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Environmental Impact Assessment Report
for the
Proposed Expansion of
Victoria Hydropower Station in Sri Lanka

2009

Environmental Impact Assessment Report

March 2009

Project Title

The Expansion of Victoria Hydropower Station in Sri Lanka

Project Proponent

Ceylon Electricity Board

Project Approving Agency

Mahaweli Authority of Sri Lanka

Technical Expertise by

JICA Study Team

The Center for Environmental Studies,
University of Peradeniya, Sri Lanka

PREFACE

This is the Environmental Impact Assessment Report (EIAR) for the Expansion of Victoria Hydropower Station in Sri Lanka. It is prepared by the Ceylon Electricity Board which is the Project Proponent (PP) with the technical expertise of the JICA Study Team and the Center for Environmental Studies, University of Peradeniya, for the purpose of obtaining environmental approval under the National Environmental Act. The EIAR is prepared according to the Terms of Reference (TOR) given by the Mahaweli Authority of Sri Lanka (MASL) which is the Project Approving Agency (PAA) for the Project appointed by the Central Environmental Authority.

The EIA study and the field scoping was carried out during the last quarter of 2008. The proposed project is in conformity with the "the Study of Hydropower Optimization in Sri Lanka" (March 2004) and its primary objective is to partially meet the growing peak electricity demand in the island.

Chapter 1 of this EIA Report provides a basic introduction and the scope of the EIA study along with the methodologies adopted.

Chapter 2 gives a detailed comparison of alternatives and a description of the preferred alternative. The study considered three project alternatives along with the no-action alternative and recommends the Basic Option as the preferred alternative. Accordingly a 5 km tunnel will be constructed parallel to the existing one as well as a powerhouse, with installed capacity of 210 MW, which will be constructed adjacent to the existing one. It is important to note that some of the infrastructure needed for the proposed project (e.g., tunnel intake, ground preparation for power house and surge tank) have already been provided by Victoria Phase I, thus greatly reducing the potential environmental impacts and avoiding the need to lower the water level of Victoria reservoir.

Chapter 3 provides a detailed description of the existing environment covering physical, biotic and social components. This description is limited to the scientifically defined project impact area of the preferred alternative, i.e., the Basic Option. The impact area is located almost entirely within the Victoria-Randenigala-Rantembe (VRR) Sanctuary.

Chapter 4 concentrates on the identification and analysis of environmental impacts. A detailed environmental and social assessment was carried out within the impact area. Accordingly, 13 significant negatives impacts and 4 positive impacts were assessed in addition to a number of minor impacts. All impacts were mitigable and a monitoring plan has been prepared to ensure the effective implementation of mitigation measures. The project does not require any resettlement. Only 57 families will be indirectly impacted by the project.

Chapter 5 provides the mitigation measures proposed for the identified significant impacts.

Chapter 6 provides an extended benefit-cost analysis. Environmental impacts and mitigation measures were valued. The project is economically viable even after integrating the environmental and mitigation costs resulting in a Benefit Cost Ratio of 2.29.

Chapter 7 presents a monitoring program to be implemented to ensure that mitigation measures are effectively carried out. An independent monitoring committee is suggested.

Chapter 8 concludes by recommending the preferred alternative – the Basic Option - as the environmentally least damaging alternative while realizing the project objectives.

In preparing the EIAR, all TOR entries were addressed. In addition, several new entries have also been introduced into the EIAR as required.

We would like to acknowledge the cooperation extended by MASL, DWLC, Divisional Secretary of Hanguranketa, Grama Niladaris and the people in the project impact area by providing data and information for the EIA study. In addition we also wish to acknowledge the guidance provided by the CEA and other members of the Technical Evaluation Committee.

CEB.

EXECUTIVE SUMMARY

1. Introduction

The Victoria hydropower extension (stage II) was envisaged under the feasibility study of the existing Victoria Power Station in 1978. The JICA Hydro Optimization Study in 2004 while studying this option concluded that thermal power generation would necessarily take a major role in the long term and that the role of the hydropower in the country should be altered from power sources for base demand to that for middle and/or peak demand, and that this requires the altering of the operation of existing reservoirs and power stations. The pre-feasibility study for the expansion of the Victoria Hydropower Station was conducted as one of the expansion projects, and the possibility of the Expansion Project confirmed. The primary objective of the project is to meet the rising peak electricity demand.

2. Alternatives

Three site alternatives, namely, Basic Option, Downstream Option and Pumped Storage Option, along with the no-action alternative were evaluated from technical and engineering, environmental and social points of view (see Table 2). It was concluded that the Basic Option, that is, the construction of a tunnel parallel to the existing tunnel and a powerhouse located next to the existing powerhouse where ground preparation has already been made, is the preferred alternative that minimizes the environmental and social impacts while achieving the objectives of the project. The Basic Option has been selected as the preferred alternative because it is the most effective environmentally significant mitigation measure as it reduces both the magnitude and the severity of the impacts on both the natural and social environment.

3. Preferred Alternative – the Basic Option

The Basic Option is to place an additional powerhouse near the existing hydropower facilities. The Basic Option consists of a 5.4 km long and 6.6 m. diameter tunnel paralleling the existing tunnel, a surge tank next to the existing one and a powerhouse adjacent to the existing powerhouse. With two power generating units each with 114 MW, the installed capacity of the powerhouse is 228 MW (see Table 3 for Technical Details of the Basic Option). The two powerhouses (the existing and the proposed) will operate mainly between 18.30 to 21.30 hours primarily to meet the peak power demand after the commissioning of the proposed expansion.

4. Impact Area

The selection of the study area for the environmental impact assessment was based on two factors.

1. The criteria given by the TOR, which includes the following:

- Project Site Areas directly affected by the project itself and areas indirectly affected (maintenance area, etc.)
- Locations affected by construction activities (quarries, refuse disposal areas, tunnel muck disposal areas, traffic diversions, work camps, temporary access roads, etc.)
- Area beyond the project site where there is potential for environmental impacts.
- Area along the transmission line route including a width of 25m on either side of the transmission line path.
- An impact study of the aquatic fauna and flora from 50 meters upstream of dam to 100 meters downstream from the tailrace outlet
- An impact study of the fauna and flora in the inundation area:
    - Fauna and flora in the area up to the high flood level

- Fauna and flora in the 60 meters reservation area from high flood level
- An impact study of the fauna and flora along the river reservation:
  Fauna and flora at a distance of 60 meters from the bank along transects at reasonable intervals. The location of line transect was determined according to habitat variation and 100 meter gradient contours.

2. Expert analysis by the Study Team and Consultants:

- The main impact area considered for the EIA study is the 600-meter-wide belt along the tunnel trace. This was selected on the basis that the most significant impact, that is, the potential reduction of ground water during tunneling, could extend up to an area twice the maximum depth of the tunnel from the surface, which is 300 meters. An area with a 600-meter radius around the other main project components, i.e., powerhouse, tunnel and surge tank site was also included into the impact area. Depending on other environmental and social data generated during the study, this zone was adjusted and/or modified but not reduced1.
- Locations affected by construction activities, e.g., crew camp sites, quarry sites, tunnel muck dumping sites, access roads, etc. The exact impact area around these sites will vary based on the impacts but will not be less than 100 meters.
- The areas up to 50 meters upstream of the entire length of the Victoria Dam and a 20-meter-wide area on either side of the Mahaweli river for 100 meters from the tailrace of the Basic Option.

The Project Impact Area (PIA) thus identified, along with the location of the project, is given in Figure 1.

5. Significant Impacts

The identification of environmental impacts was done using the following methods:

- Study of previous projects similar to the present study - the EIA team referred to the EIA reports and empirical information from similar projects in Sri Lanka such as the Upper Kotmale Hydropower Project, the Kukule Ganga Hydropower Project, etc.
- Consulting EIA reports of similar projects in other parts of the world, for example, India, China, etc.
- Consulting checklists, for example, the Checklist of Environmental Characteristics – Document 5, prepared by the Department of Environmental Affairs, Republic of South Africa.
- Review of published documents such as the Environmental Assessment Source Book Volume II Sectoral Guidelines, published by the Environment Department, The World Bank.
- Expert judgment – the consultants held several rounds of discussions to identify the impacts.
- Use of the Modified Leopold Matrix. The EIA consultants engaged in an exercise using a modified version of the Leopold Matrix to identify the impacts and also to assess the significance. The process identified is given below.

The exercise enabled the Team to identify thirteen (13) significant negative impacts and four (4) positive impacts (see Table 1).

[1] All impact areas identified in the TOR fall inside the 600 m buffer zone defined by the Study Team and Consultants.

Table 1 Identified significant impacts (not in any order of priority)

Type of Impact	The Description of the Impact
NEGATIVE	
1	Temporary lowering of ground water affecting domestic uses
2	Temporary reduction in agricultural production (paddy) due to lowering of ground water
3	Impact on the integrity of the existing tunnel and other structures
4	Pollution of surface water from tunnel discharge and dumping sites
5	Increase in work related accident
6	Reduction of forest cover at dumping sites
7	Disturbance of some species due to noise and other activities
8	Soil erosion due to tunnel muck dumping and access road construction
9	Ground Water Pollution
10	Disturbances to the community from the workers
11	Damages to roads due to increase in heavy traffic
12	Disturbance to the migration patterns of elephants
13	Loss of private land at tunnel muck dumping site in Kohombagana
POSITIVE	
1	Reduction of carbon fuel/foreign exchange savings
2	Injection of capital to the local economy
3	Increase in regional employment opportunities
4	Building a positive impression of the project

It is important to note that the project will not lead to relocation of people. In addition, the proposed project will complement the DWLC's Management Plan for the VRR Sanctuary.

6. Mitigation and Monitoring

While most of the significant impacts could be mitigated, others are internalized by the project by planning and design thus preventing the impact from occurring to a large extent. To ensure the effective implementation of mitigation measures, a monitoring program is proposed. An independent Monitoring Committee led by a leading environmental consultancy organization is proposed to oversee the monitoring program (Table 4, Table 5).

7. Conclusion

The primary objective of the EIAR is to provide a scientific assessment of the potential environmental impacts of the proposed Expansion of Victoria Hydropower Project and to make recommendation to make the project environmentally sustainable.

This was achieved by several methods.

- Selecting the least damaging alternative. It became amply clear that of the three site alternatives and the no-action alternative, the Basic Option is environmentally the most desirable.
- Identifying the environmental impacts and screening them to define the most significant impacts. Complex methods were employed for this purpose and the

findings were fed to the feasibility study team to integrate mitigation into the planning and designing of the project.

- Using the latest technologies in tunneling and constructing the hydropower station of the project, which will either avoid or minimize the construction-related environmental impacts such as excessive noise and vibration, work-related accidents, waste, and the accidental discharge of oil, chemicals and other waste material into the environment.
- Identification by the EIA team, independently of the TOR entries, 13 negative impacts and 4 positive impacts.
- Integration of some of the significant impacts into the planning and design of the projects.
- Proposing mitigation measures for impacts that were not integrated into the project planning and design.
- Developing a Monitoring Program to ensure the effective implementation of mitigation measures.
- Proposing a Monitoring Committee comprising of the Project Proponent, PAA, other stakeholders and an independent institution to supervise and implement the monitoring program.

The proposed expansion of Victoria is a national need, especially to meet the rapidly growing peak hour electricity demand in the country. Alternative sources of energy, i.e., coal and diesel are both expensive and cause harmful environmental pollution. The environmental impacts of the proposed project in comparison are relatively less and they can be successfully mitigated. The example and the lessons learnt from the first Victoria project clearly demonstrate that, in the long term, the proposed project will also complement the objectives of the Management Plan of the VRR Sanctuary. Thus, the proposed project, in addition to being a power generation project, will also contribute to the conservation of the environment in which the project is located.

The extended benefit-cost analysis with a BC Ratio of 2.29 also concludes that the proposed project is economically viable even after environmental and social impact costs and the mitigation cost are considered.

Taking all these factors into consideration, the EIA team highly recommends the project - the Basic Option - subject to the effective implementation of the mitigation and monitoring plan.

Table 2 Analysis of Alternatives

		Item	No-action Alternatives	Basic Option	Downstream Option	Pumped Storage Option
Technical and Economic Aspects	1)	Tunnel Length (km)	0	5.8	9.1	10.9
	2)	Effective head Gross head (m) Head loss (m) Effective head (m)	 - - -	 183 13.2 170	 194 19.1 175	 191 25.8 165
	3)	Annual Energy, Power output Annual Energy (GWh) Net Annual Energy (GWh)	 - -	213 651 651	219 652 652	198 711 643
	4)	Geological Conditions	-	not meet the fault	may encounter the fault	may encounter the fault
	5)	New access tunnel and road				
		New access Tunnel	0	Not necessary	1 tunnel with 500 m	1 tunnel with 500 m and 1 tunnel with 600 m
		New Access Road	0	Not necessary	2 roads with total length of 2.8 km	2 roads with total length of 3.7 km
	6)	Construction Period Construction Period (year) Period of Drawdown of Randenigala Reservoir (year)	 - -	 5.0 0.0	 5.5 1.0	 6.0 1.5
	7)	Project Construction Cost	-	172	213	336
	8)	Benefit-Cost Ratio	-	1.83	1.43	0.89
Environmental and Social Aspects[2]	1)	Magnitude of the Impact Area	0	842	1436	1817
	2)	Disturbance to bed rock stability	0	Low	Medium	High
	3)	Soil Erosion	low	Low	Medium	High
	4)	Ground Water Pollution from tunnel discharge	0	Low	High	High
	5)	Pollution of surface water from tunnel discharge	0	Low	Medium	High
	6)	Loss of Forest	0	210 ha	381 ha	486 ha
	7)	Disturbance to wildlife in the VRR	0	Low	High	Very High
	8)	Loss of biodiversity	low	Low	Medium	High
	9)	The number of HHs affected by temporary loss of ground water	0	57	111	174
	10)	The number of agricultural plots affected by temporary loss of ground water	0	57	135	182
	11)	The impacts on existing roads (kms)	0	13.9	16.1	17.7
	12)	Integrity of the existing tunnel	0	same	same	same
	13)	Impact of blasting on the existing houses	0	Low	Medium	High
	14)	Increase in work related accidents	0	Low	High	High
	15)	Disturbances from the outside workers	0	Low	High	High
	16)	The impact on Elephant Migration across the river	0	Low	Medium	Medium
	17)	Compensation for the loss of land due to tunnel muck dumping at Kohombagana	0	Low	Medium	High
	18)	Mitigation Cost	0	Rs. 235,559,339.40	Rs 299,969,763.25	Rs 342,434,491.72

[2] Where specific quantification of an impact is not possible, a three stage ranking (e.g., low, medium or high) was used to compare the three alternatives). The ranking is based on relative comparison of the four alternatives and not against any objective and absolute value.

Table 3 Technical Details of the Preferred Alternative: The Basic Option

Item		Dimension
Headrace Tunnel	Number	One (1)
	Inner Diameter	6.6 m
	Total Length	5,003 m
Surge Tank	Type	Restricted Orifice Type
	Diameter	20.0 m (Upper Section) 6.6 m (Lower Section)
	Height	117.0 m (Upper Section) 32.9 m (Lower Section)
Penstock	Type	Tunnel & Open-air
	Number	Tunnel: One (1) Open-air: Two (2)
	Inner Diameter	Tunnel: 6.6 m to 5.6 m Open-air: 3.95 m to 2.85 m
	Length: Tunnel	575 m
	Length Open-air	175 m for Unit 4* 160 m for Unit 5*
	Total Length	750 m for Unit 4* 735 m for Unit 5*
Powerhouse	Type	Surface type
	Size	37m wide × 44m high × 69m long
Development Plan	Normal Intake Water level	430.0 m
	Tail Water Level	231.2 m
	Gross Head	199.0 m
	Effective Head	183.3 m
	Maximum Discharge	140 m3/s
	Number of Unit	Two (2)
	Installed Capacity	228 MW (only expansion)
	Peak Time	3 hours
	Peak Firm Capacity	393 MW (with existing)
	Annual Generation Energy	716 GWh (with existing)
	(Primary Energy**)	468 GWh (with existing)
	(Secondary Energy***)	248 GWh (with existing)
Turbine	Type	Vertical Shaft, Francis Turbine
	Number	Two (2)
	Rated Output	122 MW per unit
	Revolving Speed	300 r/min
Generator	Type	Three-phases, Synchronous Generator
	Number	Two (2)
	Rated Output	140 MVA per unit
	Frequency	50 Hz
	Voltage	16.5 kV
	Power Factor	0.85 lag
Main Transformer	Type	Outdoor Special Three-phase Type or Outdoor Single Phase Type
	Number	Two (2)
	Capacity	145 MVA per unit
	Voltage	Primary 16.5 kV Secondary 220 kV
	Cooling	Natural Convection Oil Forced Air Type
Switchyard	Type	Conventional Type
	Bus System	Double Bus
	Number of Lines Connected	Three (3) cct Transmission Lines
	Voltage	220 kV

Note: * Units 4 and 5 refer to the two units in the proposed expansion project
** "Firm energy" means the total of power generated during 3-hour peak duration.
*** Secondary energy" means the total of power generated in duration except 3-hour peak time.

Table 4 Mitigation and Monitoring (Negative impacts)

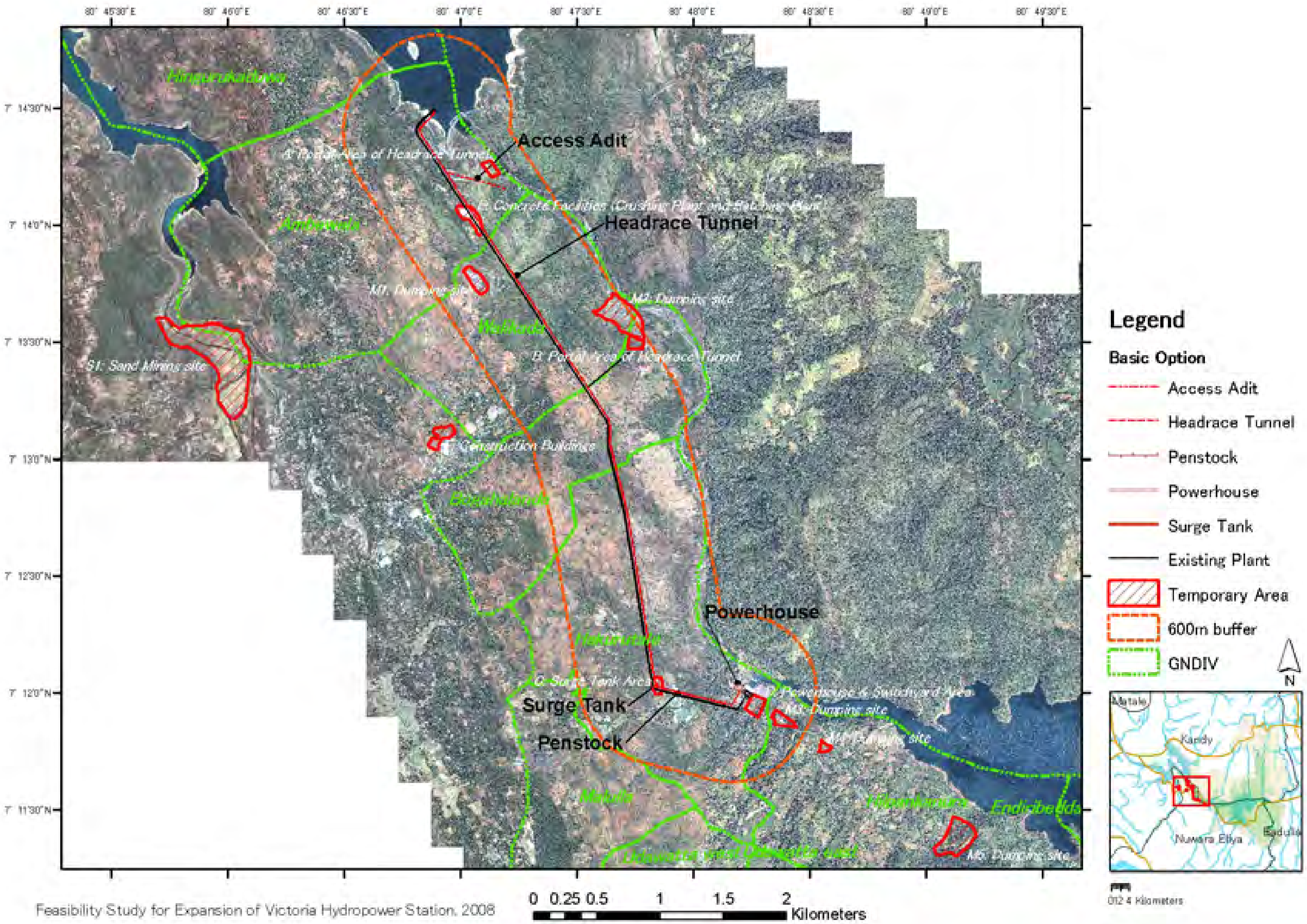
Impact	Nature of Impact	Mitigation Measure	Monitoring					
			Parameter	Locations	Method	Frequency	Duration	Responsibility
NEGATIVE								
(1) Temporary lowering of ground water affecting domestic uses	57 house holds will be affected.	Provision of mobile water supply to the affected families	The number of affected houses getting the supply	Houses	Enumeration of changing ground water level	Weekly	One year in pre-construction stage if possible, construction period and additional one year	Monitoring committee/ Preconstruction ground and surface water levels and quality survey is recommended.
(2) Temporary reduction in agricultural production (paddy, home garden) due to lowering of ground water	139.2 ha (Rice field and vegeTable field)	Cash compensation for the loss	The affected agricultural plots	Plots	Enumeration	Every four months	Construction period and additional six months	Monitoring Committee
(3) Impact on the integrity of the existing tunnel and other structures	Blasting is controlled by the use of appropriate specific charges in the blasting rounds to limit peak particle velocity not exceeding 2cm/sec.	Use modern and safe technology Recording actual status of the existing structures in the pre-construction stage is recommended	Blasting vibration	Dam/Power House/Other affected places and houses (Tunnel will not be directly monitored as it is in operation)	Continuous monitoring using vibrometers and spot checks	Continuous/ when required	Construction period	MASL and CEB

Impact	Nature of Impact	Mitigation Measure	Monitoring					
			Parameter	Locations	Method	Frequency	Duration	Responsibility
(3b) Impact on the integrity of the existing houses	Blasting is controlled by the use of appropriate specific charges in the blasting mentioned in (3) above.	Use modern and safe technology Pre-construction structural distress survey (crack survey) is recommended	Blasting vibration	Houses in he vicinity of Sites of Operations	Observation	During Blasting	Construction period	Monitoring Committee
(4) Pollution of surface water from tunnel discharge	Tunnel discharge will contain chemicals used for blasting	Control spillage/Treating the tunnel discharge through oil traps	Water Quality parameters and the proper functioning of the systems	Tunnel Discharge sites. 3 possible outlets. But no houses will be affected.	Inspection and measure	Fortnightly	Construction period	Monitoring Committee
(5) Increase in work-related accidents	Traffic accidents, tunnel accidents, fire etc.	Follow strict safety measures	Use of safety methods and equipment	Workplaces	Observation	Daily	Construction period	Monitoring Committee
(6) Reduction of forest cover at dumping sites	Reduction of late grown forest cover is 8.14 ha. All dumping sites were used by Victoria Project I for the same purpose.	Implement a environmenetal restoration program	Regrowth Establishment and regeneration	Dumping sites	Observation measure and count	Twice a year for flora/Monthly for Fauna	Construction period and additional three years	Monitoring Committee with an ecologist
(7) Disturbance of some species due to noise	During construction some species will be disturbed ,especiall y during the night	Use low noise machinery/ some noise is not mitigable.	Sound levels	Sites of Operations	Measure sound levels	spot checks	Construction period	Monitoring Committee
(8) Soil erosion due to tunnel muck dumping and access road preparation	Length of the rubble is 1253 meter	Use appropriate soil conservation methods during construction (parallel with impact 6)	Soil conservation Methods	Dumping sites and access roads	Observation	Monthly	Construction period and additional six months	Monitoring Committee

Impact	Nature of Impact	Mitigation Measure	Monitoring					
			Parameter	Locations	Method	Frequency	Duration	Responsibility
(9) Ground Water Pollution from Tunnel discharge	Partially mitigable	Treating the waste water before discharging into the ground	Ground Water Quality parameters	Selected wells in the PIA	Measure	Once in two months	Construction period	Monitoring Committee
(10) Disturbances to the community from the workers	Partially mitigable	Awareness programs for the workers	Complaints from villagers	Villages	Enumeration	When required	Construction period and additional six months	Monitoring Committee
(11) Damages to Road due to increase of heavy traffic	Affected road is 18 km, 4 years.	Immediate repairing of the damaged roads	Road damages	Along the roads	Inspection and observation	Weekly	Construction period	Monitoring Committee
(12) Disturbance to the migration patterns of elephants	Migration routes from Power station to Randenigala Reservoir will be affected during operation.	Installing 8CCTVs to monitor elephants on the bed. And flash lights at 8points along right bank of the channel from the powerhouse	The presence of elephants on the river bed	Location where lights and CCTVs are installed.	Observation and monthly review	Automatic recording and monthly review	During construction and continue only if there is a need. Flash light will be used only if necessity is confirmed.	Monitoring Committee with the DWLC. The information will be useful for DWLC.
(13) Loss of private land at tunnel muck dumping site in Kohombagana	5.79 ha may have to be acquired for the dumping site in Kohombag ana if the other sites are not adequate	Payment of compensation for the loss of land at Rs. 100,000 per acre	Amount paid	Village	Check and verification	Twice	At the time of valuation and paying compensation	Monitoring Committee

Table 5 Enhancement measures and monitoring (positive impacts)

Impact	Nature of Impact	Enhancement Measure	Monitoring					
			Parameter	Locations	Method	Frequency	Duration	Responsibility
POSITIVE								
Reduce carbon fuel/foreign exchange savings	Beneficial	CEB to explore the possibility of getting carbon credit benefits						No monitoring required
Injection of capital to the local economy	Enhanceable	Buy local raw material/employ local people	The amount of locally produced bought/ The number of locals hired	Project Area and adjoining villages	Rapid Survey	Every six months	Construction period	Monitoring Committee
Increase in regional employment opportunities	Enhanceable	Give preference to locals in hiring for all jobs	The number of locals hired	Project Area and adjoining villages	Rapid Survey	Every six months	Construction period	Monitoring Committee
Building a positive impression on the project	Enhanceable	Open an office to the public/ Contribute to community development programs	Functioning state of the art audio visual equipments at the visitor center	Visitor Center and villages	Observation	Every six months	Construction period and additional six months	Monitoring Committee



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ABBREVIATIONS

Organizations	
BOI	Board of Investment
CEA	Central Environmental Authority
CEB	Ceylon Electricity Board
CIDA	Canadian International Development Agency
DCS	Department of Census and Statistics
DWLC	Department of Wildlife Conservation
GN Division	Grama Niladari division
JICA	Japan International Cooperation Agency
LECO	Lanka Electricity Company
MASL	Mahaweli Authority of Sri Lanka
MOENR	Ministry of Environment and Natural Resources
MOFP	Ministry of Finance and Planning
MPE	Ministry of Power and Energy
MSO	Mahaweli Security Organization
NGO	Non-Governmental Organization
PAA	Project Approval Agency
PP	Project Proponent
PUC	Public Utilities Commission
RDA	Road Development Authority
TEC	Technical Evaluation Committee
WB	World Bank

General and technical terms	
B/C	Benefit-Cost Ratio
BOD	Biological Oxygen Demand
CDM	Clean Development Mechanism
COD	Chemical Oxygen Demand
D/D	Detailed Design
DP	Dynamic Program
DSWRPP	Dam Safety and Water Resources Planning Project
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return

EL.	Elevation
F/S	Feasibility Study
FSL	Full Supply Level
IDC	Interest during Construction
IEE	Initial Environmental Evaluation
MOL	Minimum Operation Level
NEA	National Environmental Act
NPV	Net Present Value
O&M	Operation and Maintenance
ODA	Official Development Assistance
OOF	Other Official Funds
PI	Project Information
PIA	Project Impact Area
TDS	Total Dissolved Solid
TOR	Terms of Reference
TSS	Total Suspended Solid
VAT	Value Added Tax
VRR Sanctuary	Victoria Randenigala Rantambe Sanctuary

Units

A	Ampere
ha	Hectare
Hz	Hertz (Cycles per second)
MCM	Million Cubic Meter
Mvar	Megavar
m^3/s	Cubic meter per second
NTU	Newton Turbidity Unit
pfu	Plaque-Forming Unit
ppm	Parts per million
V	Volt
kV	Kilovolt = 10^3 V
VA	Volt Ampere
kVA	Kilovolt Ampere = 10^3 VA
MVA	Megavolt Ampere = 10^6 VA

W	Watt
kW	Kilowatt = 10^3 W
MW	Megawatt = 10^6 W
Wh	Watt Hour
kWh	Kilowatt Hour = 10^3 Wh
MWh	Megawatt Hour = 10^6 Wh
GWh	Gigawatt Hour = 10^9 Wh
Rs	Sri Lankan Rupees
US$	US Dollar
Mill. US$	Million US Dollar
USc	US Cent
°C	Celsius degrees

CHAPTER 1

INTRODUCTION

1 INTRODUCTION

1.1 Background of the project

Victoria hydropower expansion (stage II) was envisaged under the feasibility study of existing Victoria Power Station in 1978. The ground for the second stage power house had been leveled at the time next to the existing power house. The intake facilities for a second tunnel have also been constructed. Therefore, shutting down the existing power station and drawing down the Victoria reservoir during the expansion work will not be necessary. The existing switchyard also has space to add two feeder bays. The Master Plan study in 1988 had also studied the expansion of the Victoria power station and considered it as a possible future capacity extension.

JICA Hydropower Optimization Study in 2004 analyzed 2 unit and 3 unit expansion and recommended further detailed study. In this study, it was expected 1) that thermal power generation would necessarily assume a major role in the long term, 2) that the role of hydropower in the country should be altered from power sources for base demand to power sources for middle and/or peak demand, and 3) that altering the operation of existing reservoirs and power stations and expanding existing facilities would be examined. The Pre-feasibility Study for the expansion of the Victoria Hydropower Station was conducted as one of the expansion projects, and the possibility of the Expansion Project was confirmed.

1.2 Objective of the proposed project and justification of the project

The annual maximum power demand in Sri Lanka has been growing at an average rate of 6.9% from 1996 to 2006, and the CEB forecasts that its growth rate might increase to around 6.4% in the next decade. Thus, the development of power resources in the country is one of the most important issues in the power sector in particular and the larger economy in general.

Of the approximately 2,000 MW which is estimated as hydropower potential in the country, 1,300 MW have been developed by the end of 2006. The number of remaining project sites that have potential from the viewpoints of economic efficiency and the natural/social environment is limited. However, development of hydropower is indispensable from the point of view of energy security in the country, which has limited domestic energy resources. "The Study of Hydropower Optimization in Sri Lanka" (March 2004) was carried out under technical assistance from JICA in such a context in order to define the remaining hydropower potential and to optimize the use of hydropower resources.

As mentioned in 1.1, in the JICA Hydro Optimization Study in 2004, the possibility of the Expansion Project was confirmed to meet the rising peak electricity demand.

The proposed expansion project has the advantage (in comparison with other expansion projects of hydropower stations) of not needing to lower the water level of the Victoria reservoir during the construction period, because the intake facilities for the expansion were already constructed during Victoria Phase I. It is also noted that the construction per kW of the proposed expansion project is around US$ 1000 which is much lower than that of other new hydropower projects.

1.3 Summary of the need or problem being addressed by the project and how the proposed project is expected to resolve the problem or the issue

The annual power demand is expanding at a rate of about 7% and the peak hour demand is expanding even rapidly. This requires sudden adjustments in power generation. However, it is not economical as well as technically unsound for thermal power plants to quickly turn on and shut down to meet the peak hour demand on a daily basis. The hydropower plants are far more flexible in this regard. As the base power generation has already moved from hydro to thermal, the former is ideally suited from both a technical and economic point of view to generate the sudden peak hour power demand in the country. The expansion of Victoria hydro power generation capacity by an additional 210 MW is envisaged to cater to this peak demand and to resolve the problem of quickly turning on and shutting down the power generation plants.

1.4 Objective of the EIA Report

1.4.1 General Objectives

EIA is defined as one of the most effective tools of achieving sustainable development. Thus, the overall objective of this EIA report is to assess the potential environmental and social impacts of the preferred alternative and to suggest mitigation measures to minimize the negative impacts and to enhance the positive impacts, thereby making the Victoria Expansion Project environmentally sustainable and socially responsible. As the EIA study process was conducted parallel to the feasibility study, the findings of the EIA study were fed into the planning and design team so that they could integrate most of the mitigation measures into the project planning. The upstreaming of the EIA process thus enabled the project to become environmentally sustainable and socially responsible from the beginning.

The EIA study process also made it possible to benefit from the informed participation of the local people including the affected people and other stakeholders. The EIA study provided an opportunity to impart to the public an accurate picture of the project on the one hand and to obtain the views and concerns of the people on the other. This two-way information flow helped the EIA study team to identify and assess both the social and environmental impacts with the help of local knowledge and expertise and to feed the information to the planning and design team to be incorporated and integrated into project planning.

1.4.2 Specific Objectives

The specific objectives of the EIAR are primarily defined by the TOR given by the MASL. Within the broader framework of the TOR, the present EIAR have also achieved the following objectives:

1. To review the main project objectives to identify the possible alternatives to the project;
2. To identify the environmentally least impacting alternative that could realize the project objectives;
3. To identify legal, institutional and administrative requirements for the project;
4. To build a solid baseline status on the physical, biotic and social environment of the impact area;

5. To identify all components of the project that are likely to have impacts on the physical, biotic and social environment;
6. To identify the most significant impacts using standard EIA methodologies;
7. To further study the most significant impacts to assess their magnitude and intensity, temporal dimension and the mitigability;
8. To propose measures to avoid, mitigate or lessen the impacts on the environment;
9. To develop a monitoring framework to ensure effective implementation of the mitigation measures.
10. To assess the sustainability of the project through an extended benefit-cost analysis.

1.5 Extent and the scope of the study

The scope of the EIAR is primarily determined by the TOR. However, the EIA team, where necessary, has gone beyond the limits of the TOR to ensure that no environmental or social impacts are left out from the study. As discussed in the next section, the EIA employed a variety of methodologies to ensure that all aspects of the environmental impacts are covered by the study. The time horizon of the study covers both the constructional and operation phases.

The impacts of the first Victoria tunnel and powerhouse are investigated through field investigations in an area 600 meters wide along the existing tunnel and a detailed questionnaire survey administered to the people who live in the close proximity to the first tunnel trace, which is mainly for the purpose of identifying the environmental impacts of the tunnel and powerhouse both during the construction and operational phases and to compile lessons learnt from this experience.

The impact area considered for the EIA study consists of the following. :

a. The main impact area, which is the 600 meter-wide belt along the tunnel trace. This was selected on the basis that the most significant impact, which is the potential reduction of ground water during tunneling, could extend up to an area twice the maximum depth of the tunnel from the surface which is 300 meters. The area which has a 600 meter radius encompasses other main project components of the project such as the powerhouse, tunnel and, surge tank site. However, depending on other environmental and social data generated during the study, this zone will be adjusted and modified but will not be reduced.
b. Locations affected by construction activities (e.g., crew camp sites, quarry sites, tunnel muck dumping sites, access roads, etc.). The exact impact area around these sites will vary based on the impacts.
c. The areas up to 50 meters upstream of the entire length of the Victoria Dam and the 20 meter-wide area on either side of the Mahaweli river for 100 meters from the tailrace of the Basic Option.

1.6 Methodologies adopted in report preparation

The complexity of the EIA study required the use of multiple methodologies. The following Tables summarizes the methodologies adopted in the study (see Annexes for the complete matrix, the list of people interviewed, the questionnaire, the details of the sample survey and the details of the scoping meetings including photos of the scoping meetings).

Table 1-1 Methodologies adopted in the study

Item	Data Type	Data collection methods	Data analysis and Impact identification	Mitigation measures	Monitoring plan
Hydrology	Surface water bodies, surface drainage pattern, flow of the river, dry season flow, surface water quality, and present use of surface water, Evidence of floods, ground water use	Secondary sources and field observations and GIS	The data obtained from different sources and in different formats were integrated using GIS technology. Maps, overlays, buffer generation, digital elevation model generation, preparation of slope maps were carried out by using above tool. Impact area was demarcated with the aid of geo-visualization method in GIS. Leopold impact matrix was employed to find the significant impacts following several brainstorming sessions. Also significant impacts have been discussed in detail. Valuation of impacts were done using standard environmental economic valuation techniques. Simple methods such as percentages, averages and range were used.	Based on consultant s' experiences in working in similar projects, the mitigation measures used in similar projects and the theoretical literature, mitigation measures have been given for each significant negative impact	Environmental monitoring plan has been given on an internationally accepted format. This includes mitigation measures, relevant place or time, criteria, responsible institutions and personnel who should carry them out.
Soil	Types of soil, erosion, soil stability, land slides	Secondary sources and field observations			
Land use	Present land use	Following maps were used to collect data on land use and related to the projects: 1:10000-Topo sheets covering the impact Area. Survey Plans; Survey Dept. 2006; Satellite imageries covering the impact area. In addition GPS was devised to collect data on constructions.			
Ambient Air Quality	Existing major sources, and ambient air quality levels	Field observation, measurements and people's perceptions			
Surface and Ground Water Quality	Existing quality levels during wet and dry conditions	Field observation, measurements at selected locations and people's perceptions			
Noise	Existing major noise sources, and ambient noise levels	Field observation and measurements and peoples perceptions			
Biological environment	Natural habitats in the area, rare, threatened and endemic fauna and flora, environmentally sensitive areas	Field investigation Transects Red List 2007			

Item	Data Type	Data collection methods	Data analysis and Impact identification	Mitigation measures	Monitoring plan
Socio-economic	Human settlement, religious and cultural centers, infrastructure, existing environmental problems and any social conflict Impacts of previous tunneling of Victoria	Through maps ,questionnaires survey, Key informant interviews, focus group discussion and direct observations.			

Table 1-2 Site Survey items and date

Item	Date and time	Details
Hydrology	Nov 13, 2008 and Dec 14, 2008	Surface water sampling
	Nov 13, 2008 and Dec 14, 2008	Underground water sampling
Soil	Sep. 15, 2008 to Dec. 20, 2008	Visual examination
Land use	Sep. 15, 2008 to Dec. 20, 2008	Visual examination
Noise	Nov 13, 2008 and Dec 14, 2008	Noise measurement
Air	Nov 13, 2008 and Dec 14, 2008	Air Sampling
Biological environment	Sep. 15, 2008 to Dec. 20, 2008	Flora
		Mammal
		Birds
		Reptile
		Amphibian
		Fish
		Insect
		Land snails
Socio-economic	Sep. 17, 2008	Reconnaissance Survey
	Sep. 8-10, 2008	Scoping meetings
	Sep. 15, 2008 to Dec. 20, 2008	Social Survey
	Sep. 15, 2008 to Dec. 20, 2008	Official meetings
	Sep 8-10, 2008	Meeting with civil institutions (temples, etc.)

1.7 The approval needed for the proposed development from state agencies

1. EIA approval from the MASL with CEA concurrence
2. Approval from Divisional Secretaries
3. Clearance from Dept. of Wild Life Conservation for all construction activities within the VRR Sanctuary
4. Approval from Pradeshiya Sabhas for construction activities
5. Approval from Mahaweli Authority of Sri Lanka to use Victoria water.
6. Approval from Road Development Authority to use the road for heavy vehicles
7. Approval from Dept. of Archaeology to ensure that no archaeologically significant sites are within the impact area

1.8 Any conditions laid down by state agencies in granting preliminary clearance for the project

At the time of preparing this EIA report, the only state agency that had laid down conditions was the MASL and that was only if the EIA recommends the pump storage (Annex I). Since the recommended option is the Basic Option, this condition is not applicable.

1.9 Conformity with other development plans in the area

Almost all the activities of the project fall within the VRR sanctuary and as such only the DWLC Management Plan is applicable to this area. No other development plans have been formulated for the area affected by the proposed project. The proposed project is generally in full conformity with the goals of the DWLC Management Plan with only some short term (construction period) disturbance to the fauna and flora around the tunnel muck dumping sites and at construction sites. As can be seen from the natural environment in the vicinity of the current Victoria Powerhouse, the proposed project will result in a better managed environment supporting the management objectives laid down in the DWLD Management Plan (Table 1-3).

Table 1-3 How the Proposed Project will Conform to DWLC MP

No	DWLC MP Objectives	How the proposed project will complement
1	To protect the catchments of VRR multipurpose reservoirs	The limited access to project sites will eliminate intervention
2	To improve the management of the intermediate zone forests including the endemic plant and animal species	Although there will be construction period disturbances, the limited access to project sites will, by eliminating external intervention, support the management of the forests. Further, the CEB security system will prevent illegal felling and anthropogenic fires in the vicinity.
3	To provide opportunities for conservation-compatible tourism, nature interpretation and conservation education.	By enhancing the existing visitor center near the Tunnel Office with audio-visual equipment, the current conservation tourism and conservation education objective will be further enhanced.
4	To develop appropriate systems, staff structure and associated infrastructure for effective law enforcement, and resource management	The expansion of security system will deter external negative impacts such as illegal felling, encroachments and anthropogenic fires in the project areas.
5	To mitigate human-elephant conflict	The 10 CCTVs installed between the Powerhouse and Randenigala reservoir will provide DWLC with valuable data on elephant migration into the settled areas across the river channel.
6	To reduce the natural resource dependencies of the adjoining communities on VRR sanctuary through eco-development measures	The proposed project will provide employment opportunities to at least 80 people in the local area during the construction period and about 20 people during the operational period. This will reduce the need for these people to depend on the forests for income.
7	To promote research, monitoring and training in biodiversity conservation	The enhanced visitor center will promote environmental education. The management of the regeneration at tunnel muck dumping sites will provide excellent research opportunities in vegetation growth and succession.

CHAPTER 2

THE PROPOSED PROJECT AND ALTERNATIVES

2 THE PROPOSED PROJECT AND ALTERNATIVES

2.1 Evaluation of Alternatives

Objective of the project is to expand the Victoria Hydropower Station in order to increase the power source to meet the peak demand. According to the JICA Hydro Optimization Study (2004), the changing role for hydropower is necessary because thermal power generation will become the base power source instead of the existing hydro power generations. As other methods of power generation will not realize the primary project objectives, no attempt was made to consider alternative sources of power.

The scale alternatives, i.e., reduction of installed capacity, will not lead to any reduction in the magnitude and severity of the environmental and social impacts as the same project components will be required even for a scaled down version of the project. Similarly, scaling down the project will not yield the desired objective.

The project will be using the latest and, environmentally, the least damaging technologies and construction techniques available and thus no attempt has been made to consider an alternative design, technology and construction techniques.

The operation and maintenance of the project will also be carried out in such a manner as to minimize any potential negative impacts and thus alternative operations and maintenance options were not considered.

2.1.1 Selected Alternatives

Three location alternatives are considered, namely: 1) Basic Option, 2) Downstream Option, and 3) Pumped Storage Option. It is important to note that the locational specificities require changes in the technology adopted for the three Options.

2.1.1.1 The No Action Alternative

The no-project option or no-action alternative means simply to not build the powerhouse. It goes without saying that if this option were chosen, none of the environmental impacts that are likely to arise from the three different project alternatives will occur. However, the no-project alternative will also not yield the positive impacts that will arise from the proposed project. Moreover, it will force the CEB to setup power plants operated on alternative sources of power, possibly diesel/heavy fuel to meet the peak demand, which is the main objective of the proposed project. This will require the import of oil requiring a large amount of foreign exchange annually where as the proposed hydropower project require only the operational expenses. Further, it will release a significant amount of carbon to the atmosphere annually thus making the no-project alternative the environmentally least desirable both nationally and globally (see Chapter 4). Thus both from an economic, environmental and social point of view, the no-project action alternative does not appear to be reasonable and therefore it is exempted from further analysis.

2.1.1.2 Basic Option

Under the Basic Option, all components of the project will be built at the adjacent location where the Victoria Phase I Hydropower Project features are located. The 5.0 km long new headrace tunnel runs parallel to the existing Phase I tunnel from the intake site at the Victoria Reservoir to a surge tank to be constructed adjacent to the existing Victoria surge tank at Hakuruthale. The headrace tunnel will be sited between the existing tunnel and the Mahaweli Rajamawatha in most part, except the section between the tunnel intake at the Victoria Reservoir and the Rajamawatha (about 2.3 km). A new powerhouse will be built next to the existing Victoria Powerhouse. Space for this has already been set aside under the Victoria Phase I project. A site for the switchyard has also been set aside in Phase I and is located within the powerhouse premises. The layout of the Basic Option is shown in Figure 2-1. The temporary facility sites e.g. tunnel muck dumping sites, sand mining site, concrete facility site, etc. were selected only after deciding on the Basic Option as the preferred alternative. However, layouts of three Options are depicted in Figures 2-1, 2-2 and 2-3 for better comprehension.

2.1.1.3 Downstream Option

The Downstream Option is to place the surface type powerhouse 2 km downstream from the existing powerhouse. By placing the powerhouse in the downstream, it is expected to gain an additional hydraulic head for hydropower generation. The location of the powerhouse is selected to avoid the power house from being placed on deposit material. The layout of the Downstream Option is shown in Figure 2-2.

2.1.1.4 Pumped Storage Option

The Pumped Storage Option is to install the new power plant as a pumped storage power plant, using a total head of 190 m between the Victoria and the Randenigala reservoirs. This option involves a lengthier tunnel and an underground powerhouse. In this option, during off peak hours, the turbines work as pumps to pump up water from Randenigala back to the Victoria reservoir. This requires the generation of power elsewhere during operation of the pumps. The layout of the Pumped Storage Option is shown in Figure 2-3. The system of the pumped storage power scheme is given in Figure 2-4.

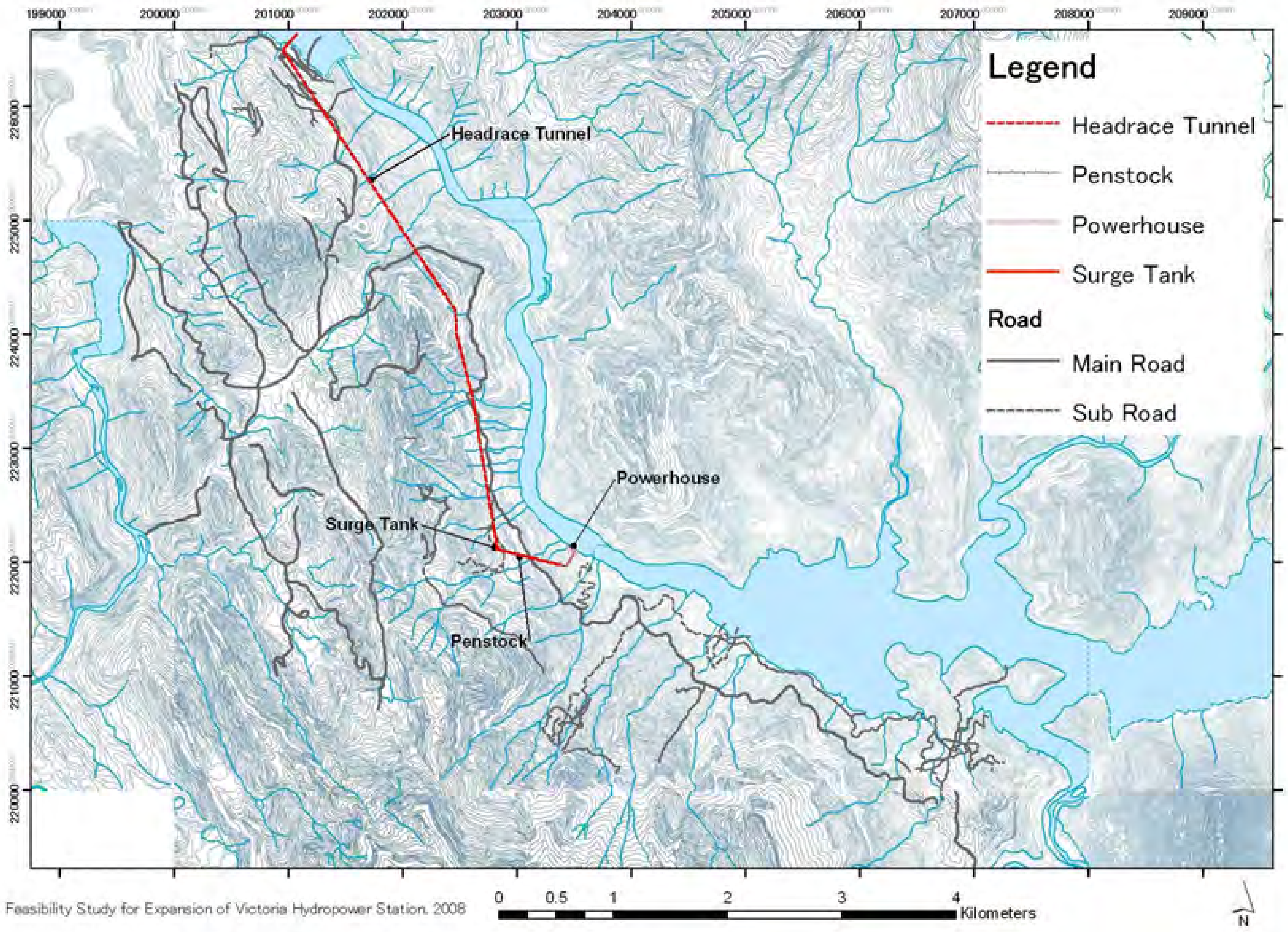


Figure 2-1 Layout of Basic Option

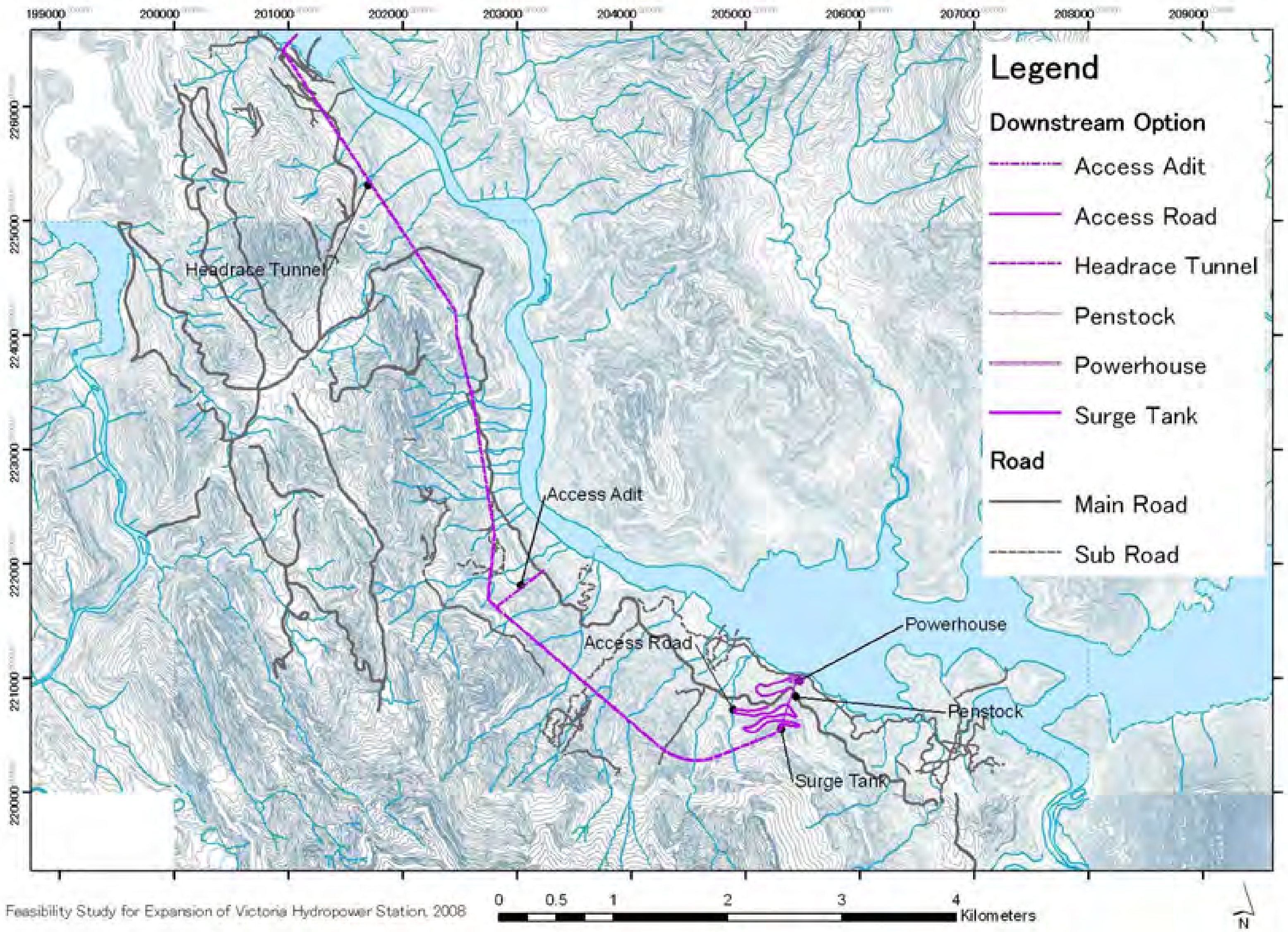


Figure 2-2 Layout of Downstream Option

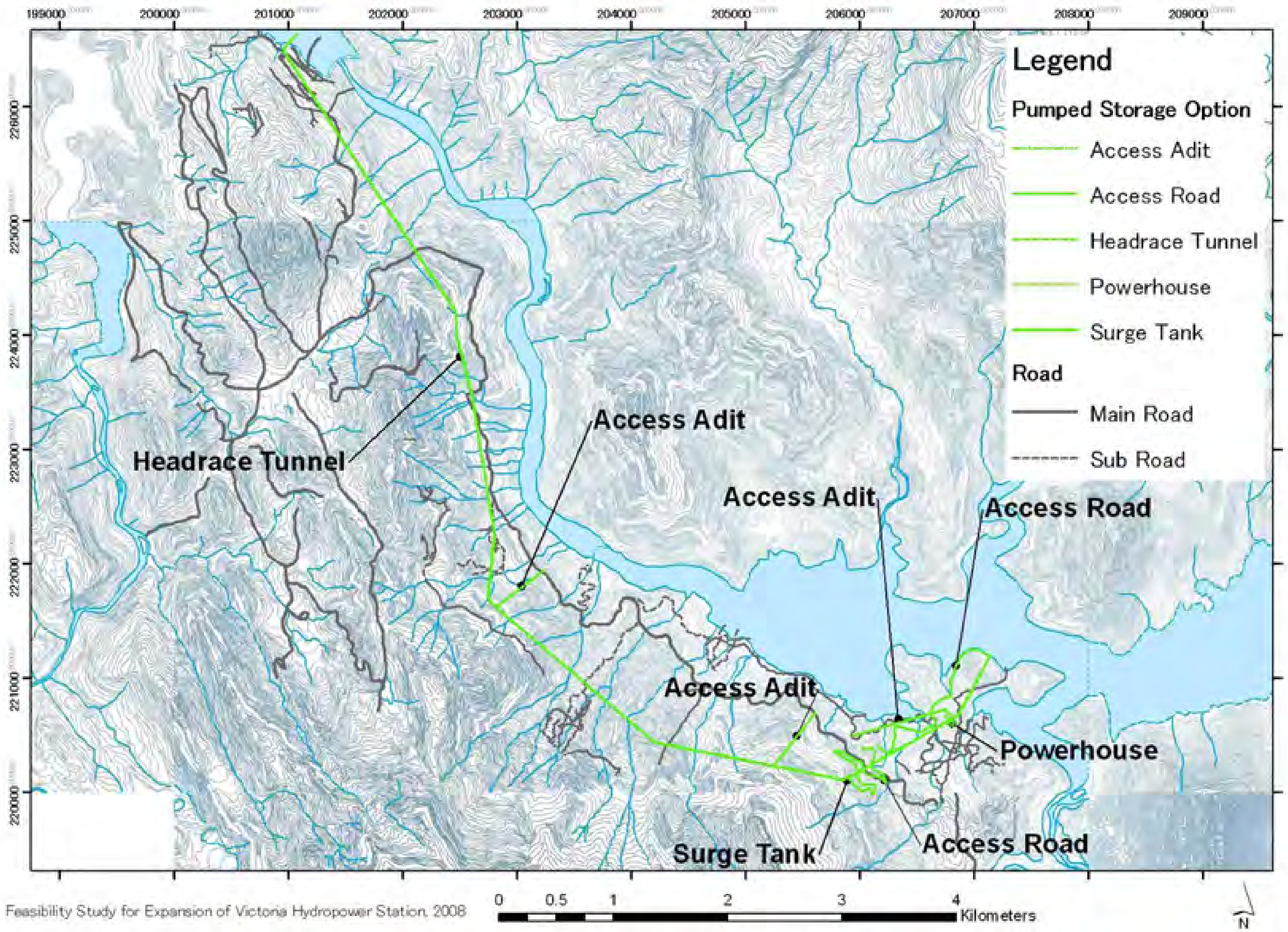


Figure 2-3 Layout of the Pumped Storage Option

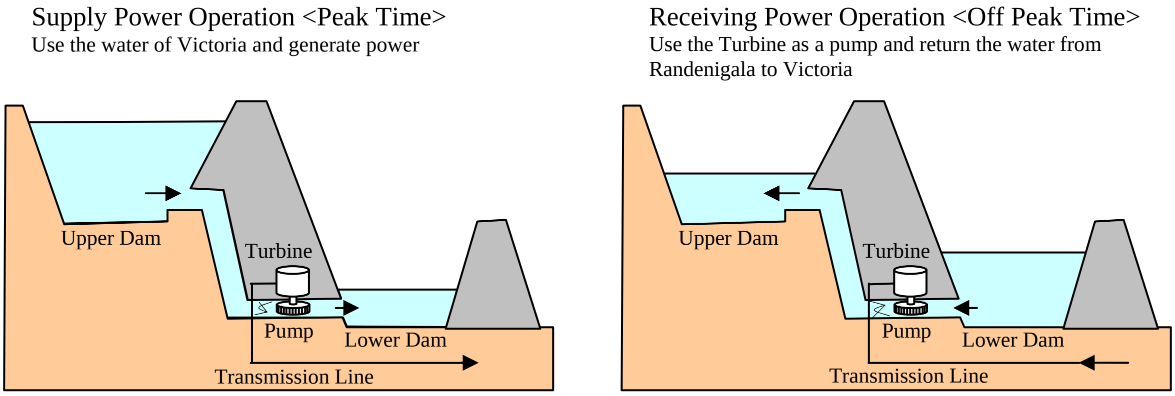


Figure 2-4 System of Pumped Storage Generation

The profiles of the three Project Options are given in the Figure 2-5. It is important to note that the tunnel length is shortest in the Basic Option and longest in the Pumped Storage Option and that the water level of Randenigala reservoir has to be lowered in order to construct the latter two options.

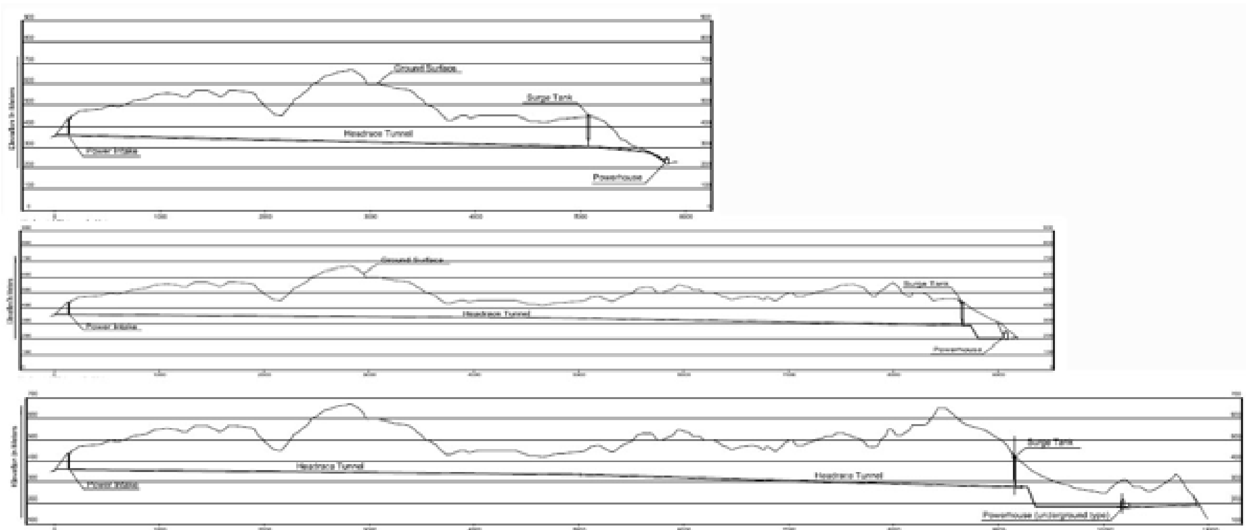


Figure 2-5 Profile of the Three Options

2.1.2 Location of the alternatives

The main structures of the proposed 'Victoria Hydropower Station Capacity Expansion Project' include a headrace tunnel, surge tank, penstock, powerhouse and switchyard. All these features are common to all three project options, but the physical location of some components or some parts are different. The proposed project and the two alternatives are located within the Hanguranketha Divisional Secretary's Division of the Nuwara Eliya District, Central Province (Figure 2-6).

The 12 GN Divisions within which the three project options are to be located are listed in Table 2-1.

Table 2-1 GN Divisions in the Project Area

	GN Division	Basic Option	Downstream Option	Pumped Storage Option
1	Hingurukadauwa	X	X	X
2	Ambewela	X	X	X
3	Welikada	X	X	X
4	Bogahalanda	X	X	X
5	Hakurutale	X	X	X
6	Malulla	X	X	X
7	Hilpenkandura	X	X	X
8	Udawatta West		X	X
9	Udawatta East		X	X
10	Galauda North		X	X
11	Endiribedda		X	X
12	Happawara			X

The project area under Basic Option covers 7 GN Divisions (Table 2-1) while the other two options will cover respectively 11 and 12 GN divisions.

Project Impact Area (PIA)[3] The main project impact area covers an area of 600 meters on either side of the tunnel trace, penstocks and the powerhouse. See section 3 for details.

Basic Option: The PIA of Basic Option is confined to an area around the existing tunnel and powerhouse at Hakurutale. The 5.8 km long tunnel trace runs from the intake at the Victoria reservoir to a point next to the existing surge tank 36 meters apart from the existing tunnel. The PIA under this option covers significant parts of 4 GN divisions and small segments of 3 other GN divisions.

Downstream Option: This alternative requires extending the tunnel further downstream from the existing surge by about another 4km. The PIA of this option thus covers all the GN divisions of Basic Option and 4 additional GN Divisions (Hilpenkandura, Udawatta East and Galauda North).

Pumped Storage Option: In Pumped Storage Option, the powerhouse is located even further downstream of the Downstream Option. It involves extending the tunnel by about another 1 km. The tunnel in this option runs through all the GN Divisions of Downstream Option and an additional division of Endiribedda.

[3] See section 1.5 for a detailed explanation of the Project Impact Area and how it was selected.

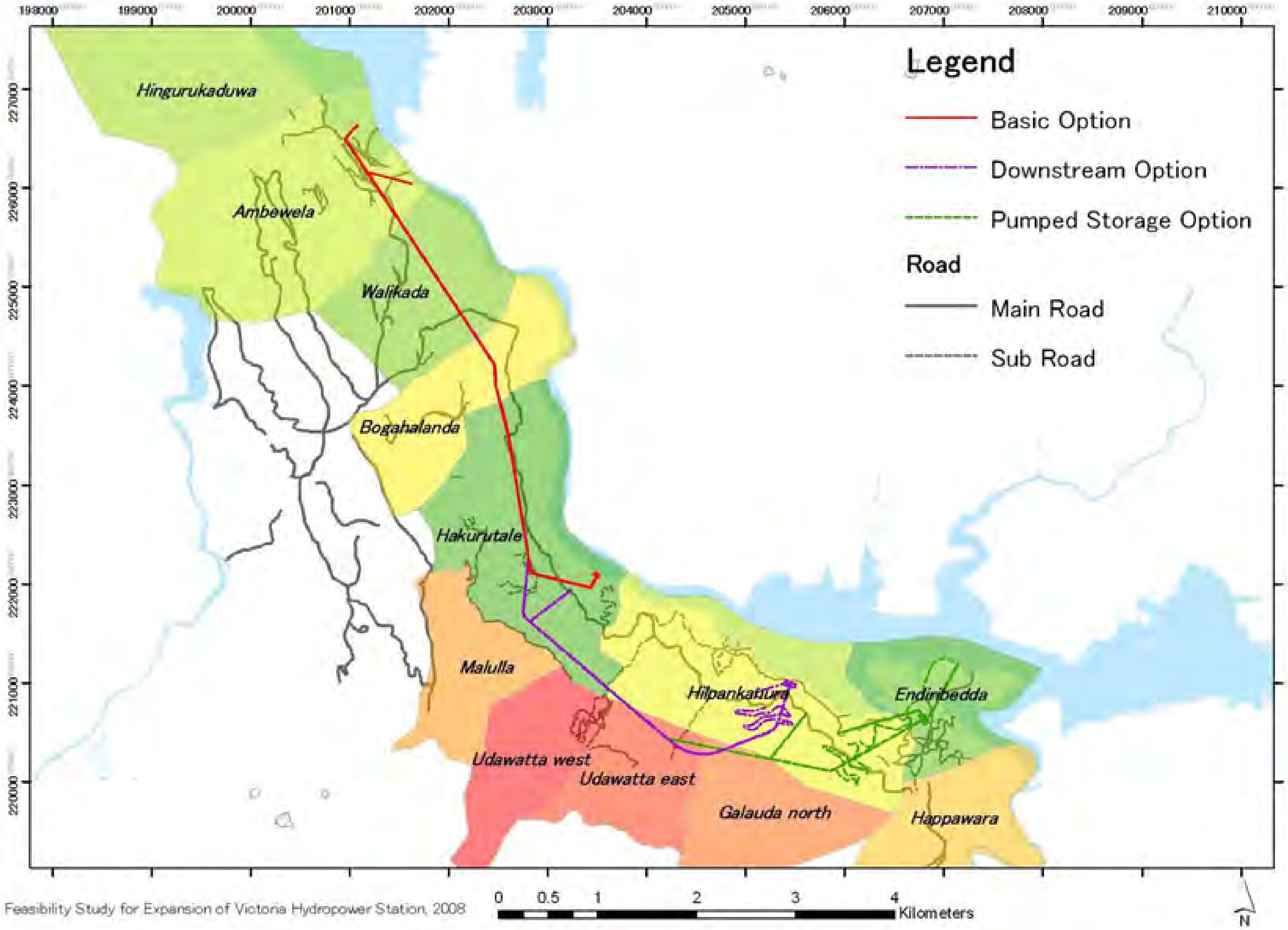


Figure 2-6 Location of the Project Impact Area and Administrative Boundary

Victoria-Randenigala-Rantambe Sanctuary All three options also fall within the limits of the Victoria-Randenigala-Rantambe (VRR) Sanctuary (Figure 2-7). The VRR Sanctuary is divided into 2 sections as the Core Area and the Periphery (Management Plan). The tunnel trace of the Basic Option is almost completely located outside the Core Area. However, some sections of the other two Options and a large part of their impact area fall inside the core area of the VRR Sanctuary.

2.1.3 Technical and Economic Comparison

2.1.3.1 Tunnel Length

The tunnel alignment was determined taking into consideration the rock coverage and elevation of sill of the outlet and the location of the powerhouse which is described in the following section. The estimated tunnel length of each option is shown in Table 2-2.

Table 2-2 Tunnel Length of Each Option (km)

Basic Option	Downstream Option	Pumped Storage Option
5.8	9.1	10.9

It is noted that the Pumped Storage Option is almost double the length of the Basic Option while the Downstream Option is 1.6 times as long as the Basic Option.

2.1.3.2 Effective Head

The effective head is used to obtain the hydropower generation output. The power output is expressed in the following equation.

$$P\ [kW] = g \times \varepsilon \times Q \times He$$

where,

- g : gravity acceleration [m/s^2]
- ε : generation efficiency
- Q : discharge [m^3/s]
- He: effective head [m]

The effective head of each option is as follows.

Table 2-3 Effective Head of Each Option

	Gross head (m)	Head loss (m)	Effective Head (m)
Basic Option	183	13.2	170
Downstream Option	194	19.1	175
Pumped Storage Option	191	25.8	165

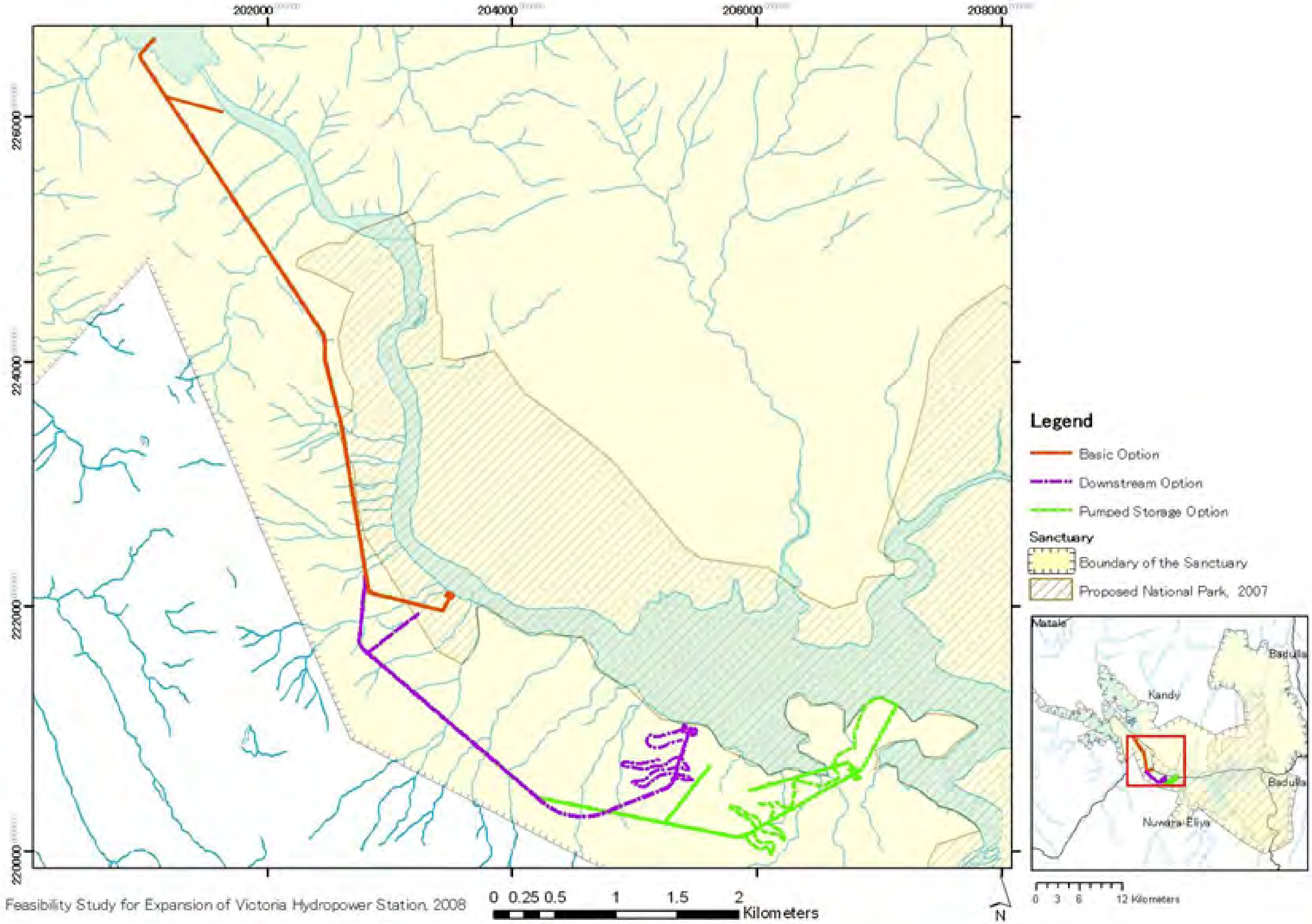


Figure 2-7 Location of the Project Impact Area and the VRR Sanctuary

2.1.3.3 Annual Energy and Power output

The hydropower simulation program, developed particularly for this study on Microsoft Excel VBA, was used for the study. The water balance simulation is carried out by applying time series data from 1985 to 2006 to the simulation program. The result of the generated annual energy, dependable power output, and firm and secondary energy of each option are shown in Table 2-4.

Table 2-4 Annual Energy and Power output

	Expansion plant	Existing + Expansion plant					
	Installed Capacity	**Annual Energy**	**Firm Energy**	**Secondary Energy**	**95% Dependable Capacity**	**Pump-up Energy**	**Net Annual Energy**
	(MW)	(GWh)	(GWh)	(GWh)	(MW)	(GWh)	(GWh)
Basic Option	213	651	452	198	359	-	651
Downstream Option	219	652	449	203	361	-	652
Pumped Storage Option	198	729	445	284	396	-68	623

2.1.3.4 Geological Conditions

The tunnel alignment of the existing Victoria Hydropower Station was changed during construction because the original alignment encountered poor geological conditions. After construction of the Power Station, a fatal fault was identified and indicated in the geological maps issued by the Geological Survey and Mines Bureau (Figure 3.5 Geological Map). The tunnel alignment for the Basic Option will not meet the fault because the selected alignment is parallel to the existing alignment but those of the Downstream Option and Pumped Storage Option may encounter the fault. Therefore, if in case the Downstream or Pumped Storage Option is selected as optimal, it would require further geological investigation during the feasibility study stage and/ or during the detailed design stage as well as mitigatory measures in order to cope with the fault before the commencement of construction works. The above geological conditions may need additional construction cost and additional time. Therefore, the Basic Option has the most favorable geological conditions.

2.1.3.5 New Access Tunnel and New Access Road

The necessity of new access tunnels and new access roads are shown in Table 2-5.

Table 2-5 New Access Tunnel and New Access Road

	New Access Tunnel	New Access Road
Basic Option	Not necessary	Not necessary
Downstream Option	1 tunnel with 500 m	2 roads with total length of 2.8 km
Pumped Storage Option	1 tunnel with 500 m and 1 tunnel with 600 m	2 roads with total length of 3.7 km

2.1.3.6 Construction Period

The total construction period for each option has been studied. The results are shown in Table 2-6.

Table 2-6 Construction Period and Period of Drawdown of Randenigala Reservoir

	Construction Period (year)	Period of Drawdown of Randenigala Reservoir (year)
Basic Option	5.0	0
Downstream Option	5.5	1.0
Pumped Storage option	6.0	1.5

2.1.3.7 Project Construction Cost

The construction cost of the three options is estimated by referring to unit prices of major items of the civil works for the Upper Kotmale Hydropower Project and by taking into account the international market price for equipment. The timing of cost estimation is for the beginning of 2007 which is the same as the estimation of cost for the alternative thermal power plant.

The environmental cost (compensation and mitigation cost), administration & engineering fee, and contingency are added to the construction cost of each option.

The construction cost of each option is given in Table 2.7.

Table 2-7 Project Construction Cost for Each Option

Item	Basic Option	Downstream Option	Pumped Storage Option
Preparatory Works	1.5	2.0	2.5
Civil Works	56.8	90.0	150.1
Equipment & Transmission Lone	82.5	82.5	123.4
Sub Total	140.8	174.5	276.0
Environmental Const	1.5	1.9	2.2
Administration & Engineering Fee	14.1	17.5	27.6
Contingency	15.7	19.4	30.6
General Total	172.1	213.3	336.4

2.1.3.8 Economic Comparison

2.1.3.8.1 Method

Three alternative options are compared by annualized economic benefit and cost of each option (B/C analysis). Economic benefit is composed of capacity and energy benefits. The capacity benefit cost comprised of capital cost (construction cost) and fixed O&M cost of the alternative gas turbine plant which has equivalent generation capacity. The energy benefit consists of the fuel cost and variable O&M cost of the alternative gas turbine (in peak duration) and coal-fired thermal plant (in off-peak duration).
The cost of the project on each option is composed of construction cost, environmental mitigation cost, pump-up cost for pumped storage option, and cost due to drawdown of the Randenigala reservoir water level for downstream and pumped storage options.

2.1.3.8.2 Result of B/C Analysis

The ratio of the benefit to the cost (B/C) for all options is 1.83 for the Basic Option, 1.43 for the Downstream Option, and 0.89 for the Pumped Storage Option. Consequently, the Basic Option is the most economical option with respect to the B/C analysis.

2.1.4 Environmental and Social Comparison

2.1.4.1 Magnitude of the Impact Area

The Project Impact Area (PIA) is described in detail in section 2.1.2. The main PIA is defined as the 600 meter buffer centering along the proposed tunnel trace from the intake to the powerhouse. In addition to this, a 100 meter buffer around the tunnel muck dumping sites, sand mining sites, access roads and other construction sites, for e.g., machine yards, construction crew camps, etc., are also included into the PIA. Although the PIA for these components of the project remains generally the same, the magnitude of the PIA thus clearly increases with the increasing length of the tunnel.

Table 2-8 Impact Area of Each Option

Alternative	Length of Tunnel (km)	Impact Area (ha.)	% increase from the Basic Option
Basic Option	5.8	842	0.0
Downstream Option	9.1	1436	170.55
Pumped Storage Option	10.9	1817	215.80

Along with the increase in the magnitude of the impact area, the impact on ground and surface water, soil, forest cover and the number of families will also proportionately increase as revealed in Table 2.8. Thus, from an environmental impact point of view, the Basic Option is likely to create the least impact on the physical, biotic and social environment.

2.1.4.2 Disturbance to bed rock stability

The disturbance to bed rock stability will increase with the increase in the length of the tunnel. Thus the least disturbance to bed rock stability can be expected from the Basic Option (see Annex VI)-4.

2.1.4.3 Soil Erosion

The new area added to the project impact area by the Pumped Storage Option is relatively flat, but the tunnel trace runs through the steepest sections of the terrain (see Figure 2-8).

Since Downstream Option and Pumped Storage Option cover larger impact areas, the terrain affected by the project is naturally more complex. Further, both these options require construction of new access roads (see Figure 2-6) and this could lead to soil erosion.

2.1.4.4 Ground Water Pollution

The degree of groundwater pollution form the project depends on

- the tunnel length – the higher the excavation length the higher is the use of blasting chemicals, tunneling refuse/wastewater generation, etc.

- the volume of tunnel muck produced – the higher the volume, there is more risk of water pollution.

Of the three alternatives, the Downstream and Pumped Storage Options record more tunnel length and produce higher amounts of tunnels muck compared to the Basic Option. As a result, the risk of groundwater pollution is much higher in the Downstream Option and Pumped Storage Option vis-à-vis the Basic Option. Thus it is apparent that the Basic Option is the best out of the three options with regard to the degree of groundwater pollution. It is worthy of note here that even in the case of the no-alterative option, there is still groundwater pollution from the prevailing agricultural practices.

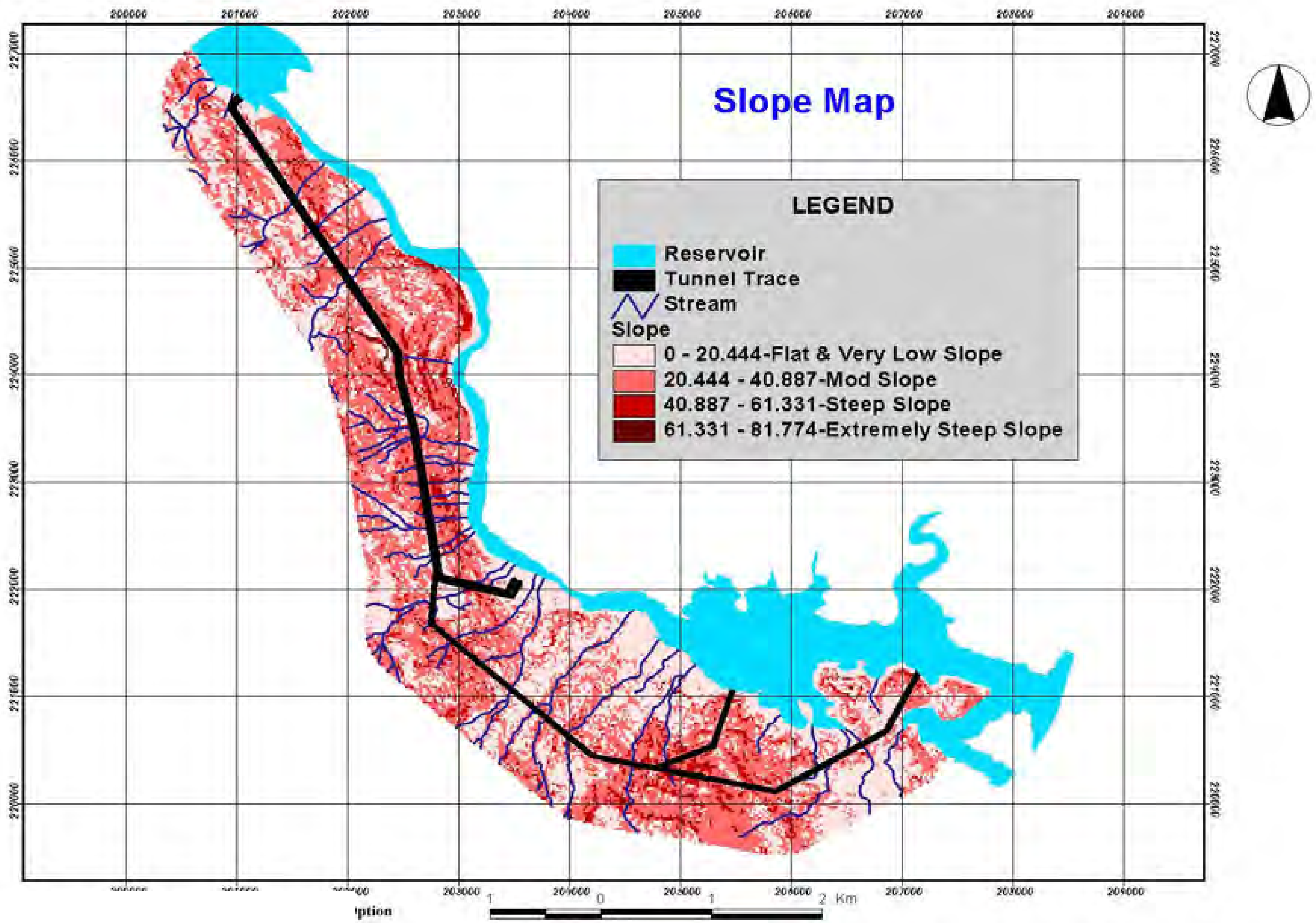


Figure 2-8 Slope Map of the Impact Area

2.1.4.5 Pollution of surface water from tunnel discharge

As described above, of the three alternatives, the tunnel length and the amount of tunnels muck produced are much higher in the Downstream and Pumped Storage Options than in the Basic Option. As a result, the potential surface water pollution is much higher in the Downstream Option and Pumped Storage Option compared to the Basic Option. Thus it is apparent that the Basic Option is the best out of the three options considered if surface water pollution is taken into account. It is also important to note here that even in the case of the no project option, water pollution from prevailing agricultural practices will continue unabated.

2.1.4.6 Impact on Forest

The impact on forest is estimated by calculating the forest cover in each indirect impact area which is the 600 m buffer from the tunnel line. The estimated impact area is 210 ha for the Basic Option, 380 ha for the Downstream Option and 486 ha for the Pumped Storage Option. In terms of the impact on forest, the Basic Option is better than the other options (see Table 2.7 and Figure 2-9).

Table 2-7 Land Use in the Impact Area (ha)

	Basic Option	Downstream Option	Pumped Storage Option
Forest	210.0	380.8	486.3
Open forest	52.0	52.0	52.0
Scrub	245.2	260.9	291.3
Chena	113.8	202.1	202.0
Homestead	10.6	68.2	116.4
Paddy/ seasonal	14.8	73.6	73.6
No vegetation	21.9	9.7	9.7
Total	668.3	1047.4	1231.4

2.1.4.7 Disturbance to wildlife in the VRR

Since the proposed development project will take place in a wildlife sanctuary, its impact will be felt by the fauna and flora inhabiting the sanctuary. There will be disturbance to the migration of elephants in the area due to the construction work and tunnel muck dumping activities in some areas such as the Kohombagna proposed dumping site. The disturbance is proportionate to the area that will be disturbed and the time duration of the construction period. In terms of both these criteria the Basic Option will record the least disturbance in comparison with the Downstream and Pumped Storage Options. Habitat fragmentation could occur due to the construction of Penstocks. However, this could happen only if the Downstream Option is considered as the Pumped Storage Option has only tunnel penstocks. The access roads to adits will also fragment the habitats in the case of the Downstream and Pumped Storage Options during construction.

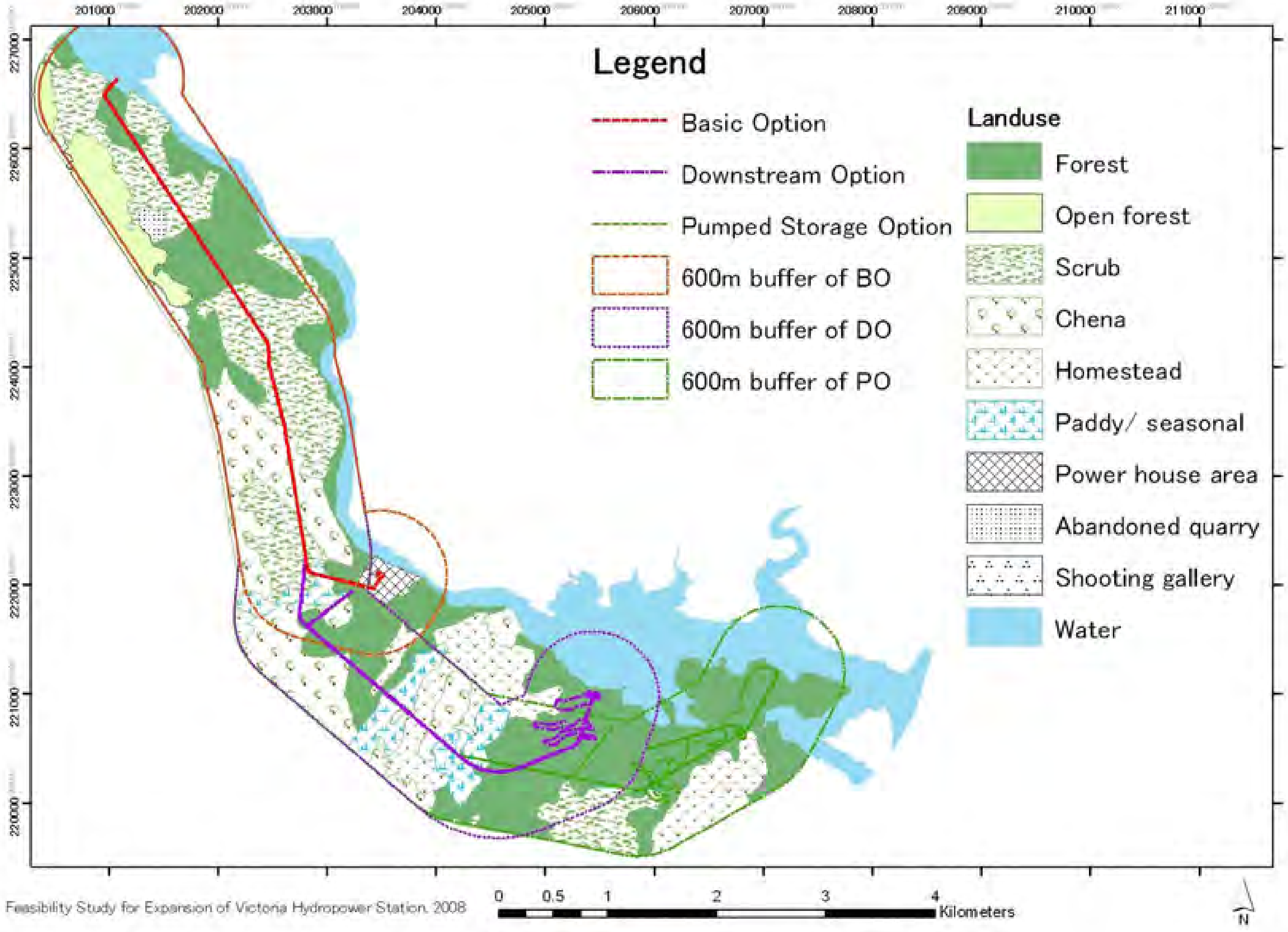


Figure 2-9 Land Use in the Impact Area of Three Options

2.1.4.8 Loss of biodiversity

Overall loss of biological diversity would be minimal in the Basic Option. Temporary loss of habitats during the construction phase will be restored at the end of the project. No species will be lost from their respective habitats as no site-specific species have been recorded from the project area. However, the loss of biodiversity will be higher in both of the other two options as they require clearing of forests for the new access roads, penstocks, new transmission lines, and the powerhouse and switchyard premises.

2.1.4.9 The number of Households affected by temporary loss of ground water

The number of households that will be affected by the temporary loss of ground water is 57 for Basic Option, 111 for Downstream Option and 174 for Pumped Storage Option. These houses are located in clusters around wells.

2.1.4.10 The number of agricultural plots affected by temporary loss of ground water

The number of households which are likely to lose agricultural plots are respectively 29 and 19 from Hakurutale and Welikada because they are the two major settlement clusters within the impact area. These households own approximately 29% of the total highlands and 28% of the paddy land in the impact area.

2.1.4.11 The impacts on existing roads

All three options will use 13.6 km of existing roads for transporting sand, tunnel muck and other construction related materials. But the Downstream Option and Pumped Storage Option will use respectively 16.1 and 17.7 kms of roads for the same purposes. Further, the number of heavy vehicles used and the construction time duration are higher in the case of Downstream and Pumped Storage Options.

2.1.4.12 Integrity of the existing tunnel

The impact on the integrity of the existing tunnel will be the same in all three alternatives. The existing tunnel is only 36 meters away from the proposed tunnel.

2.1.4.13 Impact of blasting on the existing houses

The impacts of blasting on the existing houses will not be different between the three alternatives. The technologies and methods used in blasting the tunnel underneath is unlikely to have significant impacts on the houses located on the surface. However, the number of houses that will be affected by blasting is lowest in the Basic Option (Figure 2- 10).

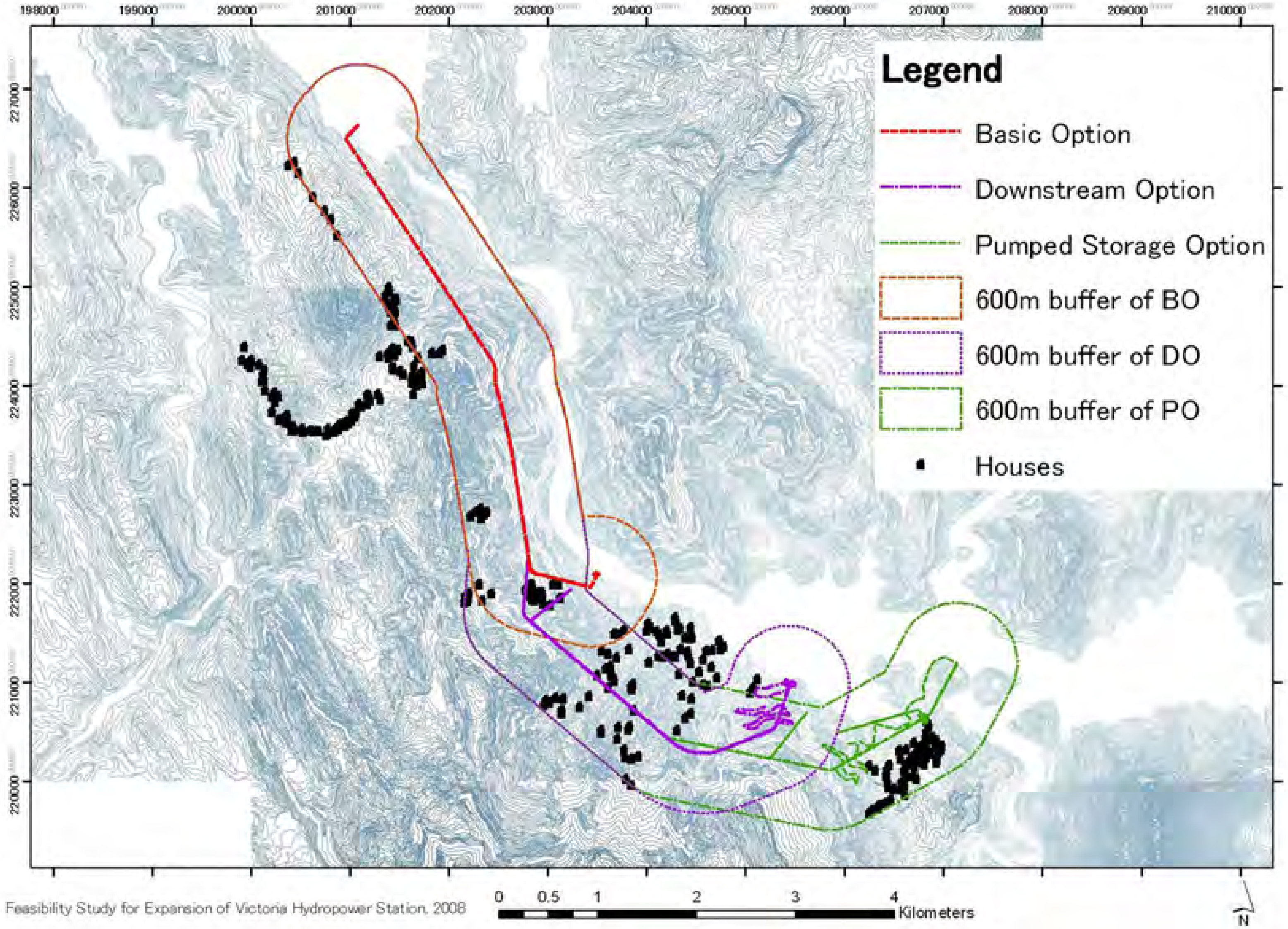


Figure 2-10 Houses in the Impact Area

2.1.4.14 Increase in work related accidents

The potential for work related accidents is directly proportional to the magnitude of the work and the time duration when safety factors remain constant. Thus, obviously, the Downstream and the Pumped Storage Options have a greater potential for work related accidents.

2.1.4.15 Disturbances from outside workers

The communities falling within the impact area could be classified as traditional villagers with life-styles connoting a traditional agricultural life style. But these people do not live isolated lives because they are exposed to the outside world both within and outside Sri Lanka in a significant way. They have at least once been exposed to the impact of outsiders in a significant manner during the Victoria Phase 1. In fact in a number of cases the local have married the outside workers of Victoria Phase 1. However, during the intervening 30 years, the traditional life style has once again been restored. Although the people living in the impact area did not express opposition to outsiders coming into area under the proposed project, the experts in the EIA team still believe that the presence of outside workers could result in some impacts such as social conflicts, socially communicated diseases in the communities, etc. The longer the construction period of the project, the greater the impacts are likely to be. Since the Basic Option has the shortest construction time period, it is likely that the impacts would be lower too for the Basic Option in comparison with the other two alternatives.

2.1.4.16 The Impact on Elephant migration across the river

The Basic Option will lead to a significant increase in the water flow in the tail race and the river bed (see the river cross section in Appendix 3.4) that is used by elephants to cross the river, which could hamper their migration patterns and could even injure elephants if proper mitigation measures are not taken. A similar impact is not anticipated in the case of the other two options since the water from the powerhouses is directly released into the Randenigala reservoir.

2.1.4.17 Compensation for the loss of land due to tunnel muck dumping at Kohombagana

As all three options will be using this dumping site, this impact will remain constant across the three alternatives. The tunnel muck dumping sites numbered M1-M4 in Figure 2-11 will be used for the Basic Option while the M5 site (Kohombagana) will be used only in case the first five sites become inadequate. However, if the Downstream and Pumped Storage Options are selected, M5 site will have to be utilized. Hence, the private land located within this site will also have to be compensated based on the NIRP principles.

2.1.4.18 Mitigation and Monitoring Cost

The mitigation cost is calculated only for the significant impacts identified using the matrix method. The impacts were screened using the ADB screening criteria to value the impacts and mitigation. The total cost of mitigating the impacts created by the proposed project and for monitoring them are estimated at is Rs. 235,559,339.40 for the Basic Option and increases respectively to Rs. 299,969,763.25 and Rs. 342,434,491.72 for the Downstream and Pumped

Storage Options. Thus the cost of mitigation and monitoring increases by 127.3 % and 145.3 % respectively for Down Stream and Pumped Storage Options.

2.1.5 General Comparison

The following Table provides a comparison of the alternatives.

Table 2-8 Summary of Comparative Study

		Item	No-action Alternatives	Basic Option	Downstream Option	Pumped Storage Option
Technical and Economic Aspects	1)	Tunnel Length (km)	0	5.8	9.1	10.9
	2)	Effective head Gross head (m) Head loss (m) Effective head (m)	 - - -	 183 13.2 170	 194 19.1 175	 191 25.8 165
	3)	Annual Energy, Power output Annual Energy (GWh) Net Annual Energy (GWh)	 - -	213 651 651	219 652 652	198 729 623
	4)	Geological Conditions	-	not meet the fault	may encounter the fault	may encounter the fault
	5)	New Access tunnel and road				
		New Access Tunnel	0	Not necessary	1 tunnel with 500 m	1 tunnel with 500 m and 1 tunnel with 600 m
		New Access Road	0	Not necessary	2 roads with total length of 2.8 km	2 roads with total length of 3.7 km
	6)	Construction Period Construction Period (year) Period of Drawdown of Randenigala Reservoir (year)	 - -	 5.0 0.0	 5.5 1.0	 6.0 1.5
	7)	Project Construction Cost	-	172	213	336
	8)	Benefit-Cost Ratio	-	1.83	1.43	0.89
Environmental and Social Aspects	1)	Magnitude of the Impact Area	0	842	1436	1817
	2)	Disturbance to bed rock stability	0	Low	Medium	High
	3)	Soil Erosion	low	Low	Medium	High
	4)	Ground Water Pollution	0	Low	High	High
	5)	Pollution of surface water from tunnel discharge	0	Low	Medium	High
	6)	Indirect Impact on Forest	0	210 ha	381 ha	486 ha
	7)	Disturbance to wildlife in the VRR	0	Low	High	Very High
	8)	Loss of biodiversity	low	Low	Medium	High
	9)	The number of HHs affected by temporary loss of ground water	0	57	111	174
	10)	The number of agricultural plots affected by temporary loss of ground water	0	57	135	182
	11)	The impacts on existing roads (kms)	0	13.9	16.1	17.7
	12)	Integrity of the existing tunnel	0	same	same	same
	13)	Impact of blasting on the existing houses	0	Low	Medium	High
	14)	Increase in work related accidents	0	Low	High	High
	15)	Disturbances from the outside workers	0	Low	High	High
	16)	The impact on Elephant migration across the river	0	Low	Medium	Medium
	17)	Compensation for the loss of land due to tunnel muck dumping at Kohombagana	0	Low	Medium	High
	18)	Mitigation and Monitoring Cost	0	Rs. 235,559,339.40	Rs 299,969,763.25	Rs 342,434,491.72

It is clear from the Table that the no-action or no project alternative will have the least impact on the environment at the site. Yet, as explained in section 2.1.1.1, the no project alternative could lead to other environmental impacts (e.g,. coal or oil) to generate electricity to meet the project objectives. Thus, the no project alternative is rejected from an environmental as well as economic point of view. But the no-action alternative will compel the CEB to look for alternative energy sources such as diesel and coal or both and they will lead to significant air pollution if appropriate measures are not taken. Thus, indirectly, the no-action alternative will be the most disastrous from an environmental point of view.

Of the other three options, all technical information clearly reveal that the Basic Option is the preferred alternative. The annual energy production, the construction time and the cost of construction, and economic viability all favour the Basic Option which takes the least amount of time for construction with the highest benefit-cost ratio.

The potential environmental impacts relating to the three options very clearly reveal the Basic Option to be the least damaging environmentally. While all three options will lead to similar types of impacts, their magnitude and severity progressively increase with the Downstream Option and the Pumped Storage Option. For example, the number of families and the agricultural lands likely to be affected as well as the forest cover to be lost are higher in both the Downstream Option and the Pumped Storage Option. Based on this analysis, the Basic Option emerges as the preferred alternative not only from an engineering and technical point of view but also from the perspective of environmental impacts.

Therefore the rest of the analysis of this EIAR will be confined to the Basic Option.

2.2 Description of the Project

2.2.1 Project Developer and Location

2.2.1.1 Project Developer

Name of the Project Developer	:	Ceylon Electricity Board
Postal Address	:	No. 50, Sir Chittampalam A Gardiner Mawatha, Colombo 02
Phone/Fax No.	:	011-232-0012
Contact Person Name	:	Rohitha Gunawardhana
Designation Phone, Fax	:	011-232-0012/ 011-243-1440

2.2.1.2 Project Location

The project area is located in 20 km south-east of Kandy, where the Mahaweli river flows in a south-easterly direction down to the low plane. The project area is in the Hanguranketha Division of the Nuwara Eliya District, in the Central Province, and covers seven GN divisions (see Figure 2-6 and Figure 2-11).

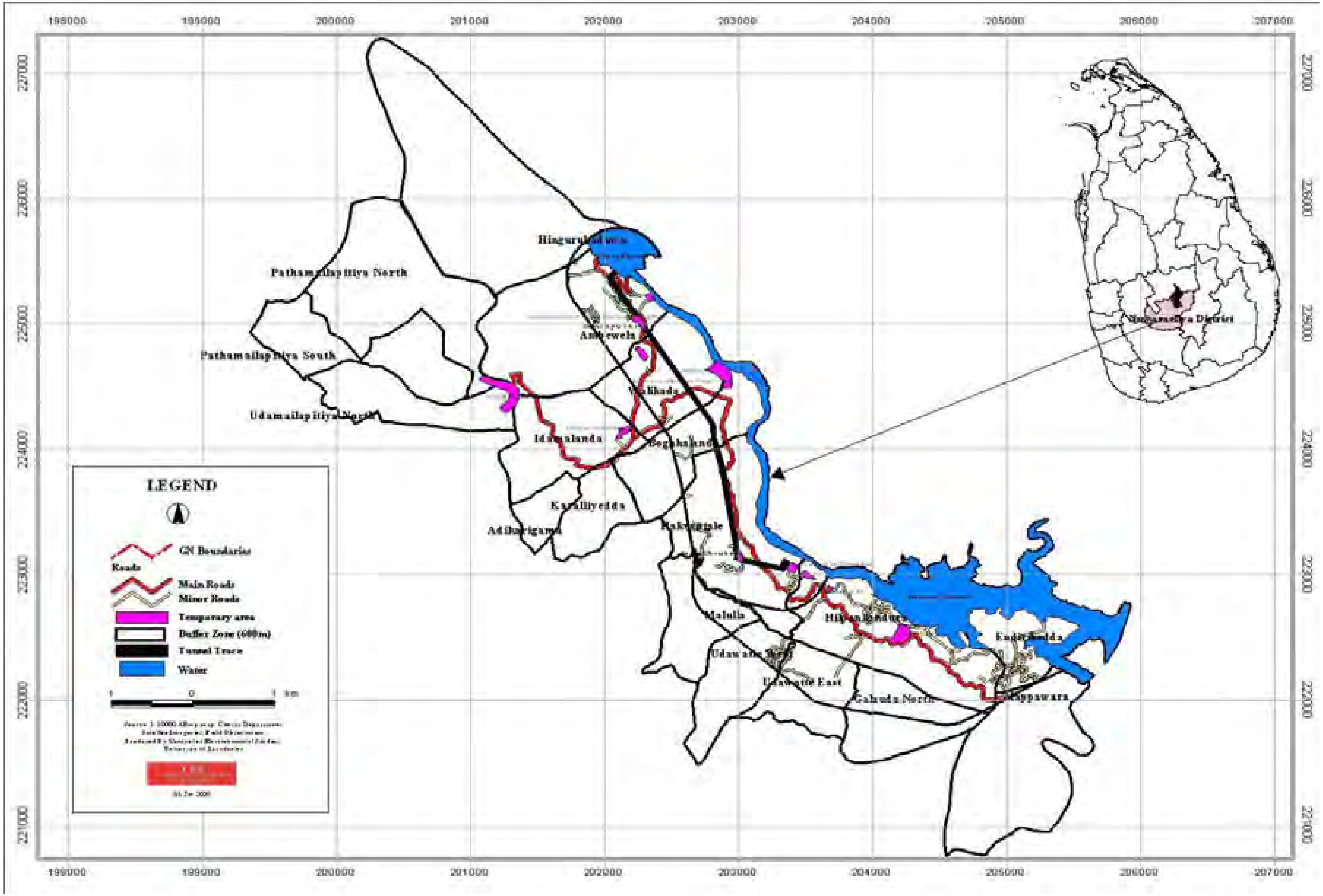


Figure 2-11 Project Location

2.2.1.3 Installed Capacity and Annual Energy

2.2.1.3.1 Installed Capacity

Based on the basic design results, the installed capacity is calculated as 228,000 kW and the unit capacity is 114,000 kW as shown in the following Table;

Item	Unit	Figure
Maximum Discharge	m3/s	140
Normal Intake Water Level	m	430
Normal Tail Water Level	m	231.04
Gross Head	m	198.96
Head Loss	m	15.57
Effective Head	m	183.30
Efficiency of Turbine ηt =		0.929
Efficiency of Generator ηg =		0.975
Installed capacity	kW	**228,000**

2.2.1.3.2 Annual Energy

The inflow to the Victoria reservoir is a total of the release at Polgolla weir and inflow from the residual basin between the Polgolla weir and the Victoria dam. The inflow from the residual basin is not measured, but it can be estimated by the difference between the total discharge from the Victoria dam and release at the Polgolla weir.
The water balance of the Victoria reservoir is shown in Figure 2-12. According to the discharge data from 1985 to 2006 provided by MASL, Polgolla weir received 1,949 MCM of water annually, and 878 MCM was diverted to the Sudu river and the rest of 1,071 MCM is released to downstream and flowing to the Victoria reservoir. While, the total annual discharge at the Victoria reservoir was 1,532 MCM. The difference between the Polgolla weir release and the total release at the Victoria dam is the inflow from the residual basin. The difference is 461 MCM (= 1,532 MCM – 1,071 MCM) and is the annual inflow volume from the residual basin

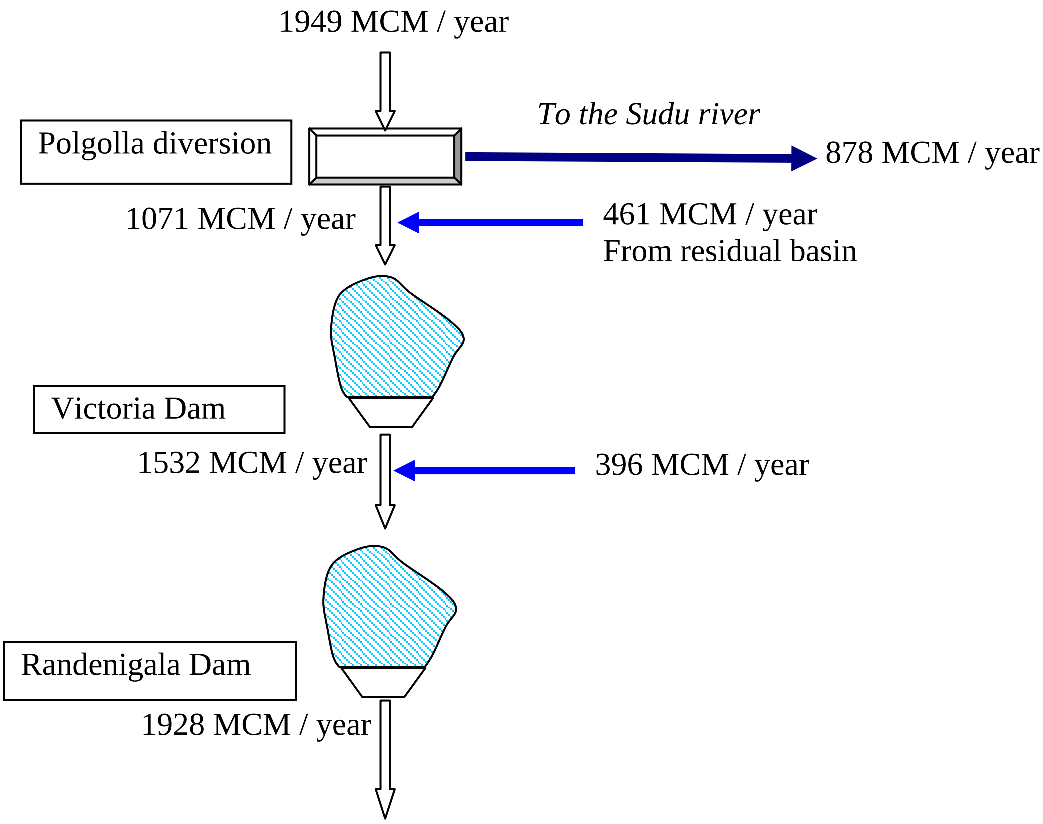


Figure 2-12 Installed capacity after the project implementation

Inflow into the Victoria reservoir is used for the energy calculation, and the average annual energy after expansion is estimated at 716 GWh. It is noted that the discharge from the Victoria reservoir in the calculation fulfils the downstream irrigation demand.

The incoming generators will add a maximum of 228 MW of power to the grid. With the existing 210 MW, therefore, the total installed capacity from the Victoria Plant would be 438 MW. Since the peak demand is for approximately 3 hours, the output from the reservoir will be increased for the said period. However, the average outflow from the reservoir must be maintained at a level similar to the pre-expansion level. Any objective function to maximize the total power generated in Victoria, Randenigala and Rantambe should not violate the downstream irrigation demand and the operation plan stipulated by MASL and agreed to by CEB. The average annual energy output from the Victoria plant will thus be maintained at almost the same predicted value of 716 GWh. However, the instantaneous peak power-output capability is doubled to support the enhanced peak power requirements as required.

The tailrace rise, due to the doubling of water from the two turbines, will not cause an unaccepTable overflow of water to the immediate surroundings of the channel. But in order to avoid possible danger to elephants who might unwittingly be crossing the stream near the tailrace at the time of the peak discharge, precautionary measures have to be implemented (see Chapter 5). Provision has already been made for the extension of the existing switch yard while the existing paths for the transmission lines will be used by the proposed project as the transmission capacity is adequate.

Based on the basic design, two generators rated at 140 MVA each, are selected. The Francis type vertical shaft turbine is used to optimally exploit the head and discharge available at the site. The efficiency of the turbines is at the highest available range for the particular type (above 90 % at the average load condition). The maximum noise level that would prevail inside the premises, after installing the additional two-machines, is estimated to be 93 dB or below. The noise level immediately beyond the building, into the sanctuary, would be much below the above value as all sound generating equipment is located inside the concrete structure.

The transformers are at 16.5 kV/220 kV, which enable the use of existing transmission lines.

2.2.1.4 Access to the Project Site

All main work sites of the project have easy access from the Kandy-Randenigala road (Mahaweli Rajamawatha) and by-roads. The project area can be reached from Kandy, Badulla and Mahiyangana towns. From Kandy, access is on road A26 up to Thennakumbura Bridge and then on Randenigala Road. The dam site entrance is on the left after passing Adhikarigama. All the other sites connected with the project are within a short distance from Rajamawatha. The sites that need road access are the tunnel intake, adits, dumping areas, sand mining and quarry sites. They are also located in close proximity to the existing road network. However, construction of new access roads and the widening and strengthening of the existing ones may be necessary in several places. But this involves short distances. The existing road network is given in Figure 2-13. The Mahaweli Rajamawatha is a well constructed Class A/B road. All other roads within the project area are minor roads, jeep tracks and foot paths. These roads need improvement for the heavy vehicular traffic during construction.

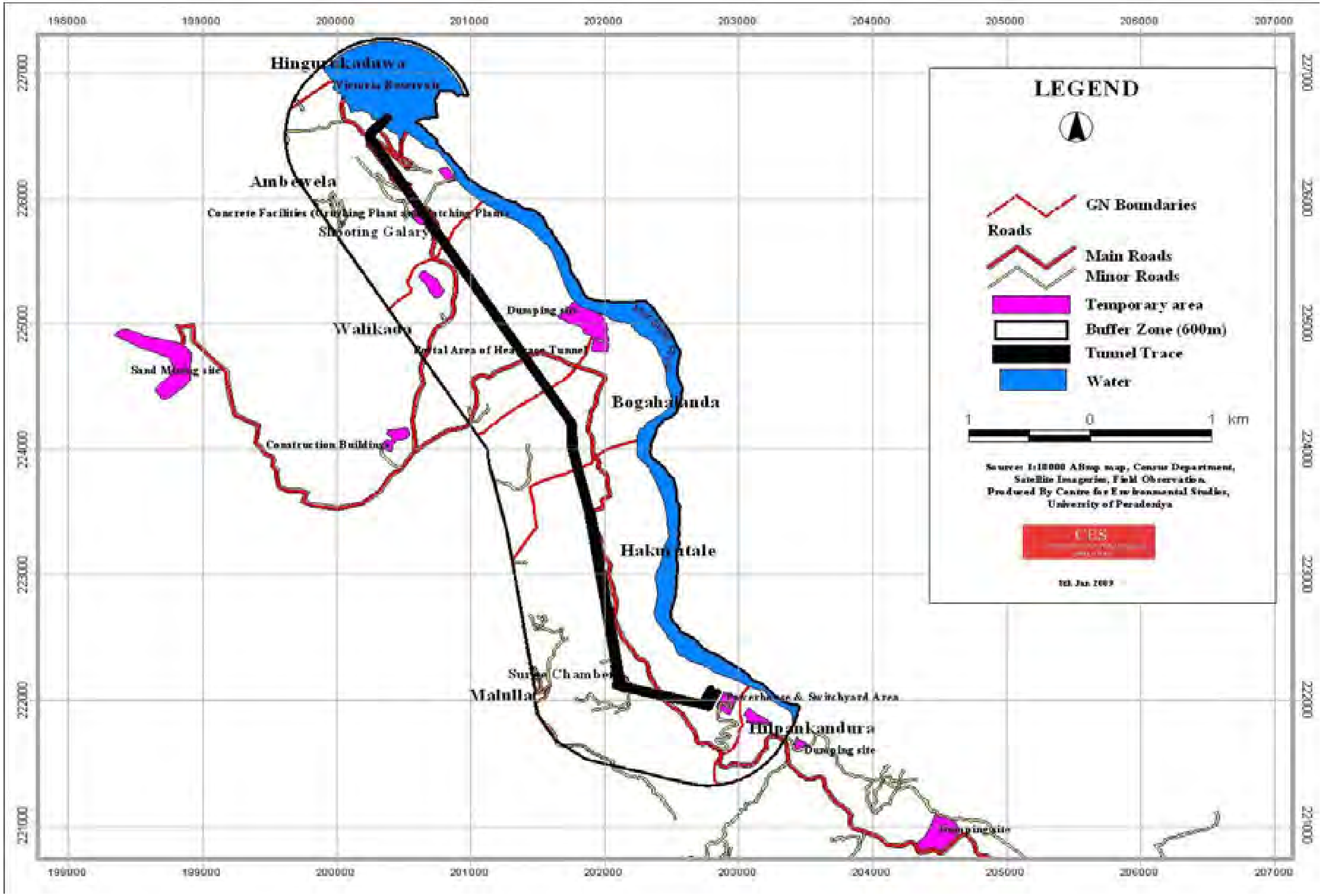


Figure 2-13 Road Access to the Project Area

2.2.1.4.1 Access to Intake

The entry to the intake is from Mahaweli Rajamawatha at Adhikarigama. Access to this road is limited to residents of the area, official vehicles and authorized vehicles. The security barrier is manned by the Mahaweli Security Division at the entrance. The length of this road is about 3.6 km and another security barrier is located next to the Dam Office.

2.2.1.4.2 Adits

Access to the existing adit is from the Mahaweli Rajamawatha at the Tunnel Office site. The road is not used at the moment and needs repairs and widening for heavy vehicular traffic.

A new adit of which the portal is located 85 m downstream of the dam will be excavated with a length of 300 m. Access to the adit portal will use the existing path with a short new access road. The adit and access road are located in the security area where the public is not allowed to enter.

2.2.1.4.3 Sand Mining, Dumping and Quarry Sites

All the identified sites have road access to a certain extent. It is, however, necessary to repair/widen existing roads and to construct new roads to improve access to the sites. The project site is well connected to the main towns of the area, Kandy, Badulla and Mahiyangana. From Kandy, there is 24-hour access but access from Mahiyangana and Badulla is limited to a period from 6 am and to 6 pm due to the closure of the sanctuary at night for security purposes. Although access from the Digana side (left bank) is possible, at present, this road is closed for security reasons. However, a boat service is provided for Mahaweli staff to reach the Dam Office from Digana.

2.2.1.5 Land ownership

The project area comes completely under the VRR Sanctuary. However, in the traditional villages, most of the land is owned by the villages themselves.

Table 2-9 Landownership of the impact area

Type of land ownership	Highlands (% of households)	Lowlands (% of households)	Chena lands (% of households)
Freehold	91.0	50.0	13.6
Rented	1.0	3.8	1.6
Encroached	3.3	0.5	0.5
Jointly owned	3.3	3.3	0.5
No answer given	0.5	42.4	83.8

Ninety one (91%) of the households in the impact area own the highlands singly while 3.3% are owned jointly among relatives. Another 3.3% of the highlands is encroached. For the lowlands, 50% indicated freehold ownership while 42.4% did not provide an answer. For chena land, 13.6% claimed freehold ownership while 83.8% chose not to answer this question.

Table 2-10 Land owners of the temporary facility area

No	Candidate for Temporary Facility Area	Owners / Management
A	Portal Area of Headrace Tunnel (Upstream)	MASL
B	Portal Area of Headrace Tunnel (Middle stream)	DWLC/ GOVT
C	Surge tank Area	CEB
D	Headrace (Downstream) Penstock, Powerhouse & Switchyard Area	CEB
E	Concrete Facilities (Crushing Plant and Batching Plant)	MASL/ DWLC
F	Construction Buildings	CEB
S1	Sand Mining site	MASL
M1	Dumping site (Existing Borrow Area)	MASL / DWLC
M2	Dumping site (Existing Spoil Bank for Headrace)	MASL / DWLC
M3	Dumping site (Existing Temporary Area for Powerhouse)	CEB
M4	Dumping site (Existing Spoil Bank for Powerhouse)	CEB / MASL
M5	Dumping site (Stream at 2.4km Downstream of Powerhouse)	MASL / Some private land

2.2.2 Project Layout

Most of the project site is in the Sanctuary (Figure 2-14 and 2-15)

2.2.2.1 Alternatives

Alternatives are mentioned in 2.1 Evaluation of Alternatives above.

2.2.3 Project Designs

2.2.3.1 Permanent Structures

Permanent Structures include Headrace Tunnel, Surge Tank, Penstock, Powerhouse with generating equipment, and Switchyard. The layout is shown in Figure 2-15. The features are shown in Table 2-11. Reservoir, Dam, and Intake for Expansion are not included because they are already made.

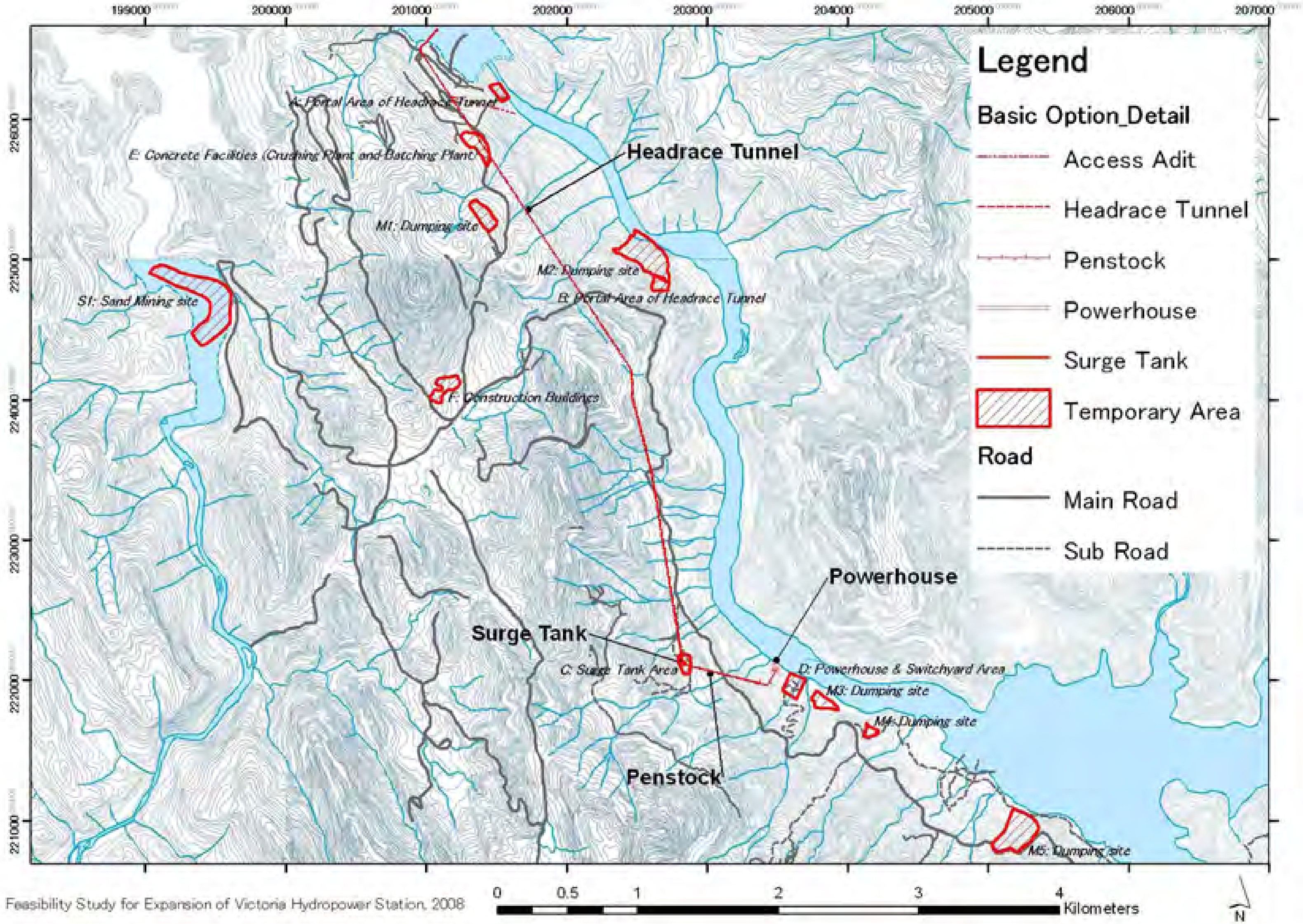


Figure 2-14 Project Layout

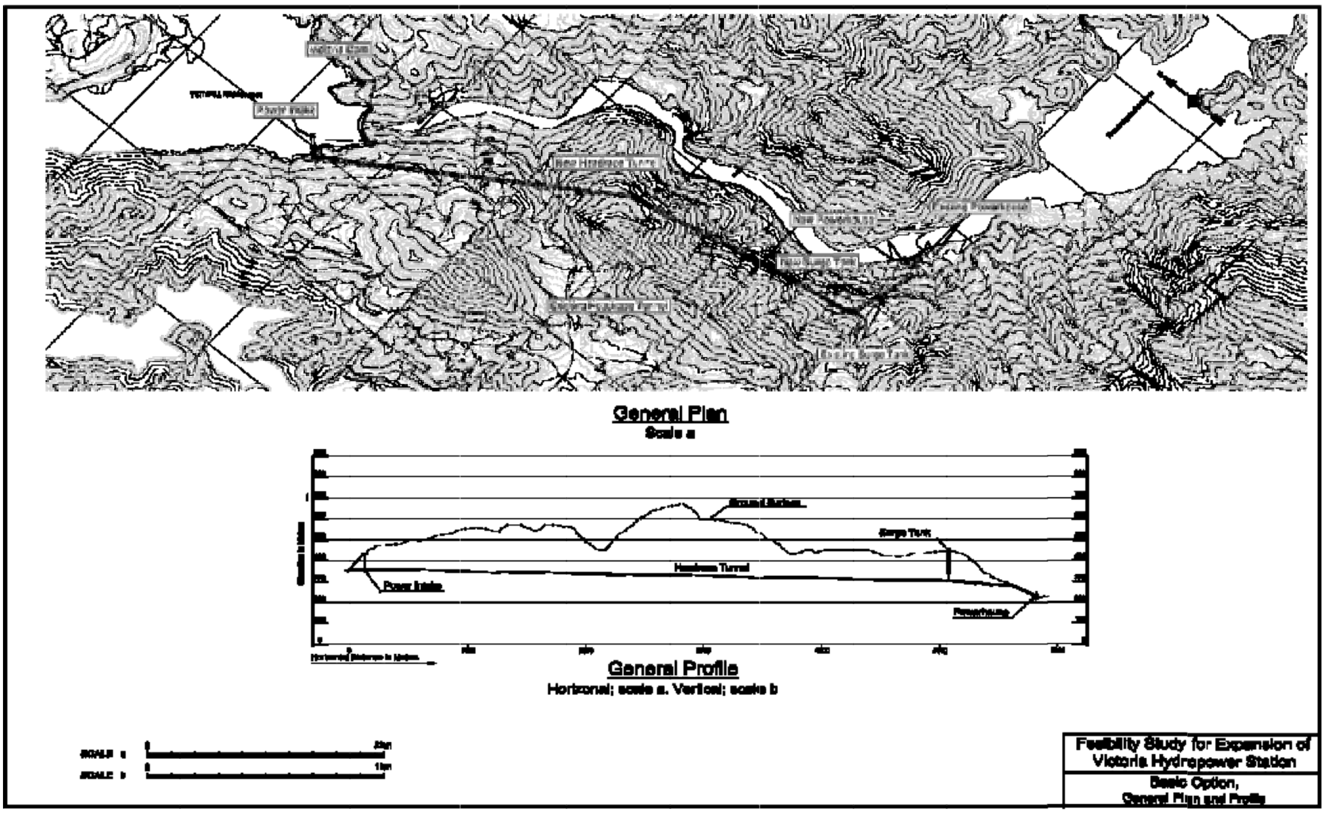


Figure 2-15 Layout of the Permanent Structures

Table 2-11 Features of the Permanent Structures

Item		Dimension
Headrace Tunnel	Number	One (1)
	Inner Diameter	6.6 m
	Total Length	5,003 m
Surge tank	Type	Restricted Orifice Type
	Diameter	20.0 m (Upper Section) 6.6 m (Lower Section)
	Height	117.0 m (Upper Section) 32.9 m (Lower Section)
Penstock	Type	Tunnel & Open-air
	Number	Tunnel: One (1) Open-air: Two (2)
	Inner Diameter	Tunnel: 6.6 m to 5.6 m Open-air: 3.95 m to 2.85 m
	Length: Tunnel	575 m
	Length Open-air	175 m for Unit 4 160 m for Unit 5
	Total Length	750 m for Unit 4 735 m for Unit 5
Powerhouse	Type	Surface type
	Size	37m wide × 44m high × 69m long

Item		Dimension
Development Plan	Normal Intake Water level	430.0 m
	Tail Water Level	231.2 m
	Gross Head	199.0 m
	Effective Head	183.3 m
	Maximum Discharge	140 m^3/s
	Number of Unit	Two (2)
	Install Capacity	228 MW (only expansion)
	Peak Time	3 hours
	Peak Firm Capacity	393 MW (with existing)
	Annual Generation Energy	716 GWh (with existing)
	(Primary Energy)	468 GWh (with existing)
	(Secondary Energy)	248 GWh (with existing)
Turbine	Type	Vertical Shaft, Francis Turbine
	Number	Two (2)
	Rated Output	122 MW per unit
	Revolving Speed	300 r/min
Generator	Type	Three-phases, Synchronous Generator
	Number	Two (2)
	Rated Output	140 MVA per unit
	Frequency	50 Hz
	Voltage	16.5 kV
	Power Factor	0.85 lag
Main Transformer	Type	Outdoor Special Three-phase Type or Outdoor Single Phase Type
	Number	Two (2)
	Capacity	145 MVA per unit
	Voltage	Primary 16.5 kV Secondary 220 kV
	Cooling	Natural Convection Oil Forced Air Type
Switchyard	Type	Conventional Type
	Bus System	Double Bus
	Number of Lines Connected	Three (3) cct Transmission Lines
	Voltage	220 kV

2.2.3.2 Temporary Structures

Table 2-12 Features of the Temporary Facilities

No.	Item	Necessay Area (m2)
A	Headrace Tunnel (Up stream) Area	2,000 m2
A−1	Motor Pool for Construction Machinery	
A−2	Materials Storage Yard	
A−3	Other Buildings (Contractor's Office, Parking Lots etc.)	
B	Headrace Tunnel (Middle stream) Area	2,400 m2
B−1	Motor Pool for Construction Machinery	
B−2	Repair Shop	
B−3	Fabricating Yard for Reinforcement Bars	
B−4	Carpentory Shop	
B−5	Materials Storage Yard	
B−6	Other Buildings (Contractor's Office, Parking Lots etc.)	
C	Surge Tank Area	2,000 m2
C−1	Motor Pool for Construction Machinery	
C−2	Materials Storage Yard	
C−3	Other Buildings (Contractor's Office, Parking Lots etc.)	
D	Headrace(Down stream), Penstock, Powerhouse & Switchyard Area	3,500 m2
D−1	(Motor Pool for Construction Machinery)	
D−2	(Repair Shop)	
D−3	(Fabricating Yard for Reinforcement Bars)	
D−4	(Carpentory Shop)	
D−5	(Explosives Warehouse)	
D−6	(Other Warehouse)	
D−7	(Materials Storage Yard)	
D−8	(Other Buildings (Contractor's Office, Parking Lots etc.))	
D−9	(Tailrace Gate Assembly Yard)	
D−10	Penstock Assembly Yard	
D−11	Welding Shop	
E	Concrete Facilities	11,000 m2
E−1	Batching Plant	
E−2	Crushing Plant	
E−3	Aggregate Stock Yard	
E−4	Laboratory	
F	Construction Buildings	36,000 m2
F−1	Owner's & Engineer's Office & Camp	
F−2	Contractor's Office & Camp	
F−3	Laboir's Camp	

Table 2-13 Location of Construction Plant, Machines and Vehicles (see also the Figure 2-14)

No	Candidate for Temporary Facility Area	Kind of work	Major Construction Plant, Machine, and Vehicle
A	Portal Area of Headrace Tunnel (Upstream)	Excavation of Tunnel Portal, Support of Tunnel Works (mucking, ventilation, transportation of materials, repair of machines, etc.)	Agitating Truck, Concrete Pump, Air Compressor, Ventilating Fan Dump Truck, Bar Bender, Welding Machine, Pump, Generator for emergency
B	Portal Area of Headrace Tunnel (Middle stream)	Support of Tunnel Works (ventilation, repair of machines, etc.)	Agitating Truck, Concrete Pump, Air Compressor, Ventilating Fan, Dump Truck, Bar Bender, Welding Machine, Pump, Generator for emergency
C	Surge tank Area	Excavation of Surge tank Shaft, Support of Surge tank Shaft Excavation (mucking, transportation of materials, repair of machines, etc.)	Muck Loader, Dump Truck, Drilling Machine, Air Compressor, Crane, Concrete Pump, Bar Bender, Welding Machine, Pump, Generator for emergency
D	Headrace (Downstream) Penstock, Powerhouse & Switchyard Area	Excavation of Tunnel Portal, Support of Tunnel Works (mucking, ventilation, transportation of materials, repair of machines, etc.) Open Excavation Works, Installation of Steel Penstock Pipes, Concreting, Installation of Electromechanical Equipment	Excavator, Muck Loader, Bulldozer, Dump Truck, Air Compressor, Crawler Drill, Ventilating Fan, Concrete Pump, Bar Bender, Welding Machine, Agitating Truck, Vibrator, Crane, Truck, Flat Bed Truck, Pump, Generator for emergency
E	Concrete Facilities (Crushing Plant and Batching Plant)	Production of concrete aggregates and concrete	Crushing Plant Batching Plant Dump Truck Wheel loader Agitating Truck, Generator for emergency, Water Treatment Plant, Pump
F	Construction Buildings	Office Work	Passenger car
S1	Sand Mining site	Mining sand, Loading sand	Backhoe, Dump Truck
M1	Dumping site (Existing Borrow Area)	Unloading of muck, Leveling	Dump Truck, Bulldozer
M2	Dumping site (Existing Spoil Bank for Headrace)	Unloading of muck, Leveling	Dump Truck, Bulldozer
M3	Dumping site (Existing Temporary Area for Powerhouse)	Unloading of muck, Leveling	Dump Truck, Bulldozer
M4	Dumping site (Existing Spoil Bank for Powerhouse)	Unloading of muck, Leveling	Dump Truck, Bulldozer
M5	Dumping site (Stream at 2.4km Downstream of Powerhouse)	Unloading of muck, Leveling	Dump Truck, Bulldozer
L1	Tunnel route	Drilling, Blasting, Scaling/Trimming, Loading of muck, Shotcrete, Concreting, Grouting	2-(3) Boom Jumbo, Muck Loader, Shotcrete Machine, Concrete Pump, Vibrator, Pump
L2	Roads (Between the sites)	Transportation of muck, Transportation of materials and equipment parts	Dump Truck, Grader, Pick-up Truck, Flat Bed Truck, Grader

2.2.4 Methodology of Construction

The methodology of construction for the proposed project is described below:

2.2.4.1 Site preparation activities

Site preparation activities of the project will correspond to several locations. They are;

- Fine aggregate borrow site,
- Tunnel access roads,
- Spoil bank areas,
- Site for powerhouse and open-air penstock,
- Site for surge tank,
- Location of crushing plant and batching plant,
- Camp and office area.

First, in all sites the land will be cleared of shrub and trees which will be disposed in spoil banks. Next, during land preparation the top fertile soil is kept aside for relaying after the use of the sites. After clearing, excavation work will commence as civil works of the structures in the site for the powerhouse and open-air penstock and in the site for the surge tank. At the location of the crushing plant and batching plant, and in the camp and office area, land leveling will be conducted. The existing access road to the portal of the existing access adit will be improved due to leveling. The new access road to the new access adit in the upstream area will be constructed. The excess earth will be used as filling and in design the filling will be balanced with land preparation as much as possible in order to prevent the disposal of excess earth.

2.2.4.2 Facility construction (temporary & permanent)

(1) Temporary facilities

The temporary facilities constructed for this project are listed in Table 2-12 and their locations are shown in Figure 2-14. These will be demolished after completion of construction of the proposed project except office camp facilities for CEB (Housing Complex for CEB) in the area F.

(2) Permanent facilities

The permanent facilities are Headrace Tunnel, Surge Tank, Penstock, Powerhouse, and Housing Complex for CEB.

2.2.4.3 Detail of access roads to be built

As mentioned, the access road to the portal of the existing access adit to the tunnel was built during the the Victoria project Phase 1. The same road can be used and need to be improved for use during the second phase construction.

The new access adit will be constructed in the upstream area of the headrace tunnel closer to the Dam (see Figure 2-14). For this new adit, the existing access road will be improved while a new access road will be partially constructed to reach the adit portal.

2.2.4.4 Construction activities related to resettlement

There is no construction activities related to resettlement.

2.2.4.5 Other construction activities such as slope protection and refuse disposal

(1) Slope protection

Relevant protection will be provided on the slopes newly constructed, such as those near the new powerhouse, new access road, etc. These protection mechanisms during/after the construction period will prevent soil loss through erosion, and they will provide sturdy construction for better serviceability.

(2) Spoil banks

The excavated volume of soil and rock for the permanent and temporary facilities has been estimated. The volume to be disposed in spoil banks has been then calculated (conversion factor from the volume of excavation to that of spoiled is estimated as 1.5). Table 2-14 shows the required volumes of the spoil banks while Figure 2-14 shows the location of candidates for the spoil banks.

Table 2-14 Excavation and Spoil Bank Volume for Main Structures

Structures	**Excavation**(Unit: m^3)	**Spoil Bank Volume**(Unit: m^3)
Headrace Tunnel	252,700	379,050
Surge tank	43,000	64,500
Penstock	41,700	62,550
Powerhouse	44,000	66,000
Outlet	30,000	45,000
Work Adit	11,600	17,400
Others (5%)	21,150	31,725
Total	444,150	666,225

As mentioned in 2.2.4.6, concrete aggregates will be produced using mucks. The rock formation through which the tunnel is constructed is composed mainly of jointed gneiss. This type of rock will yield angular fragments suiTable for construction. The total volume to be disposed in the spoil bank will be reduced as part of muck is used as concrete aggregate. However, in the volume calculation of each candidate, the muck used for aggregates has not been considered because it is not clear muck from which excavation section is used as aggregates.

2.2.4.6 Material to be used- sources and amounts

The main material requirement is the concrete for tunnel lining and the construction material for the powerhouse and other facilities. Therefore coarse and fine aggregates will be the main material requirement for construction. The required volume of fine and coarse aggregates is estimated as around 55,000 m^3 each.

Two sources have been identified for them. The first is to use mucks from the tunnel and other structures. Since those mucks has already been used for the aggregates at Phase I, its quality is considered accepTable. At the crushing plant, fine and coarse aggregates will be produced.

Second, it is proposed that sand will be taken at a sand burrowing area located in a tributary of the Mahaweli river, around 5 km upstream of the CEB tunnel office. Since the area is submerged during the rainy season, sand will be taken only during the dry season. A screening plant will be constructed in the area to produce fine aggregates with accepTable quality.

It should be noted that a few thousand cubic meters of aggregates will be purchased from aggregates suppliers near the project area at the initial stage of the construction until the crushing plant commences operations.

2.2.4.7 Method / installation

The construction will begin with camp site constructions and access road improvement and construction. Construction of the permanent structures will commence thereafter. Methods for the construction of the structures and installation of equipment are described blow;

2.2.4.7.1 Preparatory Work

The preparatory work includes the improvement of the existing roads, the construction of the access road from the Victoria Dam right abutment to the work adit for the new headrace tunnel, the temporary power supply facilities for construction work, and the camp for the CEB and engineers. This work should be completed under another contract before starting the main civil works.

2.2.4.7.2 Intake

The structure from the intake screen to the Ch.15m of the headrace has been completed as part of the previous project, and it is filled with water now. The intake gate has also been installed in the gate shaft. Therefore the existing headrace section will be dewatered after closing the intake gate and connected to the new headrace tunnel in the Expansion Project. The water tightness of the gate shall be checked prior to this work.

2.2.4.7.3 Headrace Tunnel

The headrace tunnel is circular in shape and 5,003 m long, 8.0 m excavation in diameter and with a 6.6 m concrete lined inner in diameter.

As shown in Figure 2-16, the tunnel will be driven from the new access adit which will be constructed at the dam right abutment (A-1), the existing access adit located in the halfway point of the headrace tunnel (A-2.1 and A-2.2), and the portal of the penstock tunnel (A-3). The new access adit from the dam right abutment will be 300 m in length and 6.8 m in diameter. The existing access adit is 400 m in length and 7.2 m in diameter.

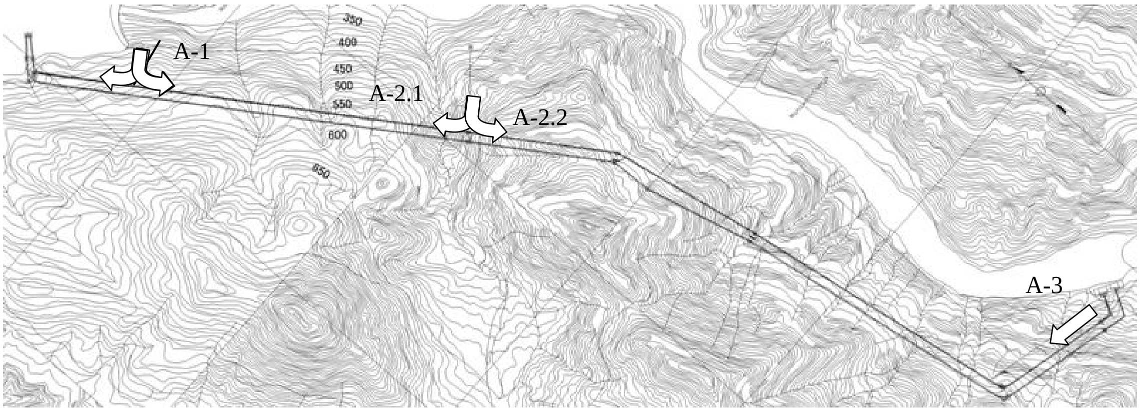


Figure 2-16 Excavation Procedure

The headrace tunnel will be excavated with the full face tunneling method using 3-boom wheel jumbos, side dump type muck loaders and dump trucks. The tunnel supporting works will be done with shotcrete and rock bolts. Steel rib supports may be used as the support system in the new tunnel portal section and weak rock sections where necessary.

The monthly progress of tunnel excavation is expected to be 125m/month based on the actual records of tunnel excavation in the Upper Kotmale Hydropower Project (These actual records take the difference of the cross section area of tunnels into consideration) and based on the limitation of negative impact on the existing structures due to the blasting which is indicated in 2.2.4.9.

The monthly progress in the tunnel portal section at 30m is expected to be 30m/month in order to adhere to Sri Lanka’s regulations on blasting.

It is necessary to estimate the velocity of vibration on the existing headrace due to the blasting and to control the blasting to limit the velocity of vibration within permitted values. This estimation shall be based on the results of the trial blasting carried out prior to the tunnel excavation. The trial blasting will be carried out at the face of the new access adit on the dam right abutment several times varying the loading amount of explosives and measuring the velocity of vibration with the vibrographs on the intake gate shaft and/or the dam inspection galleries.

The lining concrete will be placed with a 10m long circular traveling steel form. The monthly progress of the lining concrete is expected to be 125m/month using three sets of traveling steel forms. The cycle of the lining concrete work is expected to have a 10m/span with an interval of 2 days (form setting 0.5day + concrete placing 1day + form removal 0.5 day). The consolidation grout will be executed at the section where the strength of the lining concrete reaches the designed strength.

The headrace tunnel work plays a critical role in the total work schedule. This work therefore should commence immediately after the completion of the preparation works. The construction period of the headrace tunnel is estimated at 17 months for tunnel excavation and as 19 months including the lining concrete work.

2.2.4.7.4 Surge Tank

The shaft excavation for the surge tank will be carried out in two steps: the pilot hole excavation and the enlargement excavation. The pilot hole will be excavated with a raise climber upward from the headrace tunnel or with a raise borer downward from the ground to the headrace tunnel, then widening it with a reaming bit upward from the headrace tunnel. After completion of the pilot hole, the enlargement excavation will be executed with the drill and blasting method downward from the ground. The muck will be dropped to the headrace tunnel through the pilot hole and then hauled outside with dump trucks through the penstock tunnel.

The construction period of the surge tank is estimated at 9 months for the shaft excavation and at 12 months for the lining after comparison with previous results. Grout consolidation will take a month from the time of concrete work.

2.2.4.7.5 Penstock Tunnel

The excavation of the penstock tunnel will be executed with the same method as the headrace tunnel excavation. The monthly progress of the penstock tunnel excavation is expected to be 125m/month as is the case with the same as the headrace tunnel excavation.

The backfill concrete placing around steel pipe will commence after the completion of the surge tank excavation because the muck from the surge tank will be carried out through the penstock tunnel. The backfill concrete will be placed with a concrete pump. The steel pipe installation and the filling concrete work will be carried out by turns.

The monthly progress of the penstock tunnel work is expected to be 36 m/month based on estimated cycle-time; steel pipe installation (6 m × 3 units) will take 12 days and the backfill concrete work 3 days.

2.2.4.7.6 Penstock

The salient features of the steel penstock are shown below:

Type	Embedded and Exposed Type Steel Penstock
Design water head	353.5 m
Component	1 line (before bifurcation), 2 lines (after bifurcation)
Length (incl. steel lining)	750 m (unit 4), 735 m (unit 5) of which 575 m of tunnel section
Inner diameter	6.6 m – 5.6 m – (after bifurcation) 3.95 m – 2.85 m
Bifurcation	Internal Reinforcement Type Y-branch
Portal valve	Butterfly Type, 2units (after bifurcation)

The steel lining and the steel penstock are fabricated in the temporary factory near the site and transported to the respective tunnel with trailers. Installation will commence after the completion of the excavation of the surge tank shaft and penstock tunnel. The parts 6.6m in diameter will be brought from the surge tank shaft and installed in the given place in the tunnel. The installation is executed from upstream to downstream simultaneously and is closed finally just below the surge tank shaft. The 5.6m parts will be brought from the tunnel entrance on the downstream side and installed from upstream to downstream.

The monthly progress of the installation work is expected to be 36m/month based on estimated cycle-time; 18m/span with 15 days (12days for connecting and welding 3 units of 6 m pipes:and 3 days for concrete placing).

The bifurcation part will be installed in the open area which is located at the end of tunnel part. The installation of the bifurcation part will be executed after the completion of installation of the penstock 5.6 m diameter. Branch pipes will then be installed continuously near the valve. The downstream parts of the branch pipes will be installed from the power station side to the valve side. The penstock will be closed when the valve is installed at the last.

2.2.4.7.7 Powerhouse

The powerhouse is the surface type, the dimensions of which are 37m in width, 44m in height and 69m in length. The powerhouse excavation will be done using the bench-cut blasting method. The trial blasting shall be executed at the beginning in order to avoid damage to the existing powerhouse due to vibration of the blasting. The trial blasting shall deploy several blasting patterns, and the impact of vibrations from which shall be measured on the existing powerhouse. The pre-splitting method may be effective if the vibration seems to exceed the allowable limit. If required, the chemical fracturing agent and/or the breaker without using explosives can also be recommended. It is important to monitor vibration on the existing powerhouse during excavation work.

After excavation reaches the bottom of the powerhouse, the required equipment and materials will be brought by using temporary cranes. The base concrete works will begin then. The concrete around the electromechanical equipment such as draft tube, casing, turbine, and generator will be cast, dividing primary and secondary stages.

After the completion of the crane girder in the erection bay, the assembly of overhead traveling cranes will begin in the erection bay. Following the completion of wall concreting and the crane girder, the turbine and generator installation will start with the crane. Finishing and utility works will be executed in parallel with the civil and the electromechanical works.

The construction of the powerhouse is expected to involve 4 months of excavation work, 27 months of concrete work and 13 months of finishing and utility work.

2.2.4.7.8 Hydraulic Turbine, Generator etc.

1) Draft Tube

The installation, welding and assembling work of the draft tube liner for Unit No. 4 will begin 14 months after the start of the construction work. The installation work of the draft tube liner will be executed by using truck cranes.

2) Spiral Casing

After the completion of over head traveling crane installation, the installation of the spiral casing will be executed.

3) Hydraulic Turbine, Generator and Main Transformer

The installations of hydraulic turbine and generator will commence after the completion of the spiral casing. The hydraulic turbine of Unit No. 4 will start 28 months after the start of the construction work. The hydraulic turbine of Unit No. 5 will begin after the completion of the hydraulic turbine of Unit No. 4.

The assembling work of the stator of Unit No. 5 will overlap with the installation work of the rotor of Unit No. 4. As it is anticipated that works at the erection bay will be complicated, it has to be conducted with maximum attention to safety. The Main Transformers will be installed outside 37 months after the start of construction work.

4) Auxiliary and Control equipment

The installation work of turbine auxiliary equipment will be conducted after hydraulic turbine installation. The control equipment will be installed after the generator installation. Piping and cabling works and the adjustment of each control board will be done during the same period.

5) 220kV Switchyard

The installation of switchgear (220kV CB, DS, CT, VT) will commence 36 months after the start of the construction works. Since the existing units, line and bus section might be in operation, the area of installation work must be carried out within the new yard, not to affect operation of the existing facilities.

6) Commissioning Test

The dry test of Unit No. 4 will commence 45 months after the start of the construction works and will take 2 months for completion. The wet test will be conducted continuously and will take 2 months for completion. The commercial operation will start after all tests including the load rejection test are completed.

2.2.4.8 Techniques and equipment to be used

The specific equipments to be used in the project are as follows:

Agitating Truck
Dump Truck
Pick-up Truck
Flat Bed Truck
Truck
Passenger car
Wheel loader
Muck Loader
Concrete Pump
Pump
Ventilating Fan
Crushing Plant
Water Treatment Plant
Batching Plant
Bulldozer
Shotcrete Machine
2-(3) Boom Jumbo
Vibrator
Crawler Drill
Excavator
Crane
Drilling Machine
Generator for emergency
Welding Machine
Bar Bender
Air Compressor
Grader

2.2.4.9 Excavation methodology for new tunnel, blasting method and parameters / if any blasting activities involved in tunnel of excavation

The open-air work and underground work of the proposed project are to be carried out near the existing Victoria dam, intake facilities, waterway and powerhouse. Hence, vibrations caused by blasting should be controlled to prevent them from damaging existing structures. In this section, the maximum allowable blasting vibration is examined and determined.

2.2.4.9.1 Characteristics of Vibration due to Blasting

2.2.4.9.1.1 Comparison of Vibrations due to Earthquakes and Those due to Blasting

Generally, the main characteristics of vibration due to blasting are compared with those due to earthquakes as follows:

1) Vibration energy caused by blasting is small and vibration occurs locally, hence, a limited area is affected by the blasting.
2) The frequency of earthquake vibration generally ranges from 1 to 5 Hz, while that of blasting vibration falls within the high frequency range from 10 to 200 Hz.
3) Vibrations caused by earthquakes last for several seconds to several minutes, while that from blasting finishes within almost one second.

Table 2-15 Comparison of Vibrations due to Earthquakes and Blasting

Item	Earthquakes	Blasting
Affected area where vibration is felt	Several 100 km from the hypocenter	At most several 100 m from the blasting point
Frequency of vibration	Around 1 to 5 Hz (depending on characteristics of ground)	10 to 200 Hz or more
Duration of Vibration	Several seconds to several minutes	Within one second

Source: Japan Explosives Industry Association

2.2.4.9.1.2 Units of Vibration

In the case of sine-curve vibration, vibration displacement (Y) at time t is shown by the following equation:

$Y = A \sin(2f\pi t)$

Where,

A: Amplitude of displacement

f : Frequency

π: Circle ratio

Vibrations can be indicated by using vibration velocity (V) or acceleration (α), and their maximum values have the following relations;

$V = 2f\pi A$

$\alpha = 2f\pi V = (2f\pi)^2 A$

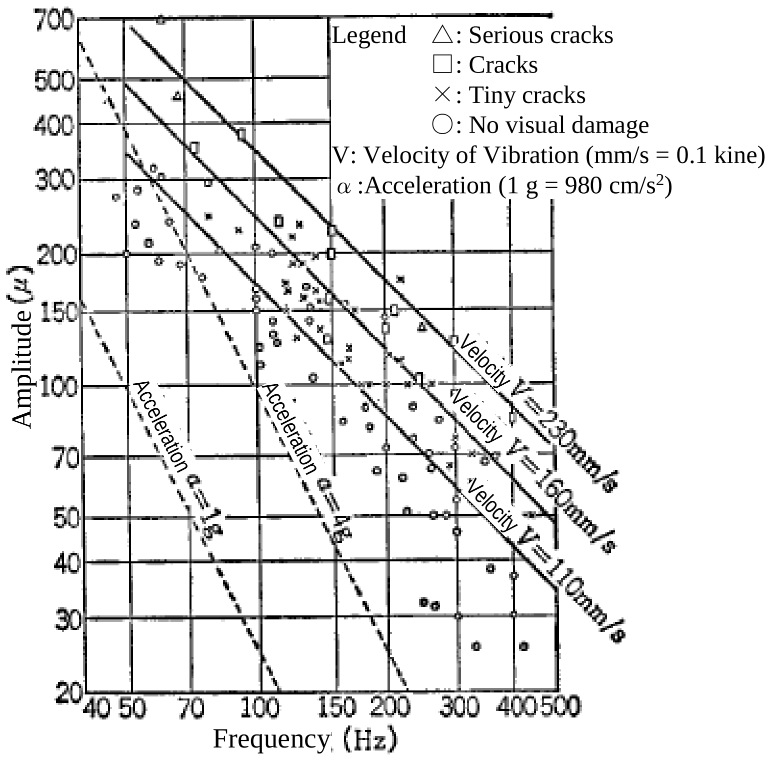
The units mentioned in Table 2-16 are used for vibration displacement, velocity and acceleration.

Table 2-16 Units for Vibration

	Standard Unit	Unit used practically
Displacement	cm	mm, μ (= 0.001 mm)
Velocity	cm/s	kine (cm/s)
Acceleration	cm/s^2	gal (= cm/s^2), g (= 980 cm/s^2)

2.2.4.9.1.3 Damages due to Blasting Vibration

Figure 2-17 shows relations among ground vibration amplitudes, vibration frequencies and damages caused by blasting observed by Langefors, et al.



(by Langefors et. al,. Source: Japan Explosives Industry Association)

Figure 2-17 Relations between Amplitude and Damages to Buildings due to Blasting

It is understood that similar damages are caused regardless of displacement or acceleration amplitudes but are caused under almost the same velocity amplitude and that there is a relation between vibration velocity amplitude and the kinds of damages. Therefore, the maximum allowable vibration value is indicated with a unit of vibration velocity. The “kine” is used as a unit of vibration velocity.

2.2.4.9.2 Damages of Blasting Vibration to Concrete Structures

2.2.4.9.2.1 Estimate by Three Dimensional Elastic Theory

Stresses caused by vibration in a certain material are calculated with the following equation using the three dimensional elastic theory:

$$\sigma = \frac{pCV}{g} x \frac{(1-2\nu)(1+\nu)}{1-\nu} \quad \text{...(1)}$$

Where,

σ : Stress (kg/cm^2)
p : Density of material (g/cm^3)
C : Elastic wave velocity of material (m/s)
γ : Poisson's ratio of material
g : Gravity acceleration (980 cm/s^2)
V : Vibration velocity(cm/s)

Hence, vibration which cause a certain stress is calculated by the equation (1) as follows;

$$V = \frac{\sigma g}{pC} x \frac{1-\nu}{(1-2\nu)(1+\nu)} \quad \text{...(2)}$$

In case the material is concrete, the following general values can be used.
p = 2.5 g/cm^3
C = 3,000 m/s = 300,000 cm/s
γ = 0.25

When concrete tensile strength = 20 kg/cm^2 *[4], the blasting vibration velocity which causes cracks in the concrete is calculated as V = 31.4 kine with the equation (2).

2.2.4.9.2.2 Experiment by Using Actual Tunnel

A few experimental tests using actual tunnel structures were conducted in Japan to clarify the blasting vibration velocity commencing to cause cracks in the lining concrete. Results are shown in Table 2-17.

Table 2-17 Experiment Result of Blasting Vibration for Crack Generation

Name of tunnel	Object	Velocity of vibration commencing to cause cracks
Hibi Tunnel	Lining concrete	more than 30 kine
Okitsu Tunnel	Lining concrete	more than 30 to 40 kine
Wakayama Tunnel	Shotcrete	more than 70 kine

Source: Japan Explosives Industry Association

The lowest values in Table 2-17 almost correspond to the calculated value in 2.2.4.9.2.1 above, which commence to cause cracks in the concrete.

2.2.4.9.3 Damages against Rock Slopes

Effects by blasting vibration on rock slopes by Oriard are shown in Table 2-18:

[4] Lining concrete of the headrace tunnel of the existing Victoria Hydropower Station had a design compressive strength of 200 kg/cm^2. In general, concrete tensile strength is estimated to be around one-tenth of compressive strength. Hence, concrete this concrete seems to have compressive strength of around 20 kg/cm^2 is adopted in this estimate.

Table 2-18 Affects on Rock Slopes due to Blasting Vibration

Vibration Velocity due to Blasting	Affects
5.1 to 10.2 kine	Rock fragments on rock slope fall
12.7 to 38.1 kine	Loose parts of rock slope collapse
63.5 kine or over	Week slopes start to damage

Source: Japan Explosives Industry Association

2.2.4.9.4 Maximum Allowable Vibration Velocity for Existing Underground Structures

2.2.4.9.4.1 Railway Tunnel to be Excavated Near Existing Structure

According to the "Manual on Measures for Tunnel Works near Existing Tunnels" prepared by the Railway Technical Research Institute in Japan, the maximum value is to be determined taking into consideration the soundness of existing tunnels. Table 2-19 shows the classification of the soundness of existing tunnels while and Table 2-20 shows the maximum allowable vibration velocity.

Table 2-19 Status (Soundness) of Lining Concrete of Existing Tunnel

Class of Soundness	Effects to Normal Operation	Deformation of Tunnel	Countermeasures for Repair
AA	Dangerous at the present time	Serious	To be taken immediately
A1	To become dangerous in near future	Large deformation and lowering function	To be taken urgently
A2	To become dangerous in future	Deformation is possible to proceed and function may lower	When required, to be taken
B	If worse, to be Classes A	If worse, to be Classes A	To be monitored and to be taken when required
C	No affect at the present time	Slight	To be inspected intensively
S	No affect	No deformation	Not necessary

Source: Japan Explosives Industry Association

Table 2-20 Maximum Allowable Vibration Velocity

Class of Soundness	Maximum Allowable Vibration Velocity
AA	2 kine
A1, A2	3 kine
B, C, S	4 kine

Source: Japan Explosives Industry Association

It is understood that the maximum allowable velocity of 2 to 4 kine means a safety factor is assumed as around 8 to 15 in comparison with the calculated value in 2.2.4.9.2 1.

2.2.4.9.4.2 Maximum Allowable Vibration Velocity of Railway and Road Tunnels in Japan

Table 2-21 shows allowable blasting vibration applied to railway and road tunnels in Japan which were constricted near the existing structures.

Table 2-21 Allowable Blasting Vibration Applied to Railway and Road Tunnel Projects in Japan

Name of Tunnel	Allowable Velocity (kine)	Shortest Distance to Existing Tunnel (m)
Hibi Tunnel (Sanyo Shinkansen)	2.5	11.4
Muikamachi Tunnel (Joetsu Shinkansen)	1.0	1.8
Sasago Tunnel (Chuo Highway)	6.5	17.0
Kinmeiro Tunnel (Sanyo Highway)	5.0	5
Gorigamine Tunnel (Joetsu Highway)	4.0	n.a.
Nagamine Tunnel (Hanwa Highway)	4.0	n.a.
Mihara No.5 Tunnel (Highway)	1.0*	15.5

*Note: *Existing tunnel was classified as AA in the manual mentioned in 2.2.4.9.4 1*
Source: Japan Explosives Industry Association, etc.

The allowable values range from 2.5 to 6.5 kine except in cases where the soundness of the existing tunnel is very poor and the distance between existing and new tunnels is very small.

2.2.4.9.4.3 Technical Guidelines for Controlled Blasting in India

What is given below are the "Technical Guidelines for Controlled Blasting" issued by the Central Institute of Mining & Fuel Research in India in October 2007.

2.2.4.9.4.3.1 Affects to rock mass

Affects to rock mass due to blasting is controlled with the strain in the rock mass in the guidelines based on observations by Richard and Moore: "Strain induced by blasting vibration leading to damages is about 10% of the tensile failure strain of the rock and this limit is considered as safe value". It is understood that the limit has the safety factor of 10.

2.2.4.9.4.3.2 Affects to mass concrete

The limit of blasting vibration is controlled with concrete age and distance to the existing structures by Oriard and indicated with vibration velocity (refer to Table 2-22).

Table 2-22 Blasting Vibration Limits for Mass Concrete (after Oriad)

Concrete Age	Allowable Velocity from Blasting (kine)	Distance Factor (D.F.)
0 – 4 hrs	10.2 × D.F.	Distance: 0-15 m; D.F. = 1.0 Distance: 15-46 m; D.F. = 0.8 Distance: 46-76 m; D.F. = 0.7 Distance: >76 m; D.F. = 0.6
4 hrs – 1 day	15.2 × D.F.	
1 day – 3 days	22.9 × D.F.	
3 days – 7 days	30.5 × D.F.	
7 days – 10 days	37.5 × D.F.	
10 days or more	50.8 × D.F.	

Source: Technical Guidelines for Controlled Blasting, Central Institute of Mining & Fuel Research, Oct 2007

The allowable vibration limits in Table 2-22 is considered as limits without any safety factor in comparison with those in 2.2.4.9.4.1 and 2.2.4.9.4.2 of this Section.

2.2.4.9.4.4 Allowable Blasting Vibration Applied to Hydropower Projects Undertaken by J-Power

Table 2-23 shows the allowable blasting vibration applied to hydropower expansion projects undertaken by the Electric Power Development Co., Ltd. (J-Power). Blasting works were carried out with the allowable vibration of 2 kine against the existing dam, waterway tunnel and powerhouse.

Table 2-23 Allowable Blasting Vibration Applied to Hydropower Expansion Project by J-Power

Project Name	Allowable Blasting Vibration Velocity (kine)	Remarks
Akiha No. 3	2	Existing structures including concrete gravity dam were located near new structures.
Okutadami Expansion *	2	Expansion of underground type powerhouse. Existing structures including concrete gravity dam, intake facilities, and underground powerhouse were located near new structures..
Ootori Expansion	2	Existing structures including concrete arch dam, intake facilities were located near new structures..

** Blasting work was carried out under operation of the existing generation equipment*
Source: Electric Power Development Co., Ltd. (J-Power)

Table 2-24 shows allowable vibration against the existing concrete gravity dam due to drilling machines which made a hole for the installation of penstock steel pipes.

Table 2-24 Allowable Vibration due to Drilling Machine to Make Opening in Concrete Gravity Dam

Project Name	Allowable Vibration Velocity (kine) due to Machine	Remarks
Akiha No. 3	2.0	To install steel penstock, make an opening with 6.5 m in diameter
Okutadami Expansion	2.0	To install steel penstock, make an opening with 6.2 m square

Source; Electric Power Development Co., Ltd. (J-Power)

It should be noted that no damages were caused to the existing structures by the above projects.

2.2.4.9.5 Maximum Allowable Vibration Velocity for the Victoria Hydropower Expansion Project

What follows is based on theoretical values, the limits applied to the projects, and guidelines:

1) According to the results of inspections conducted in 2000 for the waterway tunnel of Victoria Hydropower Station, the class of soundness in 2.2.4.9.4.1 is estimated as C to S. Hence the maximum blasting vibration velocity for the existing tunnel is 4 kine.
2) However, a stricter limit than 4 kine should be applied to the proposed project because blasting works are conducted near the existing arch dam and pressure tunnel.

3) Therefore, 2 kine should be applied to the project, in consideration of the allowable vibration velocity applied to J-Power's hydropower expansion projects. The limit of 2 kine means that the safety factor of around 15 is considered against vibration to cause cracks in concrete calculated in 2.2.4.9.2.1.

An examination of the tunnel alignment, construction planning, preparation of construction schedule, etc., should be carried out taking into consideration the limit of 2 kine in the basic design. Construction methods without blasting will be examined for works near the existing intake facilities for expansion and the existing powerhouse.

2.2.4.9.6 Determination of Explosives

To determine the among of explosives for excavation of headrace tunnel, the following empirical equation will be used to limit the velocity of vibration on the existing headrace and other structures to less than 2 cm/s.

$$V = K \cdot W^{\frac{2}{3}} \cdot D^{-2}$$

Where,

V : velocity of vibration (cm/s)
K : Coefficient related to blasting conditions
W : loading amount of explosive per 1 rotation (kg)
D : distance from the center of blasting (m)→ 36m for headrace tunnel

When K = 750 for center-cut and 350 for the side blasting hole, and W = 9.0 kg and 15.5 kg for the side blasting hole is adopted, the vibration velocity due to the blasting against the existing tunnel is confirmed to be less than 2 cm/s. When the above loading amount is used for blasting, the relation between D and V is shown in Table 2-25

Table 2-25 Relation between D and V

D (m)		50	100	150	200
V (cm/s)	Center cut	1.29	0.32	0.14	0.08
	Side hole blasting	0.87	0.22	0.10	0.05

With regard to blasting, the feasibility study report proposes the following;

a. The trial blasting should be carried out at the face of the new access adit on the dam right abutment before the commencement of blasting work by varying the loading amount of explosives several times and by measuring the velocity of vibrations with the vibrographs on the intake gate shaft, and/or the dam inspection galleries, and other relevant structures/rock surfaces.
b. Vibration due to the blasting during the construction works should be measured with the vibrographs on the existing structures and/or rock surfaces during construction period, to confirm safety of the existing structures.

2.2.5 Methodology of Operation

2.2.5.1 Water Utilization Schedule

The total water volume per year for power generation will not change, but the timing of utilizing water will change because of operation for peak demand. Total water release will be determined through the existing mechanism of water management which optimally uses the water among all its multidisciplinary uses such as irrigation, power generation, water supply, downstream demands, etc. Therefore, no change in the quantity or pattern of water releases is expected. However, as the purpose of the extension of the power capacity is for higher generation during the peak hours, the generation will now be limited to a few hours during the peak period within a day. The water released during power production will be stored in the Randenigala reservoir and will be used for power production and irrigation releases as it has been done in the past. For this reservoir too, no change in the power generation pattern will be made and it will be as done in the past.

The planned discharge of daily pattern will be limited to the peak hour, from 18:30 to 21:30 except during the rainy season. The total amount of water volume per day will hardly be changed before and after construction. The typical operation pattern is shown in Figure 2-18.

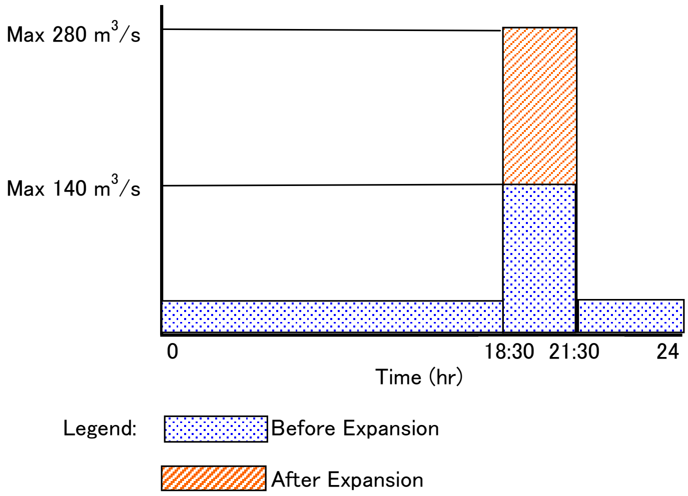


Figure 2-18 Typical Operation Pattern

2.2.5.2 Repairs & maintenance activities

The standard repair and maintenance procedures that are used in the current powerhouse and other components will be used in the proposed project too by the CEB.

The transformers for the two turbines and auxiliary transformers will use non hazardous coolant. The governor oil, bearing oil and the penstock guard valve of the plant are to contain non hazardous oil coolant. The coolant will be purified almost every year to maintain quality and optimal usage without disposal. Should it be disposed, the correct disposal procedure which requires that they be sent to the recycling agent will be adopted. The used oil of the selected type (non-hazardous) has several other applications after being used up and thus will be in high demand by others. The coolant water from the generators and bearings are around 30 ˚C, thus disposing it to the tailrace is not a threat to the environment.

2.2.6 Infrastructure facilities required / provided by the project

The main infrastructure facility that is required by the proposed project is the main road (Raja Mawatha) between the sand mining site and the turn off to the existing powerhouse, and the section of the road from Adikarigama to the former quarry site (see Figure 2-14). The power required for the project will be obtained from the existing power grid. The water for construction and worker camps will be obtained from the Mahaweli River or its tributaries through a temporary water supply system.

No new major paved roads will be constructed by the project as it is dependent on the existing roads except for the temporary access road that will be constructed to transport tunnel muck from the new Adit site located downstream of the dam to the existing road in the dam area. The road will not be available for public use after the completion of the project. The project will establish a state-of-the-art visitor and information center which is open to public.

2.2.7 Implementation plan and time schedule

The proposed project will be developed as a one-phase development. The construction period would be around 52 months (four years and 4 months) including the preparatory works period.

2.2.8 Workforce

During the construction period for the expansion project, the skilled laborers, foremen, and supervisors for the contractors will be brought from outside of the project area as has been the case with similar projects. The number of unskilled labors required for the works is estimated at around 80 unskilled laborers per day maximum. Almost all of them will be employed from in or around the project area.

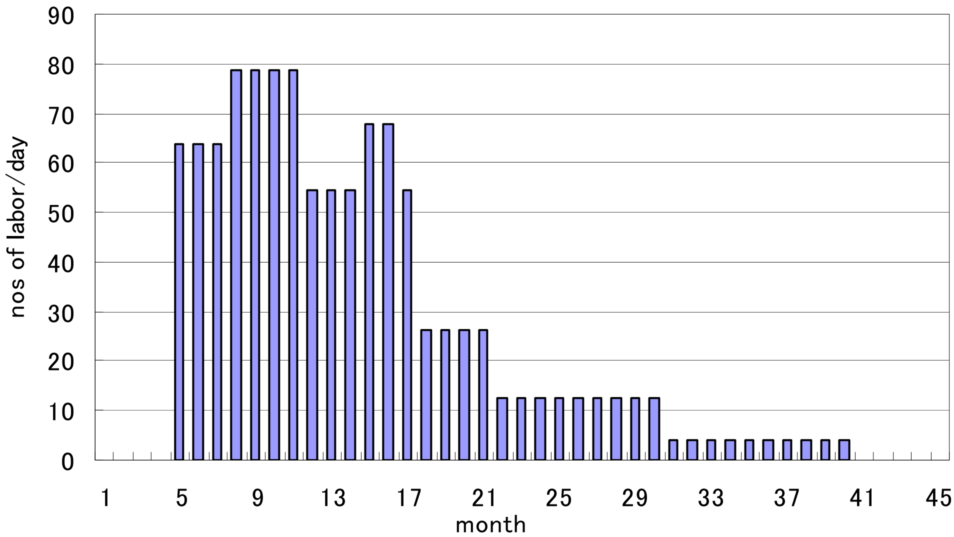


Figure 2-19 Workforce during construction

If we assume that the future workforce at the operational stage will be 1.5 times as large as the number for the existing power station, thre will be 12 Engineers (CE,ME,EE (9)), 13 Superintendents (CS,MS(3),ES(9)), 30 Skilled force, 45 Semi Skilled & Unskilled force, 45 CEB security personnel and 9 Clerks working at the power plant. Altogether the total would come to 153 members at work. These figures cover all the existing facilities including the power station, surge tank, intake, etc.

2.2.9 Investment and funding sources

The project construction cost would be US$ 221,971,154- (see Table 2-26). Investment and funding sources would be ODA (official development assistance) from foreign countries.

Table 2-26 Project Construction Cost

No.	Item	Amount (US$)		
		Total	Foreign	Local
1	Preparatory Works	3,186,329	430,556	2,755,773
2	Civil Works	74,856,634	40,400,088	34,456,546
3	Hydromechanical Equipment	21,966,000	17,721,100	4,244,900
4	Elecromechanical Equipment	81,480,000	67,900,000	13,580,000
5	Environmental Cost	2,154,099	0	2,154,099
6	Administration and Engineering Fee	18,148,896	12,645,174	5,503,722
7	Contingency	20,179,196	13,909,692	6,269,504
	Project Construction Cost (1 to 7)	221,971,154	153,006,611	68,964,544

2.2.10 Civil structures, dimensions, drawings etc.

Drawings of the main Structures are shown in ANNEX VI. They include headrace tunnel section, penstock open-air plan, penstock open-air profile, penstock tunnel section, powerhouse plan, powerhouse profile, surge tank, switchyard, and waterway.

2.2.11 Arrangement for discharge of forecasted probable maximum flood

According to information on the Victoria dam, the probable maximum flood is forecasted as 9,510 m^3/s and the discharge capacity of the gated flood spillway is calculated as 7,900 m^3/s. As the drawings attached to the operation manual of Powerhouse civil structures show, the retaining wall of the existing Victoria powerhouse is designed against the highest water level of EL. 240 m corresponding to the water level caused by the spillover of 7,900 m^3/s. The new powerhouse of the proposed project is also designed under the same condition to protect the structure from flooding.

2.2.12 Requirement for the associated structures

There is no requirement for additional structures other than what is described above as associated with the project.

2.2.13 Proposal for Emergency Action Plan

An emergency action plan will be prepared in detail at the design stage. An Emergency Action Plan for the existing power house is already available. As this document specifies contingencies on facing possible terrorist attacks, it is kept as a confidential document. The proposed emergency action plan will also contain similar contingencies.

2.2.14 Limitation to Randenigala Minimum Operation Level

As the preferred alternative is the Basic Option, limitations to Randenigala Minimum Operation Level and possible changes associated with the Downstream Option and Pumped Storage Option will not occur.