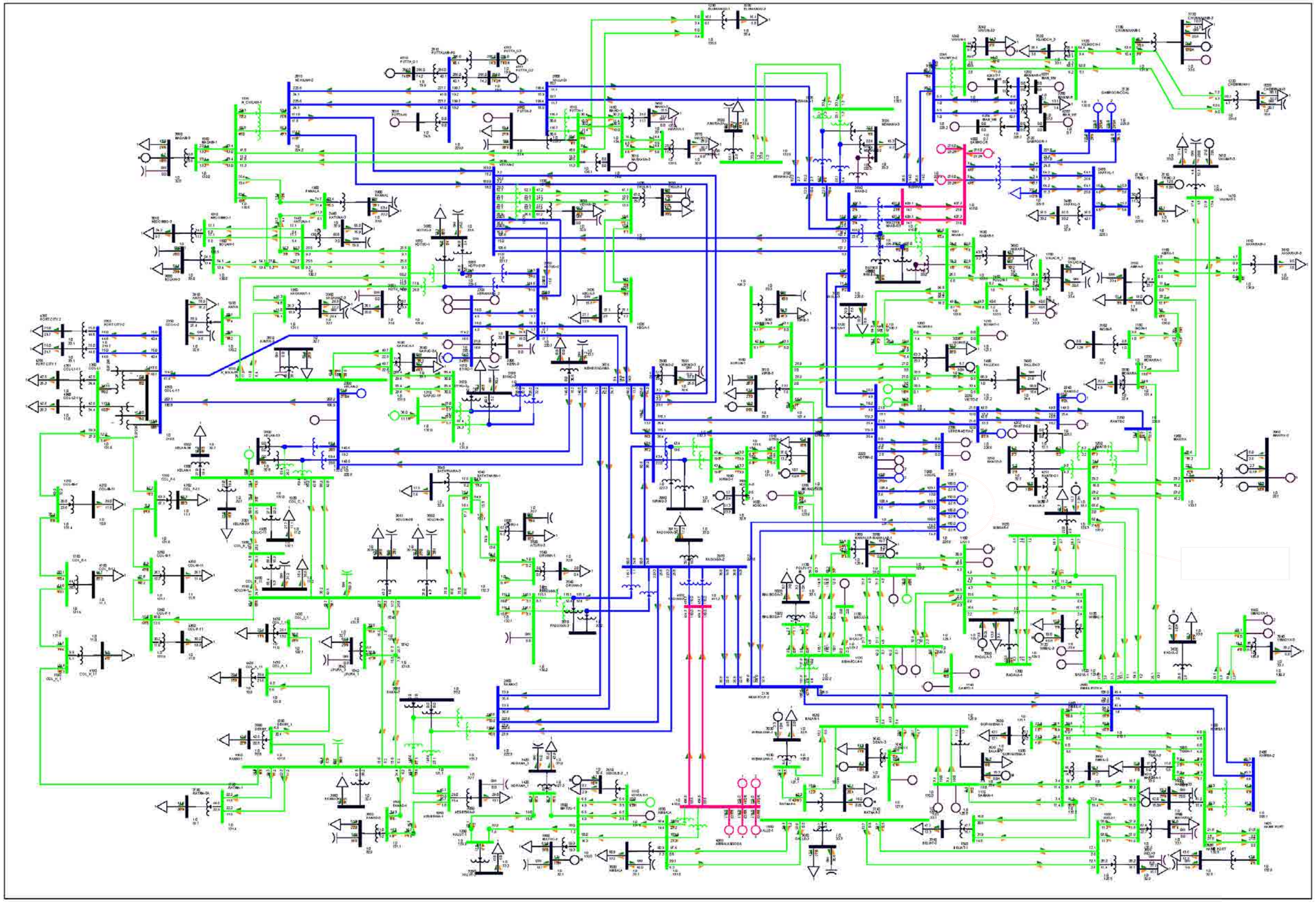


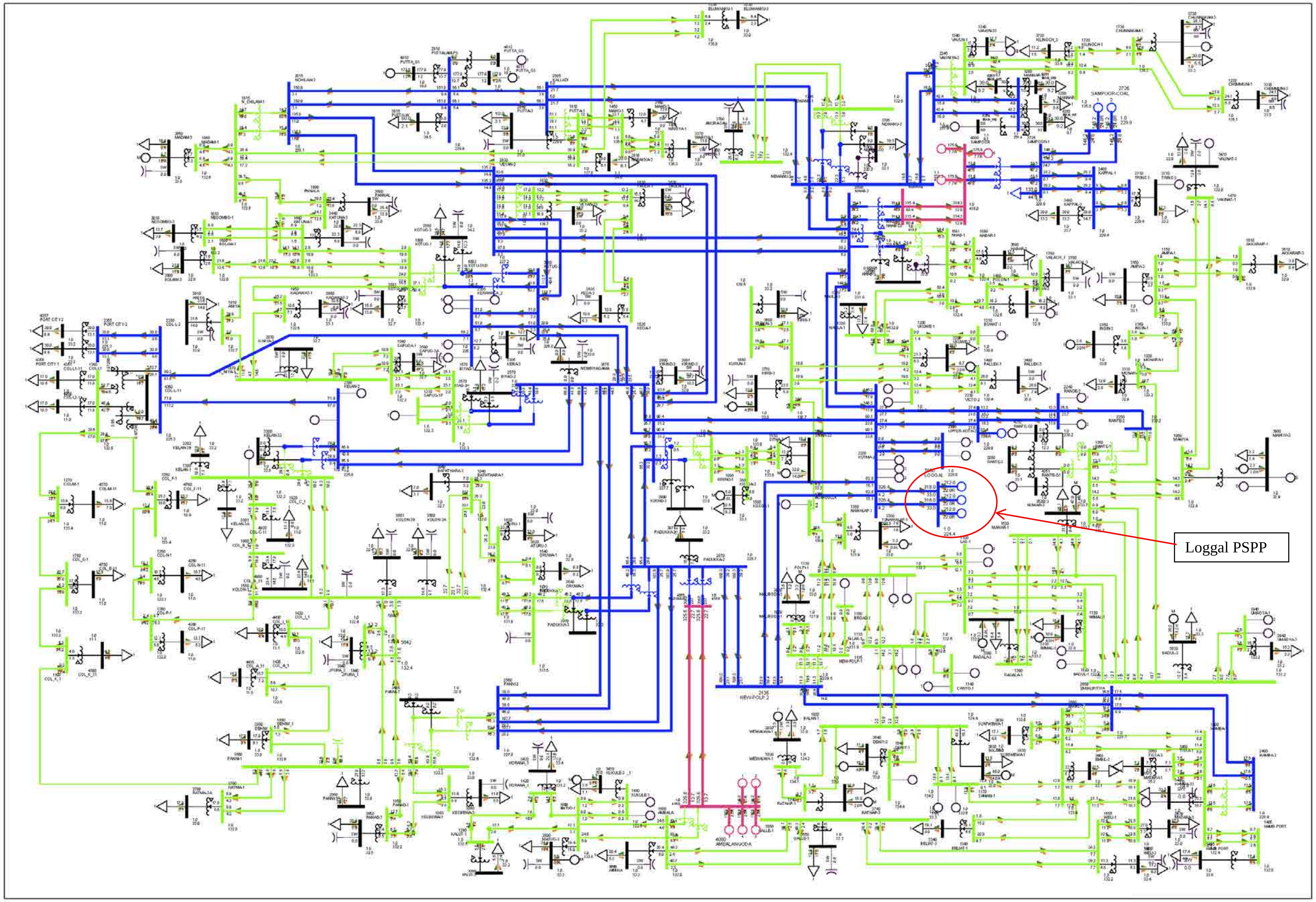
(Source: JICA Study Team)

Figure 10.6.5-7 Power Flow Diagram (Thermal Maximum Night Peak in 2025, Generating Operation, Connected to Kotmale and New Polpitiya,Loggal Unit Capacity 200MW)



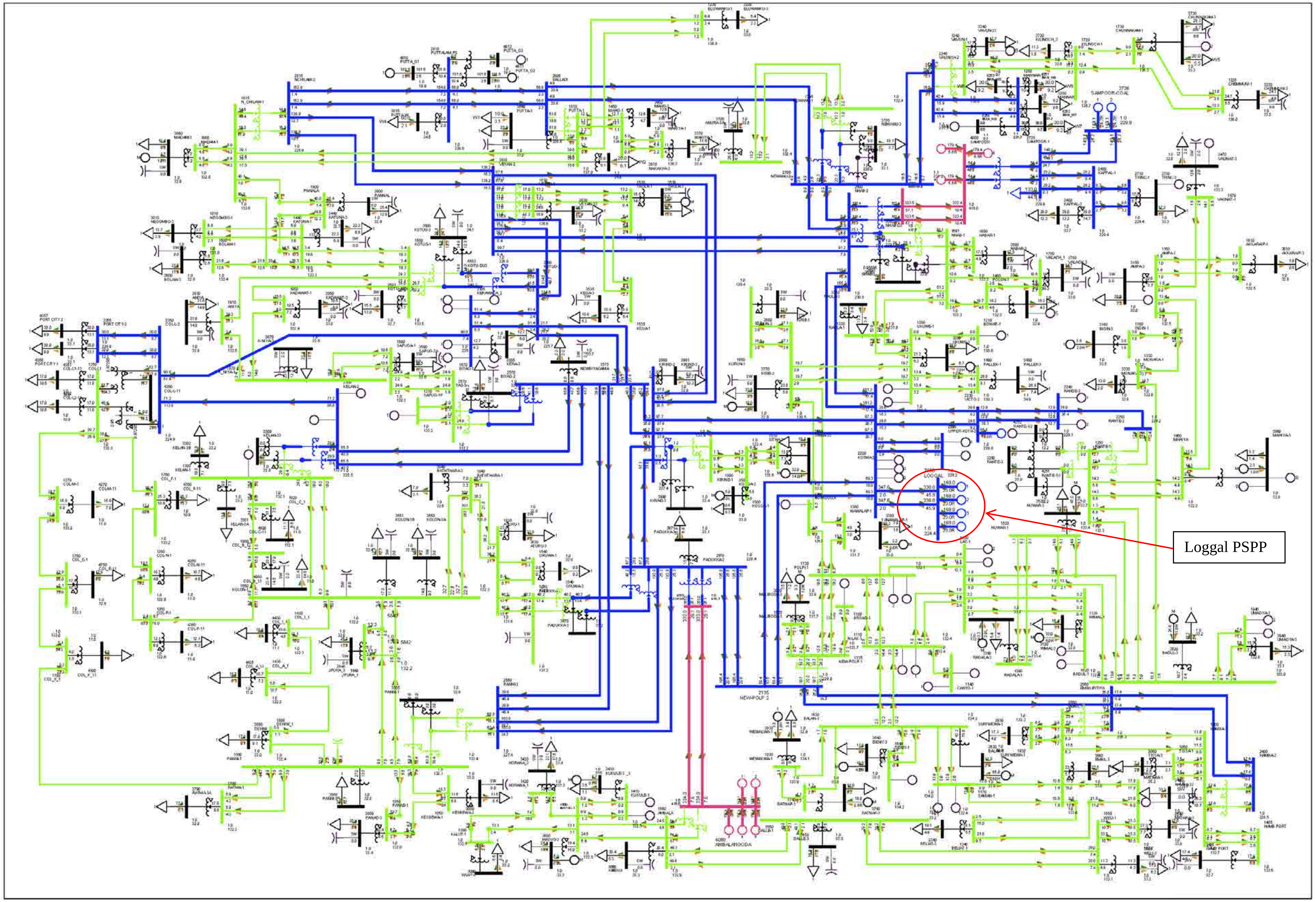
(Source: JICA Study Team)

Figure 10.6.5-8 Power Flow Diagram (Thermal Maximum Night Peak in 2025, Generating Operation, Connected to Kotmale and New Polpitiya, Loggal Unit Capacity 150MW)



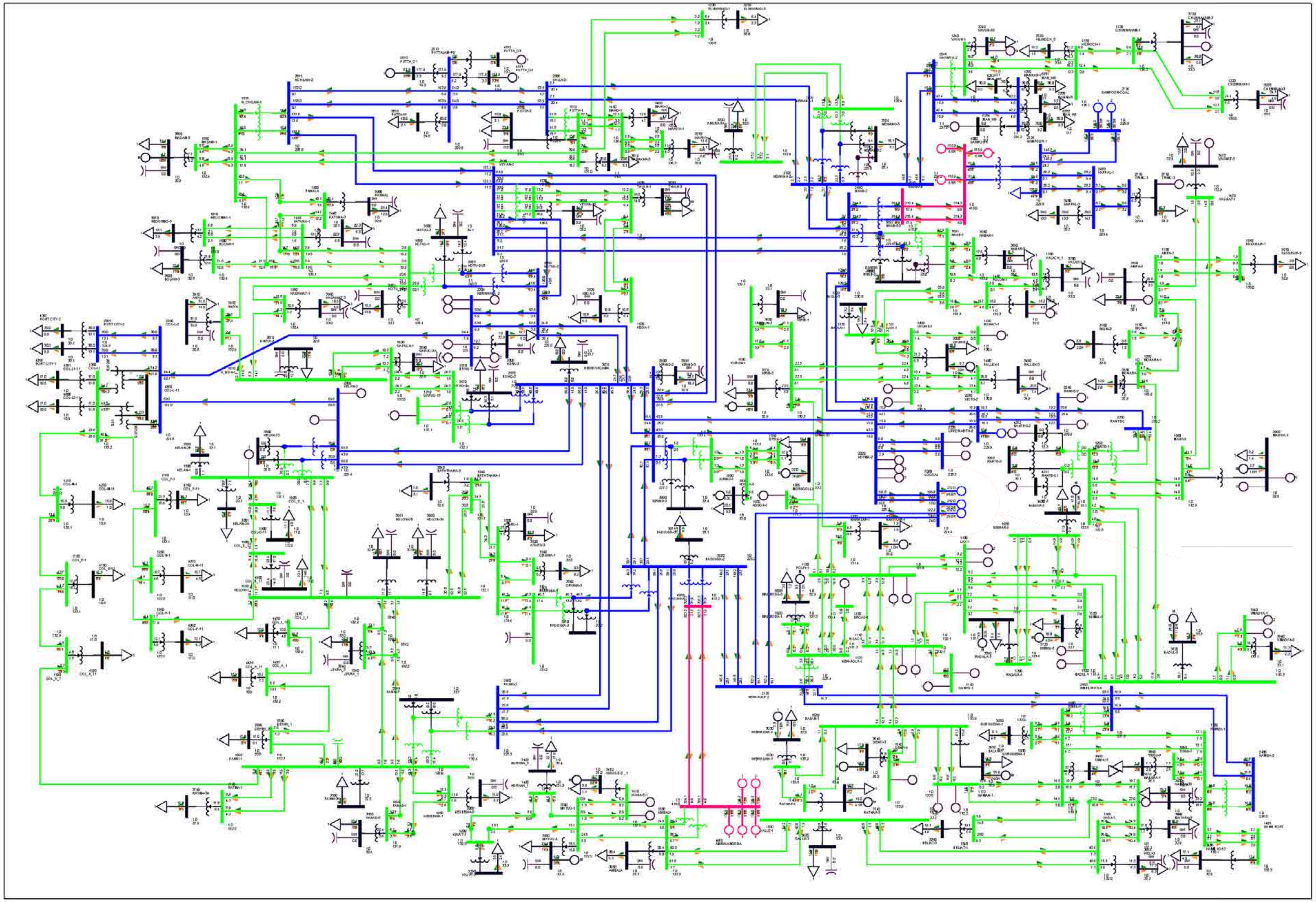
(Source: JICA Study Team)

Figure 10.6.5-9 Power Flow Diagram (Off Peak in 2025, Pumping Operation, Connected to Kotmale,Loggal Unit Capacity 200MW)



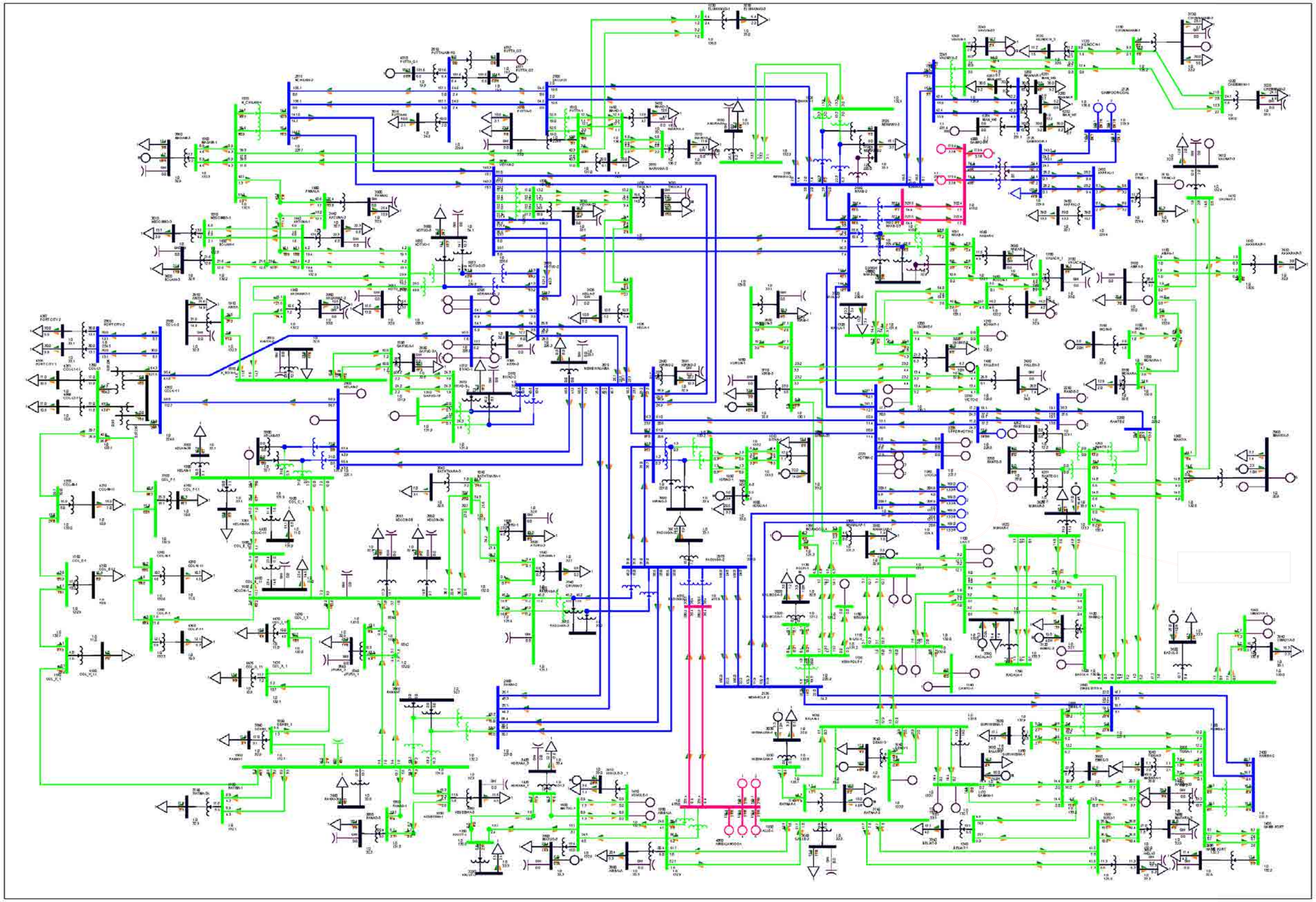
(Source: JICA Study Team)

Figure 10.6.5-10 Power Flow Diagram (Off Peak in 2025, Pumping Operation, Connected to Kotmale,Loggal Unit Capacity 150MW)



(Source: JICA Study Team)

Figure 10.6.5-11 Power Flow Diagram (Off Peak in 2025, Pumping Operation, Connected to Kotmale and New Polpitiya, Loggal Unit Capacity 200MW)



(Source: JICA Study Team)

Figure 10.6.5-12 Power Flow Diagram (Off Peak in 2025, Pumping Operation, Connected to Kotmale and New Polpitiya, Loggal Unit Capacity 150MW)

(2) Short Circuit Current Analysis

The three phase fault current analyses at bus conductors of Loggal PSPP, Kotmale P/S, and New Polpitiya are carried out for Hydro Maximum Night Peak cases and Thermal Maximum Night Peak cases, as the most severe loading cases. As shown in Table 10.6.5-1, it is confirmed that the currents satisfies the criteria for all cases.

Table 10.6.5-1 The Three Phase Short Circuit Currents (in 2025)

Loading Scenario	T/L	Unit Capacity of PSPP	P/S, S/S		Current
Hydro Maximum Night Peak	To Kotmale P/S	200MW	Kotmale	220kV	25.3kA
			Loggal	220kV	9.2kA
		150MW	Kotmale	220kV	25.3kA
			Loggal	220kV	9.1kA
	PI Connection	200MW	Kotmale	220kV	24.0kA
			Loggal	220kV	18.7kA
			New Polpitiya	220kV	20.1kA
		150MW	Kotmale	220kV	23.9kA
			Loggal	220kV	18.4kA
			New Polpitiya	220kV	20.0kA
Termal Maximum Night Peak	To Kotmale P/S	200MW	Kotmale	220kV	21.3kA
			Loggal	220kV	8.8kA
		150MW	Kotmale	220kV	21.2kA
			Loggal	220kV	8.7kA
	PI Connection	200MW	Kotmale	220kV	20.7kA
			Loggal	220kV	17.8kA
			New Polpitiya	220kV	18.2kA
		150MW	Kotmale	220kV	20.6kA
			Loggal	220kV	17.5kA
			New Polpitiya	220kV	18.1kA

(Source: JICA Study Team)

(3) Transient Stability Analysis

1) Three phase line fault at Loggal PSPP

In case that T/L from Loggal PSPP is connected to T/L between Kotmale P/S and New Polpitiya S/S with PI connection, it is set that three phase line fault occurs at a point in T/L shown below since the power flow is heavier than the other sections.

Peak: Loggal- New Polpitiya, Off-peak: Loggal- Kotmale

The results of transient stability analysis of three phase line fault are shown in Figure 10.6.5-13 to Figure 10.6.5-24.

The results in cases for pumping operation (Figure 10.6.5-21, Figure 10.6.5-22) show that the network becomes unstable and steps out occurs in case that Loggal PSPP is connected to Kotmale P/S. The cause is assumed that length of T/L is longer than that of Maha PSPP to Kotmale P/S and from Halgran PSPP to Kotmale P/S. In order to keep Power system stable, the conductor of the transmission line from Loggal PSPP to Kotmale should be reconsidered so that the impedance of T/L can be reduced.

The other results of transient stability analysis show that network can be in stable. However, the weak damping phenomena are observed within around initial 10 seconds. From the results of these, it is suggested that the power system stabilizer is to be equipped with large size units to be developed in the future.

2) One Unit Tripping at Loggal PSPP

a) Frequency drop followed by loss of generator

The results of the dynamic simulation for one unit tripping Loggal PSPP are shown in Figure 10.6.5-25 to Figure 10.6.5-32.

The results of the study show in all cases that the system frequency drops to 48.75Hz which is the criteria; the load shedding is taken place.

In this regard, it is calculated that the system frequency dropping in Thermal maximum scenario is larger than that in Hydro maximum scenario. This is because there is difference of the number of power plants operated with free governor mode in Hydro Maximum cases (HMNP) and in Thermal Maximum cases (TMNP).

HMNP: Samanalawewa, Bowathenna, Kotmale, Upper Kotmale, Victoria, Puttalam, Ambalangoda, Sampoor

TMNP: Victoria, Kotmale, Kelanitissa

Considered the above-mentioned calculation results, it is assumed that the mumber of power plants with governor free mode has considerable impact on the power system stability. Therefore, it is suggested that free governor operation system should be considered for relatively large plants to be constructed in the future.

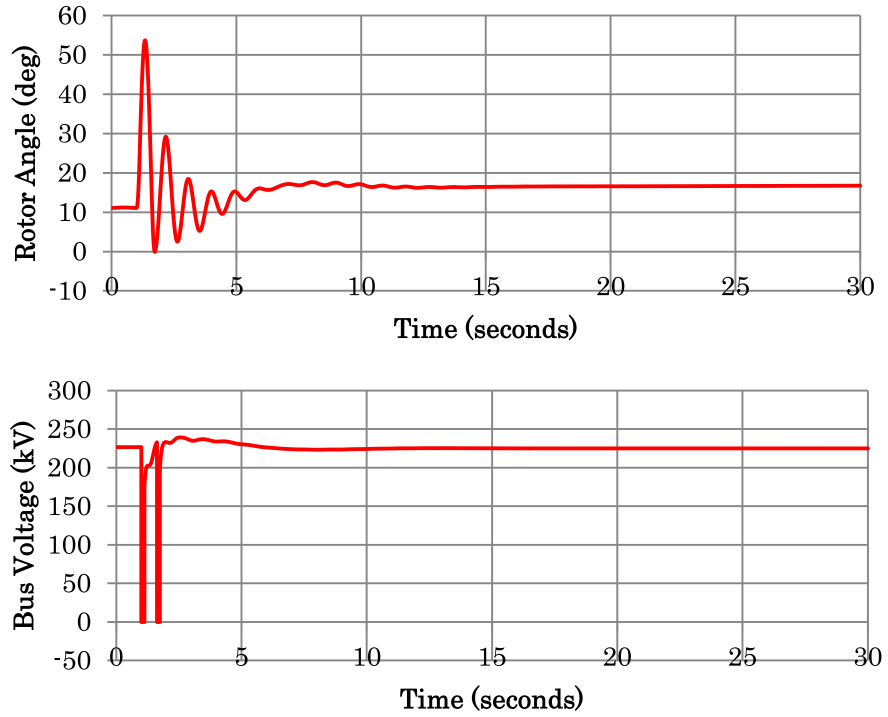
b) Frequency rise by loss of generator of pumping operation

The results of the dynamic simulation for one unit tripping Loggal PSPP are shown in Figure 10.6.5-33 to Figure 10.6.5-36.

The results show that in very case, the system frequency does not excess 51.5Hz which is the criteria; the alarm of thermal power plants occurs for the system frequency rise.

In this regard, in the simulation, it is set that the coal power plants in the power grid (Puttalam, Ambalangoda, and Sampoor) are operated with free governor mode in the same manner as “a) Frequency drop followed by loss of generator”.

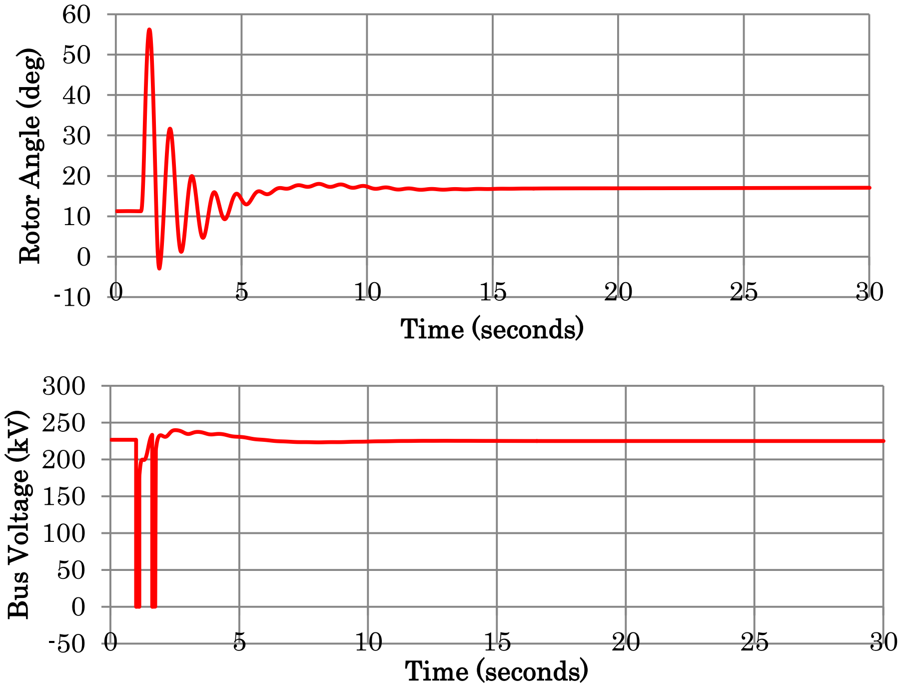
Therefore, it is suggested that free governor operation system should be considered for relatively large plants to be constructed in the future.



(Hydro Maximum Night Peak in 2025,Generating Operation, Connected to Kotmale, Loggal Unit Capacity 200MW)

(Source: JICA Study Team)

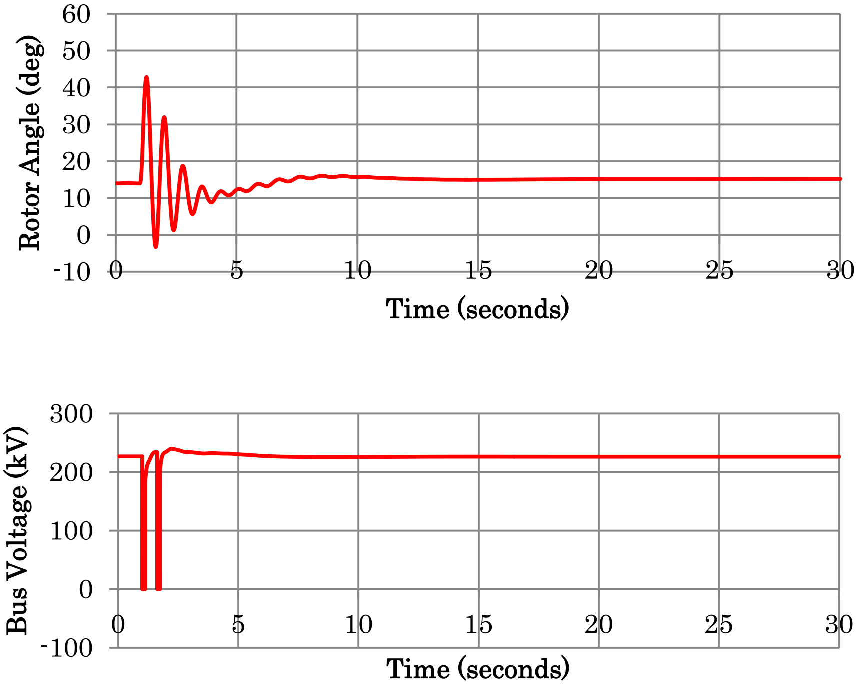
Figure 10.6.5-13 Three-phase Fault at Loggal end of Loggal-Kotmale 220kV Line-USR



(Hydro Maximum Night Peak in 2025,Generating Operation, Connected to Kotmale, Loggal Unit Capacity 150MW)

(Source: JICA Study Team)

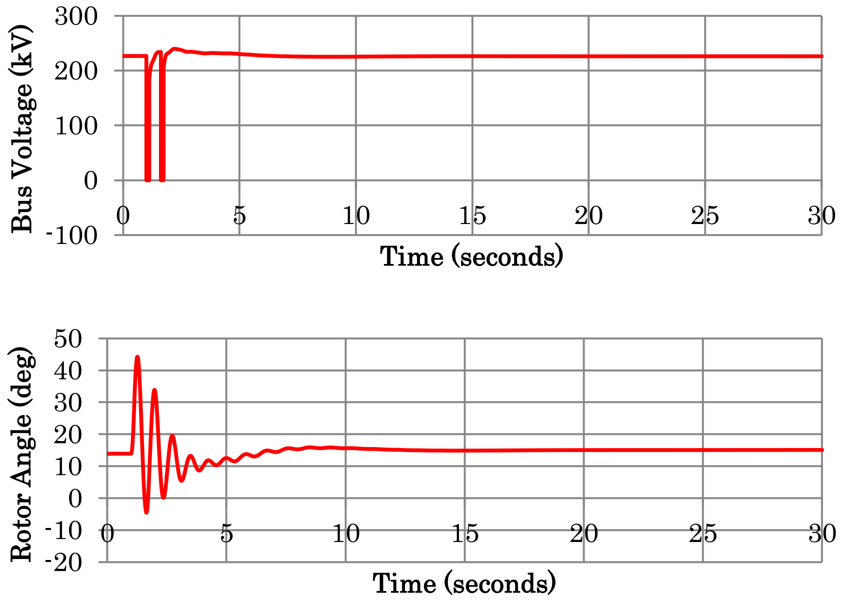
Figure 10.6.5-14 Three-phase Fault at Loggal end of Loggal-Kotmale 220kV Line-USR



(Hydro Maximum Night Peak in 2025,Generating Operation, Connected to Kotmale and New Polpitiya, Loggal Unit Capacity 200MW)

(Source: JICA Study Team)

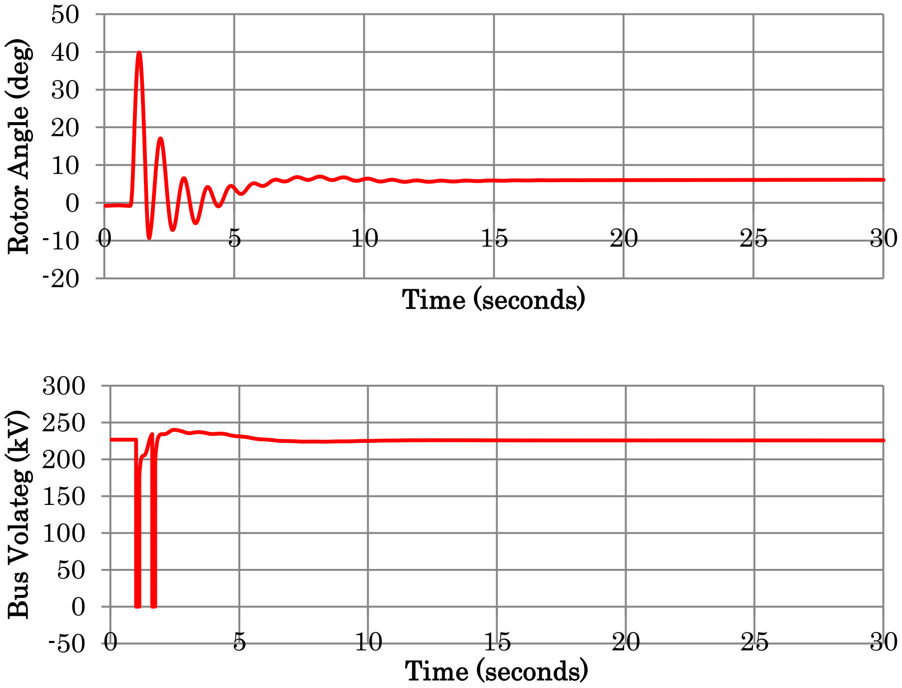
Figure 10.6.5-15 Three-phase Fault at Loggal end of Loggal-New Polpitiya 220kV Line-USR



(Hydro Maximum Night Peak in 2025,Generating Operation, Connected to Kotmale and New Polpitiya, Loggal Unit Capacity 150MW)

(Source: JICA Study Team)

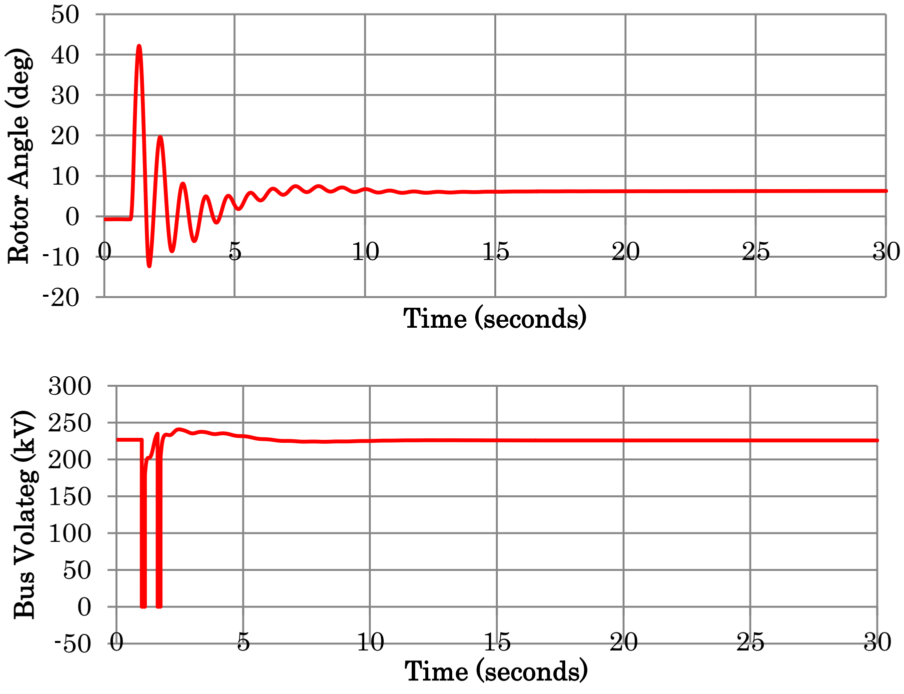
Figure 10.6.5-16 Three-phase Fault at Loggal end of Loggal- New Polpitiya 220kV Line-USR



(Thermal Maximum Night Peak in 2025,Generating Operation, Connected to Kotmale, Loggal Unit Capacity 200MW)

(Source: JICA Study Team)

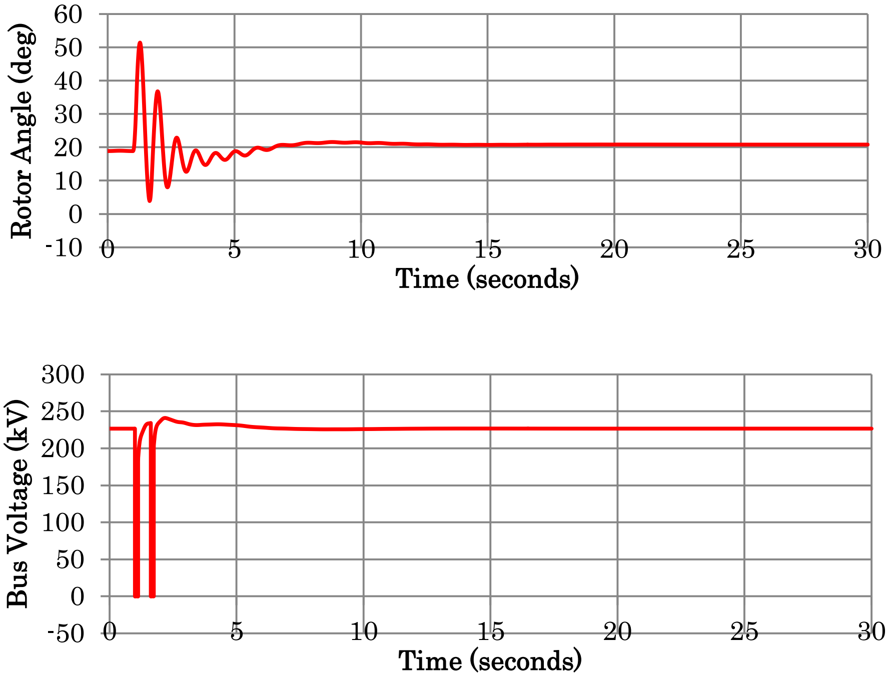
Figure 10.6.5-17 Three-phase Fault at Loggal end of Loggal-Kotmale 220kV Line-USR



(Thermal Maximum Night Peak in 2025,Generating Operation, Connected to Kotmale, Loggal Unit Capacity 150MW)

(Source: JICA Study Team)

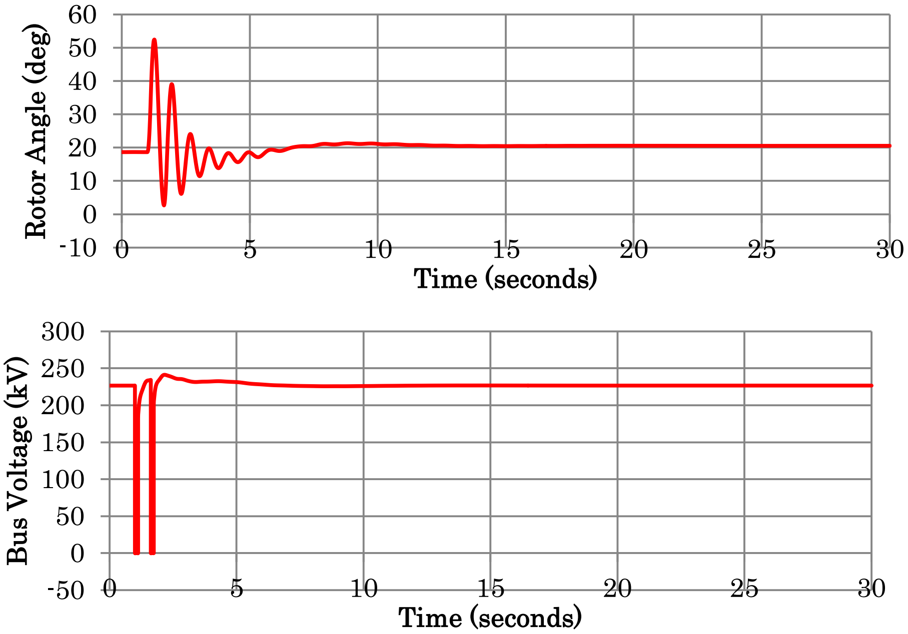
Figure 10.6.5-18 Three-phase Fault at Loggal end of Loggal-Kotmale 220kV Line-USR



(Thermal Maximum Night Peak in 2025,Generating Operation, Connected to Kotmale and New Polpitiya, Loggal Unit Capacity 200MW)

(Source: JICA Study Team)

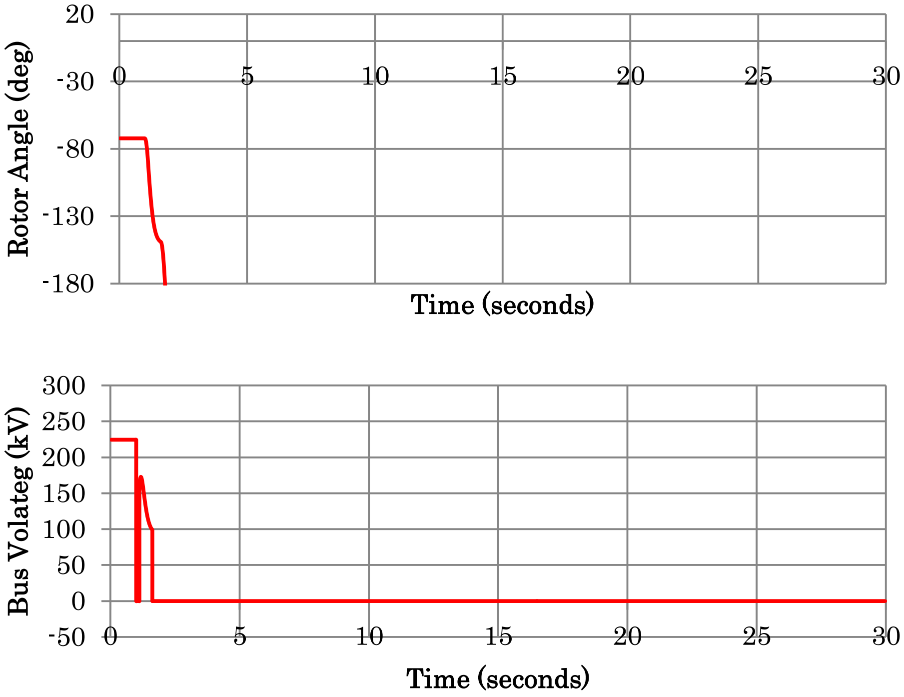
Figure 10.6.5-19 Three-phase Fault at Loggal end of Loggal- New Polpitiya 220kV Line-USR



(Thermal Maximum Night Peak in 2025,Generating Operation, Connected to Kotmale and New Polpitiya, Loggal Unit Capacity 150MW)

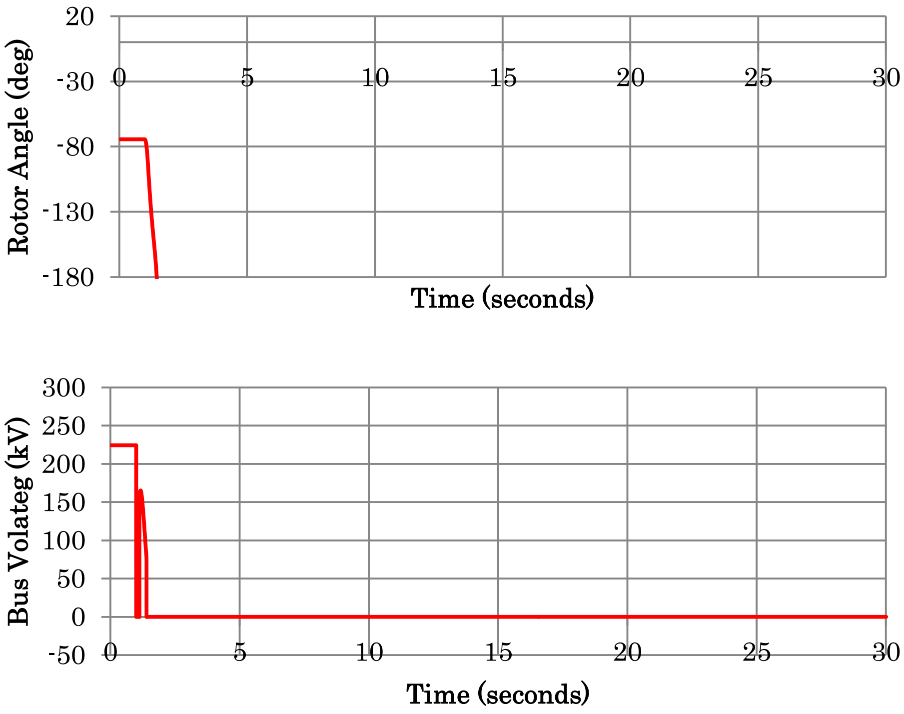
(Source: JICA Study Team)

Figure 10.6.5-20 Three-phase Fault at Loggal end of Loggal- New Polpitiya 220kV Line-USR



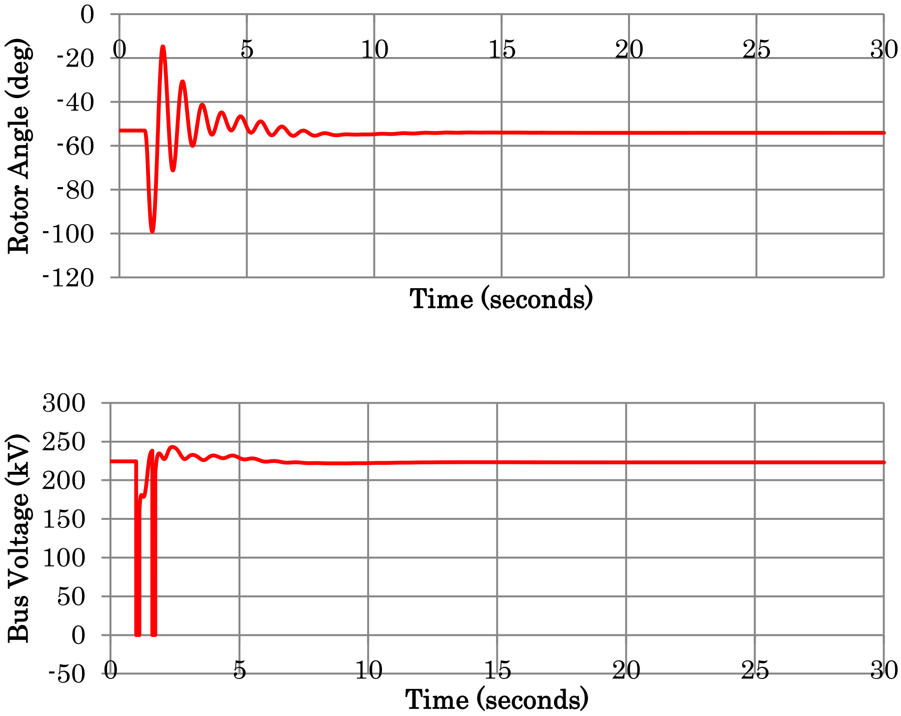
(Off Peak in 2025,Pumping Operation, Connected to Kotmale, Loggal Unit Capacity 200MW)
(Source: JICA Study Team)

Figure 10.6.5-21 Three-phase Fault at Loggal end of Loggal-Kotmale 220kV Line-USR



(Off Peak in 2025,Pumping Operation, Connected to Kotmale, Loggal Unit Capacity 150MW)
(Source: JICA Study Team)

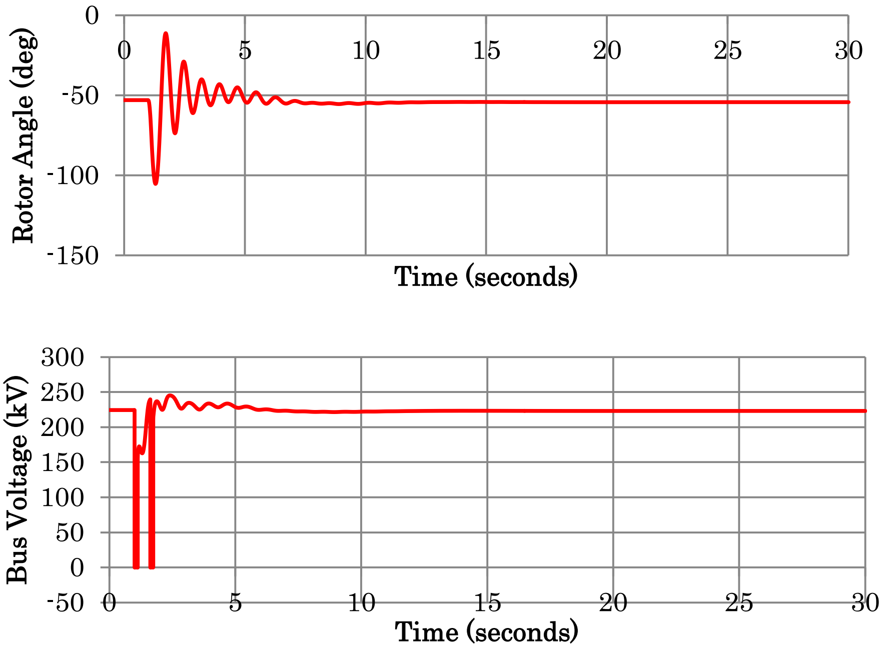
Figure 10.6.5-22 Three-phase Fault at Loggal end of Loggal-Kotmale 220kV Line-USR



(Off Peak in 2025,Pumping Operation, Connected to Kotmale and New Polpitiya, Loggal Unit Capacity 200MW)

(Source: JICA Study Team)

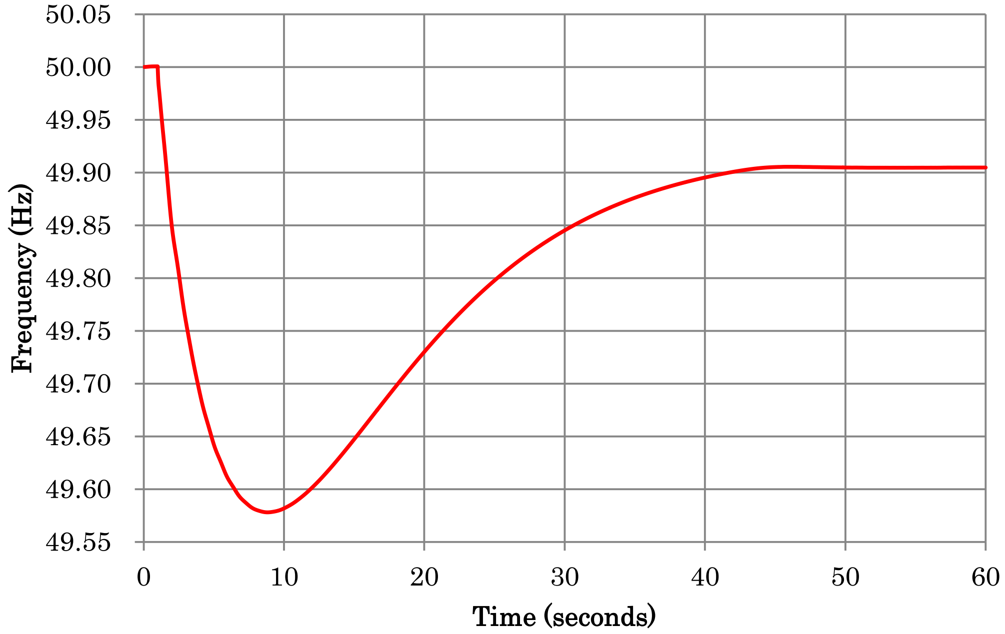
Figure 10.6.5-23 Three-phase Fault at Loggal end of Loggal-Kotmale 220kV Line-USR



(Off Peak in 2025,Pumping Operation, Connected to Kotmale and New Polpitiya, Loggal Unit Capacity 150MW)

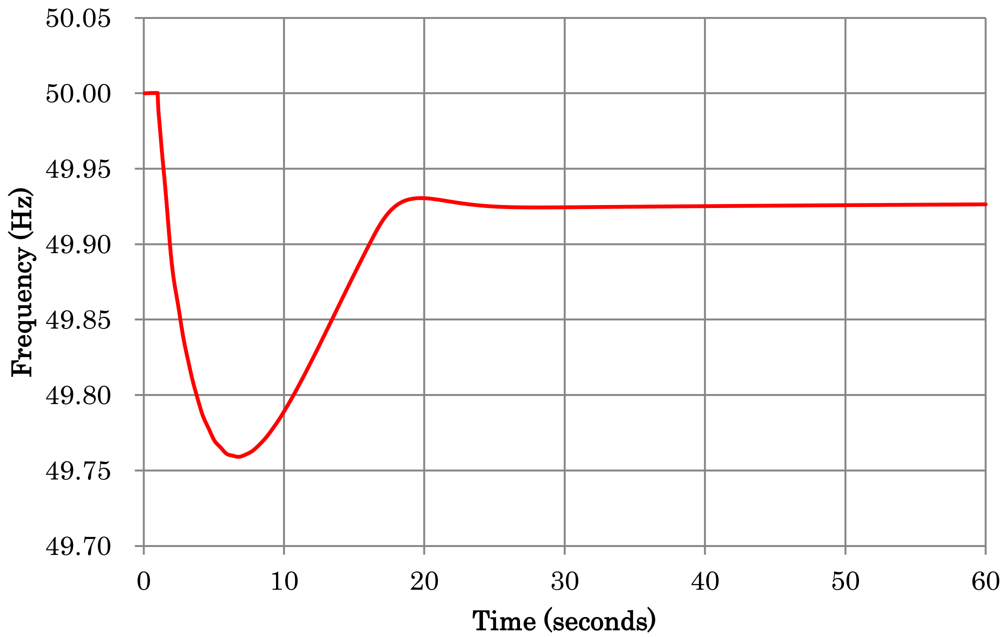
(Source: JICA Study Team)

Figure 10.6.5-24 Three-phase Fault at Loggal end of Loggal-Kotmale 220kV Line-USR



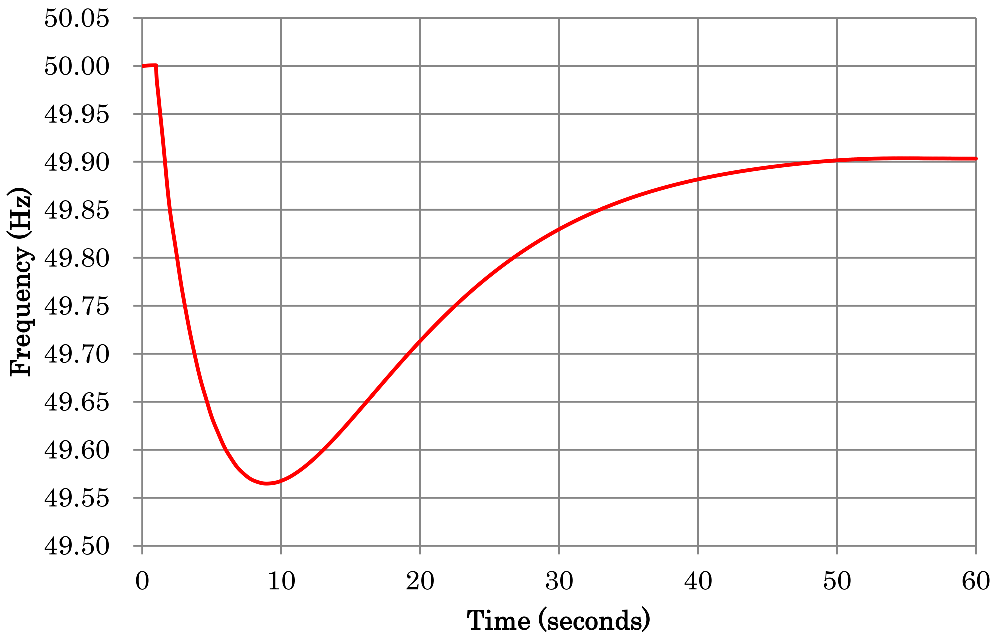
(Hydro Maximum Night Peak in 2025, Connected to Kotmale, Generating Operation)
(Source: JICA Study Team)

Figure 10.6.5-25 200MW Unit Tripping at Loggal PSPP



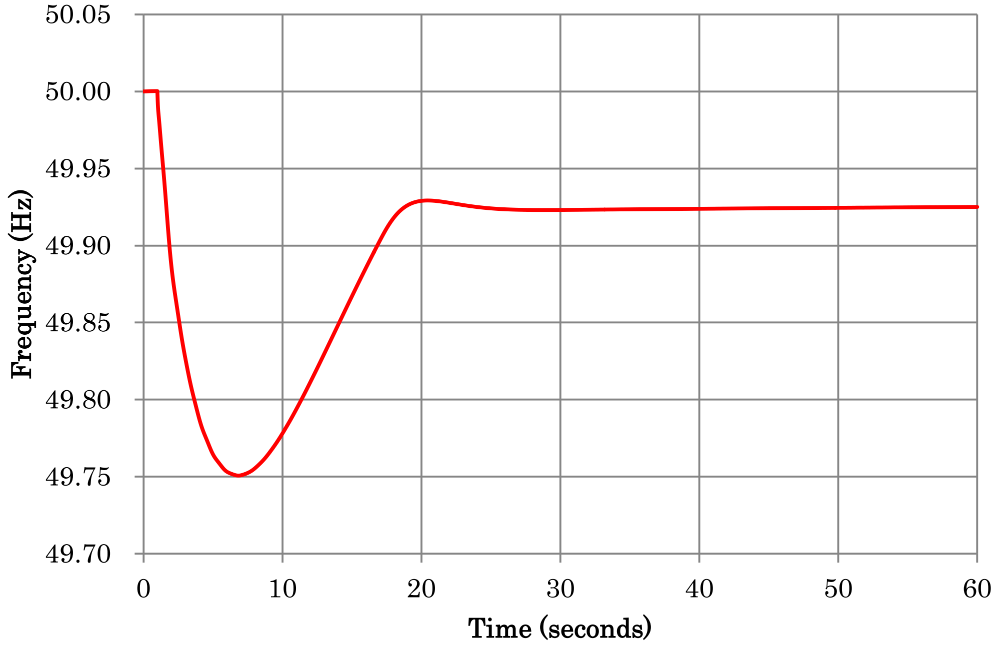
(Hydro Maximum Night Peak in 2025, Connected to Kotmale, Generating Operation)
(Source: JICA Study Team)

Figure 10.6.5-26 150MW Unit Tripping at Loggal PSPP



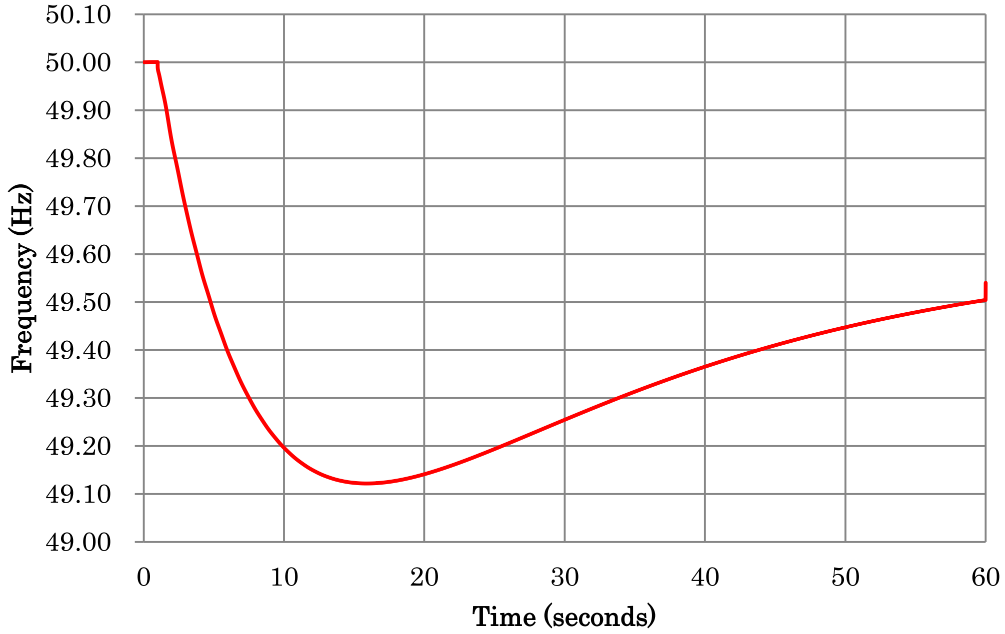
(Hydro Maximum Night Peak in 2025, Connected to Kotmale and New Polpitiya, Generating Operation)
(Source: JICA Study Team)

Figure 10.6.5-27 200MW Unit Tripping at Loggal PSPP



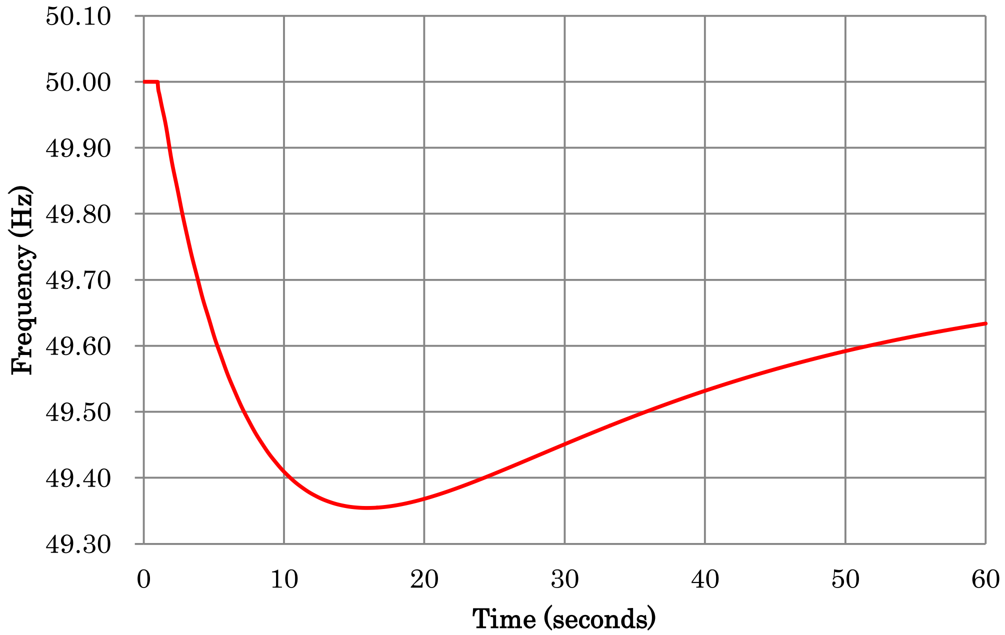
(Hydro Maximum Night Peak in 2025, Connected to Kotmale and New Polpitiya, Generating Operation)
(Source: JICA Study Team)

Figure 10.6.5-28 150MW Unit Tripping at Loggal PSPP



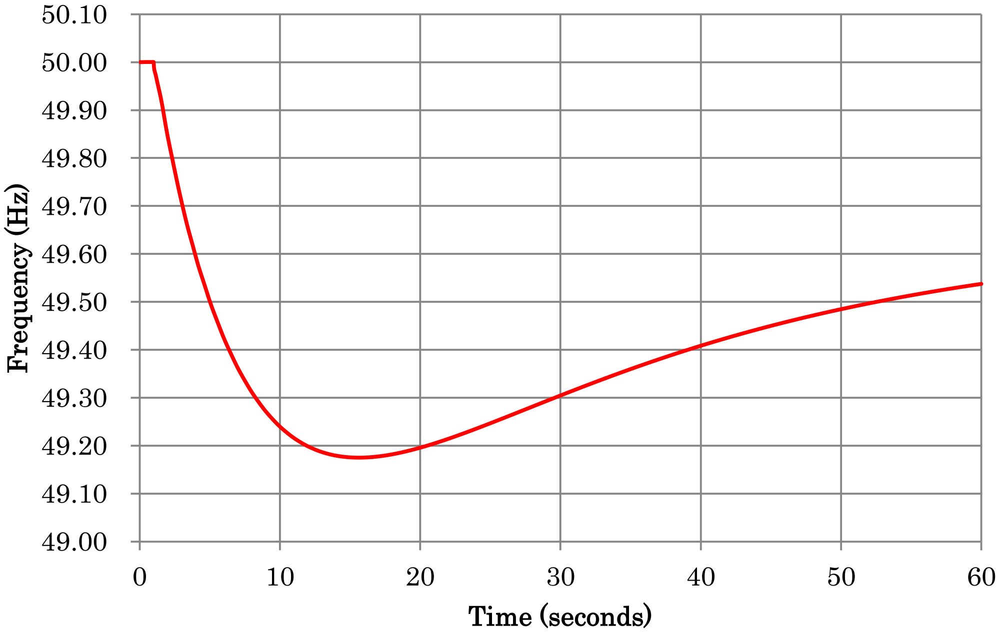
(Thermal Maximum Night Peak in 2025, Connected to Kotmale, Generating Operation)
(Source: JICA Study Team)

Figure 10.6.5-29 200MW Unit Tripping at Loggal PSPP



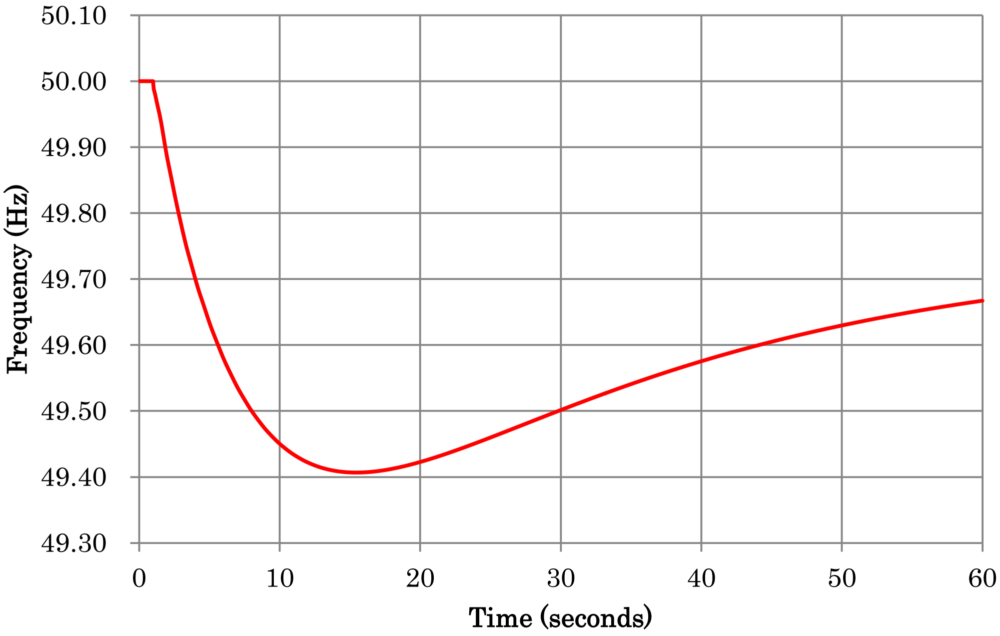
(Thermal Maximum Night Peak in 2025, Connected to Kotmale, Generating Operation)
(Source: JICA Study Team)

Figure 10.6.5-30 150MW Unit Tripping at Loggal PSPP



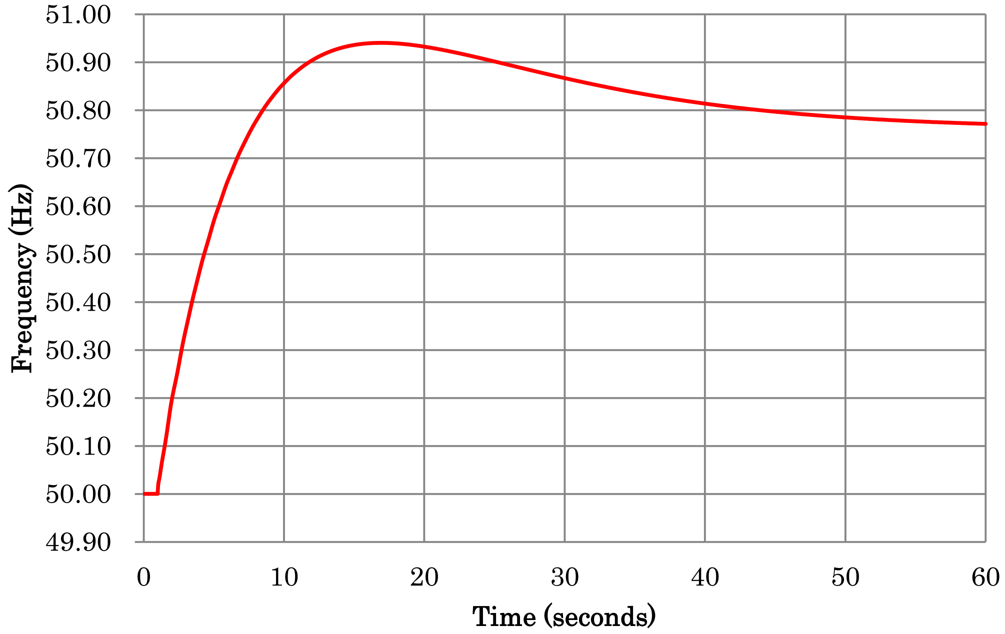
(Thermal Maximum Night Peak in 2025, Connected to Kotmale and New Polpitiya, Generating Operation)
(Source: JICA Study Team)

Figure 10.6.5-31 200MW Unit Tripping at Loggal PSPP



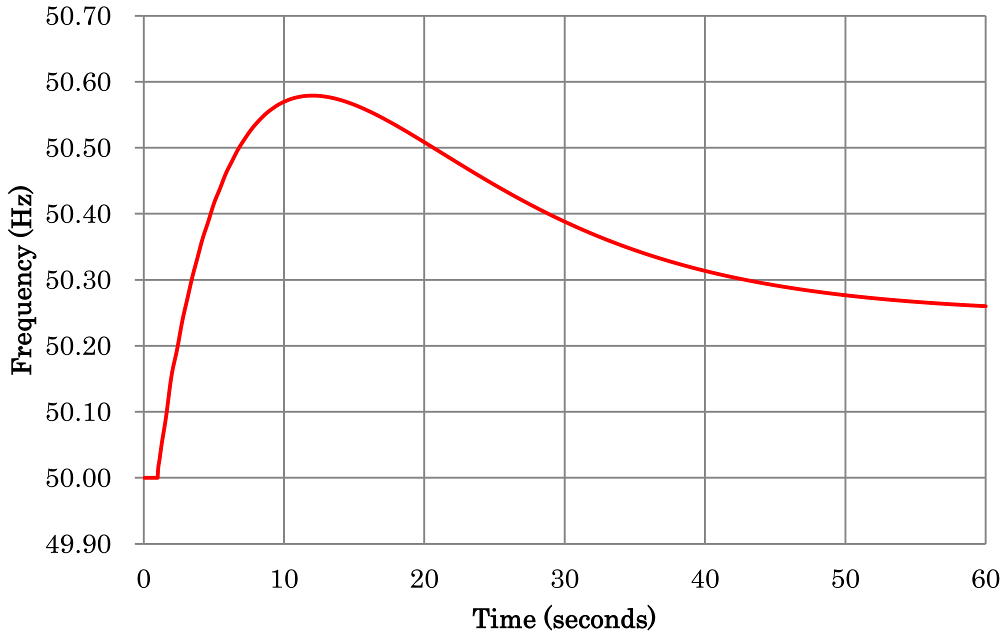
(Thermal Maximum Night Peak in 2025, Connected to Kotmale and New Polpitiya, Generating Operation)
(Source: JICA Study Team)

Figure 10.6.5-32 150MW Unit Tripping at Loggal PSPP



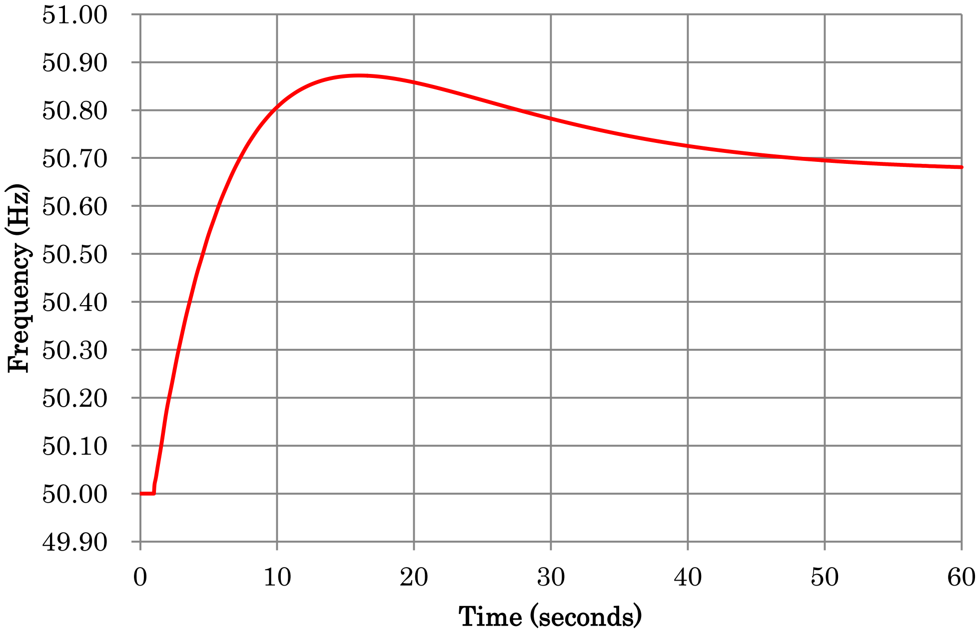
(Off Peak in 2025, Connected to Kotmale, Pumping Operation)
(Source: JICA Study Team)

Figure 10.6.5-33 200MW Unit Tripping at Loggal PSPP



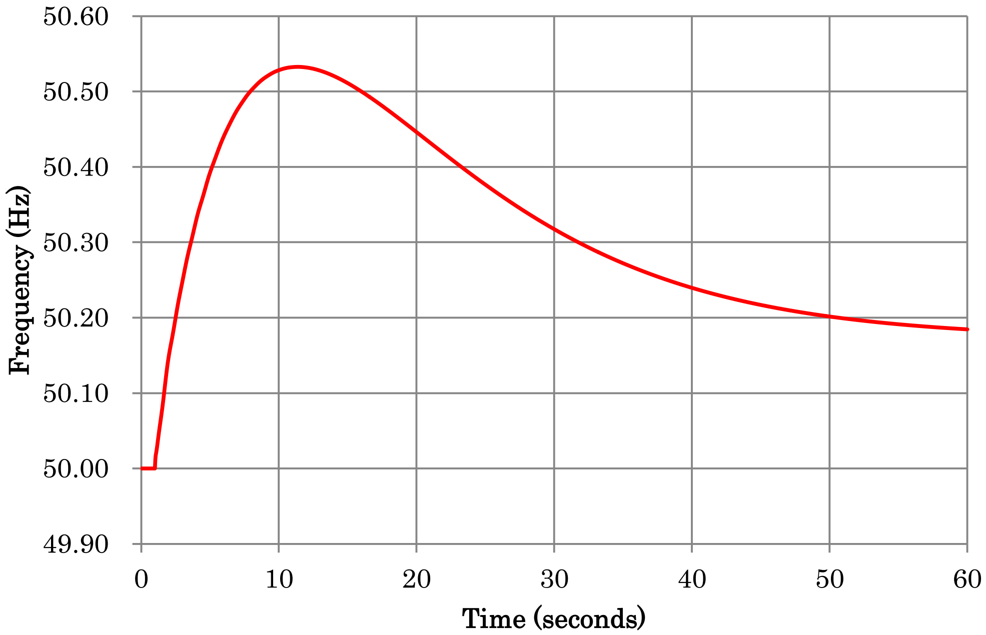
(Off Peak in 2025, Connected to Kotmale, Pumping Operation)
(Source: JICA Study Team)

Figure 10.6.5-34 150MW Unit Tripping at Loggal PSPP



(Off Peak in 2025, Connected to Kotmale and New Polpitiya, Pumping Operation)
(Source: JICA Study Team)

Figure 10.6.5-35 200MW Unit Tripping at Loggal PSPP



(Off Peak in 2025, Connected to Kotmale and New Polpitiya, Pumping Operation)
(Source: JICA Study Team)

Figure 10.6.5-36 150MW Unit Tripping at Loggal PSPP

(9) Conclusion of Power System Analysis

- Under the normal condition and N-1 condition, no thermal criteria violations and no voltage violations are observed in case that T/L (the conductor is Low Loss ACSR/AS 550 × 2) from Loggal PSPP is connected to Kotmale P/S.
- Under the normal condition and N-1 condition, no thermal criteria violations and no voltage violations are observed in case that T/L from Loggal PSPP is connected to T/L between Kotmale P/S and New Polpitiya S/S with PI connection, which is constructed in the future.
- In generating mode, the results of the transient stability study show that the network envisaged in 2025 can be kept in stable in all cases. In pumping mode, however, the results show that the network cannot be kept in stable in case that T/L from Loggal PSPP is connected to Kotmale P/S. In order to keep the network in stable, the conductor of T/L from Loggal PSPP should be reconsidered. Also, since weak damping phenomena are seen in around the initial 10 seconds in several cases, it is suggested that relatively large plants should be equipped with power system stabilizers.
- The results of the dynamic simulation for one unit tripping show that no frequency violations are resulted. However, it is suggested to operate plants considering frequency controlling, and to equip with free governor system for relatively large plants to be developed in the future.

10.6.6 Construction Cost

Table 10.6.6-1 shows construction cost of Loggal. As mentioned in the sub-chapter 10.6.1, since the topographic survey of scale 1/5,000 was not be able to be carried out, shown construction cost is same as that of the chapter 9; however, cost of the transmission line, the route of which the construction is calculated is Loggal to Kotmale P/S, and the interest during construction period are include in it.

Furthermore, this site is applicable for unit capacity of 200 MW and 150 MW; therefore construction costs of the both scheme; 200 MW/unit * 3 units and 150 MW/unit * 4 units are calculated.

Table 10.6.6-1 Construction Cost of Loggal

	Item/Project	Loggal 200 MW (US$)	Loggal 150 MW (US$)	Remarks
1.	Preparation and Land Acquisition	6,915,636	7,053,835	
2.	Environmental Mitigation Cost	10,373,454	10,580,752	3. Civil Works * 3%
3.	Civil Works	345,781,796	352,691,748	
4.	Hydromechanical Works	62,287,324	62,978,428	
5.	Electro-Mechanical Equipment	188,900,000	196,700,000	
6.	Transmission Line	46,300,000	46,300,000	
	Direct Cost	660,558,210	676,304,763	
7.	Administration and Engineering Servic	99,083,731	101,445,714	Direct Cost * 15%
8.	Contingency	66,055,821	67,630,476	Direct Cost * 10%
9.	Interest during Construction	44,422,540	45,481,495	Σ(1,2,…8)*0.4*i*T
	Total Cost	870,120,301	890,862,448	
	Power Output	600,000	600,000	
	USD per kW	1,450	1,485	
	Notes; i: interest rate(=2.69%), T; Construction Period(=5years)			

(Source: JICA Study Team)

Furthermore, the main features of civil structures are shown in Table 10.6.8-2.

Table 10.6.6-2 General Features of Main Civil Structure of Loggal

Loggal	200MW	150MW
Upper Dam		
Type	RCC	RCC
Height * CrestLength	42m * 220m	42m * 220m
Volume	112,000m^3	112,000m3
Lower Dam		
Type	Rockfill	Rockfill
Height * CrestLength	76m * 540m	76m * 540m
Volume	5,200,000m^3	5,200,000m3
Headrace Tunnel		
Dia.*Length*lines	5.3m * 1,750m *1line	3.7m * 1,750m *2line
Penstock Tunnel		
Dia.*Length*lines	4.1m *1,106m * 1line	2.9m * 1,106m * 2line
Tailrace Tunnel		
Dia.*Length*lines	5.8m * 1,230m * 1line	4.1m * 1,230m * 2line

(Source: JICA Study Team)

10.6.7 Natural Environment

(1) Upper dam/reservoir

1) Area of Forests

Forests that are directly affected by inundation are home gardens with tea plantations (16.2 ha including home gardens with tea which covers 7.4 ha), tree plantations (pine and acacia: 0.6 ha) and riverine forests (0.8 ha). The total area is 17.6 ha. The total area of the reservoir is 35.4 ha, and the ratio of the forests to the reservoir is 47.9% (refer to Table 10.6.8-2, Figure 10.6.8-1).

Home gardens are developed around the houses with some tea plantation.	A riverine forest remains along the river but not for a long distance.

(Source: JICA Study Team)

Figure 10.6.7-1 Forests at Loggal Upper

2) Endangered species (flora)

The list of the endangered species (flora) at Loggal upper dam/reservoir that were recorded during the Environmental Study (2) is shown as Table 10.6.7-1.

Table 10.6.7-1 Threatened Floral Species at Loggal Upper

Family	Species	NCS	GCS
Anacardiaceae	Mangifera zeylanica*	LC	VU
	Semecarpus nigro-viridis	LC	VU
Lauraceae	Alseodaphne semecarpifolia	VU	
	Cinnamomum zeylanicum	VU	
	Litsea longifolia*	LC	VU
Loganiaceae	Strychnostricho calyx*	VU	
Moraceae	Plecospermum spinosum	VU	
Myristicaceae	Myristica ceylanica	VU	VU
Rubiaceae	Lasianthus gardneri*	EN	
	Psychotria gardneri*	NT	EN

NOTE: refer to the note of Table 10.3.7-1.
(Source: JICA Study Team)

3) Endangered species (fauna)

The list of the endangered species (fauna) at Loggal upper dam/reservoir that were recorded during the Environmental Study (2) is shown as Table 10.6.7-2.

Table 10.6.7-2 Threatened Faunal Species at Loggal Upper

Group	Family	Species	English Name	NCS	GCS
BEES	Apidae	Apis cerana		VU	
MOLLUSCS	Ariophantidae	Euplecta semidecussata		VU	
	Cyclophoridae	Theobaldius parma*		EN	
		Corilla adamsi*		EN	
DRAGONFLIE S	Calopterygdae	Vestalis apicalis *	Black-tipped flashwing	VU	LC
	Euphaeidae	Euphaea splendens *	Shining Gossamerwing	NT	
BUTTERFLIES	Papilionidae	Troides darsius *	Common birdwing	LC	
		Papilio helenus	Red helen	VU	
FRESHWATER CRABS	Gecarcinucidae	Ceylonthelphusa rugosa*		NT	LC
FRESHWATER FISH	Cyprinidae	Garra ceylonensis*	Stone sucker	VU	EN
AMPHIBIANS	Ranidae	Hylarana temporalis *	Common wood frog	NT	
REPTILES	Scincidae	Lankascincus deignani *	Deignan'slankaskink	EN	EN
		Lankascincus fallax *	Common Lankaskink	LC	
	Viperidae	Trimeresurus trigonocephalus *	Green pit viper	LC	
BIRDS	Ramphastidae	Megalaima flavifrons *	Sri Lanka Yellow fronted Barbet	LC	LC
	Psittacidae	Loriculus beryllinus *	Sri Lanka Hanging Parakeet	LC	LC
		Psittacula calthropae *	Sri Lanka Layard's Parakeet	NT	LC
	Ciconiidae	Ciconia episcopus	Woolly-necked Stork	NT	LC
	Timalidae	Pellorneum fuscocapillus *	Sri Lanka Brown-capped Babbler	LC	LC
	Zosteropidae	Zosterops ceylonensis *	Sri Lanka White-eye	NT	LC
MAMMALS	Cercopithecidae	Macaca sinica *	Sri Lanka toque monkey	LC	EN
	Felidae	Prionailuru sviverrinus	Fishing cat	EN	EN
	Sciuridae	Ratufa macroura	Giant squirrel	LC	NT

NOTE: refer to the note of Table 10.3.7-1.
(Source: JICA Study Team)

4) Ecosystems

The major ecosystems at Loggal upper dam/reservoir are shown with their characteristics as Table 10.6.7-3.

Table 10.6.7-3 Ecosystems of Loggal Upper

Ecosystem	Characteristics
Reservoir area	
Paddy fields	The valley bottom with gentle slope, especially the upstream area from the backwater area is covered by paddy fields. They occupy 41.2 % of the reservoir.
Tree plantations	They are pine and acacia plantations. They occupy 2% of the reservoir.
Shrubs	There are savanna type shrubs on the steep slopes. They occupy 1% of the reservoir.
Home gardens	There two types of home gardens: home gardens with tea, and home gardens with multi-layer structure. Multi-layer type ones are located around houses, and usually have canopy, middle and shrubs layers, but each layer is not developed well. They occupy 45.8% of the reservoir.
Riverine forests	The forests have received interferences from the local people, and they only remain along the river as secondary forests. They have three layers but only some native species are found. They occupy 2.2 % of the reservoir.
Others	There is a temple.
Buffer Zone	
There is a cemetery other than paddy fields, tree plantations, home gardens and riverine forests.	
Aquatic ecosystem	
At the bottom of the valley, there is a river with the width of a few meters. There are small tributaries into the river.	

(Source: JICA Study Team)

(2) Lower dam/reservoir

1) Area of Forests

Forests that are directly affected by inundation are home gardens (5.0 ha), secondary forests (5.0 ha), and riverine forests (0.03 ha). The total area is 10.0 ha. The total area of the reservoir is 17.6 ha, and the ratio of the forests to the reservoir is 56.8 % (refer to Table 10.6.8-4, Figure 10.6.8-2).

Home gardens and secondary forests remain around the houses and the agricultural lands.

A very poor riverine forest remains besides the agricultural lands.

(Source: JICA Study Team)

Figure 10.6.7-2 Forests at Loggal Lower

2) Endangered species (flora)

The list of the endangered species (flora) at Loggal lower dam/reservoir that were recorded during the Environmental Study (2) is shown as Table 10.6.7-4.

Table 10.6.7-4 Threatened Floral Species at Loggal Lower

Family	Species	NCS	GCS
Anacardiaceae	Mangifera zeylanica*	LC	VU
Anacardiaceae	Semecarpu snigro-viridis*	LC	VU
Cycadaceae	Cycas nathorstii	VU	VU
Phyllanthaceae	Margaritaria indicus	VU	

NOTE: refer to the note of Table 10.3.7-1.
(Source: JICA Study Team)

3) Endangered species (fauna)

The list of the endangered species (fauna) at Loggal lower dam/reservoir that were recorded during the Environmental Study (2) is shown as Table 10.6.7-5.

Table 10.6.7-5 Threatened Faunal Species at Loggal Lower

Group	Family	Species	English Name	NCS	GCS
BEES	Apidae	Apis cerana		VU	
MOLLUSCS	Ariophantidae	Euplecta semidecussata		VU	
		Ratnadvipia irradians*		VU	
	Cyclophoridae	Theobaldius parma*		EN	
		Pterocyclus cingalensis*		NT	
		Corilla adams*		EN	
DRAGONFLIES	Calopterygdae	Vestalis apicalis *	Black-tipped flashwing	VU	LC
	Cholorocyphidae	Libellago greeni *	Green's Gem	EN	
	Euphaeidae	Euphaea splendens*	Shining Gossamerwing	NT	
BUTTERFLIES	Papilionidae	Troides darsius*	Common birdwing	LC	
	Nymphalidae	Ideopsis similis	Blue glassy tiger	VU	
		Tirumala septentrionis	Dark blue tiger	NT	
	Hesperiidae	Sarangesa dasahara	Common Small Flat	NT	
FRESHWATER CRABS	Gecarcinucidae	Ceylonthelphusa rugosa*		NT	LC
FRESHWATER FISH	Cyprinidae	Esomus thermoicos*	Flying barb / Bearded rasbora	LC	LC
		Garra ceylonensis*	Stone sucker	VU	EN
		Puntius kamalika*	Kamalika's barb	EN	
		Pethia melanomaculata*	Tic tac-toe barb	VU	
	Balitoridae	Schistura notostigma*	Banded mountain loach	NT	
AMPHIBIANS	Ranidae	Hylarana gracilis*	Sri Lanka wood frog	LC	
		Hylarana temporalis*	Common wood frog	NT	
REPTILES	Testudinidae	Geochelone elegans	Indian star tortoise	NT	
	Agamidae	Calotes liolepis*	Whistling lizard / Forest lizard	NT	
		Otocryptis wiegmanni*	Sri Lankan kangaroo lizard	LC	
	Scincidae	Lankascincus deignani*	Deignan's lankaskink	EN	EN
		Lankascincus fallax*	Common lankaskink	LC	
	Colubridae	Aspidura copei*	Cope's roughside	DD	
	Viperidae	Trimeresurus trigonocephalus*	Green pit viper	LC	
	Cylindrophidae	Cylindrophis maculata*	Sri Lanka Pipe snake	NT	
BIRDS	Phasianidae	Gallus lafayetii*	Sri Lanka Junglefowl	LC	LC
	Ramphastidae	Megalaima flavifrons*	Sri Lanka Yellow-fronted Barbet	LC	LC
	Bucerotidae	Ocyceros gingalensis*	Sri Lanka Grey Hornbill	LC	LC
	Cuculidae	Surniculus lugubris	Drongo Cuckoo	NT	
	Psittacidae	Loriculus beryllinus*	Sri Lanka Hanging Parakeet	LC	LC
	Timalidae	Pellorneum fuscocapillus *	Sri Lanka Brown-capped Babbler	LC	LC
MAMMALS	Cercopithecidae	Macaca sinica*	Sri Lanka toque monkey	LC	EN
	Soricidae	Suncus montanus*	Highland shrew	EN	VU
	Felidae	Prionailurus viverrinus	Fishing cat	EN	EN
	Sciuridae	Ratufa macroura	Giant squirrel	LC	NT

NOTE: refer to the note of Table 10.3.7-1.
(Source: JICA Study Team)

4) Ecosystems

The major ecosystems at Loggal lower dam/reservoir are shown with their characteristics as Table 10.6.7-6.

Table 10.6.7-6 Ecosystems of Loggal Lower

Ecosystem	Characteristics
Reservoir area	
Paddy fields	The valley bottom with gentle slope is covered by paddy fields. They occupy 39.8 % of the reservoir.
Home gardens	They are developed around the paddy fields and houses. Multi-layer type home gardens are found around houses. They occupy 28.4% of the reservoir.
Secondary forests	They are developed the abandoned slash-and-burn agricultural lands. Native species are mainly found in the secondary forests. They occupy 28.4% of the reservoir.
Riverine forests	The forests have received interferences from the local people, and they only remain along the river as secondary forests. The area is 0.03 ha.
Buffer Zone	
They are shrubs, a school and a temple other than paddy fields, home gardens, secondary forests and riverine forests.	
Aquatic ecosystem	
At the bottom of the valley, there is a river with the width of a few meters. When it rains, it has water flow. There are small tributaries into the river.	

(Source: JICA Study Team)

10.6.8 Social Environment

(1) Upper dam/reservoir

1) Outlines of the Social Environment

Based on the results of the Environmental Study (1) and (2), the outlines of the social environment in Loggal upper is shown in Table 10.6.8-1.

Table 10.6.8-1 Social Conditions at Loggal Upper

Name of site / Characteristics	Loggal Upper dam/reservoir
Location	The directly affected area and the buffer zone fall into Pitamaruwa (GN) and Wewatenna (GN) in Meegahakiuala DS division in Badulla District.
Demographic status of the GND	Pitamaruwa: 945 population, 270 families, Average No. of family 3.49 Wewatenna : 502 population, 143 families, Average No. of family 3.49
The number of sampling social survey	The social survey was not conducted due to a strong opposition by the local people.
Residence year of the family	Majority of the local people have been living there since their birth.
Ethnic and Religion	Majority of the local people are Sinhalese, and Buddhism. Some people are Tamil, and Hinduism.
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. The road is in very dilapidated condition for the last 6 kms. At least 0.5 km of access road need to be constructed to reach the dam site from the nearest road.
Number of those who to be resettled	The inundated area: 21 families The buffer zone: 99 families will be indirectly affected (People might have to relocate their houses and/or might lose their paddy fields and home gardens tempolarily during the construction period).
Area of land to be acquired	35.40ha
Number of those who to be affected by losing livelihood	21 families who are in directly affected area will lose their livelihood due to inundated.
Major occupation	Agriculture and private employee (majority of the people are employed nearby the tea estate.
Impacts on public facilities	A certain portion of existing road will be inundated.
Existence of poverty people	66 families of Pitimadura GN receive Samurdhi of government aid. No identify who receive Samurdhi in the directly affected area and the buffer zone due to refusing the environmental survey.
Existence of indigenous people	None
Water Utilization	The people of Pitimadura GN get water for drinking from springs and wells. 33 ha of paddy get water from small irrigation where is outside of the project area. Since no social survey in the area, there is no detail data, but local people of the directly affected area and the buffer zone use river water for bathing and for vegetable fields, but not for drinking. There is a mini-hydropower plant downstream of river where is outside of the buffer zone will be indirectly affected during construction.
Impacts on agriculture	Paddy, home garden, and home garden with tea
Non timber forest product Utilization	The local people collect fire wood nearby home gardens and forests.
Impacts on tourism	There are no tourism spot or tourism resources in the directly affected area.
Religious, cultural and archeological heritages	The directly affected area: one (1) Buddhist temple
Impacts on landscape	The proposed project site is located in a mountainous area and there are isolated villages where most of the local people are engaged in farming of paddy, home gardens and forest plantation. Except that scenery, there is no landscape resource which has to be protected.
People's consciousness toward the proposed project	About 50 local people attended an awareness meeting of the Project in January 2014. When the outline of the Project was explained to them, some of them strongly opposed it because of losing a temple, paddy and some households by the Project. They did not want to relocate their houses.

(Source: JICA Study Team)

2) Land Use

Table 10.6.8-2 shows the present land use pattern in the proposed dam/reservoir.

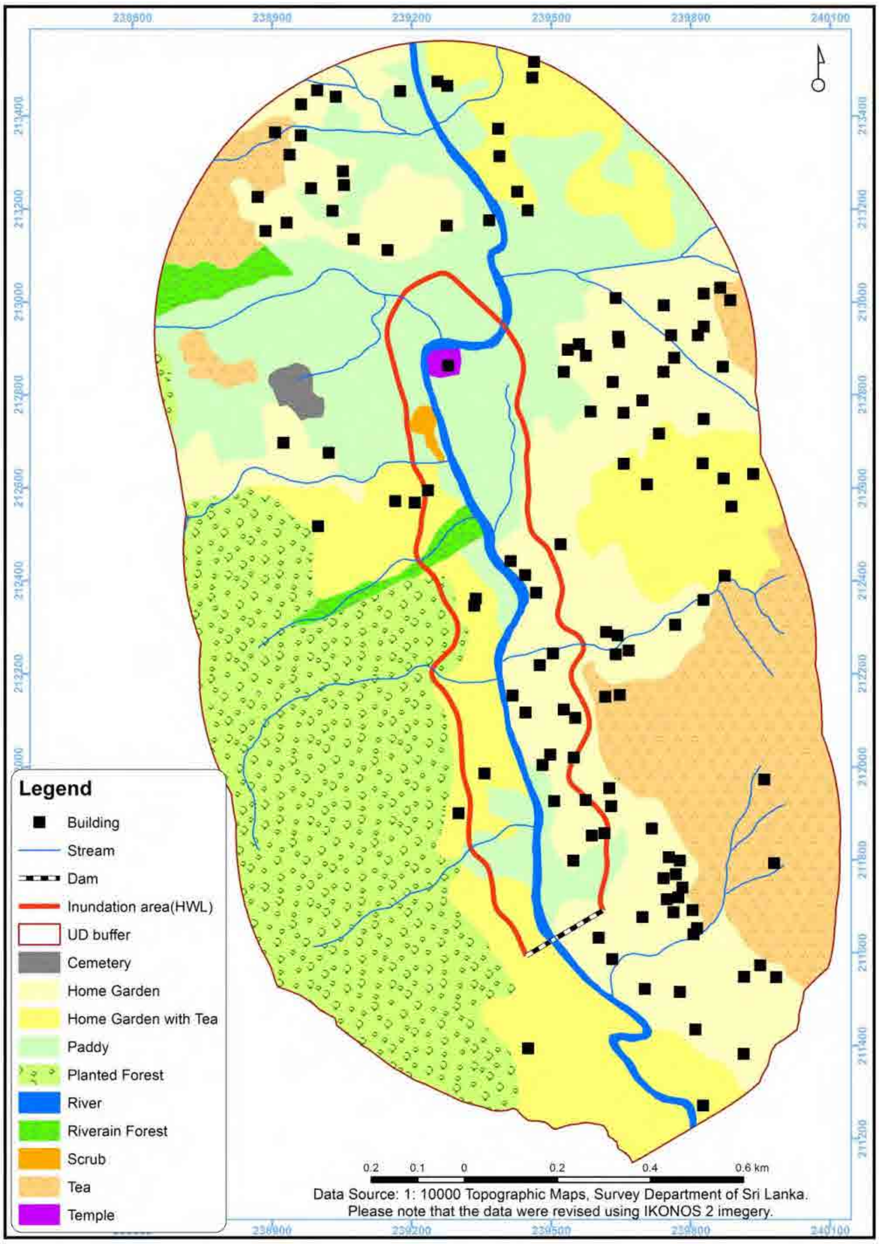
Table 10.6.8-2 Land use Pattern of Loggal Upper

Land Use Type	Inundation Area (ha)	with Buffer (ha)
Cemetery	0.00	0.91
Home Garden	8.76	62.67
Home Garden with Tea	7.44	50.77
Paddy	14.60	53.38
Planted Forest	0.60	55.67
River	2.31	4.07
Riverain Forest	0.88	3.72
Scrub	0.40	0.40
Tea	0.00	35.81
Temple	0.42	0.42
TOTAL	**35.41**	**267.82**

(Source: JICA Study Team)

3) Location of houses and the present land use in inundation area and the 500m buffer zone in Loggal upper

Figure 10.6.8-1 shows the location of houses and present land use pattern in and around Loggal upper.



(Source: JICA Study Team)

Figure 10.6.8-1 Land use Pattern and Locations of Houses of the inundated Area the Buffer Zone of Loggal Upper

(2) Lower dam/reservoir

1) Outlines of the Social Environment

Based on the results of the Environmental Study (1) and (2), the outlines of the social environment in Loggal lower is shown in Table 10.6.8-3.

Table 10.6.8-3 Social Conditions of Loggal Lower

Name of site / Characteristics	Loggal Lower dam/reservoir
Location	The directly affected area and the buffer zone fall into Kalugahakandura (GN) in Meegahakiuala DS Division in Badulla District.
Demographic status of the GND	Pitamaruwa: 651 population, 187 families, Average No. of family 3.49
The number of sampling social survey	The social survey was not conducted due to a strong opposition by the local people.
Residence year of the family	Majority of the local people have been living there since their birth.
Ethnic and Religion	Majority of the local people are Sinhalese, and Buddhism.
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 this road to the dam crest site through home gardens. At least 1- 1.5 km access roads need to be constructed to reach the dam site on both banks.
Number of those who to be resettled	The inundated area: 4 families The buffer zone: 24 families will be indirectly affected (People might have to relocate their houses and/or might lose their paddy fields and home gardens tempolarily during the construction period).
Area of land to be acquired	17.59ha
Number of those who to be affected by losing livelihood	Four (4) families who are in directly affected area will lose their livelihood due to the inundation.
Major occupation	Agriculture, government employee, and private employee
Impacts on public facilities	A school will be inundated by the Project.
Existence of poverty people	96 families of Kalugahakandura GN receive Samurdhi of government aid. No identify who receive Samurdhi in the directly affected area and the buffer zone due to refusing the environmental survey.
Existence of indigenous people	None
Water Utilization	The people of Kalugahakandura GN get water for drinking from springs and wells. 65 ha of paddy during Maha, and 21 ha of paddy during Yala get water from irrigation where is located outside of the project area. Since no social survey in the area, there is no detail data, but local people of the directly affected area and the buffer zone do not use river water for drinking.
Impacts on agriculture	Home gardens, paddy, and plantation forests
Non timber forest product Utilization	The local people collect fire wood from the home gardens and the plantation forests.
Impacts on tourism	There are no tourism spot or tourism resources in the directly affected area.
Religious, cultural and archeological heritages	A Buddhist temple is situated bordering the inundation area by the Project. It will not be inundated, but will be indirectly affected during its construction.
Impacts on landscape	The proposed project site is located in a mountainous area and there are isolated villages where most of the local people are engaged in farming of paddy, home gardens and forest plantations. Except that scenery, there is no landscape resource which has to be protected.
People's consciousness toward the proposed project	About 80 local people attended an awareness meeting of the Project in January 2014. When the outline of the Project was explained to them, some of them strongly opposed it because of losing a temple, paddy and some households by the Project. They did not want to relocate their houses.

(Source: JICA Study Team)

2) Land Use

Table 10.6.8-4 shows the present land use pattern in the proposed dam/reservoir.

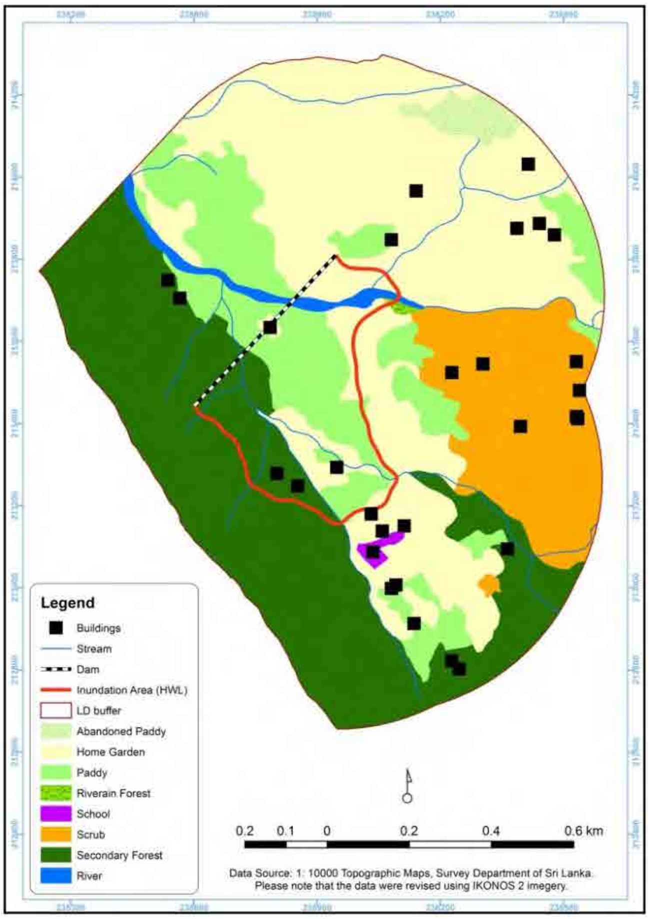
Table 10.6.8-4 Land Use Pattern of Loggal Lower

Land Use Type	Inundation Area (ha)	with Buffer (ha)
Abandoned Paddy	0.00	2.14
Home Garden	4.98	58.16
Paddy	7.02	24.71
Riverine Forest	0.03	0.17
School	0.00	0.44
Scrub	0.00	20.04
Secondary Forest	4.96	48.97
Stream	0.61	1.68
TOTAL	**17.60**	**156.30**

(Source: JICA Study Team)

3) Location of houses and the present land use in inundation area and the 500M buffer zone in Loggal lower

Figure 10.6.8-2 shows the location of houses and present land use pattern in and around Loggal lower.



(Source: JICA Study Team)

Figure 10.6.8-2 Land Use Pattern and Locations of Houses of the inundated Area the Buffer Zone of Loggal Lower

10.7 Selection of the Most Promising Site

10.7.1 Outline

In the promising candidate 3 sites, (4 schemes: Halgran 3, Maha 2, Maha 3, and Loggal), 1/5,000 topographic surveys were planned to be conducted by the local consultant. In the primary site selection as mentioned in the chapter 9 (the selection of the promising candidate sites), 1/10,000 topographic maps (published by Survey Department of Sri Lanka) was utilized for pumped storage planning. Therefore, the topographical survey as the above-mentioned was planned to improve precision of the pumped storage planning for the most promising site selection. In Loggal, however, due to strong opposition for the environmental survey, which was also planned to be conducted in every promising site, the planned topographic survey was canceled by consultation with CEB. Accordingly, review of the pumped storage planning by 1/5,000 topographic map, as mentioned in the sub-chapter 10.2.3, has been carried out in following 3 sites; Halgran 3, Maha 2, and Maha 3.

Table 10.7.1-1 shows reviewed general features of the promising candidate sites.

As mentioned in the sub-chapters from 10.2 to 10.6, every 4 reviewed pumped storage scheme is evaluated from geological condition, easy of construction works, transmission line, impact on the power system, construction cost, and natural/social environmental impacts. In this sub-chapter, ranking study is conducted based on results of evaluation from various aspects as the above-mentioned in order to select the most promising site in 4 promising sites. Evaluation results from every aspect, which are utilized for the ranking study, are summarized in the following sub-chapters.

Table 10.7.1-1 General Features of Promising Sites

Candidate Site		unit	Halgran 3	Maha 2 case1	Maha 2 case2	Maha 3 case1	Maha 3 case2	Logal case1	Logal case2
Installed Capacity		MW	600	600	600	600	600	600	600
Unit Capacity		MW	200	200	150	200	150	200	150
Number of Units		unit	3	3	4	3	4	3	4
Peak Generating Time		hours	6.03	6.00	6.00	6.09	6.03	6.16	6.16
Gross Head		m	677.34	448.93	450.40	512.00	513.06	591.33	591.33
Rated Head		m	643.47	426.48	427.88	486.40	487.40	561.76	561.76
Rated Discharge		m^3	111.94	168.89	168.34	148.09	147.78	128.22	128.22
Upper Pond	Latitude		7°02'14"	7°07'20"	7°07'20"	7°06'23"	7°06'23"	7°06'20"	7°06'20"
	Longitude		80°52'31"	80°27'26"	80°27'26"	80°28'49"	80°28'49"	81°07'46"	81°07'46"
	Catchment Area	km^2	2	5	5	1	1	5	5
	Reservoir Area	km^2	0.16	0.15	0.15	0.23	0.23	0.43	0.43
	Crest Elevation	E.L.-m	1400.0	765.0	764.0	821.0	819.5	1002.0	1002.0
	High Water Level	E.L.-m	1,394.0	759.0	758.0	815.0	813.5	996.0	996.0
	Low Water Level	E.L.-m	1,366.0	724.0	720.6	795.4	792.0	985.0	985.0
	Drawdown	m	28.0	35.0	37.4	19.6	21.5	11.0	11.0
	Sediment Level	E.L.-m	1,354.6	710.5	710.5	782.1	782.1	369.3	369.3
	Gross Capacity	MCM	2.77	4.35	4.21	3.94	3.58	4.59	5
	Available Capacity	MCM	2.45	3.65	3.69	3.25	3.29	3.16	3
	Dam Height	m	70	80	79	61	60	42	42
	Crest Length	m	210	250	250	275	275	220	220
Lower Pond	Latitude		7°03'57"	7°07'50"	7°07'50"	7°07'50"	7°07'50"	7°7'23"	7°7'23"
	Longitude		80°54'11"	80°28'27"	80°28'27"	80°28'27"	80°28'27"	81°05'46'	81°05'46'
	Catchment Area	km^2	16	35	35	35	35	5	5
	Reservoir Area	km^2	0.17	0.15	0.15	0.23	0.23	0.15	0.15
	Crest Elevation	E.L.-m	720.0	310.5	307.5	308.0	305.0	416.0	416.0
	High Water Level	E.L.-m	714.0	304.5	301.5	302.0	299.0	410.0	410.0
	Low Water Level	E.L.-m	694.0	286.2	282.4	285.4	281.8	383.0	383.0
	Drawdown	m	20.0	18.3	19.1	16.6	17.2	27.0	27.0
	Sediment Level	E.L.-m	681.6	271.8	271.8	271.8	271.8	369.3	369.3
	Gross Capacity	MCM	3.79	6.92	6.21	6.33	5.65	3.66	4
	Available Capacity	MCM	2.43	3.73	3.67	3.28	3.21	2.84	3
	Dam Height	m	75	71	68	68	65	76	76
	Crest Length	m	280	350	350	350	350	540	540
Headrace Tunnel									
	Inner Diameter	m	4.90	6.00	4.30	5.70	4.00	5.30	3.70
	Length	m	1,350	510	510	1,100	1,100	1,750	1,750
	Nos. of lines	-line	1	1	2	1	2	1	2
Penstock Tunnel									
	Inner Diameter	m	3.80	4.70	3.30	4.40	3.10	4.10	2.90
	Length	m	1,212	885	889	979	983	1,106	1,106
	Nos. of lines	-line	1	1	2	1	2	1	2
Tailrace Tunnel									
	Inner Diameter	m	5.40	6.60	4.70	6.20	4.40	5.80	4.10
	Length	m	2,200	1,000	1,000	500	500	1,230	1,230
	Nos. of lines	-line	1	1	2	1	2	1	2
Access Tunnel to PH									
	Length	m	1,500	1,000	1,000	900	900	1,600	1,600

(Source: JICA Study Team)

10.7.2 Geological Evaluation

As mentioned in every previous sub-chapter, any serious geological problems are not found in every promising site. Results of geological evaluation for every promising site are shown in Table 10.7.2-1. Evaluation on upper dams and lower dams is made from following aspects; rock quality, permeability, existence of faults, volume of river bed deposition, and slope stability of reservoir rim, as well as evaluation on waterway is from following aspects; rock quality, existence of faults, relation of direction of tunnel axis and dominant joints. Evaluation results are expressed by four-grade rate; A, B, C, and D. Meaning of every rate is “from Excellent to Poor; A>B>C>D”.

In addition, evaluation results in Loggal is made based on those in Chapter 9, because the geological survey by the local consultant was not able to be carried out in Loggal; therefore, Overall evaluation of Loggal is discounted due to its rather inferior accuracy of the evaluation compared to those in other promising sites.

Table 10.7.2-1 Evaluation on Site Geology

Items	Halgran 3			Maha 2			Maha 3			Loggal		
	UD	LD	Route	UD	LD	Route	UD	LD	Route	UD	LD	Route
Rock Quality	B	C	B	A	B	B	B	B	B	A	B	B
Permiability	C	C		B	B		B	B		B	B	
Faults	B	B	C	A	C	B	A	C	A	A	A	B
River bed	A	B		A	A		A	A		A	C	
Slope	A	C		A	C		B	C		A	B	
Direction			C			A			C			A
Overall Evaluation	C			A			B			C		

(Source: JICA Study Team)

10.7.3 Evaluation from Construction Works

As for evaluation from easy of construction works, it is made from following aspects; access to upper reservoirs and lower reservoirs, easiness of land reclamation for temporary yards, length of access tunnel to powerhouse caverns, and drawdown depth based on topographic conditions in and around every site. In a pumped storage scheme, a deeper drawdown depth is one of unfavorable conditions due to influence on the slope stability of reservoir rim considering repeated saturation and drain condition caused by daily operation. It is obvious that deeper drawdown depth cause larger influence on the slope stability; consequently, it causes difficulties of construction works. In this regards, 30m is upper limitation for the drawdown depth of upper reservoirs and lower reservoirs of pumped storage schemes in general, which is operated on the daily basis. The evaluation results are expressed by four-grade rate; A, B, C, and D. Meaning of every rate is “from Excellent to Poor; A>B>C>D”.

Table 10.7.3-1 Evaluation from Construction Works

Items	Halgran 3	Maha 2	Maha 3	Loggal
Access to Upper Dam	C	B	A	C
Access to Lower Dam	B	B	B	B
Temporary Yards	B	B	B	B
Length of Access to PH	C	B	A	C
Drawdown depth	B	C	B	B
Overall Evaluation	C	B	A	C

(Source: JICA Study Team)

10.7.4 Transmission Connection and Power system Stability

As mention in previous sub-chapters, the candidate routes of connecting transmission lines are envisaged considering to the existing transmission lines passing and existing sub-stations around the sites, environmental protected area and urban areas on the routes. Furthermore, the power system analysis is carried out for every determined transmission line routes in order to confirm impact on the existing power system. As a result, the most preferable transmission line routes are selected from technical and economic aspect and environmental consideration aspect.

For Halgran 3 and Loggal, the route to Kotmale P/S is selected, distance and numbers of conductor of which are 45km × 1 cct for Halgran 3 and 65km × 1cct for Loggal. On the other hand, the route with PI connecting to the existing transmission line between Kotmale P/S and Kirindiwela S/S, distance and numbers of conductor of which is 3.8km × 2cct. In this regard, the distance and numbers of conductor of the connecting transmission line are excluded from evaluation criteria because those are finally reflected to the construction cost.

Table 10.7.4-1 shows evaluation results by rates for impact on the existing power system which was derived from the power system analysis. As the serious impact, the step-out is simulated in case of 3-phase fault in Loggal. Other than that, any serious impacts are not detected by the analysis. The evaluation results are expressed by four-grade rate; A, B, C, and D. Meaning of every rate is "room from the criteria; A>B>C and D means out of the criteria"

Table 10.7.4-1 Evaluation for System Analysis Results

Items	Halgran 3	Maha 2	Maha 3	Loggal
Power Fault Analysis	A	B	B	A
Short Circuit Currents Analysis	A	A	A	A
Stability to 3-phase line fault	A	A	A	D
200 MW unit Trip	B	B	B	B
Overall Evaluation	A	B	B	D

(Source: JICA Study Team)

10.7.5 Manufacturing Limitation of Pump-turbine

As mentioned in the previous sub-chapter, applicability of the unit capacity 200MW is examined based on the revised pumped storage scheme as well as that of the unit capacity 150MW for every promising site. Table 10.7.5-1 shows results of the examination. It is revealed that for Halgran 3, applicability of unit capacity 200 MW is plotted near the boundary between applicable extent and inapplicable extent as well as unit capacity 150MW is plotted on near the boundary for Loggal.

The evaluation results are expressed by four-grade rate; A, B, C, and D. Meaning of every rate is as follows; “room from the criteria; A>B>C and D means out of the criteria” and in Overall evaluation, A; both 200MW and 150MWare applicable, C; only 200MW is applicable, D; both 200MW and 150MW are inapplicable.

Table 10.7.5-1 Evaluation for Manufacturing Limitation of Pump-turbine

	Halgran 3	Maha 2	Maha 3	Loggal
200 MW	B	A	A	A
150 MW	D	A	A	B
Overall Evaluation	C	A	A	B

(Source: JICA Study Team)

10.7.6 Construction Cost

Based on the revised pumped storage scheme, the construction cost is reviewed for every promising site. Reviewed construction cost of every promising site is shown in Table 10.7.6-1, which includes the construction cost of connecting transmission line. Shown construction cost for Loggal is same one with calculated in the Chapter 9; however, construction cost for the connecting transmission line is newly added to that. The evaluation results are expressed by four-grade rate; A, B, C, and D. Meaning of every rate is as follows; A: less than 1,200USD/kW, B; from 1,200kW to 1,300USD/kW, C; from 1,300USD/kW to 1,400USD/kW, D; more than 1,400USD/kW.

Table 10.7.6-1 Evaluation on Construction Cost

Unit Capacity	Item	Halgran 3	Maha 2	Maha 3	Loggal
200 MW	Construction Cost	724,521,769	751,103,052	672,351,670	870,120,301
	per kW	1,208	1,252	1,121	1,450
150 MW	Construction Cost		759,946,784	680,846,576	890,862,448
	per kW		1,267	1,135	1,485
Evaluation		B	B	A	D

(Source: JICA Study Team)

10.7.7 Evaluation from the Environmental Considerations

(1) Evaluation Criteria

At the first site screening stage (refer to Chapter 9), A to C is allocated to each site and cluster according to its impacts to the environments. At the second site screening stage, A to D is allocated to each site and cluster according to its impacts but their magnitudes are given as A＜B＜C＜D. A criterion is given to each score.

The reasons why four scores are given are (1) it can more appropriately reflect the results of the detailed study; and (2) it can give clear differences among three candidate sites and clusters.

Table 10.7.7-1 shows the evaluation criteria.

Table 10.7.7-1 Selection Criteria from the Environmental Considerations

<table>
<tr><th colspan="2"></th><th>item</th><th>Evaluation criterion</th><th>Notes</th></tr>
<tr><td rowspan="4">Impacts on fauna and flora</td><td>1</td><td>Inundated forest area (including natural, secondary forest, and home garden)</td><td>Criterion: ratio of the area of forests to the reservoir area.
A: 0-24%
B: 25-49%
C: 50-74%
D: 75-100%</td><td>Areas of the upper reservoirs are 0.15-0.43 km^2, and ones of the lower reservoirs are 0.15-0.24 km^2, which are far smaller than the large hydropower reservoirs in Sri Lanka. For example, the area of the Victoria reservoir is 22.7km^2.
Impact is thought to be limited in the case of this Project. When this item is weighed, it is therefore not to give big weight to this item.</td></tr>
<tr><td>2</td><td>Impacts on faunal endangered species (including aquatic species)</td><td rowspan="2">All observed species shall be classified into the Global and Sri Lankan endangered categories, and the categories are used as the criterion.
If there are two or three categories in a site, the category which is bigger is selected as the category of the site because of the precautionary approach.</td><td rowspan="2">The table below shall separately be formulated for both fauna and flora endangered species of site.
<table><tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr><tr><td>CR</td><td>D</td><td>D</td><td>D</td><td>D</td></tr><tr><td>EN</td><td>D</td><td>D</td><td>D</td><td>D</td></tr><tr><td>VU</td><td>C</td><td>C</td><td>B</td><td>B</td></tr><tr><td>Others</td><td>B</td><td>B</td><td>A</td><td>A</td></tr></table>CR: Critically Endangered, EN: Endangered, VU: Vulnerable
Global category by IUCN, Sri Lankan category: Government of Sri Lanka (2012)
Others: NT (Near Threatened), LC (Least Concern) and non-classified

The Sri Lankan categories are considered to be more important than the Global ones. This is because a species which is rare in Sri Lanka will be more sensitive and receive bigger impact.</td></tr>
<tr><td>3</td><td>Impacts on floral endangered species (including aquatic species)</td></tr>
<tr><td>4</td><td>Impacts on ecosystem</td><td>Ecosystems of a site are classified into the following four categories.

A: Monoculture area
B: Secondary ecosystem (single stratum)
C: Secondary ecosystem (multiple strata)
D: Natural habitat

Regarding the “Secondary ecosystem (multiple strata)” and “Natural habitat”, their areas are also considered when category is finally given.</td><td>Monoculture area: One species is uniformly grown and managed such as tea plantation, rice field and Eucalyptus plantation.
Secondary ecosystem (single stratum): Several cash crops and native species are grown and managed but its structure is simple such early stage of home garden.
Secondary ecosystem (multiple strata): Several cash crops and native species are grown and managed for long time to form good ecosystems with multiple strata such as mature home garden.
Natural habitat: 1.（a）Natural habitats are land and water areas where （i）the ecosystems' biological communities are formed largely by native plant and animal species, and （ii）human activity has not essentially modified the area's primary ecological functions.”(World Bank OP4.04 Annex A). An example is a riverine forest.

Regarding the secondary ecosystem (multiple strata), if the affected area is small (i.e. less than 1/3</td></tr>
</table>

				of reservoir area), it may be classified as category "B". Regarding the natural habitat, if it exists in a site, category "D" is given no matter how small it is from the point of precautionary approach.

Social		**item**	**Evaluation criterion**	**Notes**
Impacts on local communities	1	Number of those who to be resettled	Number of affected households A: 0 B: 1-14 C: 15-29 D: more than 30	The numbers of affected households (hhs) in other hydropower development projects are shown as a reference. Upper Kotmale hydropower development project: 497 hhs Moragola hydropower development project: 26 hhs Victoria expansion project: 57 hhs
	2	Area of land to be acquired	Affected land area A: less than 15ha B: 15-19ha C: 20-24ha D: more than 25ha	
	3	Number of those who to be affected by losing livelihood	Number of affected households A: 0 B: less than 15 C: 15-29 D: More than 30	
	4	Impacts on public facilities (e.g. school, road)	Number of public facilities (school, road and hospital) to be inundated A: 0 B: Of those facilities, one of them is inundated. C: Of those facilities, two of them are inundated, or two of the same facility are inundated. D: Of those facilities, three of them are inundated, or three of the same facility are inundated.	
	5	Impacts on the poor people and minorities	Number of affected households of the poor people and minorities A: 0 B: Less than 10 C: 11-19 D: More than 20	No minority lives or works in the selected sites. The upcounry Tamils are considered to be "poor people". Vedda, indigenous and minority in Sri Lanka, do not live nor work in the selected sites.
	6	Impacts on water utilization (e.x. drinking water, bathing, washing, irrigation,	Number of drinking water facility, irrigation facility and mini-hydropower plant A: 0 B: Of those facilities, one of them is found.	Three major water utilizations such are considered in this assessment exercise. There is no fishery at each site, and fishery is not considered. Although washing and bathing are practiced at the sites, they are excluded since they receive relatively small impacts in this project.

		mini-hydropower plant) of rivers and wells	C: Of those facilities, two of them are found. D: More than 3 of those facilities are found.	
Impacts on industries	7	Agriculture (including tea & rubber plantation)	Area of affected tea plantation, home garden, rice field, and other plantations A: Less than 15ha B: 15-19ha C: 20-24ha D: More than 25ha	
	8	Tourism (e.g. water fall)	Existence of tourism projects, and impacts on tourism resources A. No tourism resources B. There are tourism resources but direct or indirect impacts can be avoided. C. There are tourism resources and they receive direct and/or indirect impacts. But the impacts can be reduced. D. No mitigation measures are taken for tourism resources.	
Impacts on culture and landscape	9	Religious, and/or cultural facilities, burial ground	A. No locally important religious and/or cultural facilities B. There are locally important religious and/or cultural facilities but direct or indirect impacts can be avoided. C. There are locally important religious and/or cultural facilities and they receive direct and/or indirect impacts. But the impacts can be reduced. D. No mitigation measures are taken for locally important religious and/or cultural facilities.	
	10	Impacts on landscape	A. There are no landscapes which are appreciated by the local people in their daily lives. B. Impacts on major landscapes in the area are avoidable. C. Impacts on major landscapes can be reduced with appropriate measures. D. No mitigation measures are taken for major landscapes.	

(Source: JICA Study Team)

(2) Evaluation results and the outlines of the environments of each site

Table 10.7.7-2 shows the evaluation results and the outlines of environments of each site. The evaluation is conducted based on Table 10.7.7-1.

Table 10.7.7-2 Outlines and Results of Evaluation of Each Site

<table>
<tr><th colspan="2" rowspan="2">Evaluation items</th><th colspan="2">Halgran</th><th rowspan="2">Evaluation</th><th colspan="2">Loggal</th><th rowspan="2">Evaluation</th></tr>
<tr><th>Upper</th><th>Lower</th><th>Upper</th><th>Lower</th></tr>
<tr><td rowspan="4">Impacts on fauna and flora</td><td>Inundated forest area (including natural, secondary forest, and home garden)</td>
<td>【Explanation】
The total area of the reservoir is 15.6 ha. There are Eucalyptus plantation (4.3 ha), and riverine forest (5.6 ha). The total area of the forests is 9.9 ha, and the ratio of the forests to the reservoir is 63.5%.
【Evaluation】C</td>
<td>【Explanation】
The total area of the reservoir is 14.6 ha. There are secondary forest (1.1 ha) and home gardens (0.3 ha). The total area of the forests is 1.4 ha, and the ratio of the forests to the reservoir is 9.6%.
【Evaluation】A</td>
<td>C</td>
<td>【Explanation】
The total area of the reservoir is 35.4 ha. There are home gardens (total 16.2 ha: the area of home garden with tea plantation is 7.4 ha), and pine and acacia plantations (0.6 ha), and riverine forests (0.8 ha). The total area of the forests is 17.6 ha and the ratio of the forests to the reservoir is 49.7%.
【Evaluation】B</td>
<td>【Explanation】
The total area of the reservoir is 17.6 ha. There are home gardens (5.0 ha), secondary forests (5.0 ha) and riverine forests (0.03 ha). The total area of the forests is 10.0 ha, and the ratio of the forests to the reservoir is 56.8%.
【Evaluation】C</td>
<td>C</td></tr>
<tr><td>Impacts on faunal endangered species (including aquatic species)</td>
<td>【Explanation】
The figure of each cell is number of species.
<table><tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr>
<tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>EN</td><td>0</td><td>2</td><td>0</td><td>8</td></tr>
<tr><td>VU</td><td>0</td><td>1</td><td>0</td><td>8</td></tr>
<tr><td>Others</td><td>0</td><td>1</td><td>0</td><td>16</td></tr></table>
【Evaluation】D</td>
<td>【Explanation】
The figure of each cell is number of species.
<table><tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr>
<tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>EN</td><td>0</td><td>1</td><td>0</td><td>5</td></tr>
<tr><td>VU</td><td>0</td><td>1</td><td>1</td><td>6</td></tr>
<tr><td>Others</td><td>0</td><td>1</td><td>0</td><td>21</td></tr></table>
【Evaluation】D</td>
<td>D</td>
<td>【Explanation】
The figure of each cell is number of species.
<table><tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr>
<tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>EN</td><td>0</td><td>2</td><td>0</td><td>2</td></tr>
<tr><td>VU</td><td>0</td><td>1</td><td>0</td><td>4</td></tr>
<tr><td>Others</td><td>0</td><td>1</td><td>0</td><td>13</td></tr></table>
【Evaluation】D</td>
<td>【Explanation】
The figure of each cell is number of species.
<table><tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr>
<tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>EN</td><td>0</td><td>2</td><td>1</td><td>4</td></tr>
<tr><td>VU</td><td>0</td><td>1</td><td>0</td><td>6</td></tr>
<tr><td>Others</td><td>0</td><td>1</td><td>0</td><td>24</td></tr></table>
【Evaluation】D</td>
<td>D</td></tr>
<tr><td>Impacts on floral endangered species (including aquatic species)</td>
<td>【Explanation】
The figure of each cell is number of species.
<table><tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr>
<tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>EN</td><td>0</td><td>0</td><td>0</td><td>9</td></tr>
<tr><td>VU</td><td>0</td><td>1</td><td>2</td><td>13</td></tr>
<tr><td>Others</td><td>1</td><td>3</td><td>4</td><td>3</td></tr></table>
【Evaluation】D</td>
<td>【Explanation】
The figure of each cell is number of species.
<table><tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr>
<tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>EN</td><td>0</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>VU</td><td>0</td><td>0</td><td>1</td><td>13</td></tr>
<tr><td>Others</td><td>0</td><td>0</td><td>1</td><td>1</td></tr></table>
【Evaluation】D</td>
<td>D</td>
<td>【Explanation】
The figure of each cell is number of species.
<table><tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr>
<tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>EN</td><td>0</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>VU</td><td>0</td><td>0</td><td>1</td><td>4</td></tr>
<tr><td>Others</td><td>0</td><td>1</td><td>3</td><td>0</td></tr></table>
【Evaluation】D</td>
<td>【Explanation】
The figure of each cell is number of species.
<table><tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr>
<tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>EN</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>VU</td><td>0</td><td>0</td><td>1</td><td>1</td></tr>
<tr><td>Others</td><td>0</td><td>0</td><td>2</td><td>0</td></tr></table>
【Evaluation】B</td>
<td>D</td></tr>
<tr><td>Impacts on ecosystem</td>
<td>【Explanation】
Monoculture area: tea plantation and Eucalyptus plantation.
Secondary ecosystem (single stratum): non.
Secondary ecosystem (multiple strata): non
Natural habitat: riverine forests with the area of 5.6 ha, and the ratio of them to the reservoir is 35.9%. The forests are with multiple strata and with high biodiversity.
【Evaluation】D</td>
<td>【Explanation】
Monoculture area: rice fields (including abandoned ones) and agricultural lands
Secondary ecosystem (single stratum): non
Secondary ecosystem (multiple strata): secondary forests and home gardens. Their total area is 1.4 ha, and the ratio of them to the reservoir is 9.6%. There are also poor secondary riverine forests (very small area).
Natural habitat: non
【Evaluation】B</td>
<td>D</td>
<td>【Explanation】
Monoculture area: rice field, pine plantation and acacia plantation
Secondary ecosystem (single stratum): home garden with tea plantation
Secondary ecosystem (multiple strata): mature home gardens with the area of 8.8 ha, and the ratio of them to the reservoir is 24.8%. Riverine forests with the area of 0.8 ha and the ratio of them is 2.2%.
Natural habitat: non
【Evaluation】B</td>
<td>【Explanation】
Monoculture area: rice fields
Secondary ecosystem (single stratum): non
Secondary ecosystem (multiple strata): secondary forests and home gardens with the area of 10.0 ha, and the ratio of them to the reservoir is 56.8%. There are also poor secondary riverine forests (very small area).
Natural habitat: non
【Evaluation】C</td>
<td>C</td></tr>
<tr><td rowspan="2">Impacts on local communities</td><td>Number of those who to be resettled</td>
<td>【Explanation】
There is no family to be resettled by the project. Two small structures are located just below the dam axis, and 5 families live within the buffer zone.
【Evaluation】A</td>
<td>【Explanation】
There are 4 families to be resettled by the project.
There are 163 families to be indirectly affected by the project in the buffer zone.
【Evaluation】B</td>
<td>B</td>
<td>【Explanation】
There are 21 families to be resettled by the project.
There are 99 families to be indirectly affected by the project in the buffer zone.
【Evaluation】C</td>
<td>【Explanation】
There are 4 families to be resettled by the project.
There are 24 families to be indirectly affected by the project in the buffer zone.
【Evaluation】B</td>
<td>C</td></tr>
<tr><td>Area of land to be acquired</td>
<td>【Explanation】
Eucalyptus plantation : 4.33ha
Riverine forests :5.65ha
Tea plantation : 5.62ha
Total : 15.60ha
【Evaluation】B</td>
<td>【Explanation】
Mixed perennial crops : 2.5ha
Paddy : 5.1ha
Abandoned paddy : 4.0ha
Secondary forest : 1.1ha
Home garden : 0.3ha
Water body) : 1.6ha
Total : 14.6ha
【Evaluation】A</td>
<td>B</td>
<td>【Explanation】
Home garden : 8.76ha
Home garden with tea : 7.43ha
Paddy : 14.6ha
Planted forest : 0.6ha
Riverine forest : 0.88ha
Scrub : 0.4ha
Temple : 0.42ha
Total : 35.4ha
【Evaluation】D</td>
<td>【Explanation】
Home garden : 4.98ha
Paddy : 7.02ha
Riverine : 0.03ha
Secondary forest : 4.96ha
Stream : 0.60ha
Total : 17.59ha
【Evaluation】B</td>
<td>D</td></tr>
</table>

Evaluation items		Halgran Upper	Halgran Lower	Evaluation	Loggal Upper	Loggal Lower	Evaluation
	Number of those who to be affected by losing livelihood	【Explanation】 There is no family to be affected by losing livelihood within the directly affected area. (There is no data for those losing livelihood within indirectly affected area of buffer zone. 【Evaluation】A	【Explanation】 4 families who live in the directly affected area, and 78 families who live in the indirectly affected area (buffer zone) will lose livelihood 【Evaluation】D	D	【Explanation】 21 families who live in the directly affected area will lose livelihood. 【Evaluation】C	【Explanation】 4 families who live in the directly affected area will lose livelihood. 【Evaluation】B	C
	Impacts on public facilities (e.g. school, road)	【Explanation】 There are no public facilities that will be affected by the project. 【Evaluation】A	【Explanation】 There are no public facilities that will be affected by the project. 【Evaluation】A	A	【Explanation】 A school and existing road will be inundated by the project. 【Evaluation】C	【Explanation】 A school will be inundated by the project. 【Evaluation】B	C
	Impacts on the poor people and minorities	【Explanation】 There are no minority people and family who receive the government aid of Samurdhi in both directly affected area by the project and buffer zone. 【Evaluation】A	【Explanation】 There are no minority people in the area. There is one family who receive the government aid of Samurdhi in the directly affected area, and 26 families receive it in the indirectly affected area of bugger zone. 【Evaluation】B	B	【Explanation】 Since it was not possible to conduct the social survey, no data is collected. 【Evaluation】No evaluation	【Explanation】 Since it was not possible to conduct the social survey, no data is collected. 【Evaluation】No evaluation	No evaluation
	Impacts on water utilization	【Explanation】 There is no family to use river water for drinking, irrigation purpose in the directly affected area by the project. There is 4 families in the buffer zone which use river water for drinking 1 km away from their home. 【Evaluation】A	【Explanation】 Some families use river water for drinking and irrigation purposes in the directly affected area by the project. 【Evaluation】C	C	【Explanation】 33 ha of paddy get water from small irrigation where is outside of the project area. Since no social survey in the area, there is no detail data, but local people of the directly affected area and the buffer zone use river water for bathing and for vegetable fields, but not for drinking. There is a mini-hydropower plant downstream of river where is outside of the buffer zone will be indirectly affected during construction. 【Evaluation】B	【Explanation】 65 ha of paddy during Maha, and 21 ha of paddy during Yala get water from irrigation where is located outside of the project area. Since no social survey in the area, there is no detail data, but local people of the directly affected area and the buffer zone do not use river water for drinking. 【Evaluation】A	B
Impacts on industries	Agriculture (including tree & rubber plantation)	【Explanation】 Eucalyptus plantation (4.33 ha), and tea plantation (5.62 ha) Total: 9.95 ha 【Evaluation】A	【Explanation】 Mixed perennial crops (2.52 ha), paddy (5.14 ha), secondary forest (1.08 ha), and home garden (0.32 ha) Total: 9.06 ha 【Evaluation】A	A	【Explanation】 Home garden (8.76 ha), home garden with tea (7.43ha), paddy (14.60 ha), secondary forest (0.60 ha) Total: 31.39 ha 【Evaluation】D	【Explanation】 Home garden (4.98 ha), paddy (7.02 ha), secondary forest (4.96 ha) Total: 16.96 ha 【Evaluation】B	D
	Tourism (e.g. water fall)	【Explanation】 There are no tourism spot or tourism resources in the directly affected area. 【Evaluation】A	【Explanation】 There are no tourism spot or tourism resources in the directly affected area. 【Evaluation】A	A	【Explanation】 There are no tourism spot or tourism resources in the directly affected area. 【Evaluation】A	【Explanation】 There are no tourism spot or tourism resources in the directly affected area. 【Evaluation】A	A
Impacts on culture and landscape	Religious, and/or cultural facilities, burial ground	【Explanation】 There are two Hindu temples which will be inundated by the project. 【Evaluation】C	【Explanation】 There are no religious and cultural facilities in the directly affected area by the project. There are 7 Buddhist temples which are not protected by the state, but important for local people in the buffer zone. 【Evaluation】A	C	【Explanation】 One Buddhist temple which is only one in the area will be inundated by the project. 【Evaluation】C	【Explanation】 One Buddhist temple which is only one in the area will be inundated by the project. 【Evaluation】C	C
	Impacts on landscape	【Explanation】 There is no house in the directly affected area and a few houses in the buffer zone. Tea plantation on the left side bank and Eucalyptus plantation are spread in the right side bank. There is no landscape resource which has to be protected. 【Evaluation】A	【Explanation】 The view of rural landscapes of paddy, home garden and vegetable fields are spread in the area. There is no landscape resource which has to be protected. 【Evaluation】A	A	【Explanation】 The proposed project site is located in mountainous area and there are isolated villages where most of local people are engaged in farming of paddy, home garden and forest plantation. Except that scenery, there is no landscape resource which has to be protected. 【Evaluation】A	【Explanation】 The proposed project site is located in mountainous area and there are isolated villages where most of local people are engaged in farming of paddy, home garden and forest plantation. Except that scenery, there is no landscape resource which has to be protected. 【Evaluation】A	A

(Source: JICA Study Team)

<table>
<tr><th colspan="2" rowspan="2">Evaluation items</th><th>Maha 2</th><th>Maha 3</th><th>Maha Lower</th><th>Maha 2 & Lower</th><th>Maha 3 & Lower</th></tr>
<tr><th>Upper</th><th>Upper</th><th>Lower</th><th>Evaluation</th><th>Evaluation</th></tr>
<tr><td rowspan="4">Impacts on fauna and flora</td><td>Inundated forest area (including natural, secondary forest, and home garden)</td><td>【Explanation】
The total area of the reservoir is 15.2 ha. There is no forest.
【Evaluation】A</td><td>【Explanation】
The total area of the reservoir is 23.2 ha. There are riverine forest (0.06 ha), home garden with tea plantation (6.1 ha). The total area of the forests is 6.2 ha, and the ratio of the forests to the reservoir is 26.7％.
【Evaluation】A</td><td>【Explanation】
The total area of the reservoir is 23.7 ha. There are secondary forest (3.1 ha), home gardens with rubber (16.3 ha), and rubber plantation (0.9 ha). The total area of the forests is 20.3 ha, and the ratio of the forests to the reservoir is 85.7%.
【Evaluation】D</td><td>D</td><td>D</td></tr>
<tr><td>Impacts on faunal endangered species (including aquatic species)</td><td>【Explanation】
The figure of each cell is number of species.<table><tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr><tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>EN</td><td>0</td><td>0</td><td>0</td><td>1</td></tr><tr><td>VU</td><td>0</td><td>0</td><td>0</td><td>2</td></tr><tr><td>Others</td><td>0</td><td>0</td><td>0</td><td>9</td></tr></table>【Evaluation】D</td><td>【Explanation】
The figure of each cell is number of species.<table><tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr><tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>EN</td><td>0</td><td>0</td><td>0</td><td>1</td></tr><tr><td>VU</td><td>0</td><td>1</td><td>0</td><td>2</td></tr><tr><td>Others</td><td>0</td><td>1</td><td>0</td><td>8</td></tr></table>【Evaluation】D</td><td>【Explanation】
The figure of each cell is number of species.<table><tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr><tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>EN</td><td>0</td><td>1</td><td>0</td><td>4</td></tr><tr><td>VU</td><td>0</td><td>2</td><td>0</td><td>10</td></tr><tr><td>Others</td><td>0</td><td>1</td><td>0</td><td>17</td></tr></table>【Evaluation】D</td><td>D</td><td>D</td></tr>
<tr><td>Impacts on floral endangered species (including aquatic species)</td><td>【Explanation】
The figure of each cell is number of species.<table><tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr><tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>EN</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>VU</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>Others</td><td>0</td><td>0</td><td>0</td><td>1</td></tr></table>【Evaluation】A</td><td>【Explanation】
The figure of each cell is number of species.<table><tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr><tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>EN</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>VU</td><td>0</td><td>0</td><td>0</td><td>2</td></tr><tr><td>Others</td><td>0</td><td>0</td><td>0</td><td>0</td></tr></table>【Evaluation】B</td><td>【Explanation】
The figure of each cell is number of species.<table><tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr><tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>EN</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>VU</td><td>0</td><td>2</td><td>0</td><td>10</td></tr><tr><td>Others</td><td>0</td><td>0</td><td>0</td><td>4</td></tr></table>【Evaluation】C</td><td>C</td><td>C</td></tr>
<tr><td>Impacts on ecosystem</td><td>【Explanation】
Monoculture area: tea plantations which occupy 81.6% of the reservoir area.
Secondary ecosystem (single stratum): degraded and scrublands which occupy 4.6% of the reservoir area.
Secondary ecosystem (multiple strata): non
Natural habitat: non

Estate settlement occupies 13.8％ of the reservoir area.
【Evaluation】A</td><td>【Explanation】
Monoculture area: abandoned rice fields, abandoned tea plantation and tea plantation
Secondary ecosystem (single stratum): home garden with tea plantation, shrubs
Secondary ecosystem (multiple strata): secondary and poor riverine forest (0.06 ha)
Natural habitat: non
【Evaluation】B</td><td>【Explanation】
Monoculture area: rice fields (with very small area) and rubber planation
Secondary ecosystem (single stratum): non
Secondary ecosystem (multiple strata): secondary forests and home gardens with rubber. Their total area is 19.4 ha, and the ratio of them to the reservoir is 81.9%.
Natural habitat: non
【Evaluation】C</td><td>C</td><td>C</td></tr>
<tr><td rowspan="2">Impacts on local communities</td><td>Number of those who to be resettled</td><td>【Explanation】
There are 3 estate line rooms where an estimated 34 families (84 people) who to be resettled.
There are 14 families who will be indirectly affected by the project in the buffer zone.
【Evaluation】D</td><td>【Explanation】
There are 28 families who to be resettled.
There are 27 families who will be indirectly affected by the project in the buffer zone.
【Evaluation】C</td><td>【Explanation】
There are 11 families who to be resettled.
There are 88 families who will be indirectly affected by the project in the buffer zone.
【Evaluation】B</td><td>D</td><td>C</td></tr>
<tr><td>Area of land to be acquired</td><td>【Explanation】
Estate settlement : 2.12ha
Scrub & Degraded land : 0.73ha
Tea plantation : 12.39ha
Total : 15.24ha
【Evaluation】B</td><td>【Explanation】
Abandoned paddy : 3.05ha
Abandoned tea plantation : 0.52ha
Home garden with tea : 6.12ha
Tea plantation : 13.22ha
Riverine forest : 0.06ha
Scrub : 0.25ha
Total : 23.22ha
【Evaluation】C</td><td>【Explanation】
Forest : 3.13ha
Paddy : 0.05ha
Land of hydropower plant : 0.15ha
Rubber plantation : 0.87ha
Rubber with Home garden : 16.25ha
Total : 23.52ha
【Evaluation】C</td><td>C</td><td>C</td></tr>
</table>

Evaluation items		Maha 2	Maha 3	Maha Lower	Maha 2 & Lower	Maha 3 & Lower
		Upper	Upper	Lower	Evaluation	Evaluation
	Number of those who to be affected by losing livelihood	【Explanation】 34 families (3 line houses, 84 people) who live in the directly affected area will lose livelihood. 【Evaluation】D	【Explanation】 28 families who live in the directly affected area will lose livelihood. 【Evaluation】C	【Explanation】 11 families who live in the directly affected area will lose livelihood. 【Evaluation】B	D	C
	Impacts on public facilities (e.g. school, road)	【Explanation】 There are no public facilities in the directly affected area. 【Evaluation】A	【Explanation】 There are no public facilities in the directly affected area. 【Evaluation】A	【Explanation】 There are no public facilities in the directly affected area. 【Evaluation】A	A	A
	Impacts on the poor people and minorities	【Explanation】 Since it was not possible to conduct the social survey, no data collect. 【Evaluation】No evaluation	【Explanation】 7 out of 28 families who will be affected by the project receive the government aid of Samurudhi can be considered as poor people. 【Evaluation】B	【Explanation】 3 out of 11 families who will be affected by the project receive the government aid of Samurudhi can be considered as poor people. 【Evaluation】B	No evaluation	B
	Impacts on water utilization	【Explanation】 Nobody uses river water for any purpose in the directly affected area. 【Evaluation】A	【Explanation】 Some families use river water for drinking and for agriculture purpose in the directly affected area. 【Evaluation】C	【Explanation】 Some families use river water for drinking and irrigation purpose in the directly affected area, and 2 small scale hydropower plants also use river water in the directly affected area. 【Evaluation】D	D	D
Impacts on industries	Agriculture (including tree & rubber plantation)	【Explanation】 Tea plantation (12.39 ha) Total: 12.39 ha 【Evaluation】A	【Explanation】 Home garden (6.12 ha), and tea plantation (13.22 ha) Total: 19.34 ha 【Evaluation】B	【Explanation】 Forest (3.13 ha), paddy (0.05ha), rubber plantation (0.87 ha), home garden with rubber (16.25 ha) Total: 20.30 ha 【Evaluation】C	C	C
	Tourism (e.g. water fall)	【Explanation】 There are no tourism spot or tourism resources in the directly affected area. 【Evaluation】A	【Explanation】 There are no tourism spot or tourism resources in the directly affected area. 【Evaluation】A	【Explanation】 There are no tourism spot or tourism resources in the directly affected area. There is one water fall which is seen from the proposed lower reservoir, the direct distance from the site is around 2 km. It is located outside of the buffer zone. The local authority has a tourism development plan by utilizing the water fall. The related infrastructure development of surrounding area will be possible through a joint development scheme with the PSPP project in future. This kind of joint venture may give positive impacts on the area. 【Evaluation】A	A	A
Impacts on culture and landscape	Religious, and/or cultural facilities, burial ground	【Explanation】 There is a Hindu Temple in the directly affected area. 【Evaluation】C	【Explanation】 There are some burial grounds in the directly affected area by the project. 【Evaluation】C	【Explanation】 There are no religious and cultural facilities in the directly affected area by the project. 【Evaluation】A	C	C
	Impacts on landscape	【Explanation】 Tea plantation covers the proposed reservoir. Except that scenery of tea plantation, there is no landscape resource which has to be protected. 【Evaluation】A	【Explanation】 Mixed scenery of well-maintained tea plantation and abandoned tea plantation covers both directly and indirectly affected areas. Except that scenery, there is no landscape resource which has to be protected. 【Evaluation】A	【Explanation】 A water fall is seen from the proposed reservoir site which 2 km is away, and the proposed project can mitigate the impact on the viewpoint and landscape resource. 【Evaluation】B	B	B

(Source: JICA Study Team)

(3) Evaluations on the proposed routes of the transmission lines

The evaluation results of the routes from Halgran, Maha and Loggal to each connecting point are shown in Table 10.7.7-3.

Table 10.7.7-3 Environmental and Social Assessment on the proposed transmission lines' routes

Assessment aspect	Halgran – Kotmale PS	Maha				Loggal – Kotmale PS
		Kirindiwela SS	Polpitiya SS	Kotmale PS -Kirindiwela SS T/L	Kotmale PS	
Population Density and its growth	A	A	A	A	A	A
Social Environment (barriers)	A	A	A	A	A	A
Overall Evaluation (Social Environment)	**A**	**A**	**A**	**A**	**A**	**A**
Natural Environment (barriers)	A	A	B	A	A	A
Overall Evaluation	**A**	**A**	**B**	**A**	**A**	**A**

(**Source: JICA Study Team**)

A: Project is not likely to have significant negative impacts on natural environment and society and/or limited to a small scale.

B: Project is likely to have negative impacts on natural environment and society.

C: Project is likely to have significant negative impacts on natural environment and society.

D: Project clearly gives significant negative impacts on natural environment and society.

10.7.8 Selection of the Most Promising Site

Based on geological evaluation, ease of the construction works, the power system analysis, the manufacturing limitation, the construction cost, and the natural/social environmental evaluation as described in the sub-chapter 10.7.1 ~ 10.7.6, the score of each promising site is calculated, and then the rank of each promising site is determined. Calculation of the score and determination of rank are done according to the following procedures;

- 1.0, 0.75, 0.50 and 0.25 are given to rating A, B, C, D, respectively.
- Evaluation criteria are divided into following four large categories and 25 points are given to each large category; 1. The technical evaluation (Geology, Construction works, Power system stability, Manufacturing limitation), 2. Construction cost, 3. Natural environmental impact and 4. Social environmental impact.
- Large categories are composed of small categories and given 25 points to a large category are

allocated to its small categories considering those importance within their large category.

- Score of each small category is calculated multiplying ranting and allocated point and total score is calculated for each large category.
- Considering the environmental survey (2) was not able to be conducted fully in the upper reservoir area of Maha 2 as well as in the upper and the lower reservoir of Loggal, "3 .Natural environmental impact" and "4. Social environmental impact" of those two projects are corrected; accordingly, a point of large category 3 and that of 4 are discounted by multiplying 0.9 in Maha 2 as well as by multiplying 0.8 in Loggal.
- Total score of each promising site is calculated to summing up score of four large categories.
- The rank of each promising site is determined by its calculated point. Such ranking study is carried out in the following two cases;

1) Even case	1. (Technical evaluation + 2. Construction Cost) : (3. Natural environment + 4. Social environment) = 50 : 50 (Calculated points of 4 large categories are summed up as those are.)
2) Environmental weighed case	(1. Technical evaluation + 2. Construction Cost) : (3. Natural environment + 4. Social environment) = 30 : 70 (Calculated points of 1. Technical evaluation and 2. Construction cost are multiplied by 15/25 as well as those of 3. Natural environment and Social environment are multiplied by 35/25)

Table 10.7.8-1 shows the score calculation of each promising site.

Table 10.7.8-1 Score Calculation of Each Promising Site

Criteria		Score	Halgran 3			Maha 2			Maha 3			Loggal		
		allocation	Eva	(rate)	Score	Eva	(rate)	Score	Eva	(rate)	Score	Eva	(rate)	Score
1. Technical Evaluation		25			15.50			22.00			21.75			12.50
1.1	Geological aspects	7	C	0.50	3.50	A	1.00	7.00	B	0.75	5.25	C	0.50	3.50
1.2	Ease of construction works	6	C	0.50	3.00	B	0.75	4.50	A	1.00	6.00	C	0.50	3.00
1.3	Manufacturing Limitation	6	C	0.50	3.00	A	1.00	6.00	A	1.00	6.00	B	0.75	4.50
1.4	System Stability	6	A	1.00	6.00	B	0.75	4.50	B	0.75	4.50	D	0.25	1.50
2. Economical Evaluation		25	B	0.75	18.75	B	0.75	18.75	A	1.00	25.00	D	0.25	6.25
3. Natural Environmental Evaluation		25			7.25			10.75			10.75			9.00
	Correction			*1.0	7.25		*0.9	9.68		*1.0	10.75		*0.8	7.20
3.1	Inundated forest area	1	C	0.50	0.50	D	0.25	0.25	D	0.25	0.25	C	0.50	0.50
3.2	Impacts on faunal endangered species	8	D	0.25	2.00	D	0.25	2.00	D	0.25	2.00	D	0.25	2.00
3.3	Impacts on floral endangered species	8	D	0.25	2.00	C	0.50	4.00	C	0.50	4.00	D	0.25	2.00
3.4	Impacts on ecosystem	7	D	0.25	1.75	C	0.50	3.50	C	0.50	3.50	C	0.50	3.50
3.5	Transmission line-Natural environment	1	A	1.00	1.00	A	1.00	1.00	A	1.00	1.00	A	1.00	1.00
4. Social Environmental Evaluation		25			17.50			11.50			13.75			11.75
	correction			*1.0	17.50		*0.9	10.35		*1.0	13.75		*0.8	9.40
3.6	Number of those who to be resettled	6	B	0.75	4.50	D	0.25	1.50	C	0.50	3.00	C	0.50	3.00
3.7	Area of land to be acquired	5	B	0.75	3.75	C	0.50	2.50	C	0.50	2.50	D	0.25	1.25
3.8	Number of those who to be affected by losing livelihood	3	D	0.25	0.75	D	0.25	0.75	C	0.50	1.50	C	0.50	1.50
3.9	Impacts on public facilities	1	A	1.00	1.00	A	1.00	1.00	A	1.00	1.00	C	0.50	0.50
3.1	Impacts on water utilization	2	C	0.50	1.00	D	0.25	0.50	D	0.25	0.50	D	0.25	0.50
3.11	Agriculture	2	A	1.00	2.00	C	0.50	1.00	C	0.50	1.00	D	0.25	0.50
3.12	Tourism	1	A	1.00	1.00	A	1.00	1.00	A	1.00	1.00	A	1.00	1.00
3.13	Religious, and/or cultural facilities, burial ground	3	C	0.50	1.50	C	0.50	1.50	C	0.50	1.50	C	0.50	1.50
3.14	Impacts on landscape	1	A	1.00	1.00	B	0.75	0.75	B	0.75	0.75	A	1.00	1.00
3.15	Transmission line-Social environment	1	A	1.00	1.00	A	1.00	1.00	A	1.00	1.00	A	1.00	1.00

（Source :JICA Study Team 出典）

In addition, Table 10.7.8-2 shows the rank of each promising site in the even case as well as Table 10.7.8-3 shows that in the environmental weighed case.

Table 10.7.8-2 Rank of Promising Site in Even Case

	Score Allocation	Halgran 3	Maha 2	Maha 3	Loggal
1. Technical Evaluation	25.00	15.50	22.00	21.75	12.50
2. Economical Evaluation	25.00	18.75	18.75	25.00	6.25
3. Natural Environment	25.00	7.25	9.68	10.75	7.20
4. Social Environment	25.00	17.50	10.35	13.75	9.40
Total	100.00	59.00	60.78	71.25	35.35
Rank		3	2	1	4

(Source: JICA Study Team)

Table 10.7.8-3 Rank of Promising Site in Environmental Weighed Case

	Score Allocation	Halgran 3	Maha 2	Maha 3	Loggal
1. Technical Evaluation	15.00	9.30	13.20	13.05	7.50
2. Economical Evaluation	15.00	11.25	11.25	15.00	3.75
3. Natural Environment	35.00	10.15	13.55	15.05	10.08
4. Social Environment	35.00	24.50	14.49	19.25	13.16
Total	100.00	55.20	52.49	62.35	34.49
Rank		2	3	1	4

(Source: JICA Study Team)

As shown in Table 10.7.8-4 and Table 10.7.8-5, Maha 3 is ranked as the first in both of Even case and Environment weighed case, which is given averagely higher rank in every four large category; because it is ranked as the second in Technical Evaluation, the first in Economical Evaluation, the first in Natural Environment, and the second in Social Environment.

From view point of environmental aspect only, the difference between the first ranked site of Halgran 3 and the second site of Maha 3 is only 0.25 points, because the total of Natural environment and Social environment is 24.75 points for Halgran 3 and that for Maha 3 is 24.5 points. It is observed that Halgran 3 gains disproportionally high scores because Natural environment points is 7.25 points against 17.50 points of Social environment, while Maha 3 gains averagely high scores because Natural environment points and Social environment points are 10.75 points and 13.75 points, respectively. If the evaluation is done from Natural environment is weighed view point, the rank of Maha 3 from environmental aspect would be higher than that of Halgran 3. Table10.7.7-4 shows an sample of ranking study in case that the weight of “3. Natural environment” and that of “4. Social environment” is changed to 30 : 70 from 50 : 50.

Table 10.7.8-4 Rank of Promising Sites from Environment Aspect

	Score Allocation	Halgran 3	Maha 2	Maha 3	Loggal
3. Natural Environment	25.00	7.25	9.68	10.75	7.20
4. Social Environment	25.00	17.50	10.35	13.75	9.40
Total	50.00	24.75	20.03	24.50	16.60
Rank		1	3	2	4

(Source: JICA Study Team)

Table 10.7.8-5 Rank of Promising Sites from Environment Aspect (Natural weighed)

	Score Allocation	Halgran 3	Maha 2	Maha 3	Loggal
3. Natural Environment	35.00	10.15	13.55	15.05	10.08
4. Social Environment	15.00	10.50	6.21	8.25	5.64
Total	50.00	20.65	19.76	23.30	15.72
Rank		2	3	1	4

(Source: JICA Study Team)

Based on the study results as above-mentioned, Maha 3 is selected as the most promising site in this study; the main reasons are again summarized as follows;

In both cases; Even case and Environmental weighed case, it is ranked as the first.

- Any serious technical difficulties to be studied in the future have not been found.
- While it is ranked as the second by the evaluation from environmental aspect only; (“3 Natural environment + “4 Social environment”), the difference of points to the first site (Halgran 3) are very limited.
- Even in view point from environment aspect only, if Natural environment is weighed to Social environment, it is ranked as the first.

Chapter 11

Economic and Financial Evaluation

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Chapter 11 Economic and Financial Evaluation

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Chapter 11 Economic and Financial Evaluation

Economic and financial evaluation has been conducted for the PSPP development plan at most promising site identified in this study. The analysis tried to confirm the project's economic viability from a viewpoint of national economy, and financial profitability to CEB (financial evaluation), as well.

11.1 Economic Evaluation

11.1.1 Methodology

Economic evaluation aims at measuring the "economic" impact brought about to a country by implementing a project from a viewpoint of national economy. Here, a comparison of **costs** and **benefits** expressed in terms of **economic prices** will be made by applying the **Discount Cash Flow Method**, which is widely adopted for such purposes.

Evaluation indices to be obtained will be the Net Present Value (NPV) and the Economic Internal Rate of Return (EIRR). The EIRR is a discount rate at which the present values of the two cash flows (benefit flow and cost flow) become equal. This rate show the return expected from the project. EIRR is expressed in the following equation

$$\sum_{t=0}^{n} C_t /(1-r)^t - \sum_{t=0}^{n} B_t/(1-r)^t = 0$$

Where,

Ct: Cost
Bt: Benefit
t: Year
n: Project life (year)
r: Discount rate (=EIRR)

In line with the reports for other projects in Sri Lanka, the following basic conditions were adopted:

- Discount Rate
  A discount rate of 10% will be used. This rate of 10% is used commonly in other projects.
- Standard Conversion Factor
  Standard conversion factor of 0.9, used commonly in other projects, was applied. This is a coefficient to calculate the economic price from the construction costs estimated at the market price. It is applied to the domestic currency portion.
- Project Life (Calculation Period)
  Calculation period for evaluation is 55 years: 50 years of service life of civil facilities and 5 years of construction works.

- Economic Life
  Economic life of each facility, according to the experience of the Consultant, was determined as follows:
  - 50 years for civil works
  - 35 years for hydro-mechanical and electro-mechanical equipment
- Cost Estimate
  Estimation of cost was based on the price level of May 2014.
- Price Escalation
  No escalation was considered, therefore, a constant price will be used.
- Tax
  Taxes and duties, including VAT, were excluded from the economic analysis, being a transfer item

11.1.2 Economic Costs of the Project

The economic costs (initial construction and replacement) of the Project were calculated from the market price as presented in Chapter 10. The method of economic pricing is (1) Exclusion of transfer items such as tax (import tax, value added tax) and subsidies; and (2) Conversion of market prices applying standard conversion factor of 0.9 for local currency. Construction costs for initial investment and replacement is summarized in Table 11.1.2-1.

Table 11.1.2-1 Factors Used for Economic Cost (construction) Calculation

Name of Input Data			Value	Unit	Remarks
A. PSPP Development					
A 1	Unit Capacity		200	MW	
A 2	Number of Unit		3	Number	
A 3	Development Cost				
A 4		*(1) Preparation*	*4,994,007*	US$	
A 5		*(2) Environmental Mitigation Cost*	*7,491,011*	US$	
A 6		*(3) Civil Works*	*249,700,365*	US$	
A 7		*(4) Hydromechanical Works*	*54,550,427*	US$	
A 8		*(5) Electro-Mechanical Works*	*194,800,000*	US$	
A 9		*(6) Transmission Line*	*3,900,000*	US$	
A10	Direct Cost Total		515,435,810	US$	
A11	Administration/Engineering Services		77,315,372	US$	15% of A10
A12	Contingency		51,543,581	US$	10% of A10
A13	Interest during Construction (IDC)		32,929,905	US$	(A10+A11+A12)*A24***0.38***A28
A14	TOTAL Cost		677,224,668	US$	A10+A11+A12+A13
A15	Unit Construction Cost		1,129	US$	A14/(A1*A2)
A16	TOTAL Cost excluding IDC		644,294,763	US$	A14-A13
A17	Base Year of Cost Estimate		2014		
A18	Replacement Cost in Yr 31st-35th		249,350,427	US$	(4) + (5) above
A19	Percentage of Foreign Currency of Direct Cost		64%		
A20					
A21	Interest Rate (Foreign)		1.40%	% p.a.	JICA Loan
A22	Percentage of Foreign Loan		85%		
A23	Interest Rate (Local)		10.00%	% p.a.	Domestic Borrowing
A24	Weighted Average Cost of Capital (WACC)		2.69%	% p.a.	A21*A22+A23*(1-A22)
A25	Standard Conversion Factor (SCF) for LKR		0.9		
A26	Economic Construction Cost after SCF		621,100,151	US$	A16*A19*1.0+A16*(1-A19)*A25
A27	Economic Replacement Cost after SCF		240,373,812	US$	A18*A19*1.0+A18*(1-A19)*A25
A28	Construction Period		5	years	
A29	Disbursement Schedule (1st - 5th; 31st-35th)				
A30		1st Year	5%		
A31		2nd Year	10%		
A32		3rd Year	25%		
A33		4th Year	40%		
A34		5th Year	20%		

(Source; JICA Study Team)

With the assumptions and parameters shown in the above, initial investment cost flow and replacement cost flow are calculated as Table 11.1.2-2 and Table 11.1.2-3.

Table 11.1.2-2 Initial Investment Cost

(Unit: US$)

Year	Initial Investment
1st Year	31,055,008
2nd Year	62,110,015
3rd Year	155,275,038
4th Year	248,440,060
5th Year	124,220,030

(Source; JICA Study Team)

Table 11.1.2-3 Replacement Investment Cost

(Unit: US$)

Year	Replacement Cost
36th Year	12,018,691
37th Year	24,037,381
38th Year	60,093,453
39th Year	96,149,525
40th Year	48,074,762

(Source; JICA Study Team)

The operation and maintenance costs of pump storage power plant consist of two components; (1) Operation and maintenance costs same as other hydro power stations; and (2) energy (electricity) cost for water pump-up.

(1) Ordinal operation and maintenance costs are calculated by multiplying the construction cost of each work item by a certain rate. This rate was determined according to the experiences with similar projects; 0.5% for civil works and 1.5% of hydraulic/electro-mechanical equipment. The calculated operation and maintenance cost of the Project is US$ 4,171,000 per year.

(2) While energy cost for water pump-up is assumed to be the cost of coal power in the Base Case, cost of LNG combined cycle (LNG-CC) for pump-up is applied in some case studies in supplemental analysis (explained later in this chapter). Two kinds of water pump-up costs i.e. from coal power and from LNG-CC power are calculated and shown in Table 11.1.2-4 and Table 11.1.2-5. Efficiency of pump-up is assumed to be 70%. The cost of water pump-up for 1kWh generation by PSPP from coal is estimated as USCts 10.29/kWh and USCts 14.96/kWh for LNG-CC.

Table 11.1.2-4 PSPP Pump-up Cost (coal power case)

Name of Input Data			Value	Unit	Remarks
D. Generation Specifications: Coal Power Plant (For Pump-up)					
	D 1	Heat Content	6,300	kCal/kg	
	D 2	Fuel Cost @ Col CIF	142.8	US$/ton	[$126/ton for Puttalam 2013]
	D 3	Fuel Cost @ Col CIF	2,267	USCts/GCal	D2/D1
	D 4	Full Load Heat Rate	2,583	kCal/kWh	
	D 5	Thermal Efficiency	33.3%		860/D4 [29.7% at Puttalam 2013]
	D 6	Fuel Cost/kWh	5.85	USCts/kWh	D3*D4 [Rs. 7.76/kWh Puttalam 2013]
	D 7	Variable OM Cost	0.56	USCts/kWh	
	D 8	Station Use	8.00%		
	D 9	Transmission Loss	3.20%		
	D 10	Pump-up cost/kWh Generation	**10.29**	USCts/kWh	(D6+D7)/((1-D8)*(1-D9))/0.7*
					*0.7= Pump-up Efficiency

(Source; JICA Study Team)

Table 11.1.2-5 PSPP Pump-up Cost (LNG-combined cycle)

E. Generation Specifications: LNGCC Plant (For Pump-up)					
	E 1	Heat Content	13,000	kCal/mmBtu	
	E 2	Heat Content	5,850	kCal/kg	E1*0.45
	E 3	Fuel Cost @ Col CIF	13.5	US$/mmBtu	
	E 4	Fuel Cost @ Col CIF	5,357	USCts/GCal	E3*3.9683
	E 5	Full Load Heat Rate	1,786	kCal/kWh	
	E 6	Thermal Efficiency	48.2%		860/E5
	E 7	Fuel Cost/kWh	9.57	USCts/kWh	E4*E5
	E 8	Variable OM Cost	0.296	USCts/kWh	
	E 9	LNGCC Generation Cost/kWh	9.86	USCts/kWh	E7+E8
	E 10	Station Use	2.70%		
	E 11	Transmission Loss	3.20%		
	E 12	Pump-up cost/kWh Generation	**14.96**	USCts/kWh	E9/((1-E10)*(1-E11))/0.7*
					*0.7= Pump-up Efficiency

(Source; JICA Study Team)

11.1.3 Economic Benefit of the Project

Economic benefit of the Project is the economic value of supplied electricity at peak time. For goods transacted in free market economy, the price shows the economic value of the goods. In case of electricity prices, it is common to make the price low from the real cost due to socio-economic policy considerations. The same is in Sri Lanka, too. Therefore, it is difficult to measure real economic value from its price instantaneously.

In this economic analysis of the Project, as used widely when evaluating hydro power projects, comparison of supplying costs for two alternatives which provide same services; namely “with project case (PSPP)”, the cost of peak electricity supply by PSPP, and “without project case (Alternative Thermal)”, the cost of peak power supply by alternative thermal. The question is which alternative is more economically advantageous than the other. Cost of without project case can be considered as the benefit of the Project.

The alternative thermal of the Project is the gas turbine generation with auto diesel fuel. The generation costs, including investment cost converted into “economic” cost, of 105MW gas turbine, which is used in Long Term Generation Expansion Plan 2013-2032 is summarized in Table 11.1.3-1.

Table 11.1.3-1 Alternative Thermal Power Plant (gas turbine 105MW auto diesel)

Name of Input Data			Value	Unit	Remarks
F. Generation Specifications: Gas Turbine 105MW (Auto Diesel)					
	F 1	GT Construction Cost			
	F 2	Foreign Portion	403.8	US$/kW	
	F 3	Local Portion	79.2	US$/kW	
	F 4	Local Discounted by SCF	71.3	US$/kW	F3*A25
	F 5	Total Construction Cost	475.1	US$/kW	F2+F4
	F 6	Rate of Cumulative IDC for 1.5 Years	6.51%		Interest Rate: 10% p.a.
	F 7	Total Construction Cost including IDC	506.0	US$/kW	F5*(1+F6)
	F 8	Station Use	2.70%		
	F 9	Forced Outage	8.00%		
	F 10	Scheduled Outage	8.20%		
	F 11	Transmission Loss	3.20%		
	F 12	kW-Value (Adjusted)	598.3	US$/kW	F7*((1-C2)*(1-C3)*(1-C4)*(1-C5))/((1-F8)*(1-F9)*(1-F10)*(1-F11))
	F 13	Fixed Annual OM Cost	6.10	US$/kW	
	F 14	Fixed Annual OM Cost (Adjusted)	7.2	US$/kW	F13*((1-C2)*(1-C3)*(1-C4)*(1-C5))/((1-F8)*(1-F9)*(1-F10)*(1-F11))
	F 15	Heat Content	10,550	kCal/kg	
	F 16	Heat Content	8,862	kCal/l	F15*0.84
	F 17	Fuel Cost @ Col CIF	128.4	US$/bbl	
	F 18	Fuel Cost @ Col CIF	9,112	USCts/GCal	F17/159/F16
	F 19	Full Load Heat Rate	2,857	kCal/kWh	
	F 20	Thermal Efficiency	30.1%		860/F19
	F 21	Fuel Cost /kWh	26.03	USCts/kWh	F18*F19
	F 22	Variable OM Cost	0.402	USCts/kWh	
	F 23	kWh-Value (adjusted)	**27.05**	USCts/kWh	(F21+F22)*((1-C2)*(1-C5))/((1-F8)*(1-F11))

(Source; JICA Study Team)

In the case used in supplementary analysis in Section 11.1.5, by assuming the situation of LNG available, alternative thermal is LNG-simple cycle gas turbine, economical alternative against auto diesel. Table 11.1.3-2 summarizes the investment and generation costs by LNG-SC.

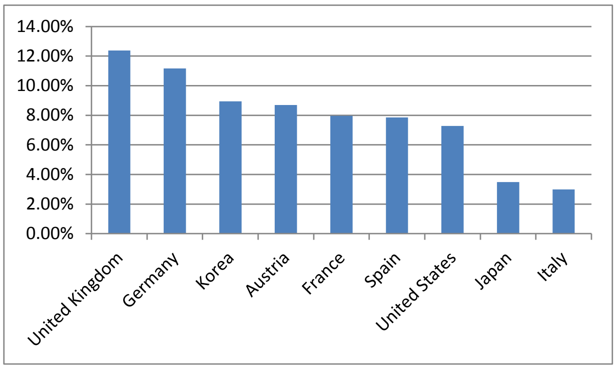
Table 11.1.3-2 Alternative Thermal Power Plant (LNG-simple cycle gas turbine)

Name of Input Data		Value	Unit	Remarks
G. Generation Specifications: Gas Turbine (LNGSC)				
G 1	GT Construction Cost			
G 2	Foreign Portion	403.8	US$/kW	
G 3	Local Portion	79.2	US$/kW	
G 4	Local Discounted by SCF	71.3	US$/kW	G3*A25
G 5	Total Construction Cost	475.1	US$/kW	G2+G4
G 6	Rate of Cumulative IDC for 1.5 Years	6.51%		Interest Rate: 10% p.a.
G 7	Total Construction Cost including IDC	506.0	US$/kW	G5*(1+G6)
G 8	Station Use	2.70%		
G 9	Forced Outage	8.00%		
G 10	Scheduled Outage	8.20%		
G 11	Transmission Loss	3.20%		
G 12	kW-Value (Adjusted)	598.3	US$/kW	G7*((1-C2)*(1-C3)*(1-C4)*(1-C5))/((1-G8)*(1-G9)*(1-G10)*(1-G11))
G 13	Fixed Annual OM Cost	6.10	US$/kW	
G 14	Fixed Annual OM Cost (Adjusted)	7.2	US$/kW	G13*((1-C2)*(1-C3)*(1-C4)*(1-C5))/((1-G8)*(1-G9)*(1-G10)*(1-G11))
G 15	Heat Content	13,000	kCal/kg	
G 16	Heat Content	5,850	kCal/l	G15*0.45
G 17	Fuel Cost @ Col CIF	13.5	US$/bbl	
G 18	Fuel Cost @ Col CIF	5,357	USCts/GCal	G17*3.9683
G 19	Full Load Heat Rate	2,857	kCal/kWh	
G 20	Thermal Efficiency	30.1%		860/G19
G 21	Fuel Cost /kWh	15.31	USCts/kWh	G18*G19
G 22	Variable OM Cost	0.402	USCts/kWh	
G 23	kWh-Value (adjusted)	**16.07**	USCts/kWh	(G21+G22)*((1-C2)*(1-C5))/((1-G8)*(1-G11))

(Source; JICA Study Team)

11.1.4 Economic Evaluation of the Project and Case Studies

Operation of the Project (PSPP Project) is assumed to be 1,000 hours per year (average four (4) hours in weekdays, and shut down due to scheduled maintenance and forced outage be ten (10) days per year). Annual generation becomes 600GWh with above assumptions. A 1,000 hours operation per year is equal to 11.4% utilization rate. As a reference, PSPP's utilization rates in OECD countries[1] are shown in Figure 11.1.4-1.



(Source：Electricity Information 2014, IEA)

Figure 11.1.4-1 Utilization Rate of PSPP in OECD Countries (2012)

[1] Countries shown in Chart are the countries having more than 2,000MW PSPP capacity. Utilization of Japan and Italy is low; utilization of Japan is affected by low operations in nuclear power plants; and Italy is affected by increase of electricity import from neighboring countries after liberalization of electricity market due to high generation cost in Italy.

The cash flow of base case is shown in Table 11.1.4-1. The economic internal rate of return (EIRR) is 21.5%, and the net present value is US$ 695.4 million (at 10% discount rate). The EIRR exceeds 10% hurdle rate of opportunity cost of capital (10% is often used for projects in developing countries). Thus, economic viability of the Project is high from national economy's view point.

Table 11.1.4-1 Cash-flow of Base Case and Its EIRR

(US$,000)

Year	PSPP Cost				Revenue				Net Cash	NPV disc	NPV disc
	Investment	Fixed OM	PumpCost	Total	Investment	Fixed OM	Fuel+Vari.	Total	Flow	@IRR	@10%
-4	31,055			31,055				0	-31,055	-67,682	-45,468
-3	62,110			62,110				0	-62,110	-111,408	-82,668
-2	155,275			155,275				0	-155,275	-229,230	-187,883
-1	248,440			248,440				0	-248,440	-301,861	-273,284
0	124,220			124,220	359,003			359,003	234,783	234,783	234,783
1		4,171	61,741	65,911		4,328	162,286	166,614	100,702	82,881	91,548
2		4,171	61,741	65,911		4,328	162,286	166,614	100,702	68,213	83,225
3		4,171	61,741	65,911		4,328	162,286	166,614	100,702	56,142	75,659
4		4,171	61,741	65,911		4,328	162,286	166,614	100,702	46,206	68,781
5		4,171	61,741	65,911		4,328	162,286	166,614	100,702	38,029	62,528
6		4,171	61,741	65,911		4,328	162,286	166,614	100,702	31,299	56,844
7		4,171	61,741	65,911		4,328	162,286	166,614	100,702	25,760	51,676
8		4,171	61,741	65,911		4,328	162,286	166,614	100,702	21,201	46,978
9		4,171	61,741	65,911		4,328	162,286	166,614	100,702	17,449	42,708
10		4,171	61,741	65,911		4,328	162,286	166,614	100,702	14,361	38,825
11		4,171	61,741	65,911		4,328	162,286	166,614	100,702	11,820	35,296
12		4,171	61,741	65,911		4,328	162,286	166,614	100,702	9,728	32,087
13		4,171	61,741	65,911		4,328	162,286	166,614	100,702	8,006	29,170
14		4,171	61,741	65,911		4,328	162,286	166,614	100,702	6,589	26,518
15		4,171	61,741	65,911		4,328	162,286	166,614	100,702	5,423	24,107
16		4,171	61,741	65,911		4,328	162,286	166,614	100,702	4,464	21,916
17		4,171	61,741	65,911		4,328	162,286	166,614	100,702	3,674	19,923
18		4,171	61,741	65,911		4,328	162,286	166,614	100,702	3,023	18,112
19		4,171	61,741	65,911		4,328	162,286	166,614	100,702	2,488	16,466
20		4,171	61,741	65,911	359,003	4,328	162,286	525,617	459,706	9,349	68,332
21		4,171	61,741	65,911		4,328	162,286	166,614	100,702	1,686	13,608
22		4,171	61,741	65,911		4,328	162,286	166,614	100,702	1,387	12,371
23		4,171	61,741	65,911		4,328	162,286	166,614	100,702	1,142	11,246
24		4,171	61,741	65,911		4,328	162,286	166,614	100,702	940	10,224
25		4,171	61,741	65,911		4,328	162,286	166,614	100,702	773	9,294
26		4,171	61,741	65,911		4,328	162,286	166,614	100,702	637	8,449
27		4,171	61,741	65,911		4,328	162,286	166,614	100,702	524	7,681
28		4,171	61,741	65,911		4,328	162,286	166,614	100,702	431	6,983
29		4,171	61,741	65,911		4,328	162,286	166,614	100,702	355	6,348
30		4,171	61,741	65,911		4,328	162,286	166,614	100,702	292	5,771
31	12,019	4,171	61,741	77,930		4,328	162,286	166,614	88,684	212	4,620
32	24,037	4,171	61,741	89,949		4,328	162,286	166,614	76,665	151	3,631
33	60,093	4,171	61,741	126,005		4,328	162,286	166,614	40,609	66	1,748
34	96,150	4,171	61,741	162,061		4,328	162,286	166,614	4,553	6	178
35	48,075	4,171	61,741	113,986		4,328	162,286	166,614	52,628	58	1,873
36		4,171	61,741	65,911		4,328	162,286	166,614	100,702	91	3,258
37		4,171	61,741	65,911		4,328	162,286	166,614	100,702	75	2,961
38		4,171	61,741	65,911		4,328	162,286	166,614	100,702	61	2,692
39		4,171	61,741	65,911		4,328	162,286	166,614	100,702	51	2,448
40		4,171	61,741	65,911	359,003	4,328	162,286	525,617	459,706	190	10,157
41		4,171	61,741	65,911		4,328	162,286	166,614	100,702	34	2,023
42		4,171	61,741	65,911		4,328	162,286	166,614	100,702	28	1,839
43		4,171	61,741	65,911		4,328	162,286	166,614	100,702	23	1,672
44		4,171	61,741	65,911		4,328	162,286	166,614	100,702	19	1,520
45		4,171	61,741	65,911		4,328	162,286	166,614	100,702	16	1,382
46		4,171	61,741	65,911		4,328	162,286	166,614	100,702	13	1,256
47		4,171	61,741	65,911		4,328	162,286	166,614	100,702	11	1,142
48		4,171	61,741	65,911		4,328	162,286	166,614	100,702	9	1,038
49		4,171	61,741	65,911		4,328	162,286	166,614	100,702	7	944
50		4,171	61,741	65,911		4,328	162,286	166,614	100,702	6	858
								IRR =	21.5%	0	695,395

(Source; JICA Study Team)

Economic evaluation results of base case and cases of sensitivity analysis, which tries to measure the impact on EIRR and NPV by changes in cost and/or benefits caused by various reasons, are summarized in Table 11.1.4-2. Assumed cases are as follows;

Case E-1 Base case

Case E-2 Initial construction cost increase by 10%

Case E-3-1 PSPP generation (kWh) increase by 10%

Case E-3-2 PSPP generation (kWh) decrease by 10%

Case E-4 Coal price for pump-up generation increase by 10%

Case E-5 Diesel fuel price for alternative gas-turbine thermal decrease by 10%

Table 11.1.4-2 Results of Economic Sensitivity Analysis

Case	Description	EIRR (%)	NPV (US$ Mil)
E-1	Base Case	21.5%	695.4
E-2	Initial Construction Cost 10% Up	19.3%	624.0
E-3-1	Generation 10% Up	22.8%	795.1
E-3-2	Generation 10% Down	20.1%	595.7
E-4	Coal Price for Pump-up 10% Up	20.7%	634.2
E-5	Fuel Price for Alternative Thermal Gas-turbine 10% Down	19.2%	534.5

(Source; JICA Study Team)

The results of sensitivity analysis show that relatively large impacts on EIRR and NPV are observed by 10% increase in initial construction cost (Case E-2), and by 10% decrease in diesel price for alternative gas-turbine (Case E-5), while relatively small impacts seen by PSPP generation volume changes (Case E-3-1, E-3-2), and coal price increase (Case E-4). In any case, impacts on results of economic analysis caused by changes in key factors are not significant.

11.1.5 Supplemental Analysis (case studies): Effects on Economic Viability of the Project under "Coal Restriction/LNG Development Scenario"

The economic evaluation of the Project in previous sections was made in line with generation expansion plan of LTGEP 2013-2032, which assumes the situation of 2025 under LTGEP 2013-2032 remains same for entire evaluation period. While keeping the LTGEP 2013-2032 as base case, GOSL commenced a study to pursue fulfilling the base/middle demand by liquefied natural gas (LNG). This supplemental analysis tries to identify the effects on economic evaluation of PSPP if LNG development scenario was materialized.

Different scenarios (cases) are developed by combing (1) source of energy for PSPP water pump-up, and (2) kind of alternative thermal for peak generation.

<u>Base Case (Case E-1)</u> is based on the case of "Revised Base Case 2012" of LTGEP 2013-2032. (1) Coal power capacity is 3,500MW, with enough capacity to water pump-up by coal power, and (2)

Alternative thermal is gas turbine with auto diesel as no LNG yet.

As case studies other than Base Case, scenarios with limitations on coal power generation are considered. Simulations are conducted for “No Coal Plants permitted after Trinco Coal Case” (Case X), and “Coal Limited around 60% from Total Generation (Case Y). In case of Case Y, the main case is 100% of water pump-up by coal power (Case Y-1) and a variation-case is water pump-up by coal 50% and by LNG 50% (Case Y-2).

Alternative thermal for peak generation in LNG available cases is the LNG-simple cycle (LNG-SC), and gas turbine with auto diesel in other case (LNG non-available case).

Scenarios in case studies are summarized in Table 11.1.5-1.

Table 11.1.5-1 Case Studies with Limitation on Coal Power Development

	Case E-1 (Base Case)	Case X Limit coal 2,000MW	Case Y-1	Case Y-2
			Coal 60% of generation	
(1) Water pump- up energy	Coal 100%	LNG-CC 100%	Coal 100%	Coal 50% LNG-CC 50%
(2) Alternative thermal	GT (Auto Diesel)	GT (LNG-SC)	GT (LNG-SC)	

(Source; JICA Study Team)

Summary of EIRRs in supplemental analysis are shown in Table 11.1.5-2. In Case X, where LNG is available for generation, the EIRR became as low as 4.3%. While cost for water pump-up increases (cost-up), cost for alternative thermal generation due to switching from auto diesel to LNG becomes much smaller (benefit-down). Interpretation of this result is; if weighted average of cost of capital is smaller than EIRR of 4.3%, PSPP is advantageous; if cost of capital is more than 4.3%, LNG becomes economical. It may be worth to note that as no official plan for LNG development is available in Sri Lanka (though LNG study is on-going, it is not recognized as accepted plan), supplemental analysis in this study is done based on LTGEP 2013-2032. This LTGEP noted that “LNG price assumptions made in the study seems optimistic in the global context”. A meaningful judgment to choose PSPP or LNG for peak demand must wait until accurate cost data becomes available based on realistic LNG development plan.

Table 11.1.5-2 Case Study Results

Scenario		Case E-1: Base Case (Coal 3,500MW at 2025)			Case X: Coal Limit at 2,000MW [Case 7 in LTGEP]			Case Y-1: Coal Generation 60% [Case 9 in LTGEP]			Case Y-2
PSPP Cost	Construction Cost (Maha 3)	Unit cost with IDC	1,129	$/kW	Unit cost with IDC	1,129	$/kW	Unit cost with IDC	1,129	$/kW	1,129
		Total Eco Cost for 600,000kW, SCF: -10% for local cost, Total from "Yr -4" to "Yr 0"	621,100	$,000	Total Eco Cost for 600,000kW, SCF: -10% for local cost, Total from "Yr -4" to "Yr 0"	621,100	$,000	Total Eco Cost for 600,000kW, SCF: -10% for local cost, Total from "Yr -4" to "Yr 0"	621,100	$,000	621,100
	Pump-up Cost	**Coal** @$142/ton Thremal efficiency 33.3% Pump-up efficiency 70%	10.29	Cts/kWh	**LNG** @$13/mmBtu Thremal efficiency 48.2% Pump-up efficiency 70%	14.96	Cts/kWh	**Coal 100%**	10.29	Cts/kWh	**Coal 50%/ LNGCC 50%** 12.63C/kWh
		1000hrs/yr=> 600GWh/yr	61,741	$/Year	1000hrs/yr=> 600GWh/yr	89,767	$/Year	1000hrs/yr=> 600GWh/yr	61,741	$/Year	75,754
		Alternative Thermal = GT (Auto Diesel)			Alternative Thermal = GT (LNG)			Alternative Thermal = GT (LNG)			GT (LNG)
PSPP Benefit (=Alternative Thermal)	Constructon Cost (GT-AuoDiesel)	Total for 600,000kW, SCF: -10% for local cost, kW-adjuestment 1.18 Total for "Yr 0", "Yr 20", "Yr 40"	359,003	$,000	Total for 600,000kW, SCF: -10% for local cost, kW-adjuestment 1.18 Total for "Yr 0", "Yr 20", "Yr 40"	359,003	$,000	Total for 600,000kW, SCF: -10% for local cost, kW-adjuestment 1.18 Total for "Yr 0", "Yr 20", "Yr 40"	359,003	$,000	359,003
	Fuel + Variable OM Cost	**Auto Diesel** @$128.4/bbl Thermal efficiency 30.1%	27.05	Cts/kWh	**LNG** @$13/mmBtu Thermal efficiency 30.1%	16.07	Cts/kWh	**LNG** @$13/mmBtu Thermal efficiency 30.1%	16.07	Cts/kWh	16.07
		kWh-adjusement 1.02, 1000hrs/yr=> 600GWh/yr	162,286	$/Year	kWh-adjusement 1.02, 1000hrs/yr=> 600GWh/yr	96,425	$/Year	kWh-adjusement 1.02, 1000hrs/yr=> 600GWh/yr	96,425	$/Year	96,425
EIRR		**21.5%**			**4.3%**			**10.9%**			**7.9%**

(Source; JICA Study Team)

11.2 Financial Evaluation

11.2.1 Methodology

(1) Evaluation Method

Financial analysis aims at measuring the expected return on investment from a viewpoint of an implementing agency. Here, the Discounted Cash Flow method was adopted. The basic approach for this method is as follows: First, the cash outflow (construction cost and O&M cost estimated at market price, i.e. financial costs) and inflow (benefits as electricity sale revenues) are developed on an annual basis over the project life. Secondly the net amount generated each year (benefit minus cost) will be discounted to the start year of the project by using “Discount Rate” and expressed it as an accumulated net present value (NPV) at the same standard year. The Financial Internal Rate of Return (FIRR) on investment is also calculated. FIRR is not affected by financing conditions; therefore, it is appropriate to evaluate the profitability of the project itself.

(2) Basic Conditions

According to the discussions with CEB, as well as in line with the existing reports for other projects in Sri Lanka, the following basic conditions were adopted:

- Economic Life

  Economic life of each facility, according to the experience of the Consultant, was determined as follows:

- 50 years for civil works
- 35 years for hydro-mechanical and electro-mechanical equipment
- Project life (Calculation Period)

Calculation period for evaluation is 55 years: 50 years of service life of civil facilities and 5 years of construction works.

- Escalation

No escalation was considered, therefore, a constant price will be used.

- Tax and Duties

In standard financial analysis, tax and duties are included as cost. CEB's investment projects, however, are usually tax exempted recognized as "Specified Project" by the Finance Ministry. Indirect taxes, such as value added tax, import duty, nation building tax, port and airport development levy, etc. are exempted. Therefore, taxes are excluded from financial analysis.

11.2.2 Financial Cost and Benefit

(1) Financial Cost

Financial cost consists of initial investment cost, equipment replacement cost, and operation and maintenance (O&M) cost, expressed in tax excluded market price. Initial investment cost and replacement cost are taken from Chapter 10 as follows;

Table 11.2.2-1 Initial Investment Cost (financial)

(Unit: US$)

Year	Initial Investment
1st Year	32,214,738
2nd Year	64,429,476
3rd Year	161,073,691
4th Year	257,717,905
5th Year	128,858,953

(Source; JICA Study Team)

Table 11.2.2-2 Replacement Investment Cost (financial)

(Unit: US$)

Year	Initial Investment
36th Year	12,467,521
37th Year	24,935,043
38th Year	62,337,607
39th Year	99,740,171
40th Year	49,870,085

(Source; JICA Study Team)

The operation and maintenance cost (O&M cost) consists of;

1) O&M cost of hydropower plant is usually estimated as certain percentage of initial investment cost. From similar projects in the past, annual O&M cost is calculated as 0.5% of civil work cost and 1.5% of hydro-mechanical and electro-mechanical works cost. Annual O&M cost is calculated as US$ 4,171,000.

2) In the base case, electricity for water pump-up will be generated by coal power plant. Pump-up cost is as shown in Table 11.1.2-4. Generation efficiency of PSPP is assumed as 70%. One kWh generation from PSPP requires US cents 10.29/kWh of coal power generation cost. To generate 600GWh of PSPP, the cost for coal power generation is US$ 61.7 million.

(2) Financial Benefit

The financial benefit of the Project is revenue from electricity sales. The average revenue of CEB was LKR 18.23/kWh in 2013. It is justifiable to use peak-time tariff, which is fixed higher than day-time tariff and off-peak tariff, for revenue calculation. Though PUCSL has its tariff road map to introduce peak/off-peak tariff for all consumer categories, peak tariff is applied only for high voltage consumers at this moment. PUCSL, in its Decision on Electricity Tariffs 2013, states that peak adjustment factor (ratio of peak tariff of 18:30-22:30 against day-time tariff of 05:30-18:30) is determined as 1.25. Based on this determination, calculated peak tariff of LKR 22.79/kWh (18.23 * 1.25) is used for average peak tariff. It is converted to US cents 17.65/kWh by applying average US$/LKR exchange rate of 2013 (LKR 129.11/US$).

From the generated 600GWh by PSPP per annum, 537GWh is salable after deducting gross loss of 10.5% (gross loss value of 2025 in LTGEP 2013-2032). Estimated annual revenue from PSPP electricity is US$ 94.8 million.

(3) Financial Evaluation

With the above explained assumptions, FIRR on investment (all equity finance basis) was calculated as 2.8%, and NPV with 10% discount rate was US$ minus (-) 464.1 million, as shown in Table 11.2.2-3. FIRR is merely above weighted average interest rate of 2.69%, consisting of JICA ODA loan of 1.4% for 85% investment cost and local loan of 10% for 15% investment cost. The Project does not make loss but only a small profit. Low profitability of peak supply may be considered inevitable, because of higher cost and not high enough peak-time electricity tariff.

It is worth to note that cost for alternative generation by gas-turbine is US cents 34.08/kWh[2] as against the expected revenue of US cents 17.66/kWh. This makes a loss of more than 16 cents per kWh sales. Thus, PSPP is much better option than gas-turbine in terms of financial aspects. The Transmission License issued to CEB includes a condition of electricity supply obligation[3]. CEB, therefore, does not have an option not to supply electricity due to financial non-attractiveness. The conclusion is that PSPP, though not very good return of investment from present tariff level, is the rational selection under demand fulfill obligation.

[2] It consists of US cents 27.05/kWh auto diesel fuel, and capital cost of US cents 7.03/kWh. Capital cost is calculated by using F12 figure of Table 11.1.3-1 (598.30

[3] Section 17 Special conditions of transmission licensees; Without prejudice to generality of section 15, a transmission license issued to a licensee shall include conditions – (b) requiring the licensee to forecast future demand, to plan the development of the licensee’s transmission system and to procure the development of new generation plant to meet reasonable forecast demand , Sri Lanka Electricity Act, No. 20 of 2009

Table 11.2.2-3 Cash-flow of Base Case and Its FIRR

(US$,000)

Year	Cash Outflow				Inflow	Net Cash	NPV disc	NPV disc
	Investment	Fixed OM	PumpCost	Total	Sales	Flow	@IRR	@10%
-4	32,215			32,215		-32,215	-36,012	-47,166
-3	64,429			64,429		-64,429	-70,046	-85,756
-2	161,074			161,074		-161,074	-170,304	-194,899
-1	257,718			257,718		-257,718	-264,999	-283,490
0	128,859			128,859		-128,859	-128,859	-128,859
1		4,171	61,741	65,911	94,779	28,867	28,074	26,243
2		4,171	61,741	65,911	94,779	28,867	27,303	23,857
3		4,171	61,741	65,911	94,779	28,867	26,553	21,688
4		4,171	61,741	65,911	94,779	28,867	25,823	19,717
5		4,171	61,741	65,911	94,779	28,867	25,114	17,924
6		4,171	61,741	65,911	94,779	28,867	24,424	16,295
7		4,171	61,741	65,911	94,779	28,867	23,753	14,814
8		4,171	61,741	65,911	94,779	28,867	23,100	13,467
9		4,171	61,741	65,911	94,779	28,867	22,465	12,243
10		4,171	61,741	65,911	94,779	28,867	21,848	11,130
11		4,171	61,741	65,911	94,779	28,867	21,248	10,118
12		4,171	61,741	65,911	94,779	28,867	20,664	9,198
13		4,171	61,741	65,911	94,779	28,867	20,096	8,362
14		4,171	61,741	65,911	94,779	28,867	19,544	7,602
15		4,171	61,741	65,911	94,779	28,867	19,007	6,911
16		4,171	61,741	65,911	94,779	28,867	18,485	6,282
17		4,171	61,741	65,911	94,779	28,867	17,977	5,711
18		4,171	61,741	65,911	94,779	28,867	17,483	5,192
19		4,171	61,741	65,911	94,779	28,867	17,003	4,720
20		4,171	61,741	65,911	94,779	28,867	16,535	4,291
21		4,171	61,741	65,911	94,779	28,867	16,081	3,901
22		4,171	61,741	65,911	94,779	28,867	15,639	3,546
23		4,171	61,741	65,911	94,779	28,867	15,210	3,224
24		4,171	61,741	65,911	94,779	28,867	14,792	2,931
25		4,171	61,741	65,911	94,779	28,867	14,385	2,664
26		4,171	61,741	65,911	94,779	28,867	13,990	2,422
27		4,171	61,741	65,911	94,779	28,867	13,606	2,202
28		4,171	61,741	65,911	94,779	28,867	13,232	2,002
29		4,171	61,741	65,911	94,779	28,867	12,868	1,820
30		4,171	61,741	65,911	94,779	28,867	12,515	1,654
31	12,468	4,171	61,741	78,379	94,779	16,400	6,914	854
32	24,935	4,171	61,741	90,846	94,779	3,932	1,612	186
33	62,338	4,171	61,741	128,249	94,779	-33,470	-13,347	-1,441
34	99,740	4,171	61,741	165,652	94,779	-70,873	-27,485	-2,774
35	49,870	4,171	61,741	115,782	94,779	-21,003	-7,921	-747
36		4,171	61,741	65,911	94,779	28,867	10,588	934
37		4,171	61,741	65,911	94,779	28,867	10,297	849
38		4,171	61,741	65,911	94,779	28,867	10,014	772
39		4,171	61,741	65,911	94,779	28,867	9,739	702
40		4,171	61,741	65,911	94,779	28,867	9,472	638
41		4,171	61,741	65,911	94,779	28,867	9,211	580
42		4,171	61,741	65,911	94,779	28,867	8,958	527
43		4,171	61,741	65,911	94,779	28,867	8,712	479
44		4,171	61,741	65,911	94,779	28,867	8,473	436
45		4,171	61,741	65,911	94,779	28,867	8,240	396
46		4,171	61,741	65,911	94,779	28,867	8,014	360
47		4,171	61,741	65,911	94,779	28,867	7,793	327
48		4,171	61,741	65,911	94,779	28,867	7,579	298
49		4,171	61,741	65,911	94,779	28,867	7,371	270
50		4,171	61,741	65,911	94,779	28,867	7,169	246
					IRR =	2.8%	0	-464,148

(Source; JICA Study Team)

11.2.3 Sensitivity Analysis

Financial evaluation results of base case and cases of sensitivity analysis, which tries to measure the impact on FIRR and NPV by changes in cost and/or benefits caused by various reasons, are summarized in Table 11.2.3-1. Assumed cases are as follows;

Case F-1 Base case
Case F-2 Initial construction cost increase by 10%
Case F-3-1 PSPP generation (kWh) increase by 10%
Case F-3-2 PSPP generation (kWh) decrease by 10%
Case F-4 Coal price for pump-up generation increase by 10%
Case F-5 Peak tariff index (ratio against day-time tariff) to 1.50 from base case value of 1.25

In Case F-5, that is to change peak tariff index from 1.25 to 1.50, FIRR improves to a certain degree. This may be a realistic option to improve financial viability of the Project due to the following reasons; (i) while peak tariff index of general purpose is 1.23, the same of industry and hotel is from 1.6 to 2.3 under current tariff structure. Thus, higher peak tariff index exists and accepted by certain category of consumers; (ii) consumer category not implemented peak tariff is domestic consumers, who may not be ready to accept high peak tariff index at beginning. But, gradual increase of peak tariff index in order to familiarize the new tariff system is a reasonable approach.

Table 11.2.3-1 Results of Financial Sensitivity Analysis

Case	Description	FIRR (%)	NPV (US$ Mil)
F-1	Base Case	2.8%	-464.1
F-2	Initial Construction Cost 10% Up	2.3%	-538.2
F-3-1	Generation 10% Up	3.5%	-431.4
F-3-2	Generation 10% Down	2.1%	-496.9
F-4	Coal Price for Pump-up 10% Up	1.4%	-525.4
F-5	Peak Tariff Index Increase from 1.25 to 1.50	6.2%	-276.2

(Source; JICA Study Team)

The above financial analysis and sensitivity test shows that financial low return is an issue, and it can be improved to FIRR 6.2% by increasing peak-time tariff by average 20% (from 1.25 to 1.50). But the expected financial improvement is not high enough. Therefore, to compensate financial low profit, it is recommended to mobilize highly concessional loan such as JICA ODA loan.

Chapter 12

Conclusion and Recommendation

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Chapter 12 Conclusion and Recommendation

12.1 Conclusion

12.1.1 Necessity of Project

The electric energy generated in 2013 in Sri Lanka was 11,962GWh (at generating end except private power generator) and the net system energy demand was 10,621GWh. According to the Annual Report 2013 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 with reservoirs for exclusive power generation that account approximately 23% of electric power plants in capacity 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, CEB has deal with such situation by operating high cost thermal power plants using petroleum fuel. In order to firmly maintain the goal of stable electricity supply and keep its adequate tariff, the Sri Lankan Government set a goal of deduction in capacity of petroleum thermal power plants, and significant development of coal thermal power plants and renewable energy as a concrete goal in national energy policy and strategy. And also the Sri Lankan Government 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.

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 disproportionate 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 economic efficiency and contribution to whole power stability of Sri Lanka.

In process of the selection of power generation options for peak power demand in this study, power generation options described in the LTGEP 2013-2032 were adopted as potential options for development, and their aptitudes for the peak power demand were examined as the first screening. Then, the second screening is carried out from viewpoints of power generation characteristics, environmental and social consideration, and economic effectiveness. As a result of the screenings, hydropower plant (expansion) and pumped storage power plant are selected, and the master plan study of pumped storage power plant is carried out.

12.1.2 Outline of the Most Promising Site

Figure 12.1.2-1 shows the location of Maha 3 site, which was selected as the most promising candidate site. Regarding the access to the lower dam site, total distance from Colombo is around 110 km, and the dam site is reached through A1, A21, B136, B278 and a path of the distance around 6.2 km. In this regard, it was confirmed in the site survey conducted by the study team that direct approaching from the lower dam site to the upper dam site is difficult for vehicles due to narrow width of the said path. However, the accessibility of the upper dam site itself is good even by vehicles due to newly constructed road and so on.

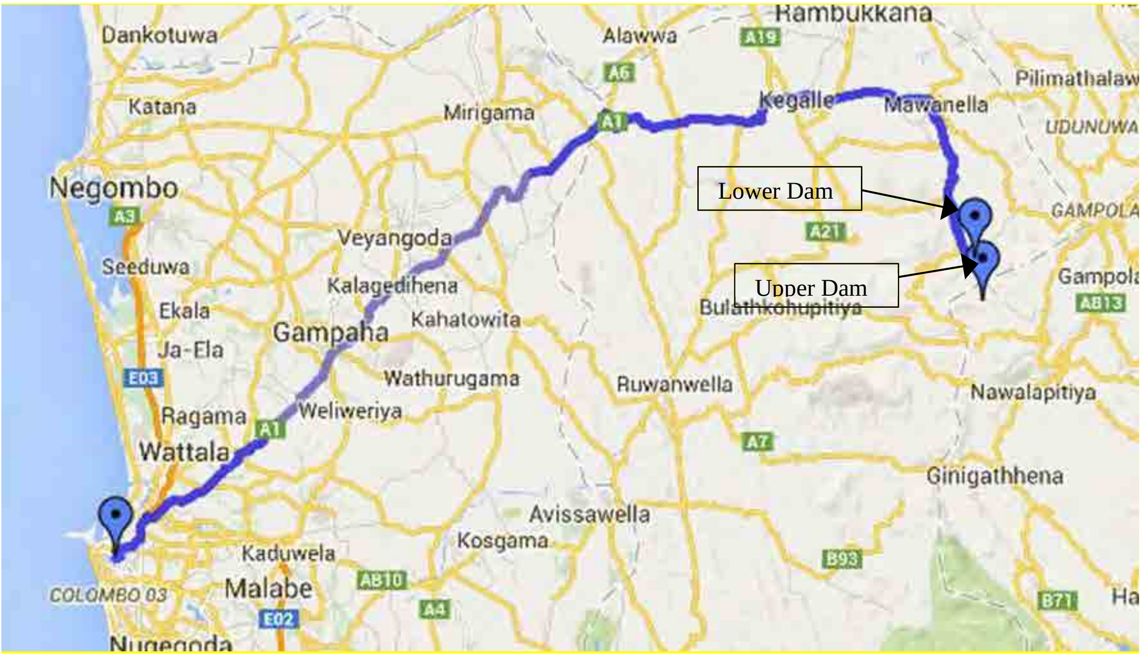


Figure 12.1.2-1 Location of Maha 3 Site

In Maha site, 1/1,000 topographic survey covering the upper reservoir area and the lower reservoir area was conducted. Based on the outcome of 1/1,000 survey, reservoir capacity curves has been created and the pumped storage scheme is reviewed following to the flowchart shown in Figure 12.1.2-2. As shown in the figure, rated head, rated discharge, and efficiency of the pump-turbine are finalized by repeated convergent calculation.

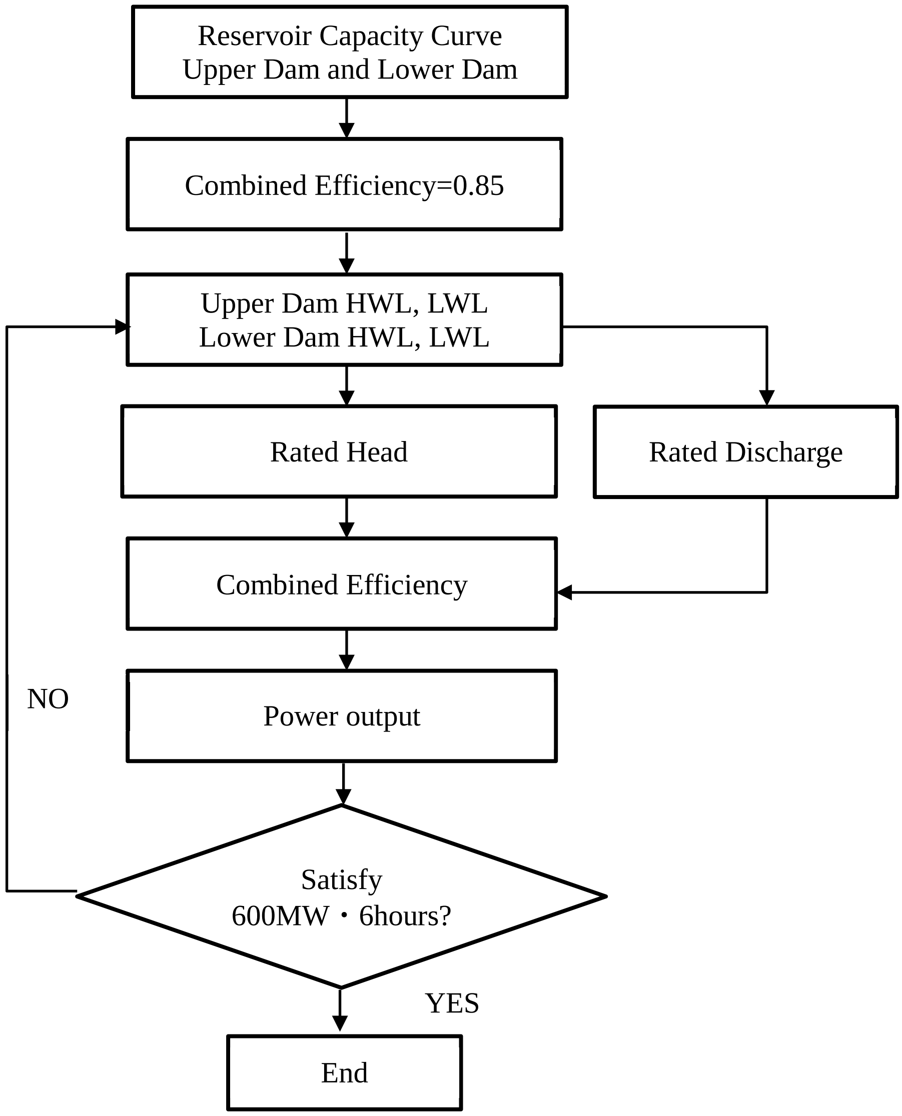


Figure 12.1.2-2 Flowchart of Pumped Storage Scheme Review

As a result, reviewed pumped storage scheme of the most promising candidate site is shown in Table 12.1.2-1, and it is understood that it is not much different one to the scheme shown in Chapter 10, which was used for selecting the most promising site from three promising candidate sites. Both of three unites of 200MW (case 1), and four unites of 150 MW (case 2), are described because both of schemes are applicable to Maha 3 in view of the manufacturing limitation as mentioned in Chapter 9.

Table 12.1.2-1 General Features of Maha 3 Scheme

Candidate Site		unit	Maha 3	
			case1	case2
Installed Capacity		MW	600	600
Unit Capacity		MW	200	150
Number of Units		unit	3	4
Peak Generating Time		hours	6.14	6.17
Gross Head		m	521.04	521.44
Rated Head		m	493.37	483.95
Rated Discharge		m^3	142.64	147.10
Upper Pond	Latitude		7°06'23"	7°06'23"
	Longitude		80°28'49"	80°28'49"
	Catchment Area	km^2	1	1
	Reservoir Area	km^2	0.22	0.22
	Crest Elevation	E.L.-m	821.0	820.5
	High Water Level	E.L.-m	815.0	814.5
	Low Water Level	E.L.-m	794.5	791.3
	Drawdown	m	20.5	23.2
	Sediment Level	E.L.-m	782.3	782.3
	Gross Capacity	MCM	3.71	3.60
	Available Capacity	MCM	3.15	3.27
	Dam Height	m	59	59
	Crest Length	m	260	260
Lower Pond	Latitude		7°07'50"	7°07'50"
	Longitude		80°28'49"	80°28'49"
	Catchment Area	km^2	35	35
	Reservoir Area	km^2	0.24	0.24
	Crest Elevation	E.L.-m	298.5	297.5
	High Water Level	E.L.-m	292.5	291.5
	Low Water Level	E.L.-m	276.4	273.0
	Drawdown	m	16.1	18.5
	Sediment Level	E.L.-m	263.2	263.2
	Gross Capacity	MCM	6.22	5.78
	Available Capacity	MCM	3.20	3.30
	Dam Height	m	73.5	72.5
	Crest Length	m	380	380
Headrace Tunnel				
	Inner Diameter	m	5.60	4.00
	Length	m	960	960
	Nos. of lines	-line	1	2
Penstock Tunnel				
	Inner Diameter	m	4.30	3.10
	Length	m	993	996
	Nos. of lines	-line	1	2
Tailrace Tunnel				
	Inner Diameter	m	6.10	4.40
	Length	m	415	415
	Nos. of lines	-line	1	2
Access Tunnel to PH				
	Length	m	900	900

(Source: JICA Study Team)

In addition, the general features of Pump-turbine and Generator-Motor for Maha 3 scheme are as shown in Table 12.1.2-2.

Table 12.1.2-2 Summary of Major Parameters of Pump-turbine, Generator-Motor

Case	unit	Case 1 200MW×3 units	Case 2 150MW×4 units
Pump-turbine			
Type		Vertical shaft, single stage, Francis type reversible pump-turbine	Vertical shaft, single stage, Francis type reversible pump-turbine
Max. output	MW	600	600
Max. discharge	m^3/s	142.64	147.1
Effective head	m	493.37	483.95
Unit quantity	unit	3	4
Frequency	Hz	50	50
Turbine output	MW/unit	204	153
Pump input	MW/unit	185	154
Revolving speed	min^{-1}	500	500
Pump efficiency	%	86.7	85.7
Inlet valve		Spherical type	Spherical type
Generator			
Rated output	MW	200	150
Rated voltage	kV	16.5	16.5
Rated current	A	7,380	5,530
Direction of rotation		Clockwise	Clockwise
Efficiency	%	98.0	98.0
Motor			
Rated output	MW	189	157
Efficiency	%	97.9	98.1

Major components of electro-mechanical equipment will be as follows;

- Pump-turbine
- Generator-motor
- Main transformer
- 220 kV XLPE Power cable
- 220 kV Switchyard
- Starter equipment (Static Frequency Converter = SFC)
- Control equipment

Other electro-mechanical equipment such as Main circuit components, station service circuit and traveling crane, will be studied in Feasibility Study stage.

12.1.3 Geology Survey

The major interest in the geology survey in this master plan survey is to 1) conduct the investigation which contribute to the selection of the most promising site among all, and 2) reveal the geology features and risks lying the candidate sites, most likely in the most promising site Maha 3.

The procedures in geology work is

- 1st grade evaluation of 11 candidate sites for extraction of some promising sites mainly based on the existing materials available (existing geology maps, aeropohotographs, etc.).
- Geology survey (phase 1), evaluation of 3 sites for extraction of most promising site, based on mainly of surface geology survey focused on the promising 3 sites
- Geology survey (phase 2), evaluation of 1 most promising site, based on mainly of drillings.

The outcome of each evaluation has been described in detail at : “9.2.4 Each candidate site geology” to “9.6.4 Evaluation from Geological Aspects” for the 1st evaluation, “10.3.2 Geology (Maha2)”, “10.4.2 Geology (Maha3)”, and “10.5.2 Geology (Halgran 3)” for geology survey (phase1), and “Appendix 12.1, Geology evaluation of the most promising site Maha 3” for the geology survey (phase 2).

The whole work has been carried out by predetermined schedule, and because of the time restraint of the project study timeline, it was so decided that the result of the geology survey (phase 2) does not give effect on the selection of the most promising site. The selection was made on the timing when the survey (phase 1) was completed. So, rather the phase 2 survey was aimed at providing preceding information which can contribute pre FS stage study in advance, making certain if there lays no critical disadvantages with the chosen site to go forward.

In the following paragraphs the major findings in the geology survey (phase 2) are summarized. The detail data is in the Appendix 12.1.

(1) Geology survey

The subcontracted survey in this study was the topography and geology survey (phase 1) and topography and geology survey (phase2).

With regard to geology survey, the phase 1 survey consists surface geological survey, and the phase 2 survey consists drilling survey and laboratory tests. The details are shown in the table below.

Table 12.1.3-1 The details of Topography and Geology Survey (phase 1)

Survey Item	Quantity	Remarks
Topography Survey (T-1)	1:5,000 scale	Mapping for 3 promising areas
	5.53 km2	ie. Maha 3 (1.14km2), Maha 2 (1.82km2), Halgran 3 (2.57km2)
Topography Survey (T-2)	1:1,000 scale	Detailed Mapping for 1 most promising site
	1.0 km2	ie. Maha 3 (1.0km2)

Table 12.1.3-2 The details of Topography and Geology Survey (phase 2)

Survey Item	Quantity	Remarks
Geological Survey (G-1)	1:10,000 scale	Surface Geology Survey for 3 promising areas
	42 km2	ie. Maha 2 & Maha3 (10km2), Halgran 3 (15km2)
		Collection of available data and maps
		Aerophotograph, satellite image study
		Geological mapping and study
Geological Survey (G-2)	6 holes	Drilling Survey for 1 most promising site
	306.13 m	ie. Maha 3
		6 holes (right bank, river bed, left bank for Upper & Lower damsite)
		Core drillings, Geological logging, Permeability test
		Laboratory test for rock cores

(2) The result of the survey (phase 2)

The followings are the summarized outcome of the geology survey (phase 1) and (phase 2).

(a) Upper dam site

The fine rock basement was confirmed at the right abutment through riverbed with fine biotite gneiss (CH at CRIEPI classification) in relatively shallow depth. However on the left abutment, it was found the depth to the sound rock basement went as large as 47m. The poor rock cover was thicker than previously had been anticipated. Presumably it is considered from the present information available that left slope of the dam site has a thick talus deposit supplied from the steep height cliffs accompanied with the probable mass movement of that deposit toward river.

It is specifically noted that NW-SE straight-shaping lineament extending alongside of the left abutment at higher elevation forming very sharp straight cliff. This implies the underlying fault and the colluviums collapsed from the cliff largely deposit on the left slope as talus deposit. The drilling site (BHU-1) was set on the talus deposit but the deposit was previously not anticipated limited in thickness at the time of the geology survey (phase 1).

However, the BHU-1 drilled in the geology survey (phase 2), a little upstream from dam axis by 20m revealed there lies thick soil deposits of 27m in depths, with confirmation of the rock material around that depth but still having very little core recoveries (≦20% at 33.3-47.0m, ≦10% at 39.0-45.7m). It never reached the fresh rock surface until 47m depth.

The 47m depth fresh rock surface corresponds to the nearly -13m beneath river bed elevation, when the interval of this zone of no/little recovery as “very poor zone”.

One more noticeable feature was that the BHU-1 had encountered the total water inflows at 32m depth which corresponds just above the river bed elevation (i.e. +2 - +3m above the river bed level).

Apart from geology, the topography survey (phase 2) with 1:1,000 scale at the upper reservoir made it clearer the shape of the left ridge slope forms low angle slope of <20 degree, and the end of the deposit at bottom forms even lower as <5 degree showing almost flat geometries.

In evaluating the whole features above, though they are still limited in accuracies and quantities, it is a likely assumption that

- the left abutment at dam site has the talus deposits a certain thickness of the collapsed materials,
- that those deposits (the talus deposits in conjunction with the beneath completely weathered residual rocks) have slipped (or collapsed) moving towards river bed with the borders at the 32m depth zones in which ground water is running through, and
- that the tail end of the mass has formed the flat end shape.

The zones beneath 32m depth, between 32 to 47m, which has almost no core recoveries are, possibly 1) the zones of old ancient surface weathered residuals before the talus had collapsed and deposited, 2) some weak zones caused due to genetic origins (ex. 39.0 to 45.7m zone contains large concentrated felsic materials of biotite or amphibole along foliations. Those are prone to be dissolved / deteriorated), 3) the zones caused by the structural origin (the deep weathered materials due to the faulting). The exact cause is not known at the present stage.

(It may be not likely the whole mass to the 47m depth has slided/collapsed as it reaches -13m beneath river bed surface but cannot be denied completely.)

It is extremely regretting to say that the drilling work which had been conducted by the subcontractor (CECB) was revealed to be relatively poor in acquiring cores in good conditions. Thus, it is not 100% excluded if they had missed obtaining cores for the particular interval without any geological reasons.

The fresh solid rocks were confirmed at the depth 47m onwards in BHU-1. On the surface the left abutment ridge peaks at the steep rock faces along the straight cliffs with fresh biotite gneiss outcrops around EL. 870m, and obviously the groundwater table is expected to rise towards the peak. In conclusion the water sealing capability is expected to be secured.

(b) Lower dam site

The fine rock basement of biotite gneiss (CH at CRIEPI classification) was confirmed at both right and left abutment along the lower dam site. The NW-SE trending fault had been estimated in the existing geology map and aerophotograph interpretation, but was not recognized in the drillings so far.

At the present stage there seem no critical issues in the geotechnical terms for the proposed dam axis location.

(c) Water route and Underground powerhouse

The water route consists of biotite gneiss and granite gneiss. As there lay no drillings, it could have been based on the surface geology survey that the following estimation was obtained. The general trends of the geological structures (NW-SE strikes with NE dips) were found unfavorable in terms of the tunneling excavation and stabilities though, the rock conditions at the depths at the water route tunnels (including headrace tunnel) are considered to be good enough (CH class or better) that geochemically no critical issues may be encountered due to such structures.

The underground power house comprises biotite gneiss. Though cares should be taken for the anisotropies of the foliations and the surface joint conditions which shall be investigated at later stages, the rock itself is anticipated no particular geological issues at this stage as the powerhouse basement.

(d) Construction materials

The laboratory tests were conducted using rock cores taken from drillings in the view to utilize the results for the foregoing stage's construction material surveys with providing typical properties required for the coarse aggregates.

The result shows that most of the properties meet the required conditions for coarse aggregates. UCS (unconfined compressive strength) values generally had shown smaller in values compared to the general solid basement biotite gneiss, thus require further additional tests.

12.1.4 Construction Costs and Schedule

(1) Construction Costs

Construction costs are calculated with the same method to shown in the subchapter 10.2.7. Main deferent points from the subchapter 10.2.7 are as following two points; the cost calculation is done with the revised project scheme based on the 1/1,000 topographic survey results as mentioned in the subchapter 12.1.2 and quantities of very items for the upper dam and the lower dam are made more precise than those calculated in the subchapter 10.2.7.

Table 12.1.4-1 shows both construction costs for the scheme 3 units of 200 MW and that for 4 units of 150 MW, and Table 12.1.4-2 shows the construction cost of the alternative scheme in which the variable speed system is applied. Only one main unit is replaced by the variable speed system in both schemes.

Table 12.1.4-1 Maha 3 Construction Costs

	Item/Project	200MW 3units (US$)	150MW 4units (US$)	Remarks
1.	Preparation and Land Acquisition	4,994,007	5,125,380	
	(1) Access Roads			@550,000US$/km
	(2) Compensation & Resettlement			
	(3) Camp & Facilities	4,994,007	5,125,380	3. Civil Works * 2%
2.	Environmental Mitigation Cost	7,491,011	7,688,070	3. Civil Works * 3%
3.	Civil Works	249,700,365	256,268,986	
4.	Hydromechanical Works	54,550,427	57,433,434	
5.	Electro-Mechanical Equipment	194,800,000	202,500,000	
6.	Transmission Line	3,900,000	3,900,000	
	Direct Cost	515,435,810	532,915,870	
7.	Administration and Engineering Service	77,315,372	79,937,381	Direct Cost * 15%
8.	Contingency	51,543,581	53,291,587	Direct Cost * 10%
9.	Interest during Construction	32,929,905	34,046,663	Σ(1-8)*0.38*i*T
	Total Cost	677,224,668	700,191,501	
	Power Output (kW)	600,000	600,000	
	USD per kW	1,129	1,167	

(Source: JICA Study Team)

Table 12.1.4-2 Maha 3 Construction Costs (Variable-speed one unit)

	Item/Project	200MW 3units (US$)	150MW 4units (US$)	Remarks
1.	Preparation and Land Acquisition	5,042,581	5,174,707	
	(1) Access Roads			@550,000US$/km
	(2) Compensation & Resettlement			
	(3) Camp & Facilities	5,042,581	5,174,707	3. Civil Works * 2%
2.	Environmental Mitigation Cost	7,563,872	7,762,061	3. Civil Works * 3%
3.	Civil Works	252,129,070	258,735,366	
4.	Hydromechanical Works	54,550,427	57,433,434	
5.	Electro-Mechanical Equipment	205,500,000	211,400,000	
6.	Transmission Line	3,900,000	3,900,000	
	Direct Cost	528,685,950	544,405,568	
7.	Administration and Engineering Service	79,302,893	81,660,835	Direct Cost * 15%
8.	Contingency	52,868,595	54,440,557	Direct Cost * 10%
9.	Interest during Construction	33,776,424	34,780,711	Σ(1-8)*0.38*i*T
	Total Cost	694,633,862	715,287,671	
	Power Output (kW)	600,000	600,000	
	USD per kW	1,158	1,192	

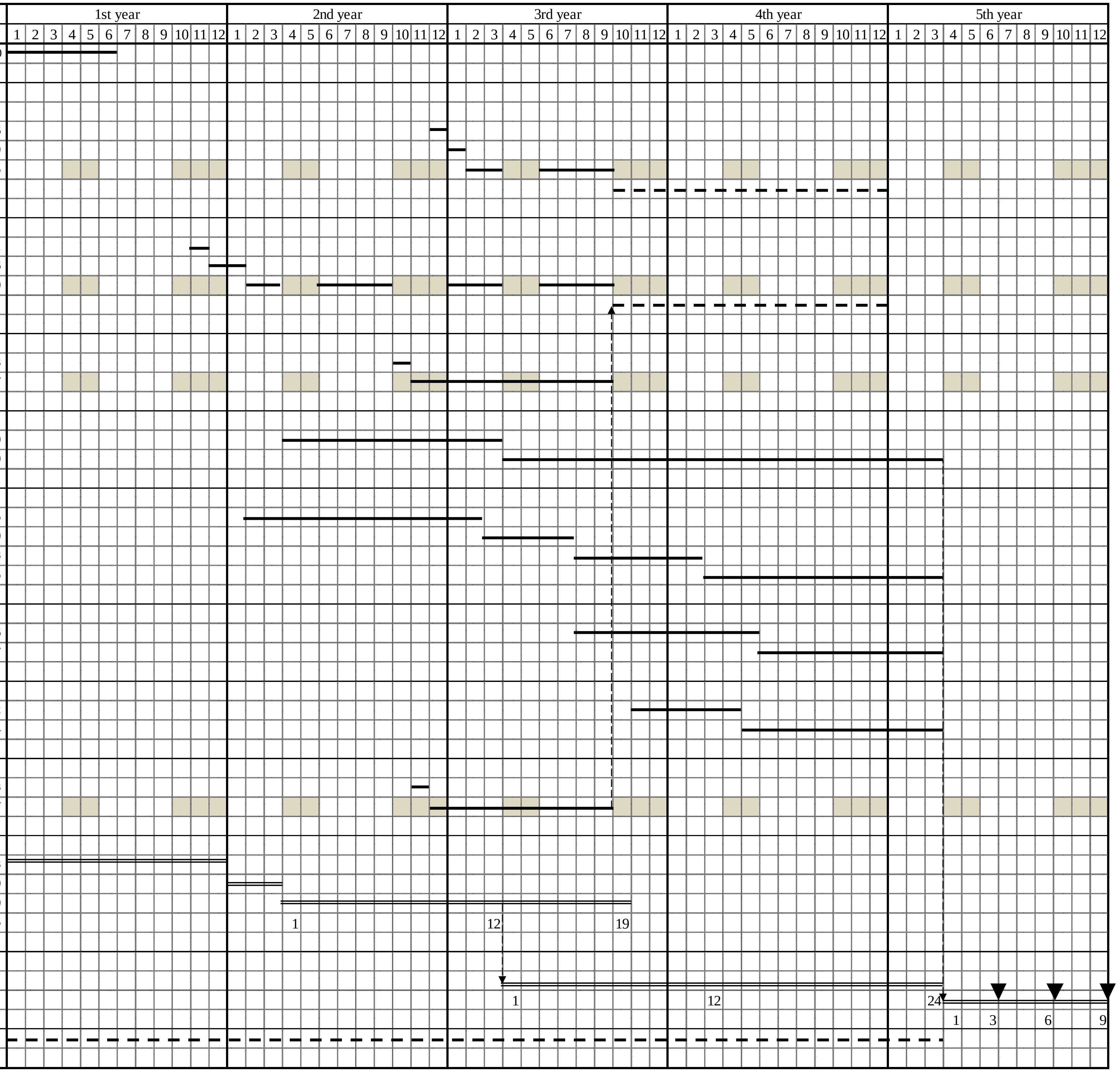
(Source: JICA Study Team)

(2) Construction Schedule

The construction schedule is shown in Figure 12.1.4-1, which is estimated with the quantities of civil works items calculated for the construction cost estimation of 3 unit of 200 MW scheme. In this schedule, it is assumed that the dam embankment work is suspended from April to May and from October to December considering rainfall in those seasons.

It is identified that the critical path is works in underground powerhouse, and it takes 60 months from the starting of access tunnel excavation to the final commissioning test for unit No. 3. As for the penstock tunnel, 4 excavation faces are to be set in order to complete in the said period.

Work Items	Duration: unit	Quantities	per month	months
1. Preparation Works				6.0
2. Civil Works				
2.1 Upper Dam				
Common Excavation	m3	55,224	100,000	0.6
Rock Excavation	m3	128,856	150,000	0.9
Embankment (Rock)	m3	814,554	150,000	5.5
Impounding				
2.2 Lower Dam				
Common Excavation	m3	100,548	100,000	1.1
Rock Excavation	m3	234,612	150,000	1.6
Embankment (Rock)	m3	1,946,755	150,000	13.0
Impounding				
2.3 Power Intake				
Excavation	m3	28,882	100,000	0.3
Concrete	m3	10,649	1,000	10.7
2.4 Headrace Tunnel				
Tunnel Excavation	m	960	80	12.0
Concrete	m	960	40	24.0
2.5 Penstock Tunnel				
Work Adit (Excavation)	m	1,000	80	12.5
(Concrete)	m	1,000	200	5.0
Tunnel Excavation	m	497	80	6.3
Steel Liner and Concrete	m	497	40	12.5
2.6 Surge Tank				
Shaft Excavation	m3	33,364	3,500	9.6
Lining Work	m3	9,658	1,000	9.7
2.7 Tailrace Tunnel				
Tunnel Excavation	m	415	80	5.2
Concrete	m	415	40	10.4
2.8 Tailrace Outlet				
Excavation	m3	26,062	100,000	0.3
Concrete	m3	9,640	1,000	9.7
2.9 Powerhouse				
Access Tunnel (Excavation)	m	900	80	11.3
(Concrete)	m	900	300	3.0
Cavern Excavation	m3	189,786	10,000	19.0
Concrete	m3	30,943	2,000	15.5
3. Electro-mechanical Equipment				
Installation				
Commsionning Test				
4. Transmission Line				



: Rainy Season

(Source; JICA Study Team)

Figure 12.1.4-1 Maha 3 Construction Schedule

12.1.5 Economic and Financial Evaluation

(1) Economic Analysis

Economic evaluation was conducted from a viewpoint of national economy for the optimum project plan identified in this study, by using Economic Internal Rate of Return (EIRR) and Net Present Value (NPV).

Base Case Cost (economic price)

- Initial investment cost US$ 621,100,000
- Replacement investment cost US$ 240,374,000
- Annual O&M cost US$ 4,171,000/year
- Annual water pump-up cost by coal US$ 61,741,000/year (for 600GWh generation)

Base Case Benefit (saved gas-turbine generation cost, economic price)

- Gas-turbine initial investment cost US$ 1,077,009,000 (total of 3 times in 50 year)
- Annual O&M cost US$ 4,328,000/year
- Fuel cost (auto diesel) US$ 162,286,000/year

Results of economic evaluation (base case and cases of sensitivity analysis, which tries to measure the impact on EIRR and NPV by changes in cost and/or benefits), are summarized in Table 12.1.5-1. Assumed cases are as follows;

- Case E-1 Base case
- Case E-2 Initial construction cost increase by 10%
- Case E-3-1 PSPP generation (kWh) increase by 10%
- Case E-3-2 PSPP generation (kWh) decrease by 10%
- Case E-4 Coal price for pump-up generation increase by 10%
- Case E-5 Diesel fuel price for alternative gas-turbine thermal decrease by 10%

Table 12.1.5-1 Results of Economic Sensitivity Analysis

Case	Description	EIRR (%)	NPV (US$ Mil)
E-1	Base Case	21.5%	695.4
E-2	Initial Construction Cost 10% Up	19.3%	624.0
E-3-1	Generation 10% Up	22.8%	795.1
E-3-2	Generation 10% Down	20.1%	595.7
E-4	Coal Price for Pump-up 10% Up	20.7%	634.2
E-5	Fuel Price for Alternative Thermal Gas-turbine 10% Down	19.2%	534.5

(Source; JICA Study Team)

The economic internal rate of return (EIRR) is 21.5%. The EIRR exceeds 10% hurdle rate of opportunity cost of capital (10% is often used for projects in developing countries). Thus, economic viability of the Project is high from national economy's view point. The results of sensitivity analysis show that impacts caused by changes in key factors are not significant to EIRR and NPV.

(2) Financial Analysis

Financial viability of the Project was evaluated from a CEB's financial viewpoint.

<u>Base Case Cost (market price)</u>

- Initial investment cost	US$ 644,295,000
- Replacement investment cost	US$ 249,350,000
- Annual O&M cost	US$ 4,171,000/year
- Annual water pump-up cost	US$ 61,741,000/year (for 600GWh generation)

<u>Base Case Benefit (market price)</u>

- Revenue from electricity sales	US$ 94,779,000 (peak-time tariff)

Results of financial evaluation (base case and cases of sensitivity analysis, which tries to measure the impact on FIRR and NPV by changes in cost and/or benefits), are summarized in Table 12.1.5-2. Assumed cases are as follows;

- Case F-1	Base case
- Case F-2	Initial construction cost increase by 10%
- Case F-3-1	PSPP generation (kWh) increase by 10%
- Case F-3-2	PSPP generation (kWh) decrease by 10%
- Case F-4	Coal price for pump-up generation increase by 10%
- Case F-5	Peak tariff index (ratio to day-time tariff) to 1.50 from base case value 1.25

Table 12.1.5-2 Results of Financial Sensitivity Analysis

Case	Description	FIRR (%)	NPV (US$ Mil)
F-1	Base Case	2.8%	-464.1
F-2	Initial Construction Cost 10% Up	2.3%	-538.2
F-3-1	Generation 10% Up	3.5%	-431.4
F-3-2	Generation 10% Down	2.1%	-496.9
F-4	Coal Price for Pump-up 10% Up	1.4%	-525.4
F-5	Peak Tariff Index Increase from 1.25 to 1.50	6.2%	-276.2

(Source; JICA Study Team)

For the base case, FIRR on investment (all equity finance basis) was calculated as 2.8%, and NPV with 10% discount rate was US$ minus (-) 464.1 million. FIRR is merely above weighted average interest rate of 2.69%, consisting of JICA ODA loan of 1.4% for 85% investment cost and local loan of 10% for 15% investment cost. The Project does not make loss but only a small profit. Low profitability of peak supply may be considered inevitable, because of higher cost and not high enough peak-time electricity tariff.

It is worth to note that cost for alternative generation by gas-turbine is US cents 34.08/kWh[1] as against the expected revenue of US cents 17.66/kWh. This makes a loss of more than 16 cents per kWh sales. Thus, PSPP is much better option than gas-turbine in terms of financial aspects. The Transmission License issued to CEB includes a condition of electricity supply obligation[2]. CEB, therefore, does not have an option not to supply electricity due to financial non-attractiveness. The conclusion is that PSPP, though not very good return of investment from present tariff level, is the rational selection under demand fulfill obligation.

In Case F-5, that is to change peak tariff index from 1.25 to 1.50, FIRR improves to a certain degree. This may be a realistic option to improve financial viability of the Project by introducing gradual increase of peak tariff index in order to give time to domestic consumers for familiarizing new tariff system (Currently, peak-time tariff is not applied to domestic consumers, but already in operation to other category of consumers). The above financial analysis and sensitivity test shows that financial low return is an issue, and it can be improved to FIRR 6.2% by increasing peak-time tariff by average 20% (from 1.25 to 1.50). But the expected financial improvement is not high enough. As it is difficult to reduce costs in investment and operations, the only option to improve financial return is to increase plant utilization rate or to raise peak-time tariff, but these options do not have much room to implement. Therefore, to compensate financial low profit, it is recommended to mobilize highly concessional loan such as JICA ODA loan.

12.1.6 Adjustable Speed Pumped Storage System

(1) Merits of Adjustable Speed Pumped Storage System

Conventional synchronous system can be operated only at a constant rotating speed determined by their pole number and the system frequency; however, Adjustable speed pumped system can be operated at arbitrary rotating speeds within a certain extent. Furthermore, Adjustable speed pumped storage system does not need a starting system for pumping mode because rotors can be started with AC exciting, which is equivalent to the thyristor starting method.

Adjustable speed pumped storage system is possible to change the rotation speed continuously; therefore it has some merits as follows:

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[1] It consists of US cents 27.05/kWh auto diesel fuel, and capital cost of US cents 7.03/kWh. Capital cost is calculated by using F12 figure of Table 11.1.3-1 (598.30

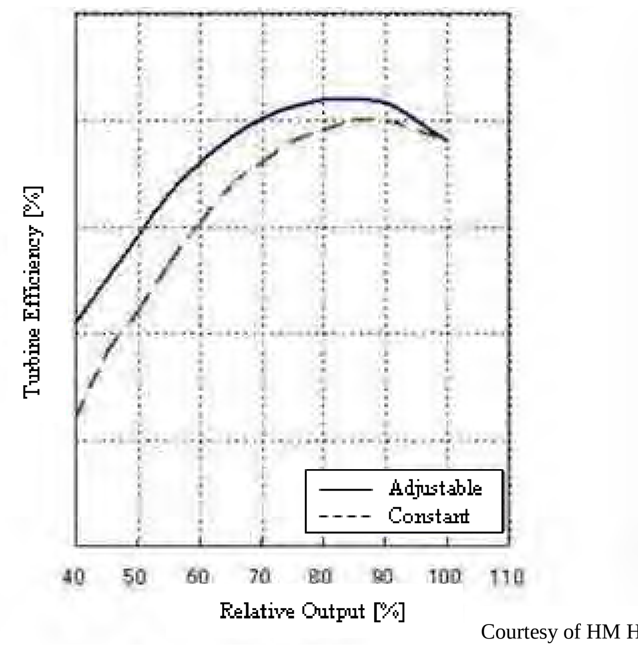
[2] Section 17 Special conditions of transmission licensees; Without prejudice to generality of section 15, a transmission license issued to a licensee shall include conditions – (b) requiring the licensee to forecast future demand, to plan the development of the licensee's transmission system and to procure the development of new generation plant to meet reasonable forecast demand , Sri Lanka Electricity Act, No. 20 of 2009

1) Contribution to the regulating of grid frequency

Since the pumping input is proportional to the cube of rotation speed, in case of Adjustable speed pumped storage system, the pumping input becomes adjustable within a certain extent by changing the rotation speed. It contributes to regulate the grid frequency by adjusting pumping input even during pumping operation mode. Also, impacts on the grid at the staring of pumping operation can be mitigated by putting it into the grid at the minimum input.

2) Improvement of Turbine efficiency at generating mode

Adjustable speed system is possible to be operated at the most efficient rotation speed under to conditions of heads and discharges varying momentarily. Therefore, the turbine efficiency becomes a few percent higher compared to that of the constant speed machine. Figure 12.1.6-1 shows an example of difference of efficiencies between an adjustable speed turbine and a constant speed turbine. In this example, the efficiency of the adjustable speed turbine is approximately 3% higher than that of the constant speed turbine in partial operation.



Courtesy of HM HYDRO

Figure 12.1.6-1 Pump-turbine Efficiency Characteristics

3) Expansion of Operation Range

As explained in (2), the pump-turbine efficiency of Adjustable speed system is a few percent higher compared to a constant speed system; therefore, it is possible to lower the minimum power output level. Generally, the minimum output of Constant speed machine is around 50% of the rated output, meanwhile, that of Adjustable Speed System is possible to lower to around 40% of the rated output. It means that adjustable range of the grid frequency controlling is expanded. In addition, the range of head for operation is also expanded. That is, the wider ranges of water level deference of the upper reservoir and the lower reservoir are allowed than Constant speeds system. It is possible to have a longer operation time compared to Constant speed pumped storage system.

4) Improvement of Power System Stability

Internal phase of generator motor is controlled more precisely, so that it contributes to the static stability of synchronous generators on the grid. Enhancement of the dynamic (transient) stability can be expected because fluctuations of the grid is stabilized by the quick adjustment function with the exciter system.

(2) Demerits of Adjustable Speed Pumped Storage System

On the other hand, some demerits are pointed out as follows:

1) High Cost of the System

Adjustable speed system needs the wire-wounded rotor and the secondary exciting system, which is one of causes of higher costs than that of the conventional system. Furthermore, the powerhouse cavern is likely to be larger than that of the conventional system because the size of main machines becomes larger a little and some auxiliary equipment is required which is not needed for the conventional system.

2) Installation Space of System

The rotor of adjustable generator-motor is excited using three phase alternative- current, therefore it is necessary to have three phase collector ring. The collector ring for the adjustable speed machine is far bigger than that of the conventional type and the cooling equipment is generally provided for the exclusive use. From these conditions, height of the generator is higher than the conventional machine. In this regard, since the maximum height of the main hook of the overhead traveling crane is to be designed taking into consideration of the taller generator-motor. Also, more wider space for the secondary exciting system is necessary.

12.1.7 Conclusions of Studied Subjects

(1) Electric Power Demand Forecast

Average annual growth rate of power generation over the past 10 years is 4.6 % in Sri Lanka, and power generation of 2013 was recorded 11,962GWh (generating end, except self-generation). Peak demand also increases firmly with the annual growth rate over the past 10 years of 3.6%, though there were negative impacts of the electricity tariff increases.

Three peaks appear in a daily load profile; in the morning / daytime / evening. Maximum demand is recorded in the evening. There are no significant changes of the load profile in the recent years. It seems that considerable years are needed until the daytime peak demand becomes bigger than that of evening peak demand. Therefore, using current load profile for the demand forecast is appropriate if there are not substantial alterations in the national policy.

CEB conducts demand forecast using econometric analysis. Effects of a load factor improvement by the DSM, the energy saving policy, and so on are considered in the forecast; therefore, it seems reasonable to select this analysis model because the coefficient of determination is high.

There is a possibility that the actual demand will not go with the past trend if there is a change of electricity use by a progress of infrastructure development and/or by a change in the industrial structure in the future. Therefore, as a future challenge, it is desired to accumulate the hourly data of power usage of the customers by utilizing smart meters, and to create a user model for each sector based on the collected data, and then to forecast future load profile considering impact of the change of industrial structure and national development plan. In addition to this, establishment of a system, including tallying and legislation for reporting private power generation / self-consumption, is needed for the purpose of optimization study on power supply of the whole country, since there is currently no system to collect information from the private power generation and the self-consumption of large customers.

(2) Selection of Optimal Options

The first screening is conducted being subject to 8 candidate projects of power development and 3 of new policies mentioned in LTGEP 2013-2032 in order to assure reliability and objectivity for the option selection in this study. As a result, 4 power sources are selected; such as the expansion of existing hydropower station, pumped storage power projects, LNG combined cycle thermal power stations, and gas turbine thermal power stations. Subsequently, 2nd screening is conducted from 3 points of view; such as Generation characteristics, Natural & social environmental considerations, and Economic aspects. Moreover, the necessity of combination development options is also studied considering effective peak power supply.

In Chapert 8, 4 of options as the above-mentioned are evaluated from Generation charactrastics; the load folloing capacity, Natural & social environmental considerations, and Economic aspects, and the ranking of options is made as shown in Table 12.1.7-1.

Table 12.1.7-1 Ranking Summary of Options

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

As shown in Table 12.1.7-1, it is obvious that the expansion of existing hydropower stations option and the pumped storage option are to be selected becuase of higher ranks in every evaluation items.

As for the expansion of existing hydropower station option, Victoria hydropower expansion project is expected to be developed in the near future becuase the feasibility study and the environmental study has been already completed under JICA's asistance . In this regard, this study is aming at projects selection to be developed after 2025 when the peak demand cannot be sustained even if Victoria expansion project is completed. Accordingly, Stage 2 and Stage 3 in this sudy, the master plan study for the pumped storage is done to deal with expanding peak demand after 2025 because those have not ever been studied in detail in spite of their high development potential.

As for the renewable energy and LNG CC, the conbination development with the pumped storage is studied.

According to "National Energy Policy" and "Mahinda Chinthana 10 year development framework", it is aimed that 10 percents of tatal electricity is to be supplied by the renewable energy. Moreover, Sri Lankan govrnment is expecting that reliable and stable electricity can be supplied through the development of renewable enegy and Sustainable Energy Authority (SEA) was established in October, 2007. However, following problems would arise along with expanding renewable energy sources.

- Fluctuation of the power system voltage
- Difficulty for keeping power system frequency stability
- Excess electricity

As countermeasures for the above-mentioned problems, installation of backup power stations having a good load following capacity; such as the pumped storage and LNG CC, and/or installation of batteries is expected; although it has still rooms for improvements on its technologies and economy. As for LNG CC, it is not likely to be an economic combination because its operation has to be limited if the renewable energy is prioritized; therefore, the combination with the pumped storage power projects could be the best option.

In the future, it is expected that the combination of the pumped storage and the LNG CC would be economic power sources; although a timing of LNG CC installation has not been cleared yet.

Until LNG CC is developed, hydro-powers and IPP thermals are expected to correspond to the meddle demand; however, CEB has a policy to make IPP thermals retired step by step so as to reduce generation costs in the future. Because costs of those, particularly in case of small scale ones, is tend to be unreasonable and unstable due to rather poor efficiency performance and fluctuation of fuel costs, which is weighing on CEB's financial condition.

Accordingly, from the view of the best mix of power sources in Sri Lanka, it is recommendable that the pumped storage takes the peak demand and LNG CC takes the middle demand.

(3) Selection of the Most Promising Site

As mentioned in Chapter 9, pumped storage schemes of total 11 candidate sites were planned and technical evaluation, economic evaluation and environmental evaluation from social aspects as well as from natural aspect were made. Consequently, 3 sites; Halgran 3, Maha 2, and Loggal, were selected as the promising sites in the second Stakeholders meeting held in June, 2013. As for Maha 2, alternative upper dam site was found and it was newly added to the promising site as Maha 3 scheme.

After the promising site selection, detailed natural and social environmental survey, 1/5,000 topographic survey and the geological reconnaissance from ground surface. More detailed evaluation from technical aspects including geological reconnaissance results, economic aspects and environmental aspects were conducted and the most promising site; Maha 3, was selected in the third stakeholders meeting held in May, 2014.

Table 12.1.7-2 shows the result of scoring and ranking carried out in the Chapter 10. Maha 3 was selected out of four promising sites evaluating from the following four main criteria: 1. Technical aspects; 2. Economic aspects; 3. Natural environmental aspects; and 4. Social environmental aspects. In the Table 12.1.7-2, the rows of “Even” show the score by “Even case” (1. Technical evaluation + 2. Construction Costs) : (3. Natural environment + 4. Social environment) = 50 : 50. The rows of “Env.” show the score by environment weighed case; (1. Technical evaluation + 2. Construction Costs) : (3. Natural environment + 4. Social environment) = 30 : 70. Maha 3 obtained the rank 2 by 1. Technical Evaluation, the rank 1 by 2. Economic Evaluation, the rank 1 by Natural Environment, and the rank 4 by Social Environment; consequently, it obtained the total rank 1 in both cases.

Table 12.1.7-2 Result of Scoring and Ranking

	Halgran 3		Maha 2		Maha 3		Loggal	
	Even	Env.	Even	Env.	Even	Env.	Even	Env.
1. Technical Evaluation	15.50	9.30	22.00	13.20	21.75	13.05	12.50	7.50
2. Economic Evaluation	18.75	11.25	18.75	11.25	25	15	6.25	3.75
3. Natural Environment	7.25	10.15	9.68	13.552	10.75	15.05	7.2	10.08
4. Social Environment	17.5	24.5	10.35	14.49	13.75	19.25	9.4	13.16
Total	59.00	55.2	60.78	52.492	71.25	62.35	35.35	34.49
Rank	3	2	2	3	1	1	4	4

(Source: Study Team)

(4) Environmental Considerations

In this section, the conclusions of the Strategic Environmental Assessment (SEA) and the Environmental Considerations (considerations on natural and social environments) are described. The conclusions of the selections of power generation options for the peak power demand and of the selection of the most suitable site for pumped storage power plant development are respectively referred to the subchapter 12.1.7-(3) and 12.1.2.

1) SEA (Strategic Environmental Assessment)

SEA is one of the most suitable environmental assessments at a master plan study stage. It was conducted in the Study at the following two stages; a) selecting power generation options for peak power demand, and b) selecting suitable sites for pumped storage power plant development. At each stage, a comparison study was conducted to select the most suitable one from realistic options (power generation options or plant development sites). The studies utilized technical, economic, and environmental (natural and social) criteria to compare the options.

Information of the SEA were disclosed. In the Study, three (3) Stakeholders Meetings (SHMs) were held inviting related central and local governmental organizations, NGOs and experts. At each SHM, discussions were held, the conclusions were agreed, and the comments from the participants were reflected into the plan as much as possible.

PI (Draft), Draft Scoping Table, and TOR of EIA (Draft) are attached as Appendix 12.2, Appendix 12.3, and Appendix 12.4 respectively.

2) Environmental considerations on the selection of power generation options for the peak power demand

A general and qualitative evaluation on the four (4) power generation options was conducted from 10 points of environmental considerations. The four options are hydro power extension, pumped storage PP, LNG CC PP and Gas turbine thermal PP.

In conclusion, the hydro power extension has the least impacts, and other three options are similar from the point of the environmental considerations.

3) Environmental considerations on the selection of sites for pumped storage power plant development

Pumped storage PP was selected as the power generation option. Two screenings were conducted to select the most suitable site for a precise analysis. At the first screening, 11 candidate sites were examined, and at the second, four (4) sites were examined to select the most suitable site. All examinations were conducted under technical, economic and environmental & social criteria.

The conclusions from environmental considerations are as follows.

- First screening

After site surveys were conducted at 11 sites, five (5) sites were excluded from detailed evaluation because they were technically unfeasible or upper and/or lower ponds were located in Sanctuaries (protected area). The conclusions of the six (6) sites are described as follows.

Regarding the natural environment, impacts especially on endangered species[3] are expected but there are no significant differences among the sites. The important point is all sites do not fall

[3] For their details, refer to "The National Red List 2012 of Sri Lanka – Conservation Status of the Fauna and Flora (Ministry of Environment, Sri Lanka, 2012)".

into any important areas for the conservation of biological diversity such as protected areas (e.g. national park) designated by the Department of Wildlife Conservation, Forest Department and Central Environment Authority, Biosphere Reserves, World Heritage sites and IBAs. Impacts on the Ramsar sites are not expected. Regarding the social environment, impacts are expected at all sites. Maha 1 (many resettlements are expected) and Loggal (a temple needs relocation) are worse than other sites.

- Second screening

Site surveys were conducted at the selected three (3) sits and newly added Maha 3. Maha 3 does not fall into any important areas for the conservation of biological diversity such as protected areas.

Regarding the natural environment, endangered species are recorded and impacts on them are expected. Regarding the social environments, site surveys were suspended because of protest by the local people at Loggal and Maha 2 sites. Some evaluation cannot be conducted, and the examination of the two sites is less sufficient than others. At Halgran and Maha 3, all survey items were surveyed. Impacts are expected but there are not significant differences between the two sites.

Transmission line routes from the four (4) sites were examined. Regarding the natural environment, they do not go through any important areas for the conservation of biological diversity (e.g. national parks and IBAs) and are not on the migration routes of birds. Regarding the social environment, it is possible to avoid populated areas and there are not big social infrastructures on the routes. It is therefore considered that impacts are not significant and/or limited to a small scale.

(5) Stakeholders Meetings

In this study, total 3 times of the stakeholders' meetings were held at milestones of the study to confirm their opinions and inclinations. Main agenda of every meeting are shown as follows;

1) The First Stakeholders Meeting (on June 27th, 2013, at Hilton Hotel in Colombo)

- Selection of the optimal power generation for peak power demand and of the justification of Pumped storage power plants.
- Confirmation of candidate sites of pumped storage power projects, Strategic environmental assessment (Phase 1), and its scope.

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 and the Study Team agreed to reflect their advices to the next survey plan. Before the first stakeholders' meeting, relevant divisional secretariats were visited and the agenda as the above-mentioned were explained to them.

2) The second Stakeholders' Meeting (on November 22nd, 2013, at Galadari Hotel in Colombo)

- Selection of 3 promising candidate sites out of 11 candidate sites including explanation of project selection process.
- Confirmation of the selection process of the most promising site out of selected 3 promising sites

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 second stakeholders' meeting, the relevant local government officers were visited and the agenda of the meeting were explained. 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.

3) The third stakeholders' meeting (May 27th, 2014, at Galadari Hotel in Colombo)

- Selection of the most promising candidate sites out of 3 promising candidate sites including explanation of project selection process.

Confirmation of the outlines of the most promising site

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.

(6) Seminar and Training

1) Seminar

The seminar of the theme "Characteristic Features required to Peak Load Power Stations & Basic Technologies of Pumped Storage Power Station" was held to the government officers of the concerned authorities.

Date : April 9, 2013 PM15:00 to PM18:30
Place : Galadari Hotel (Colombo)
Participants : total 45 participants (from MOPE, CEA, ERD, SEA, MASL, CEB)

In the seminar, following contents were explained; such as the present situation of peak load in Sri Lanka, technology of the pumped storage system, the method of the strategic environmental assessment to be conducted in this study, etc. And discussions included the necessity of pumped storage systems for the Sri Lankan power grid, the possibility of the existing power stations for the peak power supply, the possibility of contributions of the pumped storage systems for expanding renewable energy development, etc.

2) C/P Training

The counterparts training was conducted in Japan, which took 16 days from August 26 to September 5, 2013. Total number of the participants were 10 officers including AGM (region 1) of CEB, and selected officers from the section charged with power development planning and the existing hydropower power stations. The training program consists of lectures and sites/factories visiting. The lectures themes included “the characteristics, the design, and O&M of pumped storage power plants” as well as “the direct-current transmission system” which was particularly requested by the participants from Sri Lankan side. As for the sites and factories visiting, two of the existing pumped storage plants, and the coal-fired thermal power station having environmental friendly facilities with high specifications.

12.2 Recommendations

In case the electric power development mainly of coal thermal power plants, which have no advantage in load following capability, would be executed in accordance with the LTGEP 2013-2032, the following troubles might occur in the Sri Lankan power supply system.

- Trouble in stable power supply such as power outage during peak demand time
- High cost operation of gas turbine and diesel generation using oil for peak power demand

In order to avoid the troubles, it is necessary to line up a dedicated power source at a fair rate for peak demand, and the pumped storage power plant is selected as the optimal power generation for peak power demand in this report (refer to Chapter 8). Consequently, recommendations for project implementation plan and next stage studies toward realization of the project are made in the following clauses.

Meanwhile, the existing hydropower plants are one of available generation option for peak power demand. However, they are affected by meteorological condition, that is wet or dry season, and they can also operate for middle power demand. When the demand is shifting from middle to peak in the evening, only their remaining capacity can be utilize for generation for peak power demand.

In addition, introduction of thermal power generation using LNG and natural gas is considered as an important option for future power demand in Sri Lanka. Since this option is widely-accepted as generation for middle power demand, the development policy of LNG and natural gas should be determined at an early date. In this sense, the national guideline for long term generation expansion plan should be revised as the solution that would resolve the future problems in each base, middle and peak power demand with the best mix of power generation options in mind.

12.2.1 Project Implementation Plan

It is assumed that the demand and supply of Sri Lankan electricity would be kept in a tight situation. Thus, installation of an appropriate peak power source; such as a new pumped storage power project is desired by around 2025; therefore, Maha 3 scheme is planned and selected as the most promising site in this study. In order to implement the project on time, it is recommended to proceed with the implementation schedule as follows;

1) Feasibility Study : from 3rd Quarter in 2015 to 2nd Quarter in 2017 (2 years)
2) Environmental Assessment : from 2nd Quarter in 2016 to 2nd Quarter in 2017 (1.25 years)
3) Environmental Clearance : from 3rd Quarter in 2017 to 4th Quarter in 2017 (6 months)
4) Arrangement of Yen Loan : from 1st Quarter in 2018 to 2nd Quarter in 2018 (6months)
5) Procurement of Consultants : 3rd Quarter in 2018 to 4th Quarter in 2018 年(6 months)
6) Detailed Design : 4th Quarter in 2019 to 4th Quarter in 2020 (2 years)
7) Construction : 1st Quarter in 2021 to 4th Quarter in 2025 (5 years)
8) Commissioning : 3rd Quarter in 2025 to 4th Quarter in 2025

Figure 12.2.1-1 shows the draft overall implementation schedule for development of PSPP in Sri Lanka.

I1) Feasibility study, the construction planning including deployment of temporary facilities, which may has impacts on the environment in the site, is to be studied by the commencement of EIA to reflect it into the environment assessment. Also, the topographical survey and the geological investigation are to be executed in the earlier stage for basic design in the later stage; therefore, total 2 years are estimated as the study period. In addition, the period for supporting environment clearance is added according to CEB’s request.

Total duration of the detailed design is estimated as 2 years, so that the detailed technical study is to be conducted in the earlier stage, and tendering including tender document preparation is to be conducted in later stage.

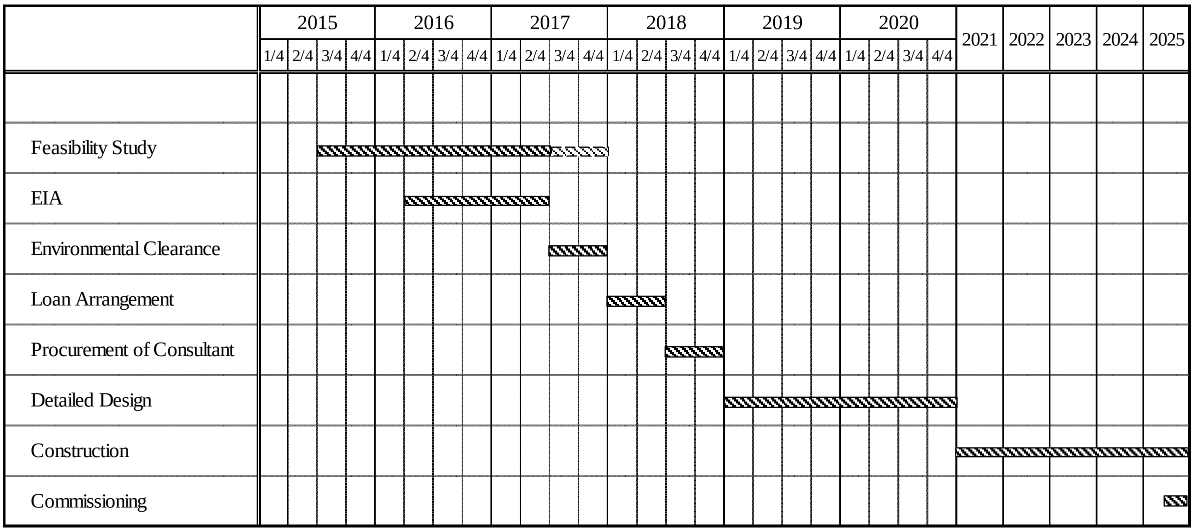


Figure 12.2.1-1 Draft Overall Implementation Schedule of Development of PSPP in Sri Lanka

12.2.2 Recommendation for the Next Stage Study

(1) Topography and geology survey

1) Topography survey

The 1:5,000 (5m inter contour) scale and 1:1,000 (1m inter contour) scale survey were made for the Maha 3 upper and lower reservoir. (re fer to 10.2.2 and 12.1.3)

The studies at the next stage require site surveys of construction material candidate sites, temporary construction sites, or temporary access roads, also the surveys along the whole water route.

The mapping surveys incorporating those required areas at 1:1,000 to 1:5,000 must be done accordingly.

2) Geology survey

The numbers of drillings at this study were limited (3 holes at upper dam site, 3 holes at lower dam site). The left dam abutment where the certain thicknesses of the talus with possible mass movement was not considered the best suitable locations, but the details information was not known for the whole reservoir areas.

When available, the left bank at upper streams and lower streams of the present dam axis shall be investigated for their subsurface conditions. At minimum 1 hole each at upper and lower area are recommended so as to clarify the distributions of the possible talus deposits, potential faults with probable fractures, the rise of the ground water tables on the left abutment, and the rock basement features. The areas of investigations may range 250m to upstream and 300m to downstream as there are anticipated solid rock basement in shallow depths with some steep ridges on the left bank heading towards river bed.

(The site in 250m upstream may be inferior to that of 300m downstream from the comparison of the right ridges shape)

Also, drilling surveys at intake, outlet, water route, seismic surveys along whole water route, drilling surveys at the power house, construction material surveys are required in due course.

(2) Environmental Considerations Study

1) EIA Process for the F/S

The EIA process follows the National Environmental (Amendment) Act No. 56 of 1988. A project proponent submits the Preliminary Information (PI) to CEA for screening. If the project needs an EIA, the Project Approving Agency (PAA) of the project invites relevant organizations to hold the Scoping Committee for the scoping of the project. At the Committee, the project proponent is required to present an outline of the project. Based on the presentation and discussions at the Committee, a Terms of Reference (TOR) of the EIA is formulated and issued to the project proponent. The Project is required to conduct an EIA because of the screening criteria of the Act.

The outline of the Project needs to be presented and explained at the Scoping Committee. A pumped storage power plant development has never been planned and realized in Sri Lanka, and it is advisable for CEB to present the outline of the Project with the support from the JICA Study Team when the outline of the Project is formulated.

Contents of the TOR from the Committee are general. If comments from JICA need to be incorporated in the EIA study, it is suggested to hold a meeting with the PAA and then the contents should be changed. For the Project, it is likely that CEA is the PAA. According to the Act, it takes 30 days to issue a TOR, but it might take two to three months. In conclusion, it could take six to nine months to start the EIA study of the Project after starting the F/S.

The Project site includes dam, reservoir, power plant, dumping site, quarry, switch yard, access road and transmission line.

In Sri Lanka, project alternatives are usually discussed and examined in its EIA study. But the alternatives of the Project have already been examined in its master plan stage. It is therefore sufficient to briefly describe the conclusion of the examination of the alternatives in the EIA report. It is not necessary to discuss and examine the alternatives at the F/S stage.

The PI (draft), scoping (draft) and TOR (draft) for the EIA are attached as appendices.

2) Natural environment

The Project does not give direct impacts to protected areas, and impacts to the natural environment are expected to be less than a project with big dam / reservoir because of the small scale of the Project site, and there are no Ramsar sites in its downstream. Impacts to the natural environment in the downstream area are expected to be small.

It is, however, unavoidable for the endangered species[4] recorded in the site to receive impacts of which scale are yet unclear. According to the Asian Development Bank[5], an important criterion is whether a development site is a "critical habitat" for an endangered species or not. But it is not known whether the Project site is critical habitats for the recorded endangered species. In addition, there is a possibility that there are more endangered species in the Project site. This is because the survey period is short in its master plan study.

At the F/S of the Project, it is recommended: a) to study the endangered species of the site for at least one year; and, b) to formulate a conservation plan to avoid, mitigate and compensate the impacts to the natural environment (especially the endangered species) based on the results of the study.

It is important to involve the Sri Lankan experts to discuss the conservation plan and to receive constructive suggestions in collaboration with the JICA Study Team, which leads the sustainability of the conservation activities at the site.

3) Social environment

The biggest impact to the social environment is expected to be induced by an involuntary resettlement. The Project formulates a resettlement action plan based on the Sri Lankan National Involuntary Resettlement Policy to mitigate the impacts as much as possible. There are, however, gaps between the Policy and the JICA Guidelines (2010). The Project fulfills the gaps based on the Guidelines. The following points are particularly considered: (a) that the compensation scheme is based replacement costs; that there is a mechanism to compensate persons who do not have the right for the land; that persons who lose livelihoods by the Project receive the compensation; and that there is a grievance redress mechanism. If they are not functional, it is necessary to identify measures to deal with these points.

The more detailed social study is conducted in and around the Project site for an adequate and sufficient resettlement action plan. The Project also studies other cases in Sri Lanka to try to formulate the plan which fits in the current conditions in the country.

4) SHM

In Sri Lanka, comments from the public are collected after the formulation of an EIA report but SHMs at and around the site are not required. In particular, there is not an opportunity to collect comments from local affected persons before project starts. The Project applies the JICA Guidelines (2010) and holds two SHMs at the site – one at the scoping stage, and the other at the

[4] For their details, refer to "The National Red List 2012 of Sri Lanka – Conservation Status of the Fauna and Flora (Ministry of Environment, Sri Lanka, 2012)".

[5] Safeguard Policy Statement（Asian Development Bank, 2009）

stage of the EIA report (draft). The main objectives of the SHMs are to collect comments from affected persons, local governmental organizations and NGOs and to reflect their comments to the Project as much as possible. At the SHMs, it is important to well explain the Project to the local people to relieve their concerns such as a fear of lack of water in the downstream because of dam construction.

(3) Civil Works

The construction cost in this study was calculated with the method prescribed in Guideline and Manual for Hydropower Development (JICA, 2011) (hereafter the guideline manual), which is prepared for a preliminary study stage as mentioned in the subchapter 9.4.4; therefore, it should be studied more detail in the next stage.

Especially, the cost of dam construction occupies the large part in the civil works, so that economically advantageous dam type was selected comparing a cost of concrete gravity type and that of a rock-fill type. The unit price of concrete was available in Sri Lankan similar projects in recent years; however, the unit price of a rock-fill type was derived from those in Indian similar projects due to non-availability in recent Sri Lankan projects. At the next stage, it is a requisite that advantageous dam type; especially the unit price of a concrete type and that of a rock-fill type, should be studied in more detail. Availability of embankment material in the vicinity of the site will be essential for suitable dam type selection.

As for the waterway and the powerhouse cavern layout, the setting elevation of pump-turbine was determined considering a suction head shown the guideline manual which tends to give more affordable one. The elevation of a pump-turbine affects much the waterway layout, so that suction head and total layout of the waterway should be reviewed more detailed in the next stage. In this regard, if a required suction head is reduced, the setting elevation of pump-turbine; the powerhouse cavern, can be set at more higher; accordingly it affects total construction period because the length of access tunnel to the powerhouse become shorter, which is on the critical path of the overall construction schedule.

(4) Electrical Equipment

According to Long Term Generation Expansion Plan 2013-2032 (LTGEP 2013-2032), the percentage of the installed capacity of coal fired power plants, which cannot change their own output frequently; accordingly those are mainly used for the base load, will increase and reach around 46% of the total power plants capacity in 2025. Under such situation, it possibly occurs that the frequency control of the grid would be tougher that under the present situation.

As mentioned in 12.1.6, the adjustable speed system can bring a lot of benefits on the enhancement of the power system quality with more effective frequency control and voltage control, as well as on reducing the risks which may be caused by unexpected incidents.

Even though the cost of the adjustable speed system will be higher than that of the conventional system, it is recommended to study more definitely on application of the adjustable speed system for the project.

(5) Transmission Line

Two-circuit PI connection to Kotmale - Kirindiwela T/L is selected as the connecting transmission lines from Maha site to the power grid. Following i) to iii) will be required to consider in the next stage.

i) Transmission Line Route

Detailed transmission line routes are not decided in this study. Any topographical difficulties and serious environmental issues have not been found on the recommended route from “Maha site” to “Kotmale - Kirindiwela T/L” so far. However, in the next stage, it will be required to consider detailed conditions (such as, topographical conditions, types of land-uses, and locations of houses and other buildings, etc.) under transmission line route area.

ii) Connecting Points to “Kotmale - Kirindiwela T/L”

Specific connecting points are not considered in this study. In the next stage, it will be required to consider conditions of existing transmission line towers, such as locations of tension-type towers, allowable horizontal angles of towers, and design loads of towers, etc. It is also to be considered that whether or not, it can be used existing transmission line towers without any reinforcements.

iii) Construction Works

Outages of Kotmale - Kirindiwela T/L will be required for connecting works of transmission lines from “Maha” site. In the next stage, it will be required to consider planning for construction works of T/L, in consideration with required time periods for outage works, and possible outage periods of Kotmale - Kirindiwela T/L.

(6) Construction Planning

In this study, the detailed construction planning was not studied. In the next stage, it is necessary to study on the layout, scale and development of the temporary facilities, as well as to study the detailed construction plan. In this regards, those studies should be conducted in the early timing in the next study and the results should be reflected to the environmental survey in the next stage. Following temporary facilities should be included in the construction planning;

1) Temporary yards for construction activities (including stock yards for construction materials)
2) Quarries and borrow area

3) Yards for concrete plants
4) Access roads
5) Penstock assembly yards
6) Disposal areas
7) Office yards for project owners and contractors

(7) Development Scale

In this study, 600 MW of the installed capacity and 6 hours of the equivalent peaking duration were set in every pumped storage scheme planning case. As for the installed capacity, it was determined considering required peak demand at the timing of the first pumped storage project installation in Sri Lanka. On the other hand, as for the equivalent peaking duration, it was determined to be flexible to possible changes of load patterns in the future in spite of assumed peaking time of around 3 hours in 2025. Also, it was considered that, in general, from 6 to 8 hours are set as an equivalent peaking duration at planning stage of pumped storage schemes.

Figure 12.2.2-1 shows a relationship among equivalent peaking duration, construction costs, and EIRR of Maha 3 of 3 units of 200 MW. It is understood that higher EIRR is obtained by larger benefits produced by longer peaking duration, even though it needs high-cost due to larger capacities of the upper dam and lower dam to sustain longer peaking duration. However, seeking too long peaking duration may bring over-investing for the first pumped storage project, if it does not match with demands in the future.

In the next stage, it is recommended that more detailed study should be done for the optimization of development scale, (i.e.: installed capacity and equivalent peaking duration).

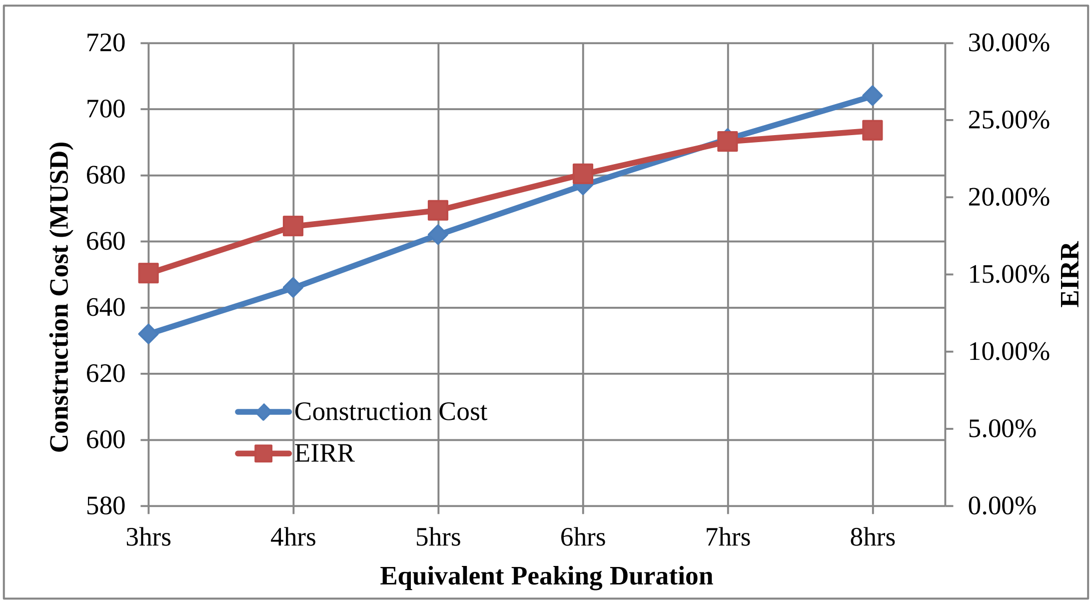


Figure 12.2.2-1 Relationship among Equivalent Peaking Duration, Construction Costs, and EIRR

Appendix

Appendix List

No.	Title
A 6.1	List of IBAs in Sri Lanka
A 7.1	Participant List of SHM-1
A 7.2	Participant List of SHM-2
A 7.3	Participant List of SHM-3
A 7.4	Presentation Material for SHM-1
A 7.5	Presentation Material for SHM-2
A 7.6	Presentation Material for SHM-3-Session I
A 7.8	Presentation Material for SHM-3-Session II to IV
A 8.1	Trial Calculation of Contribution to Greenhouse Gas Reduction by Pumped Storage Power Project
A 9.1	Flow Gauge Stations in Sri Lanka
A 9.2	Rain Gauge Stations Functioning
A 9.3	Peak Flow Data
A 9.4	Evaporation and Wind Speed Data
A 9.5	Kiriketi 1, Kiriketi 2 Plan
A 9.6	Mausakelle A, Mausakelle B Plan
A 9.7	Hargran 1, Hargran 2 Plan
A 9.8	Hargran 3, Hargran 4 Plan
A 9.9	Maha 1, Maha 2, Maha 3 Plan
A 9.10	Loggal Plan
A 12.1	Geology evaluation of the most promising site Maha 3
A 12.2	Basic Information Questionnaire (PI Draft)
A 12.3	Draft Scoping Table of the Proposed Pumped Storage Power Plant Development at Maha area
A 12.4	Terms of Reference Environmental Impact Assessment Study (TENTATIVE AND DRAFT ONLY)
A 12.5	Drawings of the most promising site (Maha 3)

Appendix 6.1: List of IBAs in Sri Lanka

No.	Name	No.	Name
1	Jafna Lagoon	36	Kithulgala
2	Araly South-Punalai	37	Gilimale-Eratna
3	Kayts Island-Mandathive	38	Bambarabotuwa
4	Amaipaddukkai	39	Dotalugala/Rassagala
5	Periyakalapuwa mouth	40	Delmella
6	Giants Tank	41	Ayagama
7	Usgala Siyambalanduwa	42	Karawita
8	Seguwantive mudflats	43	Waratalgoda
9	Periyakadawela	44	Udawalawa
10	Mundel Lake	45	Delgoda/Kudumiriya/Kobahadukanda
11	Anaiwilundawa complex	46	Delwela/Panilkanda/Walankanda
12	Neugalkanda	47	Sinharaja
13	Padaviya	48	Rammalkanda
14	Anuradhapura	49	Namunukula
15	Minneriya/Girithale/Kaudulla	50	Tangamalai
16	Kumbuk Wewa	51	Haputale
17	Polonnaruwa	52	Muturajawela
18	Wasgomuwa	53	Bellanwila-Attidiya
19	Pimburettewa Tank	54	Labugama
20	Kantale Tank	55	Bodhinagala
21	Rugam Tank	56	Morapitiya-Runakanda
22	Madura Oya	57	Kalugala
23	Ampara	58	Yagirala
24	Senanayake Samudraya/Nilgala	59	Beraliya-Kudagala
25	Sigiriya	60	Haycock/Habarakada
26	Knuckles	61	Malambure
27	Udawattakele	62	Kombala-Kottawa
28	Kandapola-Seethaeliya/Pedro	63	Beraliya-Akurassa
29	Nuwara Eliya	64	Nakiyadeniya/Kanneliya/Dediyagala
30	Hakgala/Meepilimana	65	Dellawa/Diyadawa
31	Dikoya	66	Welihena
32	Agrapatana-Bopaththalawa	67	Mulatiyana
33	Horton plains / Ohiya / Pattipola-Ambewela	68	Bundala complex
34	Peak Wilderness	69	Wirawila
35	Amanawala	70	Yala

Appendix 7.1 Participant List of SHM-1

(omitted due to confidentiality of personal information)

Appendix 7.2 Participant List of SHM-2

(omitted due to confidentiality of personal information)

Appendix 7.3 Participant List of SHM-3

(omitted due to confidentiality of personal information)

Development Planning on Optimal Power Generation for Peak Power Demand

(1st Stakeholders Meeting)

June 27, 2013

CEYLON ELECTRICITY BOARD Enrich Life through Power

1

Contents

2

1. Introduction

- Purpose of the Study
  - ・to make Development Planning on optimal power generation for Peak Power Demand
- Purpose of Stakeholders Meeting
  - ・to reflect stakeholders comments to the Planning through dialogues
- Stakeholders Meetings (SHMs)
  - ・1st SHM (June 27, 2013): Proposal of Optimal Power Generation for Peak Power Demand
  - ・2nd SHM (November 2013)
  - ・3rd SHM (April 2014)

3

2. Purposes of the 1st Stakeholders Meeting

Purposes of Discussion in the 1st Stakeholder Meeting

§ I Power Generation for Peak Power Demand

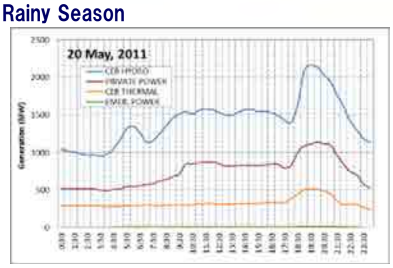
§ II Optimization Process of Planning of Pumped Storage Power Plant

§ III Scoping of Strategic Environmental Assessment (SEA) for Development of Pumped Storage Power Plant

4

3. Present Daily Load Curve

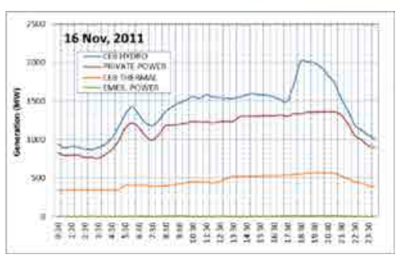
3.1 Rainy Season



During the peak power demand period, CEB Hydro, CEB Thermal and Private Power Producers supply power.

5

3.2 Dry Season



During the peak power demand period, CEB Hydro supplies power. CEB Thermal & Private Power Producer are almost at their full capacities.

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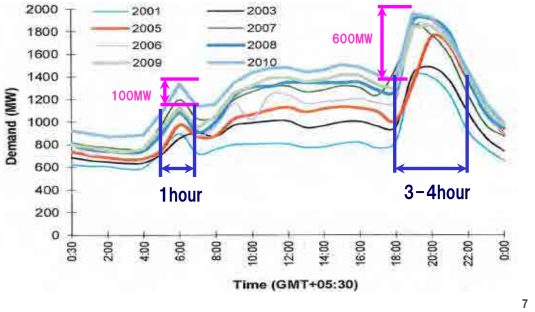
4. Demand Forecast

4.1 Peak Load – Present situation



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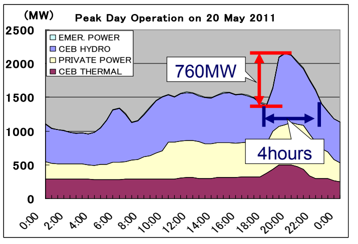
4.2 Peak Load on 20 May 2011

- Peak load was 760 MW. The peak period was around 4 hours.
- Peak load rapidly increased to 760MW within 1 and half hours.
- The minimum load was 959MW at 3:30. It is 44% of the peak demand (2,163MW).



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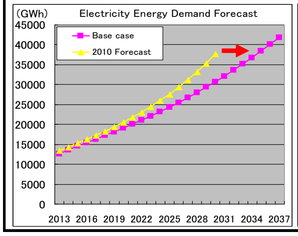
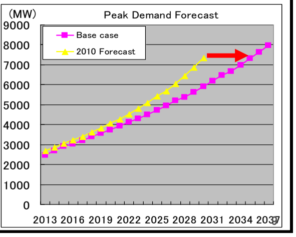
4.3 Demand Forecast of LTGEP2013-32

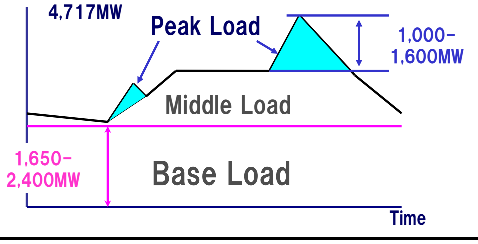
- The energy demand forecast shows 4-5 years' delay from the 2010 forecast. The peak demand in 2025 is 4,717MW. It is 700MW lower than the last one.
- Load Factor is 58.8%, which is almost as same as the 2010.





4.4 Demand Forecast in 2025

- Generation energy is assumed at 24,284 GWh.
- Peak demand is 4,717MW.



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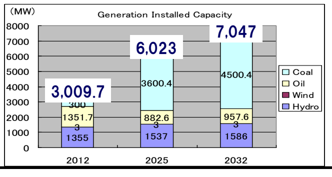
5. Necessity of Peak Power Supply

5.1 LTGEP 2013-2032

- The share of Coal thermal capacity becomes 60% and 64% of Generation Installed Capacity in 2025 and 2032.
- The forecasted load factor is less than 60%.
- Coal thermal plant's minimum output is 75%.
- The existing hydro could supply around 700MW at the peak power demand period in 2011. In 2025, the supply capacity is assumed to be 700MW.



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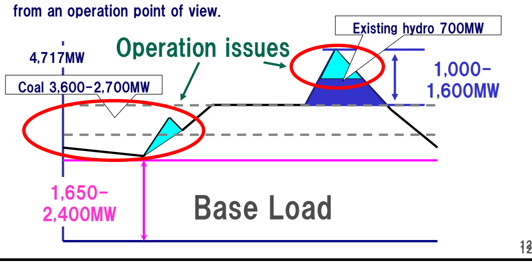
5.2 Operation issues in 2025

- Peak Load would be 1,000-1,600MW (20-35% of peak demand).
- Peaking supply was 760MW in 2011. The existing hydro may supply 700MW in 2025.
- Lack of peaking supply capacity and oversupply from the coal plants are issues from an operation point of view.



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5.3 Countermeasures to the Operation Issue

- Options of Peak Power Generation
  - Hydropower Plant (New Construction)
  - Hydropower Plant (Expansion)
  - Pumped Storage Power Plant
  - Coal-Fired Thermal Power Plant
  - LNG Integrated Gas Combined Cycle Power Plant
  - Gas Turbine Plant
  - Diesel Plant
  - Renewable Energy
- Other options for Peak Power Generation
  - Independent Power Producer
  - Demand Side Management
  - Inter Connection with Indian System

6. Options of Peak Power Generation

6.1 Hydropower Plant (New Construction)

The hydro potential in Sri Lanka has already been developed to a great extent.

Broadlands	35 MW	Committed, Run-of River Type
Uma Oya	120 MW	Committed, Multipurpose
Moragolla	27 MW	Multipurpose
Gin Ganga	49 MW	Run-of River Type
Total	231 MW	(reference: LTGEP 2013-2032)

Multipurpose and Run-of River Types are not suitable for peak power generation.

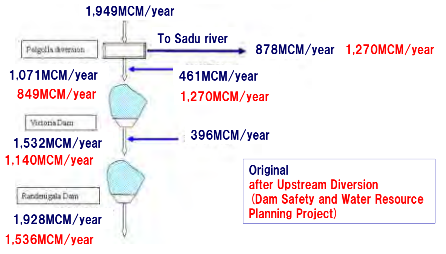
6.2 Hydropower Plant (Expansion)

Smanarawewa	120 MW	for peaking duty, environmental issues
Wimalasurendra	–	upgrading
New Laxapana	–	upgrading
Old Laxapana	–	upgrading
Victoria	228 MW	for peaking duty, irrigation intake issue
Kotmale	–	30m dam raising, 20% energy to be increased
Total	348 MW	

(reference: LTGEP 2013-2032)

These projects are not included in the Base Case Plan (2013-2032).
The irrigation issue of Victoria should be resolved as early as possible.

Expansion of Victoria HPP, Irrigation Diversion



A. Basic

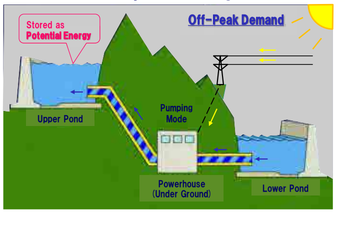
	unit	Existing	After Expansion
Installed Cap.	MW	210	438
Annual Energy	GWh	704.6	715.9
-Firm	GWh	229.8	468.2
-Secondary	GWh	474.9	247.7
95% Dependable	MW	210	393
B. After U/S Diversion of DSWRPP (878 → 1,270MCM/yr)			
Installed Cap.	MW	210	438
Annual Energy	GWh	572	572
-Firm	GWh	227	399
-Secondary	GWh	346	173
95% Dependable	MW	207	352

▲69.2GWh
▲41MW

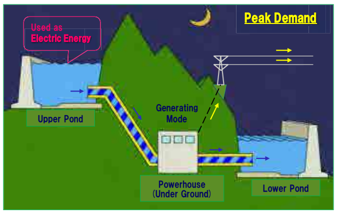
Source: Victoria Expansion Feasibility Study Report in 2009, JICA

6.3 Pumped Storage Power Plant

- What is Pumped Storage Power Plant?



During the off-peak time, electric energy generated mainly by base load power stations is stored in Upper Pond as Potential energy.



During the peak time, power is generated using stored energy in Upper Pond as a peak power station.

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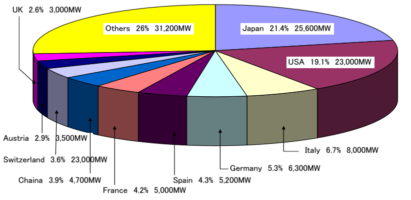
➢ Technical Maturity

1904	Ruppoldingen PSPP in Switzerland; 1st PSPP in the world.
1963	Taum Sauk PSPP in U.S; the first large scale pump-turbine.
-present	Total 86,100 MW in the world. (Total of Euro 26,800 MW excluding UK)



One of the options for Peak Power Generation in combination with Coal Thermal Power Plant and Renewable Energy Power Plant

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6.4 Coal-Fired Thermal Power Plant

Comparatively Low Fuel Cost

Mainly used for Base Load Power Generation

Puttalam	300MW x 3unts	2nd and 3rd units are under construction
Trincomalee	250MW x 4units	Not committed
New Site	300MW x 6units	Expected up to 2025

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6.5 LNG Integrated Gas Combined Cycle Power Plant

Generally used for Middle Peak Load or Base Load

Relatively expensive for utilized for Peak Load

6.6 Gas Turbine Plant

Short Start-up time

Good response to Load Fluctuation

Relatively low Efficiency

Short Life and High Fuel Cost

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6.7 Diesel Plant

No construction since 1999

Not for Peak Load Power Plant from anti-oil policy

Small Scale and High Fuel Cost

6.8 Renewable Energy

Micro Hydropower (Economically feasible potential 400MW)

Wind (Feasible potential 200MW among meteorological potential)

Solar (Substantial potential in dry zone)

Bio (Fuel wood, municipal waste, industrial w., agricultural w.)

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7. Other Options for Peak Power Generation

7.1 IPP

Current Total Capacity: 804.5 MW (small D:371.5MW, CC:433MW)

They are used for Middle Peak Load and Peak Load.

PPA with IPP will not be extended, as a CEB policy.

7.2 Demand Side Management

Introduction of energy-saving equipment, hourly varied tariff

Necessary activity but uncertainty of effect in Peak Demand

7.3 Inter Connection with Indian System

Inter connection makes Sri Lankan System Stable

India has the same daily load curve as Sri Lanka

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1) Study Progress

- The study was initiated in 2006.
- 500MW connection as the first stage would be expanded to 1,000MW.
- MOU was signed between CEB and PGCIL for a feasibility study.

Transmission interconnection could be a countermeasure for Peak Power Supply?
…considering following situation in INDIA

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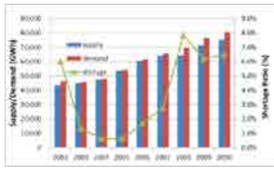
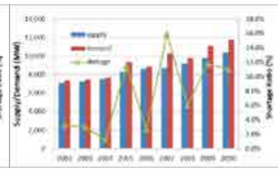
2) Situation in INDIA

- Shortage of the power supply capability has not been improved.
- It is forecasted that the demand keeps growing rapidly (e.g. Peak demand in 2016 will be 1.6 times from 2010).
- Achievement of power development was 51.5% (in 2002-2006).



Balance GWh Basis in Tamil Nadu



Balance MW Basis in Tamil Nadu

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8. Characteristics Required for Peak Power Generation (Screening 1)

➢ Requirements for Peak Power Generation

Options	Power Control Range	Power Variation	Start-up Time	Ability to Adapt
Hydropower	25-100%	50%/min	1-2 min	Very good
PSPP	25-100%	50%/min	1-2 min	Very good
Thermal Power (Oil)	30-100%	3%/min	3-5 hr	Fair
Thermal Power (Coal)	30-100%	1%/min	3-5 hr	Poor
Thermal Power (LNG)	20-100%	3%/min	3-5 hr	Fair
LNG IGCC	20-100%	10%/min	1 hr	Good
Gas Turbine	-	-	15-20 min	Good

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9. Evaluation of Options from Various Angles (Screening 2)

	Hydropower (Expansion)	PSPP	LNG IGCC	Gas Turbine
Construction Period	Good	Fair	Good	Very good
Potential Capacity	Fair-Good	Very good	Very good	Fair
Procurement of Fuel	- (Very good)	-	Fair	Good
Life	Fair	Very good	Good	Fair
External Restriction	Fair	Very Good	Fair	Fair
Economical Efficiency	Very good	Good (to be studied)	Good (to be studied)	Fair

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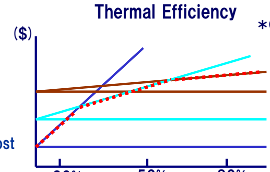
9.1 Economic Characteristics of the generators

➢ Generation unit cost ($/kWh) = Capital cost + Energy cost

$$\text{Capital cost} = \frac{\text{Construction unit cost x CRF}^{*}}{\text{Plant Factor x 8760 (hour)}}$$

$$\text{Energy cost} = \frac{\text{Fuel unit cost (\$/kcal) x 860 (kWh/kcal)}}{\text{Thermal Efficiency}}$$

*CRF: Capital Recovery Factor



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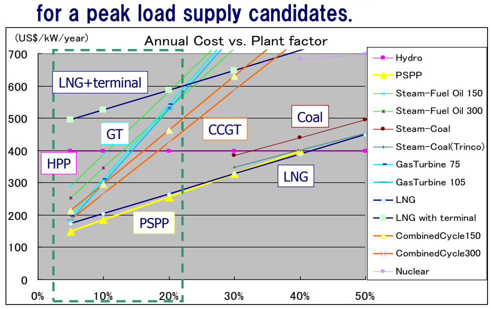
➢ LTGEP 2013-2032

✓ GT, CCGT, LNG and PSPP are the least annual cost for a peak load supply candidates.



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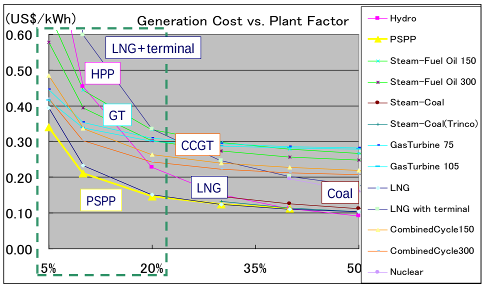
✓ PSPP is one of the most economical generators for the peak load use.



9.2 Environmental and Social Considerations

➢ 10 environmental and social aspects

(1) air pollution;
(2) water pollution;
(3) greenhouse gas emissions;
(4) impacts on ecosystems;
(5) impacts caused by resettlement;
(6) impacts on water right / water resources;
(7) impacts on agriculture;
(8) impacts on fishery;
(9) impacts on tourism; and,
(10) impacts on human health

(1) Air pollution

Power Generation Option	SO_2 (t SO_2/TWh)	NOx (t NOx/TWh)	Particulate Matter (t/TWh)	Rating
Hydro capacity expansion	Less than New hydro PP	Less than New hydro PP	Less than New hydro PP	1
Pumped storage PP	More than New hydro PP	More than New hydro PP	More than New hydro PP	2
Gas combined cycle thermal PP	4 to 15,000+	13+ to 1,500	1 to 10+	2
Gas turbine thermal PP	N/A	N/A	N/A	2
Diesel PP	84 to 1,550	316+ to 12,300	122 to 213+	3
Transmission interconnection	Depending on the situation in the Indian side.			2
Demand side management	Nil	Nil	Nil	0

(2) Water pollution

Power Generation Option	Impacts	Probability of occurrence	Severity of impacts with mitigation	Rating
Hydro capacity expansion	・ Alternation of the water temperature ・ Prolongation of turbid water discharging	Low	Low	1
Pumped storage PP	・ Alternation of the water temperature ・ Prolongation of turbid water discharging	Low	Low	1
Gas combined cycle thermal PP	・ Change of the water temperature due to heated effluent ・ Boiler blowdown ・ Boiler cleaning wastes	Low	Low	1
Gas turbine thermal PP	・ Change of the water temperature due to heated effluent ・ Boiler blowdown ・ Boiler cleaning wastes	Low	Low	1
Diesel PP	・ Boiler cleaning wastes	Low	Low	1
Transmission interconnection	Depending on the situation in the Indian side.			1
Demand side management	Nil	Nil	Nil	0

(3) Greenhouse gas emissions

Power Generation Option	Greenhouse Gas Emissions (kt eq. CO_2/TWh)	Rating
Hydro capacity expansion	Less than New hydro PP	1
Pumped storage PP	More than New hydro PP	2
Gas combined cycle thermal PP	389 to 511	2
Gas turbine thermal PP	Similar to Gas combined cycle thermal PP.	2
Diesel PP	555 to 883	3
Transmission interconnection	Depending on the situation in the Indian side.	2
Demand side management	Nil	0

(4) Impacts on ecosystems

Power Generation Option	Impacts	Local and regional ecosystems	Biomass	Genetic diversity at the world level	Rating
Hydro capacity expansion	Nil	Nil	Nil	Nil	0
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
Gas combined cycle 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	3
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	3
Diesel PP*	・ Climate change ・ Acid precipitation	x x	x	x	2
Transmission interconnection	・ Loss of terrestrial habitats ・ Loss of marine substrates	x x			1
Demand side management	Nil	Nil	Nil	Nil	0

(5) Impacts caused by resettlement

Power Generation Option	Land Requirements (km^2/TWh/y)	Severity of impacts with mitigation	Rating
Hydro capacity expansion	Nil	Nil	0
Pumped storage PP	Less than New hydro PP	High to Low	2
Gas combined cycle thermal PP	Small	Medium to Low	2
Gas turbine thermal PP	Small	Medium to Low	2
Diesel PP	Small	Low	1
Transmission interconnection	Small	Low	1
Demand side management	Nil	Nil	0

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(6) Impacts on water right/water resources

Power Generation Option	Impacts	Probability of occurrence	Severity of impacts with mitigation	Rating
Hydro capacity expansion	Nil	Nil	Nil	0
Pumped storage PP	・ Change in the flow pattern	Low	Low	1
Gas combined cycle thermal PP	・ Change of the water temperature due to heated effluent	Low	Low	1
Gas turbine thermal PP	・ Change of the water temperature due to heated effluent	Low	Low	1
Diesel PP	Nil	Nil	Nil	0
Transmission interconnection	Nil	Nil	Nil	0
Demand side management	Nil	Nil	Nil	0

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(7) Impacts on agriculture

Power Generation Option	Impacts	Probability of occurrence	Severity of impacts with mitigation	Rating
Hydro capacity expansion	Nil	Nil	Nil	0
Pumped storage PP	・ Loss of land ・ Degradation of water quality ・ Change in the flow pattern	Low	Low	1
Gas combined cycle thermal PP	・ Loss of land ・ Degradation of air quality	Low	Low	1
Gas turbine thermal PP	・ Loss of land ・ Degradation of air quality	Low	Low	1
Diesel PP	・ Loss of land ・ Degradation of air quality	Low	Low	1
Transmission interconnection	・ Loss of land	Low	Low	1
Demand side management	Nil	Nil	Nil	0

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(8) Impacts on fishery

Power Generation Option	Impacts	Probability of occurrence	Severity of impacts with mitigation	Rating
Hydro capacity expansion	Nil	Nil	Nil	0
Pumped storage PP	・ Change in the flow pattern	Low	Low	1
Gas combined cycle 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
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
Diesel PP	Nil	Nil	Nil	0
Transmission interconnection	・ Degradation on substrate	Low	Low	1
Demand side management	Nil	Nil	Nil	0

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(9) Impacts on tourism

Power Generation Option	Impacts	Probability of occurrence	Severity of impacts with mitigation	Rating
Hydro capacity expansion	Nil	Nil	Nil	0
Pumped storage PP	・ Change in the flow pattern	Low	Low	1
Gas combined cycle thermal PP	・ Impacts on sport / leisure ・ Impacts on landscape	Low	Low	1
Gas turbine thermal PP	・ Impacts on sport / leisure ・ Impacts on landscape	Low	Low	1
Diesel PP	・ Impacts on sport / leisure ・ Impacts on landscape	Low	Low	1
Transmission interconnection	・ Impacts on landscape	Low	Low	1
Demand side management	Nil	Nil	Nil	0

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(10) Impacts on human health

Power Generation Option	Impacts	Probability of occurrence	Severity of impacts with mitigation	Rating
Hydro capacity expansion	・ Risks from water-borne diseases, particularly when there is irrigation ・ Dam break	Low	Low	1
Pumped storage PP	・ Dam break ・ Climate change ・ Acid precipitation	High to Low	Low	2
Gas combined cycle thermal PP	・ Climate change ・ Acid precipitation ・ Photochemical smog ・ Fire ・ Explosion	High to Low	Medium	2
Gas turbine thermal PP	・ Climate change ・ Acid precipitation ・ Photochemical smog ・ Fire ・ Explosion	High to Low	Medium	2
Diesel PP	・ Climate change ・ Acid precipitation ・ Photochemical smog ・ Particulate matter ・ Fire	High to Low	Medium	2
Transmission interconnection	・ Electromagnetic wave	High	Low	2
Demand side management	Nil	Nil	Nil	0

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➢Result of assessment

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 expansion	1	1	1	0	0	0	0	0	0	1	4
Pumped storage PP	2	1	2	2	2	1	1	1	1	2	15
Gas combined cycle thermal PP	2	1	2	3	2	1	1	2	1	2	17
Gas turbine thermal PP	2	1	2	3	2	1	1	2	1	2	17
Diesel thermal PP	3	1	3	2	1	0	1	0	1	2	14
Transmission interconnection	2	1	2	1	1	0	1	1	1	2	12
Demand side management	0	0	0	0	0	0	0	0	0	0	0

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➢ Result

✓Demand side management is the lowest score and has no negative impacts.

✓Hydro capacity expansion has the second, and Transmission interconnection has the third lowest score.

✓The rest of the options are not very different in the aspects of environmental and social considerations.

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➢ Second Screening: Result

Power Generation Options / Evaluation Point	Hydropower (Expansion)	PSPP	LNG IGCC	Gas Turbine
Technical aspect	Good	Very good - Good	Good	Good
Economical aspect	Very good	Good	Good	Fair
Environmental aspect	Very good	Good	Good	Good
OVERALL EVALUATION	Very good	Very good - Good	Good	Good

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10. Special Considerations on Possible Options

➢ Hydropower Expansion

The Victoria expansion is the most possible option. It is almost ready for construction, but the intake for the irrigation project is not determined.

➢ PSPP

It is free from draught risk, but it may be affected by fuel supply for pumping power from base load power plants.

➢ LNG IGCC

The JICA Study for Energy Diversification Enhancement Project (E/S) for the Construction of LNG Thermal is ongoing.

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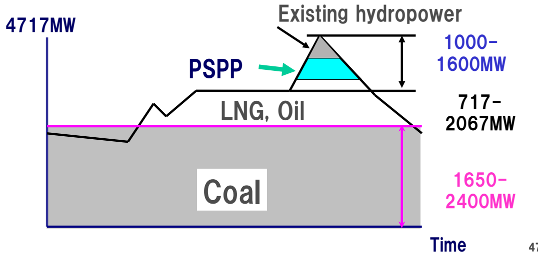
11. Combination of peaking supply in 2025

➢ (1) PSPP and Existing hydropower

➢ (2) PSPP and LNG Combined Cycle



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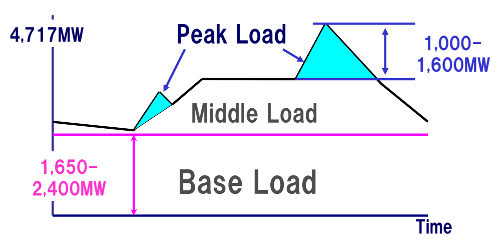
➢ Generation energy is assumed at 24,284 GWh.

➢ Peak demand would be 4,717MW.



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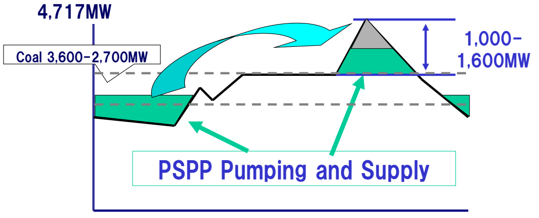
12 Additional values of PSPP

- PSPP has functions for peak power supply.
- It improves efficiency of base power supply.



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- A variable speed PSPP can improve off-peak system stability. It can absorb system turbulence, during pumping operation by changing its pumping speed.
- PSPP can absorb surplus supply from unstable power sources such as wind and solar power generators.

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13. Conclusions on Power Generation for Peak Power Demand

- Pumped Storage Power Plant (PSPP) is one of the suitable options to solve the peak power demand in 2025.
- The JICA Study Team hereafter starts site selection PSPP and its optimization.
- Combination Development of PSPP with Hydropower Expansion will contribute to stable supply of electricity and sustainable development in Sri Lanka.

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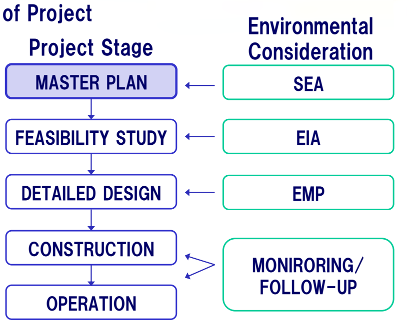
14. Optimization Policy of Pumped Storage Power Project -Steps of Project



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14.1 Study stages

Stage1
- Selection of Suitable Power Generation Option for Peak Power Demand (1st SHM)

Stage2
- Study on 10 Candidate Sites of PSPP
- Review of Long Term Power Development Plan

Stage 3
- Selection of 3 Promising Sites (2nd SHM)
- Study on the 3 Candidates
- Selection of the Most Promising Site (3rd SHM)

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14.2 Policy

(1) Procedure

- To proceed to the next stage by forming consents to the results of the previous study in each SHM.

(2) Methodology

- To respect the Sri Lankan Laws and Regulations as well as the JICA's Guidelines.
- To examine the candidate sites from 1) Environmental aspects, 2) Technical Aspect, and 3) Economical aspects.
- To deepen the study level by a step-by-step approach.

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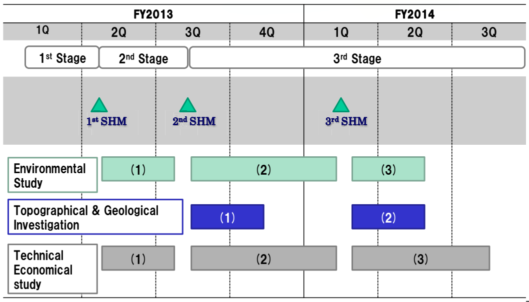
14.3 General Schedule

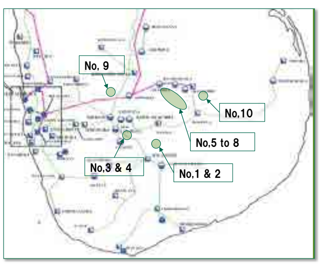


14.4 Criteria for Project Evaluation

Preliminary Design (main structure layout, reservoir capacity, acquired potential head, etc.) are identified on topographical maps (scale 1:50,000 or 1:10,000)) will be carried out and then the ranking study will be conducted from the following aspects:

Environmental Aspects	Laws and regulations Social environmental impacts Natural environmental impacts → Later explained
Technical Aspects	Topographical condition, Geological condition Hydrological Condition (Design Flood, Sedimentation) Construction Condition (Access, Temporary facility, etc.) Others (Operation, Distance from demand area, Project scale, relation to Transmission lines and substations, etc.)
Economical Aspects	Construction cost per kW Benefit/Cost Economic IRR, Financial IRR

14.5 Candidate Sites: (1) Location



NO.1 No.2	Kiriketi (2 candidates)
No.3 No.4	Maussakelle (2 candidates)
No.5 No.6 No.7 No.8	Halgran (4 candidates)
No.9	Maha (1 candidate)
No.10	Loggal (1 candidate)

Source: Study Formation Report by JICA in 2012

14.5 Candidate Sites: (2) General features

	Name	P (MW)	H (m)	Upper Pond V (MCM) A (km2)	Lower Pond V (MCM) A (km2)
NO.1 No.2	Kiriketi	500	780 -700	1.8-2.0 0.17-0.05	2.1-2.4 0.08-0.10
No.3 No.4	Maussakelle	500	490	3.4 0.4	3.9-4.3 0.24-0.25
No.5 No.6 No.7 No.8	Halgran	500	620 -870	2.0-3.9 0.13-0.22	2.3-5.9 0.13-0.25
No.9	Maha	500	500	2.0 0.18	5.0 0.20
No.10	Loggal	500	780	3.2 0.20	13.1 0.85

Source: Study Formation Report by JICA in 2012

Reference: Performance of PSPP as "Battery Device"

Item	Pumped Storage	Sodium-sulfur (NaS)	Redox Flow	Li-ion
Capacity	500 - 2,100MW (6-8hrs)	1MW (10hrs)	6MW (10hrs)	0.003MW (8hrs)
Efficiency	70 %	70 % (total)	70 % (total)	85 %
Cost	~1,000 USD/kW	2,000 USD/kW	2,500 USD/kW	–
Life Span	50 years	15 years	10 years	10 years
Merits	Large scale Technical maturity Long lifespan Cost	Dispersed placement Flexibility in charging and discharging	Dispersed placement Flexibility in charging and discharging	High efficiency Compactness Dispersed Placement Flexibility of charging and discharging
Demerits	Inflexibility in operation Depending on topological conditions	Temperature control (400℃) and sodium control are required.	Temperature control is required.	Using Li (rare metal) Expensive Complexity in control

15. Draft scoping items for the site selection

Strategic Environmental Assessment (SEA)

- SEA at the site selection stages.

- The important considerations are:

i. To equally consider environmental, social and economic aspects of the project;

ii. To conduct comparison examination of sites; and,

iii. To disclose information in a participatory manner.

➢ SEA steps at the site selection stage

2nd stage	2nd SEA: Site selection (10 sites)	July – Oct. 2013
	3rd SEA: Site selection (best 3 sites out of 10)	Nov. 2013 – Apr. 2014
	Last SEA: Site selection （the best site out of 3)	May – Jun. 2014

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➢ Comments from SHM participants

Comments from SHM participants are collected as absolute requirements and/or priority requirements.

The followings are examples:

"XX site should be excluded because of the previous land disputes"

"a development plan is not allowed in an area where it is likely that endangered species occur"

"a development plan along XX road needs to be given high priority"

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➢ Initial environmental study

	Candidate site	Name of DS division
Jun. 11	Loggal	Meegahakiula
Jun. 12	Halgran	Walapane
Jun. 13	Maha	Ganga Ihala Korale Aranayaka
Jun. 18	Kiriketi	Imbulpe
Jun 19	Maussakelle	Ambagamuwa

Maussakelle / Ambagamuwa DS Division, June 19

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Candidate site	Present situation
Loggal (Kekale)	- Under construction of mini-hydropower plant - Mini-hydropower plan - No protected area - Tea plantation
Halgran	- Prone to landslides - Paddy cultivation - Tea plantation - Settlements - Shortage of water for paddies during dry season
Maha	- Tea plantation - Rock outcrops - Existing mini-hydropower plants
Kiriketi	- Water shortage during dry season - Natural forest - Tea plantation
Maussakelle	- Big waterfalls - Natural forest - Tea plantation

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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 appropriated
		Impacts on water utilization (e.g. drinking water)
		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 and/or cultural facilities
		Impacts on landscape

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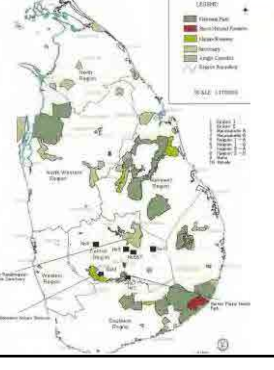
Protected areas



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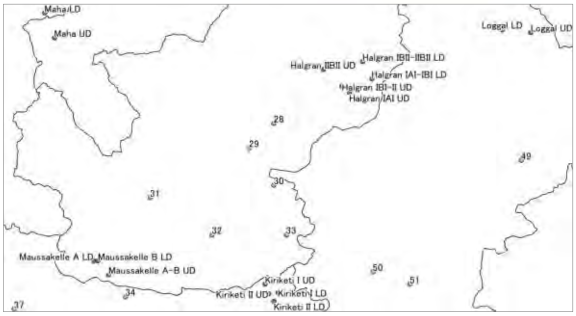
Important Bird Areas (IBAs) and Candidate sites



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Ramsar wetlands & Biosphere reserves and Candidate sites

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Impacts on agriculture

Irrigation

Paddies

Tea plantation

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Cultural heritages

Site	Properties	Registered year
1. Sacred City of Anuradhapura	Cultural heritage	1982
2. Ancient City of Polonnaruwa	Cultural heritage	1982
3. Ancient City of Sigiriya	Cultural heritage	1982
4. Sinharaja Forest Reserve	Natural heritage	1988
5. Sacred City of Kandy	Cultural heritage	1988
6. Old Town of Galle and its Fortifications	Cultural heritage	1988
7. Golden Temple of Dambulla	Cultural heritage	1991
8. Central Highlands of Sri Lanka	Natural heritage	2010

Source: UNESCO. 2012. http://whc.unesco.org/en/statesparties/lk (Accessed on 1 May 2012).

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Are there any comments or suggestions for the scoping items?

1. …
2. …
3. …

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Development Planning on Optimal Power Generation for Peak Power Demand

(Stake Holders Meeting- 2)

November 21, 2013

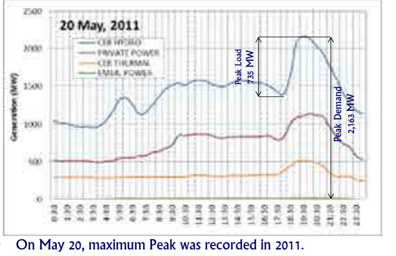
CEYLON ELECTRICITY BOARD Enrich Life through Power

CONTENTS

Session I Introduction

1. Briefing of the Project
2. Present Progress of the Project
3. Points of Stake Holders Meeting-2

1-(1) Necessity of Study



- On May 20, maximum Peak was recorded in 2011.
- Peak Load was around 735MW.
- It was supplied by the Power Source of CEB Thermal (180 MW) Private Power (130 MW) and CEB Hydro (420 MW).

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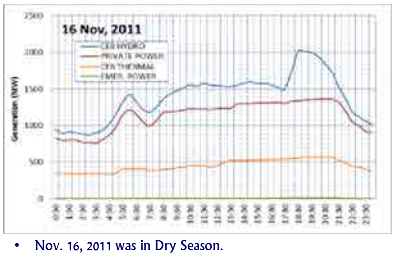
1-(1) Necessity of Study



- Nov. 16, 2011 was in Dry Season.
- CEB Thermal and Private Power was almost full capacity.
- CEB Hydro was 514MW for Peak Power Demand.

1-(2) Outline of Study

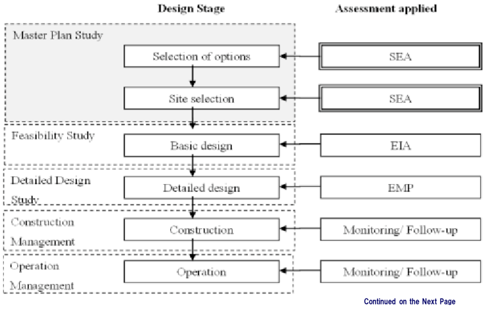
Stage 1: Initial Evaluation Stage
- March 2013 to June 2013
- JCC1: Inception Presentation
- Seminar: Pumped Storage
- SHM1: Option for Peak Power Demand

Stage 2: Formation of Power Development Plan for Peak Demand
- July 2013 to October 2013
- JCC2: Confirmation of Criteria for Site Selection
- Interim Report

Stage 3: Investigation on Candidate Sites for Peak Load Power Plants
- November 2013 to October 2014
- SHM2: Confirmation of Identified 3 Sites
- JCC3: Confirmation of Most Promising Site
- SHM3:Confirmation of Most Promising Site
- Pre-DF/R, DF/R and Final Report

1-(3) SEA Procedure for Master Plan Study

Strategic Environment Assessment



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1-(3) SEA Procedure for Master Plan Study

Key Points of SEA

- To equally consider environmental, social and economic aspects of the Project
- To conduct comparison examination of possible options
- To share information of the project in a participatory manner

2-(1) Progress of the Study

- March 2013: Commencement of the Study
- March 28, 2013: First Joint Coordinating Committee (JCC-1)@MOPE
  - Confirmation of scope and schedule of the Study
- April 9, 2013: Seminar on Power Generation for Peak Demand
  - Explanation on power generation for peak demand

Continued on the Next Page

2-(1) Progress of the Study

- June 27, 2013: First Stake Holders Meting (SHM-1)
  - Explanation on power generation options for peak power demand and forming consensus that Pumped Storage Power Plant is the optimal option
  - Screening method for from 11candidate sites for Pumped Storage Power Plant to 3 suitable sites
- September 25, 2013: JCC-2@MOPE
  - Forming Consensus on Evaluation Criteria

2-(2) Daily Load Curve Projection

As of 2011
- Peak Load (Ave) : 514 MW (28% of Peak Demand)
- Peak Load Period: 4 hours
- Minimum Demand: 1,000 MW (44% of Peak Demand) at 3:30

From LTGEP (2013 to 2032)
- Share of Coal thermal capacity: 60% of Generation Installed Capacity in 2025
- Minimum Operation Output of Coal Thermal Plant: 75%.
- Supply Capacity of CEB Hydro in 2025: 570 MW (420 MW + 150 MW UKHP)
- Generation Energy in 2025: 24,284 GWh.
- Peak Demand in 2025: 4,717MW

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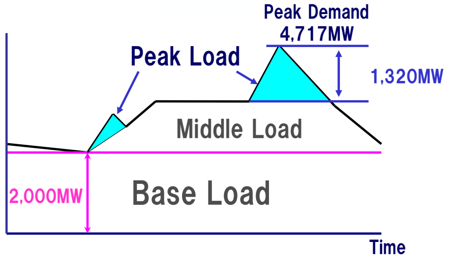
2-(2) Daily Load Curve Projection



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2-(2) Daily Load Curve Projection

Expected Power Generation for Peak Load

- Supposedly 1,320 MW (Average)
- Existing 570 MW + Victoria Expansion 228 MW + New Power Generation for Peak Load 522 MW

Expected Power Generation for Middle Load

- Supposedly 1,400 MW (Average)
- CEB Oil Fired Thermal + IPP + LNG CC

Expected Power Generation for Base Load

- Supposedly 2,000 MW (Average)
- CEB Coal Fired Thermal

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2-(3) Options for Peak Power Demand

Options of Peak Power Generation

- Hydropower Plant (New Construction)
- Hydropower Plant (Expansion)
- Pumped Storage Power Plant
- Coal-Fired Thermal Power Plant
- LNG Combined Cycle Power Plant
- Gas Turbine Plant
- Diesel Plant
- Renewable Energy

Other Options for Peak Demand

- Independent Power Producer
- Demand Side Management
- Inter Connection with Indian System

Continued on the Next Page

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2-(3) Options for Peak Power Demand

By Screening of Options in Sheet 14, Following Options are suitable for Peak Power Demand.

- Hydro Power Expansion
- Pumped Storage Power Plant
- LNG CC
- Demand Side Management
- Inter Connection with Indian System

Screening was done by considering perspective of;

- Adaptability to Load Change
- Economical Efficiency
- Environmental Aspect

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2-(4) Most Practical Power Generation

Special Comment on Suitable Options for Determination of Most Practical Power Generation for Peak Power Demand

i. Hydro Power Expansion

- Victoria Expansion is an Option of Hydro Power Expansion.
- Its F/S and EIA have already prepared and are ready to implement.
- However, its Capacity is not enough for Peak Load in 2025.

ii. Pumped Storage Power Plant

- Sri Lanka has many Suitable Sites for PSPP.
- It can have big enough capacity for Peak Load in 2025.

Continued on the Next Page

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2-(4) Most Practical Power Generation

iii. LNG CC

- Available for Peak Power Load
- For its Economic Efficiency, It should be used for Middle Load
- Its Development Schedule has still uncertainty

iv. Demand Side Management

- Peak Demand comes from Domestic Use that cannot be shifted except introducing Battery System
- Hourly Electricity Tariff may not be applied

v. Inter Connection with Indian System

- No merit for Peak Power Load because of Same Peak in India
- Substantial merit for power stability

Continued on the Next Page

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2-(4) Most Practical Power Generation

As a result of Selection of Options

Optimal Power Generation for Peak Power Demand is:

Combination of Victoria Expansion and Pumped Storage Power Plant

- Victoria Expansion (228MW) for Demand in 2020
- Pumped Storage Power Plant for Demand in 2025

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2-(5) Special Merits of Pumped Storage Power Plant

- Free from Drought Risk
- Enabling coal fired power plants to operate continuously at high efficiency level
- Absorption of Surplus Supply from Unstable Power Sources such as Wind and Solar Power Generators.
- Improvement of Off-peak System Stability in case a Variable Speed PSPP Applied.

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2-(6) Outline of PSPP Planning

- 11 Candidates Sites
- Plant Capacity 600 MW
- Generating hours per day 6 hours

and

- Unit Capacity 200 MW * 3 units (as Base Plan)
- Unit Capacity 150 MW * 4 units (additonal Plan)

Continued on the Next Page

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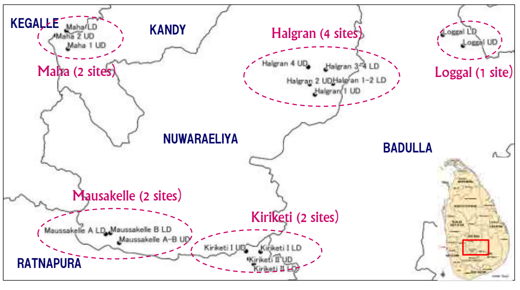
2-(6) Outline of PSPP Planning
Location of 11 candidates sites



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2-(6) Outline of PSPP Planning
General Features of 11 Candidates Sites

		Kir 1	Kiri 2	Mau A	Mau B	Hal 1	Hal 2
UD reservoir capa.	MCM	1.9	0.9	3.6	3.7	2.8	2.3
LD reseroivr capa.	MCM	1.5	0.7	3.7	3.5	2.9	2.3
Discharge (generating)	m^3/s	108	98	156	155	125	106
Gross Head	m	700	770	474	488	606	715
Installed capa.	MW	600	600	600	600	600	600
Generating hours	hrs	3.80	2.52	6.42	6.28	6.19	6.11
Upper Dam H*L	m	40*250	85*300 +S200	40*1200 +S1,000	40*1200	85*250	120*500
Lower Dam H*L	m	95*320	75*270	60*300	55*350	85*420	85*420
Waterway Length	m	2,830	1,630	3,290	2,540	4,370	4,460

Kir; Kiriketi, Mau; Mausakelle, Hal; Halgran, S; Saddle Dam

Continued on the Next Page

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2-(6) Outline of PSPP Planning
General Features of 11 Candidates Sites

		Hal 3	Hal 4	Mah 1	Mah 2	Log
UD reservoir capa.	MCM	2.4	3.4	3.7	3.7	3.1
LD reservoir capa.	MCM	2.5	3.4	3.4	3.6	2.8
Discharge (generating)	m^3/s	110	155	155	166	128
Gross Head	m	692	490	489	458	591
Installed capa.	MW	600	600	600	600	600
Generating hours	hrs	6.05	6.10	6.03	6.09	6.16
Upper Dam H*L	m	60*200	90*550	55*200	80*310	45*220
Lower Dam H*L	m	70*220	75*290	80*360	80*360	80*540
Waterway Length	m	4,790	3,360	3,360	2,410	4,090

Hal; Halgran, Mah; Maha, Log; Loggal

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2-(7) Criteria for Civil Works

- **Geological conditions**
  for example;
  - strength of foundation rock
  - water tightness
  - major faults
  - thickness depositions on river beds at dams' axises
  - slope stability around reservoirs

  …etc.

So far, no serious geological problems are identified in candidates sites

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2-(7) Criteria for Civil Works

- **Ease of construction works**

evaluated by accessibility to candidates site

So far, following sites have accessibility problems

- Kiriketi 1 Upper Dam
- Kiriketi 2 Upper Dam
- Mausakelle A, B Upper Dam
- Halgran 1 Upper Dam
- Halgran 4 Upper Dam

Continued on the Next Page

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2-(7) Criteria for Civil Works

- **Drawdown depth of reservoirs**

- Water level moves from Maximum water level to minimum water level basically once a day
- Large drawdown depth may induce slope instability around reservoir
- Generally, maximum drawdown level is set within around 30 m

Identified problems in terms of Drawdown depth:

Kiriketi 2 Upper Dam 38 m
Halgran 4 Upper Dam 52 m

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2-(8) Criteria for Electromechanical Works

- **Manufacturing Limitation Pump-Turbines**

Due to stability of the power grid system in case of unit trip, …etc.

unit capacity (MW) limited to ***less than 200 MW per unit***

Generally

- high head and small discharge → small turbine
- low head and large discharge → large turbine

Continued on the Next Page

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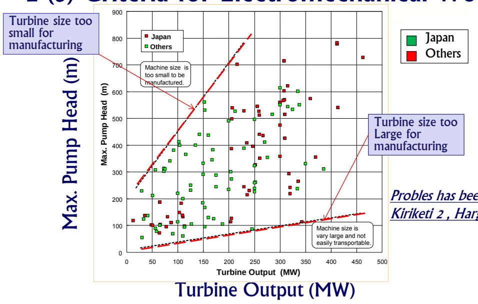
2-(8) Criteria for Electromechanical Works



Probles has been identified in Kiriketi 2 , Harglan 2

In actual study, Dimension of Turbine, Specific pump speed, etc. are studied at every candidates

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2-(9) Economic Evaluation

Project cost calculation

- JICA Hydropower Development Guide Manual 2011
- Layout on 1:10,000 topographic map
- Civil Works: unit prices of similar works in Sri Lanka
  (Upper Kotmale HPP, Umaoya HPP, etc. Some of items referring from other countries)
- Electro-mechanical Works: international prices

Including land acquisition and compensation, environmental mitigation, design and engineering services, contingency, etc. and all of those are on standard basis

Economy of every project is evaluated by "Cost per kW"

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2-(10) Environmental Study

The following table was presented at the 1st SHM, and the Environmental Study (1) has been conducted to study these items at the 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

Continued on the Next Page

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2-(10) Environmental Study

The survey items requested by the participants of the 1st SHM.

1) Protected areas

The candidate sites within the protected area are excluded.

2) Aquatic species (e.g. fresh-water crabs and fresh-water fishes)

They have been surveyed.

3) Transmission lines

It will be considered in the next stage.

Continued on the Next Page 31

2-(10) Environmental Study

1) Environmental Study (1) was undertaken at the 11 candidate sites to collect information on the scoping items.
2) The Environmental Study (1) was conducted by the University of Peradeniya, headed by Prof. Hennayake.
3) Draft Final Report of the study was submitted by end of September 2013, and the findings in the Environmental Study (1) was briefly reported by Prof. Hennayake at CEB.

Continued on the Next Page 32

2-(10) Environmental Study

(2) Methodology

a) Based on the information (existing data, and collected data by brief site surveys), firstly the Sri Lankan experts examined the scale of expected impacts and gave ratings.

b) The following ratings were given to each point:

0: No negative impact, 1: small negative impacts, 2: medium negative impacts, and 3: large negative impacts.

c) Finally the JICA Study Team examined the results.

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2-(11) Summary of Project Evaluation

sample form of project evaluation

Criteria		Rating	Allocation	Score
1. Technical Evaluation sub-total				
1.1	Geological Aspect			
1.2	Ease of construction works			
1.3	Manufacturing Limitation			
2. Economical Evaluation sub-total				
3. Environmental Evaluation sub-total				
3.1	Impact on fauna and flora			
3.2	Impact on local communities			
3.3	Impact on industries			
3.4	Impact on cultural heritages			
Total Score				

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3 Points of Stake Holders Meeting-2

- Confirmation of 3 Promising Candidate Sites
  - Hearing of Opinions about 3 Promising Sites
  - Hearing of Weighing Method for Evaluation
- Selection of Most Promising Candidate Site
  - Hearing of Evaluation Method
  - Hearing of Priority and/or absolute Condition for site selection

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Section II

4. Primary Screening Result (from 11 sites to 3 promising sites)

1) First screening
2) Evaluation from Geological Aspects
3) Evaluation from Ease of construction works
4) Manufacturing Limitation of Pump Turbine
5) Construction cost
6) Evaluation from Natural and Social Environmental Aspect
7) Ranking of Candidate sites by even evaluation
8) Ranking of Candidates sites by Environment weighed evaluation
9) Selection of 3 Promising sites
10) Discussion

5. Briefing of 3 sites

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1) First Screening

◆ Pumped Storage Planning

- 11 Candidates Sites
- Plant Capacity 600 MW
- Generating hours per day 6 hours

and

- Unit Capacity 200 MW * 3 units (as Base Plan)
- Unit Capacity 150 MW * 4 unit (additional Plan)

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1) First Screening

Evaluated by two issues

1. "Out of manufacturing limit for 200 MW/unit pump-turbine",
2. Location related with "Sanctuary"

Eliminating candidates sites having applied two issues

Because if a candidate site falls into these two issues, it cannot be realized.

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1) First Screening

"Out of manufacturing limit for 200 MW/unit pump-turbine"

Power System stability in 2025 → 150 MW/unit applicable
Power System stability in 2031 → 200 MW/unit applicable

Examining manufacturing limitation of Pump Turbine; for 150 MW /unit and 200 MW/unit

Kitiketi 2 (770m*) and Halgran 2 (715m*) → "out of manufacturing limitation" (*: Gross head)

Refer to the slide 28

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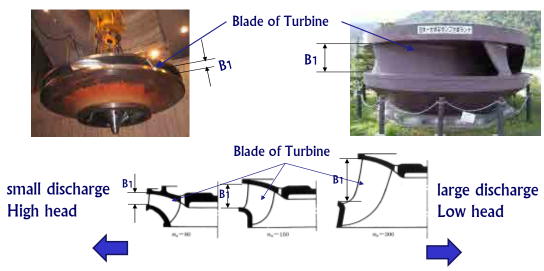
1) First Screening

manufacturing limitation of Pump-turbine



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1) First Screening

◆ **Location related with Sanctuary**

Development actions are not permitted within sanctuaries.

Candidate sites having their Upper and/or Lower reservoirs in sanctuaries.

→Kiriketi 1, Kiriketi 2, Maussakelle A, Maussakelle B

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1) First Screening

Results

Candidate sites to be eliminated 4 sites

◆Out of Manufacturing Limitation of Pump-turbine: Kiriketi 2, Halgran 2

◆Located within Sanctuary:
- Kiriketi 1 (Peak Wildness Sanctuary)
- Kiriketi 2 (Peak Wildness Sanctuary)
- Maussakelle A (Peak Wildness Sanctuary)
- Maussakelle B (Peak Wildness Sanctuary)

Halgran 1, Halgran 3, Halgran 4, Maha 1, Maha 2, and Loggal, total six candidate sites → Selecting → Three promising candidates sites

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2) Evaluation from Geological aspects

Rating
- A Not likely to have major problems or limited, if any
- B Likely to have some problems
- C Expected to have some major problems

	Halgran 1	Halgran 3	Halgran 4	Maha 1	Maha 2	Logal
Strength	B	B	A	B	B	A
Impermeability	A	B	B	B	B	A
Faults	B	B	B	B	B	A
Riverbed Deposit	A	A	A	A	A	B
Slope	B	A	B	B	B	A
Overall evaluation	B	B	B	B	B	B

Evaluation were done by literatures, site reconnaissance, etc.

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3) Evaluation from Ease of Construction aspects

Rating
- A Not likely to have major problems or limited, if any
- B Likely to have some problems
- C Expected to have some major problems

	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						
(Drawdown depth)			C			
(Access Tun. to PH)				A		
Overall Evaluation	C	B	C	A	A	B

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4) Manufacturing limitation of Pump-turbine

Rating
- A 150 MW/unit and 200 MW/unit applicable
- B Only 200 MW/unit applicable
- C 200 MW/unit not applicable

	Halgran 1	Halgran 3	Halgran 4	Maha 1	Maha 2	Logal
Overall Evaluation	B	B	A	A	A	A

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5) Evaluation from Construction cost

Rating
- A Less than 1,200 USD/kW
- B 1,200 – 1,400 USD/kW
- C More than 1,400 USD/kW

	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

Note;
- Cost for 600MW Pumped Storage Projects (for example, 800 -1,000 USD/kW for more than 1,000 kW class PSPP in South-west & South-east Asian countries)
- Interest during construction cost not included
- Construction Cost for Transmission lines not included
- Calculated based on JICA Hydropower Development Manual
- Level of construction costs would be less than conventional hydropower plants because of their scale merits, …etc.

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5) Evaluation from Construction cost

Reference

$$P(kw) = g(m/s^2) \times \eta t \times \eta g \times Q(m^3/s) \times H(m)$$

	Conventional Hydro	Pumped Storage Power
Q	Large river flow preferable; - Broad catchment area (downstream area) - Plenty of precipitation	Large river flow not needed (determined by only capacities of upper/lower reservoir)
H	High potential energy is preferable - steep riverbed (upstream area), or - a long waterway or a high dam	Same or rather sever than the conventional; however, - (comparatively) easier to use a high potential between two different basins
(storage)	for annual regulation; a large dam and reservoir	For daily operation; two small dams

Flexibility for pumped storage projects planning makes large output (kW) easier than conventional hydropower projects, which contributes to find cost effective projects ; lower cost/kW.

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4-6) Evaluation from Natural and Social Environmental Aspects

Site / Evaluation Items	Halgran 1	Halgran 3	Halgran 4	Maha 1	Maha 2	Loggal
Impacts on fauna and flora	B	B	B	B	B	B
Impacts on local communities	B	B	B	C	B	B
Impacts on industries	B	B	B	B	B	B
Impacts on culture and landscape	A	A	A	A	A	B

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4-6) Evaluation from Natural and Social Environmental Aspects

Natural environment: Impacts on fauna and flora

- All sites are similar to each other. Ratings are all "B".
- Biodiversity and species richness are low to high.
- Several upper and/or lower dams have a few endangered species.

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4-6) Evaluation from Natural and Social Environmental Aspects

Social environment: Impacts on local communities

- All sites are similar to each other (Rating "B") except for Maha 1.
- Maha 1

  There are 76 houses in the upper dam/reservoir site of Maha 1 (Rating "C").

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4-6) Evaluation from Natural and Social Environmental Aspects

Social environment: Impacts on industries

- All sites are similar to each other (Rating "B").
- Agriculture is mainly considered.

  Tea plantations, home gardens and paddy fields. The biggest area is 50 ha (tea plantation at Maha 1 upper). Others are less than 30 ha.

51

4-6) Evaluation from Natural and Social Environmental Aspects

Social environment: Impacts on culture and landscape

- All sites are similar to each other (Rating "A") except for Loggal.
- Loggal

  There is a Buddhist temple in each upper and lower reservoir (Rating "B").

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4-6) Evaluation from Natural and Social Environmental Aspects

Site / Evaluation Items	Halgran 1	Halgran 3	Halgran 4	Maha 1	Maha 2	Loggal
Impacts on fauna and flora	B	B	B	B	B	B
Impacts on local communities	B	B	B	C	B	B
Impacts on industries	B	B	B	B	B	B
Impacts on culture and landscape	A	A	A	A	A	B

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Sample form of score calculation
…Before ranking of candidate sites

Criteria	Rating	Score allocation	Score
1. Technical Evaluation sub-total	--	25	15.75
1.1 Geological Aspect	A (1.0)	7.5	7.5
1.2 Ease of construction works	C (0.3)	7.5	2.25
1.3 Manufacturing Limitation	B (0.6)	10	6
2. Economical Evaluation sub-total	B (0.6)	25	15
3. Environmental Evaluation sub-total	--	50	37.2
3.1 Impact on fauna and flora	B (0.6)	12	7.2
3.2 Impact on local communities	B (0.6)	20	12
3.3 Impact on industries	A (1.0)	9	9
3.4 Impact on cultural and landscape	A (1.0)	9	9
Total Score	--	100	67.95

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7) Ranking of Candidate Sites (Even evaluation case)

Criteria		Score allocation	Halgran 1		Halgran 3		Halgran 4		Maha 1		Maha 2		Loggal	
			Eva	Score	Eva	Score	Eva	Score	Eva	Score	Eva	Score	Eva	Score
1. Technical Evaluation		25		12.75		15.00		16.75		22.00		22.00		19.00
1.1	Geological aspects	7.5	B	4.50	B	4.50	B	4.50	B	4.50	B	4.50	B	4.50
1.2	Ease of construction works	7.5	C	2.25	B	4.50	C	2.25	A	7.50	A	7.50	B	4.50
1.3	Manufacturing Limitation	10	B	6.00	B	6.00	A	10.00	A	10.00	A	10.00	A	10.00
2. Economical Evaluation		25	B	15.00	A	25.00	C	7.50	A	25.00	B	15.00	B	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	7.20	B	7.20	B	7.20	B	7.20	B	7.20	B	7.20
3.2	Impact on local communities	20	B	12.00	B	12.00	B	12.00	C	6.00	B	12.00	B	12.00
3.3	Impact on industries	9	B	5.40	B	5.40	B	5.40	B	5.40	B	5.40	B	5.40
3.4	impact on cultural heritages	9	A	9.00	A	9.00	A	9.00	A	9.00	A	9.00	B	5.40
	Total	100		61.35		73.60		57.85		74.60		70.60		64.00
	Rank			5		2		6		1		3		4

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7) Ranking of Candidate Sites (Even evaluation case 2)

Criteria		Score allocation	Halgran 1		Halgran 3		Halgran 4		Maha 1		Maha 2		Loggal	
			Eva	Score	Eva	Score	Eva	Score	Eva	Score	Eva	Score	Eva	Score
1. Technical Evaluation		25		12.75		15.00		16.75		22.00		22.00		19.00
1.1	Geological aspects	7.5	B	4.50	B	4.50	B	4.50	B	4.50	B	4.50	B	4.50
1.2	Ease of construction works	7.5	C	2.25	B	4.50	C	2.25	A	7.50	A	7.50	B	4.50
1.3	Manufacturing Limitation	10	B	6.00	B	6.00	A	10.00	A	10.00	A	10.00	A	10.00
2. Economical Evaluation		25	B	15.00	A	25.00	C	7.50	A	25.00	B	15.00	B	15.00
3. Environmental Evaluation		50		32.80		32.80		32.80		27.40		32.80		30.00
3.1	Impact on Fauna and Flora	18	B	10.80	B	10.80	B	10.80	B	10.80	B	10.80	B	10.80
3.2	Impact on local communities	18	B	10.80	B	10.80	B	10.80	C	5.40	B	10.80	B	10.80
3.3	Impact on industries	7	B	4.20	B	4.20	B	4.20	B	4.20	B	4.20	B	4.20
3.4	impact on culture and landscape	7	A	7.00	A	7.00	A	7.00	A	7.00	A	7.00	B	4.20
	Total	100		60.55		72.80		57.05		74.40		69.80		64.00
	Rank			5		2		6		1		3		4

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8) Ranking of Candidate Sites (Env. weighed case)

Criteria		Score allocation	Halgran 1		Halgran 3		Halgran 4		Maha 1		Maha 2		Loggal	
			Eva	Score	Eva	Score	Eva	Score	Eva	Score	Eva	Score	Eva	Score
1. Technical Evaluation		15		7.65		9.00		10.05		13.20		13.20		11.40
1.1	Geological aspects	4.5	B	2.70	B	2.70	B	2.70	B	2.70	B	2.70	B	2.70
1.2	Ease of construction works	4.5	C	1.35	B	2.70	C	1.35	A	4.50	A	4.50	B	2.70
1.3	Manufacturing Limitation	6	B	3.60	B	3.60	A	6.00	A	6.00	A	6.00	A	6.00
2. Economical Evaluation		15	B	9.00	A	15.00	C	4.50	A	15.00	B	9.00	B	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	9.60	B	9.60	B	9.60	B	9.60	B	9.60	B	9.60
3.2	Impact on local communities	30	B	18.00	B	18.00	B	18.00	C	9.00	B	18.00	B	18.00
3.3	Impact on industries	12	B	7.20	B	7.20	B	7.20	B	7.20	B	7.20	B	7.20
3.4	impact on culture and landscape	12	A	12.00	A	12.00	A	12.00	A	12.00	A	12.00	B	7.20
	Total	100		63.45		70.80		61.35		66.00		69.00		62.40
	Rank			4		1		6		3		2		5

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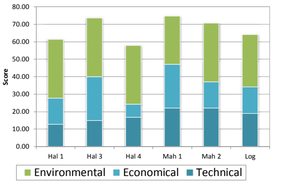
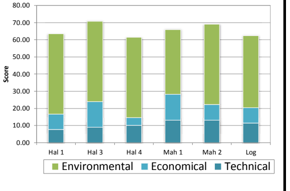
8) Ranking of Candidate Sites

Even case



Environment weighed case



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9) Selection of Three promising sites

One site from one region, because…

- to avoid concentrating candidate site in one region
- if one is selected, others cannot be developed due to common reservoirs with neighboring sites (Halgran 3 and Halgran 4, Maha 1 and Maha 2)

Sites Selection

- Halgran 3 is the best in Halgran region.
- Maha 1 is ascendant in the even evaluation; however it is reversed in the environmental weighed case. In Maha 1's upper reservoir area, the number of inundated houses is 76 houses; the largest in 6 candidate sites. Maha 2 is selected; ranking 3 in even case.
- Loggal is selected because …
    1) one candidate site from one region
    2) score difference to Halgran 1 is limited

Halgran 3, Maha 2, and Loggal is selected as three promising sites

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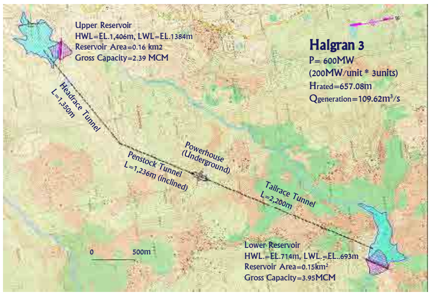
5. Briefing of Promising Three Candidate Sites



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5-1) Environments of Halgran 3

Upper dam/reservoir


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5-1) Environments of Halgran 3

Lower dam/reservoir


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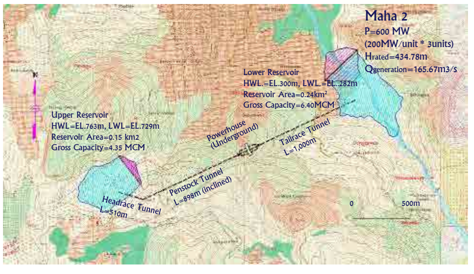
5. Briefing of Promising Three Candidate Sites



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5-2) Environments of Maha 2

Upper dam/reservoir

64

5-2) Environments of Maha 2

Lower dam/reservoir


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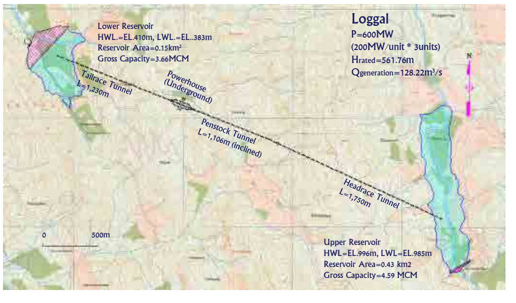
5. Briefing of Promising Three Candidate Sites



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5-3) Environments of Loggal

Upper dam/reservoir


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5-3) Environments of Loggal

Lower dam/reservoir


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Section III

4. Methodology of Secondary Screening
(from 3 promising sites to the most promising sites)

1) Technical and Economical Aspects
2) Environmental Aspects from Results of Detailed Sites Survey

69

2) Assessment from Economic Aspects

By local Consultants,

◆Topographical survey in three candidates sites
◆Geological survey on the ground surface

For making three candidate sites
more accurate and attractive

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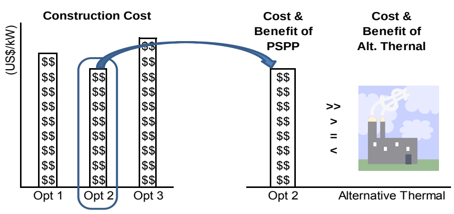
1) Assessment from Economic Aspects



Step 1: Select lowest cost option among candidate sites

Step 2: Confirm economic efficieicy of selected PSPP over alternative thermal power

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2) Economic Aspects
Cost-Benefit Analysis

- Cost
  - Capital cost: Construction, engineering, environment, land acquisition, compensation
  - OM cost
  - Electricity cost for pump-up by coal power
- Benefit (Avoidable cost of thermal power)
  - Capital cost of gas-turbine
  - OM cost
  - Fuel cost for generation

=> Assessment of economic efficiency by B-C, B/C, IRR

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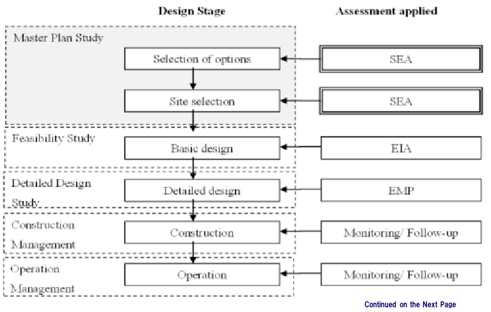
6-1) SEA Procedure for Master Plan Study



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6-1) SEA Procedure for Master Plan Study

Key Points of SEA

- To equally consider environmental, social and economic aspects of the Project
- To conduct comparison examination of options
- To disclose information of the project in a participatory manner

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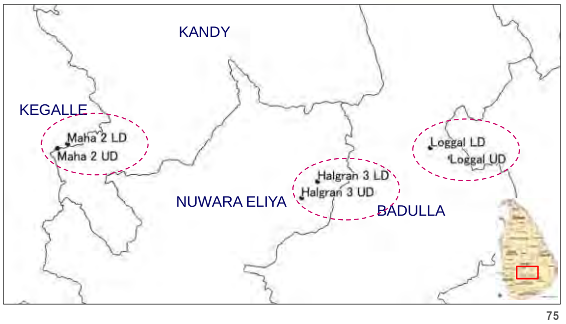
6-1) Locations of the three promising sites



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6-1) Hearings from GN Divisions

Date	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

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6-1) Hearings from GN Divisions

	Halgran 3 (5 GNs)	Maha 2 (6 GNs)	Loggal (2 GNs)
Opinions and concerns for the proposed project	➢ Request to hold consultation meetings when it is realized at the site with local authorities and communities ➢ Afraid of landslide. The local people have never experienced it, though.	➢ Request to hold consultation meetings when it is realized at the site with local authorities and communities. ➢ Compensation should be properly negotiated (lower). ➢ Afraid of landslide. They said that some small stones fell from the mountain (lower).	➢ The monk of Pitamadura (upper) suggested to hold consultation meetings with the local people. ➢ The local people basically do not like to relocate the Buddhist temple, because it is only the one in the area (lower).

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6-1) Scoping for the three 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

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6-1) Environmental Study (2)

1) Environmental Study (2) will be conducted at the three promising sites to collect information on the scoping items by the University of Peradeniya.
2) The Study will start in December 2013 and finish in May 2014.

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6-1) Information collection to identify one site from the environmental point of view

(1) Objective

To collect information on the three promising sites from the environmental aspects to identify the most promising site with less impacts on the environments.

(2) Methodology

a) Based on the information (existing data, and collected data by the field surveys), firstly the Sri Lankan experts examine the scale of expected impacts.

b) Secondly the JICA Study Team examines the results with other aspects (technical and economic aspects).

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Opinions, comments or suggestions we need,

- Confirmation of 3 Promising Candidate Sites
  - about 3 promising sites
  - about applied method for evaluation and selection
- Selection of Most Promising Candidate Site
  - Evaluation Method
  - Priority and/or absolute Condition for site selection

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Are there any comments or suggestions

1. …
2. …
3. …

E-mail address: cegp@ceb.lk, and Katsu_Hagihara@jpower.co.jp

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Development Planning on Optimal Power Generation for Peak Power Demand

(Stake Holders Meeting- 3)

May 27, 2014

CEYLON ELECTRICITY BOARD Enrich Life through Power

1

CONTENTS

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Session I Review of the Study

1. Necessity of the Study
2. Progress of the Study to date
3. Review of Prior Stakeholders Meetings
4. Briefing of 3 Promising Sites of PSPP
5. Integrated Development of PSPP with CST & LNGCC

Notes	
PSPP:	Pumped Storage Power Plant
CST:	Coal Steam Thermal
LNGCC:	LNG Combined Cycle

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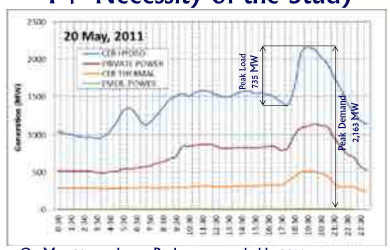
I-1 Necessity of the Study



- On May 20, maximum Peak was recorded in 2011.
- Peak Load was around 735MW.
- It was supplied by the Power Source of CEB Thermal (180 MW) Private Power (130 MW) and CEB Hydro (420 MW).

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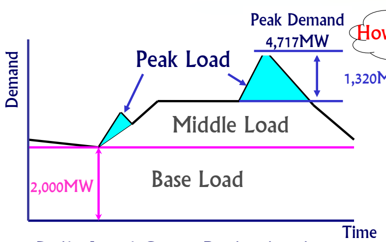
I-1 Necessity of the Study



Daily Load Curve Projection in 2025

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I-1 Necessity of the Study

Peak Load was supplied by;

a) Thermal Power ⇨ Expensive because of high price of petroleum fuel

b) Hydropower ⇨ Uncertain under the influence of precipitation level

Current Studies in practice in Energy Sector:

a) Reduction in Electricity Tariff ⇨ Coal Fired Steam Thermal

b) Diversification of Fuel to generate power ⇨ LNG Combined Cycle

c) Reliable and Economical Power for Peak Load ⇨ Pumped Storage

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I-2 Progress of the Study to date

Stage 1: Initial Evaluation Stage

- March 2013 to June 2013
- JCC1: Inception Presentation
- Seminar: Pumped Storage
- SHM1: Option for Peak Power Demand

Stage 2: Formation of Power Development Plan for Peak Demand

- July 2013 to October 2013
- JCC2: Confirmation of Criteria for Site Selection
- Interim Report

Stage 3: Investigation on Candidate Sites for Peak Load Power Plants

- November 2013 to October 2014
- SHM2: Confirmation of Identified 3 Sites
- JCC3: Confirmation of Criteria for Most Promising Site Selection
- SHM3:Confirmation of Most Promising Site
- Pre-DF/R, DF/R and Final Report

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CEYLON ELECTRICITY BOARD

I-2 Progress of the Study to date

Project Stage		Time Scale
Master Plan Stage	Selection of Options	June 27, 2013 SHM - 1
	Site Selection	May 27, 2014 SHM - 3
Feasibility Study Stage	Basic Design	2015 to 2017
Detailed Design Stage	Detailed Design	2018 to 2020
Construction Stage	Construction	2019 to 2025
Operation Stage	Operation	from 2025

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CEYLON ELECTRICITY BOARD

I-3 Review of Prior Stakeholders Meetings

- June 27, 2013: First Stakeholders Meting (SHM-1)
  - Among power generation options for peak power demand, it was confirmed that Pumped Storage Power Plant is the optimal option.
  - Selection method of 3 Promising Sites from 11 candidate sites for Pumped Storage Power Plant was accepted.
- November 21, 2013: Second Stakeholders Meeting (SHM-2)
  - Halgran 3, Maha 2, and Loggal were selected as 3 promising sites among 11 candidate sites from the environmental, technical & economical point of view.

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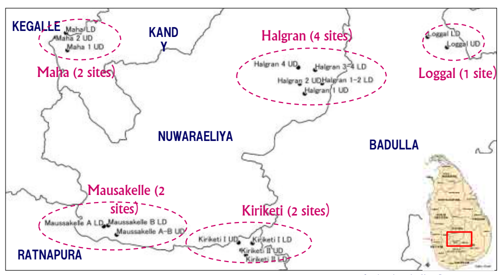
I-4 Briefing of 3 Promising Sites of PSPP

Location of 11 candidates sites



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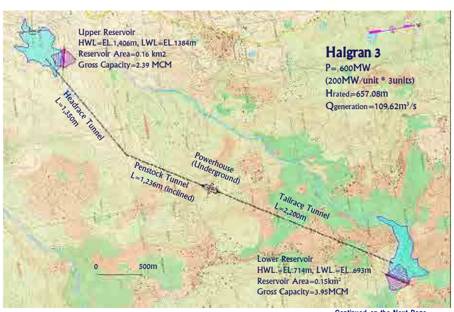
I-4 Briefing of 3 Promising Sites of PSPP



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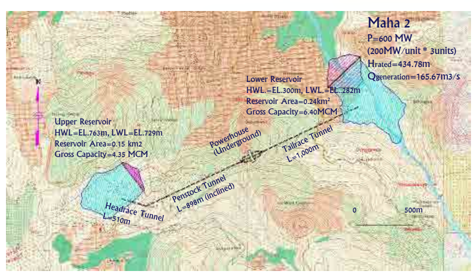
I-4 Briefing of 3 Promising Sites of PSPP



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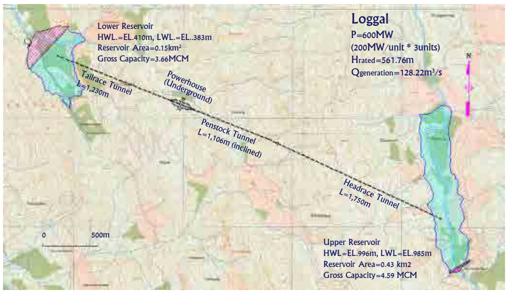
I-4 Briefing of 3 Promising Sites of PSPP



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I-5 Integrated Development of PSPP with CST & LNGCC

- March 27, 2014, Joint Coordinating Committee Held at MOPE
  - Explained & confirmed on the criterion for the site selection.
  - MOPE requested to check the PSPP feasibility for other scenario of coal restricted cases.
- Study Team selected following cases in addition to Revised Base Case
  - Case 9: Coal limited around 60% from Total Generation
    (Plant Mix up to 2025)
    Coal; 2,600 MW, LNG; 750 MW (New Plants)
  - Case 7: No coal plants permitted after Trincomalee Development
    Coal; 2,000 MW, LNG; 1,250 MW (New Plants)

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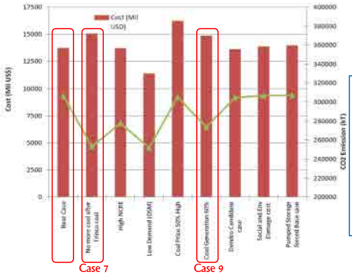
I-5 Integrated Development of PSPP with CST & LNGCC



This Figure is quoted from LTGEP 2013-2032.

Among Base case and LNG scenario cases in LTGEP;

- Base Case is least PV cost.
- Case 7 is highest PV cost, but lowest CO2 emission case.
- Case 9 is high PV cost, but low CO2 emission case.

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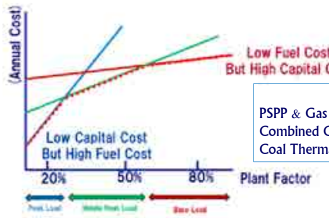
I-5 Integrated Development of PSPP with CST & LNGCC

- Conceptual Explanation of Best Mix of Power Sources



In General
PSPP & Gas Turbine for Peak Load
Combined Cycle for Middle Load
Coal Thermal for Base Load

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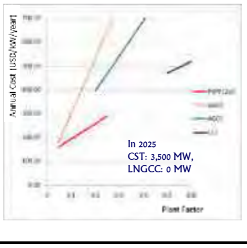
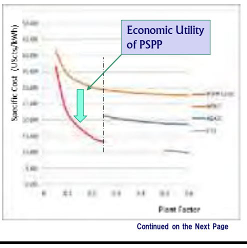
I-5 Integrated Development of PSPP with CST & LNGCC

- Annual Cost and Specific Cost in LTGEP Scenario Revised Base Case





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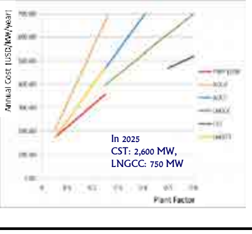
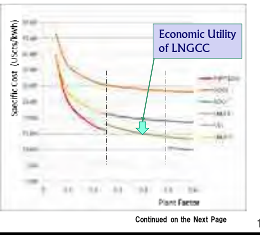
I-5 Integrated Development of PSPP with CST & LNGCC

- Annual Cost and Specific Cost in LNGCC Scenario Case 9
  (Coal Limited around 60% from Total Generation)





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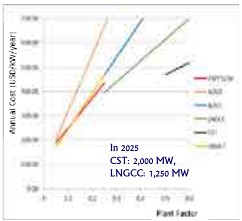
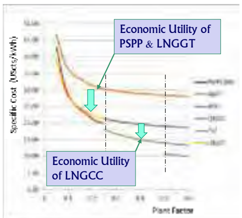
I-5 Integrated Development of PSPP with CST & LNGCC

➢ Annual Cost and Specific Cost in LNGCC Scenario Case 7
(No Coal Plants permitted after Trinco Coal Case)





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I-5 Integrated Development of PSPP with CST & LNGCC

➢ Superiority of PSPP compared with other options for Peak Power Generation
- Better Economical Efficiency as Peak Load Generation even in coal restricted cases
- Stable Peak Power Generation free from Drought
- Contribution to efficiency improvement of Base Load Generation
- Contribution to Stability of Power System
- Facilitation of Renewable Energy Development
- Suitable as Stand-by Generator when system major outage

I-5 Integrated Development of PSPP with CST & LNGCC

Three Studies for New Power Generation using Japanese ODA Scheme are Ongoing:
- Coal Steam Thermal PP as a base load generation project for reduction of electricity tariff
- Pumped Storage PP as an optimal peak power generation for reduction of electricity tariff & stable electric system
- LNG Combined Cycle PP with LNG terminal for energy security, best mix of power sources & reduction of CO_2 emission in future

Continued on the Next Page

Development Planning on Optimal Power Generation for Peak Power Demand

Stake Holders Meeting- 3

Session II, III, IV

May 27, 2014

CEYLON ELECTRICITY BOARD Enrich Life through Power

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CONTENTS

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Session II

II-1 Technical/Economic Evaluations

- Topographic and Geological Survey[*1] (by Local Consultants)
- Review of Pumped Storage Project Planning
- Evaluation from Geological Aspects, Manufacturing Limitations
- Transmission Planning & Power System Analysis

II-2 Environmental Evaluations

- Detailed Environmental Survey [*2](by Local Consultants)
- Evaluations of 3 Promising Sites by the results of "Detailed Survey"

Note *1, *2;) In *Loggal* site, both of the survey works was suspended for a certain period due to protesting of local people, so that the topographic & geological surveys were canceled and some parts of the environmental surveys were also canceled.
In *Maha 2 Upper dam* site, some parts of the environmental surveys were canceled due to similar reasons.

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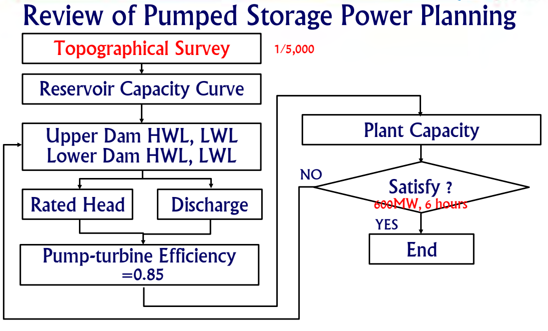
Session II-1

Review of Pumped Storage Power Planning



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Session II-1

Three Promising Candidate Sites

	Halgran 3	Maha 2		Maha 3		Loggal	
Location	Nuwara Eliya	Kandy, Kegalle		Kandy, Kegalle		Badulla	
Installed Capacity	600 MW	600 MW		600 MW		600 MW	
Unit Numbers	3	3	4	3	4	3	4
Unit Capacity	200 MW	200 MW	150 MW	200 MW	150 MW	200 MW	150 MW
Generating Hours	6 hours	6 hours		6 hour		6 hours	
Upper Dam	H70m*L210m	H80m*L250m		H61m*L275m		H42m*L220m	
Lower Dam	H75m*L280m	H71m*L350m		H68m*L350m		H76m*L540m	
Headrace Tun.	D4.9m*L1,350m	D6.0m*510m		D5.7m*L1,100m		D5.3m*1,750m	
Penstock Tun.	D3.8m*L1,212m	D4.7m*L885m		D4.4m*L979m		D4.1m*L1,106m	
Tailrace Tun.	D5.40*2,200m	D6.6m*1,000m		D6.2m*500m		D5.8m*L1,230m	

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Session II-1

Three Promising Candidate Sites Location

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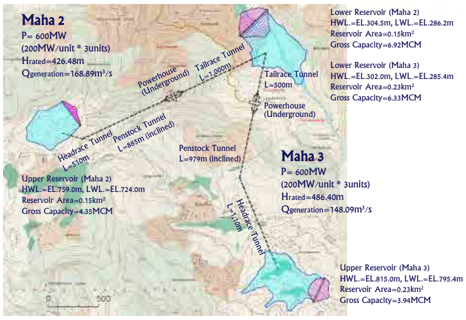
Session II-1

Reviewed Maha Sites



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Session II-1

Technical Evaluation

(1) Geological Aspect
Evaluated by results of *Geological survey (1)*

(2) Ease of Construction Works
Evaluate the ease of construction works on main civil works (Upper dam, Lower dam, Intake/Outlet structures, waterways, Powerhouse, etc.

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Session II-1

Technical Criteria (cont.)

(3) Limitation of Pump-turbine Manufacturing
- Reviewed by revised specifications
- Applicability of 200 MW/unit 150MW/unit

(4) Stability of Power System
- Evaluated by Power System Analysis

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Session II-1

Geological Aspects

Excellent, Good, Fair, Poor: A, B, C, D

Items	Halgran 3			Maha 2			Maha 3			Loggal		
	UD	LD	Route	UD	LD	Route	UD	LD	Route	UD	LD	Route
Rock Quality	B	C	B	A	B	B	B	B	B	A	B	B
Impermeability	C	C		B	B		B	B		B	B	
Faults	B	B	C	A	C	B	A	C	A	A	A	B
River bed Deposit	A	B		A	A		A	A		A	C	
Slope Sliding	A	C		A	C		B	C		A	B	
Direction			C			A			C			A
Overall Evaluation	C			A			B			C		

Evaluation on Loggal is made by the data of previous stage.

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Session II-1

Evaluation from Ease of Construction Aspects

Easiness of works; A>B>C>D
Construction Cost; D>C>B>A

	Halgran 3	Maha 2	Maha 3	Loggal
Access to Upper Dam	C	B	A	B
Access to Lower Dam	B	B	B	C
Temporary Yards	B	B	B	B
Length of Access to PH	C	B	A	C
Drawdown depth	B	C	B	B
Overall Evaluation	C	B	A	C

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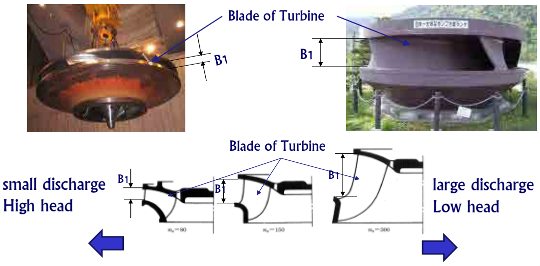
Session II-1

Manufacturing limitation of Pump-turbine



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Session II-1

Manufacturing limitation of Pump-turbine

- Margin to the criteria; A>B>C, not applicable; D,
- for "Overall Evaluation" A; both applicable, C; only 200 MW applicable, D; both not applicable)

	Halgran 3	Maha 2	Maha 3	Loggal
200 MW/unit	B	A	A	A
150 MW/unit	D	A	A	B
Overall Evaluation	C	A	A	B

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Session II-1

Transmission Line; Maha2 and Maha 3

1 To "Kotomale – Kirindiwela T/L" (PI Connection)

2 To "Kotomale PS"

3 To "New Polpitiya SS"

4 To "Kirindiwela SS"

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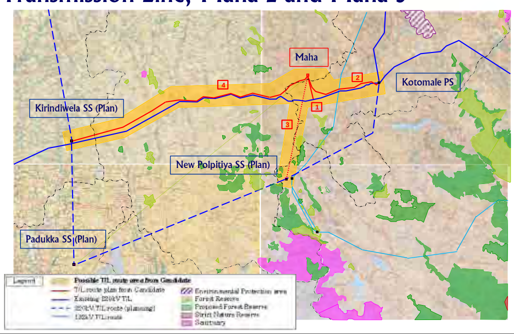
Session II-1

Transmission Line; Maha 2 and Maha 3



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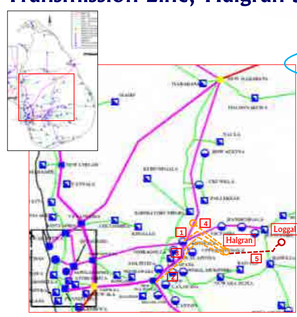
Session II-1

Transmission Line; Halgran 3 and Loggal



From "Halgran"

1 To "Kotomale PS"

2 To "New Polpitiya SS"

3 To "Existing T/L" near Kotomale PS (PI Connection)

4 To "New GS" near Kotomale PS

From "Loggal"

5 To "Kotomale PS" through "Halgran area" (T or PI Connection)

As for "Halgran area" to each connecting point, T/L routes are same as 1 to 4 of "Halgran" as above.

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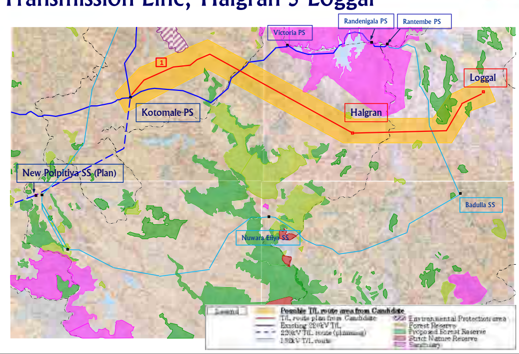
Session II-1

Transmission Line; Halgran 3 Loggal



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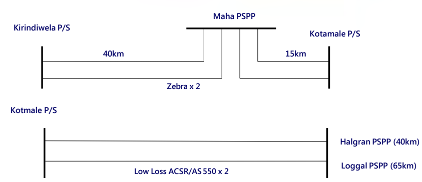
Session II-1

Power System Analysis; Conditions

Transmission Line



Generating & Loading Scenario

- Hydro Maximum Night Peak – Generating Operation
- Thermal Maximum Night Peak – Generating Operation
- Off Peak – Pumping Operation

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Session II-1

Power System Analysis; Results

Margin for the criteria; A>B>C, less than the criteria: D

Items	Halgran 3	Maha 2	Maha 3	Loggal
Power Fault Analysis	A	B	B	A
Short Circuit Currents Analysis	A	A	A	A
Stability to 3-phase line fault	A	A	A	D
200 MW unit Trip	B	B	B	B
Overall Evaluation	A	B	B	D

Power fault analysis: No thermal criteria violation in N-1 but Maha 2 and Maha 3 margins are smaller Halgran and Loggal
Stability to 3-phase line fault: Unstable and Step out in Loggal due to rather long transmission line
200 MW unit Trip in off-peak: Stable and within 49.0 to 51.0 Hz

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Session II-1

Economic Evaluation
Construction Cost

Power Plants: *1/5,000 topographic maps* → Review of PSPP Planning → Construction Cost

Transmission Line: *1/50,000 maps* → (Technical, Environmental) → T/L routes → Distance of T/L → Construction Cost

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Session II-1

5) Evaluation from Construction cost

Rating
- A Less than 1,200 USD/kW
- B 1,200 - 1,300 USD/kW
- C 1,300 – 1,400 USD/kW
- D More than 1,400 USD/kW

	Unit	Halgran 3	Maha 2	Maha 3	Loggal
Construction Cost	MUSD	725	750	672	855
	USD/kW	1,209	1,251	1,120	1,425
Evaluation		B	B	A	D

Note;
- Cost for 600MW Pumped Storage Projects (for example, 800 -1,000 USD/kW for more than 1,000 kW class PSPP in South-west & South-east Asian countries)
- Interest during construction included
- Construction Cost for Transmission lines included
- Calculated based on JICA Hydropower Development Manual

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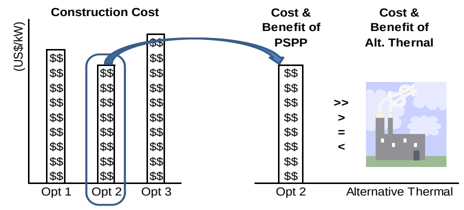
Session II-1

Economic Analysis (for reference)



Step 1: Select lowest cost option among candidate sites

Step 2: Confirm economic efficieicy of selected PSPP over alternative thermal power

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Session II-1

2) Economic Aspects
Cost-Benefit Analysis

- **Cost**
  - Capital cost: Construction, engineering, environment, land acquisition, compensation
  - OM cost
  - Electricity cost for pump-up by coal power
- **Benefit (Avoidable cost of thermal power)**
  - Capital cost of gas-turbine
  - OM cost
  - Fuel cost for generation

=> Assessment of economic efficiency by IRR

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Session II-1

Economic Analysis (reference)

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Session II-2

Environmental Evaluations

1) The Environmental Study (2) has been was conducted at the three (3) promising sites to collect information on the scoping items. The scoping items were presented at the 2nd SHM and agreed among the participants.
2) The Study has been undertaken by the University of Peradeniya, headed by Prof. Hennayake.
3) The results have been utilized by the JICA Study Team to compare the three candidate sites to select the most promising site.

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Session II-2

Environmental Study (2); 3 Promising Sites

The following scoping table was presented at the 2nd SHM, and the Study has been conducted.

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

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Session II-2

Environmental Study (2); Transmission Line

An assessment on **the transmission lines** is conducted as part of the Study.

1) Alternative routes with buffer zones are selected by CEB and the transmission experts considering the following points.
   - To connect to the existing and planned facilities
   - To avoid major barriers (populated areas, major public facilities, cultural heritages)
   - To avoid protected areas, forest reserves and IBAs
2) The routes are assessed by the Study.

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Session II-2

Evaluation from Environmental Aspects

Site / Evaluation Items		Halgran	Maha 2	Maha 3	Loggal
Impacts on fauna and flora	Forest area	C	D	D	C
	Endangered species (fauna)	D	D	D	D
	Endangered species (flora)	D	C	C	D
	Ecosystem	D	C	C	C
Impacts on local communities	Resettlement	B	D	C	C
	Acquired land	B	C	C	D
	Losing livelihood	D	D	C	C
	Public facilities	A	A	A	C
	Water utilization	C	D	D	D
Impacts on industries	Agriculture	A	C	C	D
	Tourism	A	A	A	A
Impacts on culture and landscape	Religious and cultural sites	A	C	C	C
	Landscape	A	B	B	A

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Session II-2

Evaluation from Environmental Aspects

Natural environment

- Area of inundated forest at each site is relatively small.
- All sites have some endangered species. Halgran site has two Critically Endangered species.
- Biodiversity and species richness are moderate to high.
- All sites are outside of the protected areas (e.g. reserved forests and national parks).

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Session II-2

Evaluation from Environmental Aspects

Social environment: Impacts on local communities

- Families to be resettled

  Halgran: 4 families; Maha 2: 45 families; Maha 3: 39 families; and 25 families
- Area to be acquired

  Halgran: 30 ha; Maha 2: 38 ha; Maha 3: 46 ha; and Loggal: 53 ha

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Session II-2

Evaluation from Environmental Aspects

Social environment: Impacts on industries

- Agriculture land to be inundated

  Halgran: 19 ha; Maha 2: 32 ha; Maha 3: 39 ha; and Loggal 48 ha.

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Session II-2

4-6) Evaluation from Environmental Aspects

Social environment: Impacts on culture and landscape

- All clusters have religious temples. They are not registered religious temples, but they are important for the local people.

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Session II-2

4-6) Evaluation from Environmental Aspects

Transmission lines

- There are no major problems on their routes / buffer zones.

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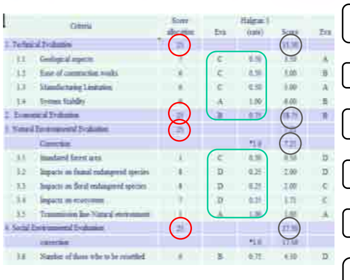
Session III

Overall Evaluation and Ranking for the Most Promising Site



Rating A, B, C, D (1.0, 0.75, 0.5, 0.25)

↓

Score Allocation

↓

Score of each criterion

↓

Total Score of 1.,2., …, 4

↓

Total Score Corrrection

↓

Ranking (Even-case, Environment Weighed-case)

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Session III-1

7) Ranking of Candidate Sites

- Even case Tech. Econo.(1+2) : Env.(3+4)=50 : 50

	Score Allocation	Halgran 3	Maha 2	Maha 3	Loggal
1. Technical Evaluation	25.00	15.50	22.00	21.75	12.50
2. Economic Evaluation	25.00	18.75	18.75	25.00	6.25
3. Natural Environment	25.00	7.25	9.68	10.75	7.20
4. Social Environment	25.00	17.50	10.35	13.75	9.40
Total	100.00	59.00	60.78	71.25	35.35
Rank		3	2	1	4

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Session III-1

7) Ranking of Candidate Sites

- Environmental weighed case (1+2) : (3+4)=30 : 70

	Score Allocation	Halgran 3	Maha 2	Maha 3	Loggal
1. Technical Evaluation	15.00	9.30	13.20	13.05	7.50
2. Economic Evaluation	15.00	11.25	11.25	15.00	3.75
3. Natural Environment	35.00	10.15	13.55	15.05	10.08
4. Social Environment	35.00	24.50	14.49	19.25	13.16
Total	100.00	55.20	52.49	62.35	34.49
Rank		2	3	1	4

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Session III-1

8) Ranking of Candidate Sites, Environment Aspects

Environmental Evaluation-Even Natural : Social = 50 : 50

	Score Allocation	Halgran 3	Maha 2	Maha 3	Loggal
3. Natural Environment	25.00	7.25	9.68	10.75	7.20
4. Social Environment	25.00	17.50	10.35	13.75	9.40
Total	50.00	24.75	20.03	24.50	16.60
Rank		1	3	2	4

Environmental Evaluation - Natural : Social = 70:30

	Score Allocation	Halgran 3	Maha 2	Maha 3	Loggal
3. Natural Environment	35.00	10.15	13.55	15.05	10.08
4. Social Environment	15.00	10.50	6.21	8.25	5.64
Total	50.00	20.65	19.76	23.30	15.72
Rank		2	3	1	4

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Session III-1

Environments of Maha 3 – upper site

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Session III-1

Environments Maha 3 – upper site

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Session III-1

Environments Maha 3 – lower site

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Session III-1

Environments of Maha 2-3 – lower site

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Session III-1

Environments of Maha 2-3 – lower site

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Session III-2

…Next Phase of the Study

For the Most Promising Site,

1. Topographic Survey; Dams Area (1:1,000)
2. Geological Survey (Drilling Investigations at Upper dam and Lower dam)
3. Preliminary design by 1 to 1,000 topographic map
4. PI preparations
5. Draft Final Report (on August by the initial schedule)
6. Final Report (on October by the initial schedule)

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Session IV

Overall Discussion & Conclusion

- Selection of Most Promising Candidate Site
  - Evaluation method applied
  - Evaluation results, etc.
- Confirmation of the Most Promising Site
- Suggestions for the next phase study

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Session IV

Are there any comments or suggestions

1. …
2. …
3. …

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Trial Calculation of Contribution to Greenhouse Gas Reduction by Pumped Storage Power Project

1. Since Pumped Storage Power Plant (PSPP) needs power sources for pumping, the emission amount of CO_2 from PSPP is expressed as the summation of that by itself and by power plants for pumping energy. Consequently, the concept of life cycle CO_2 emission as eigenvalue index, which is commonly used for power generation option, seems unfit for PSPP, because CO_2 emission from PSPP is subject to the lineup of power plant of whole power supply system.

2. CO_2 emission from PSPP is expressed as follows;
(CO_2 emission of pumping energy) × (1/70%) + (indirect CO_2 emission from PSPP) – (contribution of PSPP to decreasing CO_2 emission)

3. The component of energy sources in 2025 (as a year for trial computation) is as following table from LTGEP 2013-2032;

Power Source	Annual Energy（GWh）	Component Ratio（%）
Major Hydro	4,692	19.3
Coal Thermal	17,731	73.0
Oil Thermal	233	1.0
Wind	869	3.6
Solar	153	0.6
Mini-hydro & Dendro	604	2.5
Total	24,282	100.0

4. Life Cycle CO_2 emission from each power source is tabulated as follows (source: CRIEPI News No. 468, August 2010);

Power Source	Direct Emission ($g\text{-}CO_2/kWh$)	Indirect Emission ($g\text{-}CO_2/kWh$)	Total ($g\text{-}CO_2/kWh$)
Hydro	0	11	11
Coal Thermal	864	79	943
Oil Thermal	695	43	738
Wind	0	25	25
Solar	0	53	53
LNG CC	376	98	474

5. Weighted average of CO_2 emission from whole power supply system can be calculated as 699 $g\text{-}CO_2/kwh$ (assuming CO_2 emission from mini-hydro and dendro is same as hydro) from the tables in the Clause 3 and 4.

6. Assuming indirect emission of PSPP is same as hydro;
699 $g\text{-}CO_2/kWh$ × 1/70% ＋ 11 $g\text{-}CO_2/kWh$ － (contribution of PSPP to decreasing CO_2 emission)
= 1,010 $g\text{-}CO_2/kWh$ － (contribution of PSPP to decreasing CO_2 emission)

7. That is, CO_2 emission of PSPP is evaluated as being equivalent or more than that of Coal Fired Thermal, in case that contribution of PSPP to decreasing CO_2 is not considered.

8. As contribution of PSPP to decreasing CO_2 emission, increment of wind power development by PSPP installation is considered, under the assumption that energy generated by wind power increment can replace that by coal thermal plant. CO_2 emission reduction is calculated as follows;
   1) Critical condition for wind power development is whether long period output fluctuation (zero-full) cause by wind power particularly in off-peak demand duration can be absorbed or not. In case of isolated Sri Lankan power system, it is usually contemplated that maximum capacity of wind powers installation is around 10% of the total system capacity.
   2) If PPSP is installed, long period output fluctuation having adverse impact to the power system as mentioned in the Clause 1) is absorbed by PPSP operation during off-peak demand.
   3) That is, if 600MW PSPP is installed, 600MW of wind powers can be developed other than 10% of the power system capacity.
   4) If the off peak power system capacity in 2025 is assumed as 2,000MW, maximum capacity of wind powers to be installed is 800MW (2,000MW×10%＋600MW). Since wind power capacity planned already is 310MW according to the table in the Clause 3, another 490 MW wind powers can be developed.
   5) Assuming plant factor of wind power as 20% and that of coal thermal 80%, 490MW wind power is equivalent to 122MW (490MW × 20% / 80%) coal thermal in respect of energy generation. This means the 600MW PSPP can replace 122MW coal thermal with 490 MW wind power in 2025.
   6) Deduction of CO_2 emission by this replacement can be considered as contribution of PSPP to decreasing CO_2 emission which is expressed as follows (assuming plant factor of PSPP as 25%);.

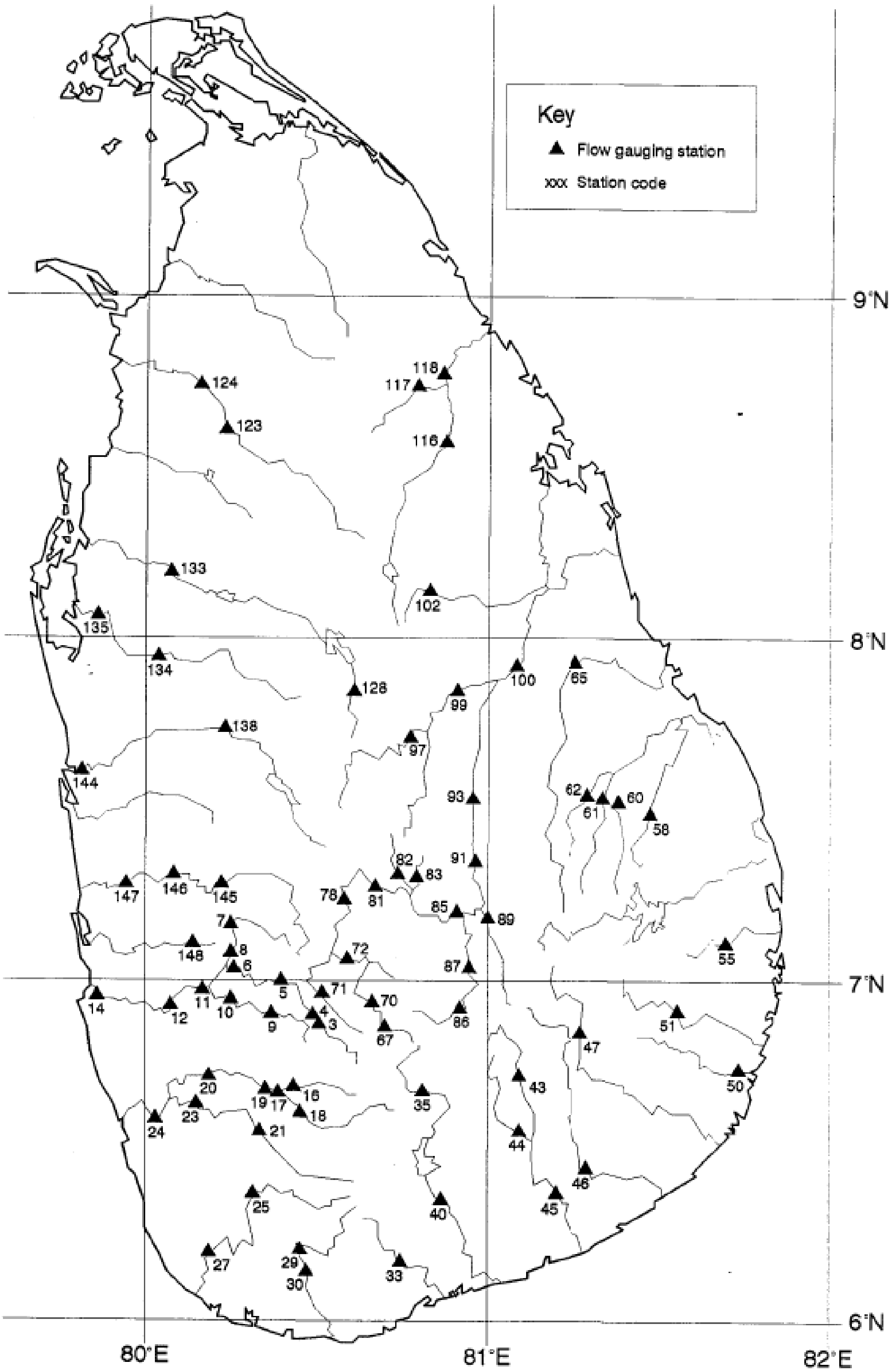
   (943 g-CO_2/kWh × 122MW×80% – 25 g-CO_2/kWh × 490MW × 20%) / (600 MW × 25 %) = 597 g-CO_2/kWh

9. Hence, CO_2 emission is calculated again by the formula in the Clause 2;

   699 g-CO_2/kWh × (1/ 70%) + 11 g-CO_2/kWh – 597 g-CO_2/kWh = 413 g-CO_2/kWh

10. If the value calculated in the Clause 9 can be regarded as basic unit of CO_2 emission in 2025, it is judged that CO_2 emission by PPSP is equivalent to that of LNG CC (474 g-CO_2/kWh) as a quantitative evaluation result including contribution of PSPP to decreasing CO_2 emission.

River Flow Gauging Stations in Sri Lanka



Station code	Name	No. years	Latitude (°N)	Longitude (°E)	MAF (m^3/s)	AREA (km^2)	AAR (mm)
SRI003	Maskeli Oya at Mausakele	'19	06:52:30	80:31:30	347	122	2820
SRI004	Maskeli Oya at Laxapana	12	06:53:10	80:31:05	274	154	3170
SRI005	Kelani Ganga at Kitulgala	40	06:59:30	80:24:45	706	383	3670
SRI006	Kelani Ganga at Matiyadola	33	07:01:34	80:16:26	802	606	3930
SRI007	Gurugoda Oya at Holombuwa	18	07:11:35	80:15:45	224	155	3330
SRI008	Gurugoda Oya at Imbulanala	26	07:03:47	80:15:40	343	329	3420
SRI009	Sitawaka Ganga at Deraniyagala	28	06:55:15	80:20:40	332	154	4950
SRI010	Sitawaka Ganga at Algoda	16	06:56:55	80:15:40	634	344	4620
SRI011	Kelani Ganga at Glencourse	39	06:58:30	80:10:51	1708	1463	4060
SRI012	Kelani Ganga at Hanwella	14	06:54:36	80:05:00	1603	1782	3840
SRI014	Kelani Ganga at Nagalagam Street	33	06:57:30	79:52:30	1314	2085	3940
SRI016	Kalu Ganga at Malwala	24	06:41:15	80:25:24	759	329	4420
SRI017	Kalu Ganga at Ratnapura	12	06:40:36	80:24:18	407	604	3420
SRI018	Wey Ganga at Dela	31	06:37:20	80:27:10	133	220	2720
SRI019	Kalu Ganga at Nambapana	22	06:41:11	80:23:05	499	629	3740
SRI020	Kalu Ganga at Ellagawa	32	06:43:52	80:13:00	674	1393	4010
SRI021	Kukule Ganga at Kukulegama	9	06:33:48	80:19:48	403	334	3280
SRI023	Kuda Ganga at Millakanda	27	06:37:25	80:10:25	438	769	4230
SRI024	Kalu Ganga at Putupaula	41	06:36:40	80:03:55	1073	2598	3970
SRI025	Gin Ganga at Tawalama	13	06:20:30	80:19:48	726	377	3910
SRI027	Gin Ganga at Agaliya	53	06:11:15	80:11:45	369	681	3850
SRI029	Nilwala Ganga at Pitabeddhara	14	06:12:42	80:29:00	208	333	3400
SRI030	Nilwala Ganga at Bopagoda	44	06:09:20	80:29:05	328	411	3360
SRI033	Urubokka Oya at Julampitiya	11	06:11:10	80:44:40	73	141	2510
SRI035	Walawe Ganga at Samanalawewa	18	06:40:30	80:48:05	527	337	2860
SRI040	Walawe Ganga at Embilipitiya	22	06:20:40	80:53:55	892	1580	2190
SRI043	Kirindi Oya at Wellawewa	29	06:43:55	81:06:25	140	159	2300
SRI044	Kuda Oya at Kuda Oya	21	06:31:30	81:07:24	543	291	1780
SRI045	Kirindi Oya at Lunuganwehera	25	06:21:40	81:13:10	560	913	1830
SRI046	Menik Ganga at Kataragama	37	06:25:25	81:19:45	335	787	1710
SRI047	Kumbukkan Oya at Nakkala	14	06:53:18	81:17:48	99	216	1390
SRI050	Wila Oya at Wedagama	9	06:45:42	81:44:36	221	404	1730
SRI051	Heda Oya at Siyambalanduwa	28	06:54:20	81:32:40	148	295	2080
SRI055	Pannal Oya at Thottama	13	07:06:30	81:41:25	168	95	1880
SRI058	Magalavadavan Aru at Periya Aru	32	07:30:05	81:29:20	268	119	2060
SRI060	Rambukkan Oya at Nilobe	30	07:30:40	81:22:40	126	161	2150
SRI061	Maha Oya at Maha Oya	11	07:31:54	81:26:36	282	300	2150
SRI062	Galodai Aru at Weragoda	35	07:33:35	81:19:50	156	224	2140

Station code	Name	No. years	Latitude (°N)	Longitude (°E)	MAF (m^3/s)	AREA (km^2)	AAR (mm)
SRI065	Maduru Oya at Welikanda	29	07:56:10	81:15:15	754	1062	2100
SRI067	Agra Oya at Holbrook	16	06:52:52	80:41:40	103	121	2390
SRI070	Kotmale Oya at Talawakele	23	06:56:25	80:39:45	269	290	2390
SRI071	Mahaweli Ganga at Watawala	18	06:56:50	80:32:10	72	65	3950
SRI072	Kotmale Oya at Morape (Nedeco)	31	07:03:40	80:37:20	481	531	2760
SRI078	Mahaweli Ganga at Peradeniya	37	07:15:42	80:35:30	1264	1189	2970
SRI081	Mahaweli Ganga at Gurudeniya	33	07:16:30	80:40:30	1412	1417	2810
SRI082	Hulu Ganga at Teldeniya	23	07:17:48	80:45:54	252	161	3560
SRI083	Galmal Oya at Moragahamula	16	07:16:57	80:48:26	161	73	3670
SRI085	Mahaweli Ganga at Randenigala (Nedeco)	24	07:12:10	80:56:10	1251	2370	2760
SRI086	Uma Oya at Welimada	17	06:54:15	80:54:30	167	179	2010
SRI087	Uma Oya at Talawakanda	19	07:00:30	80:58:25	262	505	1890
SRI089	Badulu Oya at Kandeketiya	15	07:10:30	81:00:24	209	387	2100
SRI091	Mahaweli Ganga at Weragantota (Nedeco)	35	07:19:02	80:59:10	2447	4040	2500
SRI093	Mahaweli Ganga at Hembarawa	10	07:31:35	80:58:20	1385	4530	2580
SRI097	Amban Ganga at Elahera (Nedeco)	33	07:40:45	80:45:25	421	772	2520
SRI099	Amban Ganga at Anagamedilla (Nedeco)	13	07:51:12	80:55:00	691	1435	2350
SRI100	Mahaweli Ganga at Manampitiya (Nedeco)	28	07:54:40	81:05:10	1666	7343	2500
SRI102	Gal Oya at Gal Oya	12	08:09:12	80:50:20	321	199	1590
SRI116	Yan Oya at Horowupotana	34	08:34:36	80:52:42	390	948	1520
SRI117	Yan Oya at Wahalkada	18	08:43:36	80:51:05	81	91	1620
SRI118	Yan Oya at Pangurugaswena	33	08:44:55	80:52:45	689	1311	1710
SRI123	Aruvi Oya at Kappachchi	35	08:35:45	80:16:30	690	2121	1450
SRI124	Malwathu Oya at Tekkam	11	08:44:30	80:11:00	1492	3072	1430
SRI128	Kala Oya at Dambulla	12	07:51:00	80:37:00	38	189	1780
SRI133	Kala Oya at Kala Oya	26	08:12:00	80:05:48	614	1948	1520
SRI134	Mi Oya at Mahauswewa	16	07:57:50	80:04:08	187	588	1450
SRI135	Mi Oya at Tabbowa	17	08:02:50	79:55:05	140	1077	1380
SRI138	Deduru Oya at Ridibandi Ela	18	07:43:42	80:15:48	746	1370	1940
SRI144	Deduru Oya at Chilaw	19	07:40:00	79:48:58	612	2611	1790
SRI145	Maha Oya at Alawwa	20	07:17:30	80:14:26	973	803	2450
SRI146	Maha Oya at Giriulla	26	07:19:30	80:06:55	815	1191	2480
SRI147	Maha Oya at Badalgama	31	07:18:10	79:58:50	860	1360	2380
SRI148	Attanagola Oya at Karasnagala	17	07:06:30	80:10:30	508	53	3170

Rain Gauge Stations Functioning

District Wise

Amparai District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01AM001E	ADDALACHENAI	7.23 N	81.85 E	0	10/1/2002
2	01AM001C	AKKARAIPATTU	7.22 N	81.85 E	16	4/1/1993
3	01AM0012	AMPARAI TANK	7.28 N	81.67 E	27.4	1879-01-01
4	01AM126C	GALMADUWA	0.00 N	0.00 E	0	1/1/2010
5	01AM0182	IRAKKAMAN	7.25 N	81.73 E	12.2	1869-01-01
6	01AM257A	KUDASIGIRIYA	7.68 N	81.13 E	0	1/1/1993
7	01AM368B	NAVATKIRI ARU TANK	7.47 N	81.72 E	16	1/1/1941
8	01AM373A	NEETHTHA	0.00 N	0.00 E	0	8/1/2009
9	43999	POTTUVIL	6.88 N	81.83 E	3.6	1868-01-01
10	01AM0459	SAGAMAM TANK	7.13 N	81.80 E	16	1879-01-01
11	01AM459A	SAMANTHURAI	7.37 N	81.68 E	0	10/1/2002
12	01AM493B	THIRUKKOVIL	7.07 N	81.82 E	5	6/8/2006
13	01AM509B	UHANA COCONUT	7.37 N	81.62 E	16	12/1/1991

Anuradhapura District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	43421	ANURADHAPURA	8.35 N	80.38 E	92.5	1870-05-08
2	01AN104A	EHETUGASWEWA	8.97 N	80.83 E	1,111.00	3/1/1990
3	01AN105B	ELAYAPATHTHUWA	8.40 N	80.32 E	16	12/1/1978
4	01AN109B	ELAYAPATHUWA-NLDB FARM	8.42 N	80.25 E	0	1/1/2004
5	01AN112A	EPPAWALA WATER SUPPLY	8.13 N	80.40 E	0	1/1/1994
6	01AN141A	HABARANA LODGE	8.05 N	80.77 E	0	4/1/2001
7	01AN172C	HOROWUPATANA,AGA OFFICE	8.55 N	80.15 E	16	10/1/1977
8	01AN174A	HURULUWEWA	8.22 N	80.72 E	16	1/1/1948
9	01AN193A	KAHATAGASDIGILIYA W/S	8.42 N	80.68 E	0	1/1/1994
10	01AN197A	KALAWEWA COCONUT	8.02 N	80.53 E	16	5/1/1993
11	01AN0197	KALAWEWA TANK	8.00 N	80.53 E	122	1888-12-01
12	01AN227A	KEBITHIGOLLEWA W/S	8.63 N	80.67 E	0	2/1/1995
13	01AN233A	KEKIRAWA WATER SUPPLY	8.03 N	80.58 E	0	1/1/1994
14	43422	MAHA ILLUPPALLAMA	8.12 N	80.47 E	117.2	1868-01-01
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Badulla District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01BD0006	ALUTHNUWARA	7.32 N	81.00 E	92	1899-10-01
2	43479	BADULLA	6.98 N	81.05 E	669.6	1868-09-01
3	01BD0034	BANDARA ELIYA ESTATE	6.78 N	81.02 E	0	1/1/1935
4	143476	BANDARAWELA	6.82 N	80.97 E	1,225.30	8/20/1990
5	01BD0036	BANDARAWELA-IRRIGATION	6.83 N	80.98 E	1,219.50	4/1/1947
6	01BD048B	BOGAHAMADITTA	6.97 N	81.05 E	111	4/1/1991
7	01BD058A	CANAWARELLA GROUP	6.90 N	81.12 E	1,237.80	1/1/1941
8	01BD074D	DAMBATENNE	6.78 N	81.00 E	1,566.00	8/1/1996
9	01BD0079	DEBEDDE ESTATE	6.95 N	81.12 E	16	11/1/1925
10	01BD093A	DIYATALAWA-SURVEY CAMP	6.82 N	80.97 E	111	10/1/1990
11	01BD0102	DYRABBA ESTATE	6.88 N	80.93 E	1,299.50	3/1/1914
12	01BD126A	GALOOLA ESTATE	7.07 N	81.15 E	16	4/1/1972
13	01BD127A	GALPURAYAYA - G/KOTTE	7.45 N	81.02 E	125	12/1/2002
14	01BD134E	GIRADURUKOTTE	7.45 N	81.02 E	80	3/1/2006
15	01BD134C	GIRANDURUKOTTE W/S	7.45 N	81.08 E	0	6/1/1995
16	01BD135A	GLEN ALPIN ESTATE	6.95 N	81.08 E	0	1/1/1993
17	01BD131A	GLENANORE	6.77 N	80.92 E	1,392.00	8/1/1996
18	01BD139B	GONAMOTAVA	6.78 N	80.98 E	1,348.00	8/1/1996
19	01BD152A	HAPUTALE FACTORY	6.77 N	80.95 E	1,418.00	8/1/1996
20	01BD159B	HILPANKANDURA ESTATE	7.52 N	80.15 E	16	4/1/1992
21	01BD193B	KAHAGALLA ESTATE	6.78 N	80.97 E	0	8/1/1996
22	01BD0207	KANDAKETIYA	7.17 N	81.02 E	16	4/1/1947
23	01BD0247	KIRKLEES ESTATE	6.98 N	80.93 E	1,432.90	2/1/1934
24	01BD0271	LEDGERWATTE ESTATE	7.03 N	81.02 E	16	1893-11-01
25	01BD0277	LOWER SPRING VALLEY	6.92 N	81.10 E	16	1884-08-01
26	01BD0290	MAHADOWA ESTATE	7.02 N	81.17 E	16	2/1/1902
27	01BD310A	MAPAKADAWEWA	7.27 N	81.03 E	16	1/1/1941
28	01BD330C	MICKLEFIELD FARM	6.85 N	80.88 E	0	1/1/1993
29	01BD368D	NAYABEDDE	6.80 N	80.00 E	0	8/1/1996
30	01BD411B	PASSARA TEA SHAKTHI	6.95 N	81.20 E	0	10/1/2005
31	02BD0025	PASSARA,AGMET	6.92 N	81.13 E	96	1/1/1990
32	01BD424C	PITARAT MALAI ESTATE	6.78 N	80.98 E	1,524.00	8/1/1996
33	01BD428F	POONAGALA GROUP, FACTORY	6.77 N	81.03 E	0	1/7/1997
34	01BD317Q	RANTEMBE	7.20 N	80.93 E	0	4/1/1997
35	01BD452A	RIDIMALIYADDA	7.22 N	80.12 E	200	6/27/2008
36	01BD473C	ST.CATHERINE DIVISION	6.78 N	81.02 E	0	8/1/1996
37	01BD501B	TISSAPURA	7.30 N	81.08 E	150	6/27/2008
38	01BD0539	WELIMADA GROUP	6.90 N	80.90 E	16	1/1/1941
39	01BD0541	WEST HAPUTALE-UDAVERIYA	6.78 N	80.83 E	1,707.00	4/1/1925
40	01BD0545	WEWESSA ESTATE	6.97 N	81.10 E	16	8/1/1913
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Batticaloa District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	43436	BATTICALOA	7.72 N	81.70 E	7.8	1869-02-01
2	01BT197B	KALKUDAH	7.88 N	81.55 E	0	7/1/1996
3	01BT0357	MYLAMBAVELLY ESTATE	7.77 N	81.63 E	16	4/1/1935
4	01BT410B	PASSIKUDA	7.93 N	81.55 E	5	4/29/2005
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Colombo District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01CB0016	ANGODA MENTAL HOSPITAL	6.93 N	79.92 E	15.2	4/1/1930
2	01CB0025	AVISSAWELLA ESTATE	6.92 N	80.18 E	228.7	1897-01-01
3	01CB0026	AVISSAWELLA HOSPITAL	6.95 N	80.22 E	30.5	1879-01-01
4	01CB0038B	BATTARAMULLA	6.90 N	79.92 E	15	4/5/2007
5	01CB469B	COLOMBO PORT	6.93 N	79.85 E	0	1/1/1993
6	2043466	COLOMBO, AGROMET	6.90 N	79.87 E	7.3	1/1/1976
7	01CB068A	CINNAMON LAKE SIDE HOTEL	6.92 N	79.83 E	0	1/1/1993
8	01CB0080	DEHIWALA ZOO	6.85 N	79.87 E	16	9/10/1936
9	01CB109A	ELSTON	6.93 N	80.17 E	16	1/1/1984
10	01CB0150	HANWELLA GROUP	6.88 N	80.12 E	16	6/1/1932
11	01CB166A	HOMAGAMA	6.83 N	80.02 E	11	11/1/1990
12	01CB0179	INDIKADE	6.88 N	80.15 E	16	1/1/1941
13	01CB0268	LABUGAMA TANK	6.83 N	80.18 E	16	1879-07-08
14	01CB369A	MEEGODA-NAWALAMULLA	6.87 N	80.03 E	0	6/3/2002
15	01CB0390	ORUWALA	6.88 N	80.00 E	16	2/1/1967
16	01CB393A	PADUKKA ESTATE	6.82 N	80.12 E	0	9/1/1993
17	43467	RATMALANA	6.82 N	79.88 E	5	1868-01-01
18	01CB469B	SRI LANKA PORT AUTHORITY	6.93N	79.85E		
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Galle District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01GL0030	BADDEGAMA ESTATE	6.18 N	80.18 E	15.2	10/1/1908
2	01GL0041	BEAUSEJOUR(LOWER)	6.15 N	80.33 E	61	1/1/1905
3	01GL041C	BENTOTA ESTATE	6.35 N	80.17 E	400	7/1/2007
4	01GL087C	DEVITURAI ESTATE	6.25 N	80.15 E	0	1/1/1994
5	43495	GALLE	6.03 N	80.22 E	12.5	1869-01-01
6	01GL164A	HINIDUMA	6.30 N	80.32 E	0	1/1/1994
7	01GL0165	HIYARE	6.07 N	80.32 E	100.6	1/1/1910
8	01GL0267	LABUDUWA	6.07 N	80.23 E	16	9/1/1928
9	01GL501A	TITAGALLA, HANDUNGODA	6.02 N	80.35 E	0	11/20/1996
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Gampaha District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01GM0011	AMBEPUSSA GOVT FARM	7.28 N	80.17 E	54.9	5/1/1927
2	01GM0158	HENARATHGODA BOT GRDNS	7.10 N	79.98 E	9.1	1891-01-01
3	43450	KATUNAYAKA	7.17 N	79.88 E	8.5	1868-01-01
4	01GM221B	KATUNAYAKE AIR FORCE	7.18 N	79.88 E	0	9/18/1996
5	01GM234A	KELEPITIMULLA	7.23 N	79.95 E	0	5/1/1996
6	01GM246A	KIRINDIWELA (COCONUT)	7.03 N	80.12 E	16	4/1/1992
7	01GM0373	NEGOMBO	7.22 N	79.83 E	3.1	1879-01-01
8	01GM378A	NITTAMBUWA	7.13 N	80.10 E	16	1/1/1993
9	01GM0412	PASYALA	7.15 N	80.13 E	16	10/1/1945
10	01GM487B	THAMMITA	7.10 N	79.95 E	0	5/1/1996
11	01GM0528	WALPITA	7.27 N	80.05 E	16	2/1/1941
12	01GM538B	WELISARA-NAVY	7.02 N	79.90 E	0	8/7/1997
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Hambanthota District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01HT0008	AMBALANTOTA GOVT. FARM	6.12 N	81.02 E	6.1	10/1/1921
2	01HT008A	AMBALANTOTA PADDY RESEAR	6.12 N	81.02 E	0	7/1/1995
3	01HT005A	ANGUNAKOLAPELESSA	6.17 N	80.88 E	16	4/1/1969
4	01HT028A	BADAGIRIYA TANK	6.23 N	81.15 E	16	3/1/1955
5	01HT0037	BATA ATA	6.10 N	80.92 E	24.4	10/1/1926
6	01HT037A	BATAATA	6.08 N	80.90 E	85	3/18/2006
7	01HT0053	BUNDALA LEWAYA	6.20 N	81.25 E	16	7/1/1947
8	43497	HAMBANTOTA	6.12 N	81.13 E	15.5	1869-01-01
9	01HT141C	HANDUNE_GALA	6.20 N	80.62 E	850	9/24/2008
10	01HT0244C	KEKIRIOBADA TANK	6.22 N	80.67 E	122	1879-01-01
11	01HT0276	LIYANGAHATOTA	6.23 N	80.93 E	16	2/1/1913
12	01HT280A	LUNUGAMWEHERA	6.33 N	81.20 E	16	5/1/1983
13	01HT0292	MAHA LEWAYA (HAMBANTOTA)	6.13 N	81.13 E	16	1/1/1937
14	01HT0303	MAMADOLA	6.13 N	80.97 E	16	1894-07-01
15	01HT356C	MURUTHAWELA WEWA	6.20 N	80.73 E	0	5/1/1995
16	01HT0396	PALATUPANA SALTERN	6.25 N	81.38 E	16	1/1/1932
17	01HT449C	RANMALA KANDA	6.23 N	80.63 E	87	10/23/2008
18	01HT0453	RIDIYAGAMA IRRIGATION	6.22 N	80.98 E	16	3/1/1923
19	01HT453A	RIDIYAGAMA IRRIGATION	6.18 N	80.97 E	0	1/1/1994
20	01HT460B	SAPUTHANTHRI KANDA	6.23 N	80.63 E	1,350.00	10/1/2008
21	01ht481a	SURIYAWEWA	6.32 N	80.00 E	200	1/1/1965
22	01HT484A	THALAPATH KANDA	6.22 N	80.62 E	1,100.00	9/1/2008
23	01HT0501	TISSAMAHARAMA IRRIGATION	6.28 N	81.30 E	16	1879-01-01
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Jaffna District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01JF062A	CHAVAKACHCHERI	9.67 N	80.17 E	16	1893-11-01
2	43404	JAFFNA	9.68 N	80.03 E	3.1	1871-01-14
3	01JF251A	KONDAVIL	9.70 N	80.03 E	16	1/1/1968
4	01JF0258	KUDATHANAI	9.73 N	80.27 E	16	6/1/1967
5	01JF360A	NAINATIVU	9.60 N	79.77 E	16	4/1/1956
6	01JF0425	POINT PEDRO	9.83 N	80.23 E	16	1891-03-01
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Kalutara District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01KT021A	ARAMANAGOLLA	6.73 N	80.05 E	0	2/1/1984
2	01KT0035	BANDARAGAMA	6.72 N	80.00 E	16	10/1/1921
3	01KT0066	CLYDE ESTATE	6.58 N	80.03 E	24.4	7/1/1952
4	01KT073A	DELKEITH	6.57 N	80.20 E	95	7/22/2006
5	01KE0120	FROCESTER ESTATE	6.67 N	80.12 E	15.2	7/1/1952
6	01KT0132	GEEKIYANAKANDA ESTATE	6.60 N	80.12 E	106.7	1872-04-01
7	01KT0145	HALWATURA	6.72 N	80.20 E	137.2	3/1/1929
8	01KT169A	HORAGODA ESTATE	6.50 N	80.25 E	16	12/1/1954
9	01KT0171	HORANA	6.75 N	80.07 E	30.5	1/1/1941
10	01KT524A	KALUTARA, VOGAN GROUP	6.53 N	80.10 E	0	1/1/1994
11	01KT0200	KALUTARA-P.W.D.	6.58 N	79.95 E	3	1879-01-01
12	01KT253C	KOROSDUWA	6.65 N	79.95 E	18	3/16/2006
13	01KT359B	NAGODA	6.57 N	80.00 E	16	1/1/1944
14	01KT400C	PALLEGODA ESTATE	6.47 N	80.05 E	0	9/1/1998
15	01KT414B	PELAWATTE	6.42 N	80.22 E	16	1/1/1959
16	01KT0450	RAYIGAMA	6.77 N	80.18 E	16	1897-05-01
17	01KT0467	SIRIKANDURA ESTATE	6.50 N	80.15 E	16	3/1/1920
18	01KT478B	ST.VINCENTS GROUP	6.52 N	80.00 E	16	1/1/1955
19	01KT513A	USK VALLEY S.P.	6.57 N	80.23 E	16	10/1/1954
20	01KT474B	YATADOLA (MATUGAMA DIV)	6.52 N	80.05 E	210	3/16/2006
21	01KT474A	YATADOLA(BOPITIYA)	6.50 N	80.08 E	100	3/16/2006
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Kandy District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01KY082E	DELTA ESTATE,EAST DIV	7.12 N	80.67 E	0	1/1/1996
2	01KY082D	DELTA ESTATE,SOUTH DIV	7.10 N	80.65 E	0	1/1/1996
3	01KY082F	DELTA NORTH DEVISION	0.00 N	0.00 E	0	9/26/2006
4	01KY0099	DUCKWARI ESTATE	7.35 N	80.78 E	1,006.10	1888-04-01
5	01KY0127	GALPHELE, WATTEGAMA	7.35 N	80.70 E	701.2	1898-01-01
6	01KY132A	GIDDAWA	7.42 N	80.73 E	480	1/29/2008
7	01KY147B	HANDESSA- DAULAGALA	7.23 N	80.57 E	16	6/1/1987
8	01KY0211	KANDY-KINGS PAVILION	7.30 N	80.63 E	510.4	8/1/1922
9	43444	KATUGASTOTA	7.33 N	80.63 E	417.1	1868-01-01
10	01KY317L	KOTHMALE POWER STATION	7.12 N	80.57 E	0	1/1/1996
11	01KY317I	KOTHMALE POWER STN -D/S	7.02 N	80.58 E	0	1/1/1990
12	01KY317N	KOTHMALE RESERVOIR	7.02 N	80.58 E	0	1/1/1998
13	01KY0262	KUNDASALE FARM	7.27 N	80.68 E	492	10/1/1947
14	01KY286B	MADULKEIE	7.37 N	80.73 E	750	2/1/2003
15	01KY286A	MAHABERIYATENNA	7.27 N	80.77 E	16	1/1/1989
16	01KY328A	MELFORT	7.12 N	80.63 E	16	4/1/1991
17	01KY0370	NAWALAPITIYA	7.07 N	80.53 E	16	7/1/1937
18	01KY0374	NEW FOREST	7.15 N	80.68 E	16	1/1/1901
19	01KY389B	OVALA RATTOTA	7.52 N	80.15 E	16	3/1/1992
20	01KY401A	PALLEKELE	7.28 N	80.72 E	470	11/16/2007
21	01KY407B	PANVILATENIYA	7.15 N	80.62 E	760	2/25/2006
22	01KY0418	PERADENIYA BOT.GARDENS	7.27 N	80.60 E	16	1883-07-01
23	01KY317O	POLGOLLA	7.32 N	80.62 E	440.8	6/1/1996
24	01KY0471	SOGAMA ESTATE	7.12 N	80.62 E	16	1884-11-01
25	01KY317P	VICTORIA	7.25 N	80.78 E	0	5/1/1994
26	01KY536B	WELIGALLA	7.18 N	80.43 E	540	11/14/2009
27	01KY0547	WOODSIDE ESTATE	7.27 N	80.83 E	950	1897-10-01
28	143444	KANDY, OLD MET	**	**	16	1868-01-01
29	01KY317K	BADULLA	**	**	0	1/1/1994
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Kegalle District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01KE009B	AMBANPITIYA ESTATE	7.23 N	80.32 E	201.2	3/1/2003
2	01KE0021	ARANAYAKE GOVT. HOSPITAL	7.18 N	80.47 E	16	8/1/1905
3	01KE021B	ARANAYAKE MINI HYDRO PRO	7.13 N	80.47 E	0	10/1/2004
4	01KE0064	CHESTERFORD	7.07 N	80.18 E	198.2	9/1/1949
5	01KE079B	DEDIGAMA	7.22 N	80.25 E	100	6/1/2003
6	01KE0089	DIGALLA ESTATE	6.95 N	80.30 E	122	1886-03-01
7	01KE0100	DUNEDIN ESTATE	7.03 N	80.28 E	122	1882-11-01
8	01KE104C	EILA ESTATE	6.98 N	80.33 E	220	11/1/2000
9	01KE0113	ERAMINIGOLLA	7.30 N	80.38 E	16	11/1/1938
10	01KE113B	ERAMINIGOLLA (COCONUT)	7.30 N	80.37 E	16	1/1/1993
11	01KE152C	HAIMATTA	7.07 N	80.25 E	50	10/5/2006
12	01KE141D	HAKBELLAWAKA	6.98 N	80.35 E	200	2/24/2010
13	301	MALIBODA	6.88 N	80.43 E	274.4	8/1/1913
14	01KE345B	MORALIOYA	7.02 N	80.22 E	90	10/1/2006
15	01KY356A	MURUTALAWA,SURIYAGODA	7.32 N	80.40 E	16	8/1/1991
16	01KE0458	RUWANWELLA REST HOUSE	7.05 N	80.25 E	16	7/1/1910
17	01KE104D	UDABAGE	6.97 N	80.35 E	440	6/24/2005
18	01KE0503	UNDUGODA	7.13 N	80.37 E	16	1/1/1950
19	01KE0523	VINCIT ESTATE	7.08 N	80.22 E	16	9/18/1925
20	01KE0526	WAGOLLA	7.30 N	80.38 E	16	11/1/1949
21	01KE530A	WARAKAPOLA(NIYADURUPOLA)	7.15 N	80.22 E	280	5/26/2003
22	01KE0544	WEWELTALAWA ESTATE	7.05 N	80.38 E	16	1/1/1944
23	01KE319A	MATHEMAGODA (COCONUT)	**	**	16	1/1/1993
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Kilinochchi District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01KI001B	AKKARAYANKULAM	9.30 N	80.35 E	31.1	12/1/1961
2	01KI0183	IRANAMADU TANK	9.35 N	80.40 E	30.5	6/1/1910
3	01KI220B	KARIYALAINAGAPODUWAN	9.27 N	80.17 E	0	3/1/1998
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Kurunegala District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01KG014A	ANDIGAMA FARM	7.37 N	80.12 E	16	5/1/1967
2	01KG024A	ATHARAGALLA	7.92 N	80.28 E	0	1/1/1957
3	01KE0038	BATALAGODA TANK	7.52 N	80.45 E	16	1897-01-01
4	01KG049A	BOPITIYA	7.32 N	80.07 E	50	6/15/2007
5	01KG074C	DAMPELLASSA - NARAMMALA	7.42 N	80.20 E	16	3/1/1993
6	01KG082C	DELHENA	7.52 N	80.55 E	111	7/1/1988
7	01KG092B	DODANGASLANDA	7.57 N	80.53 E	165	6/1/1987
8	01KG0103	EGODAGAMA ELA	7.43 N	80.42 E	16	3/1/1941
9	01KG0253	HAKWATUNA-OYA	7.65 N	80.38 E	16	1/1/1991
10	01KG159D	HETTIPOLA	7.58 N	80.67 E	50	11/16/2007
11	159C	HINDAWA ESTATE				
12	01PU169B	HORAGASAGARA	7.57 N	79.95 E	16	1/1/1989
13	01KG175A	IBBAGAMUWA	7.52 N	80.42 E	140	11/16/2007
14	01KG0201	KAMALASRAM (UDUBADDAWA)	7.48 N	79.98 E	16	6/1/1950
15	01KG0256	KOULWEWA	7.53 N	79.93 E	16	3/1/1978
16	01KG258D	KULIYAPITIYA	7.45 N	80.08 E	60	10/4/2002
17	43441	KURUNEGALA	7.47 N	80.37 E	116.1	1885-06-01
18	01KG290A	MAHAGALKADAWLA,GALGAMUWA	8.07 N	80.28 E	111	11/1/1987
19	01KE300B	MAKANDURA	7.32 N	79.98 E	26	3/28/2007
20	01ke312A	MARANDAWILA FARM	7.63 N	79.95 E	0	1/1/1993
21	01KG0326	MEDIYAWA TANK	7.88 N	80.28 E	16	1/1/1905
22	01KG301B	MELCIRI PURA	7.63 N	80.60 E	170	11/16/2007
23	01KG0329	MELLAWA ESTATE	7.32 N	79.95 E	16	8/1/1978
24	01KG0377	NIKAWERATIYA	7.75 N	80.12 E	16	1/1/1941
25	01KG404A	PANDUWASNUWARA	7.60 N	80.12 E	1	3/1/1990
26	01KG407A	PANNALA VIRIDIYAWA EST	7.33 N	80.03 E	0	4/1/1996
27	01KG426A	POLGAHAWELA (COCONUT)	7.32 N	80.30 E	16	12/1/1992
28	01KG427A	POLONTALAWA	7.72 N	80.00 E	16	10/1/1953
29	01KG0452	RIDIBENDI ELA	7.73 N	80.25 E	16	6/1/1937
30	01KG469A	SIYAMBALANGAMUWA	7.95 N	80.45 E	16	12/1/1953
31	01KG0470	SIYAMBALAWEWA ESTATE	7.65 N	79.97 E	16	5/15/1936
32	01KG0532	WARIYAPOLA EXPTL.STATION	7.63 N	80.25 E	16	4/1/1930
33	01KG540C	WELLEWA	6.55 N	80.35 E	100	5/1/2007
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Mannar District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01MN220A	KARUKKAIKULAM	8.92 N	80.02 E	16	1/1/1941
2	43413	MANNAR	8.98 N	79.92 E	3.6	1870-05-01
3	01MN0356	MURUNKAN	8.83 N	80.05 E	16	1/1/1901
4	01mu0356	MURUNKAN	0.13 N	80.05 E	40	1/1/1901
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Matale District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01ML317M	BOWATENNA	7.65 N	80.65 E	0	6/1/1996
2	01ML0072	CRYSTAL HILL ESTATE	7.50 N	80.65 E	426.8	1880-07-01
3	01ML107A	ELKADUWA ESTATE	7.42 N	80.68 E	762	12/1/1999
4	01ML150A	HAPPUWIDDE DIV (ELKADUWA	7.42 N	80.68 E	1,068.00	1999-12-91
5	01ML0177	ILLUKKUMBURA	7.55 N	80.77 E	1,219.50	6/1/1936
6	01ML0208	KANDALAMA	7.87 N	80.68 E	16	5/25/1952
7	01ML277A	LOOLKADE DIVISION	7.65 N	80.55 E	0	1/1/1989
8	01ML0318	MATALE-P.W.D.	7.47 N	80.62 E	16	1879-01-01
9	01ML324A	MEDAPEELLA	7.70 N	80.73 E	200	5/1/2008
10	01ML0337	MILLAWANA ESTATE	7.67 N	80.55 E	16	11/1/1937
11	01ML0361	NALANDA EXPER.STATION	7.67 N	80.63 E	16	11/1/1922
12	01ML389B	OWELLA - RATTOTA	7.52 N	80.65 E	16	9/1/1990
13	01ML0416	PELWEHERA	7.90 N	80.68 E	16	10/1/1929
14	01ML317J	UKUWELA	7.40 N	80.65 E	16	1/1/1993
15	01ML0531	WARIYAPOLA ESTATE	7.47 N	80.63 E	16	1887-01-01
16	01ML540D	WELLEWALA	7.67 N	80.82 E	160	5/1/2008
17	01ML544A	WEWELMADA	7.48 N	80.68 E	833.8	10/1/2003
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Matara District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01MT0018	ANNINGKANDA ESTATE	6.35 N	80.62 E	533.5	1884-06-01
2	01MT074B	DAMPAHALA TEA FACTORY	6.27 N	80.63 E	176	12/1/1992
3	01MT0076	DANDENIYA TANK	6.00 N	80.65 E	16	1880-01-15
4	01HT079C	DEHIGAHAHENA	6.20 N	80.62 E	300	10/23/2008
5	01MT0085	DENAGAMA	6.10 N	80.65 E	16	1879-01-01
6	01MT085B	DENIYAYA, WILLIE GROUP	6.33 N	80.55 E	0	11/20/1996
7	01MT232A	KEKANADURA FARM	5.97 N	80.57 E	11	1/1/1989
8	01MT0232	KEKENADURA (MATARA)	5.97 N	80.57 E	48.8	1879-02-01
9	01MT0311	MAPALANA	6.07 N	80.57 E	16	5/1/1941
10	01MT0322	MAWARELLA ESTATE	6.20 N	80.58 E	16	3/1/1925
11	01MT0400	PALLEGAMA,RATHNAYAKE GP	6.35 N	80.53 E	16	1/1/1989
12	01MT404B	PANETIYANA	6.03 N	80.45 E	200	7/1/2003
13	01MT484A	TALAPATH KANDA	6.22 N	80.62 E	1,100.00	9/3/2008
14	01MT537A	WELIGAMA (COCONUT)	5.98 N	80.40 E	16	4/1/1993
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Monaragala District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01MG044A	BIBLE AGRI,TRAINING CEN	7.15 N	81.22 E	820	6/1/2000
2	01MG055C	BUTTALA - KONKETIYA	6.65 N	81.27 E	0	6/1/2004
3	01MG141B	HANDAPANAGALA	6.65 N	81.12 E	150	11/16/2007
4	01MG260A	KUMBUKKANA	6.77 N	80.28 E	440	3/10/2006
5	00043MMM	MONARAGALA	6.50 N	81.30 E	165	3/1/2009
6	01MG343B	MONARAGALA WATER SUPPLY	6.87 N	81.35 E	475	6/1/2000
7	01MG0385	OKKAMPITIYA	6.75 N	81.30 E	16	1/1/1941
8	01MG488A	TANAMALWILA WATER SUPPLY	6.47 N	81.12 E	250	6/1/2000
9	01MG501B	TISSAPURA	7.30 N	81.08 E	150	6/27/2008
10	01MG538A	WELIPITIYA COCONUT	7.15 N	81.25 E	16	1/1/1992
11	01MG540A	WELLAWAYA	6.73 N	81.10 E	16	10/1/1983
12	01MG540B	WELLAWAYA WATER SUPPLY	6.72 N	81.08 E	300	6/1/2000
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Mullaitivu District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01MU0216	KANNUKKENI TANK	9.20 N	80.80 E	30.5	3/1/1905
2	01MU357A	MUTU IYANKADDU	9.22 N	80.65 E	16	5/1/1978
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Nuwara Eliya District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01NE0010	AMBEWELA	6.88 N	80.80 E	1,828.40	1/1/1952
2	01NE0017	ANNFIELD ESTATE	6.87 N	80.63 E	1,311.00	1887-11-01
3	01NE033A	BAMBRAKELLY - LINDULA	6.88 N	80.65 E	0	9/1/1995
4	01BD042B	BEAUVAIS ESTATE	6.78 N	80.90 E	0	8/1/1996
5	01NE0049	BOPATTHALAWA	6.83 N	80.72 E	1,539.60	11/1/1941
6	01NE0058	CAMPION ESTATE	6.78 N	80.70 E	1,820.30	1885-08-01
7	01NE317A	CANYON	6.88 N	80.53 E	16	1/1/1983
8	01NE317B	CASTLEREIGH	6.87 N	80.57 E	16	1/1/1983
9	01NE098A	DRAYTON	6.92 N	80.62 E	0	4/1/1996
10	01NE140B	GAURAVILLA ESTATE	6.78 N	80.60 E	1,443.00	10/1/1999
11	01NE138A	GOONAPITIYA	7.05 N	80.80 E	0	3/1/1996
12	01NE0142	HAKGALA BOTANICAL GDNS	6.92 N	80.82 E	1,701.20	1883-07-01
13	01ne0153	HATTUN ROSITA	6.92 N	80.60 E	1,311.00	6/1/1978
14	01NE0156	HELBODDE ESTATE	7.08 N	80.67 E	834.1	1885-01-01
15	01NE0157	HELBODDE NORTH	7.08 N	80.68 E	1,493.90	4/15/1929
16	01NE159A	HIGH FOREST ESTATE	7.07 N	80.83 E	16	3/1/1986
17	01NE157B	HOLLY ROOD ESTATE	6.95 N	80.67 E	0	4/1/1996
18	01NE0166	HOLMWOOD ESTATE	6.85 N	80.72 E	1,685.00	1881-08-01
19	01NE0167	HOPE ESTATE	7.10 N	80.75 E	1,432.90	1885-10-01
20	01NE0236	KENILWORTH (STRATHELLIE)	7.00 N	80.48 E	762.2	1/1/1912
21	01NE236A	KENILWORTH ESTATE	6.08 N	80.48 E	520	9/27/2006
22	01NE0264	KURUNDU OYA	7.07 N	80.83 E	16	1882-07-01
23	01NE0266	LABUKELLE	7.02 N	80.72 E	16	1/1/1941
24	01NE317D	LAXAPANA	6.90 N	80.52 E	16	1/1/1983
25	01NE0274	LIDDES DALE	7.02 N	80.85 E	1,570.00	1/1/1923
26	01NE277C	LOOLECONDERA ESTATE	7.12 N	80.70 E	1,080.00	1/1/2003
27	01NE315A	MARIGOLD FACTORY	7.07 N	80.82 E	0	4/1/1996
28	01NE0316	MASKELIYA HOSPITAL	6.83 N	80.57 E	16	1882-08-01
29	01NE317F	MAUSSAKELLE	6.85 N	80.55 E	16	1/1/1983
30	01NE317E	NORTON	6.92 N	80.52 E	16	4/1/1984
31	01NE317G	SAMANALA POWER STATION	6.98 N	80.47 E	16	1/1/1989
32	01NE0460	SANDRINGHAM ESTATE	6.85 N	80.75 E	16	1881-07-01
33	01NE464A	SHANNON ESTATE	6.90 N	80.57 E	0	4/1/1996
34	01NE467B	SITA ELIYA	6.93 N	80.80 E	0	1/1/1966
35	01NE467C	SITAELIYA GOVT FARM	6.95 N	80.78 E	0	11/19/1996
36	01NE485D	ST. CLAIR	6.93 N	80.65 E	0	11/18/1996
37	01NE362A	SUMMERSET	6.93 N	80.70 E	0	11/18/1996
38	01NE166B	SUTTON DIVISON HOLMWOOD	6.85 N	80.70 E	1,440.00	9/28/2006
39	01NE506B	UDARADELLA	6.97 N	80.82 E	16	1/1/1989
40	01NE0534	WATAWALA	6.97 N	80.52 E	16	4/1/1910
41	01NE534B	WATAWALA, MOUNT JEAN	6.95 N	80.52 E	0	11/19/1996
42	01NE534A	WATAWALA,RAILWAY STATION	6.97 N	80.52 E	16	1/1/1993
43	01NE317H	WIMALASURENDRA POWER ST	6.90 N	80.53 E	16	1/1/1983
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Polonnaruwa District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01PL0015	ANGAMEDILLA	7.85 N	80.92 E	16	1/1/1941
2	01PL020A	ARALAGANWILA	7.80 N	81.15 E	60	3/1/2003
3	01PL0031	BAKAMUNA	7.77 N	80.82 E	16	1/1/1941
4	01PL092A	DIYABEDUMA	7.93 N	80.87 E	16	1/1/1960
5	01PL093B	DIYASENAPURA	8.12 N	81.02 E	0	1/1/1993
6	01PL104B	ELAHERA	7.68 N	80.82 E	16	6/1/1991
7	01PL134A	GIRITALE	8.00 N	80.93 E	16	7/1/1953
8	01PL134D	GIRITALE (Wild Life)	8.00 N	80.93 E	16	1/1/2004
9	01PL141A	HABARANA LODGE	8.03 N	80.75 E	0	4/1/2001
10	01PL0162	HINGURAKGODA-AGRICULTURE	8.05 N	80.95 E	39.6	1/1/1941
11	01PL224A	KAUDULLA WEWA	8.13 N	80.93 E	16	5/1/1953
12	01PL0340	MINNERIYA TANK	8.05 N	80.90 E	16	1899-03-01
13	00043PPP	POLONNARUWA	7.87 N	81.05 E	43	2/1/2009
14	01PL0427	POLONNARUWA AGRI.STATION	7.92 N	81.03 E	16	1/1/1940
15	01PL0538C	WELIKANDA (SINGHAPURA)	8.00 N	81.22 E	40	1/1/2002
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Puttalam District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01PU0013	ANAMADUWA DISPENSARY	7.88 N	80.00 E	76.3	5/1/1933
2	01PU040A	BATTULUOYA	7.72 N	79.82 E	5	1/1/2005
3	01PU0065	CHILAW-P.W.D	7.58 N	79.78 E	3	11/1/1911
4	01PU307A	DEVISIPURA	7.85 N	79.82 E	130	1/1/2005
5	01PU099A	DUMMALASOORIYA	6.00 N	80.85 E	260	11/1/2005
6	02PU0013	ELUVANKULAMA,AGMET	8.27 N	79.85 E	100	9/29/1975
7	01PU0170	HORAKELLE ESTATE	7.45 N	79.85 E	15.2	1868-10-01
8	01PU201A	KAMANDALUWA	7.77 N	80.00 E	0	4/1/1999
9	01PU216A	KARANDIPOOVAL	8.15 N	79.85 E	0	4/1/1999
10	01PU0221	KARUKKUWA ESTATE	7.50 N	79.83 E	16	5/1/1911
11	01PU256A	KOTTUKACHCHIYA	7.92 N	79.97 E	16	6/1/1939
12	01PU0281	LUNUWILA (BANDIRIPPUWA)	7.33 N	79.87 E	16	8/1/1950
13	01PU313A	MARAWILA	7.40 N	79.83 E	0	7/1/1995
14	353E	MUNDALAMA				
15	01PU282C	NORACHOLAI	8.05 N	79.82 E	3	11/8/2006
16	01PU0397	PALAVI SALTERN	7.98 N	79.83 E	16	4/1/1919
17	01PU353D	PALMGROVE ESTATE	7.77 N	79.82 E	0	1/1/2005
18	01PU0402	PALUGASWEWA ESTATE	7.65 N	79.87 E	16	1/1/1910
19	01PU428B	POOTTWALA ESTATE	7.65 N	79.88 E	16	11/1/1992
20	43424	PUTTALAM	8.03 N	79.83 E	2.1	1869-01-01
21	2043424	PUTTALAM, AGMET	8.03 N	79.83 E	2.1	2/9/1993
22	01PU0449	RATHMALAGARA AGMET	7.55 N	79.90 E	28	7/1/1938
23	01PU473B	ST. ANNES ESTATE, DALUWA	8.08 N	79.75 E	0	12/1/1990
24	01PU0483	TABBOWA AGRICULTURE	8.05 N	79.95 E	16	8/1/1938
25	01PU514B	VANATHAWILLU	0.00 N	0.00 E	0	11/8/2006
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Ratnapura District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01RT0005	ALUPOLLA GROUP	6.72 N	80.58 E	762.5	12/1/1931
2	01KE016A	ANHETIGAMA ESTATE	6.93 N	80.37 E	11	6/1/1990
3	01RT0032	BALANGODA POST OFFICE	6.65 N	80.70 E	527.4	7/1/1922
4	01RT042C	BELIHULOYA	6.72 N	80.77 E	670	6/7/2006
5	01RT050C	BELIHULOYA UPPER DIV	6.77 N	80.80 E	0	11/16/1996
6	01RT050B	BRAMPTON	6.75 N	80.82 E	0	4/1/1996
7	01RT0086	DEPEDENA GROUP	6.47 N	80.55 E	16	1/1/1942
8	01RT0087	DETANAGALLA	6.73 N	80.68 E	16	9/1/1912
9	01RT0104	EHELIYAGODA S.P.	6.85 N	80.27 E	225.6	3/1/1916
10	01RT0111C	EMBILIPITIYA,COCONUT	6.32 N	80.85 E	76.2	7/1/1930
11	01RT120A	GALABODA ESTATE	6.70 N	80.47 E	1	8/1/1990
12	01RT0124	GALATURA ESTATE	6.70 N	80.28 E	16	12/1/1936
13	01RT128A	GANGEYAYA	6.37 N	80.83 E	0	5/1/1995
14	01RT140D	GURULUWANA	6.75 N	80.43 E	0	10/1/2004
15	01RT0151	HAPUGASTENNA ESTATE	6.72 N	80.52 E	594.5	1/1/1944
16	01RT177B	ILLUBULUWA ESTATE	6.68 N	80.32 E	90	1/16/2007
17	01RT0195	KALATUWAWA	6.85 N	80.20 E	16	1/1/1941
18	01RT196A	KALAWANA	6.48 N	80.38 E	0	11/1/2005
19	01RT0237	KERAGALA	6.78 N	80.35 E	121.9	9/1/1912
20	01RT258A	KUDAWA	6.43 N	80.42 E	16	1/1/1980
21	01RT264A	KUTTIGALA,CHANDRIKAWEWA	6.25 N	80.90 E	16	1/1/1989
22	01RT269B	LANDSDOWN,MIDDLE DIV	6.67 N	80.47 E	0	4/1/1996
23	01RT271A	LELLOPITIYA ESTATE	6.68 N	80.50 E	16	12/1/1954
24	01RT345A	MORAHELA	6.67 N	80.67 E	0	7/1/1995
25	01NE0360	NAGRAK ESTATE	6.77 N	80.78 E	16	10/1/1933
26	01RT382B	NON PAREIL (BELIHULOYA)	6.75 N	80.78 E	0	4/1/1996
27	01RT0435	PUSSELLA S.P.	6.80 N	80.35 E	16	11/1/1951
28	43486	RATNAPURA	6.68 N	80.40 E	34.4	1869-09-01
29	01RT481B	SOORIYAKANDA	6.43 N	80.63 E	884	7/1/2003
30	01RT539A	WELLANDURA ESTATE	6.53 N	80.57 E	16	1/1/1955
31	01RT539B	WELLANDURA TEA FACTORY	6.55 N	80.57 E	0	1/1/1993
32	01RT111C	EMBILIPITIYA,COCONUT NUR	**	**	16	1/1/1992
33						
34						
35						
36						
37						

Vavuniya District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01VA414A	PAVATKULAM	8.68 N	80.43 E	16	11/1/1955
2	43415	VAVUNIYA	8.75 N	80.50 E	97.5	1880-09-01
3	01VA0517	VAVUNIYA AGRICULTURE	8.77 N	80.48 E	16	4/1/1927
4	01VA0518	VAVUNIYA P.W.D.	8.75 N	80.50 E	16	1879-01-01
5						
6						
7						
8						
9						

Trincomalee District

	STN-ID	STN-NAME	LAT	LON	ELEVATION	BEGIN-DATE
1	01TC0004	ALLAI TANK	8.40 N	81.32 E	6.1	1879-03-01
2	01TC0194	KAL AAR	8.30 N	81.27 E	12.2	1/1/1941
3	01TC0215	KANTALAI TANK	8.35 N	80.98 E	76.2	1879-01-01
4	01TC0395	PALAMPODDAR,THAMBALAGAMU	8.55 N	81.07 E	16	2/1/1944
5	43418	TRINCOMALEE	8.58 N	81.25 E	23.9	1869-01-01
6						
7						
8						
9						
10						

Kelani Ganga at Glencourse

Water Year	Flood Peaks in Cumecs	Date
70/71	2038.79	1971.09.23
71/72	1399.26	1972.05.13
72/73	826.00	1973.08.01
73/74	3120.49	1974.07.28
74/75	2981.79	1975.05.23
75/76	1322.95	1975.11.03
76/77	1380.43	1977.05.25
77/78	1680.53	1978.05.14
78/79	4219.17	1978.11.25
79/80	573.41	1979.11.11
80/81	2695.06	1981.09.17
81/82	1973.66	1982.06.09
82/83	1060.60	1983.08.20
83/84	4285.71	1984.07.12
84/85	2095.73	1985.06.06
85/86	1766.53	1985.10.05
86/87	781.25	1986.10.13
87/88	1585.73	1987.10.27
88/89	3500.00	1989.06.04
89/90	831.00	1989.11.01
90/91	1146.00	1990.11.03
91/92	1318.28	1992.06.03
92/93	1346.17	1992.10.14
93/94	1519.46	1993.10.08
94/95	660.00	1995.06.04
95/96	1361.18	1995.10.08
96/97	1550.00	1997.09.16
97/98	787.00	1997.11.04
98/99	1407.00	1999.04.20
99/00	810.58	2000.09.20
00/01	491.93	2001.02.04
01/02	595.97	2002.06.07
02/03	561.29	2003.05.17
03/04	516.70	2004.09.24
04/05	810.51	2004.11.02
05/06	1134.20	2006.06.20
06/07	1009.34	2006.11.11
07/08	1733.30	2008.04.29
08/09	921.43	2009.08.17
09/10	516.70	2010.05.20
10/11	1690.25	2011.05.27
11/12	380.24	2012.07.09

Kelani Ganga at Kithulgala

Water Year	Flood Peaks in Cumecs	Date
84/85	925.00	15-07-85
85/86	497.00	12-11-85
86/87	268.00	01-10-86
87/88	808.00	04-08-88
88/89	2157.00	30-05-89
89/90	704.00	17-05-90
90/91	247.00	02-11-90
91/92	886.00	03-06-92
92/93	853.00	28-06-93
93/94	577.00	08-10-93
94/95	704.00	17-06-95
95/96	727.00	08-10-95
96/97	337.00	16-09-97
97/98	406.00	29-09-98
98/99	726.00	19-05-99
99/00	288.00	04-05-00
00/01	228.00	27-07-01
01/02	365.00	12-06-02
02/03	503.00	06-05-03
03/04	178.00	27-05-04
04/05	439.00	05-10-05
05/06	379.00	06-11-05
06/07	244.00	15-06-07
07/08	704.00	28-04-08
08/09	403.00	20-05-09
09/10	403.00	02-10-09
10/11	288.00	02-05-11
11/12	269.00	09-07-12

Gurugoda Oya at Holombuwa

Water Year	Flood Peaks in Cumecs	Date
85/86	431.76	04-10-85
86/87	174.12	02-06-87
87/88	484.18	26-10-87
88/89	644.11	03-06-89
89/90	248.15	18-11-89
90/91	193.00	02-11-90
91/92	280.00	03-06-92
92/93	475.00	13-10-92
93/94	316.73	08-10-93
94/95	228.00	09-05-95
95/96	192.94	08-10-95
96/97	525.00	20-07-97
97/98	204.70	24-07-98
98/99	246.89	20-04-99
99/00	137.82	24-09-00
00/01	179.03	30-07-01
01/02	190.44	21-04-02
02/03	102.82	17-05-03
03/04	175.66	03-11-03
04/05	279.35	02-11-04
05/06	172.29	22-10-05
06/07	297.67	12-11-06
07/08	329.24	19-07-08
08/09	173.13	17-08-09
09/10	241.54	30-04-10
10/11	456.40	27-05-11
11/12	189.23	23-10-11

Seethawaka Ganga at Daraniyagala

Water Year	Flood Peaks in Cumecs	Date
84/85	2312.60	31-.5-85
85/86	654.44	12-11-85
86/87	932.83	15-10-86
87/88	701.42	03-06-88
88/89		03-06-89
89/90	2079.00	17-05-90
90/91	509.00	02-11-90
91/92	1476.00	03.06.92
92/93	1708.00	13-10-92
93/94	954.16	08-10-93
94/95	540.00	04-06-95
95/96	656.00	22-09-96
96/97	644.00	21-07-97
97/98	462.00	24-07-98
98/99	362.00	20-04-99
99/00	282.00	20-09-00
00/01	368.00	18-05-01
01/02	497.00	12-06-02
02/03	508.00	06-05-03
03/04	266.00	27-05-04
04/05	426.00	05-09-05
05/06	458.00	20-06-06
06/07	601.00	12-05-07
07/08	920.00	28-04-08
08/09	572.00	16-08-09
09/10	416.00	15-08-10
10/11	580.00	27-05-11
11/12	278.00	26-05-12

Kalu Ganga at Rathnapura

Water Year	Flood Peaks in Cumecs	Date
77/78	370.94	27-09-78
78/79	520.31	24-11-78
79/80	349.71	12-07-80
80/81	453.06	17-09-81
81/82	579.15	08-06-82
82/83	339.14	28-11-82
83/84	506.58	12-07-84
84/85	472.59	24-05-85
85/86	513.48	04-10-85
86/87	395.43	01-10-86
87/88	531.00	02-06-86
88/89	764.54	31-05-89
89/90	492.78	07-05-90
90/91	370.99	02-06-91
91/92	446.05	03-06-92
92/93	458.79	31-05-93
93/94	589.06	08-10-93
94/95	360.37	04-06-95
95/96	477.90	08-10-95
96/97	463.04	21-07-97
97/98	419.00	29-09-98
98/99	552.00	20-04-99
99/00	320.00	01-06-00
00/01	268.00	29-09-01
01/02	392.00	12-06-02
02/03	686.88	18-05-03
03/04	350.00	30-05-04
04/05	459.00	05-09-05
05/06	356.68	20-06-06
06/07	322.02	01-09-07
07/08	547.27	28-04-08
08/09	355.20	30-06-08
09/10	368.45	19-05-10
10/11	395.33	29-04-11
11/12		

Kalu Ganga at Ellagawa

Water Year	Flood Peaks in Cumecs	Date
68/69	597.68	30-05-69
69/70	495.54	31-03-70
70/71	930.48	23-09-71
71/72	861.67	15-05-72
72/73	577.66	06-10-72
73/74	770.21	29-07-74
74/75	1113.41	08-05-75
75/76	679.31	25-10-75
76/77	529.10	05-06-77
77/78	1336.54	15-05-78
78/79	670.37	26-11-78
79/80	663.17	03-06-80
80/81	809.85	19-09-81
81/82	1387.51	10-06-82
82/83	641.09	29-11-82
83/84	1005.24	14-07-84
84/85	889.14	25-05-85
85/86	852.33	06-10-85
86/87	815.52	02-10-86
87/88	1042.05	04-06-88
88/89	1121.34	06-06-89
89/90	745.00	09-05-90
90/91	824.01	03-06-91
91/92	883.60	05-06-92
92/93	1081.69	01-06-93
93/94	1047.86	10-10-93
94/95	668.36	05-06-95
95/96	1222.50	09-10-95
96/97	1005.00	17-09-97
97/98	1000.00	05-11-97
98/99	1860.00	22-04-99
99/00	680.00	21-09-00
00/01	432.00	26-09-01
01/02	360.00	23-10-01
02/03	2620.00	19-05-03
03/04	548.00	24-09-04
04/05	690.00	06-09-05
05/06	750.00	22-06-06
06/07	710.00	01-09-07
07/08	1680.00	01-06-08
08/09	691.20	02-07-09
09/10	1100.00	21-05-10
10/11	880.00	30-04-11
11/12	246.50	10-07-12

Badulu Oya at Taldena		
Water Year	**Flood Peaks in Cumecs**	**Date**
95/96	42.18	05-02-96
96/97	78.72	28-11-96
97/98	258.38	09-03-98
98/99	32.08	03-03-99
99/00	309.23	29-02-00
00/01	56.81	29-01-01
01/02	26.31	07-12-01
02/03	32.08	19-12-02
03/04	21.26	11-01-04
04/05	73.33	16-12-04
05/06	49.96	14-01-06
06/07	258.38	20-12-06
07/08	730.22	13-03-08
08/09	198.85	29-11-08
09/10	295.96	12-12-09
10/11	585.17	02-02-11
11/12	309.23	25-11-11

Attanagalu Oya at Dunamale

Water Year	Flood Peaks in Cumecs	Date
05/06	36.44	22-11-05
06/07	48.70	26-10-06
07/08	58.66	31-05-08
08/09	36.44	21-10-08
09/10	50.88	01-05-10
10/11	41.32	02-10-10
11/12	31.33	24-10-11

Mahaweli Ganga at Nawalapitiya		
Water Year	**Flood Peaks in Cumecs**	**Date**
89/90	238.00	06-08-90
90/91	199.40	31-07-91
91/92	294.80	03-06-92
92/93	360.27	28-06-93
93/94	218.60	01-08-94
94/95	262.50	17-06-95
95/96	266.40	20-09-96
96/97	238.64	21-07-97
97/98	259.25	29-09-98
98/99	250.00	20-04-99
99/00	112.00	01-06-00
00/01	154.60	27-07-01
01/02	199.07	09-08-02
02/03	187.00	10-07-03
03/04	166.00	27-05-04
04/05	187.00	31-08-05
05/06	130.00	20-06-06
06/07	145.00	03-11-06
07/08	212.04	23-09 -09
08/09	205.80	20-05-09
09/10	190.60	15-08-10
10/11		
11/12		

COLOMBO MET

Monthly Mean Pan Evaporation - (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	4.10	4.76	5.39	3.13	4.31	4.66	4.53	4.78	4.35	4.14	3.98	4.57
1982	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1983	N/A	N/A	N/A	N/A	N/A	N/A	3.91	1.97	N/A	4.57	4.25	3.34
1984	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1985	4.33	4.10	4.76	4.46	4.28	N/A	4.06	3.99	3.86	4.12	3.35	3.48
1986	3.07	4.36	3.78	3.90	4.10	4.17	2.93	3.58	3.38	2.89	3.44	3.23
1987	3.70	4.58	5.33	3.99	4.21	3.86	4.42	2.45	4.18	3.12	2.73	3.37
1988	5.70	4.06	3.18	3.98	3.73	3.89	3.45	3.75	N/A	N/A	N/A	N/A
1989	3.48	4.39	5.07	4.27	3.49	3.16	3.05	3.86	4.18	3.93	3.67	4.02
1990	3.47	4.58	4.41	4.32	3.53	3.42	3.27	3.33	4.14	3.53	N/A	2.66
1991	3.40	4.07	4.75	4.07	4.23	3.73	3.85	4.27	4.13	2.99	3.35	N/A
1992	3.93	4.47	5.07	4.88	3.74	3.77	3.47	3.87	4.04	3.48	2.94	3.13
1993	3.79	4.66	4.14	4.68	3.82	3.75	3.42	3.76	4.38	3.74	2.69	2.63
1994	3.03	3.50	4.26	4.26	3.85	3.80	3.78	3.71	3.86	2.82	2.72	3.55
1995	3.54	3.95	4.65	3.83	3.71	3.34	3.65	3.70	4.11	3.77	3.48	3.70
1996	3.81	3.69	4.79	3.29	3.78	2.81	3.37	4.14	3.18	3.42	3.80	2.84
1997	4.17	3.49	3.88	4.02	3.17	3.33	3.20	4.33	3.06	3.00	2.89	2.42
1998	3.06	4.12	4.90	4.40	3.37	3.36	3.13	3.03	3.50	3.07	2.75	2.59
1999	3.03	3.22	3.72	3.26	3.21	3.51	3.31	3.23	3.04	2.22	2.70	3.03
2000	3.01	3.32	3.85	3.71	3.35	3.15	3.80	3.43	3.18	3.47	3.07	3.22
2001	2.92	3.67	4.32	3.55	3.41	3.60	3.48	4.59	4.45	3.42	3.23	3.59
2002	3.64	4.11	4.47	3.87	3.30	3.68	4.02	4.24	4.72	3.13	2.68	2.61
2003	3.40	3.18	3.62	3.64	3.42	3.12	3.07	3.42	3.52	3.36	2.45	3.62
2004	4.39	4.61	4.30	4.06	2.94	3.24	3.08	3.53	2.72	2.68	2.24	2.98
2005	3.69	4.37	4.54	3.98	3.49	3.28	3.34	4.00	3.72	2.85	2.63	3.03
2006	3.38	3.91	3.73	3.81	3.28	3.14	3.39	3.27	3.42	3.41	2.99	2.87
2007	3.60	4.21	4.44	3.75	3.58	3.31	3.20	3.34	3.30	2.76	3.40	2.97
2008	3.22	3.78	3.22	3.47	3.47	3.33	2.97	3.34	4.04	3.41	2.70	3.40
2009	3.92	4.49	3.89	3.60	3.65	3.16	3.53	3.53	3.49	3.44	2.15	4.24
2010	4.25	4.33	4.19	3.64	3.14	3.27	3.17	3.44	3.29	3.35	2.49	2.19
Average	3.67	4.07	4.32	3.92	3.61	3.49	3.49	3.64	3.74	3.34	3.03	3.20

Monthly Mean Wind Run - (km/h)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	3.3	3.4	3.3	3.8	4.1	5.6	5.1	5.3	4.9	3.2	3.7	3.3
1982	3.8	3.4	3.3	3.5	3.7	5.5	4.9	4.8	4.2	2.9	2.3	3.5
1983	3.9	3.2	3.2	3.5	3.8	3.6	3.4	3.8	2.9	3.0	3.0	3.1
1984	3.0	3.1	N/A	2.8	5.5	4.1	3.9	4.2	3.8	3.3	2.9	4.0
1985	3.5	3.0	4.6	5.4	6.9	7.2	6.7	6.7	5.8	5.2	5.2	5.3
1986	7.0	5.5	4.6	4.7	5.7	6.8	7.6	6.2	6.6	5.0	5.4	5.1
1987	6.7	6.2	5.5	4.9	5.1	7.3	5.9	5.8	5.1	3.9	7.0	6.0
1988	7.6	5.7	4.8	4.5	6.4	5.7	5.8	5.5	5.6	5.3	N/A	N/A
1989	6.2	5.5	4.7	4.9	6.4	7.0	N/A	N/A	6.5	4.5	4.1	4.4
1990	5.0	4.9	4.4	4.8	6.5	7.3	5.8	6.9	6.3	4.5	4.2	3.9
1991	4.3	4.7	4.4	4.9	4.9	8.0	7.1	7.6	6.3	4.8	3.8	4.3
1992	5.9	4.6	4.9	5.3	5.5	7.3	6.1	7.3	5.8	5.1	3.4	4.5
1993	4.8	5.1	4.5	4.3	5.6	7.8	7.3	6.9	6.2	5.2	3.5	3.5
1994	4.3	3.9	4.8	4.4	4.2	5.6	6.3	6.2	5.4	2.6	3.4	5.4
1995	4.7	4.4	4.6	4.3	6.6	6.3	6.2	6.7	5.7	4.5	2.6	4.1
1996	4.1	3.0	4.3	4.1	5.9	5.5	5.8	6.8	6.4	4.6	3.8	3.2
1997	4.4	4.5	4.1	4.1	4.5	4.5	6.0	6.7	4.4	2.4	2.0	2.3
1998	3.7	4.3	4.6	4.3	5.1	6.1	6.8	5.8	6.8	4.9	2.3	3.2
1999	4.2	3.7	3.6	5.5	6.0	6.4	6.5	5.8	4.8	3.8	2.9	3.4
2000	3.8	3.5	3.6	4.8	5.1	6.5	6.6	6.5	4.2	4.2	2.8	4.9
2001	3.9	3.2	4.3	3.1	4.8	5.9	5.5	7.0	5.8	5.0	3.3	4.8
2002	5.0	4.3	4.0	3.3	4.8	5.8	6.0	5.5	5.8	3.5	3.5	4.5
2003	4.4	3.1	3.4	3.6	6.1	5.7	5.7	6.2	5.7	4.8	3.4	5.7
2004	6.4	5.7	4.9	4.7	5.9	6.3	6.1	6.2	4.8	3.0	3.8	4.7
2005	5.4	4.9	4.1	3.4	4.8	6.6	5.7	5.5	6.0	4.3	4.7	8.3
2006	5.6	5.1	4.1	4.6	5.5	5.4	6.0	4.9	5.7	4.4	3.4	5.4
2007	5.8	5.2	4.7	3.8	6.0	5.6	5.6	5.5	6.3	4.5	4.6	4.8
2008	5.1	4.2	3.8	4.4	7.4	5.2	6.2	6.1	5.1	3.8	4.6	5.0
2009	5.6	5.2	4.1	5.0	7.1	6.7	5.4	6.4	7.0	4.5	2.3	3.3
2010	6.0	5.4	4.2	3.5	5.4	1.4	5.2	6.4	5.0	6.1	3.9	4.9
Average	4.9	4.4	4.3	4.3	5.5	6.0	5.9	6.0	5.5	4.2	3.6	4.4

RATNAPURA TRI

Monthly Mean Pan Evaporation - (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	4.30	5.30	4.90	4.00	3.40	3.60	3.30	3.30	3.10	3.70	3.80	2.90
1982	3.53	4.03	4.21	3.94	3.70	3.51	3.50	2.98	3.54	2.39	3.48	2.94
1983	3.50	5.06	5.74	4.90	4.28	3.74	3.57	3.49	2.55	3.73	3.71	2.28
1984	3.00	3.24	3.37	3.01	3.65	3.82	2.89	4.25	4.34	3.67	3.58	3.47
1985	3.16	4.00	4.58	4.01	3.63	2.76	3.39	3.43	3.42	3.81	3.83	3.02
1986	3.42	4.41	3.73	4.09	3.59	4.40	3.23	3.83	2.81	3.63	3.39	3.39
1987	3.72	5.36	5.55	4.87	4.12	4.05	4.46	3.03	4.17	2.79	3.64	3.80
1988	3.86	4.42	4.40	3.78	3.07	**	3.02	3.54	4.05	4.51	4.34	3.43
1989	3.54	4.90	5.50	4.20	**	2.84	3.35	**	**	4.03	4.25	3.44
1990	4.32	5.10	4.59	3.87	3.96	3.15	3.23	3.47	3.69	3.12	**	3.83
1991	3.62	4.56	4.38	3.34	4.29	**	4.25	**	3.97	**	3.76	3.38
1992	3.70	5.53	6.21	4.97	**	**	3.61	3.47	**	**	**	2.89
1993	3.93	4.67	3.91	4.43	**	**	3.00	3.21	3.24	3.15	3.23	2.63
1994	2.77	3.84	4.11	3.98	**	3.54	3.32	3.40	3.04	3.58	**	2.83
1995	2.94	3.60	3.13	**	3.75	3.00	3.31	2.40	3.63	3.19	3.15	3.14
1996	2.95	2.98	5.09	3.39	4.08	3.02	3.01	3.19	***	3.24	3.10	3.16
1997	4.39	4.66	4.10	3.86	3.01	3.90	2.75	3.39	2.82	3.91	2.73	2.70
1998	3.32	4.33	4.73	4.17	3.28	2.93	3.81	3.01	2.93	3.14	4.52	1.40
1999	3.21	3.58	4.42	3.18	3.19	4.16	3.82	3.66	3.42	2.97	3.33	3.55
2000	2.74	3.55	3.67	4.01	4.10	2.90	4.10	2.58	3.10	3.77	2.40	2.74
2001	2.40	3.73	4.50	3.38	2.91	4.00	3.01	2.99	3.01	***	3.55	2.82
2002	2.84	3.17	3.53	2.79	2.64	3.34	2.48	2.97	3.71	2.15	2.83	2.07
2003	3.07	3.40	3.58	3.40	2.61	2.86	2.70	2.90	3.16	2.10	1.94	3.36
2004	3.24	3.46	3.43	2.79	2.84	3.20	2.41	2.81	3.01	2.77	2.48	2.62
2005	2.27	3.58	3.13	3.23	3.75	3.03	2.85	2.92	3.39	3.23	2.72	2.65
2006	2.40	2.66	2.74	2.61	2.67	2.65	2.62	2.82	2.36	2.66	2.07	2.05
2007	2.70	3.10	3.41	3.10	3.09	2.81	2.15	1.75	1.71	1.45	2.18	1.91
2008	1.92	1.94	1.16	0.75			0.95	1.51	2.80	2.36	2.19	2.33
2009	3.13	3.88	2.77	2.28	2.31	1.93	2.45	1.80	2.33	2.92	1.40	1.35
2010	2.86	3.08	2.97	2.13	2.97	2.06	2.43	2.26	2.10	2.53	1.62	1.71
Avearge	3.22	3.97	4.05	3.53	3.40	3.25	3.10	3.01	3.16	3.13	3.08	2.79

Monthly Mean Wind Run - (km/h)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	2.3	2.6	2.3	2.4	2.5	4.0	3.8	3.6	2.6	2.5	2.6	1.6
1982	1.7	2.9	1.8	1.9	1.4	2.3	2.3	2.8	2.4	0.9	0.7	0.7
1983	2.2	3.5	3.7	3.5	3.6	4.1	4.2	4.3	3.2	4.1	3.5	3.8
1984	2.6	2.7	3.4	3.0	3.3	4.8	4.3	5.3	4.3	***	3.3	3.1
1985	2.3	2.3	2.9	3.1	3.8	4.6	4.1	4.1	3.3	3.3	2.9	2.0
1986	2.8	2.8	2.3	2.8	3.1	4.5	4.3	3.8	3.3	2.5	2.4	1.7
1987	2.0	2.6	2.7	2.4	2.3	4.5	3.7	2.6	2.6	1.9	2.1	2.5
1988	1.7	2.1	2.2	2.2	1.6	1.8	2.6	2.4	2.2	2.4	2.0	1.6
1989	5.3	8.0	7.7	7.1	4.3	2.2	2.3	2.6	1.7	2.1	3.2	2.4
1990	2.1	2.3	2.3	2.3	2.5	2.9	2.6	3.6	2.6	2.1	2.2	1.4
1991	1.6	1.9	2.0	2.0	2.0	2.1	2.4	2.9	2.7	2.4	1.7	1.5
1992	1.5	2.6	2.7	2.3	2.0	3.2	2.1	2.7	2.4	2.2	1.8	1.4
1993	1.4	2.1	2.0	1.8	1.8	2.7	3.0	2.4	2.0	1.8	1.4	1.5
1994	1.2	1.6	2.0	1.9	1.9	2.9	2.6	2.4	1.9	1.5	1.8	1.3
1995	1.6	1.9	2.2	2.3	2.6	2.5	3.8	2.7	3.1	2.2	2.4	1.7
1996	1.8	2.1	2.5	2.5	2.6	3.9	3.2	3.0	2.3	2.3	2.5	2.0
1997	2.1	2.5	2.3	2.9	2.1	2.3	2.5	3.1	2.1	1.7	1.9	1.4
1998	1.4	1.8	1.8	1.8	1.9	2.6	3.1	2.4	2.5	2.2	2.3	1.6
1999	1.5	1.8	1.7	1.6	1.9	2.3	2.7	2.0	1.8	1.8	1.8	1.7
2000	1.2	1.6	1.7	1.6	1.9	2.3	2.8	2.6	1.3	1.3	1.0	1.1
2001	0.9	1.1	1.3	0.9	1.5	1.9	1.9	2.0	1.7	1.7	1.4	1.1
2002	1.0	1.4	1.5	1.4	1.6	2.0	1.8	2.0	1.9	1.2	1.1	0.8
2003	0.9	1.0	1.1	1.2	1.7	1.3	1.5	1.5	1.3	1.1	0.9	1.0
2004	0.9	1.2	1.3	1.4	1.5	2.2	1.8	1.9	0.9	1.0	0.7	0.6
2005	0.8	0.9	0.9	0.8	1.1	1.4	1.7	1.8	1.7	1.0	1.1	1.2
2006	0.7	0.7	1.2	1.4	1.0	1.2	1.6	0.9	0.7	0.5	0.4	0.2
2007	***	***	***	***	***	***	***	***	***	***	***	***
2008	0.3	0.3	0.4	***	***	***	***	***	***	0.9	0.8	0.8
2009	0.72	1.16	1.00	1.10	1.17	1.21	2.08	1.43	1.64	1.49	0.92	0.76
2010	0.73	0.81	1.13	1.00	1.13	1.69	2.10	2.24	1.51	2.03	1.09	1.32
Average	1.62	2.07	2.14	2.16	2.13	2.70	2.74	2.68	2.20	1.86	1.79	1.51

Bandarawela

EVAPORATION - Monthly Mean (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	2.70	3.20	3.00	2.50	2.80	3.90	3.40	4.50	3.20	2.50	2.30	1.90
1982	2.60	3.90	3.40	3.20	2.30	3.70	3.70	3.90	3.70	1.30	1.30	2.00
1983	2.40	4.70	4.70	4.30	3.30	4.00	4.10	3.70	3.80	3.30	2.30	1.30
1984	2.70	3.60	3.40	2.40	2.80	3.40	3.90	4.20	2.90	2.80	2.20	1.90
1985	1.70	3.10	2.70	3.10	3.40	3.60	3.20	2.90	3.40	3.70	2.50	2.90
1986	2.80	2.80	2.70	2.80	3.20	3.90	3.90	3.20	3.40	2.70	2.70	1.90
1987	2.10	3.20	2.90	2.90	2.90	4.20	4.20	2.90	4.20	XXX	2.40	2.10
1988	2.10	3.50	3.30	2.00	2.90	4.10	3.30	3.00	2.80	2.30	XXX	XXX
1989	XXX	3.69	3.89	3.21	2.76	3.21	2.41	3.69	2.81	2.70	2.30	2.01
1990	3.00	2.78	3.06	2.98	3.54	3.82	3.67	3.84	2.94	2.82	2.11	1.50
1991	1.63	3.00	3.12	2.62	2.44	3.29	3.45	4.08	2.80	2.42	1.94	1.35
1992	1.98	3.53	4.49	3.30	2.54	4.65	3.33	3.38	2.68	2.80	1.60	1.40
1993	2.34	2.90	2.95	3.61	2.73	3.03	3.70	3.89	2.93	2.23	1.40	1.21
1994	1.66	2.37	2.91	2.65	2.72	3.86	3.22	3.35	2.26	1.65	1.25	1.44
1995	1.78	2.89	2.85	2.67	2.98	3.34	3.54	3.43	3.19	2.28	2.03	2.01
1996	1.72	2.19	3.05	2.17	3.54	3.02	2.69	3.10	2.64	2.64	2.15	1.98
1997	2.80	2.98	3.86	2.76	2.54	3.06	3.46	3.93	2.54	2.23	1.87	1.46
1998	2.07	2.81	3.20	2.89	2.73	3.15	3.11	2.39	3.15	2.34	1.96	1.28
1999	1.77	1.81	2.63	2.48	2.80	2.91	3.77	3.69	2.93	1.79	1.65	1.75
2000	1.43	1.93	2.69	2.52	2.74	2.99	3.63	2.81	2.52	2.00	1.65	1.14
2001	1.57	3.05	3.52	2.51	3.18	3.91	3.28	3.78	2.83	2.59	2.26	2.17
2002	2.24	2.76	3.67	3.11	3.59	3.66	4.22	3.56	3.76	2.62	2.01	1.69
2003	2.40	3.00	3.40	3.31	3.38	3.35	2.81	3.42	3.19	3.37	1.40	2.92
2004	2.38	2.91	3.70	3.10	3.06	3.86	3.46	3.67	2.29	2.05	1.36	1.84
2005	1.92	4.25	3.33	3.03	3.10	3.78	3.77	3.79	2.97	1.97	1.76	2.43
2006	1.84	2.42	2.77	2.87	2.68	3.35	3.47	3.55	3.36	2.25	2.23	1.33
2007	2.07	2.66	3.93	2.43	3.16	2.54	3.35	3.27	3.07	2.10	2.33	1.67
2008	1.83	2.62	2.06	2.62	2.88	2.81	3.41	2.94	3.34	1.99	1.62	2.10
2009	2.48	3.33	3.04	2.46	2.86	3.86	3.54	3.27	2.94	2.95	1.76	1.62
2010	2.40	3.18	3.18	2.77	2.59	2.79	2.69	2.81	2.46	2.98	1.76	1.61
Average	2.60	3.14	3.04	2.89	3.22	3.48	3.46	3.25	2.75	2.20	1.86	1.79

WIND SPEED - Monthly Mean (km/h)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	3.5	3.3	3.6	3.4	3.3	5.2	4.7	6.3	3.8	2.6	1.9	2.6
1982	3.2	3.0	3.0	2.5	3.2	5.0	5.5	3.7	3.7	1.6	2.0	1.9
1983	2.4	2.6	2.9	2.8	1.8	3.0	3.6	4.1	4.9	1.9	0.9	1.7
1984	1.4	2.0	1.2	0.9	0.8	4.6	3.7	2.6	1.4	1.5	1.4	1.0
1985	1.5	2.2	2.7	2.0	2.9	5.6	4.2	3.9	4.8	3.3	3.2	2.9
1986	2.9	3.1	3.2	2.7	3.4	6.1	6.5	4.9	4.0	2.0	2.6	3.0
1987	3.6	3.4	3.4	3.2	3.1	6.6	4.5	5.4	5.3	2.7	2.7	3.3
1988	3.2	2.1	0.9	0.8	0.8	3.1	2.4	2.5	2.3	0.5	NA	NA
1989	1.1	1.2	1.4	1.6	1.8	2.4	3.1	2.2	2.0	0.6	0.4	0.6
1990	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1991	NA	NA	NA	3.8	3.8	8.5	6.6	6.2	4.8	5.4	3.9	4.0
1992	4.5	4.5	5.0	4.4	4.6	8.0	6.0	6.4	4.2	4.6	3.6	2.8
1993	2.7	1.9	2.4	1.8	1.6	2.7	4.4	2.8	2.9	2.4	1.7	1.4
1994	1.3	1.5	1.8	1.5	2.5	3.2	3.3	2.5	2.4	1.4	0.7	0.7
1995	0.7	0.9	1.1	0.9	2.0	2.8	1.6	1.7	1.4	0.6	0.3	0.5
1996	0.4	0.5	0.6	0.2	0.6	4.1	2.7	0.9	2.4	0.9	0.2	0.3
1997	17.7	0.9	2.5	2.6	2.7	4.1	4.4	4.9	4.1	2.4	3.0	2.7
1998	3.4	3.6	3.5	3.2	3.4	6.0	5.5	3.7	4.7	3.6	2.8	2.8
1999	3.3	3.2	3.3	3.5	4.8	4.6	5.7	5.8	4.6	3.1	2.8	3.3
2000	3.4	3.1	3.4	3.0	3.2	5.6	6.5	6.5	3.7	3.2	3.2	3.4
2001	3.4	3.4	3.7	3.3	3.5	5.4	4.5	5.0	4.1	2.9	2.5	2.9
2002	3.1	3.5	3.7	3.2	3.9	5.2	5.5	5.6	4.4	3.3	2.8	3.5
2003	3.5	3.8	3.5	3.4	4.0	5.3	4.8	5.2	4.3	5.3	3.4	3.7
2004	4.0	3.8	4.0	3.4	5.4	6.5	5.2	5.6	4.0	3.3	3.1	3.4
2005	3.4	4.2	3.4	3.4	3.0	5.1	5.9	4.7	4.9	3.2	3.2	3.1
2006	3.7	3.9	3.5	3.1	3.9	4.4	5.4	5.3	6.3	3.4	2.8	3.4
2007	3.9	3.5	3.9	3.0	3.5	4.8	4.5	5.1	4.9	3.7	2.8	3.4
2008	3.0	3.4	3.6	NA	3.0	4.1	5.4	4.9	4.2	3.5	3.1	3.2
2009	3.8	3.7	3.4	3.1	3.9	5.4	5.4	4.8	4.5	3.9	3.3	3.0
2010	3.4	3.3	3.5	2.9	3.2	4.8	5.3	4.7	3.3	4.0	1.0	4.2
Average	3.4	2.8	2.9	2.6	3.0	4.9	4.7	4.4	3.9	2.8	2.3	2.6

Sitaeliya

EVAPORATION - Monthly Mean (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	3.22	4.17	3.33	3.76	4.28	XXX	XXX	2.70	XXX	XXX	XXX	XXX
1982	2.44	4.99	3.96	4.22	XXX	XXX	XXX	3.50	2.97	2.72	XXX	XXX
1983	2.60	5.10	5.00	5.10	2.90	3.10	3.79	2.86	2.87	3.60	2.60	2.20
1984	XXX	XXX	XXX	XXX	XXX	XXX	XXX	3.89	XXX	XXX	2.57	3.00
1985	3.03	4.09	3.86	3.79	3.82	1.81	2.56	2.59	2.80	3.77	2.73	4.02
1986	2.70	2.78	3.60	2.50	3.43	3.45	3.15	3.77	2.07	2.87	3.43	2.90
1987	2.54	3.31	4.26	3.78	3.71	4.30	3.86	3.79	3.73	2.60	2.38	1.95
1988	2.66	3.38	3.46	3.87	3.26	3.05	2.72	2.44	3.59	3.00	3.08	2.60
1989	3.75	3.70	3.99	3.17	3.04	3.27	2.61	3.36	2.77	2.69	2.20	2.55
1990	3.61	2.05	2.75	3.29	2.93	2.48	2.70	2.89	2.78	XXX	2.97	XXX
1991	3.17	3.71	3.78	3.12	3.22	2.41	2.37	2.53	2.57	2.31	2.31	1.97
1992	2.63	4.51	5.29	4.21	2.93	2.67	2.05	2.65	2.32	2.98	2.43	2.29
1993	3.22	4.12	4.56	4.96	3.65	3.39	2.57	XXX	XXX	1.69	1.74	0.85
1994	1.71	2.88	3.71	XXX	2.78	2.28	2.08	2.15	2.03	1.91	1.74	0.85
1995	2.13	2.62	3.82	2.58	XXX	1.70	2.26	2.27	2.40	2.31	2.43	2.73
1996	XXX	XXX	4.11	2.54	3.51	2.65	1.77	1.61	2.08	2.98	1.66	1.93
1997	2.52	3.22	3.80	2.37	2.41	2.17	1.67	2.10	2.10	1.90	1.54	1.51
1998	1.83	2.86	4.31	3.65	2.71	1.98	1.73	1.92	1.74	1.75	1.66	1.54
1999	2.14	1.94	3.73	1.94	1.90	2.12	2.17	2.21	2.49	1.13	1.80	1.94
2000	1.84	2.03	3.23	2.94	2.50	1.56	2.46	1.51	2.09	2.13	2.02	1.21
2001	1.80	4.01	5.00	2.35	3.06	2.08	2.22	1.94	2.24	1.48	1.80	1.56
2002	2.36	2.78	4.06	2.73	2.83	2.70	2.20	2.18	3.18	2.01	1.99	1.67
2003	XXX	XXX	2.95	2.92	3.09	2.24	2.68	3.17	3.03	3.70	2.09	3.11
2004	2.74	3.22	3.95	3.53	2.91	2.74	2.65	3.35	2.52	2.63	1.92	2.20
2005	1.90	4.00	3.64	3.02	2.81	2.26	2.19	2.80	2.66	1.78	1.68	1.90
2006	2.45	2.87	3.29	3.02	2.09	3.09	2.52	2.49	2.37	2.45	1.97	1.64
2007	2.40	3.16	5.07	2.60	2.95	2.30	2.14	2.25	2.22	1.57	1.90	2.01
2008	2.53	2.83	2.18	3.00	2.69	1.93	2.26	2.21	3.07	2.08	1.99	2.03
2009	2.71	3.73	3.30	2.51	2.55	2.19	2.09	1.85	2.14	2.85	1.58	1.86
2010	2.86	4.07	4.18	2.76	3.77	3.26	**	**	**	**	**	1.30
Average	2.57	3.41	3.87	3.22	3.03	2.56	2.44	2.61	2.57	2.42	2.16	2.05

WIND SPEED - Monthly Mean (km/h)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1982	4.6	4.7	5.1	3.9	7.5	24.1	23.1	18.4	15.7	2.8	2.8	6.8
1983	6.2	5.2	5.0	5.8	6.8	17.1	16.5	21.3	18.7	10.2	7.1	5.3
1984	6.4	8.1	7.4	7.1	10.2	29.5	20.2	16.3	16.8	14.1	8.0	5.8
1997	5.9	5.9	6.6	4.5	6.4	9.4	16.9	16.7	10.2	4.9	5.1	7.0
1998	7.2	5.6	6.2	5.6	9.3	21.0	16.8	12.7	17.6	13.0	7.5	7.1
1999	8.1	7.5	7.0	11.5	16.6	17.1	21.0	15.7	12.5	13.0	6.2	7.1
2000	8.6	5.9	6.4	6.1	9.7	21.6	17.6	20.6	9.9	10.7	7.5	7.2
2001	6.9	6.9	6.5	5.2	11.8	21.7	15.7	18.0	13.8	11.0	5.9	6.9
2002	7.0	8.0	7.6	6.1	15.7	19.2	17.3	18.1	13.0	8.4	6.2	8.9
2003	7.1	7.5	6.2	5.4	10.7	14.3	15.1	16.0	14.2	13.0	9.5	6.9
2004	6.8	5.9	6.7	4.9	17.6	21.7	17.7	15.6	10.4	9.8	8.8	8.5
2005	6.3	8.8	4.9	7.4	7.2	17.7	5.1	12.5	17.4	10.1	6.2	6.8
2006	9.6	7.7	6.1	5.3	11.6	15.1	18.2	14.1	14.0	8.6	6.2	9.3
2007	10.2	5.7	7.9	5.9	9.0	16.1	15.7	14.4	16.9	12.3	4.3	7.2
2008	6.7	5.7	5.8	5.0	7.7	16.8	15.3	11.5	11.1	7.8	6.9	5.2
2009	7.2	6.0	6.2	6.1	14.0	17.2	16.6	12.6	15.2	8.6	5.6	6.0
2010	5.9	6.8	7.6	5.2	7.6	14.3	15.5	14.5	9.7	16.3	na	na
Average	7.4	6.7	6.5	6.0	11.1	17.4	16.0	15.2	13.3	10.5	6.6	7.2